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Excess Comovements between the Euro/US dollar and British pound/US dollar exchange rates

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The aim of this paper is to discuss excess comovements for the Euro/US dollar and British pound/US dollar exchange rates, i.e. we look for comovements of exchange rates which are stronger than implied by fundamentals. The results of the empirical analysis give evidence that excess comovements indeed exist. A long-run analysis on correlations can verify that the correlations dynamics of exchange rates, relative inflation rates, long-term interest rates, economic sentiments and money supply are linked. We found that money supply and prices play major roles. From the investigation of our exchange rate pair it becomes obvious that non-fundamental factors in exchange rates have an important meaning for modelling foreign exchange rates.

JEL classification: E44, F31, G15

Keywords: Foreign Exchange Market, DCC-GARCH, Excess Comovements

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1 Introduction

The aim of this paper is to discuss comovements of exchange rates which are beyond comovements that can be explained by fundamentals. Exchange rates are driven by non-fundamental factors in the short and medium run (e.g. Frankel and Froot, 1986; De Grauwe and Grimaldi, 2005, 2006; Ahrens and Reitz, 2004). These non-fundamental factors account for longer deviations from a fundamental value in such a way that the long swings discovered in US dollar exchange rates (Engel and Hamilton, 1990; Klaasen, 2005) can be explained by interactions between fundamental and technical traders. In this strand of the literature, most papers limit themselves to looking at impact factors that only cause bilateral exchange rates. In this paper we explicitly take account of common non-fundamental factors.

To the best of our knowledge, there is no contribution that has explicitly taken account of linkages in exchange rates based upon non-fundamental factors. Although the implications of common non-fundamental factors are important for the exchange rates neither are their consequences highlighted nor is empirical evidence thereof quite clear. Non-fundamental factors cannot only distort the bilateral exchange rates in which these factors are present, they can also have an impact on the cross rates. From this point of view, non-fundamental impact factors that are generated in a specific market sector can scatter across different exchange rates. If such factors are present over a longer horizon, joint deviations from their fundamental values occur, i.e. excess comovements of exchange rates come into play. Such effects can alter the external competitiveness of a country and the global portfolio diversification with negative consequences on the domestic economy.

In reality, linkages among exchange rates do exist. Short-run interlinkages are mostly due to information processing (Engle et al., 1990; Cai et al. 2008) and long-term linkages to the convergence of macroeconomic variables (e.g. Haug et al., 2000). Regarding the volatility, long-run volatility trends among major exchange rates can be observed (Alexander, 1995, Black and McMillan, 2004). Furthermore, volatility spillovers can be discovered for the most traded exchange rates, namely the Deutsche mark/US dollar, the Japanese yen/US dollar and the British pound/US dollar, whereas the causality always runs from the Deutsche mark/US dollar to the Japanese yen/US dollar rate (Hong, 2001, Inagaki, 2007; Perez-Rodriguez, 2006). The results indicate that the Euro/US dollar market acts as a source of information for the other exchange rates. Particularly, news coming from the USA significantly affects exchange rates as well as global stock and bond prices (Andersen et al., 2007; Faust et al. 2007).

During the late 1980s and the 1990s longer comovements prevail for exchange rates that participated in the EMS before the introduction of the Euro (Norrbin, 1996; Haug et al., 2000). However, causalities between exchange rates denominated in the British pound can also be found in the pre-Euro era (Brooks and Hinich, 1999). Most recently, there is a strong linkage between

Euro/US dollar exchange rate (EUR/USD) and the British pound/US dollar (GBP/USD) exchange rates since the introduction of the Euro, whereas the causality runs from the Euro/US dollar rate (Kühl, 2009). Other papers show time-varying correlations of important European currencies denominated in US dollar (Engle, 2002), between the Deutsche mark and the Japanese yen both expressed in US dollar (Tse and Tsui, 2002), and between the Euro/US dollar exchange rate and other non-Euro currencies expressed in the US dollar (van Dijk et al., 2005).

Hence, linkages between currencies in the short-run are related to information processing, in particular of private information; linkages in the medium-run exist and seem to be associated with the coincidence of fundamentals but with room for non-fundamental factors. For this reason, the linkages among exchange rates can indeed be influences by common non-fundamental factors. If these factors are important, exchange rates can be more closely linked than they will be without non-fundamental factors.

Our strategy to detect excess comovements bases upon the idea of testing for dynamic conditional correlations (DCC-GARCH model by Engle, 2002) in the residuals of benchmark models for the EUR/USD and GBP/USD exchange rates. For this reason we need to estimate structural benchmark models. After having quantified the magnitude of excess comovements we shed light on the correlation dynamics by testing for long-run relationships among correlations of exchange rates and fundamentals.

For the EUR/USD and GBP/USD exchange rates we indeed find strong positive comovements after controlling for important fundamental variables; this means that excess comovements are very important for the two exchange rates. The correlation dynamic of the exchange rates shares common stochastic trends with the correlations of changes in relative money supply, changes in the relative producer price index, changes in the long-term interest rates and changes in economic sentiment indicators, whereas the exchange rate correlations react to the other correlations indicating that the exchange rates are not completely segmented from fundamentals. This paper is the first which tests for excess comovements on the foreign exchange market and explains the dynamic of exchange rate correlations obtained. The results show that common sentiments exist and that they affect the dynamic.

The paper is organized as follows. In section 2, we introduce a model in which non-fundamental factors are important for exchange rate determination. In this section, we show theoretically the extent to which sentiments and common sentiments influence exchange rates and highlight the consequences for the cross rate. In section 3 we discuss the data and present the framework for testing excess comovements among exchange rates. In section 4 we provide the empirical results. Robustness checks accompany the empirical analysis.

2 Economic Framework

2.1 Sentiments in a behavioural finance framework

Financial market models which take account of non-fundamental traders generally differentiate between fundamental traders and noise traders (DeLong et al. 1990; Shleifer and Summers, 1990). Traders that form rational expectations correctly are those that are called "arbitrageurs" because they know the correct value of the asset and can exploit profit opportunities. In contrast to them, noise traders trade on useless information, i.e. on noise, because they believe that the information is useful (Black, 1986, p. 531). Noise traders have an impact on prices when the trading horizon of fundamental traders is longer than that of non-fundamental traders (DeLong et al., 1991).

One probable trading strategy for extracting information relies on technical analysis. Many contributions show for various markets that technical trading, i.e. chartism, is important for foreign exchange traders.[1] Noise traders are generally approximated by technical analysts in the literature. However, this is not necessarily the case.

Shiller (1984) argues that social movements, fashions, or fads can have a significant impact on the determination process of asset prices. For this reason, it is expected that beliefs and sentiments of market participants significantly affect prices on speculative markets, including the foreign exchange market. Menkhoff (1998) can confirm the existence of noise traders on the foreign exchange market in the sense that traders agree on the hypothesis that beliefs and sentiments are important. However, so-called fundamentalists are also subject to beliefs and sentiments to the same extent as the non-fundamentalists (p. 554-561).

Based upon these findings, the market consists of two traders: fundamentalists and noise traders, whereas noise traders are more broadly defined and are not restricted to technical analysts. The exchange rate observed on the market, s_t^{j1}, between currency 1 and currency j with $j = [2, 3]$, is a weighted average of the impact of fundamentalists and noise traders via their expectations which are formed from trading rules.[2]

$$s_t^{j1} = \gamma_t^{j1} E(s_t^{r,j1} | \Phi_{t-1}^{r,j1}) + (1 - \gamma_t^{j1}) E(s^{b,j1} | \Phi_{t-1}^{b,j1}) \qquad (1)$$

The term $E(s_t^{r,j1} | \Phi_{t-1}^{r,j1})$ in equation (1) represents the fundamentalists' expectations based upon the information set $\Phi_{t-1}^{r,j1}$ while $E(s_t^{b,j1} | \Phi_{t-1}^{b,j1})$ represents those of the noise traders based upon the information set $\Phi_t^{b,j1}$. The information set $\Phi_{t-1}^{r,j1}$, which contains information about fundamental factors, is orthogonal to the information set $\Phi_{t-1}^{b,j1}$ that summarizes non-fundamental factors, i.e. the covariance of sentiments is zero. For the case of the fundamentalists their exchange rates' expectations can be seen as an equilibrium exchange rate which is formed with the help of the

[1] Cheung et al. (2004) show this for the market in the UK, Cheung and Chinn (2001) for the US market and Gehrig and Menkhoff (2006) for Austria and Germany.

[2] This setting bases upon the one used in Frankel and Froot (1986) and Cutler et al. (1990) and is similar to Altavilla and De Grauwe (2005) and De Grauwe and Grimaldi (2006). An important difference is that we use levels instead of changes.

purchasing power parity or another structural exchange rate determination model. γ_t^{j1} is the weight of fundamentalists in the market and is time-varying. Its value in period t depends on a specific function of determination parameters which are summarized in Ω_t^{j1}, i.e. $\gamma_t^{j1} = f^{j1}(\Omega_t^{j1})$.[3] The rational traders form their expectations according to a simple rule: they assume that the exchange rate is determined by fundamental factors, summarized in F_t^{j1}, and non-systematic factors ν_t^{j1}, i.e. with zero mean. An increase in F_t^{j1} shall result in a depreciation of currency 1. For the two exchange rates the following equilibrium rates result

$$s_t^{r,j1} = F_t^{j1} + \nu_t^{j1}, \tag{2}$$

whereas ν_t^{j1} are i.i.d. error terms and $j = [2, 3]$. Since exchange rates are relative prices F_t^{j1} contains the fundamental processes of both countries, i.e. $F_t^{j1} = F_t^j - F_t^1$. The non-fundamental part in equation (1) shall consist, similarly to Barberis et al. (2005), of a white noise term (ϵ_t^{21}) and a sentiment term (u_t^{j1})

$$s_t^{b,j1} = u_t^{j1} + \epsilon_t^{j1}. \tag{3}$$

The sentiment term reflects all persistent non-fundamental factors which determine the level of the exchange rate, whereas the noise term captures transitory non-fundamental factors which are not systematic by assumption.[4] In order to be consistent with the fundamental analysis, we assume that higher sentiments reflect a weakening of the economy. Similarly to the fundamental process, traders are confronted with sentiments directed to both countries involved, i.e. the sentiment term u_t^{j1} is a relative process and covers the sentiments directed to country 1 and to country j, i.e. $u_t^{j1} = \phi_t^{j1} u_t^j - \lambda_t u_t^1$, whereas ϕ_t^{j1} and λ_t are the factor loadings.[5] From this follows that the sentiments directed to country 1 (u_t^1) can generally influence all exchange rates.
By using equations (1), (2) and (3), we get the exchange rate determination process

$$s_t^{j1} = \gamma_t^{j1} F_t^{j1} + (1 - \gamma_t^{j1}) u_t^{j1} + e_t^{j1} \tag{4}$$

with $e_t^{j1} = \gamma_t^{j1} \nu_t^{j1} + (1 - \gamma_t^{j1}) \epsilon_t^{j1}$. The error term can be neglected in the following because the conditional expectations of e_t^{j1} are zero. For the sake of simplicity, we assume that λ_t, ϕ_t^{21} and ϕ_t^{31} are binary-coded variables and can only take the values 0 and 1, i.e. the sentiments are either absent or present. It is imaginable that λ_t, ϕ_t^{21} and ϕ_t^{31} are functions of various macroeconomic and financial factors.[6] An economic foundation shall not be explicitly modelled here and is left

[3] The weights can be determined by a backward-looking profit function (e.g. Brock and Hommes, 1997), for instance.
[4] The difference to Barberis et al. (2005) is that they focus on the change of the asset price and that they only deal with common sentiments because of their classification by investigating the stock market.
[5] Since investors are faced with framing effects (e.g. Barberis and Shleifer, 2003), we reasonably assume that λ_t^{21} and λ_t^{31} are identical, i.e. $\lambda_t^{21} = \lambda_t^{31} = \lambda_t$.
[6] Menkhoff and Rebitzky (2008) show, for instance, that sentiments in the EUR/USD market depend on long-term interest rates and deviations from the purchasing power parity and that they become stronger when the deviation from PPP is high.

open for future research.

