Exchange rates and interest rate differentials: recent developments since the introduction of the euro

The euro's exchange rate has fluctuated considerably since the beginning of monetary union. Against the US dollar, in particular, the euro recovered strongly after losing ground in 1999 and 2000. At the end of 2004 it peaked at US$1.36. Since then, however, it has once again lost some of its value; its level is currently somewhat higher than when monetary union was launched in 1999. The ups and downs of the exchange rate have coincided with varying interest rate differentials between investments in euro and in US dollars. These are considered in analyses as often being key determinants of exchange rate movements.

This article studies the theoretical and empirical connections between exchange rates and interest rate differentials. It discusses both covered interest parity and uncovered interest parity as well as various hypotheses which claim to explain deviations from uncovered interest parity. It is based on the period since the introduction of the euro. This article also explains the importance of currency carry trades for exchange rate dynamics.

Interest rate differentials as a motive for international capital flows

Global foreign exchange turnover has risen sharply in the past few years. In April 2004 – the latest date for which survey data exist – it averaged an estimated US$1.9 trillion per

Interest rate differential between the USA and the euro area

Daily data

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trading day.[1] By contrast, global goods trade, in terms of exports, amounted to "only" around US$9 trillion for all of 2004, according to IMF information. These figures, despite not being directly comparable, illustrate the vast scale that international financial transactions have taken on in recent times. The exploitation of international interest rate differentials is often cited as a motive for such cross-border activity.

Interest rate differentials between the USA and the euro area

Movements in money market rates are largely a reflection of the impact of monetary policy measures. Accordingly, US money market funds had a yield spread of up to 3 percentage points over the euro area in the first two years of monetary union. The economic upturn at the end of the 1990s had resulted in US monetary policy being relatively restrictive. The slowdown in US economic growth during 2001, however, led the Federal Reserve to rapidly ease its monetary policy, whereas key interest rates in the euro area, starting at a lower level, were cut only later and – given the persistent inflationary risks – to a lesser extent. The interest rate differential consequently shifted to the euro area's advantage. The renewed tightening of monetary policy in the United States caused its interest rate to rise continuously in the past year, overtaking the euro-area interest rate in late 2004. Long-term interest rates tend to follow a similar, if more stable, pattern to short-term rates. This is also a reflection of long-term growth and inflation expectations.

Covered interest parity and exchange rates to the euro

Covered interest parity in theory

A foreign interest rate advantage, such as is currently enjoyed by investments in the USA over the euro area at both the short and long end, can act as a stimulus to invest abroad. However, the yield spread between a foreign currency investment and a domestic investment is determined not just by international interest rate differentials but also by fluctuations in the exchange rate. An appreciating US dollar would amplify the return on an investment in the US financial market for investors in the euro area, while a depreciating dollar would reduce the gain or even turn it

1 This was the result of a survey conducted by the Bank for International Settlements, in which the Bundesbank took part. See BIS (2004), Triennial Central Bank Survey of Foreign Exchange and Derivatives Market Activity in April 2004.

Covered and uncovered interest rate parity

With the free international movement of capital, a domestic investor has the option of investing in the euro area or elsewhere, for example in the USA. If he chooses the USA, he must first change the investment amount G into US dollars at the current spot exchange rate w_0 – defined as the price of one euro in units of US dollars. Let us assume that the resulting US dollar amount is then invested at an interest rate i^* in twelve-month funds on the US money market.[1] After one year, the amount invested will have grown to $G \cdot w_0 \cdot (1 + i^*)$ US dollars and will then be reconverted to euro at the prevailing spot rate w_1. Differences between the future and current euro-dollar exchange rate affect the final value in the domestic currency ($G \cdot (1 + i^*) \cdot w_0 / w_1$). Were the euro to weaken against the dollar, this would amplify the return in euro on a US investment; conversely, the return would be reduced, or even outweighed, by a stronger euro.

Forward exchange markets allow investors to eliminate the exchange rate risk of an investment in a foreign currency through an appropriate hedge. This means that an investor is able to exchange the final US dollar value $G \cdot w_0 \cdot (1 + i^*)$ of his investment due on a future date at today's forward exchange rate $f_{0,1}$. It is then guaranteed to be worth $G \cdot (1 + i^*) \cdot w_0 / f_{0,1}$ in the domestic currency after one year.

Alternatively, the investor could have invested on the domestic money market at an interest rate i and generated an equally secure[2] final value of $G \cdot (1 + i)$. Since the final value is known in advance under both investment strategies, differing returns offer potential arbitrage opportunities. The investment offering the greater return – be it domestic or international – would generally be favoured. This would result in exchange and interest rate adjustments which would tend to equalise the returns (disregarding transaction costs). Covered interest rate parity therefore applies

$$G \cdot (1 + i) = G \cdot (1 + i^*) \cdot w_0 / f_{0,1}$$

or

$$\frac{f_{0,1}}{w_0} = \frac{1+i^*}{1+i}.$$

The correlation can also be expressed in the following form

$$\frac{f_{0,1} - w_0}{w_0} = \frac{i^* - i}{1+i}.$$

Thus, the swap rate (the relative difference between the forward rate and the current spot rate) broadly corresponds to the interest rate differential.

