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ABSTRACT

One and three-month forward exchange rates for the deustche mark, french franc, sterling pound, yen and peseta, relative to the US dollar, seem to be cointegrated with *future* spot rates, but not with *current* exchange rates. We confirm the *unbiasedness* hypothesis for this data set, as a robust cointegrating relation between forward and *future* spot rates, although forward rates are poor predictors of future exchange rates.

We also argue that the behaviour of exchange rates seems to be quite consistent with unpredictability of exchange rates at one and three-month horizons. Forward rates seem to be rather *passive*, mostly reflecting current exchange rates, rather than anticipating future exchange rates fluctuations. These results suggest that reducing the analysis of the information content of forward rates to cointegration tests with current and future exchange rates would be misleading.

We find some evidence of a risk/term premium but, being of minimium size, suggests that recent arguments on the inefficiency of currency markets are theoretically sound, but of minor empirical relevance.

1. INTRODUCTION

Currencies have gradually become some of the more liquid and actively traded assets in spot markets as well as in markets for derivatives, so understanding price determination in them is now a crucial issue in theoretical finance. Consequently, analysis of the dynamic relation between spot and forward currency prices has been a central subject of empirical work on exchange rates for a number of years, although there is still a continuing debate on some of the important characteristics of their joint fluctuations.

Some of these studies have devoted their attention to the unbiasedness hypothesis of the forward exchange rate. Domowitz and Hakkio (1985) reject the unbiasedness hypothesis of the forward exchange rate for most of the currencies they analyze. They also find evidence of non-constant risk premia in some cases. Ayuso, Dolado and Sosvilla-Rivero (1992) use cointegration techniques to also reject the unbiasedness hypothesis. They find evidence of existing time-varying risk premia, although they seem to be negligible. In a similar line McFarland et al. use the Phillips and Hansen procedure (1990) to reject the unbiasedness hypothesis in three of the five currencies they consider. On the other hand, Sosvilla-Rivero and Park (1992) present Wald tests, fully modified via semiparametric corrections to take into account serial correlation and argue in favour of the unbiasedness hypothesis at the one-month horizon in most cases. They find evidence to be less favourable to the hypothesis at longer maturities. Overall, empirical evidence seems to be against unbiasedness of forward exchange rates.

Whether or not currency markets are efficient is a second, broader issue, on which contrary evidence is continuously brought up from different markets. Taking a two-county asset pricing model as starting point, Hakkio and Rush (1989) focus their attention on the cointegration properties of forward and future spot rates, finding evidence against efficiency both for sterling pound and deutsche mark. Frankel (1987) specifies ARCH models for time-varying risk premiums. Baillie and Osterberg (1991) specify a GARCH-in-mean model to evaluate the possible risk premium, analyzing the impact of Central Bank interventions. A different approach is followed by Kaminsky and Peruga (1990), who use a standard intertemporal equilibrium asset pricing model as a benchmark and use a GARCH-in-mean methodology, to obtain evidence of non-zero risk premiums, being a function of the probability of a regime change. Gokey (1991) argues that risk premiums are unobservable and time-varying, being their variability close to the exchange rate volatility. Bergés and Manzano (1990) support the null hypothesis of efficient markets, while Hansen and Hodrick (1980), Hakkio and Rush (1989) and Ayuso, Dolado and Sosvilla-Rivero (1992) argue against efficiency due to the rejection of unbiasedness. Crowder (1994) also argues on the inefficiency result but on a different basis, the existence of common stochastic trends in exchange rates and a unit root in the forward premium. By and large, empirical results lead to inefficiency, even though Ligeralde (1994) suggests that the inefficiency result can sometimes be spurious, coming "from the choice of band covariance estimators that are only asymptoticaly valid".

We examine in this paper daily data on spot and 1 and 3 month forward prices for the yen, german mark, sterling pound, french franc, and spanish peseta, all relative to the *US* dollar, from january 1990 to april 1996. We relate forward rates both, to the future spot rates they are supposed to proxy, and also to the current exchange rate. In the first relationship, we a) test for unbiasedness, and b) examine possible evidence of risk or term premia. The second relation helps us discussing whether forward rates depart from current rates, anticipating future exchange rates fluctuations or, rather, they stay close to current rates, not being able to anticipate much of future fluctuations. Rather than reducing efficiency to a test of unbiasedness, we use those results, together with our conclusions on possible term/risk premia to evaluate efficiency.

The rest of the paper is organized as follows: we discuss concepts and tests related to market efficiency in Section 2, and present our data set and stationarity tests for spot and forward exchange rates in Section 3. Section 4 contains the analysis of the joint dynamics of forward and future spot rates, while section 5 contains the results on current spot and forward exchange rates. In section 6 we analyze the role of expectations on the formation of forward rates, and we close with some conclusions.

2. THE EFFICIENCY HYPOTHESIS OF EXCHANGE RATE FORMATION

The standard approach developed by Fama (1984) to price formation on futures markets envisions forward exchange rates as embracing current expectations of future spot exchange rates plus a possible risk premium:

$$F_t^k = E_t\, S_{t+k} + \pi_t^k \qquad [1]$$

where F_t^k denotes the forward rate at time t for period $t+k$, S_t is the spot exchange rate, and π_t^k is a *risk premium* paid at t on forward transactions maturing at time $t+k$. Under rationality of expectations, which we take for granted, E_t denotes the conditional expectation operator. Expectations are not observable, but [1] can be transformed into:

$$F_t^k = S_{t+k} + \pi_t^k + (E_t\, S_{t+k} - S_{t+k}) = S_{t+k} + \pi_t^k - \varepsilon_{t+k}^k \qquad [2]$$

where ε_{t+k}^k, the k-period ahead rational expectations error follows a $MA(k$-1) stochastic structure [Hansen and Hodrick(1980)]. The difference between current forward and *future* spot exchange rates:

$$F_t^k - S_{t+k} = \pi_t^k - \varepsilon_{t+k}^k \qquad [3]$$

is the *ex-post realized premium*, being the sum of the risk premium, if it exists, and the expectations error, with a minus sign. Whether risk premia exist in forward currency markets is still open to debate. They would not exist in a world of risk neutral traders, but risk aversion of traders and investors in general is a well accepted working hypothesis. If there is a systematic risk premium, it should be expected to be positive so, under rationality, future spot exchange rates will be below current forward rates on average.

We can also transform [1] into:

$$F_t^k - S_t = \left(E_t S_{t+k} - S_t\right) + \pi_t^k = (S_{t+k} - S_t) + \pi_t^k - \varepsilon_{t+k}^k \qquad [4]$$

showing that the *forward premium*, i.e., the difference between forward and *current* spot rates, is the sum of expected appreciation/depreciation and the *risk premium*. Alternatively, the *forward premium* is the sum of actual currency appreciation/depreciation, the risk premium, if it exists, and the expectation error in future spot rates with a minus sign. If a risk premium exists, it should lead to a *forward premium* above expected appreciation/depreciation, on average.

Forward and *ex-post realized premia* are related in an obvious way, which will be helpful for our future discussion:

$$F_t^k - S_t = \left(F_t^k - S_{t+k}\right) + (S_{t+k} - S_t) \qquad [5]$$

the *forward* premium being above (below) the *ex-post* premium in periods when the currency experiences depreciation (appreciation).

Forward markets are said to be *efficient* when current forward prices summarize all available information which is relevant to predict spot exchange rates at maturity. Whether risk premia exist is then central to tests of efficiency since, if they existed, they could be used to improve forecasts of future exchange rates based on just current exchange rates [see [1]]. An extended view on price formation in forward markets, the *expectations hypothesis*, postulates that there is no risk premium embedded in forward rates, the difference between future spot prices and forward exchange rates being a pure expectation error. Indeed, if we set π_t^k to zero in [2], we get:

$$F_t^k = S_{t+k} - \varepsilon_{t+k}^k \qquad \textit{that is:} \qquad S_{t+k} = F_t^k + \varepsilon_{t+k}^k \qquad [6]$$

so that in a regression of future spot on current forward rates at the appropriate horizon:

$$S_{t+k} = \beta_0 + \beta_1 F_t^k + \varepsilon_{t+k}^k \qquad [7]$$

we would have no significant constant, and a slope equal to one: H_0: $\beta_0 = 0$, $\beta_1 = 1$, the error term in the regression being the currency prediction error. This restriction, together with an appropriate serial correlation structure for the error term in [7], is known as the *unbiasedness hypothesis,* which is a necessary condition for efficiency. Prediction errors at long horizons k might produce notorious deviations between S_{t+k} and F_t^k but, being unpredictable, they should not have any systematic component, nor could they be used to improve trading strategies. Because of the accumulation of forecast errors over a long k, unbiasedness does not guarantee that the forecasting ability of forward rates to predict future spot rates is any good.

In spite of not being equivalent to each other, unbiasedness and efficiency have traditionally been so identified with each other, that markets are usually said to be *strongly efficient* when the unbiasedness condition holds. If a constant risk premium existed, it would show up as a significant constant in [7], but a unit coefficient in forward rates in that regression would still be an interesting proposition, consistent with current forward rates containing all available information on future spot rate fluctuations. This has usually been known as *weak efficiency*. With a time varying risk premium, orthogonal to forward prices, we might still have a unit slope in [7], but the forecasting ability of forward rates would deteriorate. However, since a possible risk premium should be expected to show some positive correlation with the forward rate, it was believed for a number of years that a bias in the estimated slope towards the origin would arise. Tests of the *unbiasedness hypothesis* were then considered to be efficiency tests, in the sense that if the unbiasedness hypothesis was rejected, that would indicate a time varying risk premium correlated with forward rates and hence, unexploited predictability in available information other than current prices, suggesting market inefficiency.

However, there is now overwhelming evidence showing exchange rates to be non-stationary [see Hsieh (1986), Milhoj (1987), Hakkio and Rush (1986), Sosvilla-Rivero and Park (1992), McFarland, McMahon and Ngama (1994), among many others], so analyzing [7] as a possible cointegration relation between forward and future spot rates, as well as using a well justified procedure to test for a unit slope has become a standard approach in testing for efficiency. In this context, efficiency tests based on unbiasedness lose power: superconsistency of the least-squares estimator under cointegration precludes the slope in [7] from deviating from 1 even when there is a time varying risk premium, so long as it is stationary[1]. Hence, evidence on F_t and S_{t+k} being cointegrated with a slope not significantly different from 1 may be consistent with a stationary time varying risk premium, as pointed out by Ayuso, Dolado and Sosvilla-Rivero(1992). In those conditions efficiency tests should not be based on the necessary *unbiasedness* condition, and different strategies are needed. Given this ambiguity, we hope to reach in this paper some evidence on efficiency and related issues on the basis of a broad set of statistical properties and moments of the series of spot and forward exchange rates, and their spreads.