With the assumption of the validity of the triangular arbitrage condition[7], we can build a linear combination of s_t^{21} and s_t^{31} which is equal to the cross rate s_t^{32}

$$s_t^{21} - s_t^{31} = \gamma_t^{21} F_t^{21} + (1-\gamma_t^{21}) u_t^{21} - \gamma_t^{31} F_t^{31} - (1-\gamma_t^{31}) u_t^{31} = s_t^{32}. \tag{5}$$

Next, the fundamental processes in equation (5) can be split up into their determinants. Hence,

$$\begin{aligned} s_t^{21} - s_t^{31} &= \gamma_t^{21}(F_t^2 - F_t^1) + (1-\gamma_t^{21})(\phi_t^{21} u_t^2 - \lambda_t u_t^1) \\ &- \gamma_t^{31}(F_t^3 - F_t^1) - (1-\gamma_t^{31})(\phi_t^{31} u_t^3 - \lambda_t u_t^1) \\ &= (\gamma_t^{31} - \gamma_t^{21}) F_t^1 + \gamma_t^{21} F_t^2 - \gamma_t^{31} F_t^3 \\ &+ \lambda_t(\gamma_t^{21} - \gamma_t^{31}) u_t^1 + \phi_t^{21}(1-\gamma_t^{21}) u_t^2 - \phi_t^{31}(1-\gamma_t^{31}) u_t^3 \\ &= s_t^{23}. \end{aligned} \tag{6}$$

From equation (6) it can be seen that the exchange rate s_t^{32} also depends on the importance of noise traders in the exchange rate determination process of s_t^{21} and s_t^{31} as well as on the fundamentals of country 1 and the sentiments directed to country 1. Here we can derive our first results: with the presence of noise traders, regardless of the impact of the sentiments, the true cross rate differs from its fundamentally implied one.

2.2 Common sentiments and excess comovements

In order to derive the linkages between exchange rates in a system of exchange rates based upon the denomination currency the unconditional expectations operator is applied to equation (4). It follows

$$E(\mathbf{s}, \mathbf{s}') = E(\mathbf{F}, \mathbf{F}') + E(\mathbf{u}, \mathbf{u}') \tag{7}$$

with $\mathbf{F}_{km} = \gamma_t^{j1} F_t^{j1}$ and $\mathbf{u}_{km} = (1-\gamma_t^{j1}) u_t^{j1}$, whereas km refers to the position in the vectors $\mathbf{F}$ and $\mathbf{u}$. By looking at the diagonals in equation (7) and assuming that fundamentals and sentiments are uncorrelated, since sentiments shall be noise the Flood and Rose (1995) notion of excess volatility can be shown in equation (8) .

$$var(s_t^{j1}) = (\gamma_t^{j1})^2 var(F_t^{j1}) + (1-\gamma_t^{j1})^2 var(u_t^{j1}). \tag{8}$$

Excess volatility prevails in our model when $var(u_t^{j1}) > 0$, i.e. variations of sentiments are important.

If the off-diagonal elements with $i \neq$ j in equation (7) are employed, the covariances between the

[7] This assumption is also appropriate within a behavioural finance framework for exchange rates because cross-market arbitrage opportunities can be exploited very quickly without the knowledge of any fundamental value in the case of the most important currencies.

exchange rates can be obtained. For a system with $j = [2, 3]$ we get a similar formulation as for the volatility

$$cov(s_t^{21}, s_t^{31}) = \gamma_t^{21}\gamma_t^{31} \cdot cov(F_t^{21}, F_t^{31}) + (1 - \gamma_t^{21})(1 - \gamma_t^{31})cov(u_t^{21}, u_t^{31}). \tag{9}$$

As can be seen in equation (9) the covariation between the exchange rates depends on the weights of the fundamentalists in both markets, the covariation between the fundamentals and the covariation between the sentiments. As long as the weights of fundamentalists in both markets are not one, the variation between the exchange rates also depends on the market activity of the noise traders. Excess comovements arise when $cov(F^{21}, F^{31}) < (cov(s_t^{21}, s_t^{31}) + (1 - \gamma^{21})(1 - \gamma^{31})cov(u^{21}, u^{31}))/(\gamma^{21}\gamma^{31})$.[8]

But where do such sentiments come from? The sources of the covariation of the sentiments are presented in equation (10) .

$$cov(u^{21}, u^{31}) = var(\lambda u^1) - cov(\lambda u^1, \phi^{21}u^2) - cov(\lambda u^1, \phi^{31}u^3) + cov(\phi^{21}u^2, \phi^{31}u^3). \tag{10}$$

Here, it can be seen that the sentiments are strongly linked when either the sentiments directed to the denomination currency or the covariation between the sentiments directed to currencies 2 and 3 have high values compared to the covariation between both countries 1 and 2 and countries 2 and 3.

Barberis and Shleifer (2003) argue that investors group investments into styles. In such a style assets share the same characteristics which can be related to legal or structural features.[9] An excess comovement of exchange rates can therefore occur in response to portfolio adjustments if two countries are perceived as being similar with respect to their macroeconomic performance or the performance of the financial market but commonly different to the country of the denomination currency.

Alternatively, excess comovements are established when the sentiments directed to the country of the denomination currency are very volatile, i.e. developments in the country of the denomination currency are perceived as being important. If the market participants predominantly focus on sentiments concerning country 1, i.e. $\lambda_t = 1$ and $\phi_t^{21} = \phi_t^{31} = 0$, the covariation between u^{21} and u^{31} is completely dominated by the variation of u^1.

3 Framework for the empirical analysis

3.1 Data

Our period of observation starts in January 1994. The reason is that we want to analyse the correlations on the foreign exchange market during a period of (official) pure free floating. By January

[8] To be precise, the presence of noise traders on the foreign exchange market can create comovements that are greater or smaller than the comovements induced by the benchmark model. In the latter case we speak of "minor comovements".

[9] Factors which are categorized as structural features are more differentiated in Barberis and Shleifer (2003). They distinguish between market factors, depending on the market capitalization, and fundamental factors.

1994 the turbulences of the EMS crisis of the previous years are expected to have been cancelled out. Our period of observation ends with December 2007. The analysis shall be done exclusively for the Euro/US dollar (EUR/USD) and British pound/US dollar (GBP/USD) exchange rates because we want to investigate the most important currencies; we exclude the Japanese yen due to the frequent Japanese interventions during the 1990s.

Exchange rates are taken from Datastream. In the fundamental analysis we use the money supply (M1), real income proxied by the production index, short-term interest rates with a maturity of 3 months, long-term interest rates which are the yields of government bonds with a maturity of 12 years, the consumer price index (CPI) and the producer price index (PPI). In the correlations analysis we additionally use a broad monetary aggregate (M3) and a sentiment indicator. All fundamental variables are taken from the International Monetary Fund's (IMF) International Financial Statistics. The sentiment indicator bases upon questionnaires filled in by professional market participants in the financial sectors and is constructed by the Center for European Economic Research in Germany (ZEW). Before the introduction of the Euro the Deutsche mark and German data are employed.[10]

3.2 Empirical framework for testing excess comovements

Since the aim of this paper is to investigate the foreign exchange market for excess comovements, in the following we tie in with the discussion in the section 2.2. In the seminal paper of Pindyck and Rotemberg (1990) it is tested for excess comovements by first regressing the changes of prices on various fundamentals over a specific period and then calculating the correlation between the residuals. If the hypothesis of uncorrelated errors can be rejected, Pindyck and Rotemberg (1990) infer that excess comovements exist.

A disadvantage of the approach in the vein of Pindyck and Rotemberg (1990) is that the approach is static. It can only be tested whether excess comovements exist during a specific pre-determined period. However, it is conceivable that the impact of common sentiments on the prices differs. As shown in section 2.1 this is the case when the weights vary. Kallberg and Pasquariello (2008) use for their investigation, in which excess comovements on the US stock markets are scrutinized, a rolling filter combined with a non-parametric approach to calculate the correlations of residuals. They conclude that non-parametric approaches are preferable over parametric approaches which base on GARCH models, for instance. In order to account for heteroskedasticity, they apply a correction from which follows that two regressions must be applied: one for a long-term and one for a short-term interval. Nevertheless, a weakness of their proceeding is that the short-term interval must not be too small. Beside the small sample problems, the resulting regression errors can be based upon a short-term dynamic which is different from a dynamic over a longer run. This

[10] The German data are level-adjusted to the EMU data. We use German data instead of aggregated data before the introduction of the Euro because we would otherwise not be able to focus on real market dynamics.

is particularly important for monthly data and few observations as in our case. Consequently, the results can be misleading. For this reason, we decide to apply the DCC-GARCH framework by Engle (2002) as outlined in the appendix. In order to test whether excess comovements exist we draw on the basic concept by Pindyck and Rotemberg which was also applied by Kallberg and Pasquariello (2008) on stock prices. The (exchange rate) returns are regressed on a constant and (changes of) a fundamental process

$$\Delta s_t^{j1} = \mu + \psi \Delta F_t^{j1} + \eta_t^{j1}. \tag{11}$$

Similarly to equation (7), the off-diagonal elements based upon equation (11) with $i \neq j$ are the covariances which can be written as

$$cov(\Delta s_t^{21}, \Delta s_t^{31}) = cov(\psi^{21} \Delta F_t^{21}, \psi^{31} \Delta F_t^{31}) + cov(\eta_t^{21}, \eta_t^{31}). \tag{12}$$

Excess comovements arise when $cov(\eta_t^{21}, \eta_t^{31})$ is different from zero. As a test on excess or minor comovements we can draw on the LM_{DCC} test which distinguishes the hypotheses of constant and time-varying correlations. If the hypothesis of constant correlations is rejected, we also can automatically conclude that excess or minor comovements are in play over the whole period of observation. The only question is whether they are present conditioned on t. However, if the hypothesis of constant correlation in the errors is not rejected we need a closer examination and cannot automatically conclude that excess or minor comovements are absent. In order to evaluate the existence of excess comovements we can look at the evolution of conditional correlations of the error processes. If they exceed zero we know that we are confronted with excess comovements.

3.3 Baseline benchmark model

In contrast to stock markets we cannot make use of a more or less accepted fundamental model like the Fama-French factor model. For this reason we have to opt for a fundamental model with whose help it can be controlled for the impact of fundamental factors. Hence, a first step must be the choice of the fundamental benchmark model. If a fundamental model is found, it will be required to estimate the model for both exchange rates. As is known in the literature, the linkages from fundamentals to exchange rates are subject to instabilities (Goldberg and Frydman, 2001) but with different lasting regimes in which the linkages are more or less stable (Sarno, Valente and Wohar, 2004; Altavilla and De Grauwe, 2005; Frömmel et al., 2005; De Grauwe and Vansteenkiste, 2007).

