Uncovering Yield Parity: A New Insight into the UIP Puzzle through the Stationarity of Long Maturity Forward Rates*

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Abstract

Results and models of this paper are based on a strikingly new empirical observation: long maturity forward rates between bilateral currency pairs of the US, Germany, UK, and Switzerland are stationary. Based on this result, we suggest a new explanation for the UIP-puzzle maintaining rational expectations and risk neutrality. The model builds on the interaction of foreign exchange and fixed income markets. Ex ante short run and long run UIP and the EHTS is assumed. We show that ex post shocks to the term structure could explain the behavior of the nominal exchange rate including its volatility and the failure of ex post short UIP regressions. We present evidence on ex post validity of long run UIP and strikingly new evidence on the stationarity of the long forward exchange rates of major currencies. We set up, calibrate and simulate a stylized model that well captures the observed properties of spot exchange rates and UIP regressions of major currencies. We define the notion of yield parity and test its empirical performance for monthly series of major currencies with favorable results.

JEL Classification: E43, F31

Keywords: EHTS, forward discount bias, stationarity of long maturity forward rates, UIP, yield parity

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1. Introduction

The connection between interest rates and exchange rates is one of the most intensively researched subjects in international macroeconomics. The uncovered interest rate parity (UIP) hypothesis, which claims the equalization of expected yields internationally, is „*the critical building block of most theoretical models, and a dismal empirical failure.*" (Flood-Rose, 2002, p.252). As it is well know from hundreds of studies and dozens of surveys, in short horizons the exchange rate tends to move the opposite direction than what is predicted by UIP in flexible exchange rate systems. Traditional explanations of this failure could be grouped into two main categories: (1) Models emphasizing the way expectations are formed. For example, the so-called peso-problem, learning, or bubbles could offer explanations which are consistent with rational expectations, or even the rejection of rational expectations could be responsible. (2) Models rejecting risk-neutrality and introducing time varying risk premium.[1] However, in our reading of the literature, the consensus is that none of these attempts offers a satisfactory answer. For example, as Rogoff (2002, p.11) makes it clear "*Now, if there is a consensus result in the empirical literature, it has to be that nothing, but nothing, can systematically explain exchange rates between major currencies with flexible exchange rates.*"

This conclusion could be devastating for further research. However, there are some new approaches shedding new light on the apparent anomalies. First, a few papers already appeared arguing that at longer maturities UIP performs much better ex post as well. Since long run UIP will be a major building block of our approach, we will briefly summarize these papers and present new evidence in the next section. Second, there is a growing literature claiming that in small macroeconomic models assuming ex ante UIP, the reaction of monetary policy could lead to ex post failure of the hypothesis. Third, there are some papers studying EHTS and UIP jointly, which papers usually do not directly address the failure of UIP directly, but have achieved interesting results in exchange rate forecasting.[2] We briefly review these papers as well since we also study EHTS and UIP jointly.

In his pioneering work, McCallum (1994) suggested that the reaction of monetary authority aiming to smooth fluctuations of turbulence in financial markets could lead to negative correlation between the interest rate differential and ex post exchange rate changes. A major element of his models is that the exchange rate appears in the monetary policy reaction function. Kugler (2000) introduces the spread between the short and long ends of the term structure into the reaction function (keeping

[1] For an overview see, for instance, Taylor (1995), Lewis (2001), and Engel (1996). In a recent paper Benczúr (2003) shows that a model, maintaining UIP with rational expectation but noise and parameter learning, could well describe the behavior of the nominal exchange rate at the beginning of disinflation periods observed in many open economies.

[2] Our grouping of papers into the second and third categories is somehow subjective, since these groups overlap.

the exchange rate in it as well). He shows that the intensity of monetary policy response to changes in the spread strongly affects the results for UIP. Meredith-Chinn (1998) extends McCallum's model to a small macroeconomic model in which they drop the assumption that the exchange rate directly appears in the reaction function. Instead, their central bank follows a Taylor-rule and the feedback from the exchange rate could go through two indirect channels, through inflation and the output gap. They calibrate and simulate their model to see whether it can reproduce the ex post failure of short run UIP and the ex post validity of long run UIP. Their results are generally favorable, although they need risk premium shocks in extreme size to fit to observed volatility. Meredith-Ma (2002) further extend McCallum's model and derive the "correct" equation for the short run exchange rate movement, which, interestingly, does not include the interest rate differential. Hence, they claim that the simple UIP equations suffer from the omitted variable bias. Hence, they conclude that the negative β-estimates along the classic Fama (1984) specification is not suitable to draw any conclusions regarding UIP. In our reading, this is the main message of the literature building on the reaction of monetary policy.

Among the papers utilizing information from the term structure, Macdonald and Marsh (1997) integrated long run interest rate differential into the PPP equation. They set up a VAR model which performed better in out of sample forecasting than the random walk for horizons longer than a few months. Juselius-MacDonald (2004) study several key parity conditions between the US and Japan and find, among others, that the link is primarily from long-term to short-term interest rates, which result supports one of our key assumptions, namely, that shocks to long term interest rates are important determinants of the short rate, and also possibly the spot exchange rate. Clarida et al. (2003) set up a model, which exploits information in the term structure, and find better than random walk forecasting performance even for within-year predictions. Inci-Lu (2003) also builds a model using term structure information which could replicate some basic properties (e.g. mean, variance) of major currencies. Alexius (2000) studies the yields of short investment into long bonds and finds regression results that does not reject the $[\alpha,\beta]=[0,1]$ hypothesis for many cases. Perhaps Bekaert and Hodrick (2001) are the first who explicitly used the term “the expectation hypotheses of the term structure of interest rates and of the foreign exchange market”. Bekaert *et. al.* (2002) test UIP and EHTS both in the short and the long run using VAR models, arguing that standard regression based tests have poor small-sample properties. Their statistical evidence against UIP is mixed and is currency- but not horizon- dependent. Their evidence against EHTS is statistically more uniform, but deviations from EHTS are economically not important.

While Bekaert *et. al.* (2002) studied parameter restrictions in a VAR estimated for the change in the exchange rate, level of nominal interest rates, and the term spreads, in this paper we base our analysis on a strikingly new claim: stationary of long run nominal exchange rate expectations. In our framework we ask the question: would it be possible that, taking long run UIP as given, shocks to the term structure are responsible for the anomalies observed in the foreign exchange markets? We assume rationality and risk neutrality; hence UIP for both short and long horizons and the EHTS are also valid ex ante. In this framework, which is rather simple compared to the highlighted papers above, we show that ex post failures of the EHTS does not determine exactly the path of the exchange rate. A shock to the EHTS can lead to exchange rate movements ranging in two corner solutions. One is the ex post validity of short run UIP, in which case the expected long-run exchange rates moves in accordance with the shock to the EHTS. In the other corner solution the expected long-run exchange rates stays constant and the spot exchange rate bears the full adjustment, hence, the actual path of the spot exchange rate deviates from what was predicted by the UIP in the previous period. We define this second corner solution as the ‘ex post parity of total yields’, which we will phrase briefly as ‘yield parity’ (YP). Yield parity is calculated as the one-period interest rate adjusted with the differential of domestic and foreign unexpected price changes of risk free discount bonds. In support of our model we present strikingly new evidence on the stationary of long forward rates, which correspond to long run exchange rate expectations under our assumptions, based on both simple unit root tests and also on a vector-error correction models.

We also test the empirical performance of yield parity in explaining the short run movement of the exchange rate for monthly series of three major currencies, the dollar, the mark/euro and the pound. The results indicate that YP strongly outperforms UIP and its properties (e.g. volatility and sign changes) are similar to that of short run exchange rate fluctuations.

We should clarify right here what our model is good for. It offers an *explanation* of ex post failure of short run UIP when it is fulfilled ex ante. However, as we relate shocks to foreign exchange and fixed income markets, it cannot be used as a direct forecasting tool.

The rest of the paper is organized as follows. Section 2 briefly surveys the literature on long run UIP and presents new evidence based on consistently calculated and publicly available high quality datasets for three major currencies. Section 3 presents evidence on the stationarity of long forward rates. Section 4 describes the theoretical model and introduces the notion of yield parity. Section 5 offers a new explanation for the failure of short-run UIP regressions. The empirical results for yield parity using monthly exchange rates of major currencies are presented in Section 6. Section 7 sets up a stylized model suitable for stochastic simulation and studies the simulated properties of the spot exchange rate, UIP regressions and yield-parity regressions. Section 8 concludes. Data is described in the Data Appendix.

2. Uncovered Interest Rate Parity in the Long Run

The hypothesis of long run uncovered interest rate parity is essential for our model. In this section we briefly survey evidence presented in the literature and present results using our dataset.

Perhaps the first paper emphasizing the differences between results for short and long horizon UIP was Flood-Taylor (1996). They studied 21 bilateral USD exchange rates in a panel framework for the period 1973-1992. One of their results, for example, is that calculations for the 3-year horizon using government bond yields led to an estimated value of 0.596 for β with a 0.195 standard error. The point estimate is substantially larger than usual estimates for short horizons, significantly positive, and at the borderline of not being significantly different from the theoretical value of one.

Alexius (2001) studies the 10-year horizon using quarterly data from the IFS for 13 OECD countries in the period 1957-1997. As she also highlights, there are two key problems for the study of UIP inherent in the long government bond yields of the IFS. First, the yields do not refer to 10-year exactly, but varies around 10 years. Second, since the data are yield to maturity but not holding period yields, interest payments disturb the results. She tries to circumvent these problems and concludes at the end that UIP might work much better for long than for short horizons.

Meredith and Chinn (1998) adopts much better data by using, besides benchmark government bond yields, zero-coupon yields as well for 5 and 10-year horizons, which were available for them for some G7 countries. They study bilateral USD rates in 1973-1998 using quarterly data. Some of their main results are that (1) at longer horizons the estimates for β are significantly positive, (2) R^2 are substantially larger for long than for short horizons, and (3) results using zero-coupon yields tend to be better and in some cases the estimate for β does not differ significantly from one. Chinn and Meredith (2000) present results for German mark based exchange rates and find less favorable results than for USD based rates, although these are still better than result for short run UIP. They suggest that liberalization of bond markets, which took place later in Germany and especially in Japan than in the US, could be responsible for the worse results. Finally, Chinn and Meredith (2005) report, using 5-year interest rate differentials and data for the US, Germany, Japan and Canada, that long-horizon results are robust to the use of different data frequencies, sample periods, yield definitions, and base currencies.

One of the main weaknesses of long run UIP estimations is the short sample. For example, in the 10-year case there are only three independent observations in the post-Bretton-Woods era (if we extended the analysis till 2003) and the intensity of overlapping is very severe, leading to strong autocorrelation of residuals. In their pioneering work, Hansen-Hodrick (1980) suggested estimating the parameters of overlapping UIP equations by OLS but correcting the covariance matrix, which became the standard practice in the literature. However, for long UIP equations the equation overlaps so much that the usually suggested order of autocovariance calculation is unfeasible. Moreover, Darvas (1998) have shown that hypothesis tests based on Newey-West heteroskedasticity and autocorrelation consistent covariance (HAC) have substantial size distortions when applied to overlapping samples, and Kirby (1997) showed that the sample R^2 used to be seemingly larger for overlapping samples, even if in the true data generating process R^2 is low.

Obviously, we cannot circumvent these problems either. Our only advantage is the more reliable data at a higher frequency. We use constant maturity zero-coupon yields for the US, Germany, and UK. Our calculations will be based on monthly frequency using end of month data.[3] Since 1999 we substituted the exchange rate of the mark with the euro rate multiplied by the conversion rate, which is a sensible choice (see, e.g. Brüggemann and Lütkepohl, 2005). Hence, we estimated the standard UIP equation:

$$(1) \qquad s_{t+n} - s_t = \alpha + \beta \cdot n \cdot \left(i_t^{(t,t+n)} - i_t^{*(t,t+n)} \right) + \varepsilon_{t+n} ,$$

where s_t denotes the log of the exchange rate (domestic currency price of a unit of foreign currency), $i_t^{(t,t+n)}$ and $i_t^{*(t,t+n)}$ are the n-month domestic and foreign zero coupon yields, which are, similarly to the notation used in the next section, are not annualized but measured at the monthly level[4], and ε_{t+n} is the error term. We attach three identifiers to the interest rate: the subscript denotes the date of the quote, while the two values bracketed in the superscript indicates the beginning and the end of the period for which the interest rate refers to. We will also add an 'F' superscript when the beginning of the period for which the interest rate refers to will be later then date of quote to emphasize forward interest rates.

Table 1 reports our results for 1-month and for 1-2-3-5-7-10-year periods, using monthly data. For the DEM/USD rate we report results for two sample periods, the longest available period (1973M1-2003M12) and the sample period of the other two relations (1979M1-2003M12). The general features of all relations are that (1) the point estimate of β is negative for shorter and positive for longer maturities, with the results improving with the horizon, (2) there are some cases when the null hypothesis of α=0 & β = 1 is not rejected, (3) the R^2 is very low for shorter maturities but substantial for longer maturities, (4) there is severe positive autocorrelation for all estimations except the non-overlapping 1-month horizon. The two different sample periods for the DEM/USD rate led to different point estimates of the parameters, but the 95% confidence bands overlap for all maturities, and the general tendencies highlighted above are valid for both cases. We may also note

[3] See the Data Appendix for the full description of the data.

that our results for the DEM/GBP is also reasonable with an R^2 of 0.42 in the case of the 10-year horizon, which is in contrast to results of Chinn-Meredith (2000), who report an almost zero R^2, but this result could be also be the consequence of overlapping observations (Kirby, 1997).

Positive autocorrelation in the regressions is due to the overlapping nature of the estimates which could not be solved in any satisfactory way. As an illustration, we calculated the parameter estimates in the case of the 1-year rate for non-overlapping samples. Since there are 12 possible samples for this exercise, we calculated all of them and plotted the point estimates and confidence bands in Figure 1. The point estimates vary widely, for example, the difference between the highest and lowest estimate is 1.1 for the DEM/USD and DEM/GBP rate and 3.1 for the GBP/USD rate, with summer months being more favorable for UIP. (This result should not have any reasonable explanations). Indeed, the confidence bands are very wide and always includes zero and only in few cases include the theoretical value of one.

There is a further problem with the estimation of the UIP relations in (1). Namely, while the left hand side, changes in the exchange rate, is stationary, the interest rate differentials tend to be non-stationary, especially for longer horizons. Table 2 reports the results of unit root and stationarity tests.

It has been argued that standard tests for unit root, like the tests of Dickey and Fuller (1979) and Phillips and Perron (1988) have bad size and power properties; see, for example, Maddala and Kim (1998) for an extensive survey, or Ng and Perron (2001) for a more recent overview. For this reason we employ six other unit root tests and a stationarity test as well.

Elliott et al. (1996) proposed a family of test statistics that are invariant to the trend parameters. They suggested two particular tests, a modified version of the Dickey-Fuller t-test, which is essentially based on a local GLS detrending, and another feasible point optimal test, both having substantially improved power when an unknown mean or trend is present. Ng and Perron (2001) exploited the findings of Elliott et al. (1996), and applied the idea of GLS detrending to modify existing tests and showed that non-negligible size and power gains can be made when used in conjunction with an autoregressive spectral density estimator at frequency zero. They suggested modifications of three test statistics studied by Perron and Ng (1996) and the feasible point optimal test statistics of Elliott et al. (1996).

Furthermore, we also use the test developed by Kwiatkowski et al. (1992) to test the null hypothesis of stationarity against the unit root alternative.

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[4] For example, a 2 percent annualized interest rate takes the value of 0.02/12 per month.

For all of these tests we allow only the constant as a deterministic component, but we do not allow a deterministic trend, because in economic terms it would be difficult to rationalize a linear trend in interest rate differentials.

The general conclusion from Table 2 is that longer-maturity interest rate differentials are clearly found to be non-stationary, while results for the short-run interest rate differentials are somewhat mixed. A unit root in interest rate differential implies that equation (1) is unbalanced.

To sum up, there are severe problems with UIP regressions. Besides regression statistics, it is instructive to simply plot yield differentials and actual future exchange rate changes, which are shown of Figure 2. For shorter horizons (i.e. 1-2 years) the variance of the exchange rate changes substantially exceeds that of the yield differential, but for longer horizons the two variables have similar variance. Moreover, for longer horizons the parallel movement of the variables is astonishing. Hence, in the long run UIP might be a reasonable hypothesis. A possible rationale for long run UIP could be that long yields predict future inflation well, and in the long run exchange rates adjust to PPP. However, even if another mechanism was at work, from the point of view of our model only long run UIP, but not the mechanism leading to it, is important.

3. Empirical Evidence on the Stationarity of the Expected Long Run Exchange Rate

Since the stationarity of the long run exchange rate expectations will be a key assumption of our model, we first present new and surprising empirical evidence on this issue, using simple charts, unit root tests, cointegration analysis, and variance calculations. Our assumption of the ex ante UIP for both short and long horizons allows us to use the forward rates as expectations, which could be calculated using the interest rate differential assuming covered interest rate parity (CIP), which is a common practice in the literature due to its widespread empirical support (see, for instance, Simpson et al., 2005, for a recent evaluation):

(2) $$s_t^L = s_t + n \cdot \tilde{i}_t^L \ ,$$

where s_t^L denotes the long maturity forward rate, which equals to the expected long run exchange rate under long run UIP, $s_t^L = E_t[s_{t+n}]$, $\tilde{i}_t^L \equiv \left(i_t^{(t,t+n)} - i_t^{*(t,t+n)}\right)$ denotes the long run interest rate differential with a "large" *n*, measured at the monthly level as before, and *n* denotes the number of months ahead, e.g. in a ten year horizon *n*=120 (number of months in 10 years).

First, Figure 3 simply plots the spot exchange rate and 10-year maturity forward rates. A visual impression does indicate that longer horizon forward rates are much stable than the spot exchange rate. For instance, the huge rise of the dollar in the first half of eighties was signaled by bond markets as partly temporary. Only in the recent low yield period follow the long forward rates closely the spot rates.

Second, Table 3 shows the results of eight unit root tests and a stationarity test (KPSS) on the logarithm of spot and forward rates. The results clearly indicate in all cases that the test statistics decline with horizon. That is, for longer horizons, we generally can reject the null hypothesis of unit root but cannot reject the null hypothesis of stationarity. These results are striking in the light of various attempts to test for unit roots in real and nominal exchange rates. We do not need breaks or non-linearity, which are frequently adopted in the literature, to find stationarity of a measure of the exchange rate of major floating currencies. We should also note that, by definition, these tests are not burdened with the problem of overlapping observations which was a quite severe problem in long-run UIP equations.

Still, we do not wish to over-interpret our findings. For the Japanese yen[5] we could not reject unit root in the 10-year forward rates, although the test statistics also declined with horizon. We attribute this result to the strong trending behaviour of the yen which is visible in about half of our sample. Hence, our results are not applicable to all currencies of the world, but applicable to at least six major currency pairs, which constitute 50 percent of foreign exchange market turnover according to the survey presented in BIS (2005, p. 10). We should also stress that the same tests that indicate non-stationarity of spot rates and short maturity forward rates indicate stationarity of long maturity forward rates. See Darvas and Schepp (2006) for more details.

Third, stationarity of the long forward rate has a clear cointegration implication: the non-stationary spot exchange rate and the non-stationary long interest rate differential cointegrate. Hence, when s_t^L is above its mean, it's expected to come back to its mean. Adjustment could be achieved by either the spot exchange rate or by the long interest rate differential. We estimated the following error correction model for the spot exchange rate:

(3) $$\Delta s_{t+1} = \alpha_{0,1} + \alpha_{1,1} \cdot s_t^L + v_{t+1} ,$$

where $\alpha_{1,1}$ should be negative when the short rate adjusts (we did not subtract the mean of s_t^L from s_t^L since there is a constant in the regression anyway). For comparison, we also estimated the simple Dickey-Fuller equation:

(4) $$\Delta s_{t+1} = \alpha_{0,2} + \alpha_{1,2} \cdot s_t + v_{t+1} ,$$

[5] Japanese government bond yield is available in the IMF: IFS database.

which should yield a non-significant (based on the Dickey-Fuller distribution) $\alpha_{1,2}$ when the spot rate follows a random walk.

In the next paragraph we show results of a fully specified VECM model, but here we briefly show the results of the simple ECM above to see the performance of this bivariate model. Table 4 indicates that $\alpha_{1,1}$ is significantly negative for almost all cases, while $\alpha_{1,2}$ is not significant for the DF equation. The R^2 of the regressions tend to be larger for the ECM than for the DF-equation, and takes values which are not negligible considering that we model future changes in nominal exchange rates. The table also shows results for sub-periods. The regression do not yield significant estimates in 1973-79, i.e. in the adjustment period after Bretton-Woods, but work nicely both in 1980-89 and in 1990-2005.