3. THE DATA

We work with daily bid and ask quotes for spot and 1 and 3-month forward exchange rates for the german mark (*DM*), french franc (*FF*), *UK* sterling pound (*SP*), spanish peseta (*Pta.*) and yen (*Yen*), all relative to the *US* dollar. Part of our study is made matching each forward exchange rate with the corresponding spot rate at maturity of the forward contract. To each one month (three months) forward rate we associate the spot rate corresponding to the same day of next month (three months hence). If that falls on a weekend or holiday, we go to the next working day. Several forward contracts could then correspond with the same future spot rate, in which case, we would drop all forward contracts except the last one, as it is usually done in this type of studies [see Baillie and Osterberg, 1991]. We use spot prices between january 1, 1990, and march 30, 1996, but our sample for forward rates starts in october 1, 1989 to allow their matching with spot rates. Spot quotes were taken from the Madrid official market, whereas forward exchange rates came from the London market, all of them between 1:30 and 1:45 PM. We have 1,518 observations for spot and forward rates, but only about 1,024 for one and three months matched forward rates. We had in all cases a few observations less for the peseta, due to some missing forward rates data.

We performed our analysis both in levels and in logarithms, without

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[1] Even though if it is stationary, it will not show a strong correlation with a non-stationary forward rate.

any noticeable difference in results[2]. Using bid or ask quotes also produced extremely similar results. Graphs and numerical results in this paper all refer to *logs of bid quotes*. Figure 1 presents the five spot exchange rates, with clear evidence of nonstationarity in all cases, sometimes in the form of the series wandering around a local mean, like the deutsche mark and french franc, which show a very similar time pattern. The sterling pound and the peseta have a behavior very similar to the mark and french franc in the first half of the sample, showing a jump in their mean in the second half. The yen follows a totally different pattern, with a decreasing trend over the sample period.

Were we to present similar graphs for the one and three-month forward rates for these five currencies, the reader would not be able to distinguish them from those in Figure 1. For any given currency, the two forward rates are very close to each other and to the spot rate at each point in time. As an example, Figure 2 exhibits the three month-forward rate for the deustche mark, shifted in time to the maturity of the contract. In each case, the shifted forward rate noticeable differs from the future spot rate [the vertical distance in Figure 2], being very similar to the current spot rate. Totally similar graphs and properties arise for one-month forward rates and other currencies. This observation already suggests, as we will later see, that forward rates at any horizon are more closely related to current than to future spot rates.

Empirical evidence on non-stationarity of exchange rates is widespread. Table 1 shows Augmented Dickey-Fuller (*ADF*) statistics to test for the presence of one and two unit roots in spot and forward exchange rates in our sample. The augmented version of the test is needed, since there is substantial autocorrelation in the first differences of this daily data, against a possible pure random walk structure in them. The left pannel shows that, in all cases, the null of two unit roots is clearly rejected in favor of the alternative of a single root. The right pannel shows that spot and forward prices seem to be $I(1)$, since at the 99% confidence level, the null of a unit root is not rejected for any price

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[2] But the log transformation avoids Siegel's paradox [see Sosvilla-Rivero and Park(1992), for instance].

series. Hence, spot and forward exchange rates seem to be non-stationary, while their daily changes are stationary. The number of lags used in each case is shown in the table, and it was chosen so as to get rid of residual autocorrelation. Results are not sensitive at all to this choice.

Reasons of different nature suggest that forward exchange rates may move closely together with both, spot exchange rates at the time of maturity of the forward contract, and also with current spot rates. We sequentially examine each one of them in the next two sections.

4. THE JOINT BEHAVIOR OF FORWARD AND FUTURE SPOT CURRENCY RATES

4.1 Cointegration between forward rates and future spot rates.

The *expectations hypothesis* on forward markets in currencies implies absence of any risk premium, differences between each forward rate and the correspondingly shifted spot rate being then just equal to the forecast error [see [6]], which is stationary. Hence, the two exchange rates must be cointegrated with coefficientes [1,-1]. The *strong* version of the *unbiasedness hypothesis* is that the cointegrating vector be as noted, with no significant constant term. A constant risk premium would show up as a significant constant in the long term relation between forward and future spot rates, maintaning the same cointegrating vector, against the strong version of the expectations hypothesis, but possibly in consonance with its *weaker* form.

Table 2 shows the results of cointegration tests between current forward rates and *future* spot rates, where forward rates have been shifted in time so as to coincide in time with spot rates at the date of maturity of the forward contract. A constant was included in the Engle-Granger type of regressions [left pannel in Table 2]. A deterministic trend was never needed to achieve stationarity of the residuals and, when tried, it never turned out to be significant. These long-term regressions between forward and future spot rates produce slope coefficients close to, but below 1, for the one-month forward rate, being even lower for the 3-month forward rate. One might conclude that the efficiency hypothesis does not seem to hold, according to these estimates.

Durbin-Watson statistics (*DW*), as well as Augmented Dickey-Fuller (*ADF*) statistics on the residuals of these regressions, to test whether they can be interpreted as cointegrating relationships, throw some contradictory evidence: *DW* statistics in Table 2 do not reject absence of cointegration, while *ADF* tests suggest the contrary. Given the consensus on the fact that *DW* tests are prone to have low power, we interpret these results as providing general evidence in favor of cointegration between forward and *future* spot rates, although against the unbiasedness hypothesis. In the framework of model [2], that would suggest the existence of a time varying and non-stationary risk premium, so this rejection is a potentially important result.

Johansen tests show, on the other hand, strong evidence of cointegration between the two forward rates and *future* spot rates. All entries in column 6, Table 2, show a very high and significant first value of the trace statistic, and a very low and non-significant second value, clearly indicating the existence of a single cointegrating relationship between spot rates and either one or three-month shifted forward rates. No constant was included in the *VAR* system in first differences when implementing the maximum likelihood estimation procedure suggested by Johansen (1988 and 1991), because it would never turn out to be significant. That, by itself, would lead us to believe that if a risk premium exists, it has a time varying nature. We included four lags in the *VAR*, which seemed to take care of residual autocorrelation in all cases. The statistics obtained were not very sensitive to the choice of lag length, but important residual autocorrelation remained when less lags were used.

A noticeable difference arises when comparing the results of the two cointegration tests. Contrary to the results in Engle-Granger regressions, slope coefficients are estimated to be very close to one by the maximum-likelihood method proposed by Johansen [as in Obstfeld(1991), Hansen and Hodrick (1980), and Hakkio and Rush (1989)]. In all cases, the unit slope falls inside two standard deviations of the maximum-likelihood estimate, both for the one and the three-month forward rate comparison with future spot rates, and in seven out of the ten cases, the unit slope is inside one standard deviation of the estimate.

Gonzalo (1994) has provided reasons why Engle-Granger type of estimates may be biased. Under the prior assumption that forward markets are efficient, one should place a heavy weight on the maximum-likelihood estimates, and admit the mentioned bias. As a summary, the mixed image emerging from the Engle-Granger type of analysis becomes, with maximum likelihood estimates, clear-cut evidence in favor of *unbiasedness* of the forward market, with the forward exchange rate being an unbiased predictor of the spot rate.

4.2 Is there any risk premium in forward currency markets?

Once we accept the cointegrating vector to be (1,-1), then the *ex-post* premium, the difference between forward and future spot exchange rates, the *ex-post* premium, $F_t^k\text{-}S_{t+k}$, which is the sum of the expectation error and any risk premium that may exist [see [3]], is stationary, and can be statistically analyzed. We perform in this section two tests on non-existence of a risk/term premium in exchange rates. First, under rationality, expectations errors in [3] have zero mean so, significance of the sample mean of the *ex-post* premium would suggest a possible risk premium. A second test is based on the autocorrelation function of the difference $F_t^k\text{-}S_{t+k}$: under rationality, the expectation error is the sum of the innovations between t and $t+k$ and hence has a $MA(k\text{-}1)$ structure so, any significant autocorrelation in $F_t^k\text{-}S_{t+k}$ beyond k periods should be interpreted as coming from a very persistent risk premium.

Ex-post premia graphs for the five currencies (Figures 3 and 4) show the type of patterns that should be expected. The *MA* component[3] should produce long autocorrelation patterns that, in fact, show in the graphs, and also arise in the estimated autocorrelation functions, which we do not

[3] $MA(k)$, with k around 13 for the 1-month forward rates, and around 39 for the 3-month case. Our matching of spot and forward rates makes us lose some observations, which explains why the number of available monthly data points is below 20.

reproduce. There is also a clear indication of a longer autocorrelation structure for the 3-month than for one-month differences.

Spreads between forward and future spot exchange rates have sample means of 0.422, 0.187, 0.472, 0.459, and 0.281 for the mark, pound, french franc, peseta and yen, respectively, with t-ratios between 1.7 and 4.7 in the one-month horizon, and between 4.1 and 10.9 in the three month case. They amount to annualized premiums of 1.4% for one-month contracts on the yen, and between 2.1% and 8.6% for european currencies, with three-month estimates being again somewhat lower: 1.5% for the yen and between 1.9% and 6.7% for the rest. All these estimates indicate the existence of non-zero risk premia in all currencies and horizons.

To avoid posible biases produced by outliers, the left pannel in Table 3 shows median values, as well as their approximate t-statistics, obtained using the standard deviation of the sample mean. Forward exchange rates are, on average, above future spot rates for all currencies and horizons, with annualized median *ex-post* premiums higher than those obtained from mean values[(4)], being of 3.0% for one month contracts on the yen, but bigger, between 6.3% and 14.0%, for the european currencies, with large t-ratios. Specially higher was the premium on the peseta over this period. With the exception of the yen, annualized median premiums on 3-month investments were somewhat lower, between 3.6% and 12.1%, suggesting that there is an additional exchange rate risk involved in frequent reinvestment because of changing currency prices.