If the investor decides not to hedge the exchange rate risk through a forward transaction, a decision on which investment to choose will depend on how he expects exchange rates to move. The secure final value of $G \cdot (1 + i)$ for a domestic investment contrasts with an expected final value of $G \cdot (1 + i^*) \cdot w_0 / w^e_{0,1}$ for a foreign investment, where $w^e_{0,1}$ denotes the spot rate a year from now expected today. Based on these conditions and assuming rational expectations and risk neutrality, speculative capital flows should ensure uncovered interest rate parity

$$\frac{w^e_{0,1} - w_0}{w_0} = \frac{i^* - i}{1+i}.$$

Uncovered interest parity implies that an expected euro depreciation is virtually matched by a correspondingly higher rate of interest on an investment in the euro area compared to an investment in the USA. While deviations from uncovered interest parity offer profit-making opportunities, they are not risk-free – in contrast to covered interest rate parity. If we additionally assume that covered interest parity holds then, in accordance with uncovered interest parity, the expected exchange rate movement must correspond to the swap rate

$$\frac{w^e_{0,1} - w_0}{w_0} = \frac{f_{0,1} - w_0}{w_0}.$$

Assuming rational expectations, the forward rate is then an unbiased forecast of the future spot rate.

1 To simplify the notation, we have assumed that the currency exchange and the acquisition of the foreign financial asset occur simultaneously. In addition, we have taken the investment period to be one year. By contrast, we used a three-month period in the empirical studies presented here. — **2** This is based on the assumption that domestic and foreign investments have the same default risk.

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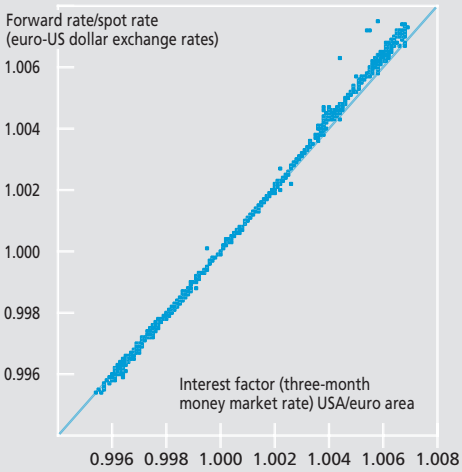
Covered interest parity between the USA and the euro area*

Daily data, 4 Jan 1999 to 30 June 2005



Source: Thomson Financial Datastream. — * Each individual point represents a ratio calculated from exchange rates and interest rates, each on a given trading day in London at 4 pm. For covered interest parity to hold, the points have to be close to the 45° line in the chart.

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into a loss. It is true that the domestic investor can hedge against this exchange rate risk by, for instance, converting the future payment amount disbursed on his US dollar-denominated investment into euro in advance. The theorem of covered interest parity states, however, that the ratio between the forward and spot rates of the euro-US dollar exchange rate must equal that between the interest factors of investments in the two currencies (see box on page 29). The respective returns on a domestic investment and a foreign investment hedged by a forward transaction are accordingly equal because otherwise they would be vulnerable to arbitrage – ie exploiting the interest rate differentials for a risk-free profit.

Covered interest parity between the USA and the euro area

Some support for covered interest parity is provided by comparing, for each trading day, the relationship between forward and spot euro-US dollar exchange rates to the interest rate factors for three-month money market funds between the USA and the euro area. Since the differences between the interest factors on either side of the Atlantic have not been all that great since the beginning of monetary union, the observed ratios are close to unity. The two-time change in signs in the interest rate differential during the reporting period is due to the fact that some values are higher than unity, while others are lower. If a point in the chart is on the 45° line, covered interest parity between the euro and the US dollar is said to hold at this time. Deviations from covered interest parity have, in fact, remained small. The picture is quite similar for other currency pairs.

Empirical results for covered interest parity

The connection can be tested econometrically by regressing the exchange rate ratio on the ratio of interest factors. For the euro's exchange rate against the US dollar and the pound sterling, the validity of covered interest parity – at least for estimations without a constant – cannot be rejected (see table on page 31 and box on page 29). For other currency pairs involving the euro, too, the estimated coefficients are numerically very close to their hypothetical value of unity, as is implied by covered interest parity. However, in these cases the hypothesis of covered interest parity is rejected at the standard levels of significance owing to extremely small standard deviations.

Newey-West estimates on interest parity theories for the exchange rates of selected currencies to the euro

