Heterogeneity in exchange rate expectations: evidence on the chartist-fundamentalist approach

Lukas Menkhoff, Leibniz Universität Hannover, Germany,
Rafael R. Rebitzky, Leibniz Universität Hannover, Germany, and
Michael Schröder, Centre for European Economic Research, Mannheim, Germany

Abstract

This paper examines heterogeneity in exchange rate expectations. Whereas agents' heterogeneity is key in modern exchange rate models, accordant evidence is missing so far. Our sample, covering expectations from about 300 forecasters over 15 years, shows enormous time variation in dispersion. Altogether, our results are consistent with the chartist-fundamentalist approach: misalignments of the exchange rate and latter's change explain heterogeneity. Whereas the risk premium influences heterogeneity as well, macroeconomic variables and exchange rate's volatility are dominated by previous determinants.

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Lukas Menkhoff, Leibniz Universität Hannover, Department of Economics, Königsworther Platz 1, D-30167 Hanover, Germany; email: menkhoff@gif.uni-hannover.de

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1 Introduction

It has become apparent that we cannot understand exchange rate behavior by relying on models with representative agents. All forms of these simplifying asset approach models have failed empirically (see Sarno and Taylor, 2002).[1] However, they do not only disappoint regarding their purpose, i.e. to explain the dynamics in exchange rates, they seem to be misleading in order to understand interactions on foreign exchange markets. There is now abundant evidence that market participants have quite different expectations on future exchange rates (e.g. Ito, 1990). This may explain why we observe tremendous trading volume on foreign exchange markets, which is larger than volume on the world's leading stock exchanges, not to mention trade in goods and services. Obviously, investor heterogeneity appears key in understanding exchange rate dynamics and thus it is crucial implementing some form of heterogeneity in accordant models (see e.g. De Grauwe and Grimaldi, 2005, 2006, Bacchetta and van Wincoop, 2006a). However, empirical studies on expectation heterogeneity have mainly studied cross-sectional differences, whereas this paper is the first – according to our knowledge – where the causes of heterogeneity in exchange rate expectations are thoroughly examined in the time-series dimension.

Motivated by the exchange rate literature, our goal is to examine the validity of the indicated determinants of investor heterogeneity. In doing so, we rely on a dataset covering monthly expectations on three major exchange rates of about 300 professionals over 15 years. This serves to proxy expectation heterogeneity by dispersion of individual expectations. Due to the very persistent nature of accordant time-series, we apply the vector error-correction (VEC) framework. Our universe of potential determinants is derived from three strands of literature (which we introduce in more detail below): first, and at the core of interest, we regard determinants introduced in those models of heterogeneous agents – fundamentalists and chartists – that have been widely used on foreign exchange markets (e.g. Frankel and Froot, 1990, Brock and Hommes, 1998). Second, we consider the argument that noise traders create risk and thus heterogeneity (e.g. Flood and Rose, 1996, Mark and Wu, 1998), and, third, we

[1] This literature starts with Meese and Rogoff (1983); since then their finding has ever so often been confirmed, see e.g. Frankel and Rose (1995), Cheung, Chinn and Garcia Pascual (2005).

take up impulses from information heterogeneity about the macroeconomic fundamentals (e.g. Sims, 2003, Bacchetta and van Wincoop, 2006b).[2] As the first strand, the modeling approach of fundamentalists and chartists, has dominated exchange rate research with respect to heterogeneous agents, one may see the examination of the two other strands as a control on the robustness of the chartist-fundamentalist approach (C&F approach).

We find that the universe of potential determinants of heterogeneity in exchange rate expectations boils down to three main variables, which provide support to models of fundamentalists and chartists: heterogeneity is positively related to, first, uncertainty among fundamentalists and, second, a shift from dominating fundamentalists to the minor group of chartists. Third, these measures even hold by introducing a risk premium, i.e. a kind of uncertainty, which increases heterogeneity as well. However, macroeconomic variables measured in absolute, in change or alternatively in volatility form, do not contribute significantly to explaining expectation heterogeneity. Finally, risk captured by lagged exchange rate volatility does explain heterogeneity only if we do not control for the three determinants introduced above. In summary, the C&F approach proves to be useful in explaining dynamics of heterogeneity in exchange rate expectations.