Because of the long serial correlation structure that arises from the rational expectations error [see [5] and footnote (3)], we may want to estimate unconditional means for *ex-post* premia using a proper autocorrelation representation. That structure would be hard to estimate precisely, due to colinearity between its many parameters, but it might be possible to approximate it by an AR model for all practical purposes. In fact, we have found that the time series for *ex-post* premia can be

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(4) Most likely because of some large negative forward-spot rates differences.

reasonably well approximated by an $AR(1)$ structure with a coefficient close to one for all currencies. Such a representation produces somewhat permanent effects, as corresponds to a long *MA* process. We estimated $AR(1)$ coefficients of 0.928, 0.938, 0.929, 0.933 and 0.940 for the one-month *ex-post* premiums on the deutsche mark, sterling pound, french franc, peseta and yen, respectively, with no evidence of residual autocorrelation in any case. The unconditional means arising from these estimated autoregressive processes were 0.318, 0.107, 0.375, 0.353 and 0.250 for the same currencies, close, but somewhat below, those obtained ignoring serial correlation. This similarity in the means is quite surprising given the lack of precision in the estimation of the constant term in the autoregression, but we prefer the risk premium estimates that emerge from median values in Table 3.

To implement the second test, we estimated a regression of time t on time $t-j$ *ex-post* premia, for $j \geq k$, to analyze the persistence of its serial correlation. This is quite a strict test for existence of a risk premium, since we jointly test not only for a risk premium to exist, but also for its persistency, a transitory risk premium not being detected through this autocorrelation test.

Table 4 shows the results of such a regression, for the one-month forward rates. Standard errors have been corrected for serial correlation by Newey-West method. Since the number of observations per month is not constant, with an average between 13 and 14 data points/month, we estimated regressions for lags j = 13, 15, 17 and 19, trying to cover all possibilities. The results in Table 4 consistently show coefficients decreasing in value and statistical significance as we move to farther lags. The R-squared statistic decreases while the residual standard deviation tends to increase with the lag length. Estimated coefficients decrease in the pattern of powers of a given number, exactly what we should expect out of the $AR(1)$ approximation we proposed before for the difference F_t^k-S_{t+k}, which seems to work fine even after so many periods. If we recover these possible underlying $AR(1)$-coefficients out of the regressions in Table 4, we have values close to 1, and very similar across currencies, being of approximately .884, .890, .877, .881 and .907 for the mark, pound, franc, peseta, and yen, a bit lower than those estimated for the previous $AR(1)$ models. The last column in the table contains the same autoregression, estimated with the data exactly covering one month span, rather than using the approximation of a constant lag. The low coefficients in the table suggest, as it is the case, that these autoregressions are of essentially no help to improve forecasts. There seems to be significant autocorrelation at long lags, although the last column, with an exact matching of data points, shows that to be the case just for the franc and the peseta[5].

Given that we have not imposed any structure in these regressions, it is quite amazing that so consistent patterns arise, not only for each currency over the different number of lags, but also across currencies. In summary, we obtain some weak evidence of significant correlation beyond what we should expect to detect if the difference F_t^k-S_{t+k} was a pure expectations error. With the remainder that this is a very demanding test for the existence of a risk premium, we must conclude that there is evidence that risk premia exist in one month forward exchange rates, and seems to be of quite a permanent nature.

Not surprisingly, this kind of evidence does not arise in three-month contracts. We have to use the 39th lag as the explanatory variable in the regression analogous to that in Table 4, and such power for any $AR(1)$ coefficient below one is essentially zero, in spite of the fact that sample mean and median values are clearly significant and provide evidence of risk premia.

In summary, we have first shown in this section that the unbiasedness hypothesis of forward prices holds for the *DM, FF, SP, Pta. and Yen*, forward prices moving in long-run coordination with spot prices at maturity, so that the difference between them seems to be stationary. However, with nonstationarity exchange rates, this is not strong evidence in favor of efficiency. Contradicting efficiency, we have also found evidence in favor of the presence of a persistent, time varying *risk or term premia* in forward currency markets, even though the length of the time

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[5] Exactly matching the data, which is not always done in empirical work, seems to make a difference in this type of tests.

period involved suggests that any possible forecasting gain from trying to exploit this persistence would be negligible.

5. THE JOINT BEHAVIOR OF FORWARD AND CURRENT SPOT PRICES

There are also reasons to believe that forward rates might not differ much from current spot rates. According to [4], if: a) there is no risk premium, and b) exchange rate expectations satisfy: $E_t S_{t+k} = S_t$, then the *forward premium* should be zero. With our overlapping data, b) will hold for any autocorrelation pattern extending to less than 13 periods. In summary, in the absence of risk premia, and if spot rates show a short autocorrelation structure, then we should not detect any significant forward premium, and forward exchange rates would be equal to current spot rates.

The right pannel in Table 3 shows median values and approximate t-statistics for percent forward premiums. On average over the sample period, there was a forward premium for one and three-month investments in the four european currencies, which was between 2% and 3% for the mark, french franc and pound, but higher, between 7% and 8% for the peseta. There was a small, negative premium for investing forward in yens. Forward premiums are very similar for both maturities, being statistically significant for all currencies, although well below *ex-post* premiums.

A negative forward premium for the yen is hardly surprising, given the continuous appreciation experienced by this currency over the sample period. In this case, the expected depreciation term more than compensates the possible risk premium. The estimated mean of 0.2835 is slightly above the product of the number of observations per month, which is around 13, times the average daily change in the yen/dollar exchange rate over the sample, which we estimated at 0.0200. That suggests, again, that a risk premium may exist in the yen, but of a very small magnitude, since forward premia are similar to realized depreciation. The other currencies did not experiment any systematic appreciation or depreciation trends, their estimated daily mean changes being negligible. For them, a significant, positive forward premium was being paid. However, as we are about to see, not much emphasis can be placed on sample averages of forward premia, since they are not stationary.

Table 5 presents the results of cointegration tests between forward and *current* spot exchange rates. At a difference of the comparisons with future spot prices, estimated slope regressions of forward on contemporaneous spot rates are close to 1 for both maturities, both in least squares and maximum-likelihood estimation. However, it is nor clear what these estimates mean, since the *ADF* statistics on Engle-Granger residuals, a well as Johansen's trace statistics show ample evidence of lack of cointegration between both series, except for the yen/dollar exchange rate, for which the evidence is not conclusive.

Figures 5 and 6 present *forward premiums* for the five currencies. There is indeed clear evidence of nonstationarity in all cases, but of a different kind across currencies. None of them seems stationary in the mean, which is specially clear in the case of the deutsche mark, and all have small but significant means[6]. Time trends, *U*-shape paterns and persistence are all quite evident. Changes in the mean are smaller for the peseta, which experiences a number of transitory jumps. Forward premiums for the deutsche mark, franc and peseta increased in the first part of the sample, decreasing later on. Finally, even though the shapes of differences to the one and three-month forward exchange rates are very similar, they are systematically twice as large for three than for one-month forward rates.

Given the cointegration between forward and future spot rates one might expect to find a similar cointegration result between forward and current spot rates. Given that this is not the case we considered convenient cutting the sample in those periods in which different patterns in forward premiuns appear as can be seen in Figures 5 and 6. The japanesse yen seems to be the only currency in our study without clear different patterns in the sample. Accordingly, we decided not to make any subsamples in this case. However, the remaining currencies exhibit

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[6] Being non-stationary, their *t* values in the right pannel of Table 3 are not justified.

different behaviours along the sample, and the changes from one pattern to another seem to take place around the turbulences in september 1992 and august 1993, being the latter the date when the EMS fluctuation bands were widened.

The analysis by subsamples, which we do not present here, basically offers the same cointegration results between forward and future spot rates, although this relation is weaker than in the whole sample case. Moreover, the slope Engle-Granger estimates present the above mentioned downward bias in comparison with those of Johansen, which are closer to one. Nevertheless, the no-cointegration result between forward and current spot rates does not seem to hold in some cases when estimating by subsamples. However, even when we reject the null of no cointegration time trends in the residuals are clearly detected. On the other hand, a quick look to the residual charts support the existence of a unit root or even a time trend, which in practice is very difficult to distinguish from a stochastic trend. All this evidence take us to conclude that the main results obtained with the whole sample do not basically change when using subsamples and, accordingly, the same conclusions seem to hold.

The cointegration tests in the last two sections could be taken to suggest that forward rates move closer to future spot rates than to current spot rates. However, we argue in the next section that such an interpretation would be misleading, given the magnitud of the spreads between forward rates and both, current and future spot exchange rates. Forward exchange rates are not cointegrated with current exchange rates, from which they seem to experience permanent deviations, but these discrepancies are minor, to the point of making that lack of cointegration essentially irrelevant for exchange rate market operations. On the other hand, they are cointegrated with future spot rates, but cannot used as practical predictors of them. These results illustrate that reducing the analysis of forward exchange rate determination to a discussion of its possible cointegration with current and future spot rates might be totally inappropriate.

We close this section with a statistical paradox: if exchange rates S_t are $I(1)$, then [5], shows that the fact that F_t^k-S_{t+k} is $I(0)$ implies that the forward premium F_t^k-S_t should also be $I(0)$. That such is not the case is contradictory with the previous results of our cointegration tests. One possibility is that the nonstationarity of exchange rates is more complex than can be represented with linear models and integer orders of integration, and that non-linear representations and fractional cointegration analysis may be needed. Alternatively, an interpretation of this cointegration puzzle is that the nonstationary component of the *ex-post* premium (the forward premium) is small enough, relative to the stationary component (the realized appreciation/depreciation) [see [5]] that it does not show up as a nonstationary residual in the long-run relationship between F_t^k and S_{t+k}.