In departing from the monetary model of exchange rate determination, we adopt the same fundamental framework most of the papers use. However, a linear formalisation of the model is inadequate. Consequently, we decide to put more attention on the modelling of structural breaks and different regimes.[11] Beckmann et al. (2009) recently show for the EUR/USD exchange rate on monthly data that a cointegration relationship exists from 1975 till 2007. However, its composition, i.e. the cointegration vector, changes considerably.

Our baseline benchmark model therefore follows the idea that specific fundamentals are central to determining the exchange rate over the long run. Thus, we also employ the monetary approach by Frenkel (1976) in the form of Frankel (1979), namely the real interest rate differentials (RID) model. In addition, we take account of the fact that prices of tradables should be predominantly important regarding the power purchasing parity (Dornbusch, 1976). Consequently, we extend the RID model by the difference between the proportion of tradables to non-tradable goods.

$$s_t = \mu + \beta_1(m_t - m_t^f) + \beta_2(y_t - y_t^f) + \beta_3(i_{s,t} - i_{s,t}^f) + \beta_4(\pi_t - \pi_t^f) + \beta_5(p^T/p_t^{NT} - p^{f,T}/p_t^{f,NT}) \quad (13)$$

In equation (13) m denotes the money supply, y real income, $i_{s,t}$ short-term, π_t inflation rates and p the price level; superscript f denotes foreign variables, T tradable goods and NT non-tradable goods.[12]

Since structural instabilities must be accounted for we consequently make use of a combination of techniques proposed by Beckmann et al. (2009) and described in the appendix. Thus, we estimate the extended RID model for the EUR/USD and the GBP/USD exchange rates controlling for structural changes. The RID model can therefore be rewritten as

$$\begin{aligned} s_t^{j1} &= \mu(t) + \beta_1^j(t)m_t^j - \beta_1^1(t)m_t^1 - \beta_2^j(t)y_t^j + \beta_2^1(t)y_t^1 \\ &- \beta_3^j(t)i_{s,t}^j + \beta_3^1(t)i_{s,t}^1 + \beta_4^j(t)\pi_t^j - \beta_4^1(t)\pi_t^1 \\ &+ \beta_5^j(t)(p^{j,T}/p_t^{j,NT}) - \beta_5^1(t)(p^{1,T}/p_t^{1,NT}) + \epsilon_t^{j1} \end{aligned}$$

when equal parameter restrictions are removed. All fundamental variables on the right-hand side encompass the fundamental processes and ϵ_t is the deviation from the long-run relationship. This model shall allow us to find ex post the closest relationship between fundamentals and exchange rates.

A cumulated fundamental process can now be obtained by taking the difference between the exchange rate and the error term at time t.

$$F_t^{j1} = s_t^{j1} - \epsilon_t^{j1} \quad (14)$$

The process F_t^{j1} is finally used to evaluate excess comovements.

Since a long-run perspective is under observation we start already with 1975 for the estimation

[11] We also run a cointegration analysis based on the real interest rate model but obtain results which are consistent with the literature: there is a long-run relationship between fundamentals but with coefficients' estimates which are not consistent with the theory. This is particularly true for the GBP/USD exchange rate. We decide to omit the results because they provide no additional insight.

[12] All data are taken from the IMF's International Financial Statistics. The money supply is M1 except for the UK for which we take M0. The real income is approximated by real production. Short-term interest rates have a maturity of 3 months and long-term interest rates are government bonds with a maturity of 10 years.

of our baseline benchmark model. Nevertheless, we only make use of the fundamental process after January 1994 which is congruent with our period of interest.[13] The estimated break points for the EUR/USD and the GBP/USD rates are presented in Table 1. As can be seen, the break points are very similar across the exchange rates. Since a closer examination of the regimes is beyond the scope of this paper it is left open for further research.

[Table 1 about here]

4 Empirical Results

4.1 Estimating fundamental benchmark models

With the fundamental process obtained we can proceed to test for excess comovements in exchange rates. In analogy to Pindyck and Rotemberg (1990) we regress exchange rate returns on changes in the fundamental process (equation (11)) because exchange rates and fundamentals are integrated of order one. Since the fundamental process is estimated using a cointegration analysis (with structural breaks) the short-run dynamic can explicitly be modelled by using an error correction term. For this reason we offer, in addition to equation (11) (model 1), the error correction representation (model 2): $\Delta s_t^{j1} = \mu - \alpha \cdot ect_{t-1} + \eta_t^{j1}$ with α as the adjustment coefficient and $ect_t = \epsilon_t$. Since autocorrelations can basically be a reflection of the technical analysis' impact (e.g. De Grauwe and Grimaldi, 2006), we neglect lagged dependent variables and employ the heteroskedasticity and autocorrelation consistent (HAC) residual covariance matrix. In addition to these two benchmark models, we control for further economic variables. Hau and Rey (2006) show that monthly exchange rate returns can be explained by monthly returns of stock prices (r_t^{j1}). Hence, we include the changes of the stock price indexes (in logs) as additional explanatory variables. An increase in the (relative) domestic stock returns results in a depreciation of the domestic currency. Since in our period of observation the current account deficit of the USA worsened remarkably - a development resulting (partly) from capital inflows into the USA - we decide to introduce (the change of) the long-term interest rates in order to catch risk-free returns on capital ($\Delta i_{l,t}^{j1}$). Capital inflows in the USA are predominantly linked with relative returns on capital. At this, government bonds are largely purchased by foreign traders. If long-term interest rates reflect returns on capital rather than expectations regarding the rate of inflation, the sign

[13] An application of the Bai and Perron test which starts in 1994 would result in false break points if the next break point actually occurs in 1994 because we allow the minimum distance between two breaks to be one year. Since we are only interested in the fundamental process our proceeding is much more adequate.

is negative. The extended models 1 and 2 are models 3 and 4, respectively.

Model 1: $\Delta s_t^{j1} = \mu + \psi_1 \cdot \Delta F_t^{j1} + \eta_t^{j1}$

Model 2: $\Delta s_t^{j1} = \mu - \alpha \cdot ect_{t-1} + \eta_t^{j1}$

Model 3: $\Delta s_t^{j1} = \mu + \psi_1 \cdot \Delta F_t^{j1} - \psi_2 \cdot \Delta i_{l,t}^{j1} + \psi_3 \cdot r_t^{j1} + \eta_t^{j1}$

Model 4: $\Delta s_t^{j1} = \mu - \alpha \cdot ect_{t-1} - \psi_2 \cdot \Delta i_{l,t}^{j1} + \psi_3 \cdot r_t^{j1} \eta_t^{j1}$

Since exchange rates are relative prices the error processes η_t^{j1} can contain shocks which stem from the common denomination currency. For this reason shocks can be correlated and will not be independently distributed across exchange rates. In order to account for this possibility we estimate equations (11) and the variations with two approaches. In the first case, we neglect the possibility of latently correlated errors and use ordinary least squares (OLS). In the second case, we take account of permanently correlated errors and use the seemingly unrelated regression approach, as also done by Kallberg and Pasquariello (2008). We estimate each model for both exchange rates in a system approach in which the unknown residuals' variance-covariance matrix is estimated using the feasible generalized least squares (FGLS) estimator.[14]

[Table 2 about here]

In Table 2 we provide the results for the regressions based upon the outlined models.[15] Panel (a) and (b) display the results for the EUR/USD and the GBP/USD, respectively. As expected, all fundamental processes are statistically significant in both exchange rates. The same is true for the error correction term. It is remarkable that the best model (as measured by both the adjusted coefficient of determination ($\bar{R}^2$) and the Akaike information criterion (AIC)) for the EUR/USD is model 3 and for the GBP/USD model 4, using the OLS method. In the first case, 28 percent and, in the second case, 24 percent of the variation in the data can be explained. From this point of view, the EUR/USD is strongly linked to the evolution of the fundamental process, whereas the GBP/USD adjusts to deviations from the long-run relationship with the fundamentals. This is an indication that error correcting is more important for the GBP/USD, i.e. there is room for other factors which have caused the deviations. For the FGLS estimation the best model is model 3 (minimal AIC) but model 4 explains a higher percentage of the variation in the data.[16] In models 3 and 4 the long-term interest rates are statistically significant and show the correct sign (panel (a) and (b), columns (3a) and (4a), coefficient ψ_2) , i.e. they seem to mirror (changes in) returns on capital. The stock market return variable ψ_3 is only significant for the GBP/USD.

[Table 3 about here]

[14] Kallberg and Pasquariello named this "latent comovement".

[15] We can use least squares techniques because based on economic theory the causality runs from the regressors to the regressand, i.e. endogeneity is not a problem. For similar one-equation approaches on empirical exchange rate modelling see Frömmel et al. (2005) and Menkhoff and Rebitzky (2008).

[16] The goodness of fit indicators refer to the system estimates.

The LM_{DCC} tests for constant correlations between the residual series based upon models 1-4, estimated by both OLS and GLS, are presented in Table 3. The hypothesis of no constant correlation is clearly rejected in favour of its alternative, i.e. excess or minor comovement, for all models and both estimation techniques. Consequently, we conclude that the residuals are indeed correlated. A question which remains is how important excess comovements are.

4.2 Time-varying correlations between EUR/USD and GBP/USD

In the next step we estimate the dynamic conditional correlations of the exchange rates. For our analysis we first estimate the DCC-GARCH model outlined in the appendix. Since exchange rates and macroeconomic fundamentals in levels are usually non-stationary I(1) processes, we cannot pursue a correlation analysis in which variables enter in levels. Nevertheless, we can apply the outlined argumentation on (stationary) first differences of both exchange rates and fundamentals without a loss in generality. Further on, when we discuss correlations of exchange rates we are referring to changes of exchange rates.

[Table 4 about here]

Furthermore, GARCH models can only be fitted to those variables in which ARCH effects are significant. Model specification tests can be found in Table 4. Since ARCH effects are not present in the exchange rate returns (for lines 1 and 2 columns 3 and 4 in conjunction with columns 7 and 8 in Table 4) we cannot exactly proceed as outlined in the appendix. Thus, we decide to estimate the mean equation by maximum likelihood from which we also obtain the unconditional variance. Despite no time-varying standard deviations it is still possible that the correlations between the exchange rates are time-varying. Hence, the unconditional variance enters the DCC part of the model.

[Table 5 about here]

To test for time-varying correlations, i.e. to ensure that the results found in the literature are also valid in our sample, we apply the LM_{DCC} test by Engle and Sheppard (2001) as outlined in the appendix. The LM_{DCC} test statistic in the first line of the first column of Table 5 gives a value of 75.616 with a corresponding p-value of 0.000 which proves that time-varying correlations are also present in our period of observation. The resulting dynamic conditional correlations between the EUR/USD and GBP/USD exchange rates are presented in Figure 1. Over the whole period of observation the correlation coefficient varies between 0.58 and 0.7 with a sloping and recovering curve around the introduction of the Euro. The minimum is achieved in mid 1998. Although time-varying correlations can be shown, they remain in a range of 0.1.

[Figure 1 about here]

4.3 Quantifying excess comovements

In order to quantify excess comovements, we also use the approach of Pindyck and Rotemberg (1990) but compute time-varying correlations of the residuals from our models 1-4 for both estimation techniques (Figure 2). Each subfigure in Figure 2 represents one model; the solid lines are the correlations obtained from the GLS estimation and the dashed line those from the OLS estimation. As can be seen at first glance, there is evidence that excess comovements really exist because all correlations series of residuals are much greater than zero. In Figures 2 (a), 2 (b) and 2 (c) it can be seen that the GLS residuals are more strongly correlated than the OLS residuals. Hence, a latent correlation in the residuals must be accounted for when evaluating excess comovements because their size would otherwise be underestimated. More or less all correlation patterns are very similar to the dynamic obtained from the raw data in Figure 1. From this point of view, the correlation dynamic of exchange rates is driven by factors which are not accounted for in our benchmark models. As can be seen, excess comovements start to shrink at the end of 1996 and achieve their minimum in mid 1998 before the introduction of the Euro.