Fourth, in addition (2) there is another cointegrating relationship among our variables, which is implied by the EHTS. The EHTS claims that term spreads within a country is stationary, $(i_t^L - i_t^S) \sim$ I(0) and $(i_t^{*L} - i_t^{*S}) \sim$ I(0), so rearranging,

$$(5) \qquad (i_t^L - i_t^S) - (i_t^{*L} - i_t^{*S}) = (i_t^L - i_t^{*L}) - (i_t^S - i_t^{*S}) = \tilde{i}_t^{\,L} - \tilde{i}_t^{\,S} = t\tilde{p}_t \sim \mathrm{I}(0),$$

where $t\tilde{p}_t$ denotes the term premium differential between the two countries. Hence, the long and short interest rate differentials, $\tilde{i}_t^{\,L}$ and $\tilde{i}_t^{\,S}$ are cointegrated with the vector (1,-1). Consequently, we have three I(1) variables and two cointegrating vectors:

$$(6) \qquad \begin{bmatrix} 1 & 0 & n \\ 0 & 1 & -1 \end{bmatrix} \begin{bmatrix} s_t \\ \tilde{i}_t^{\,S} \\ \tilde{i}_t^{\,L} \end{bmatrix} = \begin{bmatrix} s_t^L \\ -t\tilde{p}_t \end{bmatrix}, \text{ with } n = 120 \text{ (10 years of monthly data).}$$

We tested for cointegration using the Johansen-test. Both AIC and SIC indicated 1 lag as the optimal for all currency pairs. We restricted the constant to be in the cointegration vector only (to allow for, say, a term premium differential between the two countries.) British data begin in 1979, while German and US data begin in 1973 (or earlier). For the German-US relation, we tested for cointegration both in the 1973-2005 and in the 1979-2005 samples, similarly to our other calculations.

Table 5 shows the results of cointegration tests. For the DEM/USD relation only one cointegration vector is found, but the rejection of the second is not sound. For the GBP/USD relation two cointegration vectors are found, although the joint stationarity of all three series can not be excluded. For the DEM/GBP relation, however, no cointegration is found. Again, the result for the DEM/GBP rate is similar to findings of other papers, and also to our other findings in this paper, in that USD-based exchange rates yield favorable results than the DEM/GBP cross rate. By and large, we evaluate all these results as evidence in favor for two cointegration vectors, and continue with testing the parameter restriction implied in (6). The unrestricted (but normalized) cointegrating vectors are the following (standard errors are in brackets):

DEM/USD, 1973-2005	DEM/USD, 1979-2005	GBP/USD, 1979-2005	DEM/GBP, 1979-2005
$\begin{bmatrix} 1 & 0 & \underset{(60.3)}{188.4} \\ 0 & 1 & \underset{(0.28)}{-1.27} \end{bmatrix}$	$\begin{bmatrix} 1 & 0 & \underset{(31.5)}{168.3} \\ 0 & 1 & \underset{(0.27)}{-0.98} \end{bmatrix}$	$\begin{bmatrix} 1 & 0 & \underset{(82.5)}{383.1} \\ 0 & 1 & \underset{(0.35)}{-0.67} \end{bmatrix}$	$\begin{bmatrix} 1 & 0 & \underset{(39.5)}{165.6} \\ 0 & 1 & \underset{(0.42)}{-0.64} \end{bmatrix}$
LR = 0.73 (p = 0.69)	LR = 1.98 (p = 0.37)	LR= 4.89 (p = 0.087)	LR = 1.06 (p = 0.59)

Hence, for the DEM/USD and DEM/GBP relations the LR test can not reject the null hypothesis of the coefficient restrictions, while for the GBP/USD relation, rejection can be made at 9%. To sum up, by and large, both cointegration vectors with parameter restrictions in (6) are supported by the Johansen-test.[6]

The result has the implication that at least one of two variables in the cointegration vector for the forward rate, that is, the spot exchange rate and the long maturity interest rate differential, could be forecasted using the previous period long maturity forward rate. Using interest rate differentials up to one year Clarida et al. (2003) have already shown that the random walk model of exchange rate forecasting can be outperformed. It remains to be analyzed whether incorporating information from long maturity interest rate can further improve the forecasting accuracy. In this direction, independently of our work and without our stationary result, Boudoukh et al. (2005) have already shown that forward rates up to 5-year maturity do help in forecasting. The question, again, is whether incorporating our stationary result helps forecasting further.

Finally, we calculate the variance of spot and forward rates. Our assumption on the stability of the long run exchange rate expectations has the implication that long forward rates should be less variable than spot exchange rate, and, our new result on the stationarity of the long forward rates imply that their variance should be time-invariant. Table 6 presents the variance of spot and forward rates. Our conjecture is true for the DEM/USD rate and for the DEM/GBP rate, while for the GBP/USD rate the variance is practically the same for spot and forward rates. In order to have a view on the sensitivity to the sample period, Figure 4 show variances calculated over 15-long sample periods. Again, results for the DEM/USD rate is the most favorable. It is notable, for example, that after the turbulent period of the seventies, the variance of the 10-year long forward rate is rather stable across different sample period.

[6] Results were similar using 7-year yields, for which univariate tests also indicated stationarity of long forward rates.

Stationarity of the expected long run exchange rate could be striking from the point of view of economic theory, since one would expect, if any, the real exchange rate to behave stationary. We will comment this anomaly in the theoretical section, by arguing that the nominal rate could be a good proxy for the real rate, at least in the recent period of low inflation. The high and volatile inflation episode of the seventies could be regarded as an adjustment period toward the long run equilibrium.

To sum up, evidence presented in this section do suggest that long run exchange rate expectations are stationary and have smaller variance than spot exchange rates, which support our assumption in the next theoretical section that shocks to the yield curve could leave the long run expectations relatively stable.

4. The Yield Parity Approach

In this section we suggest a new explanation of the forward-bias puzzle. We integrate the expectation hypotheses of the term structure (EHTS) and of the foreign exchange market (UIP). Ex ante all of these hypotheses, both in the short run and in the long run, are assumed. The short run ex post movement of the exchange rate, however, is primarily determined by capital gains/losses of long term fixed income securities created by shocks to the term structure. In the ex post relation of fixed income investments and the foreign exchange rate, we are going to define a concept that we call as 'ex post parity of total yields', or 'yield parity' to phrase it briefly.

4.1. The Basic Setup

We adopt the standard assumptions of perfect markets (free international capital movements, domestic and foreign investment opportunities being perfect substitutes, government bonds are risk free, risk neutral and rational investors) and the assumption of flexible exchange rate regime. We assume both short run and long run UIP and the EHTS without any risk or term premium. Term premium is frequently found by papers studying the EHTS, however, we will always use the interest rate differential between two countries. If term premiums in the US, Germany, and UK had similar magnitude then our assumption of no term premium was not restrictive.

We set up our model in discreet time. We start with the hypothesis that the whole investment period contains '*n*' individual time periods. The length of an individual period could be anything, e.g. one day, week, month, etc. We assume that '*n*' is larger than one and, depending on the frequency of the underlying individual time period, could take values representing, say, from one year to ten years. For the exposition of our model presented in this section, the exact length of the investment horizon is not important (apart from the assumption that it is larger than one). In the empirical analysis presented in the next section of this paper, we will assume, which we regard as a safe assumption, that usual investment horizons fall within the range of one to ten years, for which we have consistently calculated available data for zero coupon yield curves. We assume that investors invest into the whole range of discount bonds; hence we do not have to bother with the issue of interest payments of fixed income securities. However, to keep in line with the wording of the literature, we will use the term 'interest rates', which we define, of course, the usual way.[7]

As we have already said, the UIP and the EHTS are assumed ex ante in every time period for both short and long maturities. Short run and long run UIP implies that

$$(7) \qquad E_t(s_{t+1}) = s_t + i_t^{(t,t+1)} - i_t^{*(t,t+1)},$$

$$(8) \qquad E_t(s_{t+n}) = s_t + n \cdot \left(i_t^{(t,t+n)} - i_t^{*(t,t+n)}\right),$$

where E_t denotes the expectations operator based on information available at time t. UIP holds in the next period as well, hence

$$(9) \qquad E_{t+1}(s_{t+n}) = s_{t+1} + (n-1) \cdot \left(i_{t+1}^{(t+1,t+n)} - i_{t+1}^{*(t+1,t+n)}\right) .$$

Combining (7) and (9) and assuming EHTS with no term premium, we have

$$(10) \qquad E_t(s_{t+n}) = s_t + \left(i_t^{(t,t+1)} - i_t^{*(t,t+1)}\right) + (n-1) \cdot \left(i_t^{F(t+1,t+n)} - i_t^{*F(t+1,t+n)}\right),$$

where $i_t^{F(t+1,t+n)}$ denotes the forward interest rate for period t+1 to t+n quoted at time t. A simple derivation using the above equations allows us to rewrite (7) as

$$(11) \qquad E_t(s_{t+1}) - s_t = n \cdot \left(i_t^{(t,t+n)} - i_t^{*(t,t+n)}\right) - (n-1) \cdot \left(i_t^{F(t+1,t+n)} - i_t^{*F(t+1,t+n)}\right).$$

The empirically tractable version of equation (11) will serve as our test equation.

4.2. Dynamics of the Exchange Rate in the Short Run

Suppose that there is an unexpected shock to the term structure at time point *t+1*, that is, the EHTS is violated ex post. In this case the ex post movement of the exchange rate from time point *t* to *t+1* could be rather different from the prediction of previous period UIP, even if UIP and EHTS held ex ante in time period *t+1* as well. This result, which we explore below, is the main contribution of our model.

The expected long run exchange rate based on time *t* and *t*+1 information can be expressed as

[7] For the ease of exposition of the model, in this section we consider continuous interest compounding, but this assumption will be easily substituted in the empirical section with the usually adopted method (simple linear interest counting for within-year maturities and compounded interest counting for over the yearl period).

(12) $E_t(s_{t+n}) = E_t(s_{t+1}) + (n-1)\cdot(i_t^{F(t+1,t+n)} - i_t^{*F(t+1,t+n)})$,

(13) $E_{t+1}(s_{t+n}) = s_{t+1} + (n-1)\cdot(i_{t+1}^{(t+1,t+n)} - i_{t+1}^{*(t+1,t+n)})$,

so the unexpected change of the exchange rate is expressed as

(14) $s_{t+1} - E_t(s_{t+1}) = [E_{t+1}(s_{t+n}) - E_t(s_{t+n})] - (n-1)\cdot\left[\left(i_{t+1}^{(t+1,t+n)} - i_{t+1}^{*(t+1,t+n)}\right) - \left(i_t^{F(t+1,t+n)} - i_t^{*F(t+1,t+n)}\right)\right]$.

Hence, whenever the EHTS is violated ex post, i.e. the second term on the right hand side of equation (14) differs from zero, then either the expected long run exchange rate could change (i.e. the first term on the right hand side), or the spot exchange rate could differ from its previous expectations (or any combinations of them).

Assume that in the second period the long (the *t*+1 to *t*+*n*) interest rate differential is larger than expected earlier (i.e. the second term on the right hand side is positive, which is multiplied with a negative number). There are two possible corner solutions. (1) The expected long run exchange rate depreciates to absorb the full adjustment (the first term on the right hand side), in which case the spot exchange rate equals to its previous period expectation according to short run UIP. (2) The expected long run exchange rate stays constant; hence the depreciation of the spot rate will be less than predicted by UIP in the previous period.

The first corner solution is consistent with, besides ex ante UIP, ex post short UIP as well. The second corner solution could be regarded as the ex post parity of total yields. The term "ex post parity of total yields" refers to the case when the expected value of total yield from *t* to *t*+*n* based on *t* information set is the same as the sum of the actual yield from *t* to *t*+1 and the expected yield from *t*+1 to *t*+*n* based on *t*+1 information set. The factor that equalizes the expected yields for the full investment period is the capital gain or loss assumed by the long maturity bond price. Hence, we can express this path as

(15) $s_{t+1} - s_t = (i_t^{(t,t+1)} + \Delta\tilde{g}_{t+1}) - (i_t^{*(t,t+1)} + \Delta\tilde{g}_{t+1}^*)$,

where $\Delta\tilde{g}_{t+1} = \Delta g_{t+1} - E_t[\Delta g_{t+1}]$ is the unexpected price change of risk free discount bond.[8] We relate these capital gains/losses to the exchange rate change over the same period, i.e. from *t* to *t*+1, hence, their values are not known ex ante but only ex post. Let us highlight again that this outcome

[8] Since a discount bond, by definition, does not pay interest, its one-period expected change equals to the one-period interest rate, $i_t^{(t,t+1)}$. Hence, we could simplify equation (15) as $\Delta s_{t+1} = \Delta g_{t+1} - \Delta g_{t+1}^*$. The reason for separating the two terms is to emphasize the known and the unexpected elements of the yields.

hinges on the assumption that shocks of the EHTS fully transmit into the spot exchange rate and to bond prices.[9]

In empirical testing of this hypothesis, the right hand side of equation (15) can be equivalently replaced with the following formula, which is equals to our notion of yield parity:

$$(16) \qquad s_{t+1} - s_t = n \cdot \left(i_t^{(t,t+n)} - i_t^{*(t,t+n)}\right) - (n-1) \cdot \left(i_{t+1}^{(t+1,t+n)} - i_{t+1}^{*(t+1,t+n)}\right) \equiv YP_{t+1}^{(t,t+1)}.$$

Note the similarity between equations (11) and (16). Equation (11) was an identity in which both the left and the right hand side variables are based on time *t* information set. Equation (16), on the other hand, is an expression for the actual change in the exchange rate from time *t* to *t*+1 expressed as the function of both time *t* and time *t*+1 information. That's why we subscripted yield parity with *t*+1. This potentially causes and endogeneity problem if we are to regress $(s_{t+1} - s_t)$ on $YP_{t+1}^{(t,t+1)}$, that is,

$$(17) \qquad s_{t+1} - s_t = \alpha + \beta \cdot \left[n \cdot \left(i_t^{(t,t+n)} - i_t^{*(t,t+n)}\right) - (n-1) \cdot \left(i_{t+1}^{(t+1,t+n)} - i_{t+1}^{*(t+1,t+n)}\right)\right] + \varepsilon_{t+1}.$$

Note that when α=0 and β=1, subtracting equation (11) from equation (17) and rearranging for the error term

$$(18) \qquad \varepsilon_{t+1} = (n-1) \cdot \left[\left(i_{t+1}^{(t+1,t+n)} - i_{t+1}^{*(t+1,t+n)}\right) - \left(i_t^{F(t+1,t+n)} - i_t^{*F(t+1,t+n)}\right)\right] + \left(s_{t+1} - E_t(s_{t+1})\right).$$

Hence, the error term is the sum of two expectation errors. Unfortunately, the expectation error of the term structure is likely correlated with the regressor, namely with $\left(i_{t+1}^{(t+1,t+n)} - i_{t+1}^{*(t+1,t+n)}\right)$, in which case estimation of equation (17) or its variants will have biased estimates. This endogeneity problem can not be handled in standard ways. Hence, although we will estimate this regression and present results in Section 6, our main emphasis are the stationarity of long forwards showed already, and the simulation evidence to be presented in Section 7.

4.3. Adjustment in the Spot *versus* in the Expected Long Run Exchange Rate

Before turning to estimation and simulation issues, we have to conclude the conceptual section by answering the key question: why the spot exchange rate should bear at least part of the adjustment, instead of the expected long run exchange rate? We propose four possible reasons.

[9] The second assumption (i.e. ex post failures of the EHTS transmit into bond prices) is the direct consequence of ex ante EHTS, since the repayment value of the discount bond at $t+n$ is known with certainty. Hence, with ex ante parities, while the exchange rate adjustment could take place either in its long run expectation or in its spot value, in the case of bonds, only the spot price can adjust under our assumption of risk-free bonds.

First, stylized facts are consistent with this assumption. Namely, the other corner solution (full adjustment of the expected long run exchange rate) implies the validity of ex post short UIP and the failure of ex post long UIP. Stylized facts, however, suggest the opposite.

Second, we think that, in response to shocks, investors could rather maintain their long run expectation and accept adjustment in the spot exchange rate, than the reverse. An argument in favor of stability of longer run expectations is the evidence presented in the previous section on long run UIP. Why? Because, taking long UIP as given, the pricing of long bonds at t is an unbiased predictor of $t+n$ nominal exchange rate, hence at $t+1$ the impetus to revise long run expectation could be lower, when the nature of the shock (i.e. whether it is a pure noise or something fundamental) could not be clearly recognized. This argument has a testable implication that the variance of the long run expected exchange rate should be lower than that of the spot rate, which we have already confirmed.

Third, one may argue that we are assuming the stability of the long run expected nominal exchange rate, although many economists would favor the stability of the long run real exchange rate. There is a strict correspondence between expectations on the nominal and real exchange rate stability only if domestic and foreign monetary authorities follow credible price level targeting policies. However, we know from the buoying literature on monetary policy rules that this is not the case in the countries we study. Hence, under inflation targeting, floating exchange rate regime, and real exchange rate stability, the level of the long run nominal exchange rate is not pinned down, which questions our assumption. This is indeed a valid critique and we can only list some arguments that weaken its strength. Namely, the current monetary regimes led to low inflation for many years, and one might say that inflation is expected to stay at low levels in the future as well. In such an environment investors could expect that shocks to domestic and foreign inflation rates are low on the average on the one hand. On the other hand, even if shocks did not sum to zero in a given country, they could have similar accumulated values at home and abroad, resulting from, for example, and the globalized world economy. This argument implies that the nominal exchange rate is a good proxy for the real rate, which has been argued in numerous papers. Moreover, this argument suggests that our assumption has more relevance in the recent history of low inflation than in the uncertain periods of the seventies and eighties.

Fourth, empirical tests of the EHTS suggest that it has more relevance for long run than for short run changes in the term structure (Shiller 1990, Campbell 1995), suggesting again, that investors could give more credit to their previous period long-term expectations. Needless to say that we do not claim that all shocks to financial markets leave the expected long run exchange rate unchanged. In fact, a simple plot of, say, the 10-year ahead “expectations” derived from the 10-year UIP shows fluctuations, although not as wide as the spot rate, for major currencies, as we have already shown in Figure 3. What we do think, however, is that a significant fraction of shocks are 'short run shocks' which leave the expected long run exchange rate relatively stable, and which is supported by our strikingly new result on the stationarity of the expected long run exchange rate in Section 3.

Before our empirical analyses and simulation study, we would like to emphasize that our approach does not exclude the possibility of the feedback from the exchange rate to the term structure, due to, for example, the reaction of monetary policy. Shock to the term structure could be rooted in monetary policy response to various events. Moreover, we assume perfect markets, but the standard imperfections, like risk premium and term premium, could be integrated into our approach as well. However, we want to go without these imperfections to see how far we can reach in understanding the forward discount bias puzzle.

5. A new explanation for the failure of short-run UIP: Exchange rate shocks are not orthogonal to the previous period short interest rate differentials

The concept of yield parity defined in the previous section could be also viewed as a measure of how much of the EHTS shocks are absorbed by the spot exchange rate. In this section we calculate values of the spot exchange rate if it had absorbed all or none of the EHTS shocks. We use this decomposition to offer a new explanation for the short-run UIP puzzle.

Let us return to equation (14). For simplicity, denote the short-run UIP error with $\varepsilon_{t+1}^{UIP} \equiv s_{t+1} - E_t(s_{t+1})$, the change in the expected long-run exchange rate as $\varepsilon_{t+1}^{sL} \equiv E_{t+1}(s_{t+n}) - E_t(s_{t+n})$, and the EHTS error as $\varepsilon_{t+1}^{EHTS} \equiv (n-1)\cdot\left[\left(i_{t+1}^{(t+1,t+n)} - i_{t+1}^{*(t+1,t+n)}\right) - \left(i_t^{F(t+1,t+n)} - i_t^{*F(t+1,t+n)}\right)\right]$. Using this notation, equation (14) can be rewritten as

(14') $\varepsilon_{t+1}^{UIP} = \varepsilon_{t+1}^{sL} - \varepsilon_{t+1}^{EHTS}$

Equation (14') is an identity: under our maintained assumptions (UIP in the short and long run plus EHTS) the magnitudes in (14') can be easily calculated from the data. Equation (14'), however, does not imply by itself any correlation structures. It could be possible, for example, that a shock to the term structure is completely offset by the opposite movement of the expected long run exchange rate, in which case the UIP error will be zero. It also could be possible that shocks to short run UIP and the expected long run exchange rate are highly correlated and the ETHS shock is independent of them, adding only a small noise to the relationship.

Equation (14') also does not imply by itself any causalities, nor it implies the sources of shocks. For example, in the case of the euro/dollar rate, in December 2004 there was a close to zero shock to the term structure, it's magnitude was 0.0008, while shocks to UIP and long run exchange rate were -

0.0241 and -0.0233, respectively, indicating that both the spot and expected long run exchange rates of the euro appreciated by more than two percent. Indeed, a simple graph showing the three shocks indicate a strong comovement of ε_{t+1}^{UIP} and ε_{t+1}^{sL} , which clearly indicates the presence of ‘generic’ foreign exchange rate shocks. We will denote this shock as $\bar{\varepsilon}_{t+1}^{s\_CF}$, where CF stands for ‘common factor’ of spot and expected long run exchange rate shocks. Hence, we aim to decompose the magnitudes in (14’) as:

(14’’) $\left(\bar{\varepsilon}_{t+1}^{s\_CF} + \bar{\varepsilon}_{t+1}^{s\_S}\right) = \left(\bar{\varepsilon}_{t+1}^{s\_CF} + \bar{\varepsilon}_{t+1}^{s\_L}\right) - \varepsilon_{t+1}^{EHTS}$,

where $\bar{\varepsilon}_{t+1}^{s\_S}$ and $\bar{\varepsilon}_{t+1}^{s\_L}$ denote the spot exchange rate specific and the expected long-run exchange rate specific components, which we will phrase briefly as ‘spot-specific’ and ‘long-specific’ components; and the tilde indicates unobserved shocks. Note that while equation (14’’) is still an identity, bracketed magnitudes can not be calculated from the data without any further assumptions.