6. THE ROLE OF EXPECTATIONS IN THE DETERMINATION OF FORWARD RATES

Forward rates are a bridge between current and future spot rates. Being influenced by current exchange rates, they are supposed to also incorporate anticipations of future fluctuations, and it is important to know the extent to which such anticipations take place. Our results so far suggest that:

a) forward rates are cointegrated with future spot rates. Besides, we have not rejected the hypothesis that the cointegrating vector is [1,-1], in agreement with the *unbiasedness* hypothesis on the formation of forward prices. However,

b) we have also found some evidence that a somewhat permanent risk premium exists in one and three-month forward currency contracts both, in terms of mean values of the differences between forward and future spot exchange rates, and also from the autocorrelation of the difference F_t^k-S_{t+k} in the one-month case, which extends beyond what should be the case for a pure rational expectations error,

c) these *risk/term premia* do not constitute significant evidence against market efficiency, since it does not seem that they could be added to information on current prices to improve on an existing trading strategy in any relevant manner at the one and three month horizons of the forward contracts. Finally,

d) forward rates do not seem to be cointegrated with current exchange rates, so that forward premia are nonstationary.

To place these results in a unified perspective, we now compare the *absolute values* of both differences: the forward premium F_t^k-S_t, and the *ex-post* premium F_t^k-S_{t+k} [Figures 7 and 8]. Table 6 shows that, in coherence with Figures 3 to 6, median absolute *ex-post* premia are much larger than those of forward premia. Median values range between .12% and .63% for one-month forward premia, but between 1.96% and 2.41% for *ex-post* premia. Three-month forward premia take values between .34% and 1.65%, while *ex-post* premia range from 3.05% to 4.82%. Hence, forward rates seem to be much closer to current than to future exchange rates. In terms of [5], the difference between these absolute values in the premiums suggests that F_t^k-S_{t+k} and S_{t+k}-S_t show a strong negative correlation, which would be the case if, in fact, F_t^k varies more with current than with future spot rates.

Let us formalize more this idea by considering the two extreme views on expectations formation on future exchange rates: Under a *perfect foresight* view, exchange rates could be thought as being perfectly predictable, with $E_tS_{t+k} = S_{t+k}$. Then, the *ex-post* premium F_t^k-S_{t+k} would have a single component, the risk or term premium[7], while the forward premium F_t^k-S_t would be the sum of actual, *ex-post* depreciation and the same risk premium [see [3] and [4]]:

$$\text{Ex-post premium}: \quad F_t^k - S_{t+k} = \pi_t^k$$

$$\text{Forward premium}: \quad F_t^k - S_t = \left(S_{t+k} - S_t\right) + \pi_t^k \qquad [8]$$

Even though the risk premium depends just on information available at t, under perfect foresight, S_{t+k} would be perfectly anticipated so S_{t+k} would be in the time t information set and, most likely, the two terms in F_t^k-S_t

[7] Term premium seems to be a better denomination in a context of perfect foresight.

would be positively correlated: if the currency is under a depreciation episode (S_{t+k}-S_t>0), it is according to intuition that term/risk premia would tend to increase with the depreciation rate. If the currency is experiencing a period of appreciation (S_{t+k}-S_t<0), we could think of term premia decreasing when the rate of appreciation increases, since the investor might have a smaller need for compensation under a bigger average appreciation rate. That kind of behavior would produce the mentioned positive correlation, making forward premia more volatile than *ex-post* premia, against the evidence we just reported.

On the other hand, under an *unpredictability* view: $E_t S_{t+k} = S_t$, the forward premium F_t^k-S_t would have a single component, the risk premium, while the *ex-post* premium F_t^k-S_{t+k} would have an additional component, the realized depreciation in exchange rates:

$$\begin{array}{ll} \text{Ex-post premium :} & F_t^k - S_{t+k} = \pi_t^k - (S_{t+k} - S_t) \\ \text{Forward premium :} & F_t^k - S_t = \pi_t^k \end{array} \qquad [8]$$

Besides, both components in F_t^k-S_t would be uncorrelated, π_t^k being in the information set at time t while S_{t+k}-S_t, is the sum of innovations occuring after that period. As a consequence, their variances would add up, so that this representation of the *ex-post* and forward premia seems to be more consistent with the previous evidence on the relative size of their fluctuations. Hence, our data seems to be closer to *unpredictability* than to a *perfect foresight* view, and forward rates seem to inherit the behavior of current spot rates much more than to anticipate future spot rates. The same cualitative results hold when dealing with subsamples, which take us to conclude that this unpredictability result is robust to the time period chosen.

Except for the yen, the median absolute values of F_t^k-S_t in Table 6 are the same as those of F_t^k-S_t in Table 3, reflecting the fact that the forward premium is mostly positive for the european currencies, changing signs over the sample for the yen. The unpredictability view seems to work less well for the latter currency, since the forward premium would then be equal to the risk premium [see [8]], which is believed to be positive. According to this representation, the wide gap to the median absolute values of F_t^k-S_{t+k} would be due to mostly unexpected exchange rate fluctuations. Hence, *risk premia* seem to be much less important than exchange rate fluctuations, these being the dominant component in *ex-post premia*[8]. In the limit version of this view, the forward premium would coincide with the risk/term premium, and the *ex-post* premium would be the realized appreciation/depreciation in exchange rates.

According to our cointegration tests, the *unpredictability* view also implies that the *risk premium* is nonstationary. The numerical dominance of actual currency appreciation/depreciation, over the *risk premium* may explain why we have not detected such nonstationarity in the cointegration tests between forward and *future* spot rates in section 4.a, or in the $AR(1)$ representation in section 4.b for the *ex-post* premium, which would contain π_t^k as one component [see [8]]. At the same time, the relative size of the two components in F_t^k-S_{t+k} would explain the paradoxical result mentioned at the end of section 5.

Moreover, the lack of cointegration between forward and current spot rates, consistent with the unpredictability view, seems to point to the fact that the forward premium is basically reflecting changes in short term interest rate differentials between the countries as a result of fluctuations in the markets perception of country risk.

All these characteristics have some bearing on the efficiency issue: Crowder (1994) has argued in favor of inefficiency of forward markets on the basis that: a) different spot rates tend to usually be cointegrated, and b) forward premiums are not stationary. Under a), spot rate markets could be efficient just if the error correction term was a proxy for a stationary risk premium. Since the error correction representation associated with coíntegration of different rates concedes somé forecasting

[8] As an alternative measure of fluctuations, standard deviations for *ex-post premia* fall between 3.2% and 3.6% for one-month contracts and between 5.6% and 6.6% for 3-month contracts, while those of *forward premia* range between 0.2% and 0.3% for one-month and between 0.6% and 0.7% for 3-month contracts. Risk premium fluctuations seem to be minor, compared to those of exchange rates themselves. Similar numerical results arise in the considered subsamples.

power to past exchange rates in addition to current rates, interpreting it as a risk premium would be the only possibility consistent with market efficiency. Otherwise, it would constitute information, known at t, useful to predict future spot rates and not incorporated in current exchange rates, contradicting the hypothesis of efficient price formation. As Crowder (1994), we have also provided evidence on non-stationarity of forward premiums. Hence, they cannot be proxied by the stationary error correction term, and we would have to reject efficiency of currency markets. However, there is no possibility of using that information to improve forecasts of future exchange rates, so the practical implications of this possible lack of efficiency are questionable.

7. CONCLUSIONS

Working with spot and forward exchange rates for the deustche mark, french franc, sterling pound, yen and peseta, relative to the US dollar, we have found one and three-month forward exchange rates to be cointegrated with *future* spot rates, but not with *current* spot rates.

In projections of *future* spot rates on forward rates, we do not reject the hypothesis of a unit slope for the forward rate. This robust cointegrating relation between forward and *future* spot rates with a unit coefficient, confirms the *unbiasedness* hypothesis for this data set, which is a necessary requirement for *efficiency* of the forward market. In this analysis, the two-step estimate of the cointegration relation seems to be biased, while the maximum-likelihood provides precise slope estimates around one.

However, since forward and spot exchange rates are nonstationary, unbiasedness does not preclude the existence of a stationary risk premium. In fact, we have found that the autocorrelation of F_t^k-S_{t+k} extends beyond what one should expect in the absence of a risk premium, suggesting somewhat persistent, but small size risk premia seem to exist, possibly against market efficiency.

Contrary to a first intuition, unbiasedness does not imply that daily forward rates are good predictors of exchange rates at one and three-month horizons and, in fact, the opposite is true. On the other hand, forward rates are cointegrated with current exchange rates, from which they experience persistent deviations, but these are minor. These results suggest that reducing the analysis of the information content of forward rates to cointegration tests with current and future exchange rates would be misleading.

We have also argued that the behaviour of exchange rates seems to be quite consistent with unpredictability of exchange rates at one and three-month horizons. Our results are more consistent with *passive* forward rates, that mostly reflect current fluctuations in spot exchange rates, than with an *active* behavior, that would try to anticipate future exchange rates fluctuations.

Unpredictability of exchange rates would imply the existence of a nonstationary *risk premium*, equal to the forward premium. We have shown the latter to be of minimum size, relative to exchange rate fluctuations over one and three months, which may explain why the *ex-post* premium, which has the risk premium as a component, is not detected to be non-stationary. Furthermore, being small, the risk premium does not help to predict future spot exchange rates and hence, it cannot be taken as a violation of market efficiency. This also suggests that recent arguments on inefficiency of currency markets are theoretically sound, but of minor empirical relevance.

Table 1

UNIT ROOT TESTS[(a)]
Augmented Dickey-Fuller statistic

		$H_0:I(2)$ versus $H_1:I(1)$		$H_0:I(1)$ versus $H_1:I(0)$		
		ADF	*k*	*Constant*	*ADF*	*k*
DM/$	Spot	-16.91	4	0.003	-2.00	4
	1m.forward	-16.93	4	0.002	-1.97	4
	3m.forward	-16.96	4	0.001	-1.88	4
SP/$	Spot	-8.88	18	0	-0.61	19
	1m.forward	-8.93	18	0	-0.60	19
	3m.forward	-9.01	18	0	-0.58	19
FF/$	Spot	-16.53	4	0.01	-2.23	6
	1m.forward	-16.55	4	0.01	-2.19	6
	3m.forward	-16.61	4	0.01	-2.11	6
Pta/$	Spot	-9.56	16	0	0.42	17
	1m.forward	-9.24	16	0	0.38	17
	3m.forward	-9.27	16	0	0.37	17
Yen/$	Spot	-9.33	12	0	-1.06	12
	1m.forward	-9.33	12	0	-1.07	12
	3m.forward	-9.32	12	0	-1.07	12

(a) *DM*: deutsche mark, *FF*: french franc, *SP*: sterling pound, *Pta*: peseta, *Yen*: yen. No constant or trend were included when computing the Augmented Dickey-Fuller *ADF* statistic for $H_0:I(2)$ versus $H_1:I(1)$. *k* denotes the number of lags used in the test. Critical values are then: -2.57, -1.94 and -1.62 at the 1%, 5% and 10% significance levels, respectively. When just a constant is included, as it is sometimes the case in testing for: $H_0:I(1)$ versus $H_1:I(0)$, critical values are: -3.44, -2.86 and -2.57 at the 1%, 5% and 10% significance levels. No deterministic trend was ever necessary to achieve residual stationarity.