Month-end data, Jan 1999 to Jan 2005

	α		β		Wald test	
Currency	Estimated coefficient	Standard deviation	Estimated coefficient	Standard deviation	1%	5%
	Estimate for covered interest parity with three-month money market funds [1] $f_{t,t+k} / w_t = \beta(1 + i_t^*) / (1 + i_t) + u_t$					
Australian dollar	–	–	1.00029	3.24e-05	(–)	(–)
Canadian dollar	–	–	1.00010	3.12e-05	(–)	(–)
Swiss franc	–	–	0.99987	1.40e-05	(–)	(–)
Pound sterling	–	–	1.00004	3.40e-05	(+)	(+)
Yen	–	–	0.99976	2.87e-05	(–)	(–)
Norwegian krone	–	–	1.00030	4.69e-05	(–)	(–)
New Zealand dollar	–	–	1.00034	3.23e-05	(–)	(–)
US dollar	–	–	1.00009	5.09e-05	(+)	(+)
	Estimate for uncovered interest parity with three-month money market funds [2] $\ln w_{t+k} - \ln w_t = \alpha + \beta(i_t^* - i_t) + u_{t+k}$					
Australian dollar	– 0.00215	0.01773	0.18615	3.03614	(+)	(+)
Canadian dollar	0.00916	0.00863	– 8.25852	3.13863	(+)	(–)
Swiss franc	– 0.03424	0.01103	– 7.74007	2.87536	(+)	(–)
Pound sterling	0.01694	0.01276	– 4.06704	3.00474	(+)	(+)
Yen	– 0.03532	0.03764	– 4.76680	4.73261	(+)	(+)
Norwegian krone	0.00039	0.00927	– 0.34200	1.50384	(+)	(+)
New Zealand dollar	– 0.01462	0.01900	1.67050	2.66282	(+)	(+)
US dollar	0.00992	0.00767	– 6.52024	1.64010	(–)	(–)
	Estimate for uncovered interest parity across three-month periods under the assumption that covered interest parity holds [2] $\ln w_{t+k} - \ln w_t = \alpha + \beta(\ln f_{t,t+k} - \ln w_t) + u_{t+k}$					
Australian dollar	– 0.00233	0.01804	0.21982	2.99968	(+)	(+)
Canadian dollar	0.00923	0.00863	– 8.04463	3.07291	(+)	(–)
Swiss franc	– 0.03371	0.01073	– 7.52651	2.77882	(–)	(–)
Pound sterling	0.01682	0.01215	– 4.15311	2.90892	(+)	(+)
Hong Kong dollar	0.00873	0.00763	– 5.45580	1.37902	(–)	(–)
Indonesian rupiah	0.00498	0.01568	0.26465	0.64625	(+)	(+)
Indian rupee	0.02772	0.01312	– 1.90536	1.10059	(+)	(–)
Yen	– 0.03520	0.03802	– 4.68140	4.70591	(+)	(+)
Malaysian ringgit	– 0.00746	0.01597	– 13.38792	13.05612	(+)	(+)
Norwegian krone	0.00030	0.00921	– 0.32359	1.48095	(+)	(+)
New Zealand dollar	– 0.01564	0.01904	1.81362	2.66376	(+)	(+)
Philippine peso	0.08928	0.02667	– 4.25374	1.98802	(–)	(–)
Saudi riyal	0.13002	0.05192	– 6.51107	2.32468	(–)	(–)
Swedish krona	0.00492	0.00390	– 6.22764	2.07552	(–)	(–)
Singapore dollar	– 0.03044	0.01478	– 9.10926	3.58031	(+)	(–)
Thai baht	0.02194	0.00732	– 4.13563	1.25224	(–)	(–)
US dollar	0.01017	0.00767	– 6.45528	1.60757	(–)	(–)

For a definition of the variables, see boxes on p 29 and 32-33; in addition, 3.24e-05≡3.24x10^{-5}≡0.0000324. — **1** In the last two columns, (+) means that the null hypothesis "β = 1", according to which a Wald test confirms covered interest parity, cannot be rejected. (–) denotes rejection. Results are given for the 1% and 5% significance levels. — **2** In the last two columns, (+) indicates that the null hypothesis "α = 0 and β = 1", according to which a Wald test confirms uncovered interest parity, cannot be rejected. (–) denotes rejection. Results are given for the 1% and 5% significance levels.

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Empirical validation of interest parity theories

Covered interest rate parity states that the relation between the foreign and domestic interest factor (disregarding transaction costs) corresponds to that between the forward and spot exchange rate (see box on page 29). This theory can be tested by regressing the exchange rate ratio ($f_{t,t+k}/w_t$) on the relationship between the interest factors ($(1 + i_t^*)/(1 + i_t)$) and a constant (α):

$$\frac{f_{t,t+k}}{w_t} = \alpha + \beta \frac{1+i_t^*}{1+i_t} + u_t,$$

where u_t denotes the error term. The index k denotes the investment period for the interest-earning instruments. Confirmation of the joint hypothesis that the estimated value for the constant (α) is 0 and that the regression coefficient for the interest factor (β) is 1 would therefore be an indication that covered interest parity holds.

This null hypothesis can be checked using the Wald test for coefficient constraints. When applying such a test to different exchange rates against the euro, the hypothesis is always rejected for the usual error probabilities of 1% and 5%, although the estimated coefficients are extremely close numerically to their hypothetical values of 0 and 1. The small standard deviations are the main reason for this. As both the exchange rate ratio and interest factor are always close to 1 for the currency pairs being studied, a weakness in the regression might lie in the way influence is assigned between the constant and the interest factor. If (disregarding the constant term) the exchange rate ratio is only regressed on the interest factor, the estimated coefficients indeed differ from unity only after three decimal places, as shown in the upper half of the table on page 31. Nevertheless, the null hypothesis of a regression coefficient of 1 is generally rejected because of standard deviations that, here too, are very small; the hypothesis cannot be rejected in the case of the US dollar and the pound sterling. The test results are much the same if dollar exchange rates are used.

Much of the literature argues that regression analyses are unable to confirm covered interest parity because of the existence of transaction costs.[1,2] However, regressions can only be used to test whether interest parity holds on average. Yet arbitrage, on which covered interest parity is based, hinges on conditions at a given point in time. The quality of the data used in the empirical application is also a key factor. Interest rates have to be selected for investments which – apart from the currency in which they are denominated – are comparable in every respect, particularly maturity, the default risk and the regulatory regime. That is why interest rates on investments on the euro currency market are usually used. Care should also be taken to ensure that interest rates and exchange rates are determined simultaneously, because even small differences in the timing render it impossible to test for arbitrage opportunities and hence might cause the hypothesis of covered interest parity to be rejected.[3]

In addition, overlaps in the time horizons for the forward rates and interest rates with the data frequency provide a source for autocorrelating the error terms. As part of the regressions undertaken here, the money market interest rates and forward interest rates were observed for a three-month time horizon based on monthly data (month-end data). This gives three monthly observations within the three-month period. Therefore, the Newey and West variance/covariance estimator is used, taking into account the autocorrelation of the residuals up to the third lag.