[Figure 2 about here]

The minimum value of the correlations coincides approximately with the introduction of the Euro. After the introduction of the Euro it depreciates strongly against other important currencies. A major source of the depreciation of the Euro was seen in the strength of the US economy (e.g. Meredith, 2001) and the weakness of the Euro area (e.g. Arestis et al. 2002). De Grauwe (2000) argues that the uncertainty regarding Euro area fundamentals leads to framing effects. Market participants perceive the initial exchange rate movement as a fundamental strength of the US economy and therefore intensify the market movement. The weakness of the Euro area economy can explain why the Euro depreciates against both the British pound and the US dollar. However, the British pound also depreciates against the US dollar. This could also be a reflection of the strength of the US economy. If framing effects were important, the depreciation of the British pound against the US dollar could be caused by common sentiments. The other way round: the perception of the Euro area's weakness could have generated the depreciation of the Euro against the British pound. Common sentiments were also in play.

4.4 Comparison of exchange rate correlations with correlations of fundamentals

The aim of this section is to provide an insight into explanations for the evolution of the exchange rates' correlations. In order to analyze the excess comovements, we decide to model the correlations of fundamental processes and of the exchange rates separately. Thus, we estimate correlations between several (relative) economic variables ($corr(F_t^{21}, F_t^{31})$). Since it is a key concept we return to the PPP and make use of the relative form. Typically, the consumer price index (CPI) is used to evaluate deviations from the PPP. However, price arbitrage is expected to occur predominantly for internationally traded goods. Consequently, prices of traded goods should also be taken into account. For this reason, we calculate correlations for both changes in the overall price index, proxied by CPI, and changes of a price index of tradables, proxied by the producer price index (PPI), i.e. $\pi_t^{j1,CPI} = \pi_t^{j,CPI} - \pi_t^{1,CPI}$ and $\pi_t^{j1,PPI} = \pi_t^{j,PPI} - \pi_t^{1,PPI}$. Since the money supply is a macroeconomic key variable we also compute correlations between the relative money supply, i.e. $\Delta M3_t^{j1} = \Delta M3_t^{j} - \Delta M3_t^{1}$.[17] As can be seen in the regressions for the excess comovement tests, the long-term interest rates enter significantly. Hence, we also estimate the correlations between long-term interest rates, i.e. $\Delta i_{l,t}^{j1} = \Delta i_{l,t}^{j} - \Delta i_{l,t}^{1}$.

In a further benchmark model, we explicitly account for sentiments. Here, we are interested in the pure correlations between the sentiments and in comparing them with the true correlations. A direct measure for (non-fundamental) sentiments is unavailable. Nevertheless, we try to offer an insight into the importance of economic sentiments. There are several sentiment indicators available which base upon questionnaires sent to market participants. In equation (4) we assume that there is no linkage between the fundamentals and sentiments. However, sentiments and the fundamentals are not unrelated (e.g. Jansen and Nahuis, 2003). As a proxy for sentiments we use evaluations of the economic situation expected in 6 months. From this point of view, the sentiments are forward-looking and mirror the expectations concerning the future. Since market participants are subject to over- or underreactions (e.g. Barberis et al., 1998; Larsen and Madura, 2001) we believe that this sentiment indicator also contains noise and is therefore suitable for pursuing our objectives. Since we are interested in sentiments of market participants we do not use consumer confidence indices. As a proxy for u_t^{t+6} we use the ZEW sentiment indicators. Although these surveys are collected from European companies we believe that the indicator adequately mirrors market sentiments because financial companies are heavily globally linked. The indicator is obtained by $\Delta u_t^{j1,t+6} = \Delta u_t^{j,t+6} - \Delta u_t^{1,t+6}$.[18]

For our benchmark variables we again use monthly data, starting with January 1994 and ending with December 2007 to obtain the variance and the correlation processes. With this period we are also congruent with the frequency of the data and the period of observation for the exchange rates.

In order to employ the DCC-GARCH model correctly, the preconditions to apply the approach must be first checked for. Table 4 presents model specification tests on the benchmark variables. For cases in which no ARCH effects are present we proceed as outlined in section 4.2, i.e. GARCH

[17] In contrast to the estimation of the monetary model, we employ a broad monetary aggregate ($M3$).

[18] We also experiment with the business and consumer confidence index published by the OECD. Since these indicators are subject to an intense standardization procedure, e.g. the consumer confidence indicator is interpolated from quarterly data, we decide against these indicators. Furthermore, we use consumer confidence indexes for Germany/Euro area and the UK and the Chicago sentiment index for the USA. We find causality running among the ZEW indicators and the corresponding sentiment indicators.

models are only fitted to those variables with ARCH effects. In all other cases we estimate the mean equation by maximum likelihood and proceed as described. In addition, we make use of the t-distribution in cases in which the Jarque-Bera test for normally distributed residuals rejects normality (column 9).

The test statistics of the Engle and Sheppard (2001) test can show that the null hypothesis of constant correlation is rejected for all benchmark variables (column 1 in Table 5). Based upon these results, we estimate the DCC model and obtain the coefficients as presented in columns 2 and 3 in Table 5. Since the sum of the coefficients is close to one, we also estimate the model by implementing the restriction that $\alpha + \beta \leq 1$. In order to find the correct model we consult the corresponding Akaike information criterion.

[Figure 3 about here]

In Figure 3 the time-varying correlations obtained by the DCC-GARCH model for the benchmark variables (bold lines) are contrasted with the correlations of exchange rates (dashed lines). Since the levels of correlations of fundamentals considerably exceed or undershoot the correlations of exchange rates, we only draw on their relative performance, i.e. the range in which two correlations meander describes the boundaries. The correlations of the exchange rates are always drawn on the right axis. Since the correlations of the money supply and the PPI annual inflation exhibit similar patterns but seem to hurry ahead of the other correlations we adjust these two series such that their minima occur at the same time as the minimum of the exchange rate correlations. For the money supply the minimum occur 2 years ago and for the PPI annual inflation rates 1.5 years ago, respectively. As can be seen in Figures 3 (a) - (e) the dynamic is very similar. Hence, the relative development of correlations seems to be linked. If there were a link, the delay between money supply and PPI annual inflation of 6 months could be explained by the time lag in the transmission channel of monetary policy. The same is true for the PPI annual inflation, whilst the exchange rates price developments are embedded into exchange rates after approximately 18 months.

4.5 Long-run relationship among correlations

From the investigation of dynamics between the correlations it is possible to conclude for dynamics which cannot be directly obtained in regression models. The idea is that the correlations between the (relative) processes must be governed by economic relationships. Causality in correlations can therefore discover relationships which cannot be observed by simple regression models except those in which a complex modelling of interrelationships is allowed for. Thus, we are interested in long-run relationships among the correlations.

For this reason we employ the vector error correction model (VECM), as given in equation (15) and test for cointegration among the correlations for exchange rates, money supply, long-term interest rates, CPI annual inflation, PPI annual inflation and the economic sentiments.

$$\Delta X_t = \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \Pi X_{t-1} + \mu + \epsilon_t, \tag{15}$$

whereas $\Gamma_i = -I + \Pi_1 + ... + \Pi_i$ with $i = 1, ..., k-1$ and $\Pi = -(I - \Pi_1 - ... - \Pi_k)$ (Johansen, 1991). The vector X_t contains the endogenously esteemed variables and has the dimension $p \times 1$, where p is the number of endogenous variables. μ is a $p \times 1$ vector of deterministic variables and ϵ_t of independent and identically distributed errors which follow a normal distribution with zero mean. If the rank of Π is greater than zero and less than one, it can be decomposed such that $\Pi = \alpha\beta'$. α is a vector of adjustment coefficients and β of cointegration parameter.

[Table 6 about here]

In order to test for cointegration we apply the cointegration rank analysis as outlined by Johansen (1988, 1991) and focus on the Trace test. However, it must be first checked for non-stationarities of the series before we can start with the cointegration analysis. In Table 6 we present the results of stationarity tests conducted in the VECM framework. For each possible cointegration rank the corresponding test statistics are provided. As can be seen, stationarity cannot be rejected for the correlations of long-term interest rates and correlations of sentiments but only with a cointegration rank of 4. In panel (a) of Table 7 the results of the cointegration analysis are given. Only the null hypothesis of zero rank can be rejected with a p-value of 0.040 from which we conclude that one cointegration relationship is present in our model. Since the Johansen test is quite robust against heteroskedasticity and excess kurtosis but not against autocorrelations (Juselius, 2006), we show in panel (g) of Table 7 that no autocorrelations remain in the residuals. For this reason we conclude that the cointegration rank is 1 for which all variables are non-stationary, i.e. there is indeed cointegration among the variables.

[Table 7 about here]

The estimation of the cointegration vector can be found in panel (b) of the same Table. In the cointegration vector which contains the contemporaneous correlations, the correlations of money supply, long-term interest rates, CPI inflation, PPI inflation and the constant enter significantly. Only the sentiment term is not statistically significant. With the exception of the PPI inflation all correlations are inside the same correlation cycle because the cointegration parameters are negative.[19] Panel (c) of Table 7 displays the adjustment coefficients. Based upon the t-statistics, the money supply and CPI inflation correlations do not participate in the adjustment process. Although the sentiment correlations do not enter the cointegration vector they adjust towards

[19] Note the formulation of the cointegration vector.

disequilibria. The adjustment coefficient of the correlations of exchange rates should have a negative sign in order to support the perpetuation of the long-run equilibrium. An increase in exchange rates correlations enforces the dynamics, whereas an increase of either money supply, long-term interest rates or CPI inflation correlations results in a decrease of the exchange rate correlations during the adjustment dynamics. An increase in the correlations of PPI inflation pushes the exchange rate correlations in the adjustment process. However, the adjustment coefficient for exchange rate correlations is only significant the 10% level. Likelihood ratio tests of weak exogeneity are presented in panel (d) of Table 7. The restriction of an adjustment coefficient of zero cannot be rejected for the correlations of money supply, the long-term interest rates, CPI inflation and the sentiments. Only the correlations of exchange rates and PPI inflation adjust towards disequilibria. Surprisingly, the correlations of long-term interest rates and of the sentiment indicator are weakly exogenous although the t-statistics show statistical significance. We rely on the direct test because it compares the models directly and there is obviously no difference between restricted adjustment coefficients and the basic model. Consequently, tests of variable exclusion directed to the cointegration vector are employed in panel (e) of Table 7. The only variables which remain in the cointegration space are the correlations of money supply and PPI inflation with a p-value of 0.085 and 0.067, respectively. For the exchange rate correlations the test of the exclusion from the cointegration vector cannot be rejected with a p-value of only 0.101. Hence, there is evidence that only the correlations of money supply and of PPI inflation are linked in the long run, which reveals the transmission channel of monetary policy.