We identify the common factor and spot and long-specific components using a common factor model. Specifically, we assume that the unobserved shocks, $\bar{\varepsilon}_{t+1} = \left[\bar{\varepsilon}_{t+1}^{s\_CF} \quad \bar{\varepsilon}_{t+1}^{s\_S} \quad \bar{\varepsilon}_{t+1}^{s\_L}\right]'$, has a multivariate normal distribution, $\bar{\varepsilon}_{t+1} \sim \mathrm{N}(0,\Omega)$, and that the observed shocks are related to these unobserved components as identities:

(19) $$\begin{aligned} \varepsilon_{t+1}^{UIP} &= \bar{\varepsilon}_{t+1}^{s\_CF} + \bar{\varepsilon}_{t+1}^{s\_S} \\ \varepsilon_{t+1}^{s\_L} &= \bar{\varepsilon}_{t+1}^{s\_CF} + \bar{\varepsilon}_{t+1}^{s\_L} \end{aligned}$$

The Kalman-filter can be used to evaluate the likelihood function of the process and, having estimated the parameters of the model by maximum likelihood, to infer the unobserved factors. For instance, continuing the example above, the model indicates that the value of the common component of the euro/dollar rate in December 2004 was -0.0208, while the spot and long specific values were -0.0033 and -0.0025, respectively.

The general feature of the estimations were that σ($\bar{\varepsilon}_{t+1}^{s\_S}$) < σ($\bar{\varepsilon}_{t+1}^{s\_L}$) < σ($\bar{\varepsilon}_{t+1}^{s\_CF}$), e.g. for the DEM/USD rate for the full period of 1973-2005 the standard deviations are 0.018, 0.025, and 0.031, respectively. Note, for comparison, that the standard deviations of $\varepsilon_{t+1}^{UIP}, \varepsilon_{t+1}^{sL}, \varepsilon_{t+1}^{EHTS}$ for the same period are 0.033, 0.043, and 0.031, respectively.

When the components are identified, the magnitudes in the trivial reduction of equation (14’’) can be calculated:

(14’’’) $\bar{\varepsilon}_{t+1}^{s\_S} = \bar{\varepsilon}_{t+1}^{s\_L} - \varepsilon_{t+1}^{EHTS}$.

Hence, an EHTS shock is either absorbed by the short or long-specific shocks, or by any combinations of the two.

The identification of foreign exchange rate shock components allows us to ask the questions: what would have been the properties of the expected long-run exchange rate, if (a) it absorbed all EHTS shocks, (b) it absorbed no EHTS shocks. For instance, when the expected long run exchange rate absorbed all EHTS shocks then $\bar{\varepsilon}_{t+1}^{s\_S} = 0$, hence, $\bar{\varepsilon}_{t+1}^{s\_L} = \varepsilon_{t+1}^{EHTS}$. When the spot rate absorbs all the EHTS shocks then $\bar{\varepsilon}_{t+1}^{s\_L} = 0$. Since ε_{t+1}^{sL} is simply the change in the expected long run exchange rate, then the magnitudes we are interested can be easily calculated as

(20.a) $s_{t+1}^{L\_all\_EHTS} = s_t^{L\_all\_EHTS} + \bar{\varepsilon}_{t+1}^{s\_CF} + \varepsilon_{t+1}^{EHTS}$,

(20.b) $s_{t+1}^{L\_no\_EHTS} = s_t^{L\_no\_EHTS} + \bar{\varepsilon}_{t+1}^{s\_CF}$,

where the recursion could be started from any values (which only modifies the mean but not the statistical properties of the constructed series). We started the recursions in (20) from the actual vale of the expected long run exchange rate, in order to be able to compare easily the actual and the constructed series.

A similar exercise could be done for the spot rate as well. Recall that $\bar{\varepsilon}_{t+1}^{s\_CF} + \bar{\varepsilon}_{t+1}^{s\_S} = \varepsilon_{t+1}^{UIP} = s_{t+1} - E_t(s_{t+1}) = s_{t+1} - \left(s_t + \tilde{i}_t^{\,S}\right)$, therefore, $s_{t+1} = s_t + \tilde{i}_t^{\,S} + \bar{\varepsilon}_{t+1}^{s\_CF} + \bar{\varepsilon}_{t+1}^{s\_S}$. When the spot rate absorbs all EHTS shocks, then $\bar{\varepsilon}_{t+1}^{s\_S} = -\varepsilon_{t+1}^{EHTS}$ from (14’’’), hence:

(21.a) $s_{t+1}^{S\_full\_EHTS\_absorb} = s_t^{S\_full\_EHTS\_absorb} + i_t^S + \bar{\varepsilon}_{t+1}^{s\_CF} - \varepsilon_{t+1}^{EHTS}$,

(21.b) $s_{t+1}^{S\_no\_EHTS\_absorb} = s_t^{S\_no\_EHTS\_absorb} + i_t^S + \bar{\varepsilon}_{t+1}^{s\_CF}$

where we started the recursion from the actual value of the spot exchange rate.

Figure 5 shows the magnitudes calculated in (21.a) and (21.b), the short-run interest differential ($\tilde{i}_t^{\,S}$), and the ‘generic’ foreign exchange rate shock ($\bar{\varepsilon}_t^{s\_CF}$), for the DEM/USD rate. The actual exchange rate lies between the two hypothetical paths.

Recall from the previous section that when the long run expected exchange rate absorbs all of the EHTS shocks and hence the spot exchange rate assumes none of these shocks, then short run UIP holds in ex-post data as well. Hence, the artificial series in (21.b) should fulfill ex post UIP. Note also that the data generating process for the difference is: $\Delta\left(s_{t+1}^{S\_no\_EHTS\_absorb}\right) = i_t^S + \bar{\varepsilon}_{t+1}^{s\_CF}$. Therefore, in a standard regression

(22) $\Delta\left(s_{t+1}^{S\_no\_EHTS\_absorb}\right) = \alpha_{UIP} + \beta_{UIP}\tilde{i}_t^{\,S} + v_{t+1}$,

we would expect that $\hat{\alpha}_{UIP} = 0, \hat{\beta}_{UIP} = 1, \hat{v}_{t+1} = \bar{\varepsilon}^{s\_CF}_{t+1}$. However, this is not the case: $\hat{\beta}_{UIP} = -0.75$. when estimating equation (22). The point estimate is slightly better than estimation for the actual exchange rate (-1.07), but still significantly different from one and zero as well.

Figure 5 indicates that the variance of $\bar{\varepsilon}^{s\_CF}_{t+1}$ is several factors larger than that of $\tilde{i}^{S}_{t}$. However, not the variance is responsible: when we generate the hypothetical value defined by (21.b) using a random number having the same variance as $\bar{\varepsilon}^{s\_CF}_{t+1}$, then $\hat{\beta}_{UIP} \approx 1$.

Hence, the only explanation why estimation of (22) gives biased estimate is that $\bar{\varepsilon}^{s\_CF}_{t+1}$ is not orthogonal to $\tilde{i}^{S}_{t}$, that is, the next period exchange rate shock is correlated with the previous period interest rate differential. In fact, a simple correlation coefficient indicates a correlation of -0.14 between $\bar{\varepsilon}^{s\_CF}_{t+1}$ and $\tilde{i}^{S}_{t}$. We conjecture that this correlation is due to the stationarity of long maturity forward rates.

6. Empirical Evidence on Yield Parity for Major Exchange Rates

This section presents some simple graphs and regression estimates for yield parities. Before presenting these results we first have to solve a data problem. Note that in equation (17) yields from *t+1* to *t+n* is used to calculate yield parities, however, data are usually not available for *n*-1 period interest rates. For example, in a monthly frequency and 10-year long bonds, *n*=120 months, so we would need 119-month interest rate which is not available. Instead, we will approximate it with the *n*-period rate (120-month in the example) and adopt the approximation:

(23) $$\left(i^{(t+1,t+n)}_{t+1} - i^{*(t+1,t+n)}_{t+1}\right) \cong \left(i^{(t+1,t+n+1)}_{t+1} - i^{*(t+1,t+n+1)}_{t+1}\right) .$$

Hence

(24) $$\widetilde{YP}^{(t,t+1)}_{t+1} \equiv n \cdot \left(i^{(t,t+n)}_{t} - i^{*(t,t+n)}_{t}\right) - (n-1) \cdot \left(i^{(t+1,t+n+1)}_{t+1} - i^{*(t+1,t+n+1)}_{t+1}\right) .$$

This approximation could be quite precise in the case of the 10-year long rates, but obviously less accurate for 1-year bonds, when we will use the 12-month rate instead of the 11-month rate.

Figure 6 simply plots Δs_{t+1} and $\widetilde{YP}^{(t,t+1)}_{t+1}$, the latter is calculated using six different maturities: 1, 2, 3, 5, 7 and 10 years. We can observe that the volatility of the yield parities heavily depends on the maturity of the interest rates which was used for calculation. For example, at 1-year horizon the volatility of the yield parity is much smaller than that of the exchange rate. However, we may also note, albeit not shown on this figure, that the volatility of yield parity is still much larger than the volatility of the simple interest rate differential. The volatility of yield parities calculated from longer maturity interest rates, e.g. from 7 and 10 years, is comparable to that of the exchange rate.

This simple volatility result is especially important since standard fundamentals, like interest rate differentials, which are frequently used to analyze exchange rate behavior, have substantially lower volatilities than exchange rates.

We use the following equation for regression analysis:

$$(25) \qquad s_{t+1} - s_t = \alpha + \beta \cdot \left[n \cdot \left(i_t^{(t,t+n)} - i_t^{*(t,t+n)} \right) - (n-1) \cdot \left(i_{t+1}^{(t+1,t+n+1)} - i_{t+1}^{*(t+1,t+n+1)} \right) \right] + \varepsilon_{t+1} .$$

We have already highlighted in Section 4.2 that OLS estimation of this equation is likely burdened with the problem of simultaneity bias. We currently do not know the direction and the magnitude of this bias (we still work on this issue). On the other hand, this equation has a favorable property compared to long-run UIP-equations: it is not burdened with the problem of overlapping observations.

Tables 7-8-9 show estimation results for the three major currencies for different time periods. We observe that, for the full period, the results are not favorable, but results are rather different if we break the sample into subperiods. Results for the seventies and eighties are bad but reasonably good for the nineties. β-estimates, especially yield parities calculated for longer maturity bonds, tend to be positive and there are a few cases when the null hypothesis of [α,β]=[0,1] cannot be rejected. Note also that there is no autocorrelation in the residuals due to the fact that the sample is not overlapping.

To get further insights into the sensitivity of our results, we estimated our equation for rolling samples of 2, 5, and 10-year long periods. As a benchmark, Figure 7 shows the estimates of β for one-month UIP (using end of month data, hence, there is also no overlapping). We observe huge variation of the point estimate, which does not seem to stay at positive regions, and very wide confidence bands. Our rolling sample yield parity coefficients are shown in Figures 8-9-10. The Figures suggest close to zero values in the first part of the sample, but in the second part, the estimates are generally positive, and in many cases the theoretical value of 1 is included in the confidence bands.

We give two possible explanations for the sample sensitivity. The first one is related to liberalization of bond markets, as we already cited this argument from Chinn-Meredith (2000) for their long run UIP results in Section 2. The second explanation is the low inflation episode since the nineties, as we argued in the third point of Section 4.3. The sample dependence of our results, namely, that we have better results for the nineties which can be explained with economic arguments, suggests us that the simultaneity problem is perhaps not devastating for our regressions.

7. Simulation Evidence on the Yield Parity Approach

In this section we ask the question that, in a model when the expected long run exchange rate follows a stationary process and both the short and the long UIP and the EHTS are assumed, then shocks to the yield curve and shocks to the expected long run exchange rate could generate a process for the spot exchange rate –in the absence of shock to the spot rate– which is similar to observed exchange rate movements. To this end, we calibrate and stochastically simulate a stylized model corresponding to these assumptions.

In Section 3 we found that the long forwards are stationary, hence we assume that the expected long run exchange rate follows the stationary process below:

$$(26) \qquad s_t^L = \alpha + \rho_{sLONG} s_{t-1}^L + \varepsilon_t^{sL} ,$$

where $s_t^L = E_t[s_{t+n}]$ denotes the log of the expected long run exchange rate, and $|\rho_{sLONG}| < 1$. We have also found that the short term and the long-term interest differentials are non-stationary, hence, with the assumption of the EHTS, these series should follow

$$(27) \qquad \left(i_t^{(t,t+1)} - i_t^{*(t,t+1)}\right) = \left(i_{t-1}^{(t-1,t)} - i_{t-1}^{*(t-1,t)}\right) + \varepsilon_t^{iS} ,$$

$$(28) \qquad \left(i_t^{(t,t+n)} - i_t^{*(t,t+n)}\right) = \left(i_t^{(t,t+1)} - i_t^{*(t,t+1)}\right) + \varepsilon_t^{iL} .$$

Note, again, that interest rates are not annualized, but measured in the unit of time period (which will be monthly frequency in our calibration). However, when calibrating the processes according to (27-28), the interest rate differentials frequently walked far from zero, in contrast to observed series, leading to much larger variance than that of the observed series. This property of the model also had the consequence that the simulated variance of the spot exchange rate became several factors larger than the actual one. To tackle this problem, we allowed some reversion toward zero in the simple form of

$$(27') \qquad \left(i_t^{(t,t+1)} - i_t^{*(t,t+1)}\right) = \rho_{iSHORT}\left(i_{t-1}^{(t-1,t)} - i_{t-1}^{*(t-1,t)}\right) + \varepsilon_t^{iS}$$

$$(28') \qquad \left(i_t^{(t,t+n)} - i_t^{*(t,t+n)}\right) = \rho_{iLONG}\left(i_{t-1}^{(t-1,t+n-1)} - i_{t-1}^{*(t-1,t+n-1)}\right) + \left(1 - \rho_{iLONG}\right)\left(i_t^{(t,t+1)} - i_t^{*(t,t+1)}\right) + \varepsilon_t^{iL} ,$$

where the parameter restriction in (28') serves to impose EHTS. We will set the autoregressive parameters equal to estimated values by ordinary least squared (the estimates values are indicated in the notes of Tables 10-13). Naturally, we know that OLS estimates are downward biased, and we have confirmed that they do not significantly differ from one. However, we will show later that (27'-28') with estimated parameters reasonably well mitigates the sample distribution of interest rate differentials. Moreover, although we set stationary processes for the interest rate differentials, we will study the results of unit root and stationary tests for their stochastically simulated realizations.

The vector of errors, $\varepsilon_t{}' = \left[\varepsilon_t^{sL}, \varepsilon_t^{iS}, \varepsilon_t^{iL}\right]$, is assumed to be multivariate normal with a non-diagonal covariance matrix Ω. We adopted the assumption of normality in order to see how this simplest distributional assumption performs in our simulations. The spot exchange rate is determined by long run UIP:

(29) $$s_t = s_t^L - n \cdot \left(i_t^{(t,t+n)} - i_t^{*(t,t+n)}\right),$$

where n is equal to the number of periods of the long interest rate, which will be 120 in our calibration (10 years of monthly data). Hence, besides shocks arriving from the money market, bond market, and the expected long exchange rate, there is no disturbance assumed for the spot rate.

We estimate the parameters of the model (26-27'-28') along with Ω for monthly series of our currencies, where, according to our previous results, the expected long run exchange rate is set equal to the 10-year forward exchange rate. The initial values of long run exchange rate and the interest rate differentials, which are needed for simulation, were set equal to sample values, that is, the actual values of 1973M1 (for the DEM/USD rate) and 1979M1 for all three rates. Then, we draw three random series from the multivariate distribution of the disturbances,[10] simulate equations (26-27'-28'), and calculate s_t from (29) for a sample period equal to that of the observed series. Finally, we study the properties of simulated series including, of course, s_t, concentrating on their variance, unit root and stationarity tests, and also on the ex post short and long UIP regressions and yield-parity regressions. Replicating the simulation procedure 1,000 times will give us 1,000 artificial samples for the inference on the properties of the simulated series.

Tables 10-13 show the simulated distribution of our series and some further statistics. The distribution of the baseline specification is shown in detail (the 2.5%, 25%, 50%, 75%, 97.5% quantiles), while for alternative scenarios we only show the median statistics of the 1,000 artificial samples. We present four alternative scenarios. In Scenario 2 we assume that Ω is diagonal. Scenario 3 assumes that the expected long run exchange rate is constant and equals to its starting value. The final two scenarios assume that either the short or the long interest rate differential is constant. Since EHTS requires that the short or the long interest rate differential to have the same

[10] Specifically, we draw three independent and identically distributed (iid) random series and use the transpose of the unique Cholesky-factor of the estimated covariance matrix of the innovations to transform the iid random series. Namely, let e denote the (n×3) matrix of the three iid innovations, so $E[e'e] = I$. Let L denote the Cholesky-factor, $LL' = \hat{\Omega}$, so for $\varepsilon \equiv eL'$ we have $E[\varepsilon'\varepsilon] = E[Le'eL'] = \hat{\Omega}$.

mean, in the final two scenarios the constant interest rate differential was set equal to zero and the initial value of the other one was set to zero.

The first block of each table shows the second moments of the innovations. The simulated series well capture the variances and covariances of the sample innovations. For the ease of reading we report correlation coefficients instead of covariance. We observe that innovations of the long run expected exchange rate and the long run interest rate differential has a substantial positive correlation in the case of all currencies examined (in the range of 0.65-0.82). This has a natural interpretation of long run shocks being correlated. This positive correlation could be an argument against our theoretical model, since it is at odds with the stability of the long exchange rate in the case of shocks to the long run interest rate differential. However, one should check the performance of the full model. The correlation coefficients of other innovations are also positive although have a much smaller value. Of these two other relations, $\rho(\varepsilon_t^{iS}, \varepsilon_t^{iL}) > \rho(\varepsilon_t^{sL}, \varepsilon_t^{iS})$ in all relations, which is in line with our expectation, and $\rho(\varepsilon_t^{sL}, \varepsilon_t^{iS})$ is not significantly different from zero. There is also a small autocorrelation in some of the innovations, which information we do not make use.

The next block of Tables 10-13 describes the properties of the expected long run exchange rate. We can see that simulation captures almost exactly the mean of the true series (the ratio of the median simulated values to the sample values is 0.99-1.04) but the variance is somehow lower (the ratio is in the range of 0.64-0.87). The later could be the consequence of our normality assumption. Unit root and stationarity tests confirm the stationarity of the variable.

The next two blocks show properties of the short and long interest rate differential. Since the mean of these series are close to zero, we are less concerned with their deviation from the true value and more interested in their variance and unit root tests. The variances of both interest rate differentials are reasonably approximated; the only large exception is the variance of the long interest rate differential in the GBP/USD case which is about four times larger than actual. Unit root and stationarity tests indicate in most cases the non-stationarity of both interest rate differentials with the short differential in the DEM/USD case being at the borderline. Hence, despite our stationary, but near unit root specification,[11] the simulated series seem to mimic well the seemingly non-stationary nature of the interest rate differential.

We can conclude by now that our stylized model captures quite well the main properties of the series that we use to deterministically generate the spot exchange rate. We turn to the main interests of our simulation, to the properties of the spot exchange rate and the short and long UIP equations,

[11] There is one exception: the long interest differential in the DEM/GBP case had a point estimate of 1.001 for the autoregressive parameter and was simulated accordingly.

that is, equation (1) with n=1 (short) and n=120 (long), and the YP regression (25). Results are shown in the final four blocks of Tables 10-13.

The variance of the spot rate is reasonably well captured: the ratio of baseline median to sample is 0.97, 0.63, 1.92, and 1.12 for the four cases shown in Tables 10-13. The large outlier value of 1.92 is likely the consequence of the extraordinary large variance of the simulated long interest rate differential in the GBP/USD case. This double variance halves, on the other hand, in Scenarios 4 and 5, i.e. when we fix either the short or the long interest rate differential.

With the exception of the model calibrated to the DEM/USD rate for 1973M1-2003M12, unit root and stationarity tests strongly indicate non-stationarity of the spot rate, despite the fact that the true data generating process is stationary, although near unit root due to the long interest rate differential. Alternative scenarios change these results in two cases. First, in Scenario 5 (when the long run interest rate differential is constantly zero) all spot rates are stationary, which has a clear interpretation: in this case the spot rate equals to the expected long exchange rate. Second, in the model calibrated to the DEM/USD rate for 1973M1-2003M12, Scenario 3 (when the expected long run exchange rate is constant) implies non-stationarity of the spot rate (and in the other three cases the non-rejection of unit root is somehow stronger), which strengthens our results. Since the short interest rate differential does not appear directly in the generation of the spot rate, this result implies that the covariance structure of the innovations matters.