Before giving more detailed results, we introduce the literature that motivates our analysis. The C&F approach is currently a common way of thinking about expectation heterogeneity in foreign exchange markets. A first observation of its potential relevance was the documentation that foreign exchange professionals heavily (and possibly also successfully) rely on technical analysis (see Goodman, 1979). This finding has been expanded into a set of stylized facts. Its main insight related to our research implies that technical analysis is, indeed, of high importance among foreign exchange professionals such as dealers and fund managers amongst others, which we trace back to the 1970s until today (see Menkhoff and Taylor, 2007). As technical and fundamental analysis coexist and typically used by the same persons (see Cheung and Wong, 2000, Cheung and Chinn, 2001), the idea of switching between these kinds of analysis emerged. Frankel and Froot paved the way with a series of papers in this direction during the mid-1980s; the most complete account of their thinking is documented in Frankel and Froot (1990). They derive fundamentalists' and chartists' weight from a process, in which decision makers learn the right model from their past performance. Whereas fundamentalists anticipate that exchange rates move towards their long-run equilibriums, modeled

[2] Referring to Mankiw and Reis' (2002) "sticky information model", Mankiw, Reis and Wolfers (2003) test its implications on inflation expectations amongst others, arising from related macroeconomic variables.

via balanced current accounts, chartists take positions in line with recent exchange rate changes – i.e. extrapolation of accordant trends.

Frankel and Froot's (1990, 1990a) contribution comprises much of the current C&F approach's intuition; however, it delivers only limited explanations, when confronted with real-world data. As a first step to overcome this limitation, Brock and Hommes (1998) simulate the dynamics of a stock market via heterogeneous agents, who choose between different trading strategies due to their prior returns. In fact, by generating complex endogenous price dynamics, the authors are able to match some stylized facts of financial time series. Since then, several papers have contributed to refine and extend this line of research. However, Frankel and Froot's (1990, 1990a) basic intuition remained unchanged.[3] So due to this fact, we rest on De Grauwe and Grimaldi's model (2005, 2006) as being indicative of the C&F approach.

De Grauwe and Grimaldi (2005, 2006) assume that market participants choose between a fundamental and a chartist trading strategy.[4] Fundamentalists are oriented on the fundamental exchange rate, stemming from e.g. the purchasing power parity concept (ppp), whereas chartists extrapolate the current trend in the exchange rate.[5] The fundamental rule predicts higher expected returns the farther the exchange rate is away from equilibrium. Additionally, they judge their rule as being less risky, depending on latter's distance. This implies that expectation heterogeneity decreases in situations, where exchange rate's misalignment increases. On the other hand, chartists' impact proves being less clear-cut. For sure, they gain market share, the stronger the trend in the exchange rate becomes. Nevertheless, if this decreases or increases heterogeneity depends on the general composition of the market. In our panel, participants rank themselves on average as mainly fundamentalist and only as about 30% as chartist (see Menkhoff, Rebitzky and Schröder, 2007).[6] Thus, subsequent switches from fundamentalism to chartism would assumable increase expectation heterogeneity. Nonetheless, questionnaires of foreign exchange professionals show throughout dominance in fundamentalism, particularly when considering longer-term horizons (see Menkhoff, 1998,

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[3] Latest contributions include Manzan and Westerhoff (2005, 2007), Alfarano and Lux (2006), Boswijk, Hommes and Manzan (2007), and Chiarella, Dieci and He (2007).

[4] In the following, we use the terms chartist and technical trading synonymously.

[5] Actually, De Grauwe and Grimaldi leave it open, on which fundamental concept the exchange rate is based; however, they presume that corresponding fundamentals follow a random walk.

[6] The share of fundamentalists and chartists varies between various surveys (see Menkhoff and Taylor, 2007). Foreign exchange traders are typically extreme short-term orientated. Hence, they rely comparatively less on fundamentals than fund managers and analysts, why the latter underlie much longer time horizons.