In the following we re-estimate the cointegration vector with the restrictions obtained by the tests of variable exclusion with the exception that we include the exchange rate correlations because this is a boundary case. The results are presented in panel (f) of Table 7. Indeed the correlations of exchange rates are not significant, whereas the correlations of money supply are highly significant. The LR test on overidentifying restrictions with a p-value of 0.470 supports the finding that the correlations of money supply and of PPI inflation are positively linked in the long run. For the correlations under observation there is only one long-run relationship which is consistent with the monetary transmission channel because the money supply correlations are weakly exogenous and cause the PPI inflation correlations in the long run. Regarding the adjustment coefficient of the PPI inflation correlations, it can be stated that 99% of a disturbance stemming from the money supply correlations dissipate over 6.7 months. This is exactly the delay between both correlations.

Although the correlation dynamics are very similar across all correlations, there is no relationship in which the exchange rate correlations enter. However, there are time lags between money supply and prices and prices and exchange rates due to the monetary transmission channel of monetary policy and adjustment processes from prices to exchange rates. These issues are widely discussed in the literature. These time lags can also be found in the correlations. Since we are interested in long-run dynamics and the time lags are to long for entering the adjustment dynamic, we decide to explicitly take account of these delays. Consequently, we draw on the series as presented in Figures 3, i.e. we adjust the series of money supply and PPI inflation correlations in a way that their minima coincide with the minimum of exchange rate correlations. The money supply correlations are lagged by 24 months and those of the PPI inflation by 18 months. Since lagged values cannot be (Granger) caused by current values we specify these correlations as weakly exogenous, i.e. they can enter the long-run relationship but cannot participate in the adjustment process. In order to do so, it is necessary that both correlations do not share common stochastic trends. For this reason we test for cointegration between the correlations of money supply lagged by 6 months (=24-18months) and of PPI inflation. As can be seen in Table 8 no long-run relationship prevails. For this reason we can proceed as planned.

[Table 8 about here]

As can be seen in Figure 3 (a) the comovement between the exchange rate and the money supply series seems to be less pronounced from January 2001 to December 2003. This is exactly two years after the introduction of the Euro and therefore coincides with the introduction of the Euro because of the two years' lags of money supplies' correlations. When the Euro came into existence global portfolio rebalancing was important for the first years (Meredith, 2001; Sinn und Westermann, 2005). A dummy variable which takes the value one in this period and zero otherwise absorbs the lack in the transmission channel of monetary policy. In Figure 3 (e) it can be seen that the correlations of the sentiments fall sharply in October 1998 and disproportionately to the other correlations. Thus, we include a dummy variable which takes the value one at the event and zero otherwise.

[Table 9 about here]

The cointegration test for the partial system is presented in panel (a) of Table 9. There is evidence that two long-run relationships among the variables exist. The null hypothesis of rank 1 can also be rejected very clearly with a p-value of 0.004. In cases of more than one cointegration vector the cointegration vectors are not automatically identified. It is required to implement identifying restrictions in order to obtain unique cointegration vectors. With an economic theory at hand, the long-run relationships among the variables can be explicitly modelled. Since we are investigating correlations the dynamics must be based on economic theories. The basic model in exchange rate determination is the PPP. Consequently, the correlations between exchange rates and prices should be linked. In addition, Menkhoff and Rebitzky (2008) argue that the EUR/USD investor sentiment is linked with exchange rates and price developments (i.e. deviations from PPP). The same could be true for economic sentiments.[20] For this reason, our first cointegration vector comprises the correlations of exchange rates, PPI inflation and the sentiment term. In addition, money supply and prices affect long-term interest rates. Since bonds are also traded on financial markets, it is reasonable that sentiments are linked with money supply, prices and bond prices without an impact of exchange rates. For this reason, our second cointegration vector contains the correlations of long-term interest rates, sentiments, money supply and PPI inflation. In addition, a constant term enters all cointegration relationships. The inclusion of the dummy variables is geared to the variables included.

The estimated cointegration vectors are given in panel (b) of Table 9. All cointegration parameters are highly significant in both cointegration vectors. In the first cointegration vector the correlations of the exchange rates, of the sentiments and of the PPI inflation are in the same cycle. The same is true for the second cointegration vector except for the PPI inflation correlations. The modelling of long-run relationships cannot be rejected by the data which shows a p-value of 0.594 of the corresponding LR test. Panels (e) and (f) in Table 9 show that no variable can be excluded from the long-run analysis.

In panel (c) together with panel (d) of Table 9 insights about the dynamics in the system can be obtained. The tests of weak exogeneity show that the correlations of exchange rates, of interest rates and of sentiments adjust to the long-run equilibriums found. Interesting to note is that the sentiments' correlations do not adjust to the first long-run relationship. Here, the other variables take the burden of adjustment. From this result follows that the correlations of sentiments positively affect the correlations of exchange rates. Since the correlations of lagged PPI inflation are modelled as weakly exogenous and also enter this cointegration vector, sentiments and price developments are important in determining exchange rates. The last issue is widely known from the literature whereas the first issue provides clear proof of the impact of economic sentiments.

The second cointegration vector highlights that correlations of sentiments and interest rates are also interlinked. In addition, the exchange rate also reacts to disequilibria regarding this relationship. Taken together, the long-run analysis can explain the evolution of correlations between the EUR/USD and the GBP/USD. The correlations of exchange rates, sentiments, long-term interest rates and prices interact such that the correlations pattern of exchange rates emerges.

5 Conclusion

The aim of this paper is to investigate excess comovements in the foreign exchange market. First, a theoretical model is outlined to model sentiments in two exchange rates. Then, the model is used to investigate the conditions under which excess comovements can occur. In the empirical

[20] As opposed to Menkhoff and Rebitzky (2008) we use the *economic* sentiments instead of the EUR/USD sentiments.

analysis an attempt has been made to gauge excess comovements for the exchange rate pair EUR/USD and GBP/USD. The results give evidence that excess comovements indeed exist. The correlations dynamics of exchange rates show similar patterns as the correlations dynamics of relative inflation rates, long-term interest rates, economic sentiments and money supply. A long-run analysis on correlations can verify that they are linked in the long run, whereas money supply and prices play a major role. From the investigation of our exchange rate pair it becomes obvious that non-fundamental factors in exchange rates have an important meaning for modelling foreign exchange rates.

If developments in one exchange rate are linked over a longer period to developments in a second exchange rate, empirical exchange rate models will fail to account for these factors. Hence, a second dimension should be borne in mind when talking about deviations from PPP. Excess comovements can also have consequences for the cross rates. Thus, two exchange rates can be contaminated by factors stemming from another exchange rate. If common behavioural factors are generated in the denomination currency, their impact on the cross rate can distort the external competitiveness between two countries not involved. Future work should explicitly use the insights obtained in this paper for modelling exchange rates.

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Appendix

A Dynamic conditional GARCH model

As is widely known, exchange rates convey heteroskedasticity (e.g. Baillie and Bollerslev, 1989). In order to model the structure of conditional variances, the class of ARCH (Engle, 1982) and GARCH (Bollerslev, 1986) models can be applied. Concerning the covariances, a time-varying structure can also be employed.
Engle and Sheppard (2001), Engle (2002) and Tse and Tsui (2002) developed models for estimating time-varying correlations. The difference between the Engle (2002) and the Tse and Tsui (2002) models is that the former makes use of a representation of the correlation process which is similar to the GARCH process, whereas in the latter the correlations are weighted sums of past correlations (c.f. a comparison Bauwens et al., 2006). We focus on Engle (2002) in the following; the model is called dynamic conditional correlation GARCH mode (DCC-GARCH).
Engle's (2002) approach bases upon a two-step estimation procedure. In the first step the volatility processes are specified and estimated univariately. In doing so, the mean equations must be formalized first for the N time series. Let

$$\phi(L)r_t = \mu + \epsilon_t \tag{16}$$
$$\epsilon_t|\Phi_{t-1} \sim N(\mu_t, H_t) \tag{17}$$

where r_t is a $(N \times 1)$ vector of time series with μ as the corresponding vector of means, $\phi(L)$ as a lag operator, ϵ_t as the vector of residuals, and Φ_{t-1} as the information set available at time $(t-1)$. r_t is conditionally normally distributed. H_t denotes the covariance matrix. The covariance matrix obtained by each element of ϵ_t can be decomposed into the product of an $N \times N$ diagonal matrix of time-varying standard deviations D_t and into an $N \times N$ matrix of time-varying correlations R_t:

$$H_t = D_t R_t D_t. \tag{18}$$

The $i-$th element in the diagonal D_t is the square root of the $i-$th conditional variance $\sqrt{h_{it}}$ of the univariate standard GARCH(p,q) model,

$$h_{i,t} = \omega_i + \sum_{p=1}^{P_i} \alpha_i \epsilon_{i,t-p}^2 + \sum_{q=1}^{Q_i} \beta_i h_{i,t-q} \tag{19}$$

with ω_i as the mean variance and α and β as coefficients for $i = 1, 2, ..., N$. In each GARCH model restrictions are imposed such that the coefficients are non-negative and that the GARCH process is stationary, i.e. $\sum_{p=1}^{P_i} \alpha_i + \sum_{q=1}^{Q_i} \beta_i < 1$.
In the second step, the correlation dynamic can be employed. Furthermore, the correlation matrix R_t can be written as

$$R_t = Q_t^{*-1} Q_t Q_t^{*-1}. \tag{20}$$

Q_t^* is a diagonal matrix of variances' square roots. Q_t contains the correlation dynamic which is formalized similar to a GARCH process

$$Q_t = (1 - a - b)\overline{Q} + a z_{t-1} z_{t-1}' + b Q_{t-1} \tag{21}$$

with $\overline{Q}$ as the unconditional covariances $(E(z_t z_t^{'}))$ of the standardized residuals $z_{i,t} = \frac{\epsilon_{i,t}}{\sqrt{h_{i,t}}}$. a and b are scalars and Q_t is positive definite for $a + b < 1$ (Engle and Sheppard, 2001). The correlation estimator $\rho_{ij,t}$ is finally obtained by

$$\rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{ii,t} q_{jj,t}}} \quad \text{with} \quad i \neq j. \tag{22}$$

In order to estimate the coefficients the log-likelihood function must be maximized. This can be done jointly for the two steps or separately. Engle and Sheppard (2001) and Engle (2002) show that the maximization of the log-likelihood function for the whole system is consistent and equivalent to the maximization of the log-likelihood of the first step, i.e. the univariate GARCH models, and of the log-likelihood of the second step.[21]

The application of the basic DCC-GARCH model in higher order systems imposes restrictions on the coefficients in the correlation equation by means of implying the same correlation dynamic. In Capiello et al. (2006) the DCC-GARCH model is also generalized and allows for different correlation dynamics among the time series. However, positive definiteness is not guaranteed in higher order systems. In order to allow for different correlation dynamics and to circumvent the problem of not positive definite matrices, we estimate bivariate models based upon the standard DCC-GARCH model by Engle (2002).

A DCC-GARCH model is only useful to work with when dynamic conditional correlations actually exist. For this reason, Engle and Sheppard (2001) propose an LM-test which has the null hypothesis of constant correlations and is therefore able to discriminate between constant and dynamic conditional correlations (equation (23)).

$$H_0 : R_t = \bar{R} \quad H_1 : vech^u(R_t) = vech^u(\bar{R}) + \beta_1 vech^u(R_{t-1}) + ... + \beta_p vech^u(R_{t-p}) \tag{23}$$

$vech^u$ denotes the vectorization of the upper diagonal of a matrix. If constant correlations prevail the residuals should be identically independently distributed from which a diagonal variance-covariance matrix results. The test can be conducted by an auxiliary regression of the outer product of the standardized residuals on a constant and lagged outer products, whereas the standardized residuals are jointly standardized with the unconditional correlations matrix divided by their conditional standard deviations. $Y_t = vech^u[(\bar{R}^{-1/2}\epsilon_t H_t^{-1/2})(\bar{R}^{-1/2}\epsilon_t H_t^{-1/2})']$.[22]

$$Y_t = \alpha + \beta_1 Y_{t-1} + ... + \beta_s Y_{t-s} + \eta_t \tag{24}$$

If the null hypothesis holds, the intercept and all coefficients in equation (24) will be zero. The test can be conducted with the help of a seemingly unrelated regression on equation (24) in which it is tested whether the estimated parameters are different from zero.[23] The test statistic is distributed as χ^2 with $(s+1)$ degrees of freedom, i.e. the number of estimated parameters.