One might argue that the properties of the simulated spot exchange rate largely reflect two features of our data generating process: (1) the near unit root process of the long interest rate differential and (2) the spot exchange rate –adjusted with the long interest rate differential– was used to calibrate the process of the long run. These two features might explain our good mach of the variance of the spot exchange rate and its seemingly non-stationary behavior despite its stationary specification. However, these two features can not be responsible for the excellent match of the three equations we turn now.

The simulated UIP equations are largely consistent with sample results. The median point estimates of β are negative in the short UIP equation in the case of all currencies in all scenarios with the sole exception of Scenario 3 in the DEM/GBP specification. On the other hand, the median point estimates of β are positive in the long UIP equation in all cases. None of the β estimates of the short UIP equation differs significantly from zero, similarly to sample results, while most of them are significant in the long UIP equations, again, similarly to sample results. R^2 is virtually zero in short UIP equations but has definitely non-zero values in long UIP regressions. These results are largely consistent with the data.

Finally, the simulated yield-parity equations are also largely consistent with sample results. It is remarkable that the estimated β-coefficients, their standard errors, and the R^2 are very close to the actual estimates of observed exchange rates, even the negative point estimate in the case of the DEM/GBP calibration is captured. The constancy of the long run exchange rate in Scenario 3 pushes the estimated β-coefficient and the R^2 to one, since in this case the change in s_t equals the negative of the change in the long interest differential *n* times (see equation 29), which is approximately equal to the regressor (see equation 25). The covariance structure of the innovations is also important in the yield parity regression: in Scenario 2 with independent innovations, the estimated β-coefficient does not differ significantly from one and the R^2 increases from the almost zero value of the baseline to the range of 0.3-0.4. This result likely reflects the lack of strong covariance between innovations to the long run exchange rate and the long interest rate differential, similarly to the long UIP regression. Constancy of the short interest differential in Scenario 4, on the other hand, does not affect the results significantly.

To sum up, we conclude that our stylized model well captures the observed properties of the spot exchange rates of major currencies. We should note, however, that our stylized model is not a casual model. We do not define the sources of shocks to the expected long run exchange rate and to the yield curve. Moreover, the absence of specific shocks to the spot exchange rate could not be distinctive as the unspecified shocks to the long rate and the yield curve could mirror short run shocks. For this reason, our model is not, say, a casual forecasting model, but a descriptive model. It shows that a setup —in which UIP and EHTS holds ex ante without any premia and the expected long run exchange rate follows a stationary process— is consistent with the volatility and the unit root finding of the spot rate, the negative β estimate with minor R^2 for the short run UIP equations, and significantly positive β estimates with substantial R^2 for the long run UIP equations, and the observed characteristics of yield-parity equations.

Our simulation model could be improved. For instance, we could take into account the uncertainty inherent in the estimation of the autoregressive parameters. We could also change the normality assumption and estimate the autoregressive parameters by maximum likelihood assuming, say *t*-distribution and draw the random series from a multivariate *t*-distribution consistently with the estimated innovations. While these extensions could improve the simulation results and perhaps could better capture higher moments of the spot exchange rate, we do not regard them as essential since our simple normality based approach well mimics the observed properties of the spot exchange rate of major currencies.

8. Summary

This paper offered a new explanation for the UIP puzzle, maintaining the assumptions of rational expectations and risk neutrality. Assuming that short run and long run UIP and EHTS hold ex ante, in the short-run, ex post deviation from the EHTS may be transmitted – trough realizations of bond-price gains/losses – to short-term exchange rate movements. We defined the concept of 'ex post parity of total yields' and phrased it briefly as 'yield parity', which is calculated as the one-period interest rate adjusted with the differential of domestic and foreign unexpected price changes of risk free discount bonds. We related yield parity to the short run fluctuations of the exchange rates.

We studied four major currencies, the US dollar, the Deutsche Mark/Euro, the British Pound and the Swiss Franc, using all six bilateral combinations of these currencies. We found five important results. First, UIP seems to hold for longer horizons in sharp contrast to short run results. Second, long forward rates, which represent expected long run exchange rates if long run UIP held, are stationary. Third, foreign exchange rate shocks are not orthogonal to previous period interest rate differentials. Fourth, some of our yield parities mirror exchange rate fluctuations and have variance comparable to that of the exchange rate and resulted in well interpretable regression statistics. , Long-run UIP regressions have already been studied in the literature, but the rest of the results listed above are our new empirical findings.

Fifth, we set up a stylized model, calibrated and stochastically simulated, and showed that the model —in which UIP and EHTS holds ex ante and the expected long run exchange rate follows a stationary process— is consistent with the large volatility and the unit root finding of the spot rate and the observed characteristics of short run and long run UIP regressions and yield-parity regressions. These results were robust to calibration to all of our currencies examined.

Although our yield parity approach could be integrated into the recent literature, that has been grown out from McCallum (1994), emphasizing the feedback of the exchange rate through fundamentals and monetary policy reaction functions, it underlines the importance of the stationarity of long run exchange rate expectations and the importance of shocks to bond markets in exchange rate determination. There are shocks, which have not received much attention in the UIP literature, but could affect both the demand and supply of bonds. For example, shocks to domestic and foreign saving, changes in the financial system, fiscal policies, or investors' anticipations could affect the bond market, but the implications of these factors for UIP have not been studied so far. We also did not attempt to identify the sources of shocks to the term structure and leave it for further research.

9. References

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10. Data Appendix

Our dataset consists of end of month data from January 1973 till December 2005, but most of the calculations use 1979 as the starting date.[12] We use constant maturity zero-coupon yields for the US, Germany, and UK for 1, 2, 3, 5, 7 and 10 years, which are freely available on the websites of St Louis FED, Deutsche Bundesbank, and Bank of England, respectively.[13] Zero-coupon yields are preferred to yield to maturity because interest payments do not disturb the results. For the Swiss Franc we could collect only 10-year long benchmark yield to maturity for our sample from the International Financial Statistics of the IMF. Therefore, we use Swiss rates for this maturity in Section 3 only to provide further evidence on the stationarity of long maturity forward rates, which is one of our central findings. Still, Swiss results should be taken with more care due to the different yield measure used.

Exchange rates are taken from the Deutsche Bundesbank. German mark rates were calculated from euro rates since 1999 with a multiplication by the conversion rate.

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[12] British zero-coupon yields are available since 1979 and German zero-coupon yields are available only at a monthly frequency up to 1997.

[13] To our knowledge, these rich datasets have not been used extensively so far. For example, to our knowledge, none of the many recent papers studying uncovered interest rate parity in the long run have used these datasets.

11. Tables

Table 1: Short and long run UIP equations

Horizon	1M	1Y	2Y	3Y	5Y	7Y	10Y
DEM/USD, 1973M1-2003M12							
T	371	360	307	336	312	288	252
α	-0.003	-0.022	-0.025	-0.037	-0.034	0.006	-0.013
$\sigma(\alpha)$	0.002	0.015	0.024	0.023	0.037	0.041	0.032
β	-1.097	-0.687	-0.309	-0.270	0.207	0.912	0.964
$\sigma(\beta)$	0.897	0.580	0.558	0.506	0.410	0.293	0.139
R^2	0.006	0.015	0.004	0.005	0.005	0.184	0.460
DW	1.86	0.14	0.06	0.04	0.03	0.04	0.07
$p(\alpha=0, \beta=0)$	0.309	0.232	0.529	0.221	0.514	0.003	0.000
$p(\alpha=0, \beta=1)$	0.064	0.011	0.051	0.009	0.136	0.908	0.913
DEM/USD, 1979M1-2003M12							
T	299	288	276	264	240	216	180
α	-0.002	-0.014	-0.005	0.010	0.063	0.105	0.125
$\sigma(\alpha)$	0.002	0.018	0.023	0.025	0.038	0.030	0.033
β	-1.082	-0.959	-0.263	0.214	1.225	1.835	1.519
$\sigma(\beta)$	0.892	0.667	0.593	0.562	0.378	0.215	0.158
R^2	0.006	0.028	0.003	0.003	0.128	0.581	0.638
DW	1.85	0.13	0.05	0.04	0.03	0.12	0.14
$p(\alpha=0, \beta=0)$	0.460	0.337	0.890	0.873	0.005	0.000	0.000
$p(\alpha=0, \beta=1)$	0.065	0.014	0.105	0.303	0.262	0.000	0.000
GBP/USD, 1979M1-2003M12							
T	299	288	276	264	240	216	180
α	0.005	0.035	0.053	0.050	0.022	-0.035	-0.007
$\sigma(\alpha)$	0.002	0.017	0.028	0.037	0.040	0.038	0.027
β	-2.604	-1.612	-0.960	-0.083	0.584	0.894	0.567
$\sigma(\beta)$	1.186	0.957	0.744	0.594	0.466	0.301	0.191
R^2	0.030	0.066	0.036	0.000	0.028	0.171	0.185
DW	1.91	0.18	0.10	0.06	0.05	0.11	0.12
$p(\alpha=0, \beta=0)$	0.043	0.104	0.166	0.175	0.108	0.001	0.002
$p(\alpha=0, \beta=1)$	0.009	0.022	0.031	0.191	0.671	0.118	0.010
DEM/GBP, 1979M1-2003M12							
T	299	288	276	264	240	216	180
α	-0.004	-0.032	-0.057	-0.031	0.118	0.285	0.211
$\sigma(\alpha)$	0.002	0.019	0.028	0.039	0.062	0.052	0.056
β	-1.097	-0.714	-0.553	0.190	1.548	2.213	1.441
$\sigma(\beta)$	0.786	0.703	0.488	0.349	0.394	0.255	0.179
R^2	0.008	0.019	0.017	0.003	0.206	0.591	0.423
DW	1.80	0.14	0.07	0.06	0.07	0.24	0.17
$p(\alpha=0, \beta=0)$	0.280	0.201	0.111	0.030	0.000	0.000	0.000
$p(\alpha=0, \beta=1)$	0.022	0.052	0.006	0.004	0.110	0.000	0.000

Notes. Estimated equation is (1), i.e. for 1M, the one-period, while for the rest multiperiod-ahead actual future exchange rate changes is regressed on the interest-differential. p(.): p-value of a joint F-test on parameters. Newey-West variance-covariance matrix for standard errors and F-test.

Table 2: Unit root and stationarity tests of interest rate differentials

	1M	1Y	2Y	3Y	5Y	7Y	10Y
			DEM/USD				
ADF	-2.01	-2.94**	-2.58*	-2.21	-2.17	-2.08	-1.93
PP	-2.75*	-2.56	-2.26	-2.21	-2.03	-1.9	-1.78
ERS DF	-1.37	-1.15	-1.36	-1.27	-1.47	-1.55	-1.51
ERS FPO	13	8.91	5.87	5.75	4.4*	4.01*	4.31*
NP MZa	-1.73	-3.06	-4.61	-4.62	-5.9*	-6.36*	-5.84*
NP MZt	-0.87	-1.19	-1.49	-1.5	-1.7*	-1.77*	-1.7*
NP MSB	0.5	0.39	0.32	0.32	0.29	0.28	0.29
NP MPT	13.28	7.94	5.39	5.36	4.2*	3.9*	4.23*
KPSS	0.65**	0.65**	0.73**	0.82***	1.02***	1.15***	1.3***
			GBP/USD				
ADF	-3.28**	-3.69***	-3.96***	-4.05***	-4.27***	-4.08***	-3.96***
PP	-3.38**	-3.02**	-3.27**	-3.63***	-4.04***	-4***	-4.07***
ERS DF	-3.05***	-3.67***	-2.88***	-2.09**	-1.59	-1.03	-0.78
ERS FPO	1.15***	1.06***	1.89***	3.35*	5.23	10.16	14.1
NP MZa	-21.86***	-26.41***	-16.85***	-9.24**	-5.6	-2.75	-1.76
NP MZt	-3.29***	-3.59***	-2.82***	-2.04**	-1.55	-1.02	-0.77
NP MSB	0.15***	0.14***	0.17***	0.22**	0.28	0.37	0.44
NP MPT	1.17***	1.06***	1.78***	3.07**	4.74	8.44	11.7
KPSS	0.23	0.23	0.22	0.2	0.21	0.27	0.34
			DEM/GBP				
ADF	-2.63*	-2.91**	-3.16**	-3.39**	-3.43**	-3.15**	-2.83*
PP	-2.7*	-3.03**	-3.17**	-3.36**	-3.29**	-2.96**	-2.7*
ERS FPO	-1.06	-0.59	-0.6	-0.57	-0.48	-0.39	-0.28
ERS	11.61	19.19	18.17	19.18	21.87	25.25	30.35
NP MZa	-2.31	-1.1	-1.17	-1.08	-0.86	-0.64	-0.41
NP MZt	-0.96	-0.58	-0.6	-0.56	-0.48	-0.38	-0.27
NP MSB	0.42	0.53	0.51	0.52	0.55	0.6	0.66
NP MPT	9.92	16.36	15.38	16.12	18.33	21.29	25.79
KPSS	0.72**	0.8***	1.01***	1.26***	1.73***	1.86***	1.94***

	CHF/USD	CHF/DEM	CHF/GBP
	10Y	**10Y**	**10Y**
ADF	-1.64	-2.34	-2.45
PP	-1.57	-2.08	-2.52
ERS DF	-0.81	-0.91	0.2
ERS FPO	12.61	13.26	58.62
NP MZa	-1.92	-1.72	0.24
NP MZt	-0.88	-0.74	0.22
NP MSB	0.46	0.43	0.91
NP MPT	11.62	11.57	50.07
KPSS	1.48***	1.43***	1.92***

Notes. The sample includes monthly data between January 1979 and December 2005. ADF: Augmented test of Dickey-Fuller (1978); PP: test of Phillips-Perron (1988); ERS DF: DF test with GLS detrending suggested by Elliott-Rothenberg-Stock (1996); ERS FPO: feasible point-optimal test of Elliott-Rothenberg-Stock (1996), NP MZa & MZt & MSB & MPT: four tests suggested by Ng-Perron (2001); KPSS: test of Kwiatkowski-Phillips-Schmidt-Shin (1992). Null hypothesis is unit root for all tests except KPSS, which has stationarity as the null. The 1%, 5%, and 10% critical values are the following. ADF and PP: –3.45, –2.87, –2.57. ERS DF: –2.57, –1.94, –1.62. ERS: 1.96, 3.23, 4.42. NP MZa -13.8, -8.1, -5.7. NP MZt: -2.58, -1.98, -1.62. NP MSB: 0.174, 0.233, 0.275. NP MPT: 1.78, 3.17, 4.45. KPSS: 0.74, 0.46, 0.35.

Table 3: Unit root and stationarity tests on spot and forward rates

	SPOT	1Y	2Y	3Y	5Y	7Y	10Y
DEM/USD							
ADF	-1.41	-1.48	-1.58	-1.68	-1.99	-2.41	-2.85*
PP	-1.58	-1.68	-1.78	-1.87	-2.06	-2.41	-2.81*
ERS DF	-1.42	-1.42	-1.46	-1.52	-1.69*	-1.92*	-2.07**
ERS FPO	5.94	5.79	5.36	4.82	3.7*	2.69**	2.1**
NP MZa	-4.13	-4.25	-4.61	-5.15	-6.76*	-9.39**	-12.12**
NP MZt	-1.41	-1.44	-1.5	-1.59	-1.83*	-2.16**	-2.45**
NP MSB	0.34	0.34	0.33	0.31	0.27*	0.23**	0.2**
NP MPT	5.97	5.79	5.34	4.79	3.67*	2.65**	2.05**
KPSS	0.63**	0.56**	0.49**	0.42*	0.28	0.16	0.14
GBP/USD							
ADF	-2.29	-2.21	-2.16	-2.16	-2.35	-3.05**	-3.35**
PP	-2.43	-2.37	-2.35	-2.36	-2.55	-2.8*	-3.17**
ERS DF	-1.17	-1.26	-1.42	-1.69*	-2.28**	-3.01***	-2.06**
ERS FPO	8.44	8.33	6.62	4.6	2.45**	1.57***	2.42**
NP MZa	-3.21	-3.24	-4.04	-5.64	-10.21**	-17.55***	-9.13**
NP MZt	-1.24	-1.25	-1.41	-1.68*	-2.25**	-2.92***	-2.03**
NP MSB	0.38	0.39	0.35	0.3	0.22**	0.17***	0.22**
NP MPT	7.6	7.53	6.08	4.35*	2.44**	1.56***	3.11**
KPSS	0.25	0.27	0.31	0.32	0.31	0.28	0.27
DEM/GBP							
ADF	-1.35	-1.36	-1.43	-1.86	-1.88	-2.33	-2.94**
PP	-1.45	-1.5	-1.58	-1.69	-2.00	-2.39	-3.00**
ERS DF	-0.68	-0.93	-1.18	-1.72*	-1.87*	-1.95**	-1.56
ERS FPO	17.13	11.87	8.36	4.27*	3.55*	3.44*	5.56
NP MZa	-1.26	-2.03	-3.00	-5.9*	-6.88*	-7.56*	-5.15
NP MZt	-0.67	-0.92	-1.17	-1.7*	-1.85*	-1.93*	-1.55
NP MSB	0.53	0.45	0.39	0.29	0.27*	0.26*	0.30
NP MPT	15.86	11.23	8.08	4.23*	3.56*	3.29*	4.91
KPSS	1.15***	1.07***	0.99***	0.9***	0.69**	0.48**	0.34

	CHF/USD		CHF/DEM		CHF/GBP	
	SPOT	10Y	SPOT	10Y	SPOT	10Y
ADF	-1.49	-2.76*	-2.32	-2.83*	-1.4	-3.36**
PP	-1.59	-2.78*	-2.27	-2.69*	-1.44	-3.51***
ERS DF	-1.44	-1.61	-1.36	-2.1**	-0.46	-1.28
ERS FPO	6.48	3.36*	10.68	2.9**	25.24	7.74
NP MZa	-3.96	-7.82*	-2.39	-9.8**	-0.58	-3.73
NP MZt	-1.3	-1.98*	-0.93	-2.16**	-0.36	-1.27
NP MSB	0.33	0.25*	0.39	0.22**	0.62	0.34
NP MPT	6.31	3.14**	9.37	2.71**	22.72	6.63
KPSS	1.01***	0.36*	1.13***	0.6**	1.42***	0.41*

Notes. The sample includes monthly data between January 1979 and December 2005. ADF: Augmented test of Dickey-Fuller (1978); PP: test of Phillips-Perron (1988); ERS DF: DF test with GLS detrending suggested by Elliott-Rothenberg-Stock (1996); ERS FPO: feasible point-optimal test of Elliott-Rothenberg-Stock (1996), NP MZa & MZt & MSB & MPT: four tests suggested by Ng-Perron (2001); KPSS: test of Kwiatkowski-Phillips-Schmidt-Shin (1992). Null hypothesis is unit root for all tests except KPSS, which has stationarity as the null. The 1%, 5%, and 10% critical values are the following. ADF and PP: –3.45, –2.87, –2.57. ERS DF: –2.57, –1.94, –1.62. ERS: 1.96, 3.23, 4.42. NP MZa -13.8, -8.1, -5.7. NP MZt: -2.58, -1.98, -1.62. NP MSB: 0.174, 0.233, 0.275. NP MPT: 1.78, 3.17, 4.45. KPSS: 0.74, 0.46, 0.35.

Table 4: Single equation ECM for the change in spot exchange rate regressed on the previous period level of the long forward, and Dickey-Fuller equations

	DEM/USD		DEM/USD		GBP/USD		DEMGBP	
Regressor:	s_t^L	s_t	s_t^L	s_t	s_t^L	s_t	s_t^L	s_t
Long sample:	**1973-2005**		**1979-2005**		**1979-2005**		**1979-2005**	
T	387	387	314	314	314	314	314	314
β	-0.024	-0.018	-0.049	-0.011	-0.044	-0.027	-0.0184	-0.0100
σ(β)	0.009	0.010	0.015	0.012	0.013	0.017	0.0096	0.0076
R^2	0.028	0.012	0.041	0.005	0.041	0.014	0.012	0.006
DW	1.88	1.86	1.83	1.83	1.87	1.84	1.77	1.78
1973-1979								
T	83	83			n.a.	n.a.	n.a.	n.a.
β	-0.008	-0.037			n.a.	n.a.	n.a.	n.a.
σ(β)	0.014	0.029			n.a.	n.a.	n.a.	n.a.
R^2	0.005	0.021			n.a.	n.a.	n.a.	n.a.
DW	1.99	1.96			n.a.	n.a.	n.a.	n.a.
1980-1989								
T	120	120			120	120	120	120
β	-0.064	-0.017			-0.052	-0.030	-0.019	-0.002
σ(β)	0.023	0.019			0.017	0.023	0.018	0.017
R^2	0.075	0.008			0.077	0.024	0.009	0.000
DW	1.94	1.90			2.03	1.97	1.82	1.85
1990-2005								
T	183	183			183	183	183	183
β	-0.037	-0.024			-0.026	-0.046	-0.016	-0.021
σ(β)	0.020	0.018			0.017	0.030	0.011	0.015
R^2	0.022	0.011			0.009	0.019	0.012	0.010
DW	1.70	1.70			1.74	1.71	1.73	1.72

Note. Estimates of equation (3) with $s_t^L \equiv s_t + 120 \cdot \tilde{i}_t^L$ as regressor (i.e. the ECM postulated by the cointegrating vector), or equation (4) with s_t as regressor (i.e. a Dickey-Fuller regression).