Table 2

COINTEGRATION TESTS
Between forward rates and future spot rates

$$S_{t+k} = \alpha + \beta F_t^k$$

		Engle-Granger cointegration tests					*Johansen test*[c]	
		α	β	*DW*[a]	*ADF*[b]	k	*Trace statistics*[d]	*slope*
DM/$	Spot/1m.forward	0.53	0.878	0.14	−5.10	14	113.6/0.5	0.999 (.0060)
	Spot/3m.forward	0.17	0.609	0.04	−4.30	23	28.9/0.6	0.995 (.0230)
SP/$	Spot/1m.forward	−0.04	0.929	0.12	−4.96	14	131.1/0.4	1.007 (.0050)
	Spot/3m.forward	−0.12	0.785	0.02	−4.14	23	23.5/0.3	1.023 (.0260)
FF/$	Spot/1m.forward	0.22	0.868	0.13	−5.11	14	119.0/0.2	0.999 (.0010)
	Spot/3m.forward	0.66	0.603	0.03	−4.10	23	27.7/0.3	0.997 (.0060)
Pta/$	Spot/1m.forward	0.16	0.966	0.13	−5.44	14	138.4/0.1	0.999 (0.005)
	Spot/3m.forward	4.01	0.913	0.03	−4.39	22	28.6/0.2	0.997 (.0020)
Yen/$	Spot/1m.forward	0.17	0.965	0.12	−4.65	16	139.2/0.8	1.001 (.0005)
	Spot/3m.forward	0.68	0.856	0.03	−3.43	9	39.2/0.6	1.002 (.0020)

a) Critical values for the Durbin-Watson (*DW*) statistic for two explanatory variables and a sample size of 200 is 0.20, at 5% significance level.
b) No constant or trend were included in the regressions in first differences of the residuals in the *ADF* tests. The number of lags used, *k*, is shown in the table. Critical values for this specification are: −2.57, −1.94 and −1.62 at 1%, 5% and 10% significance levels, respectively.
c) A constant was included when estimating the cointegrating relation by Johansen's procedure, although it turned out not to be statistically significant. No constant was included in the *VAR* in first differences and four lags were used for all currencies. Standard deviations in brackets.
d) The two values refer to the trace statistics for the null of no cointegration and a single cointegration relation, respectively. Critical values for the null hypothesis of no cointegration for this specification are 12.53 and 16.31 at 5% and 1% significance levels, respectively, while those for the hypothesis of a single cointegrating relation are 3.84 and 6.51 at 5% and 1% significance levels.

Table 3

DIFFERENCES BETWEEN FORWARD AND SPOT RATES DESCRIPTIVE STATISTICS[a]

		Differences to future spot rates: $F_t^k - S_{t+k}$ *Risk premiums-Expectations errors*			*Diferences to current spot rates: $F_t^k - S_t$* *Forward premiums*		
Currency		*Median*10 ²*	*t*	*Annualized rate*	*Median*10 ²*	*t*	*Annualized rate*
DM/$	1m.forward	0.538	5.2	6.7%	0.179	29.7	2.2%
	3m.forward	1.608	9.9	6.6%	0.529	31.0	2.1%
SP/$	1m.forward	0.510	4.6	6.3%	0.274	51.5	3.3%
	3m.forward	0.875	5.0	3.6%	0.726	49.1	2.9%
FF/$	1m.forward	0.784	7.9	9.8%	0.236	41.6	2.9%
	3m.forward	1.864	12.1	7.7%	0.687	43.4	2.8%
Pta/$	1m.forward	1.100	9.8	14.0%	0.629	74.3	7.8%
	3m.forward	2.887	16.3	12.1%	1.652	93.2	6.8%
Yen/$	1m.forward	0.246	2.3	3.0%	-0.047	-21.5	-0.6%
	3m.forward	1.122	6.2	4.6%	-0.119	-7.8	-0.5%

(a) Column *t* shows ratios between the median and the standard deviation of the sample mean.

Table 4

THE DYNAMICS OF $S_{t+k}-F_t$, k=1 month
Regressions on own lags[a]

$$S_{t+k} - F_t^k = \alpha + \beta\ (S_{t+k-j} - F_{t-j}^k)$$

j=		13	15	17	19	Matched data
DM/$	β (t-ratio)	.200 (3.0)	.161 (2.4)	.125 (1.9)	.095 (1.4)	.109 (1.4)
	R^2	.040	.025	.015	.008	.010
	σ*100	3.34	3.34	3.34	3.35	3.32
SP/$	β (t-ratio)	.219 (2.5)	.177 (1.9)	.148 (1.6)	.115 (1.4)	.108 (1.0)
	R^2	.048	.030	.021	.012	.010
	σ*100	3.52	3.52	3.52	3.52	3.44
FF/$	β (t-ratio)	.182 (2.7)	.146 (2.2)	.111 (1.6)	.084 (1.2)	.216 (2.2)
	R^2	.033	.021	.011	.006	.043
	σ*100	3.19	3.16	3.17	3.18	3.36
Pta/$	β (t-ratio)	.193 (2.4)	.140 (1.7)	.111 (1.3)	.091 (1.0)	.087 (2.2)
	R^2	.037	.019	.012	.007	.007
	σ*100	3.51	3.54	3.56	3.57	3.53
Yen/$	β (t-ratio)	.291 (3.7)	.224 (2.8)	.181 (2.3)	.158 (2.1)	.094 (1.2)
	R^2	.084	.049	.032	.024	.008
	σ*100	3.30	3.36	3.40	3.42	3.17

(a) Newey-West's correction for serial correlation was used to compute the standard deviations of estimated β's in all regressions. The resulting t-ratios are shown in brackets.

Table 5

COINTEGRATION TESTS
Between forward rates and current spot rates

$$S_t = \alpha + \beta F_t^k$$

		Engle-Granger cointegration tests					*Johansen test*[c]		
		α	β	*DW*[a]	*ADF*[b]	*k*	*Trace statistics*	*intercept*	*slope*
DM/$	Spot/fwd1	0.004	0.99	.03	−1.49	6	2.8/0.3	---	.997 (.003)
	Spot/fwd3	0.014	0.96	.01	−1.42	6	2.1/0.2	---	.981 (.016)
SP/$	Spot/fwd1	−0.005	1.018	.05	−1.94	7	8.9/1.0	−.01 (.01)	1.034 (.011)
	Spot/fwd3	−0.017	1.054	.03	−1.92	12	10.3/1.1	−.03 (.01)	1.077 (.023)
FF/$	Spot/fwd1	0.01	0.99	.02	−1.80	12	3.5/0.5	---	.999 (.001)
	Spot/fwd3	0.04	0.97	.01	−1.38	12	2.5/0.7	---	.996 (.003)
Pta/$	Spot/fwd1	−0.04	1.01	.85	−2.35	14	38.2/1.6	−.05 (.02)	1.009 (.003)
	Spot/fwd3	−0.13	1.02	.22	−1.25	14	12.8/2.2	−.16 (.07)	1.030 (.015)
Yen/$	Spot/fwd1	0.300	0.995	.02	−2.61	4	18.1/4.7	.05 (.02)	.990 (.003)
	Spot/fwd3	0.095	0.981	.01	−2.31	4	22.6/4.8	.20 (.05)	.960 (.010)

a) Critical values for the Durbin-Watson statistic for two explanatory variables and a sample size of 200 is 0.20, at 5% significance level.

b) A constant and a deterministic trend were included in the regressions in first differences of the residuals in the *ADF* tests. The number of lags used, *k*, is shown in the table. Critical values for this specification are: −3.9706, −3.4159 and −3.1299 at 1%, 5% and 10% significance levels, respectively.

c) A constant (shown under *intercept*) was sometimes significant in the cointegrating relation estimated by Johansen's procedure. No constant was included in the *VAR* in first differences, and four lags were used for all currencies. Critical values for the null hypothesis of no cointegrating relationship for this specification were 12.53 and 16.31 at 5% and 1% significance levels, respectively, while critical values for the hypothesis of a single cointegrating relation were 3.84 and 6.51 at 5% and 1% significance levels, when a constant was not included. With a constant in the cointegrating relation, critical values for the null hypothesis of no cointegrating relationship were 19.96 and 24.60 at 5% and 1% significance levels, respectively, while critical values for the hypothesis of a single cointegrating relation were 9.24 and 12.97 at 5% and 1% significance levels.