B Time-varying coefficient framework

In a first step we apply the Bai and Perron (1998, 2003) test for structural breaks on equation (13). In order to select the correct number of breaks, we take the regression with the minimal Bayesian information criterion (BIC) (e.g. Carrion-Silvestre and Sano, 2006) with whose help consistent estimates of the breaks can be obtained for non-stationary variables (Morales-Zumaquero and Peruga-Urrea, 2002, p. 9). In the next step, the estimated breaks enter an indicator function with which the cointegration vector can be estimated. For the estimation of the cointegration vector we make use of the fully modified ordinary least squares estimator (FM-OLS) by Phillips and Hansen (1990).[24]

$$Y_t = \mu(t) + X_t'\beta(t) + \epsilon_t \tag{25}$$

$$\begin{aligned} \mu(t) &= \mu_1 + \mu_2 1_{2t} + ... + \mu_m 1_{mt} \\ \beta_j(t) &= \beta_{j,1} 1_{j,1t} + ... + \beta_{j,m} 1_{j,mt} \end{aligned} \tag{26}$$

with m as the maximum number of breaks and

$$1_{kt} = 1(T_k \le t < T_{k+1} - 1), \text{ with } k = 1, ..., m \text{ and for } k = m : T_T. \tag{27}$$

[21] Derivations and a detailed description can be found in the cited papers.

[22] Instead of the correlation matrix, the unconditional variance-covariance matrix can also be used, see Engle and Sheppard (2001), footnote 7.

[23] In the bivariate case the system reduces itself to a univariate approach.

[24] In cases in which the cointegration rank of the system is unknown the FM-OLS estimator should be preferred over the Johansen system estimator. See Hargreaves (1994).

C Tables

Table 1: Estimated breaks of the baseline model (1975:01-2007:12)

EUR/USD
1976:12, 1981:09, 1985:03, 1988:10, 1991:02, 1993:12, 1999:03, 2004:11

GBP/USD
1976:10, 1981:03, 1985:05, 1990:06, 1993:03, 2000:04

Note: The table reports the break points which are obtained by applying the Bai-Perron (1998, 2003) breakpoint test on the extended real interest rate differential model without parameter restrictions. The breaks are filtered out by choosing the estimation in which the Bayesian information criterion (BIC) has the minimal value.

Table 2: Estimation of the fundamental baseline models in first differences

Panel (a): Estimation for the EUR/USD, dependent variable is $\Delta s_t^{EUR/USD}$

	OLS estimates				FGLS estimates			
	(1a)	(2a)	(3a)	(4a)	(1b)	(2b)	(3b)	(4b)
μ	-0.001	-0.002	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
	[-0.583]	[-0.718]	[-0.594]	[-0.721]	[-0.639]	[-0.717]	[-0.647]	[-0.723]
ψ_1	0.514***		0.500***		0.355***		0.358***	
	[8.311]		[8.083]		[7.483]		[7.165]	
α		-0.342***		-0.317***		-0.308***		-0.301***
		[-4.447]		[-4.082]		[-5.090]		[-4.648]
ψ_2			-0.034***	-0.034***			-0.033***	-0.032***
			[-3.280]	[-2.765]			[-3.128]	[-2.825]
ψ_3			-0.038	-0.035			-0.006	-0.001
			[-0.604]	[-0.539]			[-0.123]	[-0.022]
$\bar{R}^2$	0.24	0.082	0.283	0.123				
AIC	-4.972	-4.782	-5.018	-4.816				

Panel (b): Estimation for the GBP/USD, dependent variable is $\Delta s_t^{GBP/USD}$

	OLS estimates				FGLS estimates			
	(1a)	(2a)	(3a)	(4a)	(1b)	(2b)	(3b)	(4b)
μ	-0.001	-0.002	-0.001	-0.001	-0.001	-0.002	-0.001	-0.001
	[-1.092]	[-1.291]	[-0.788]	[-0.998]	[-1.229]	[-1.368]	[-1.044]	[-1.177]
ψ_1	0.350***		0.264***		0.218***		0.185***	
	[3.803]		[3.101]		[3.255]		[2.958]	
α		-0.356***		-0.319***		-0.172***		-0.166***
		[-5.780]		[-5.365]		[-3.825]		[-3.452]
ψ_2			-0.018**	-0.018**			-0.017**	-0.018**
			[-2.227]	[-2.450]			[-2.270]	[-2.410]
ψ_3			0.178***	0.176***			0.120***	0.128***
			[3.440]	[3.987]			[2.618]	[2.907]
$\bar{R}^2$	0.071	0.139	0.172	0.246	0.071	0.111	0.179	0.23
AIC	-4.972	-5.393	-5.421	-5.514	-10.929	-10.796	-11.033	-10.899

Note: The table reports the results of the regressions: (1) $\Delta s_t = \mu + \psi_1 \Delta F_t + \eta_t$, (2) $\Delta s_t = \mu + \alpha \Delta ect_{t-1} + \eta_t$, (3) $\Delta s_t = \mu + \psi_1 \Delta F_t + \psi_2 \Delta i_{l,t} + \psi_3 r_t + \eta_t$ and (4) $\Delta s_t = \mu + \alpha \Delta ect_{t-1} + \psi_2 \Delta i_{l,t} + \psi_3 r_t \eta_t$. Δs_t is the exchange rate and ΔF_t the fundamental process. Δect_{t-1} describes an error correction term based upon the regression $s_t = \mu + \beta F_t + ect_t$. $\Delta i_{l,t}$ stands for the change in the long-term interest rate differential and r_t is the stock market return of the leading stock market index. $\bar{R}^2$ is the adjusted coefficient of determination. AIC refers to the Akaike information criterion. Columns (1a-4a) contain ordinary least squares (OLS) estimates and columns (1b-4b) feasible generalized least squares (FGLS) estimates. Columns (1b)-(4b) base upon seemingly unrelated regressions in which panel (a) and panel (b) enter. For this reason $\bar{R}^2$ and AIC are related to the system. *, ** and *** denote the rejection of the null hypothesis at the 10%, 5% and 1% level. t-values are in parentheses. Newey-West standard errors are used. All fundamantal processes are relative processes, i.e. the difference between the fundamentals in country i and country j.

Table 3: LM-test on excess comovements

	Model 1	Model 2	Model 3	Model 4
LM_{DCC}-test on OLS residuals	68.61***	48.984***	64.963***	50.416***
	(0.000)	(0.000)	(0.000)	(0.000)
LM_{DCC}-test on FGLS residuals	77.394***	59.961***	72.148***	58.495***
	(0.000)	(0.000)	(0.000)	(0.000)

Note: The table reports LM_{DCC} -tests by Engle and Sheppard (2001) which are distributed as χ^2 with 6 degrees of freedom. The null hypothesis is constant correlation in residuals of two regression which base upon benchmark models. OLS refers to ordinary least squares estimates and FGLS to feasible generalized least squares estimates. The FGLS residuals base upon seemingly unrelated regressions. Model 1 is $\Delta s_t = \mu + \psi \Delta F_t + \eta_t$, model 2 $\Delta s_t = \mu + \alpha \Delta ect_{t-1} + \eta_t$, model 3 $\Delta s_t = \mu + \psi_1 \Delta F_t + \psi_2 \Delta i_{l,t} + \psi_3 r_t + \eta_t$ and model 4 $\Delta s_t = \mu + \alpha \Delta ect_{t-1} + \psi_2 \Delta i_{l,t} + \psi_3 r_t \eta_t$. Δs_t is the exchange rate and ΔF_t the fundamental process. Δect_{t-1} describes an error correction term based upon the regression $s_t = \mu + \beta F_t + ect_t$. $\Delta i_{l,t}$ stands for the long-term interest rate differential and r_t is the stock market return of the leading stock market index. *, ** and *** denote the rejection of the null hypothesis at the 10%, 5% and 1% level. p-values are in brackets. All fundamantal processes are relative processes, i.e. the difference between the fundamentals in country i and country j.

Table 4: Model specification tests for the univariate models

	lags	p	q	AR(1)	AR(5)	ARCH(1)	ARCH(5)	JB
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\Delta s^{EUR/USD}$	1	0	0	0.535	5.553	1.081	5.117	3.912
				(0.465)	(0.352)	(0.298)	(0.402)	(0.141)
$\Delta s^{GBP/USD}$	3	0	0	0.003	1.824	0.007	2.921	4.159
				(0.959)	(0.873)	(0.935)	(0.712)	(0.125)
$\pi^{CPI,EMUUS}$	2	0	1	0.399	5.559	0.245	3.908	57.199***
				(0.527)	(0.351)	(0.621)	(0.563)	(0.000)
$\pi^{CPI,UKUS}$	2	0	1	0.55	8.426	0.077	5.791	34.828***
				(0.458)	(0.134)	(0.781)	(0.327)	(0.000)
$\Delta\pi_{12}^{PPI,EMUUS}$	3	1	1	0.016	3.428	0.151	9.188	71.363***
				(0.900)	(0.634)	(0.697)	(0.102)	(0.000)
$\Delta\pi_{12}^{PPI,UKUS}$	3	1	1	0.633	4.429	0.753	2.997	52.066***
				(0.426)	(0.489)	(0.385)	(0.700)	(0.000)
$\Delta M3^{EMUUS}$	6	0	0	1.645	3.258	0.112	0.197	13.306***
				(0.200)	(0.660)	(0.737)	(0.999)	(0.000)
$\Delta M3^{UKUS}$	6	0	0	1.262	3.803	0.022	0.263	19.89***
				(0.261)	(0.578)	(0.882)	(0.998)	(0.000)
Δi_l^{EMUUS}	1	1	1	0.136	7.033	0.015	3.086	1.889
				(0.712)	(0.218)	(0.904)	(0.687)	(0.389)
Δi_l^{UKUS}	2	1	1	0.275	4.586	0.482	7.295	0.85
				(0.600)	(0.468)	(0.488)	(0.200)	(0.654)
$\Delta u^{t+6,EMUUS}$	7	0	0	0.901	2.369	1.106	5.425	24.792***
				(0.343)	(0.796)	(0.293)	(0.366)	(0.000)
$\Delta u^{t+6,UKUS}$	6	0	1	0.323	1.093	0.743	2.264	22.776***
				(0.570)	(0.955)	(0.389)	(0.812)	(0.000)

Notes: Column (1) shows the lag order of the autoregressive mean equation, columns (2) and (3) give the order of the GARCH model. P is the order of lagged conditional variances and q of the lagged squared residuals. Columns (5) and (6) present the LM-tests on serial correaltion up to lag 1 and 5. Columns (7) and (8) present the LM-tests on autoregressive heteroskedasticity up to lags 1 and 5. The LM-test are distributed as χ^2 with 1, 5, 1 and 5 degrees of freedom. JB denotes the Jarque-Bera test on normally distributed errors. All tests base upon the standardized residuals. *, ** and *** denote the rejection of the null hypothesis at the 10%, 5% and 1% level. p-values are in brackets. Δs_t is the exchange rate, ΔF_t the fundamental process, π the rate of inflation, whereas *CPI* refers to the consumer price index and *PPI* to the producer price index. π_{12} denotes the annual change. Δ*M3* is change of the money supply measured by M3 and Δi_l is the change of the long-term interest rates. Δu is the change of the sentiment index, whereas superscript $t+6$ denotes the sentiments about the economic situation in 6 months. All fundamantal processes are relative processes, i.e. the difference between the fundamentals in country i and country j.