Table 5: Johansen unrestricted cointegration rank tests for spot exchange rate and short and long interest rate differentials

Hypothesized number of CE(s)	DEM/USD 1973-2005	DEM/USD 1979-2005	GBP/USD 1979-2005	DEMGBP 1979-2005
Trace test				
None	38.375 (p=0.022)	37.795 (p=0.026)	53.819 (p=0.000)	23.780 (p=0.476)
At most 1	15.379 (p=0.205)	16.394 (p=0.154)	26.785 (p=0.005)	12.015 (p=0.446)
At most 2	3.268 (p=0.532)	3.217 (p=0.571)	8.192 (p=0.076)	3.533 (p=0.486)
Maximum Eigenvalue test				
None	22.996 (p=0.040)	21.400 (p=0.066)	27.034 (p=0.010)	11.784 (p=0.676)
At most 1	12.111 (p=0.180)	13.178 (p=0.128)	18.593 (p=0.018)	8.481 (p=0.491)
At most 2	3.268 (p=0.532)	3.217 (p=0.571)	8.192 (p=0.076)	3.533 (p=0.486)

Note: p-values in brackets correspond to MacKinnon-Haug-Michelis (1999).

Table 6: Variance of the logarithm of spot and forward rates

	DEM/USD 1973-2003	DEM/USD 1979-2003	GBP/USD 1979-2003	DEM/GBP 1979-2003
Spot	0.0367	0.0375	0.0192	0.0356
1Y	0.0335	0.0339	0.0194	0.0336
2Y	0.0311	0.0309	0.0193	0.0321
3Y	0.0291	0.0283	0.0191	0.0306
5Y	0.0255	0.0234	0.0191	0.0268
7Y	0.0228	0.0195	0.0190	0.0232
10Y	0.0226	0.0179	0.0204	0.0223

Note. Forward rates were calculated assuming CIP.

Table 7: Yield parity equations: DEM/USD

Horizon	1Y	2Y	3Y	5Y	7Y	10Y
DEM/USD, 1973M1-2003M12						
T	371	330	371	371	371	371
α	-0.002	-0.001	-0.002	-0.002	-0.002	-0.002
$\sigma(\alpha)$	0.002	0.002	0.002	0.002	0.002	0.002
β	0.446	0.349	0.228	0.137	0.092	0.093
$\sigma(\beta)$	0.305	0.199	0.140	0.094	0.073	0.055
R^2	0.01	0.01	0.01	0.01	0.00	0.01
DW	1.83	1.92	1.84	1.85	1.85	1.85
$F(\alpha=0, \beta=1)$	1.83	5.38	15.53	42.45	78.15	135.12
$p(\alpha=0, \beta=1)$	0.162	0.005	0.000	0.000	0.000	0.000
DEM/USD, 1973M1-1982M12						
T	120	79	120	120	120	120
α	-0.001	0.000	-0.002	-0.002	-0.002	-0.002
$\sigma(\alpha)$	0.003	0.004	0.003	0.003	0.003	0.003
β	0.659	0.338	0.115	0.017	0.002	0.042
$\sigma(\beta)$	0.379	0.268	0.194	0.136	0.107	0.081
R^2	0.02	0.02	0.00	0.00	0.00	0.00
DW	1.80	2.18	1.86	1.87	1.87	1.86
$F(\alpha=0, \beta=1)$	0.45	3.09	10.61	26.75	44.62	70.73
$p(\alpha=0, \beta=1)$	0.640	0.051	0.000	0.000	0.000	0.000
DEM/USD, 1983M1-1992M12						
T	120	120	120	120	120	120
α	-0.004	-0.003	-0.003	-0.003	-0.003	-0.003
$\sigma(\alpha)$	0.004	0.003	0.003	0.003	0.003	0.003
β	-0.186	0.299	0.320	0.204	0.122	0.084
$\sigma(\beta)$	0.789	0.418	0.285	0.185	0.139	0.107
R^2	0.00	0.00	0.01	0.01	0.01	0.01
DW	1.90	1.90	1.91	1.94	1.94	1.93
$F(\alpha=0, \beta=1)$	1.35	1.53	2.93	9.34	19.82	36.56
$p(\alpha=0, \beta=1)$	0.263	0.221	0.057	0.000	0.000	0.000
DEM/USD, 1993M1-2003M12						
T	131	131	131	131	131	131
α	0.000	0.000	0.000	0.000	0.000	0.000
$\sigma(\alpha)$	0.002	0.002	0.002	0.002	0.002	0.002
β	-0.283	0.453	0.546	0.471	0.380	0.303
$\sigma(\beta)$	0.905	0.502	0.351	0.218	0.168	0.123
R^2	0.00	0.01	0.02	0.03	0.04	0.04
DW	1.69	1.71	1.74	1.78	1.79	1.79
$F(\alpha=0, \beta=1)$	1.01	0.59	0.84	2.94	6.85	16.11
$p(\alpha=0, \beta=1)$	0.369	0.553	0.435	0.057	0.001	0.000

Notes. Estimated equation is (25), i.e. one-period change of the exchange rate is regressed on the yield parity. By definition, the sample is not overlapping.

Table 8: Yield parity equations: GBP/USD

Horizon	1Y	2Y	3Y	5Y	7Y	10Y
GBP/USD, 1979M1-2003M12						
T	299	299	299	299	299	299
α	0.000	0.000	0.000	0.000	0.000	0.000
$\sigma(\alpha)$	0.002	0.002	0.002	0.002	0.002	0.002
β	0.412	0.379	0.268	0.152	0.102	0.060
$\sigma(\beta)$	0.294	0.164	0.114	0.074	0.058	0.047
R^2	0.01	0.02	0.02	0.01	0.01	0.01
DW	1.83	1.83	1.83	1.83	1.83	1.83
$F(\alpha=0, \beta=1)$	2.11	7.25	20.59	66.56	118.29	203.35
$p(\alpha=0, \beta=1)$	0.123	0.001	0.000	0.000	0.000	0.000
GBP/USD, 1979M1-1982M12						
T	48	48	48	48	48	48
α	0.005	0.005	0.005	0.005	0.005	0.005
$\sigma(\alpha)$	0.004	0.004	0.005	0.005	0.005	0.005
β	0.931	0.565	0.358	0.208	0.155	0.121
$\sigma(\beta)$	0.388	0.219	0.156	0.103	0.086	0.073
R^2	0.11	0.13	0.10	0.08	0.07	0.06
DW	1.59	1.61	1.64	1.66	1.68	1.69
$F(\alpha=0, \beta=1)$	0.76	2.52	8.74	29.53	48.41	72.87
$p(\alpha=0, \beta=1)$	0.473	0.092	0.001	0.000	0.000	0.000
GBP/USD, 1983M1-1992M12						
T	120	120	120	120	120	120
α	0.002	0.000	0.000	0.000	0.000	0.000
$\sigma(\alpha)$	0.004	0.004	0.004	0.004	0.004	0.004
β	-0.683	-0.114	-0.040	-0.044	-0.055	-0.070
$\sigma(\beta)$	0.625	0.339	0.235	0.151	0.116	0.090
R^2	0.01	0.00	0.00	0.00	0.00	0.01
DW	1.78	1.78	1.78	1.78	1.79	1.80
$F(\alpha=0, \beta=1)$	3.78	5.49	9.84	23.94	41.42	71.30
$p(\alpha=0, \beta=1)$	0.026	0.005	0.000	0.000	0.000	0.000
GBP/USD, 1993M1-2003M12						
T	131	131	131	131	131	131
α	-0.003	-0.002	-0.002	-0.002	-0.002	-0.002
$\sigma(\alpha)$	0.002	0.002	0.002	0.002	0.002	0.002
β	2.011	1.417	1.036	0.566	0.401	0.244
$\sigma(\beta)$	0.746	0.381	0.257	0.152	0.113	0.081
R^2	0.05	0.10	0.11	0.10	0.09	0.06
DW	2.09	2.14	2.16	2.16	2.15	2.11
$F(\alpha=0, \beta=1)$	1.65	1.27	0.68	4.72	14.96	44.27
$p(\alpha=0, \beta=1)$	0.196	0.284	0.508	0.010	0.000	0.000

Notes. Estimated equation is (25), i.e. one-period change of the exchange rate is regressed on the yield parity. By definition, the sample is not overlapping.

Table 9: Yield parity equations: DEM/GBP

Horizon	1Y	2Y	3Y	5Y	7Y	10Y
DEM/GBP, 1979M1-2003M12						
T	299	299	299	299	299	299
α	-0.003	-0.002	-0.002	-0.002	-0.002	-0.002
$\sigma(\alpha)$	0.002	0.001	0.001	0.001	0.001	0.001
β	-0.972	-0.554	-0.379	-0.263	-0.223	-0.190
$\sigma(\beta)$	0.307	0.169	0.118	0.077	0.059	0.045
R^2	0.03	0.04	0.03	0.04	0.05	0.06
DW	1.85	1.86	1.86	1.84	1.83	1.84
$F(\alpha=0, \beta=1)$	21.11	42.86	68.68	136.00	212.13	346.55
$p(\alpha=0, \beta=1)$	0.000	0.000	0.000	0.000	0.000	0.000
DEM/GBP, 1979M1-1982M12						
T	48	48	48	48	48	48
α	-0.003	-0.002	-0.002	-0.001	-0.001	-0.001
$\sigma(\alpha)$	0.005	0.005	0.005	0.005	0.005	0.005
β	-1.107	-0.630	-0.429	-0.269	-0.212	-0.162
$\sigma(\beta)$	0.565	0.312	0.213	0.132	0.103	0.079
R^2	0.08	0.08	0.08	0.08	0.09	0.08
DW	2.12	2.12	2.09	2.04	2.01	2.00
$F(\alpha=0, \beta=1)$	7.21	14.05	23.15	46.83	70.93	109.44
$p(\alpha=0, \beta=1)$	0.002	0.000	0.000	0.000	0.000	0.000
DEM/GBP, 1983M1-1992M12						
T	120	120	120	120	120	120
α	-0.010	-0.006	-0.005	-0.005	-0.005	-0.005
$\sigma(\alpha)$	0.003	0.002	0.002	0.002	0.002	0.002
β	-1.656	-0.779	-0.509	-0.362	-0.313	-0.280
$\sigma(\beta)$	0.506	0.263	0.187	0.126	0.096	0.072
R^2	0.08	0.07	0.06	0.07	0.08	0.11
DW	1.74	1.76	1.75	1.72	1.71	1.72
$F(\alpha=0, \beta=1)$	13.80	22.94	32.73	58.77	92.58	157.32
$p(\alpha=0, \beta=1)$	0.000	0.000	0.000	0.000	0.000	0.000
DEM/GBP, 1993M1-2003M12						
T	131	131	131	131	131	131
α	0.001	0.001	0.001	0.001	0.001	0.001
$\sigma(\alpha)$	0.002	0.002	0.002	0.002	0.002	0.002
β	0.191	0.195	0.176	0.094	0.038	-0.017
$\sigma(\beta)$	0.825	0.465	0.338	0.238	0.188	0.140
R^2	0.00	0.00	0.00	0.00	0.00	0.00
DW	1.89	1.89	1.89	1.89	1.89	1.89
$F(\alpha=0, \beta=1)$	1.07	2.03	3.45	7.69	13.61	27.23
$p(\alpha=0, \beta=1)$	0.346	0.136	0.035	0.001	0.000	0.000

Notes. Estimated equation is (25), i.e. one-period change of the exchange rate is regressed on the yield parity. By definition, the sample is not overlapping.

Table 10: Simulated moments and test statistics of the stylized model calibrated to monthly DEM/USD for 1973M1-2003M12

	Sample	Baseline						Scen.2.	Scen.3.	Scen.4.	Scen.5.
		2.5%	25%	median	75%	97.5%	ratio	no cov.	const. s_t^L	const. $\tilde{i}_t^S$	const. $\tilde{i}_t^L$
Innovations											
$\sigma^2(\varepsilon_t^{sL})$	1.85e-03	1.58e-03	1.74e-03	1.84e-03	1.94e-03	2.12e-03	0.99	1.84e-03	0.00e+00	1.84e-03	1.83e-03
$\sigma^2(\varepsilon_t^{iS})$	4.63e-07	3.99e-07	4.40e-07	4.62e-07	4.85e-07	5.31e-07	1.00	4.61e-07	4.62e-07	0.00e+00	4.63e-07
$\sigma^2(\varepsilon_t^{iL})$	9.78e-04	8.41e-04	9.27e-04	9.75e-04	1.02e-03	1.13e-03	1.00	9.77e-04	9.74e-04	9.78e-04	0.00e+00
$\rho(\varepsilon_t^{sL}, \varepsilon_t^{iS})$	0.037	-0.072	0.002	0.037	0.071	0.135	1.00	-0.002	NA	NA	0.035
$\rho(\varepsilon_t^{sL}, \varepsilon_t^{iL})$	0.651	0.589	0.631	0.652	0.671	0.708	1.00	0.001	NA	0.652	NA
$\rho(\varepsilon_t^{iS}, \varepsilon_t^{iL})$	0.121	0.009	0.086	0.119	0.156	0.220	0.98	0.001	0.119	NA	NA
$\rho(\varepsilon_t^{sL}, \varepsilon_{t-1}^{sL})$	0.012	-0.103	-0.037	-0.003	0.029	0.093	-0.25	-0.002	NA	-0.006	-0.008
$\rho(\varepsilon_t^{iS}, \varepsilon_{t-1}^{iS})$	0.164	-0.104	-0.036	-0.001	0.035	0.098	-0.01	-0.004	-0.002	NA	-0.003
$\rho(\varepsilon_t^{iL}, \varepsilon_{t-1}^{iL})$	0.030	-0.112	-0.037	-0.005	0.034	0.099	-0.16	-0.007	-0.004	0.000	NA
Logarithm of the expected long run exchange rate											
μ	0.618	0.479	0.564	0.607	0.656	0.738	0.98	0.611	1.363	0.611	0.608
σ^2	0.054	0.026	0.038	0.048	0.058	0.083	0.89	0.047	0.000	0.047	0.046
Skewness*	1.16	-0.25	-0.09	-0.01	0.07	0.23	-0.01	0.00	0.00	0.00	-0.01
Kurtosis*	3.89	2.57	2.82	2.95	3.11	3.49	0.76	2.96	0.00	2.95	2.97
adf	-2.92	-4.60	-3.69	-3.29	-2.91	-2.21	1.13	-3.26	NA	-3.27	-3.31
pp	-3.21	-4.70	-3.87	-3.44	-3.09	-2.50	1.07	-3.50	NA	-3.46	-3.50
kpss	0.64	0.23	0.49	0.82	1.18	1.83	1.30	0.83	NA	0.80	0.87
Logarithm of one plus the short interest rate differential											
μ	-0.001	-0.002	-0.001	0.000	0.001	0.002	-0.05	0.000	0.000	0.000	0.000
σ^2	5.34e-06	2.57e-06	3.93e-06	4.96e-06	6.31e-06	1.02e-05	0.93	4.97e-06	5.09e-06	0.00e+00	5.08e-06
adf	-2.34	-4.04	-3.19	-2.80	-2.44	-1.85	1.20	-2.83	-2.81	NA	-2.76
pp	-2.74	-4.19	-3.35	-2.94	-2.57	-2.00	1.08	-2.96	-2.92	NA	-2.92
kpss	0.41	0.10	0.25	0.40	0.69	1.37	0.98	0.39	0.39	NA	0.38
***n* times the logarithm of one plus the long interest rate differential**											
μ	-0.074	-0.235	-0.041	0.057	0.145	0.366	-0.78	0.054	0.070	0.001	0.000
σ^2	0.029	0.012	0.024	0.034	0.052	0.099	1.16	0.031	0.035	0.022	0.000
adf	-2.11	-3.14	-2.10	-1.69	-1.30	-0.42	0.80	-1.73	-1.65	-1.90	NA
pp	-2.07	-3.05	-2.11	-1.67	-1.29	-0.34	0.81	-1.76	-1.67	-1.94	NA
kpss	0.40	0.18	0.48	0.85	1.35	2.04	2.12	0.81	0.84	0.64	NA
Logarithm of the spot exchange rate											
μ	0.692	0.280	0.472	0.552	0.634	0.800	0.80	0.560	1.294	0.613	0.608
σ^2	0.041	0.017	0.029	0.039	0.052	0.092	0.96	0.064	0.035	0.042	0.046
Skewness*	0.28	-0.25	-0.09	-0.01	0.08	0.25	-0.03	0.00	0.00	-0.01	-0.01
Kurtosis*	2.12	2.56	2.81	2.95	3.12	3.51	1.39	2.95	2.96	2.95	2.97
adf	-1.87	-4.33	-3.23	-2.72	-2.25	-1.44	1.46	-2.55	-1.65	-3.41	-3.31
pp	-2.26	-4.52	-3.49	-2.97	-2.48	-1.63	1.31	-2.71	-1.67	-3.68	-3.50
kpss	1.03	0.17	0.40	0.65	1.11	1.99	0.63	0.60	0.84	0.87	0.87
Short UIP equation											
β	-1.097	-2.859	-1.772	-1.233	-0.659	0.394	1.12	-1.199	-0.944	NA	-0.092
σ_β	0.897	0.498	0.656	0.763	0.868	1.132	0.85	1.195	0.700	NA	0.953
R^2	0.006	0.000	0.002	0.007	0.015	0.035	1.21	0.003	0.005	NA	0.001
DW	1.86	1.77	1.92	1.99	2.07	2.18	1.07	2.01	2.01	NA	2.02
Long UIP equation											
β	0.964	-0.955	-0.110	0.311	0.794	1.810	0.32	0.835	1.173	0.377	NA
σ_β	0.139	0.072	0.130	0.173	0.230	0.428	1.25	0.226	0.105	0.200	NA
R^2	0.460	0.000	0.022	0.101	0.279	0.685	0.22	0.187	0.625	0.094	NA
DW	0.07	0.01	0.03	0.05	0.07	0.15	0.66	0.07	0.05	0.05	NA
Yield parity equation											
β	0.093	0.002	0.075	0.110	0.150	0.219	1.18	0.998	1.002	0.100	NA
σ_β	0.056	0.045	0.051	0.055	0.058	0.065	0.98	0.071	0.002	0.054	NA
R^2	0.008	0.000	0.005	0.011	0.019	0.041	1.39	0.339	0.998	0.009	NA
DW	1.85	1.77	1.90	1.97	2.05	2.17	1.07	2.00	0.02	1.98	NA

Notes. Sample: estimated statistics using the 1973M1-2003M12 sample of the DEM/USD rate. Further data columns: results of a Monte Carlo simulation with 1,000 draws for 372 observations. Baseline: simulation results using the baseline model described in equations (26),(27'),(28') and (29) with $\rho_{sLONG} = 0.969$, $\rho_{iSHORT} = 0.963$, $\rho_{iLONG} = 0.989$. Ratio: median simulated valued/sample statistics. Scenario 2: diagonal Ω. Scenario 3: constant long run expected exchange rate. Scenario 4: constant short interest differential. Scenario 5: constant long interest differential.