Finally, regressions using the least squares method are only appropriate if the time series used are stationary. However, the standard tests to check for the existence of a unit root or stationarity suffer from low statistical

1 In this connection, the fact that the null hypothesis could not be rejected for a regression without a constant in the case of the US dollar and pound sterling could be interpreted as an indication of the comparatively narrow bid/offer spread in these very liquid markets. — **2** Other empirical studies dispute the assumption of the absence of restrictions of capital flows on which covered interest parity is based. These studies assume that covered interest parity holds and interpret empirically observed deviations from it as an indication of the existence of restrictions in international capital flows. See, for example, S Herrmann and A Jochem (2003), "The international integration of money markets in the central and east European accession countries: deviations from covered interest parity, capital controls and inefficiencies in the financial sector", Deutsche Bundesbank, *Discussion paper 07/03*. — **3** The interest rates on which the regressions cited here are based are middle rates on the euro/US dollar market recorded in London at 4 pm by Garban Information Services (GIS). Accord-

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power in the case of near-unit roots. Because of the combination of low variance and long memory in the data, the null hypothesis is rarely rejected. Based on these data, neither the Dickey-Fuller test nor the Phillips-Perron test are able to reject the null hypothesis of a unit root as regards the correlation between the forward and spot rate or the interest factor. Conversely, the null hypothesis of stationarity is not usually rejected by the KPSS test either. Given the diverging test results, the regressions described assume stationarity.

Uncovered interest parity requires the expected exchange rate change to approximately match the interest rate differential. Assuming rational expectations, then for it to be valid a regression in the form

$$\ln w_{t+k} - \ln w_t = \alpha + \beta (i_t^* - i_t) + u_{t+k}$$

should produce values for α and β that do not deviate significantly from 0 or 1.[4] The difference between the logarithmic spot rates is used to approximate the percentage change in the exchange rate.[5] The estimated coefficients for some euro exchange rates are shown in the middle of the table on page 31. The estimated values for β are generally negative and are often well below -1. Even so, at a significance level of 1% the null hypothesis that uncovered interest parity holds is only rejected in a Wald test in the case of the US dollar; at a significance level of 5%, it is also rejected for the relationship between the euro and the Canadian dollar and the Swiss franc. The fact that a similar null hypothesis cannot be rejected for the other currency pairs is attributable, however, to the comparatively high standard deviations which, in turn, permit a very wide range of possible coefficient values, thereby substantially reducing the statistical power of the test. This is demonstrated particularly clearly when the two interest parity theories are compared. Ignoring statistical significance, it turns out that the deviations from covered interest parity in comparison to those from uncovered interest parity are negligible in absolute terms (see also the chart on page 36).

The conclusions do not alter substantially if, assuming that covered interest parity holds, the change in the exchange rate is regressed on the swap rate. Using logarithms, the regression equation is

$$\ln w_{t+k} - \ln w_t = \alpha + \beta (\ln f_{t,t+k} - \ln w_t) + u_{t+k}.$$

As the interest rate differential has been replaced by the swap rate, such that the constraint on the congruence between interest rates and exchange rates is replaced by the requirement for congruent spot and forward rates, this approach allows us to analyse a broader range of currency pairs. The additional currency pairs – which mainly encompass exchange rates between the euro and currencies from certain emerging markets – confirm the impression that the regression coefficient is generally negative, as shown in the bottom half of the table on page 31. This is consistent with the academic literature, which holds that these types of regressions do indeed often produce estimated coefficients closer to -1 than to +1.[6] In the case of a negative coefficient, which is clearly of particular empirical relevance, the currency with the higher interest rate appreciates. Therefore, an investment denominated in this currency will on average, in addition to the higher interest, also gain from the exchange rate change. The estimated coefficients, which often exceed 1 in absolute value, in fact indicate that this exchange rate gain was frequently appreciably larger than the interest gain during the test period since the start of EMU. However, this average view masks phases during which an investment denominated in a currency with a higher interest rate ultimately resulted in a loss because of a countervailing movement in the exchange rate.

ingly, the spot and forward exchange rates were also determined in London at 4 pm by WM Company on the basis of Reuters data. The data source for interest rates and exchange rates is Thomson Financial Datastream. — **4** In addition, the error term u_{t+k} is not likely to correlate with the information available at time t. — **5** This avoids the Siegel paradox which fundamentally states that – depending on the definition of the exchange rate – the appreciation rate of one currency does not match the depreciation rate of the other. Unit root and stationarity tests regularly show that the difference between the logarithms is stationary. — **6** See K A Froot and R H Thaler (1990), "Anomalies: foreign exchange", *Journal of Economic Perspectives*, 4, pp 179-192 and C Engel (1996), "The forward discount anomaly and the risk premium: A survey of recent evidence", *Journal of Empirical Finance*, 3, pp 123-192.

Interpreting the findings

It should be noted when interpreting these results that such a regression-based test can at most check whether covered interest parity holds on average. However, the underlying theory postulates that international interest arbitraging cannot be profitable at any point in time. Moreover, the real question is not whether observed deviations from covered interest parity are statistically significant but instead whether they represent the opportunity of a risk-free profit. Yet covered interest arbitrage is profitable only if its guaranteed return exceeds the attendant transaction costs. Accordingly, observed deviations from covered interest parity which are smaller than the transaction costs associated with arbitrage trading cannot refute this hypothesis. Transaction costs are determined, in particular, by the bid-offer spread. Since this article uses interest rates and exchange rates taken as the mean from bid-offer spreads, no allowance has been made for transaction costs.[2] Moreover, the use of such middle rates may also entail approximations that distort the results. Finally, the data used here are not necessarily prices at which trades were actually transacted. The observed deviations from interest parity – after taking transaction costs into account – are more likely to indicate imperfect data than market inefficiencies.[3] On the whole, therefore, covered interest parity should be assumed to hold.