Table 6

ABSOLUTE VALUES OF EX-POST AND FORWARD PREMIUMS

One and three-month forward contracts

	Median values * 100		Standard deviations	
	$S_{t+k} - F_t^k$	$S_t - F_t^k$	$S_{t+k} - F_t^k$	$S_t - F_t^k$
DM/$ 1 m.	2.28	0.20	3.34	0.23
3 m.	4.21	0.54	5.93	0.66
SP/$ 1 m.	1.96	0.27	3.52	0.21
3 m.	3.58	0.73	6.44	0.58
FF/$ 1 m.	2.24	0.24	3.19	0.22
3 m.	3.05	0.69	5.62	0.62
Pta/$ 1 m.	2.41	0.63	3.57	0.33
3 m.	4.82	1.65	6.46	0.69
Yen/$ 1 m.	2.10	0.12	3.43	0.21
3 m.	4.18	0.34	6.61	0.60

Figure 1
SPOT EXCHANGE RATES

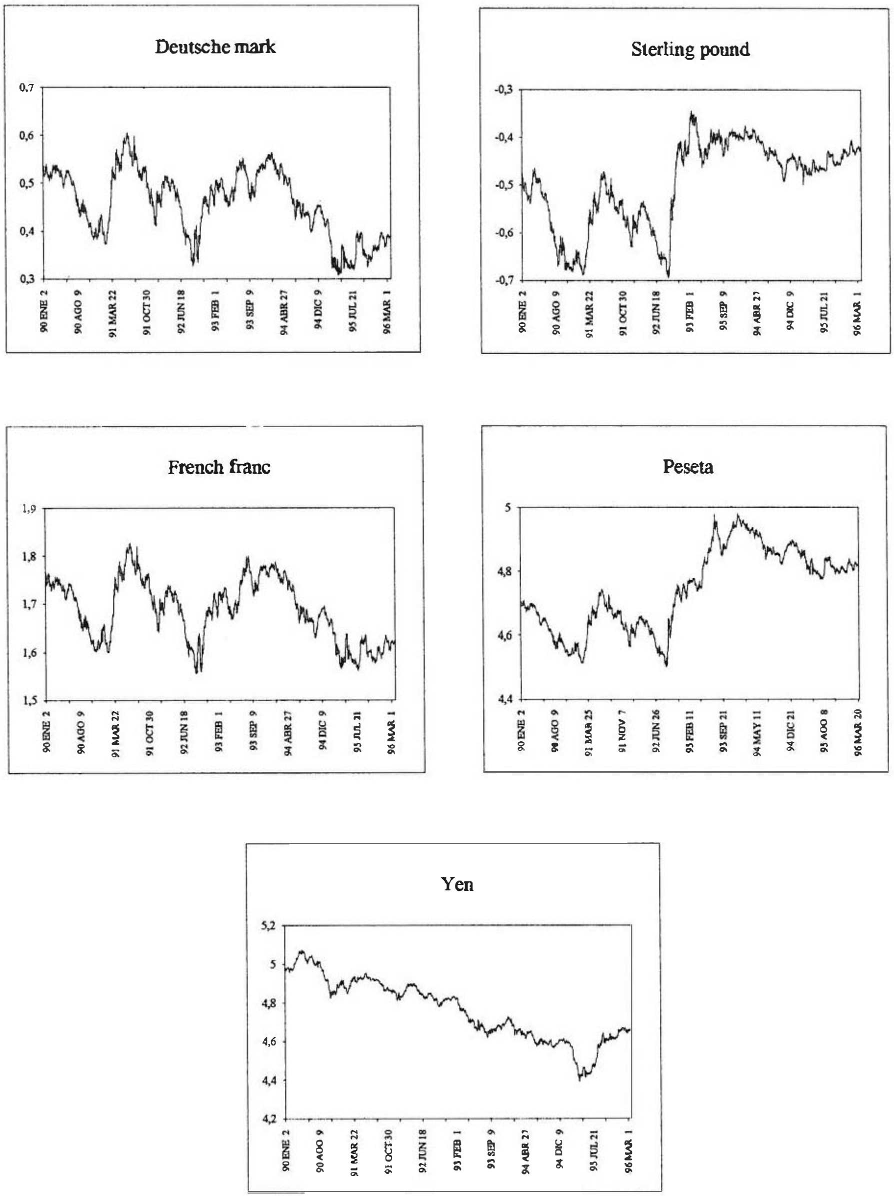


Figure 2
SPOT AND SHIFTED THREE-MONTH FORWARD RATE

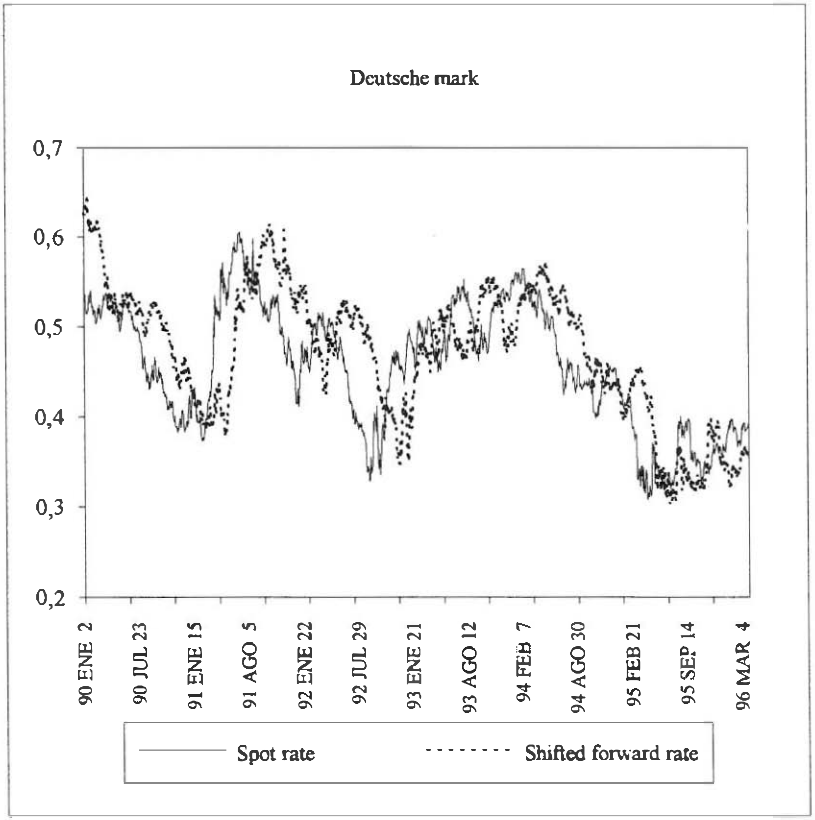


Figure 3
ONE-MONTH EX-POST PREMIUMS

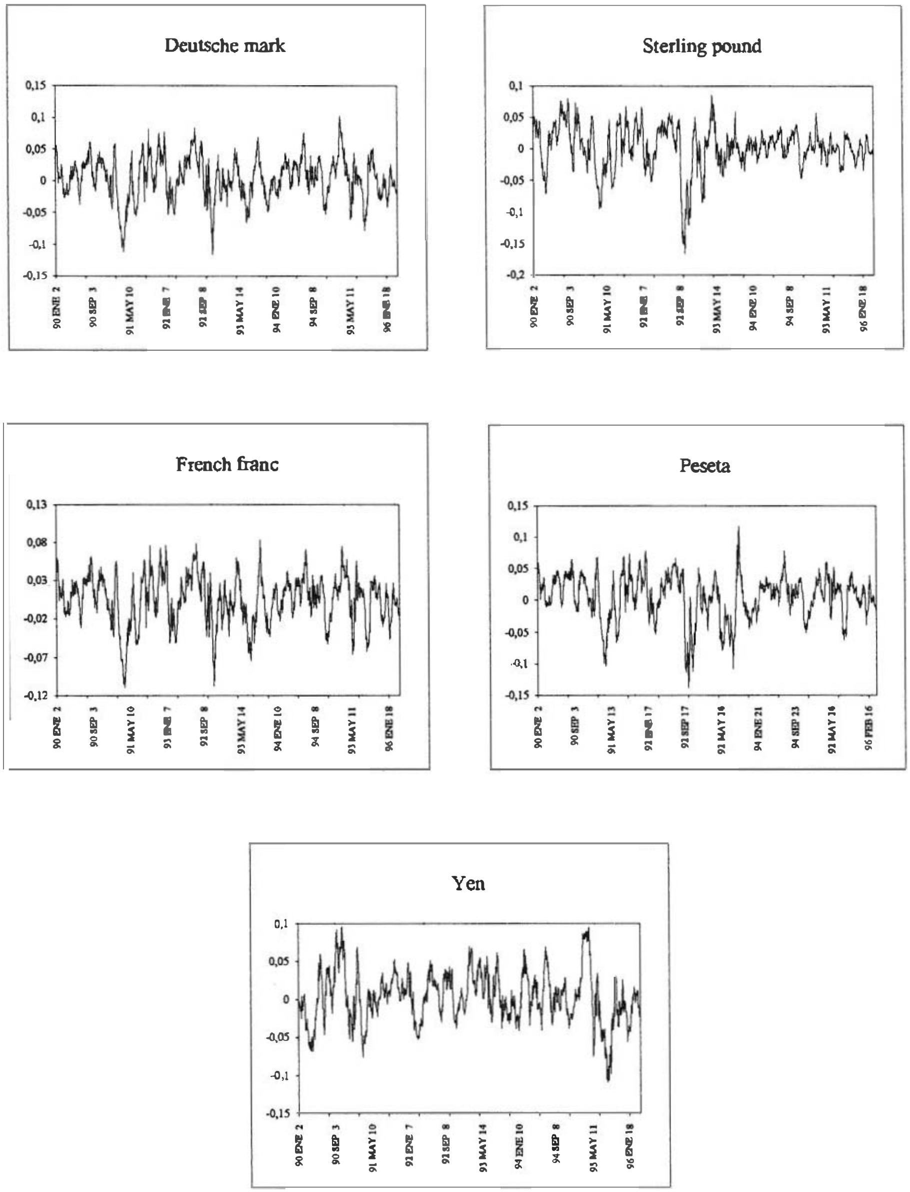


Figure 4
THREE-MONTH EX-POST PREMIUMS

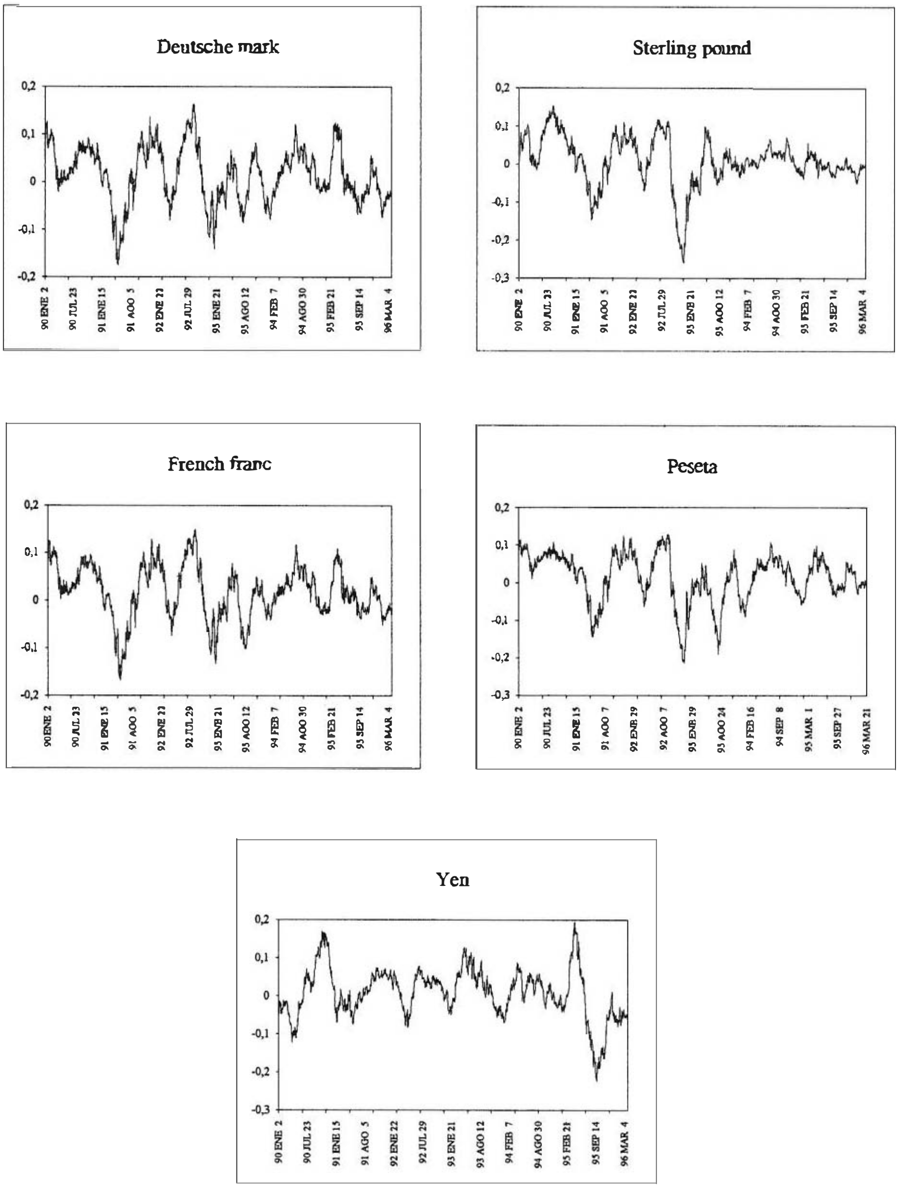


Figure 5
FORWARD PREMIUMS
One-month forward exchange rates

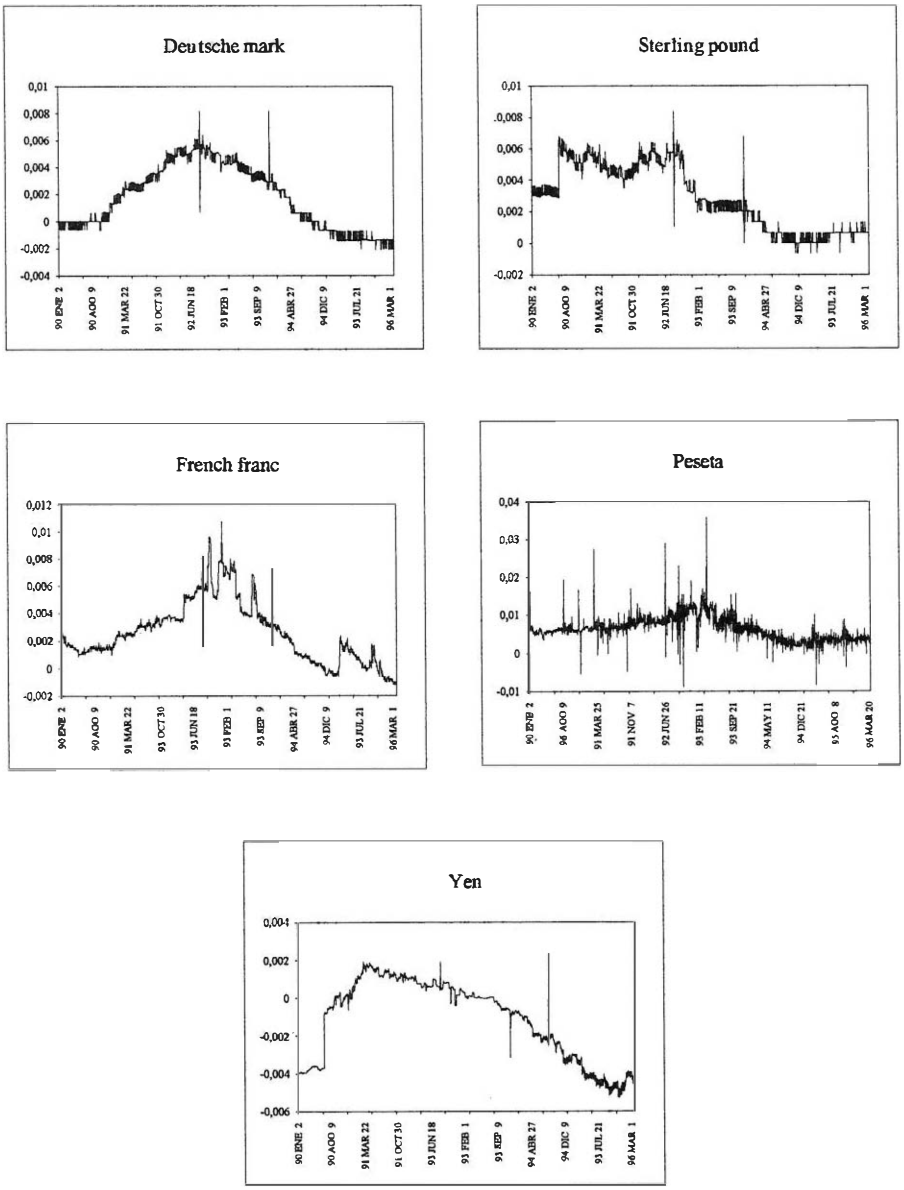


Figure 6
FORWARD PREMIUMS
Three-month forward exchange rates

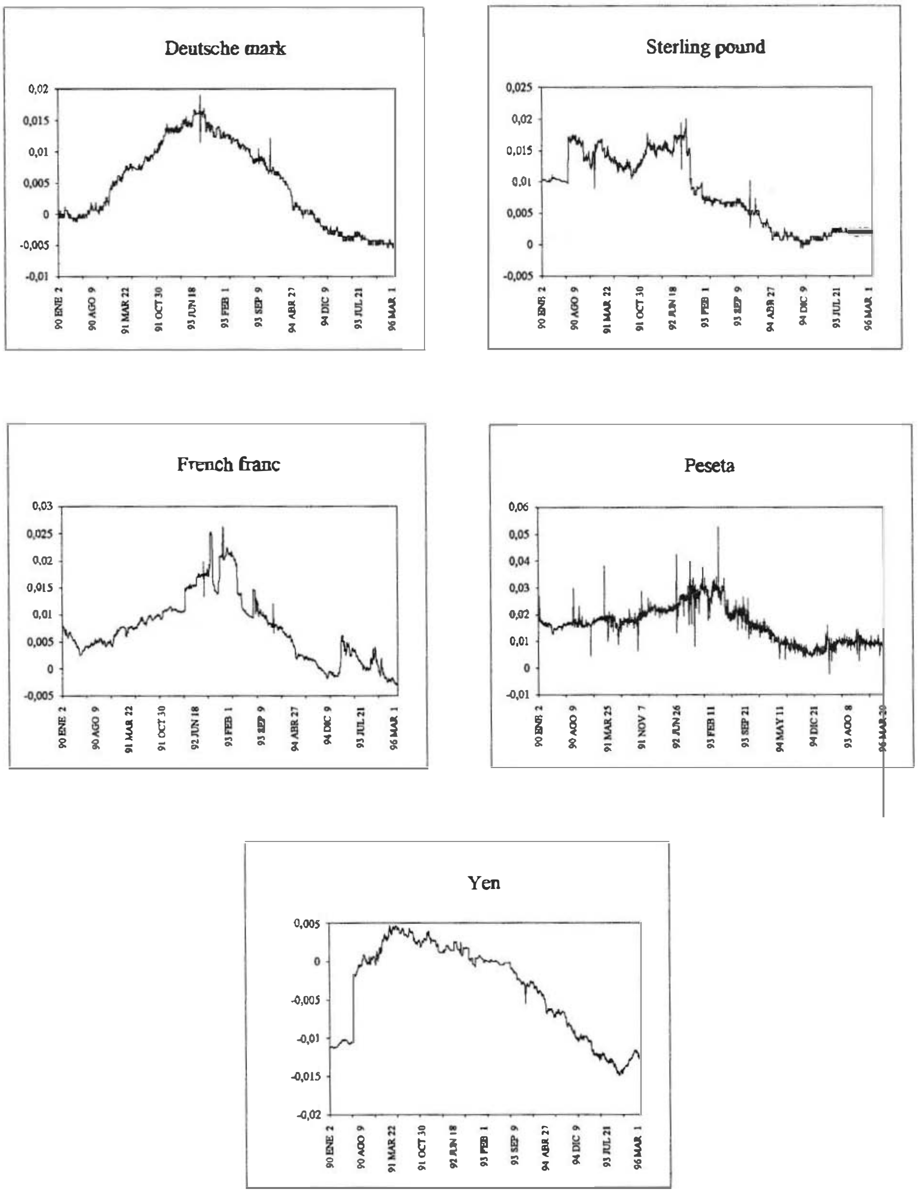


Figure 7
ABSOLUTE VALUES EX-POST FORWARD PREMIUMS
One-month forward rates

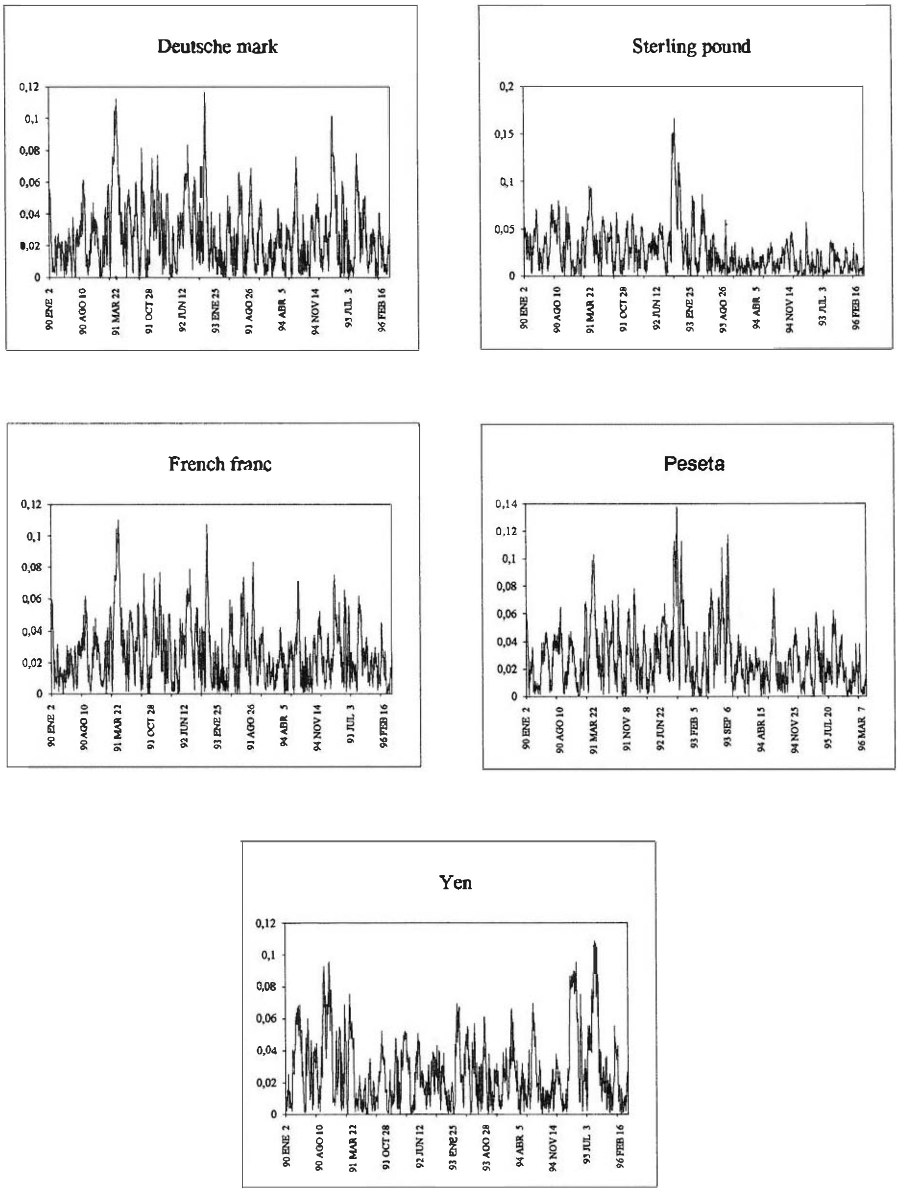
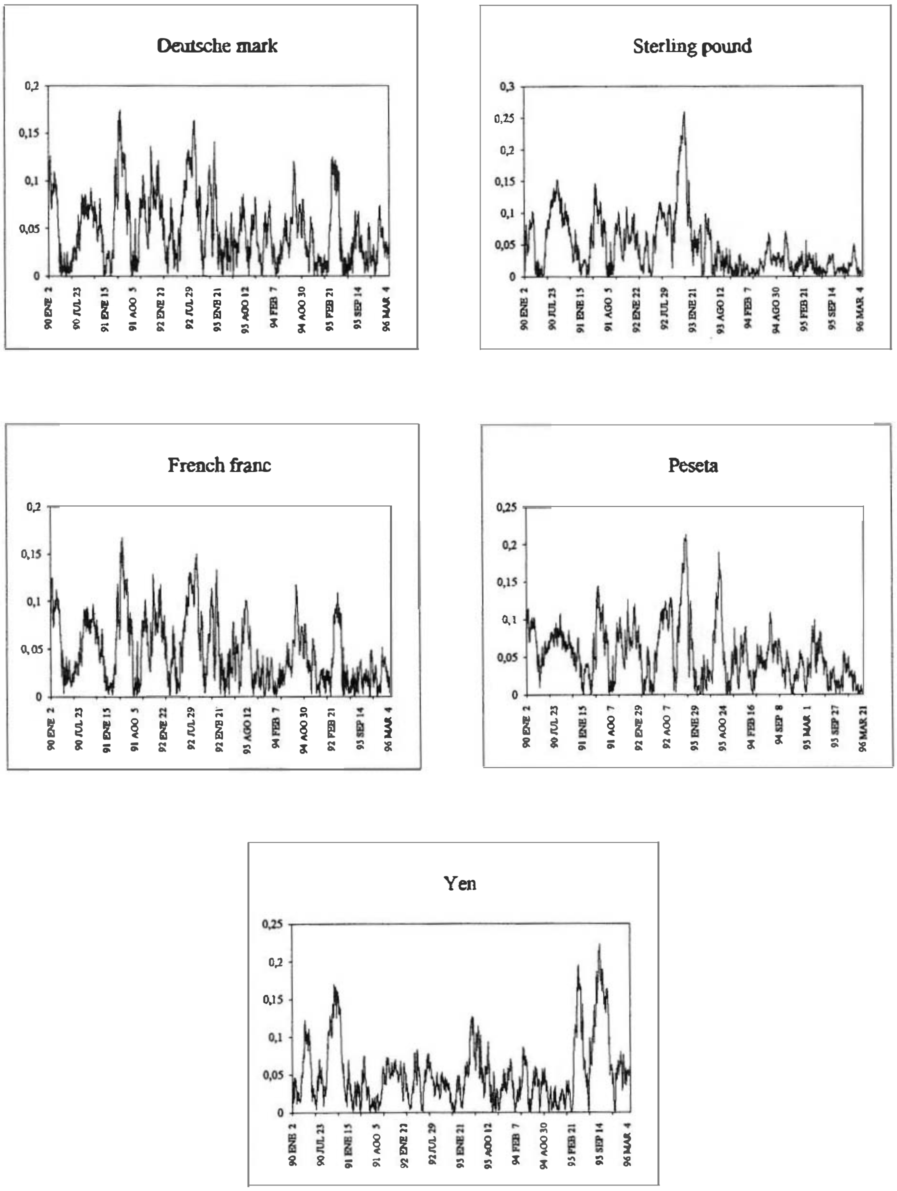


Figure 8
ABSOLUTE VALUES EX-POST FORWARD PREMIUMS
Three-month forward rates



REFERENCES

Ayuso, J., J.J.Dolado, and S.Sosvilla-Rivero, "¿Es el tipo forward un predictor insesgado del tipo spot futuro?: El caso del tipo de cambio peseta/dólar reconsiderado", *Revista Española de Economía*, 1992.

Baillie, R.T., and W.P.Osterberg, "The risk premium in forward foreign exchange markets and G-3 Central Bank intervention: Evidence of daily effects, 1985-1990", *Federal Reserve Bank of Cleveland*, working paper 9109, 1991.