Table 11: Simulated moments and test statistics of the stylized model calibrated to monthly DEM/USD for 1979M1-2003M12

	Sample	**Baseline**						**Scen.2.**	**Scen.3.**	**Scen.4.**	**Scen.5.**
		2.5%	25%	**median**	75%	97.5%	ratio	**no cov.**	**const.** s_t^L	**const.** $\tilde{i}_t^S$	**const.** $\tilde{i}_t^L$
Innovations											
$\sigma^2(\varepsilon_t^{sL})$	**1.75e-03**	1.47e-03	1.65e-03	**1.74e-03**	1.83e-03	2.03e-03	0.99	**1.74e-03**	**NA**	**1.75e-03**	**1.74e-03**
$\sigma^2(\varepsilon_t^{iS})$	**4.11e-07**	3.48e-07	3.89e-07	**4.11e-07**	4.33e-07	4.75e-07	1.00	**4.09e-07**	**4.10e-07**	**NA**	**4.10e-07**
$\sigma^2(\varepsilon_t^{iL})$	**9.88e-04**	8.39e-04	9.30e-04	**9.80e-04**	1.04e-03	1.15e-03	0.99	**9.82e-04**	**9.84e-04**	**9.76e-04**	**NA**
$\rho(\varepsilon_t^{sL}, \varepsilon_t^{iS})$	**0.037**	-0.081	-0.003	**0.036**	0.079	0.152	0.98	**-0.002**	**NA**	**NA**	**0.038**
$\rho(\varepsilon_t^{sL}, \varepsilon_t^{iL})$	**0.659**	0.588	0.636	**0.660**	0.681	0.718	1.00	**0.001**	**NA**	**0.658**	**NA**
$\rho(\varepsilon_t^{iS}, \varepsilon_t^{iL})$	**0.130**	0.021	0.094	**0.132**	0.168	0.242	1.01	**0.001**	**0.127**	**NA**	**NA**
$\rho(\varepsilon_t^{sL}, \varepsilon_{t-1}^{sL})$	**0.020**	-0.116	-0.047	**-0.006**	0.034	0.110	-0.28	**0.000**	**NA**	**-0.004**	**-0.003**
$\rho(\varepsilon_t^{iS}, \varepsilon_{t-1}^{iS})$	**0.283**	-0.106	-0.037	**0.000**	0.035	0.109	0.00	**-0.004**	**-0.003**	**NA**	**-0.004**
$\rho(\varepsilon_t^{iL}, \varepsilon_{t-1}^{iL})$	**0.063**	-0.124	-0.044	**-0.005**	0.040	0.108	-0.08	**-0.002**	**-0.005**	**-0.001**	**NA**
Logarithm of the expected long run exchange rate											
μ	**0.539**	0.441	0.504	**0.534**	0.563	0.622	0.99	**0.535**	**0.454**	**0.532**	**0.533**
σ^2	**0.018**	0.008	0.012	**0.015**	0.018	0.028	0.81	**0.015**	**0.000**	**0.015**	**0.015**
Skewness*	**0.29**	-0.27	-0.10	**-0.01**	0.09	0.27	-0.02	**0.01**	**0.00**	**0.00**	**0.00**
Kurtosis*	**2.52**	2.52	2.78	**2.94**	3.14	3.70	1.17	**2.94**	**0.00**	**2.94**	**2.94**
adf	**-2.44**	-4.13	-3.28	**-2.88**	-2.50	-1.83	1.18	**-2.86**	**NA**	**-2.87**	**-2.90**
pp	**-2.70**	-4.27	-3.49	**-3.06**	-2.70	-2.00	1.14	**-3.02**	**NA**	**-3.06**	**-3.07**
kpss	**0.29**	0.08	0.20	**0.32**	0.60	1.25	1.12	**0.32**	**NA**	**0.34**	**0.32**
Logarithm of one plus the short interest rate differential											
μ	**-0.001**	-0.002	-0.001	**0.000**	0.000	0.001	0.46	**0.000**	**0.000**	**0.000**	**0.000**
σ^2	**5.71e-06**	2.67e-06	4.14e-06	**5.21e-06**	6.72e-06	1.11e-05	0.91	**5.17e-06**	**5.21e-06**	**0.00e+00**	**4.14e-06**
adf	**-2.04**	-4.00	-3.12	**-2.75**	-2.35	-1.72	1.35	**-2.76**	**-2.73**	**NA**	**-2.59**
pp	**-2.53**	-4.09	-3.25	**-2.86**	-2.50	-1.83	1.13	**-2.89**	**-2.85**	**NA**	**-2.73**
kpss	**0.65**	0.11	0.29	**0.46**	0.76	1.53	0.70	**0.47**	**0.49**	**NA**	**0.40**
***n* times the logarithm of one plus the long interest rate differential**											
μ	**-0.108**	-0.490	-0.257	**-0.122**	0.002	0.237	1.12	**-0.111**	**-0.107**	**-0.011**	**0.000**
σ^2	**0.024**	0.008	0.018	**0.029**	0.045	0.107	1.21	**0.027**	**0.029**	**0.022**	**0.000**
adf	**-1.34**	-3.15	-2.11	**-1.60**	-1.13	-0.04	1.19	**-1.65**	**-1.53**	**-1.77**	**NA**
pp	**-1.58**	-3.19	-2.14	**-1.62**	-1.13	-0.07	1.03	**-1.66**	**-1.56**	**-1.77**	**NA**
kpss	**1.38**	0.18	0.45	**0.83**	1.31	1.86	0.60	**0.85**	**0.88**	**0.76**	**NA**
Logarithm of the spot exchange rate											
μ	**0.648**	0.345	0.545	**0.658**	0.773	0.970	1.02	**0.647**	**0.560**	**0.544**	**0.533**
σ^2	**0.037**	0.008	0.016	**0.025**	0.039	0.086	0.68	**0.041**	**0.029**	**0.020**	**0.015**
Skewness*	**0.70**	-0.27	-0.09	**0.01**	0.10	0.29	0.01	**0.00**	**0.00**	**0.00**	**0.00**
Kurtosis*	**2.85**	2.53	2.77	**2.93**	3.12	3.58	1.03	**2.94**	**2.95**	**2.96**	**2.94**
adf	**-1.40**	-3.28	-2.20	**-1.71**	-1.20	-0.15	1.22	**-2.12**	**-1.53**	**-1.91**	**-2.90**
pp	**-1.43**	-3.31	-2.26	**-1.74**	-1.23	-0.12	1.22	**-2.19**	**-1.56**	**-1.96**	**-3.07**
kpss	**0.60**	0.16	0.43	**0.76**	1.24	1.83	1.26	**0.67**	**0.88**	**0.70**	**0.32**
Short UIP equation											
β	**-1.082**	-2.242	-1.253	**-0.822**	-0.322	0.813	0.76	**-0.842**	**-0.619**	**NA**	**-0.162**
σ_β	**0.892**	0.501	0.675	**0.782**	0.893	1.175	0.88	**1.258**	**0.767**	**NA**	**1.118**
R^2	**0.006**	0.000	0.001	**0.004**	0.009	0.027	0.57	**0.002**	**0.003**	**NA**	**0.001**
DW	**1.85**	1.78	1.94	**2.02**	2.10	2.25	1.10	**2.03**	**2.01**	**NA**	**2.05**
Long UIP equation											
β	**1.519**	**-0.589**	**0.322**	**0.696**	1.104	1.874	0.46	**1.155**	**1.115**	**0.665**	**NA**
σ_β	**0.158**	**0.065**	**0.114**	**0.154**	0.218	0.384	0.97	**0.202**	**0.120**	**0.163**	**NA**
R^2	**0.638**	**0.000**	**0.090**	**0.279**	0.512	0.819	0.44	**0.359**	**0.610**	**0.231**	**NA**
DW	**0.14**	**0.03**	**0.07**	**0.11**	0.16	0.29	0.82	**0.13**	**0.09**	**0.11**	**NA**
Yield parity equation											
β	**0.119**	0.003	0.086	**0.121**	0.164	0.237	1.02	**1.000**	**1.002**	**0.117**	**NA**
σ_β	**0.059**	0.046	0.054	**0.058**	0.062	0.072	0.98	**0.077**	**0.003**	**0.059**	**NA**
R^2	**0.013**	0.000	0.007	**0.014**	0.025	0.053	1.04	**0.356**	**0.998**	**0.013**	**NA**
DW	**1.86**	1.78	1.94	**2.02**	2.09	2.25	1.08	**2.04**	**0.02**	**2.02**	**NA**

Notes. Sample: estimated statistics using the 1979M1-2003M12 sample of the DEM/USD rate. Further data columns: results of a Monte Carlo simulation with 1,000 draws for 300 observations. Baseline: simulation results using the baseline model described in equations (26),(27'),(28') and (29) with $\rho_{sLONG} = 0.950$, $\rho_{iSHORT} = 0.963$, $\rho_{iLONG} = 0.993$. Ratio: median simulated valued/sample statistics. Scenario 2: diagonal Ω. Scenario 3: constant long run expected exchange rate. Scenario 4: constant short interest differential. Scenario 5: constant long interest differential.

Table 12: Simulated moments and test statistics of the stylized model calibrated to monthly GBP/USD for 1979M1-2003M12

	Sample	Baseline						**Scen.2.**	**Scen.3.**	**Scen.4.**	**Scen.5.**
		2.5%	25%	**median**	75%	97.5%	ratio	**no cov.**	**const. s_t^L**	**const. $\tilde{i}_t^S$**	**const. $\tilde{i}_t^L$**
Innovations											
$\sigma^2(\varepsilon_t^{sL})$	**2.22e-03**	1.85e-03	2.07e-03	**2.19e-03**	2.33e-03	2.59e-03	0.99	**2.20e-03**	**NA**	**2.20e-03**	**2.21e-03**
$\sigma^2(\varepsilon_t^{iS})$	**4.85e-07**	4.06e-07	4.57e-07	**4.81e-07**	5.08e-07	5.60e-07	0.99	**4.82e-07**	**4.83e-07**	**NA**	**4.83e-07**
$\sigma^2(\varepsilon_t^{iL})$	**1.48e-03**	1.26e-03	1.39e-03	**1.47e-03**	1.56e-03	1.72e-03	0.99	**1.47e-03**	**1.47e-03**	**1.47e-03**	**NA**
$\rho(\varepsilon_t^{sL}, \varepsilon_t^{iS})$	**0.206**	0.096	0.166	**0.205**	0.240	0.309	1.00	**0.000**	**NA**	**NA**	**0.205**
$\rho(\varepsilon_t^{sL}, \varepsilon_t^{iL})$	**0.766**	0.716	0.749	**0.768**	0.782	0.810	1.00	**-0.004**	**NA**	**0.767**	**NA**
$\rho(\varepsilon_t^{iS}, \varepsilon_t^{iL})$	**0.251**	0.146	0.209	**0.249**	0.283	0.357	0.99	**0.002**	**0.247**	**NA**	**NA**
$\rho(\varepsilon_t^{sL}, \varepsilon_{t-1}^{sL})$	**0.182**	-0.121	-0.045	**-0.008**	0.033	0.108	-0.04	**-0.006**	**NA**	**-0.001**	**-0.003**
$\rho(\varepsilon_t^{iS}, \varepsilon_{t-1}^{iS})$	**0.249**	-0.115	-0.046	**-0.004**	0.036	0.100	-0.02	**0.000**	**-0.004**	**NA**	**-0.004**
$\rho(\varepsilon_t^{iL}, \varepsilon_{t-1}^{iL})$	**0.105**	-0.111	-0.043	**-0.008**	0.030	0.097	-0.08	**0.002**	**-0.006**	**-0.005**	**NA**
Logarithm of the expected long run exchange rate											
μ	**-0.418**	-0.515	-0.454	**-0.424**	-0.393	-0.322	1.01	**-0.423**	**-0.289**	**-0.426**	**-0.425**
σ^2	**0.020**	0.009	0.014	**0.017**	0.021	0.032	0.83	**0.017**	**0.000**	**0.017**	**0.017**
Skewness*	**-0.36**	-0.28	-0.10	**-0.01**	0.09	0.26	0.02	**0.00**	**0.00**	**0.00**	**0.00**
Kurtosis*	**3.78**	2.55	2.79	**2.95**	3.14	3.64	0.78	**2.95**	**0.00**	**2.96**	**2.96**
adf	**-2.76**	-4.30	-3.39	**-3.01**	-2.66	-2.05	1.09	**-3.01**	**NA**	**-3.02**	**-3.03**
pp	**-3.11**	-4.49	-3.62	**-3.24**	-2.87	-2.26	1.04	**-3.23**	**NA**	**-3.23**	**-3.24**
kpss	**0.31**	0.06	0.13	**0.21**	0.36	0.85	0.67	**0.22**	**NA**	**0.22**	**0.20**
Logarithm of one plus the short interest rate differential											
μ	**0.002**	-0.002	0.000	**0.000**	0.001	0.002	0.09	**0.000**	**0.000**	**0.000**	**0.000**
σ^2	**4.29e-06**	2.42e-06	3.84e-06	**4.98e-06**	6.73e-06	1.21e-05	1.16	**5.40e-06**	**5.16e-06**	**0.00e+00**	**5.13e-06**
adf	**-2.86**	-3.86	-2.98	**-2.56**	-2.18	-1.39	0.89	**-2.47**	**-2.56**	**NA**	**-2.54**
pp	**-3.20**	-4.01	-3.14	**-2.70**	-2.28	-1.52	0.84	**-2.60**	**-2.69**	**NA**	**-2.67**
kpss	**0.25**	0.10	0.23	**0.39**	0.67	1.42	1.56	**0.40**	**0.39**	**NA**	**0.41**
***n* times the logarithm of one plus the long interest rate differential**											
μ	**0.077**	-0.226	-0.006	**0.111**	0.223	0.471	1.43	**0.108**	**0.113**	**-0.006**	**0.000**
σ^2	**0.012**	0.016	0.034	**0.051**	0.080	0.162	4.35	**0.048**	**0.051**	**0.026**	**0.000**
adf	**-2.42**	-3.05	-2.09	**-1.64**	-1.23	-0.23	0.68	**-1.78**	**-1.73**	**-1.96**	**NA**
pp	**-3.78**	-2.98	-2.11	**-1.67**	-1.24	-0.23	0.44	**-1.79**	**-1.75**	**-1.99**	**NA**
kpss	**0.29**	0.19	0.49	**0.84**	1.32	1.86	2.91	**0.87**	**0.85**	**0.58**	**NA**
Logarithm of the spot exchange rate											
μ	**-0.496**	-0.830	-0.631	**-0.532**	-0.435	-0.246	1.07	**-0.529**	**-0.402**	**-0.415**	**-0.425**
σ^2	**0.019**	0.011	0.024	**0.037**	0.058	0.126	1.93	**0.060**	**0.051**	**0.017**	**0.017**
Skewness*	**-0.66**	-0.30	-0.09	**0.00**	0.09	0.28	0.00	**0.00**	**0.00**	**0.01**	**0.00**
Kurtosis*	**4.04**	2.53	2.78	**2.93**	3.11	3.61	0.73	**2.95**	**2.94**	**2.96**	**2.96**
adf	**-2.46**	-2.83	-1.95	**-1.51**	-1.08	0.07	0.61	**-2.10**	**-1.73**	**-2.03**	**-3.03**
pp	**-2.30**	-2.72	-1.89	**-1.45**	-1.06	0.06	0.63	**-2.16**	**-1.75**	**-2.11**	**-3.24**
kpss	**0.39**	0.21	0.50	**0.88**	1.36	1.84	2.28	**0.70**	**0.85**	**0.52**	**0.32**
Short UIP equation											
β	**-2.604**	-3.508	-2.323	**-1.783**	-1.298	-0.317	0.68	**-1.388**	**-0.943**	**NA**	**-0.786**
σ_β	**1.186**	0.464	0.654	**0.760**	0.907	1.218	0.64	**1.432**	**0.958**	**NA**	**1.135**
R^2	**0.030**	0.001	0.009	**0.017**	0.030	0.058	0.57	**0.003**	**0.003**	**NA**	**0.002**
DW	**1.91**	1.79	1.92	**2.01**	2.08	2.22	1.05	**2.03**	**2.00**	**NA**	**2.05**
Long UIP equation											
β	**0.567**	-0.407	0.357	**0.735**	1.071	1.820	1.30	**1.005**	**1.132**	**0.550**	**NA**
σ_β	**0.191**	0.053	0.086	**0.118**	0.162	0.344	0.62	**0.166**	**0.106**	**0.141**	**NA**
R^2	**0.185**	0.003	0.136	**0.418**	0.649	0.860	2.26	**0.389**	**0.668**	**0.212**	**NA**
DW	**0.12**	0.02	0.07	**0.10**	0.14	0.28	0.80	**0.13**	**0.08**	**0.12**	**NA**
Yield parity equation											
β	**0.060**	-0.015	0.041	**0.071**	0.104	0.168	1.19	**1.002**	**1.002**	**0.056**	**NA**
σ_β	**0.060**	0.037	0.042	**0.046**	0.049	0.057	0.76	**0.070**	**0.003**	**0.046**	**NA**
R^2	**0.006**	0.000	0.003	**0.008**	0.016	0.043	1.41	**0.397**	**0.998**	**0.005**	**NA**
DW	**1.83**	1.76	1.90	**1.98**	2.05	2.19	1.08	**2.05**	**0.02**	**2.01**	**NA**

Notes. Sample: estimated statistics using the 1979M1-2003M12 sample of the USD/GBP rate. Further data columns: results of a Monte Carlo simulation with 1,000 draws for 300 observations. Baseline: simulation results using the baseline model described in equations (26),(27'),(28') and (29) with $\rho_{sLONG} = 0.944$, $\rho_{iSHORT} = 0.965$, $\rho_{iLONG} = 0.985$. Ratio: median simulated valued/sample statistics. Scenario 2: diagonal Ω. Scenario 3: constant long run expected exchange rate. Scenario 4: constant short interest differential. Scenario 5: constant long interest differential.

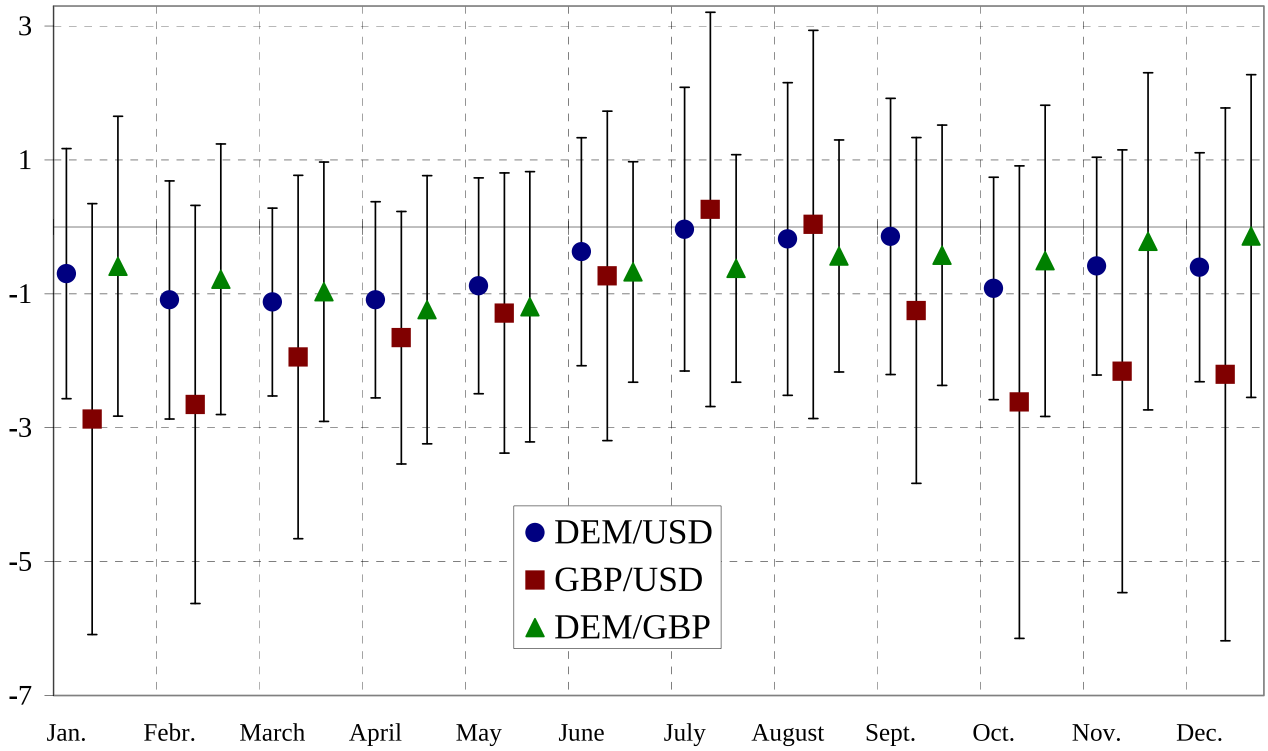
Table 13: Simulated moments and test statistics of the stylized model calibrated to monthly DEM/GBP for 1979M1-2003M12