Uncovered interest parity and exchange rates to the euro

Uncovered interest parity in theory

However, an investor may still seek to make a profit from international interest rate differentials by, for instance, choosing not to hedge a transaction on the forward market. In this case, the investor's profit (or loss) hinges decisively on future changes in the spot exchange rate. A domestic investor will earn more on a US investment than on a comparable euro-area investment as long as a US interest rate advantage is not neutralised by a depreciation of the US dollar against the euro.[4] If he bases his investment decisions on this approach, he will, under these circumstances, weight his portfolio more heavily in favour of US debt instruments. If a majority of investors follows this line of thinking, the result will be a significant capital export to the United States. This will tend to have two consequences: falling interest rates in the United States, reflecting a rise in the price of the relevant debt instruments, as well as an appreciation of the US dollar, which, as long as the fundamentals remain unchanged, will engender expectations that the US dollar will depreciate. Both developments will reduce the attractiveness of US bonds and cause it to converge with the popularity of comparable euro-area investments. Uncovered interest parity therefore claims that, in the medium term, a state of equilibrium will be reached, in which the expected returns on an unhedged investment in foreign currency (but calculated in domestic currency) should match those of a comparable investment in

2 In this connection, the empirical confirmation of covered interest parity in the euro-US dollar and euro-pound sterling cases may be interpreted as a sign of high market liquidity and low transaction costs.
3 See M P Taylor (1987), Covered interest parity: a high-frequency, high-quality data study, *Economica* 54, pp 429-438.
4 The following remarks are contingent on the absence of a risk premium. This problem will be revisited further below in this article.

domestic currency (see box on page 29). Thus, an interest rate advantage of US financial investments over investments in the European market would have to be associated with an expected appreciation of the euro against the US dollar. Assuming rational expectations among market participants and foreign exchange market efficiency, moreover, the expected exchange rate movements correspond, on average, to subsequent actual movements; deviations are likely to be random.

Uncovered interest parity between the USA and the euro area

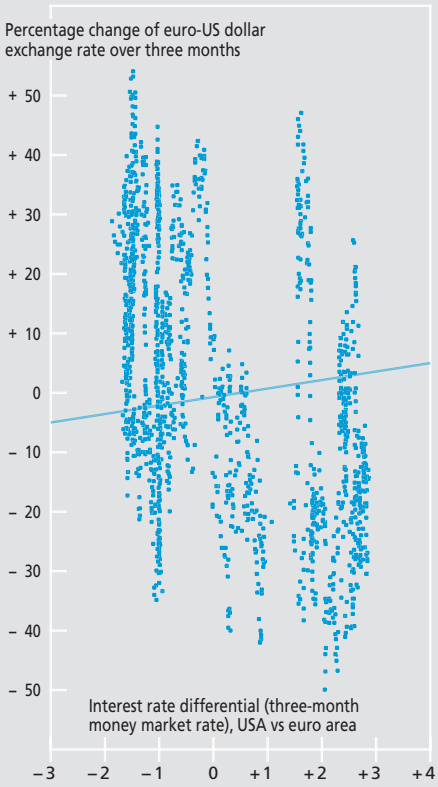
However, the euro-US dollar exchange rate has, if anything, tended to run counter to the interest rate differential: thus an interest rate advantage of US investments over euro-area investments was often followed by an appreciation of the US dollar. The exchange rate movement was, moreover, far larger than the interest spread on average. The contrast to covered interest parity could therefore hardly be more striking (see chart on page 36)

Empirical results for uncovered interest parity and their implications

The impression gained from a simple comparison of time series can only partly be confirmed through a systematic analysis, however. If, for instance, the exchange rate change is regressed on the interest rate differential and a constant, the hypothesis of uncovered interest parity can often not be rejected owing to the high variance of the values at the usual levels of significance, even though the estimated regression coefficients vary strongly from the theoretical values. What remains, however, is the empirical finding that, on average, the higher-interest currency will tend to appreciate. Similar results are reached by – assuming that covered interest parity holds – testing alternatively for uncovered interest parity by regressing the exchange rate change on the swap rate, ie on the relative deviation of the forward exchange rate from the spot exchange rate, and on a constant. It becomes apparent that the swap rate, due to the negative correlation with the interest rate differential, is not capable of correctly anticipating the direction of the exchange rate change. This means that

Uncovered interest parity between the USA and the euro area*

Daily data, 4 Jan 1999 to 30 June 2005, annualised, %



Source: Thomson Financial Datastream. — * Each individual point represents a ratio calculated from exchange rates and interest rates, each on a given trading day in London at 4 pm. For uncovered interest parity to exist, the points have to be close to the 45° line in the chart, which is very flat owing to the different scales of the two axes. Deviations should be distributed randomly.

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Theories of interest parity in empirical practice*

End-of-month levels, annualised, %

Source: Thomson Financial Datastream. — * Based on US and euro-area three-month money market rates and euro-US dollar exchange rates.

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Forward rate alone not suited to forecasting the value of the spot rate

the forward exchange rate is, by itself, not suitable for forecasting the value of the future spot exchange rate.[5] These results generally call into question the role of uncovered interest parity as a condition for international capital market equilibrium.[6]

Potential causes of deviation from uncovered interest parity

The academic literature lists time-varying risk premia and forecasting errors concerning rational expectations and heterogeneous expectations as causes of the low empirical support for the uncovered interest parity theorem. These causes are considered below.

Varying risk premia over time

If risk awareness is factored into economic agents' investment decisions, the composition of the portfolio will be shaped not only by expected returns but also by the risk structure of international investments. For foreign investments, not only default risk but also, and in particular, exchange rate risks are important. They are the factors prompting risk-averse investors to demand a risk premium. Therefore, realistically, a risk premium has to be added to uncovered interest parity, which means that, on average, a given interest rate advantage of foreign investments (and, if covered interest parity holds, the swap rate, too) exceeds the expected rate of appreciation of the domestic currency by the amount of the risk premium. The empirical findings on uncovered interest parity could then be explained by a quantitatively significant, time-varying risk premium.