Bekaert, G., and R.J.Hodrick, "On biases in the measurement of foreign exchange risk premiums", *Journal of International Money and Finance,* 1993.

Bergés, A., and D.Manzano, "El tipo de cambio a plazo de la peseta", *Moneda y Crédito* (2ª Época) 189, 157-185, 1990.

Crowder, W.J. "Foreign exchange market efficiency and common stochastic trends", *Journal of International Money and Finance*, 1994.

Cumby, R.E., and J.Huizinga, "The predictability of real exchange rate changes in the short and long run", *National Bureau of Economic Research*, working paper 3968, 1990.

Domowitz, I. and C.S.Hakkio, "Conditional variance and the risk premium in the foreign exchange market", *Journal of International Economics*, nº19, 1985.

Engle, R.F., and G.W.J.Granger, "Cointegration and error correction: Representation, estimation and testing", *Econometrica* 55, 251-276, 1987.

Fama, E.F. "Forward and spot exchange rates", *Journal of Monetary Economics* 14, 319-338, 1984.

Frankel, J.A. “Recent estimates of time-variation in the conditional variance and in the exchange risk premium”, *National Bureau of Economic Research* 2367, 1987.

Gonzalo,J., “Five alternative methods of estimating long-run equilibrium relationships”, *Journal of Econometrics*, 60, 203-33, 1994.

Gokey, T.C., “Characterizing the risk premium in foreign exchange returns”, *Institute of Economics and Statistics*, Oxford University, 1991.

Hakkio, C.S., and M.Rush, “Market efficiency and cointegration: An application to the Sterling and Deutschemark exchange markets”, *Journal of International Money and Finance*, nº8, 1989.

Hansen, L.P., and R.J.Hodrick, “Forward exchange rates as optimal predictors of future spot rates: An econometric analysis”, *Journal of Political Economy*, 1980, vol 88 nº5, 829-853.