Table 5: LM-tests on constant correlation and estimation results of the DCC part of the DCC-GARCH model

	LM_{DCC}	α	β
	(1)	(2)	(3)
Δs_t	75.616***	0.01	0.944***
	(0.000)	(0.648)	(0.000)
π^{CPI}	44.553***	0.044***	0.956***
	(0.000)	(0.008)	(0.000)
$\Delta\pi_{12}^{PPI}$	36.147***	0.087***	0.907***
	(0.000)	(0.000)	(0.000)
$\Delta M3$	16.512	0.070***	0.915***
	(0.123)	(0.029)	(0.000)
Δi_l	72.900***	0.131***	0.816***
	(0.000)	(0.001)	(0.000)
Δu^{t+6}	27.987***	0.116*	0.759***
	(0.003)	(0.082)	(0.000)

Note: Column (1) shows the LM_{DCC} -test by Engle and Sheppard (2001) which is distributed as χ^2 with 11 degrees of freedom. Columns (2) and (3) stem from $Q_t = (1 - a - b)\bar{Q} + az_{t-1}z_{t-1} + bQ_{t-1}$ with $\bar{Q}$ as the unconditional covariance matrix, Q_t the conditional covariance matrix and z_t as the standardized residuals. *, ** and *** denote the rejection of the null hypothesis at the 10%, 5% and 1% level. p-values are in brackets. s_t is the exchange rate, F_t the fundamental process, π the inflation rate, whereas CPI refers to the consumer price index and PPI to the producer price index. π_{12} denotes the annual change. $M3$ is the money supply measured by M3 and i_l is the long-term interest rates. u is the sentiment index, whereas superscript $t + 6$ denotes the sentiments about the economic situation in 6 months. Δ denotes the one-period change. All fundamantal processes are relative processes, i.e. the difference between the fundamentals in country i and country j.

Table 6: Stationarity tests for correlations

r	DGF	CV	ρ_s	ρ_{M3}	ρ_{il}	$\rho_{\pi^{CPI}}$	$\rho_{\pi^{PPI}}$	$\rho_{u^{t+6}}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	5	11.07	32.697***	33.579***	22.04***	36.512***	27.731***	27.416***
			(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
2	4	9.488	30.113***	30.659***	18.729***	32.854***	27.092***	23.754***
			(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
3	3	7.815	11.807***	12.051***	10.536**	14.388***	11.838***	7.642*
			(0.008)	(0.007)	(0.015)	(0.002)	(0.008)	(0.054)
4	2	5.991	5.13*	6.211**	4.227	7.696**	4.913*	3.269
			(0.077)	(0.045)	(0.121)	(0.021)	(0.086)	(0.195)
5	1	3.841	2.811*	5.471**	0.367	4.101**	4.649**	0.027
			(0.094)	(0.019)	(0.544)	(0.043)	(0.031)	(0.870)

Note: The table reports stationarity tests conducted in the framework of a vector error correction model (VECM). The null hypothesis is that the variable is stationary. For each possible cointegration rank, as given in column (1), the LR test is computed. In doing so, all variables except the variable under observation are exluded from the cointegration vector and are tested against the unrestricted model. The test statistic is distributed as χ^2 with degrees of freedom as given in column (2). The critical values are given in column (3). ρ denotes the time series of correlations. π Is the rate of inflation, whereas CPI and PPI are the consumer price index and the producer price index, respectively. The latter reflects annual changes. $M3$ is the money supply measured by M3, i_l long-term interest rates and u^{t+6} sentiment index. The u^{t+6} refers to the sentiments about the economic situation in 6 months. All fundamantal processes are relative processes, i.e. the difference between the fundamentals in country i and country j. *, ** and *** denote the rejection of the null hypothesis at the 10%, 5% and 1% level. p-values are in brackets.

Table 7: Johansen cointegration test and VECM estimation

Panel (a): Cointegration rank test

		r=0	r=1	r=2	r=3	r=4	r=5
Eigenval.		0.21	0.192	0.094	0.055	0.031	0.006
Trace test		105.117**	76.813	53.945	35.07	20.164	9.142
		(0.040)	(0.241)	(0.859)	(0.935)	(0.940)	(0.947)

Panel (b): Cointegration vector

	ρ_s	ρ_{M3}	ρ_{il}	$\rho_{\pi^{CPI}}$	$\rho_{\pi^{PPI}}$	$\rho_{u^{t+6}}$	μ
β_i	1	0.121***	0.069***	0.053***	0.208***	0.013	0.719***
		[4.697]	[2.795]	[2.592]	[5.490]	[0.548]	[21.940]

Panel (c):Adjustment coefficients

	ρ_s	ρ_{M3}	ρ_{il}	$\rho_{\pi^{CPI}}$	$\rho_{\pi^{PPI}}$	$\rho_{u^{t+6}}$
α_i	0.027*	0.063	0.635**	0.139	0.493***	0.501**
	[1.933]	[0.418]	[2.515]	[1.033]	[3.941]	[2.103]

Panel (d): Test of weak exogeneity

5% C.V.	ρ_s	ρ_{M3}	ρ_{il}	$\rho_{\pi^{CPI}}$	$\rho_{\pi^{PPI}}$	$\rho_{u^{t+6}}$
3.841	2.781*	0.145	0.667	0.37	3.158*	1.988
	(0.095)	(0.704)	(0.414)	(0.543)	(0.076)	(0.159)

Panel (e): Test of variable exclusion

5% C.V.	ρ_s	ρ_{M3}	ρ_{il}	$\rho_{\pi^{CPI}}$	$\rho_{\pi^{PPI}}$	$\rho_{u^{t+6}}$	μ
3.841	2.688	2.966*	0.596	1.001	3.358*	0.044	3.579*
	(0.101)	(0.085)	(0.440)	(0.317)	(0.067)	(0.834)	(0.059)

Panel (f): Restricted cointegration vector

	ρ_s	ρ_{M3}	ρ_{il}	$\rho_{\pi^{CPI}}$	$\rho_{\pi^{PPI}}$	$\rho_{u^{t+6}}$	μ
	1.215	0.603***			1		1.486***
	[1.219]	[8.178]					[2.274]
Test of restriction:		LR(3):	2.531	(0.470)			

Panel (g): Test for autocorrelation

LM(1):	31.092	(0.701)	LM(5):	37.321	(0.408)	

Note: The table reports analyses in the vector error correction model (VECM). In panel (a) the cointegration test of Johansen (1988, 1991) is applied. The null hypothesis is that the cointegration rank is equal to r. Based upon the cointegration rank test panel (b) gives the estimated cointegration vector. The adjustment coefficients which show the adjustment towards the long-run equilibrium are presented in panel (c). In panel (d) the LR test of weak exogeneity is presented. The null hypothesis is that the variable is weakly exogenous and does not participate in the adjustment process. The test statistic is distributed as χ^2 with 1 degree of freedom. Panel (e) reports the LR test of variable exlusion concerning the cointegration vector. The null hypothesis is that the variable does not enter the cointegration vector. The test statistic is distributed as χ^2 with 1 degree of freedom. Panel (f) gives the estimate of a restricted cointegration vector. In panel (g) LM(p) denotes the Lagrange multiplier test (LM) of autocorrelations in the residuals up to lag p. The test statistics are distributed as χ^2 with 36 degrees of freedom. ρ denotes the time series of correlations. Δ is the one-period change. *, ** and *** denote the rejection of the null hypothesis at the 10%, 5% and 1% level. p-values are in brackets and tstatistics in parentheses. π is the rate of inflation, whereas CPI refers to the consumer price index and PPI to the producer price index. The latter reflects annual changes. $M3$ is the money supply measured by M3, i_l longterm interest rates and u^{t+6} sentiment index. u^{t+6} refers to the sentiments about the economic situation in 6 months. All fundamantal processes are relative processes, i.e. the difference between the fundamentals in country i and country j.

Table 8: Cointegration rank test for ρ_{M3}^{t-6} and $\rho_{\pi^{PPI}}$

	Eigenval.	Trace test	Test for autocorrelation	
r=0	0.02	5.445 (0.963)	LM(1):	4.708 (0.319)
r=1	0.014	2.242 (0.729)	LM(5):	4.883 (0.299)

Note: The table reports analyses in the vector error correction model (VECM). In the left part of the table the cointegration test of Johansen (1988, 1991) is applied. The null hypothesis is that the cointegration rank is equal to r. The right part of the table reports the Lagrange multiplier test (LM(p)) of autocorrelations in the residuals up to lag p. The test statistics are distributed as χ^2 with 4 degrees of freedom. ρ_{M3} is the money supply (M3), π^{PPI} the rate of inflation based upon the producer price index. The correlation series of M3 is lagged by 6 months and then enters the cointegration analysis. *, ** and *** denote the rejection of the null hypothesis at the 10%, 5% and 1% level. p-values are in brackets and t-statistics in parentheses.

Table 9: Johansen cointegration test and VECM estimation

Panel (a): Cointegration rank test						
		r=0	r=1	r=2		
Eigenval.		0.342	0.232	0.083		
Trace test		109.058***	49.669***	12.27		
		(0.000)	(0.004)	(0.408)		
Panel (b): Cointegration vectors						
	ρ_s	ρ_{il}	$\rho_{u^{t+6}}$	ρ_{M3}^{t-24}	$\rho_{\pi^{PPI}}^{t-18}$	μ
1: β_i	1		-0.052***		-0.116***	-0.54***
			[-6.434]		[-8.199]	[-45.477]
2: β_i		-0.413***	1	-0.696***	0.932***	-0.75***
		[-3.323]		[-3.466]	[2.800]	[-3.463]
Test of restricted model			LR(2)-Test:	1.04	(0.594)	
Panel (c): Adjustment coefficients						
	$\Delta\rho_s$	$\Delta\rho_{il}$	$\Delta\rho_{u^{t+6}}$			
1: α_i	-0.243***	1.986**	-0.229			
	[-5.689]	[2.440]	[-0.375]			
2: α_i	-0.013***	0.125**	-0.174***			
	[-4.858]	[2.377]	[-4.406]			
Panel (d): Test of weak exogeneity						
5% C.V.	ρ_s	ρ_{il}	$\rho_{u^{t+6}}$			
5.991	18.692***	5.246*	46.953***			
	(0.000)	(0.073)	(0.000)			
Panel (e): Test of variable exclusion						
5% C.V.	ρ_s	ρ_{il}	$\rho_{u^{t+6}}$	ρ_{M3}^{t-24}	$\rho_{\pi^{PPI}}^{t-18}$	μ
5.991	22.814***	7.442**	16.785***	9.892***	9.018**	22.129***
	(0.000)	(0.024)	(0.000)	(0.007)	(0.011)	(0.000)
Panel (f): Dummy variables in cointegration space						
		cv 1	cv 2	Test of exclusion:		
DUM1998		-0.234***	3.611***	45.987***		
		[-7.178]	[7.768]	(0.000)		
DUM2001			-0.236***	16.693***		
			[-4.613]	(0.000)		
Panel (g): Test for autocorrelation						
	LM(1):	53.694	(0.299)	LM(5):	53.608	(0.302)