However, to avoid the tautology of interpreting all deviations from uncovered interest parity as risk premia, an empirical test of the risk premium approach must be able to distinguish between the existence of a risk premium and the alternative explanatory approaches explained below, which focus on forecast errors of market participants. Various

5 This does not imply, however, that the forward rate is wholly devoid of information for exchange rate forecasts in a more general model. See R H Clarida and M P Taylor (1997), The term structure of forward exchange premiums and the forecastability of spot exchange rates: correcting the errors, Review of Economics and Statistics, 79, pp 353-361, and R Clarida, L Sarno, M P Taylor and G Valente (2002), The out-of-sample success of term structure models as exchange rate predictors: a step beyond, CEPR Discussion Paper 3281.

6 See K Lewis (1995), Puzzles in international financial markets, in G M Grossman and K Rogoff (eds), Handbook of International Economics, Vol 3, pp 1913-1971, and R Flood and A Rose (2002), Uncovered interest parity in crisis, IMF Staff Papers, 49, pp 252-266.

authors have therefore begun to approximate expected exchange rate changes by using survey data in order to isolate the influence of risk premia on the swap rate.[7] The resulting estimation results indicate that, although forward exchange rates contain risk premia, these premia do not completely explain the fluctuations in the swap rate.[8] If, in the light of this empirical finding, the risk premium approach cannot be regarded as the sole determinant of the mixed results concerning uncovered interest parity, further explanatory approaches have to focus on systematic forecasting errors.

Rational speculative bubbles

A common explanation for the lack of empirical support for uncovered interest parity, which nonetheless permits the assumption of rational expectations to be retained, is the hypothesis of "rational speculative bubbles". They are defined as exponentially increasing deviations of the spot exchange rate from its fundamental level, which is determined by macroeconomic variables. Once a bubble has formed, for example, in the foreign exchange market, the currency initially continues to appreciate because market participants, at least for some time, expect a continuing increase in exchange rates and thus also in profit opportunities. For that reason, market participants carry on investing in the currency despite being aware that this is not consistent with the fundamentals. According to this theory, bubbles burst in the end, with the spot exchange rate collapsing to its fundamental level. The general discussion of the bubble phenomenon spilled over to the foreign exchange market following the considerable – albeit temporary – appreciation of the US dollar in the first half of the 1980s. As early as 1982, most economists had come to regard the US dollar as being substantially overvalued in terms of its fundamental value. Yet market participants apparently persisted in believing in an – at least temporary – continuation of the upward trend, and so they ignored this publicly available assessment and kept investing in dollar-denominated instruments. The fact that expecting further appreciation up to the beginning of 1985 proved to be rational is regarded as evidence of a rational speculative bubble.

Because speculative bubbles are not easily distinguishable from other phenomena, there is a danger that speculative bubbles may be seen as the cause of all exchange rate movements that cannot be explained by standard fundamental variables. An evaluation of econometric studies shows that no empirical test so far has been able to conclusively prove the existence of rational speculative bubbles.[9]

The "peso problem"

A further approach to explaining forecasting errors which *ex post* appear systematic, such as may occur in the empirical findings on uncovered interest parity, was introduced to the literature as the "peso problem". This term was coined in the mid-1970s when the Mexican peso, despite its peg to the US dollar and

7 See K Froot and J Frankel (1989), Forward discount bias: is it an exchange risk premium?, *Quarterly Journal of Economics*, 104, pp 139-161.
8 An overview is provided by R Jongen, W Verschoor and C Wolff (2002), Perspectives on survey-based exchange rate expectations, Working Paper, Maastricht University.
9 See R Flood und R Hodrick (1990), On testing for speculative bubbles, *Journal of Economic Perspectives*, 4, pp 85-101 and Y Wu (1995), Are there rational bubbles in foreign exchange markets? Evidence from an alternative test, *Journal of International Money and Finance*, 14, pp 27-46.

an economic policy that looked sustainable, was consistently traded at a discount on the forward exchange market. The explanation given for this phenomenon is that market participants did not completely rule out a return to an expansionary monetary and fiscal policy, ie an economic policy that could only be associated with a depreciation of the Mexican peso. Since then, the term "peso problem" has been used to describe situations in which market participants see the possibility of a discretionary change in one or more fundamentals in the future. The influence of such potential regime shifts usually makes itself felt in the average expected future exchange rate, which, as long as the regime shift does not occur, seems to be decoupled from the actual exchange rate for the above reason, in some cases over long stretches of time. The greater the expected regime shift, and the greater the likelihood of it occurring, the larger the forecasting error will be. Once the regime shift actually occurs, the peso effect disappears again, provided no new shocks to the fundamentals are expected.

When a peso problem exists, systematic forecasting errors are, accordingly, not an expression of irrational expectations but instead reflect the rational way of taking into account possible future events. A comparison with speculative bubbles shows that both explanatory approaches are based on a distinction between several potential future exchange rate paths. However, the peso effect is affected by the dynamics of fundamentals whereas speculative bubbles are maintained by self-fulfilling expectations. The empirical work undertaken to date, however, fails to indicate that the peso effect can make a decisive contribution to explaining the observed deviation from uncovered interest parity. Such deviations are generally too large to support the theory of the peso effect being a predominant phenomenon.[10]

Learning approaches

In contrast to the peso problem, the "learning" approach[11] in exchange rate theory hypothesises that agents cannot exactly gauge the extent of change from the fundamentals or that they are not sure whether a suspected change has actually taken place. Announced changes in economic policy may serve as an example of such "shocks". In a state of uncertainty about the time path of fundamentals, market participants only "learn" the true extent of the changes by carefully interpreting the current observations. Thus, in their expectations concerning the future exchange rate, they take into account both the possibility – to stay within the example – that the regime change has taken place and the possibility that this change has not (yet) taken place. The expected exchange rate will then include both (weighted) economic policy alternatives. However, in the next period, new information about the current state of the fundamentals will be available, which means that the actual exchange rate will be much closer to the level now considered more likely than the initially expected exchange rate was.