Cheung and Wong, 2000, Cheung and Chinn, 2001, Gehrig and Menkhoff, 2004). Thus, from this angle we judge our expectations data, upon which we derive heterogeneity, as being representative. Furthermore, the fact that we specifically consider 6-month expectations is due to the fact that corresponding time horizon is most useful in order to pick up short- as well as long-term impacts. Whereas shorter expectation horizons are mainly affected by technical means (see e.g. Osler, 2003, Olsen, 2004), longer horizons are much more influenced by fundamentals (see e.g. MacDonald, 1999, Kilian and Taylor, 2003). So, 6-month expectations take up a stance on it in between (see MacDonald, 2000).

As a second strand of literature, we consider the influence of noise trading on the risk premium in exchange rates (see e.g. Mark and Wu, 1998, Jeanne and Rose, 2002). By pulling up Jeanne and Rose's model (2002), a positive impact arises from noise trading on the risk premium, which in turn could cause rising expectation heterogeneity – albeit Jeanne and Rose primarily focus on the implication of the current exchange rate regime on noise trading. Their model shows that the appearance of more unsophisticated traders drives noise trading up and subsequently expectation heterogeneity which in turn causes distortions of uncovered interest parity. Though, noise traders drive a wedge between the expected exchange rate and the forward rate and so, they create risk (see also Flood and Rose, 1996).

Finally, a third strand of literature is provided by studies linking uncertainty about fundamentals to expectation heterogeneity. Bacchetta and van Wincoop (2006a) implement information heterogeneity in a standard monetary model in order to explain the "exchange rate determination puzzle" in the shorter run. Assuming the existence of dispersed information without any investor holding superior information, investors have to learn about fundamental information from unobserved hedge trades. As time goes by, agents learn more from future fundamentals and rational confusion gradually reduces. In another paper, Bacchetta and van Wincoop (2006b) replicate the forward discount puzzle by using the concept of rational inattention (see also Sims, 2003, and more recently Reis, 2007). Since potential gains from active trading upon complete information processing prove being rather small, agents are not fully informed and therefore make infrequent portfolio decisions. Hence, new information process rather slowly into asset prices, which explains the apparent puzzle of predictable excess returns.[7] Therefore, agents' expectations differ, because they hold different sets of fundamental

[7] Mankiw, Reis and Wolfers (2003) test Mankiw and Reis' "sticky information model" (2002). Particularly, they do so by analyzing heterogeneity in inflation expectations. Amongst others, changes and volatility in inflation seem to be most important.

information. Accordingly, heterogeneity should rise in periods of higher news frequency, which would in turn increase the asymmetric distribution of information among agents. Such periods should be indicated by higher volatility of the fundamentals or alternatively, by higher exchange rate volatility.[8]

Our relatively long and broad dataset allows us examining the inherent relations of the above discussed strands of literature. Actually, we find conforming evidence with inherent implications of the C&F approach: heterogeneity in exchange rate expectations increases with less deviation of the actual exchange rate from purchasing power parity (PPP) – indicating declining consensus among fundamentalists – and with increasing changes in the exchange rate – indicating a shift towards chartism. In addition to that, another significant determinant shows up, as presumed by the second strand of literature, i.e. a rising risk premium boosts expectation heterogeneity. Further variables as argued by the third strand, such as volatility in exchange rate fundamentals or in exchange rates, do not provide additional insights. This pattern holds exactly for euro versus US-dollar and versus GB-pound and it largely for euro versus JP-yen, as the latter is possibly also influenced by a particular exchange rate policy.

The remainder is structured as follows. Section 2 describes the dataset we use for our analysis. Ancillary results revealing the existence of expectation heterogeneity are presented in Section 3. The following Section 4 contains the main results concerning the determinants of heterogeneity and Section 5 concludes.

2 Data

Our analysis is built on two sorts of data: first, we use a dataset comprising 15 years of individual exchange rate expectations in order to calculate heterogeneity and, second, we use a large dataset of standard fundamental determinants of exchange rate.