	Sample	**Baseline**						**Scen.2.**	**Scen.3.**	**Scen.4.**	**Scen.5.**
		2.5%	25%	**median**	75%	97.5%	ratio	**no cov.**	**const. s_t^L**	**const. $\tilde{i}_t^S$**	**const. $\tilde{i}_t^L$**
				Innovations							
$\sigma^2(\varepsilon_t^{sL})$	**1.96e-03**	1.63e-03	1.83e-03	**1.95e-03**	2.05e-03	2.28e-03	0.99	**1.96e-03**	**NA**	**1.94e-03**	**1.95e-03**
$\sigma^2(\varepsilon_t^{iS})$	**2.84e-07**	2.38e-07	2.66e-07	**2.81e-07**	2.97e-07	3.29e-07	0.99	**2.84e-07**	**2.82e-07**	**NA**	**2.83e-07**
$\sigma^2(\varepsilon_t^{iL})$	**9.95e-04**	8.44e-04	9.31e-04	**9.82e-04**	1.04e-03	1.15e-03	0.99	**9.87e-04**	**9.89e-04**	**9.92e-04**	**NA**
$\rho(\varepsilon_t^{sL}, \varepsilon_t^{iS})$	**0.270**	0.159	0.233	**0.271**	0.304	0.367	1.01	**0.000**	**NA**	**NA**	**0.270**
$\rho(\varepsilon_t^{sL}, \varepsilon_t^{iL})$	**0.824**	0.785	0.811	**0.824**	0.836	0.857	1.00	**-0.006**	**NA**	**0.824**	**NA**
$\rho(\varepsilon_t^{iS}, \varepsilon_t^{iL})$	**0.347**	0.234	0.311	**0.346**	0.380	0.435	1.00	**-0.002**	**0.350**	**NA**	**NA**
$\rho(\varepsilon_t^{sL}, \varepsilon_{t-1}^{sL})$	**0.124**	-0.120	-0.044	**-0.003**	0.038	0.127	-0.03	**-0.002**	**NA**	**-0.001**	**-0.003**
$\rho(\varepsilon_t^{iS}, \varepsilon_{t-1}^{iS})$	**-0.024**	-0.121	-0.045	**-0.009**	0.035	0.108	0.36	**-0.005**	**-0.004**	**NA**	**-0.003**
$\rho(\varepsilon_t^{iL}, \varepsilon_{t-1}^{iL})$	**0.024**	-0.121	-0.045	**-0.007**	0.035	0.118	-0.27	**-0.002**	**0.000**	**-0.006**	**NA**
				Logarithm of the expected long run exchange rate							
μ	**0.957**	0.860	0.925	**0.959**	0.995	1.058	1.00	**0.959**	**0.743**	**0.956**	**0.959**
σ^2	**0.022**	0.009	0.014	**0.018**	0.022	0.035	0.82	**0.018**	**0.000**	**0.018**	**0.018**
Skewness*	**-0.05**	-0.28	-0.09	**0.00**	0.09	0.28	-0.06	**-0.01**	**0.00**	**0.00**	**0.00**
Kurtosis*	**2.18**	2.54	2.78	**2.95**	3.12	3.57	1.35	**2.93**	**0.00**	**2.96**	**2.94**
adf	**-2.41**	-4.24	-3.34	**-2.92**	-2.55	-1.87	1.21	**-2.87**	**NA**	**-2.92**	**-2.91**
pp	**-2.95**	-4.44	-3.53	**-3.11**	-2.72	-2.04	1.05	**-3.06**	**NA**	**-3.09**	**-3.10**
kpss	**0.34**	0.09	0.22	**0.37**	0.62	1.27	1.06	**0.37**	**NA**	**0.38**	**0.37**
				Logarithm of one plus the short interest rate differential							
μ	**-0.003**	-0.004	-0.002	**-0.001**	0.000	0.002	0.46	**-0.001**	**-0.001**	**0.000**	**0.000**
σ^2	**4.29e-06**	2.51e-06	4.77e-06	**6.74e-06**	9.23e-06	1.63e-05	1.57	**6.97e-06**	**6.67e-06**	**0.00e+00**	**4.30e-06**
adf	**-2.31**	-3.67	-2.67	**-2.27**	-1.81	-0.98	0.98	**-2.20**	**-2.23**	**NA**	**-2.11**
pp	**-2.70**	-3.69	-2.72	**-2.31**	-1.89	-1.12	0.85	**-2.27**	**-2.33**	**NA**	**-2.17**
kpss	**0.70**	0.18	0.47	**0.83**	1.31	1.82	1.18	**0.91**	**0.89**	**NA**	**0.54**
				***n* times the Logarithm of one plus the long interest rate differential**							
μ	**-0.186**	-1.271	-0.855	**-0.633**	-0.403	0.032	3.41	**-0.654**	**-0.658**	**-0.010**	**0.000**
σ^2	**0.021**	0.009	0.022	**0.040**	0.072	0.196	1.86	**0.042**	**0.039**	**0.038**	**0.000**
adf	**-1.22**	-3.15	-2.05	**-1.50**	-0.90	0.36	1.22	**-1.42**	**-1.51**	**-1.54**	**NA**
pp	**-2.55**	-3.24	-2.06	**-1.52**	-0.89	0.40	0.59	**-1.41**	**-1.54**	**-1.54**	**NA**
kpss	**1.98**	0.21	0.72	**1.31**	1.71	2.00	0.66	**1.30**	**1.30**	**1.27**	**NA**
				Logarithm of the spot exchange rate							
μ	**1.143**	0.995	1.384	**1.593**	1.801	2.155	1.39	**1.607**	**1.402**	**0.964**	**0.959**
σ^2	**0.036**	0.009	0.022	**0.039**	0.073	0.196	1.11	**0.062**	**0.039**	**0.038**	**0.018**
Skewness*	**0.30**	-0.26	-0.09	**0.01**	0.09	0.27	0.03	**-0.01**	**0.00**	**0.01**	**0.00**
Kurtosis*	**2.46**	2.54	2.76	**2.94**	3.11	3.54	1.20	**2.92**	**2.95**	**2.95**	**2.94**
adf	**-1.50**	-3.22	-2.13	**-1.48**	-0.82	0.73	0.99	**-1.94**	**-1.51**	**-1.45**	**-2.91**
pp	**-1.34**	-3.24	-2.20	**-1.53**	-0.85	0.65	1.14	**-2.04**	**-1.54**	**-1.48**	**-3.10**
kpss	**1.22**	0.21	0.75	**1.39**	1.78	2.03	1.14	**1.08**	**1.30**	**1.35**	**0.37**
				Short UIP equation							
β	**-1.097**	-2.141	-1.202	**-0.806**	-0.376	0.406	0.73	**-0.194**	**0.238**	**NA**	**-1.001**
σ_β	**0.786**	0.354	0.470	**0.568**	0.684	0.986	0.72	**1.139**	**0.676**	**NA**	**1.149**
R^2	**0.008**	0.000	0.002	**0.007**	0.014	0.034	0.84	**0.001**	**0.002**	**NA**	**0.002**
DW	**1.80**	1.77	1.91	**1.99**	2.08	2.22	1.11	**2.03**	**2.00**	**NA**	**2.04**
				Long UIP equation							
β	**1.441**	-0.961	0.033	**0.456**	0.922	1.764	0.32	**0.896**	**0.882**	**0.476**	**NA**
σ_β	**0.179**	0.055	0.099	**0.139**	0.206	0.427	0.77	**0.189**	**0.112**	**0.140**	**NA**
R^2	**0.423**	0.001	0.062	**0.233**	0.489	0.805	0.55	**0.309**	**0.526**	**0.226**	**NA**
DW	**0.17**	0.02	0.05	**0.09**	0.14	0.27	0.52	**0.13**	**0.08**	**0.09**	**NA**
				Yield parity equation							
β	**-0.190**	-0.264	-0.198	**-0.167**	-0.132	-0.068	0.88	**1.007**	**1.002**	**-0.163**	**NA**
σ_β	**0.057**	0.038	0.044	**0.047**	0.051	0.058	0.82	**0.081**	**0.003**	**0.047**	**NA**
R^2	**0.056**	0.006	0.025	**0.039**	0.053	0.096	0.69	**0.332**	**0.997**	**0.036**	**NA**
DW	**1.84**	1.73	1.88	**1.96**	2.04	2.18	1.07	**2.03**	**0.02**	**1.95**	**NA**

Notes. Sample: estimated statistics using the 1979M1-2003M12 sample of the DEM/GBP rate. Further data columns: results of a Monte Carlo simulation with 1,000 draws for 300 observations. Baseline: simulation results using the baseline model described in equations (26),(27'),(28') and (29) with $\rho_{sLONG} = 0.952$, $\rho_{iSHORT} = 0.985$, $\rho_{iLONG} = 1.001$. Ratio: median simulated valued/sample statistics. Scenario 2: diagonal Ω. Scenario 3: constant long run expected exchange rate. Scenario 4: constant short interest differential. Scenario 5: constant long interest differential.

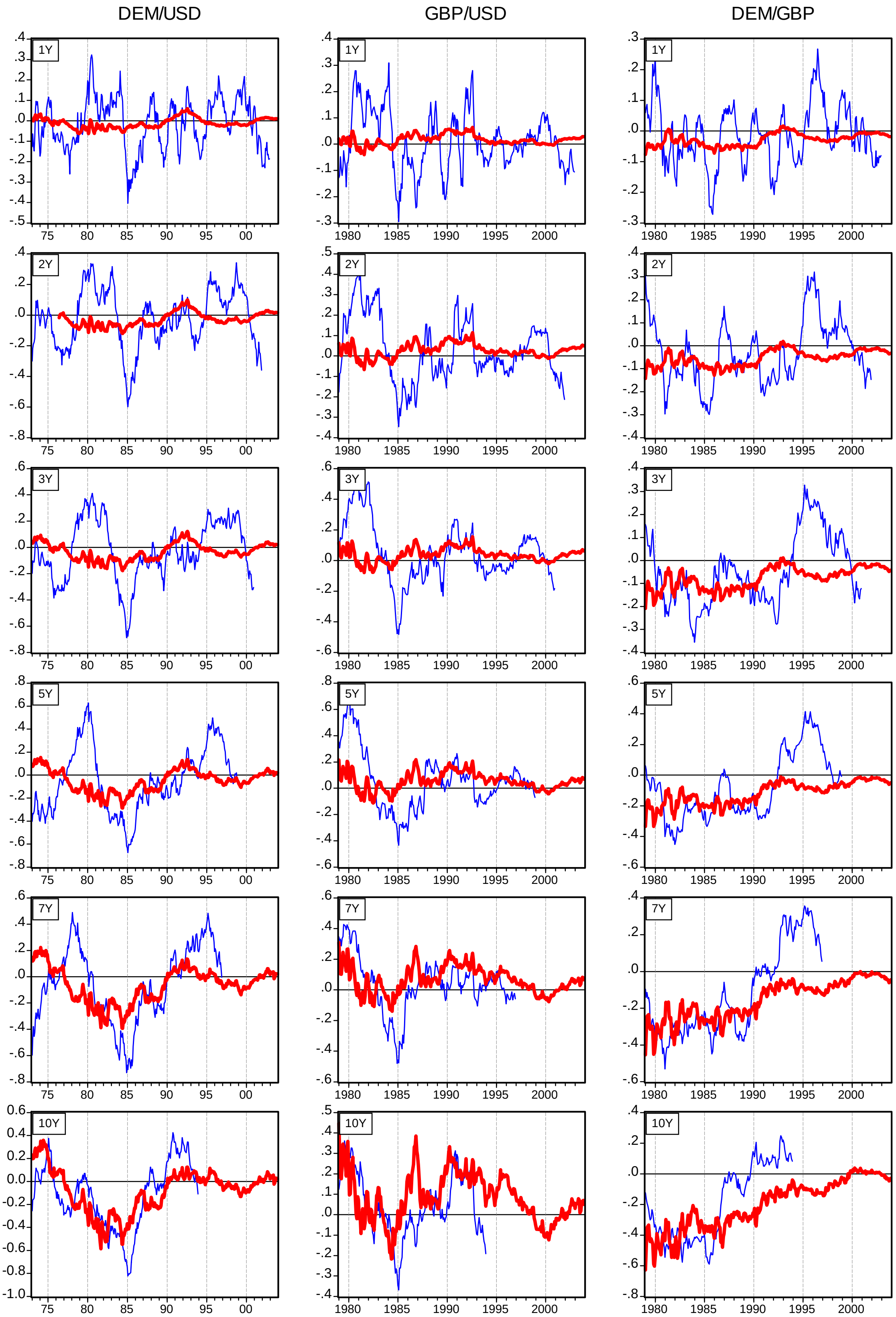
12. Figures

Figure 1: 1-year UIP regression – β-estimates with confidence bands for non-overlapping samples, using different months of the year



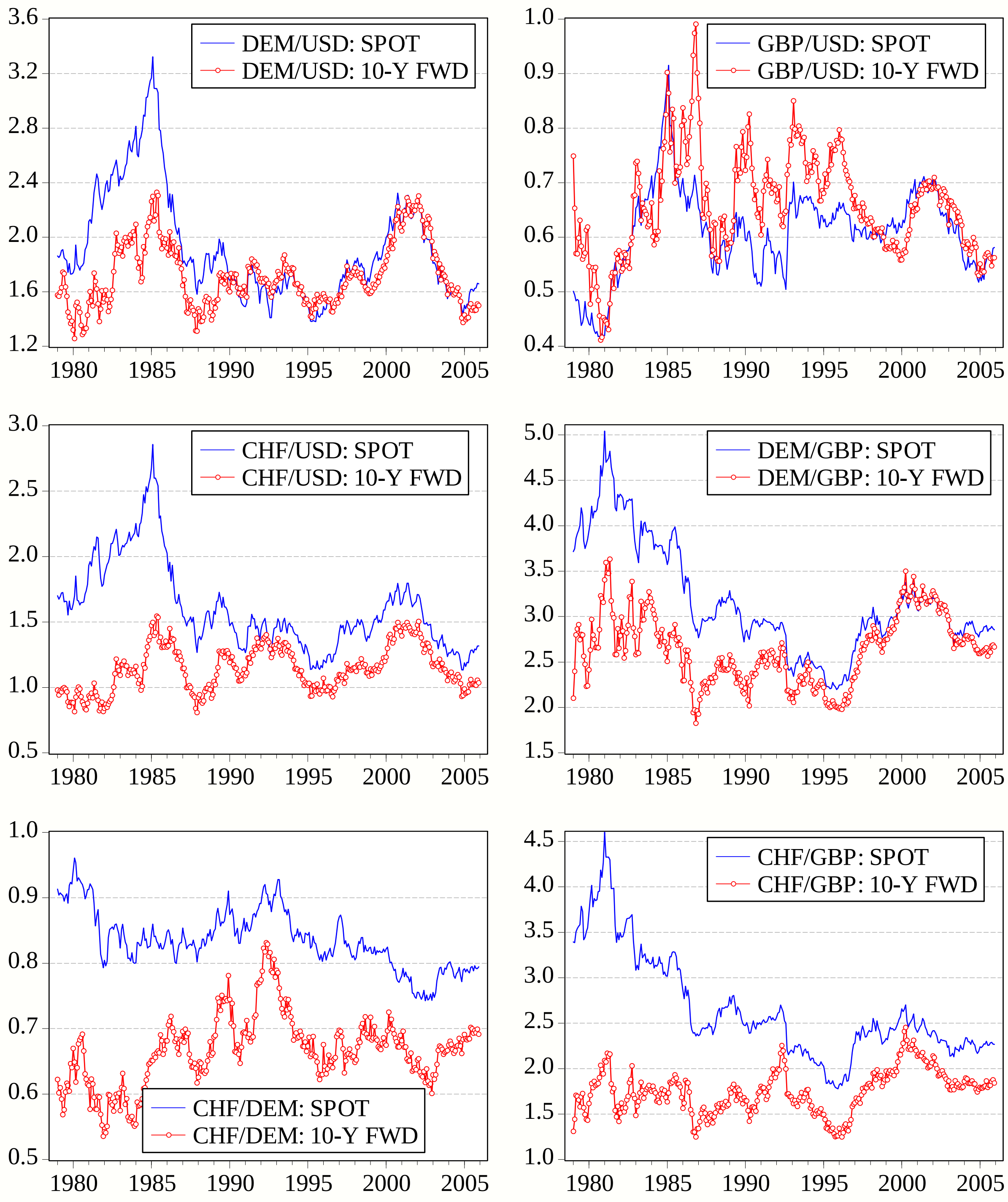
Notes. Number of observation is 30 for the DEM/USD rate is 25 for the GBP/USD and DEM/GBP rates. The full sample (i.e. the overlapping sample using all month of the year) point estimates and confidence bands are DEM/USD: -0.65 [-1.72, 1.42], GBP/USD: -1.48 [-3.20, 0.24], DEM/GBP: -0.63 [-1.93, 0.66].

Figure 2: Long run UIP: Yield differentials and actual future exchange rate changes



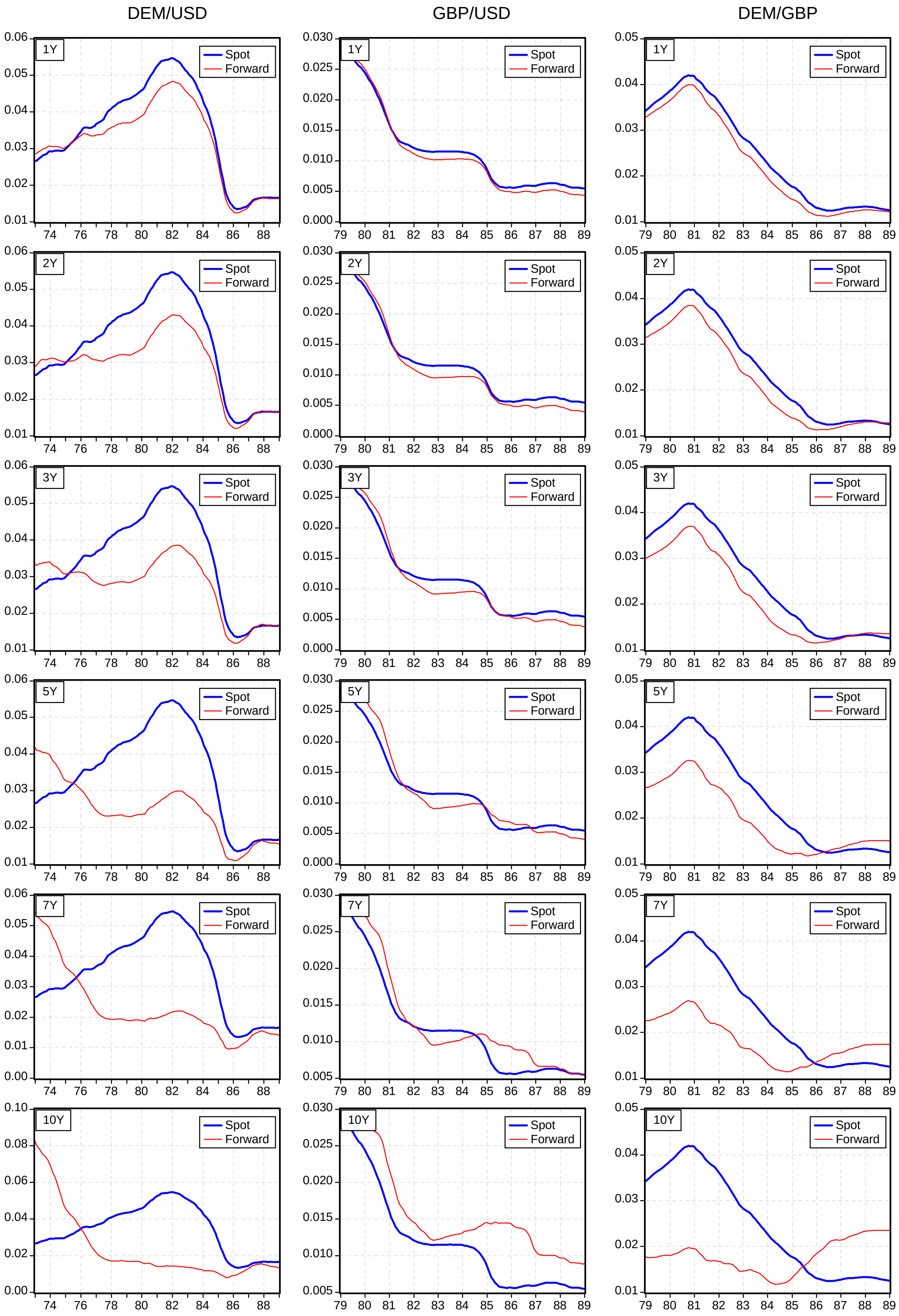
Notes. bold curves: yield differential, thin curves: actual future exchange rate changes.

Figure 3: Stability of the long run expected exchange rate: Spot and 10-year maturity forward rates



Notes: Forward rates were calculated by assuming CIP.

Figure 4: Variance of spot and long forward rate in 15-year long rolling samples



Notes: The series show the variance of the logarithm of spot and forward rates calculated assuming CIP. The dates indicated on the horizontal axis refer to the first observation of the 15-year period used for estimation.