Note: The table reports analyses in the vector error correction model (VECM). In panel (a) the cointegration test of Johansen (1988, 1991) is applied. The null hypothesis is that the cointegration rank is equal to r. Based upon the cointegration rank test panel (b) gives the estimated cointegration vectors. The adjustment coefficients which show the adjustment towards the long-run equilibra are presented in panel (c). In panel (d) the LR test of weak exogeneity is presented. The null hypothesis is that the variable is weakly exogenous and does not participate in the adjustment process. The test statistic is distributed as χ^2 with 2 degrees of freedom. Panel (e) reports the LR test of variable exlusion concerning the cointegration vector. The null hypothesis is that the variable does not enter the cointegration vector. The test statistic is distributed as χ^2 with 2 degrees of freedom. Panel (f) gives estimates of the dummy variables included in the cointegration vectors, whereas cv1 refers to the first cointegration vector and cv2 to the second. DUM1998 takes the value 1 in 1998:10 and zero otherwise, while DUM2001 takes the value one from 2001:01 to 2003:12 and zero otherwise. In panel (g) LM(p) denotes the Lagrange multiplier test (LM) of autocorrelations in the residuals up to lag p. The test statistics are distributed as χ^2 with 36 degrees of freedom. ρ denotes the time series of correlations. Δ is the one-period change. *, ** and *** denote the rejection of the null hypothesis at the 10%, 5% and 1% level. p-values are in brackets and t-statistics in parentheses. π is the rate of inflation, whereas CPI refers to the consumer price index and PPI to the producer price index. The latter reflects annual changes. $M3$ is the money supply measured by M3, i_l long-term interest rates and u^{t+6} sentiment index. u^{t+6} refers to the sentiments about the economic situation in 6 months. The correlations of money supply are lagged by 24 and those of PPI inflation by 18 months. All fundamantal processes are relative processes, i.e. the difference between the fundamentals in country i and country j.

D Figures

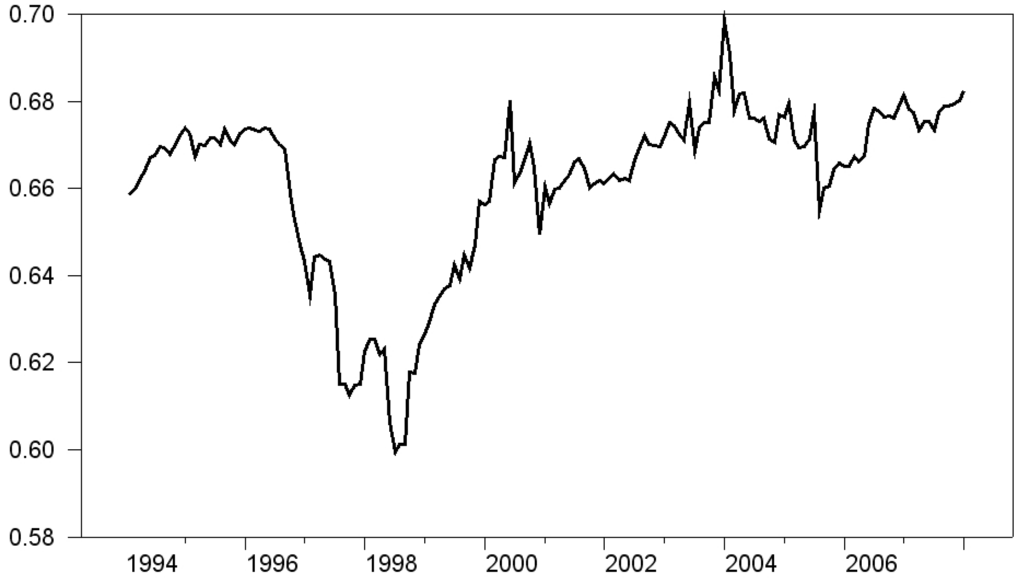
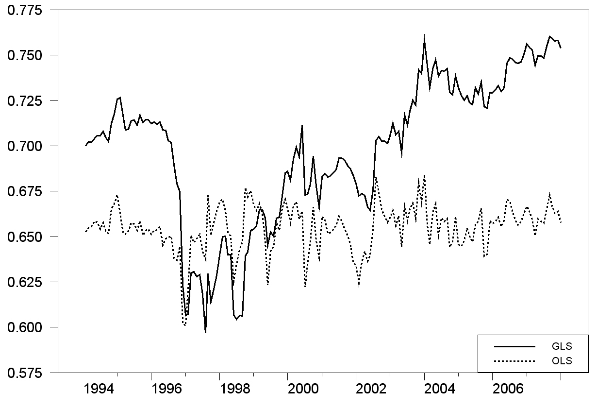
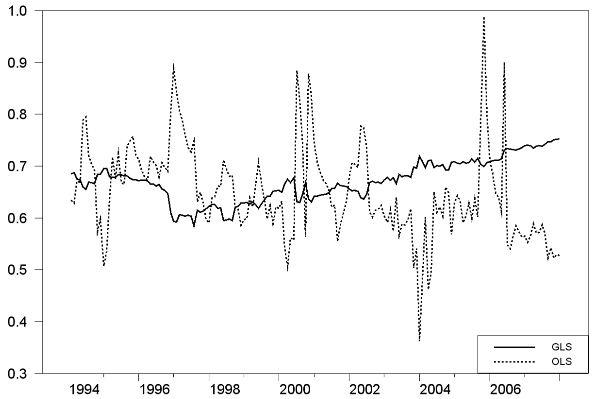


Figure 1: Correlations of exchange rates. Note: Correlations are dynamic conditional correlations between the Euro/US dollar and the British pound/US dollar exchange rates. Before the introduction of the Euro the Deutsche mark/US dollar exchange rate is employed and converted by the official Deutsche mark/ Euro exchange rate into Euro. The correlations are estimated by applying the dynamic conditional GARCH model by Engle (2002).



(a) Model 1

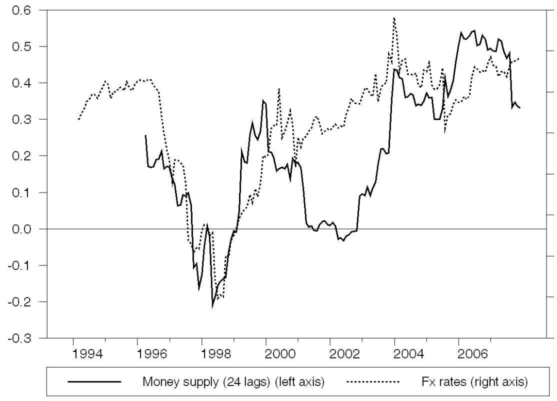
(b) Model 2



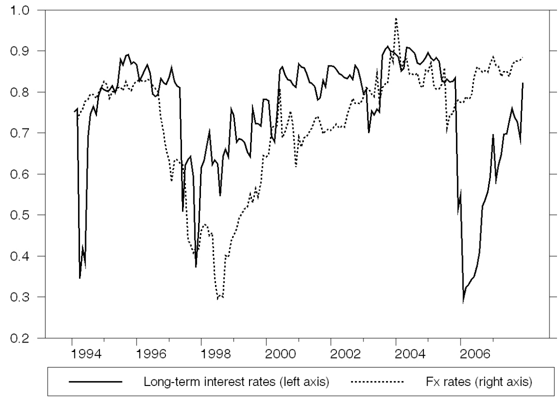
(c) Model 3

(d) Model 4

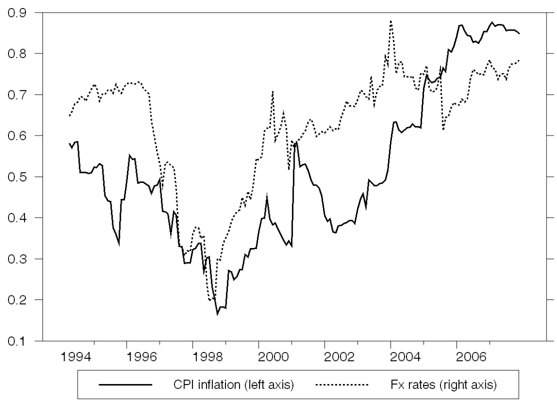
Figure 2: Correlations between residuals of fundamental benchmark models. Note: The figures show the dynamic conditional correlations of the residuals. Model 1 is $\Delta s_t = \mu + \psi \Delta F_t + \eta_t$, model 2 $\Delta s_t = \mu + \alpha \Delta ect_{t-1} + \eta_t$, model 3 $\Delta s_t = \mu + \psi_1 \Delta F_t + \psi_2 \Delta i_{l,t} + \psi_3 r_t + \eta_t$ and model 4 $\Delta s_t = \mu + \alpha \Delta ect_{t-1} + \psi_2 \Delta i_{l,t} + \psi_3 r_t \eta_t$. Δs_t is the exchange rate and ΔF_t the fundamental process. Δect_{t-1} describes an error correction term based upon the regression $s_t = \mu + \beta F_t + ect_t$. $\Delta i_{l,t}$ stands for the long-term interest rate differential and r_t is the stock market return of the leading stock market index. The solid lines represent correlations which base upon residuals obtained by FGLS estimations and the dashed lines by OLS estimations.



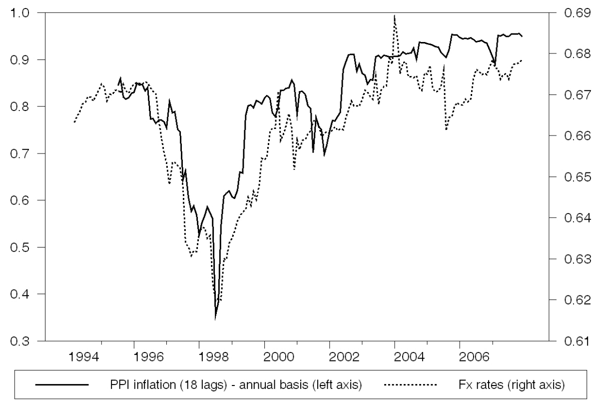
(a) Money supply - lagged by 24 months



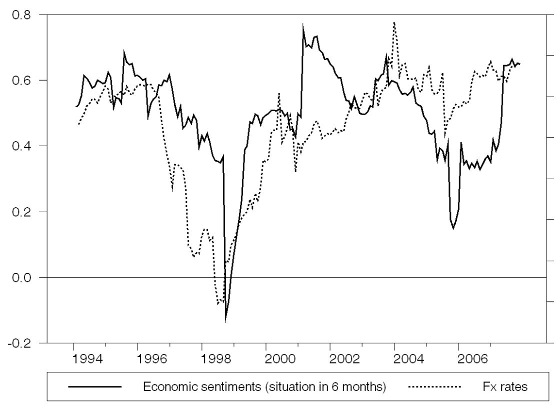
(b) Long-term interest rates



(c) CPI monthly inflation



(d) PPI annual inflation lagged by 18 months



(e) Economic sentiments (situation in 6 months)

Figure 3: Correlations of Fundamentals and Correlations of Exchange rates - relative performance. Note: The figures show the dynamic conditional correlations between the EUR/USD and GBP/USD exchange rates (dashed lines) and relative fundamentals (solid lines). In 3 (a) the correlations of money supply are lagged by 24 months. In 3 (d) the correlations of the relative producer price inflation are lagged by 18 months.

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