By generating dispersion, as representing our measure of heterogeneity in exchange rate expectations, we rely on individual expectations from the well-established financial market survey of the Centre for European Economic Research (ZEW) in Mannheim, Germany. It is about a monthly census of financial market professionals, asking them for various 6-month forecasts. Our sample contains expectations for the US-dollar/euro, GB-pound/euro and JP-yen/euro (until end of 1998 /D-mark respectively), from December 1991 until August 2006, which sums up each with 177 observations. Compared to other financial market surveys, the

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[8] Frankel and Froot (1990a) find a correlation between exchange rate volatility and dispersion, which they rather attribute with model heterogeneity–such as the C&F approach–than with heterogeneity in information.

ZEW's survey structure is conventional and similar to Consensus Forecasts (London). Nevertheless, it is worth mentioning, that its participation is rather large with about 300 responses on average. Moreover, the design of the survey is of qualitative nature, such that participants only have to judge whether the corresponding variable goes up, down or stays unchanged. Due to the fact that our analyses require quantitative forecasts, we have to transform the data by means of a quantification technique. We do so by using Carlson and Parkin's method (1975), which in turn enables us to run appropriate analyses.

The expectation data is presented in Table 1 that contains descriptive statistics of the aggregated exchange rate expectations. Two figures present the core variable of our analyses, i.e. heterogeneity in exchange rate expectations. For each of the three exchange rates, Figure 1 shows the histogram of dispersion, whereas Figure 2 presents its time-series next to the corresponding exchange rate. In sum, one can see easily remarkable variations in heterogeneity.

Since the main purpose of our work lies in discovering the determinants of heterogeneity, we need further data. First of all we use daily exchange rate data of the US-dollar/euro, GB-pound/euro and JP-yen/euro (-/D-mark respectively) from the Deutsche Bundesbank, in order to calculate amongst others exchange rate changes and respective volatilities. Moreover, we consider core fundamentals, which are used in standard exchange rate models. Taking the monetary model as the reference model, these variables are the following: differences of changes in money and income as well as of interest rates between the euro zone (Germany until December 1998 respectively) and the United States, Great Britain and Japan. In detail, we use a broader definition of money, i.e. M3, and a narrower one, M2. In order to proxy income growth on a monthly basis, we rely on industrial production; additionally, quarterly GDP is interpolated to generate a monthly frequency. With respect to interest rates, we use 6-month Libor rates. Furthermore, considering Frankel's real interest differential model (1979) we also incorporate 10-year government bond yields. Finally, and somewhat more pragmatic, we use several further variables beyond our reference model. First, inflation is often seen to be a better proxy to capture price trends than money aggregates. Second, the trade balance is often assessed as a further exchange rate determinant (see e.g. Obstfeld and Rogoff, 1995) and, third, capital flows reach out money market instruments why we consider stock index returns too (see Hau and Rey, 2006).[9]

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[9] 6-month Libor rates and stock indices are taken from EcoWin. M2, M3, industrial productions, GDP, CPI inflation and trade balances stem from IMF's International Financial Statistics. German government bond yields are taken from the Deutsche Bundesbank and equivalent US yields from the Federal Reserve.

In the following section we examine, which of the above introduced variables – as suggested by the three strands of literature – are related to heterogeneity in exchange rate expectations.

3 Determinants of expectation heterogeneity

In order to get a first idea about the relevant explanatory variables in order to explain heterogeneity in exchange rate expectations, we conduct basic regression analyses. Actually, we find three variables, which we will pick up again in Section 4. Before we discuss our results, we define the required variables introduced in Section 1, which have to be constructed.

The following variables are derived from the first strand of literature, underlying the C&F approach. Frankel and Froot (1990) explicitly draw on a relation between the expectation formation, the related time horizon and the preferred kind of information. They characterize fundamentalists as forming regressive expectations and having a longer time horizon whereas chartists form extrapolative expectations and are shorter term oriented. Accordingly, considering fundamentalists' tracked economic equilibriums, we rely on the concept of ppp. Since it is well-known and popular amongst professionals in order to generate exchange rate equilibrium values, we take the absolute difference between the current exchange rate and its ppp-value.[10] Regarding chartists' stance, we simply take the most recent 1-month change of the exchange rate, again in absolute terms. We feel quite confident that these two variables, i.e. a regressive based upon PPP and a 1-month extrapolative term adequately capture the behavior of fundamentalists and chartists accordant to the C&F-approach.