Figure 5: The spot DEM/USD rate, and its hypothetical values if had absorbed all or none of EHTS shocks; the short-run interest rate differential; and the 'generic' foreign exchange shock, 1979-2005

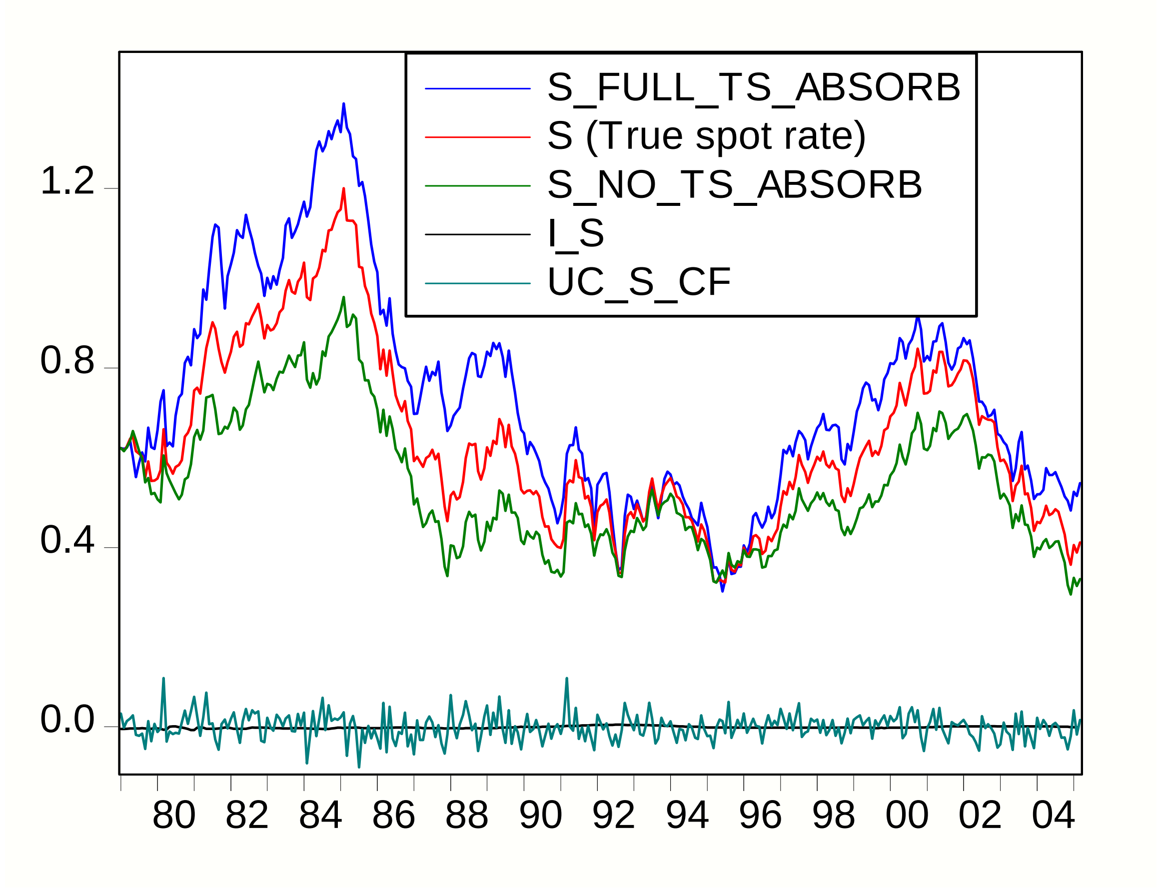


Figure 6: Monthly exchange rate changes and yield parities 1990-2003

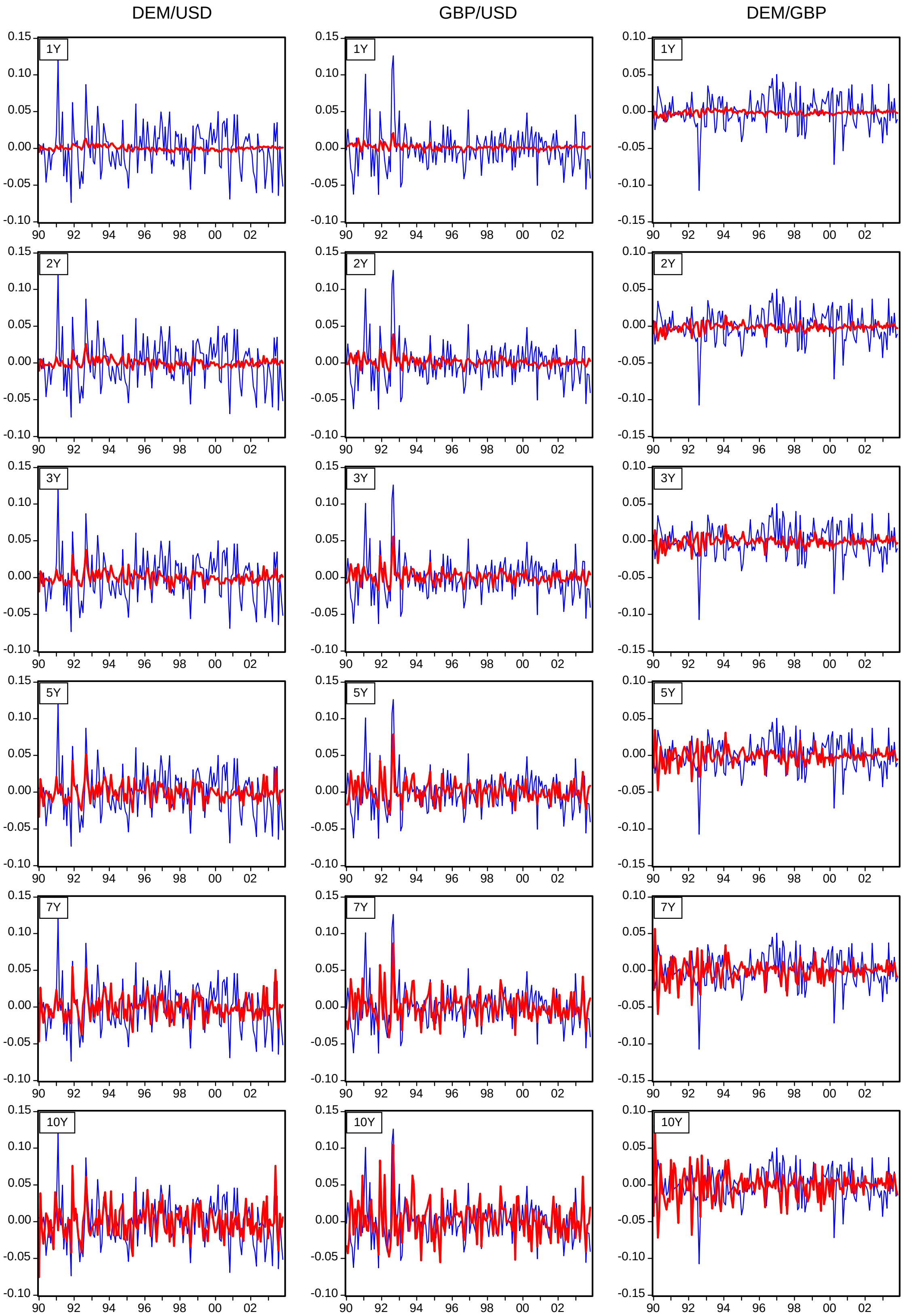
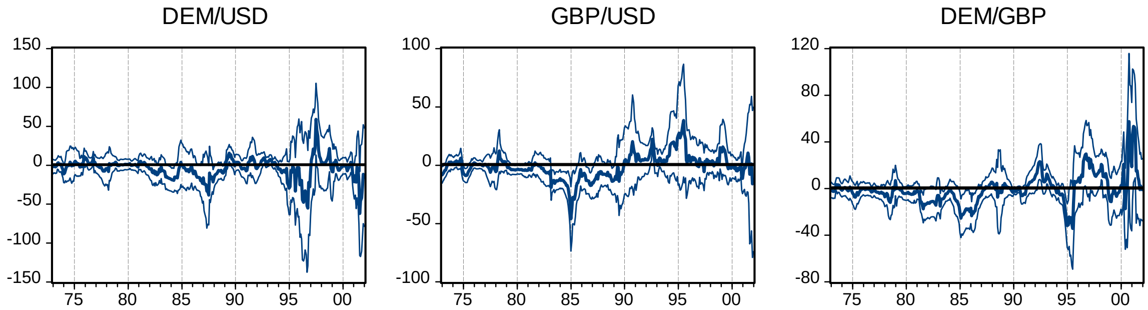
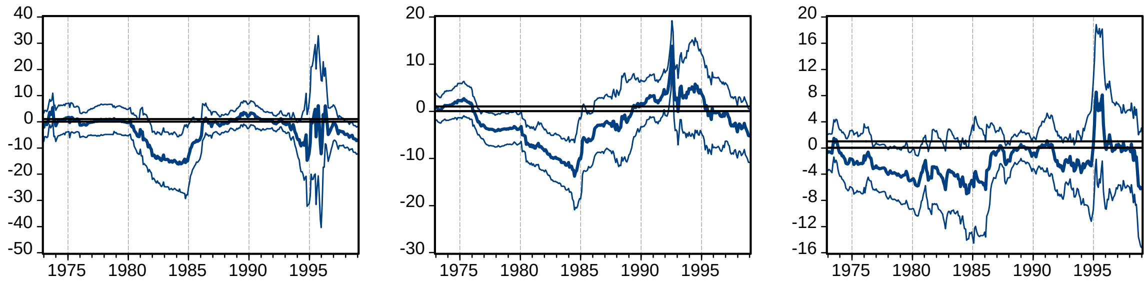


Figure 7: Short-run UIP β-coefficients for rolling samples of 2, 5, and 10 years long

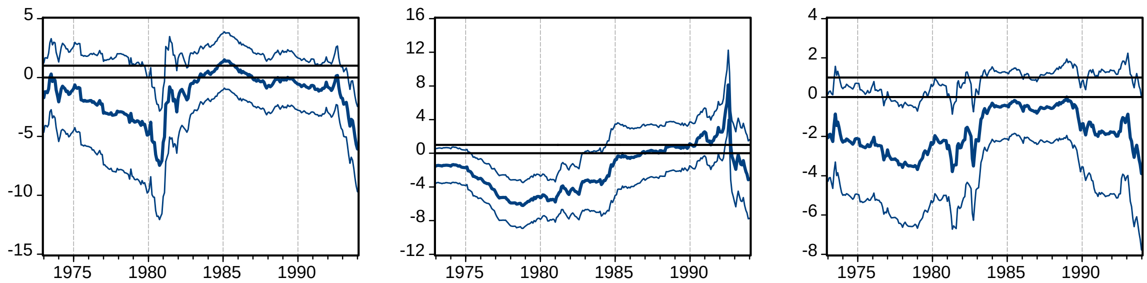
(a) 2-year rolling samples



(b) 5-year rolling samples

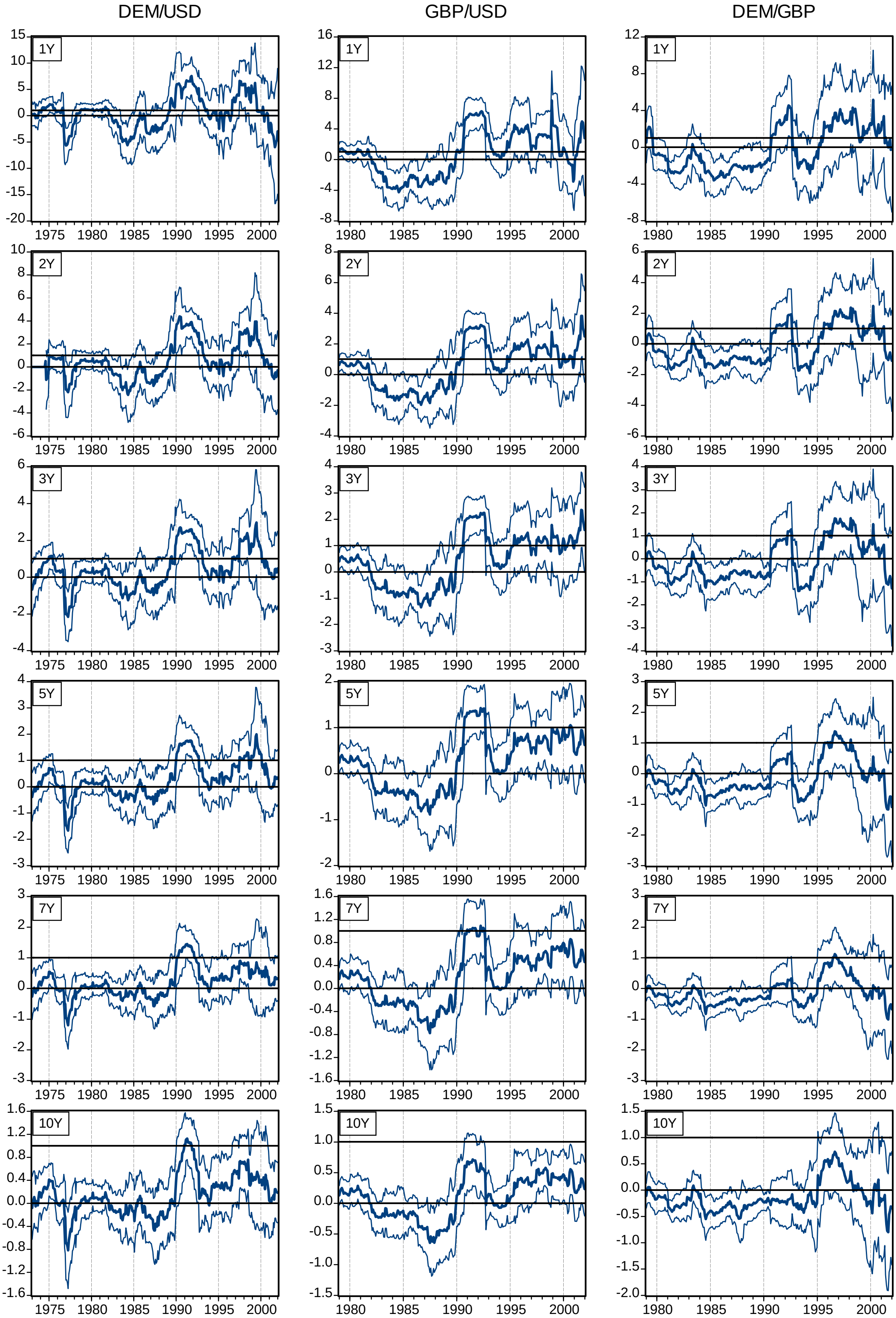


(c) 10-year rolling samples



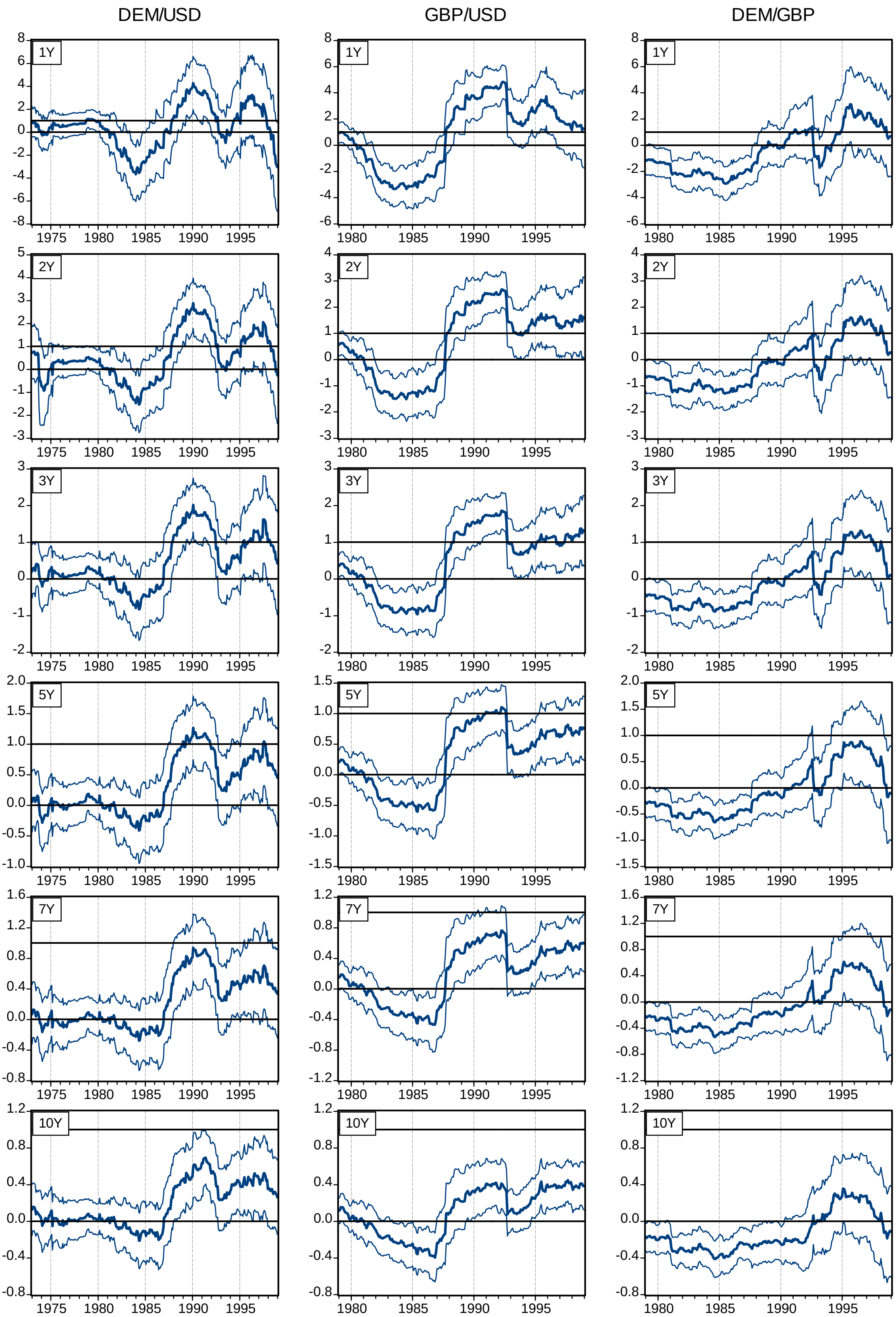
Notes. The dates indicated on the horizontal axis refer to the first observation of the period used for estimation. Thin lines correspond to +/- 2 standard errors. Zero and the theoretical value of 1 are indicated as horizontal lines.

Figure 8: Yield parity β-coefficients for 2-year rolling samples



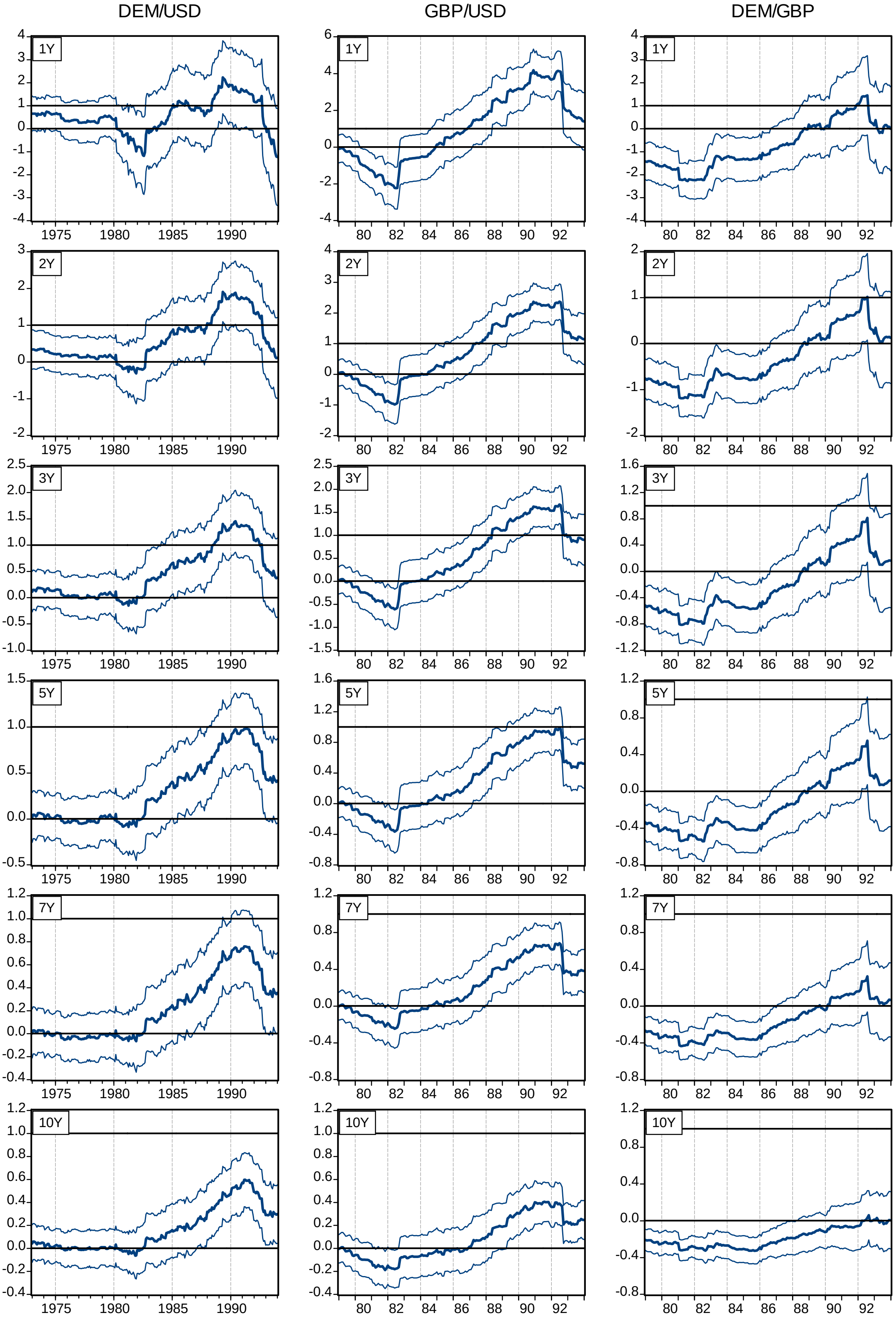
Notes. The dates indicated on the horizontal axis refer to the first observation of the 2-year period used for estimation. Thin lines correspond to +/- 2 standard errors. Zero and the theoretical value of 1 are indicated as horizontal lines.

Figure 9: Yield parity β-coefficients for 5-year rolling samples



Notes. The dates indicated on the horizontal axis refer to the first observation of the 5-year period used for estimation. Thin lines correspond to +/- 2 standard errors. Zero and the theoretical value of 1 are indicated as horizontal lines.

Figure 10: Yield parity β-coefficients for 10-year rolling samples



Notes. The dates indicated on the horizontal axis refer to the first observation of the 10-year period used for estimation. Thin lines correspond to +/- 2 standard errors. Zero and the theoretical value of 1 are indicated as horizontal lines.