Hodrick, R.J. “*The empirical evidence on the efficiency of forward and futures foreign exchange markets*”, Harwood Academic Publishers, W.Branson (ed.), Princeton University, 1987.

Hsieh, David A., "The statistical properties of daily foreign exchange rates: 1974-1983", *Journal of International Economics*, 24, 1988, 129-145, North-Holland.

Hsieh, David A., "Modeling heroscedasticity in daily foreign-exchange rates", *Journal of Business and Economic Statatistics*, 7, 1989.

Kaminsky, G., and R.Peruga, “Can a time-varying risk premium explain excess returns in the forward market for foreign exchange?”, *Journal of International Economics*, 28, 1990, 47-70, North Holland.

Kräger, H., and P.Kugler, “Non-linearities in foreign exchange markets: A different perspective”, *Journal of International Economics* 12, 1993.

Ligeralde, A.V. “Simple foreign exchange market efficyency revisited”, *Economics Letters* 46, 257-262, 1994.

McFarland, J.W., P.C.McMahon, and Y.Ngama “Forward exchange rates and expectations during the 1920´s: A re-examination of the evidence”, *Journal of International Money and Finance*, 1994.

Milhoj, Anders, "A conditional variance model for daily deviations of an exchange rate", *Jounrnal of Business and Economic Statistics*, 5, 1987, 99-104.

Pérez-Jurado, M., and J.L.Vega, “Paridad del poder de compra: Un análisis empirico”, *Investigaciones Económicas*, 1994.

Sosvilla-Rivero, S., and Y.B.Park, “Further test on the forward exchange rate unbiasednesss hypothesis”, *Economics Letters* 40, 1992, North Holland.

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