With respect to the second strand of the literature, we apply the standard definition of the risk premium, i.e. the difference between exchange rate expectation and accordant forward rate (see e.g. Froot and Frankel, 1989, Cavaglia, Verschoor and Wolff, 1994, and Bams, Walkowiak and Wolff, 2004).

This brings us to the third strand of the literature, hypothesizing that further fundamentals determine heterogeneity. It is known that consider fundamentals when forming exchange rate expectations (see Cheung and Wong, 2000, Cheung and Chinn, 2001), why fundamentals may impact dispersion. Hence, we examine the influence of the variables, which have been introduced in Section 2, in three ways: first, we take them in algebraic signed form in order to allow for potential asymmetries (see related studies of heterogeneity in inflation expectations,

[10] The ppp-values are based upon long-run validity of the relative ppp-concept. Respective nominal values are derived from the average real exchange rate by using actual Consumer Price Indices.

e.g. Mankiw, Reis and Wolfers, 2003, and Capistrán and Timmermann, 2006). Second, we consider the fundamentals in their absolute form, which somewhat reduces complexity since it does not allow for the above effects. Third, we calculate their volatilities by relying on the 1-month standard deviation in order to capture potential second-moment-elements in dispersion.

As a first analysis, we run univariate OLS-regressions, where we regress each of the above variables separately on expectation heterogeneity. To cut a long story short, there are only few mentionable results worth being mentioned. In particular, all different forms of fundamental measurements do not show any significant relation with heterogeneity in exchange rate expectations. This is somewhat surprising in first place, but possibly less so when we remember that there hardly exist any stable relations between exchange rate fundamentals and exchange rates (see e.g. Meese, 1990, Sarno and Taylor, 2002).

The few relations that we find are presented in Table 2. The table shows the R-squares of regressions of the regressive term, the extrapolation variable and the risk variable as well as exchange rate volatility on heterogeneity. Obviously, measuring the series in absolute terms better explains dispersion than otherwise. Thus, asymmetric effects underlying heterogeneity do not exist. However, conducting multivariate regressions, we see in Table 3 that the correlation of volatility with dispersion is completely absorbed by the other variables, for any exchange rate. Volatility becomes insignificant whereas the other variables are significant in the multivariate setting.[11]

Overall, we find that our bulk of potentially relevant variables boils down to three, i.e. the two variables derived from the C&F approach and the risk premium. Moreover, since we do not reveal any sign of asymmetric effects underlying influences on dispersion, we define the respective variables in absolute terms. In the next section, we apply a vector error-correction approach in order to discriminate between possible temporary and permanent effects. Furthermore, we cannot rule out a priori, that the explanatory variables are truly exogenous – to quote an example, dispersion could have an impact on the risk premium. Finally, because of the very persistent behavior of some of our, an error-correction approach appears

[11] Since Durbin Watson statistics indicate strong autocorrelation, we implement in the multivariate regressions dispersion with lag one.

justified in order to pick up the common stochastic trends, which could be present amongst the variables (see the somewhat mixed results based on standard unit-root tests in Appendix 1).[12]

4 Expectation heterogeneity in a VEC approach

By applying a VEC model, the resulting picture reveals permanent and temporary effects, with some differences between the three exchange rates under consideration. However, we emphasize that all three empirical models contain a similar structure, indicating the existence of common determinants of heterogeneity in exchange rate expectations.

Our baseline model contains the four variables identified in Section 3, i.e. dispersion as our measure of expectations heterogeneity, the ppp-deviation term, the 1-month extrapolation variable and the risk premium. In addition to this, we test each exchange rate model separately for constants and dummy variables.[13] So, our baseline model shows up as follows:

$$\Delta x_{1,t} = A_0 \cdot \Delta x_{2,t} + \Gamma_{1.1} \cdot \Delta x_{1,t-1} + \cdots + \Gamma_{1.t-k+1} \cdot \Delta x_{1,t-k+1} + \alpha \cdot \beta' \cdot x_{t-1} + \Phi_1 \cdot D_t + \mu_0 + \varepsilon_t \quad (2)$$

with $\{x_t\} = \{x_{1,t}, x_{2,t}\}$ and $\{\alpha\} = \{\alpha_1, \alpha_2\}$, whereas $\alpha_2 = 0$,

with $\varepsilon_t \sim N_p(0, \Sigma)$ and $\{x_t\} = \{x_{1,t}, x_{2,t}\}$.