10 See K A Froot and R H Thaler (1990), Anomalies: foreign exchange, *Journal of Economic Perspectives*, 4, pp 179-192 and M Evans (1996), Peso problems: their theoretical and empirical implications, in G Maddala and C Rao (eds), Handbook of Statistics: Statistical Methods in Finance, pp 613-646.
11 See K Lewis (1989), Changing beliefs and systematic rational forecast errors with evidence from foreign exchange, *American Economic Review*, 79, pp 79-100.

This means that the actual exchange rate may deviate from the expected rate during the time in which learning is taking place. In this case, systematic forecasting errors are not due to irrational behaviour but are a symptom of imperfect information which, depending on the type, could impact on exchange rate movements with varying degrees of permanence.

In some respects, the similarities between the peso effect and the impact of learning on exchange rate movements are strong. In the latter case, the deviation of the actual exchange rate from the expected exchange rate is eliminated gradually, and not abruptly as in the case of the peso effect. However, it seems difficult to distinguish between these two alternatives using traditional econometric techniques. In addition, there are some conceptual problems. For instance, events that can trigger learning processes cannot be directly read off the data. Moreover, it stands to reason that, owing to the numerous fundamental variables which affect the exchange rate, several learning processes will be in progress at the same time. Testing the empirical relevance of learning approaches is therefore confined to cases of significant monetary and real disruptions.

Heterogeneous exchange rate expectations

Whereas the approaches described in the foregoing maintain the assumption of rational expectations at least in the long run, a more recent branch of exchange rate theory seeks to explain deviations from uncovered interest parity by the heterogeneity of exchange rate expectations. Prompted by weak empirical support for structural exchange rate models, this school of thought holds that market participants, in real life, cannot be assumed to have complete knowledge of the true relationship between exchange rates and its fundamentals. Current foreign exchange market developments may therefore be interpreted in a variety of ways by market participants. The hypothesis of heterogeneous expectations has been tested repeatedly using survey data, with the robust finding that market expectations are based on different forecast techniques.[12] Whereas many market participants forecast short-run exchange rate movements by extrapolating past trends, thereby departing from the theoretical ideal of rational expectations, long-run exchange rate movements are forecast almost exclusively on the basis of fundamental variables. There appears to be a consensus among market participants that the exchange rate can be determined by non-fundamentals in the short run but that, in the long run, it returns to its fundamental level. This "term structure of exchange rate expectations" causes the market expectations aggregated from survey data, on average, to understate the current exchange rate trend.[13] Where survey data are actually capable of consistently reflecting agents' exchange rate expectations, it is possible to make a direct inference concerning the observed deviations from uncovered interest parity. In this theoretical approach – similar to the learning model described above – such deviations result because agents

12 See M Taylor and H Allen (1992), The use of technical analysis in the foreign exchange market, *Journal of International Money and Finance*, 11, pp 304-314.
13 See S Takagi (1991), Exchange rate expectations: a survey of survey studies, IMF Staff Papers, 38, pp 156-183 and R Jongen, W Verschoor and C Wolff (2002), loc cit.

distinguish between two regimes, thus causing the aggregate expected future exchange rate to comprise the weighted sum of the short-run and long-run forecast value.

Testing the hypothesis of heterogeneous expectations is difficult because short-run exchange rate expectations, long-run exchange rate expectations and the weights of both sets of expectations all have to be specified. This gives these empirical tests an arbitrary component which makes it more difficult to interpret the findings. Initial work that has been done up to now in this new branch of empirical research has shown, however, that the hypothesis of heterogeneous expectations can often not be rejected.[14]

Deviations from uncovered interest parity not fully explained by theoretical approaches

One interim result of the foregoing discussion of exchange rates and interest rate differentials is that arbitrage trading on integrated international capital markets will generally ensure that covered interest parity holds. By contrast, the postulation of uncovered interest parity as a condition of equilibrium in international capital transactions is mostly called into question despite the fact that it often cannot be rejected using the standard econometric tests. In practice, this may create significant profit-making opportunities on foreign exchange markets. One strategy used by international investors to make a profit from persistent deviations from uncovered interest parity is the currency carry trade.

Currency carry trade strategies

The currency carry trade strategy

A currency carry trade involves borrowing funds in a low-interest currency and investing them in a high-interest currency. Such trades are not hedged (on the forward exchange market, for instance) because – according to covered interest parity – this would preclude any chance of a profit whatsoever.[15] This means that the carry trade is speculative, with the profit depending crucially on actual exchange rate movements over the investment period. If the exchange rate does not change, the yield on the carry trade is equal to the interest rate differential. If uncovered interest parity holds, the interest income would be offset by a loss caused by the depreciation of the higher-interest currency, in which case a carry trade strategy would not make any sense. If, however, the higher-interest currency appreciates, the total profit from the carry trade will supplement the interest rate advantage by the margin of the favourable exchange rate change.

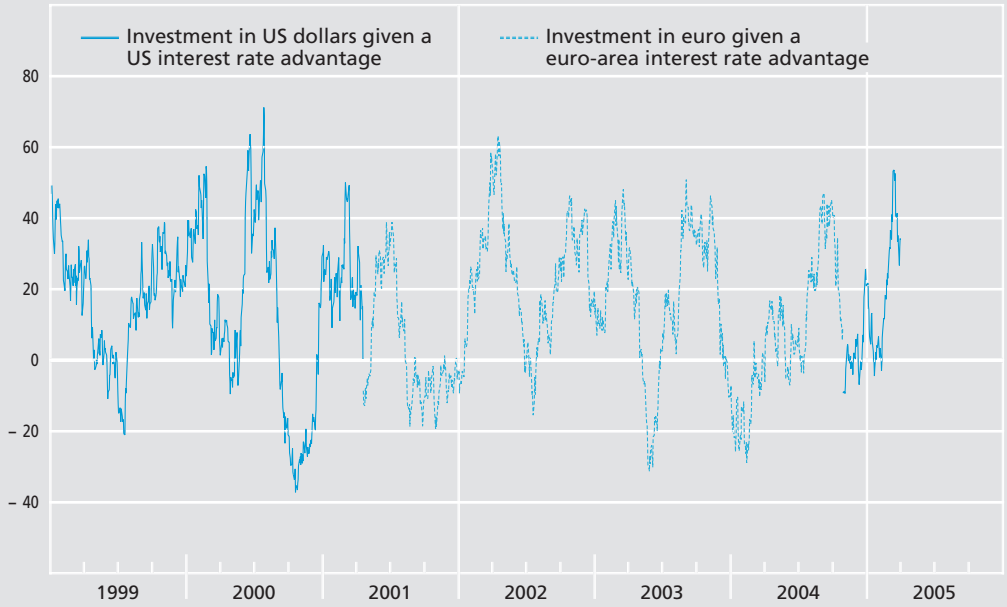
Carry trades between the USA and the euro area

The chart on page 41 shows the annualised returns of a carry trade investment strategy in three-month money market funds which a euro-area investor would have achieved if his investments had been oriented solely to the interest rate differential between the euro area and the United States known at the time of the investment. As outlined above in the section on the empirical testing of uncovered interest parity, a higher-interest currency

14 See R Ahrens and S Reitz (2005), Heterogeneous expectations in the foreign exchange market, *Journal of Evolutionary Economics*, 15, pp 65-82.
15 An option-based hedge, though conceivable, would diminish the expected return.

Return on hypothetical currency carry trades*

Daily data, annualised, %



* In a currency carry trade (CCT), an investor borrows funds in a low-interest currency and invests them in a higher-interest currency. The return was calculated for euro-US dollar CCTs on investments in three-month money market funds from the point of view of euro-area investors.

Deutsche Bundesbank

Potential exchange rate implications of carry trade strategies

tends to appreciate rather than to depreciate. Consequently, the carry trade strategy between the euro area and the United States would have achieved an average annualised return of 15% since the start of European monetary union, several times the interest rate differential. The return is thus largely determined by relatively sharp fluctuations in exchange rates. The chart also indicates, however, that the returns vary considerably from month to month. Although peaking at 71% in the extreme, the returns can also be clearly negative over a period of up to several months. This highlights the speculative character of carry trades.

An important question, however, is whether the return calculated for hypothetical carry trades is perhaps itself partly the result of actual carry trades. Exchange rate movements, after all, are likely to be affected by financing and investment decisions taken by international investors. Shifting funds borrowed in a low-interest currency into a higher-interest currency should tend to cause the latter to appreciate. The carry trade could thus generate an exchange rate movement that ultimately helps it to become profitable. In addition, the observation that a currency in which interest rates were already higher is also tending to appreciate could encourage international investors to initiate additional carry trades, which could then lead to a protracted exchange rate trend.

Conversely, the unwinding of a carry trade generally leads to a depreciation of the higher-interest currency and reduces the re-

turn on outstanding carry trades. If the exchange rate change that then emerges is viewed as a trend reversal, more investors might feel the need to unwind their carry trades, thereby accelerating the depreciation process: the more carry trades are unwound, the larger the depreciation, and the less sustainable the positions of those investors who are still holding on to their carry trades. Accordingly, one agent's investment behaviour has an externality on other agents' strategies, ie the agents' strategies are interdependent. If this leads to general selling pressure, then, according to theoretical models, bottlenecks and exaggerated exchange rate reactions could occur even on relatively liquid markets. [16]

Absence of empirical evidence

On foreign exchange markets, exchange rate dynamics are repeatedly attributed to the execution or reversal of carry trades. However, it is nearly impossible to quantify the impact of carry trades on the exchange rate. It would be particularly interesting to find out the link between exchange rate movements and the portfolio allocations of hedge funds, which are often named as actors that pursue carry trading strategies. However, the requisite data are not available. Moreover, carry trades can be carried out with a variety of instruments, which is why they are difficult to identify among international financial transactions – such as are recorded, for instance, in the balance of payments. [17]

Conclusion

Exchange rate and interest rate differentials: their importance to central banks

In practice, the links between exchange rate movements and interest rate differentials are much more complex than is usually assumed in simple models. Deviation from (uncovered) interest parity seems to be the rule rather than the exception. As this article has shown, this also applies to the period since the introduction of the euro. To date, the hypotheses discussed in the literature have been incapable of providing a satisfactory explanation for this phenomenon. Carry trades are therefore a possibility – albeit a highly speculative one – of exploiting deviation from uncovered interest parity.

Carry trades can be significant for central banks in several ways. They can extend the leverage of interest rate policy measures to cover the exchange rate channel, thus making it more effective. However, they can also amplify exchange rate swings in a potentially undesirable manner. They therefore represent a particular challenge to monetary policy makers, to market agents' risk management practices and to financial market and banking regulators and supervisors.

16 See S Morris and H S Shin (1999), Risk management with interdependent choice, Oxford Review of Economic Policy, 15, pp 52-62.
17 See Bank for International Settlements (1998), Carry trade strategies, in *International banking and financial market developments*, February 1998, p 23.