Vector X_1 includes dispersion, the ppp term and the risk premium. However, since the extrapolation variable is stationary, it would definitely attract a common stochastic trend in the system for itself. So we treat the difference in the exchange rate as weakly exogenous, i.e. entering X_2. Furthermore, we put reasonable economical permanent effects via dummy variables in D. Note that those dummies, which affect at least one of the cointegration relations, would be additionally incorporated in X_2.

Consulting the specification tests, we construct the specific models for dispersion in the US-dollar, the GB-pound and the JP-yen respectively. By examining for significant outliers in our data, respective test results notify that we need to consider two dummy variables in the VEC models. Regarding the GB-pound, two permanent-intervention dummies have to be con-

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[12] Treating misleadingly nonstationary data as stationary, we would generate spurious regressions without any economic meaning. On other hand, unit-root approximations of persistent variables produce reliable inference results, more than otherwise (see, Johansen, 1995, 2006).

[13] Separated for each dispersion model, we use the residual series generated by the system estimation and set accordant dummies, when standardized errors exceed critical values. Considered dummies need then to be statistically significant in the respective model and additionally, have to be accompanied by a reasonable economical explanation (see Nielsen, 2004).

sidered, one in December 1998 and the other in September 2000. Regarding the JP-yen, we need only the permanent-intervention dummy in September 2000. Considering the US-dollar, a dummy effect show up in June 1993, but since we cannot find any economical explanation for this effect, we will not include it in the model.[14] Furthermore, whilst US-dollar and GB-pound trace tests show one cointegration relation being sufficient in respective systems, the JP-yen in contrast requires two long-term relations (see Table 4). Finally, testing all three models for the existence of unit-roots, no variable shows up being well approximated by an I(1)-process (see test results in Appendix 2 and 3).[15] Thus, we receive structurally similar models for dispersion in all three exchange rates.

Table 5 shows the results of the unrestricted model estimation of US-dollar dispersion. Regarding the long-term relation, dispersion increases significantly if the ppp-deviation becomes smaller and the exchange rate trend or the risk premium rises. As the first two determinants are derived from the C&F approach, our findings confirm the relevance of the C&F approach. Whereas modern exchange rate models based upon heterogeneous agents arrive endogenously at results, which are consistent with stylized facts, we can approve agent's behavior according to the C&F approach; in fact, it is supported by real world professionals' expectations. However, we associate the risk variable with noise trading, which is unrelated to the C&F approach variables.[16] Turning to dispersion's short-term relation, dispersion error-corrects significantly towards its long-term equilibrium. Moreover, in the short run, the extrapolation variable strongly pushes dispersion. This impact works the way that the contemporaneous speed of the exchange rate change positively impacts dispersion, indicating the enormous relevance of extrapolation in the short run.[17]

Regarding the GB-pound, the model has almost the same structure as the one for the US-dollar, except for two permanent dummies, which enter the error-correction equations, so-called "blips", i.e. one-time effects (see Table 6). The December 1998 dummy seems to be associated with uncertainty about the future implications of the oncoming introduction of the euro for the United Kingdom. In our analyses, this should only affect the GB-pound and, in-

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[14] Anyhow, implementing this dummy variable does not change related results in a meaningful way.

[15] By selecting the lag-length of the models, we rely on LR-tests, which show one lag being sufficient.

[16] It may also be caused by information heterogeneity (e.g. Bacchetta and van Wincoop, 2006a, 2006b).

[17] We do not discuss the other error-correction equations as they are not of direct interest for our research.

deed, does this effect does not show up in one of the other models.[18] Regarding the September 2000 dummy, we can connect this reaction to the change of ECB's monetary policy. Since at this time, the devaluation of the euro showed up as being fundamentally absolutely unjustified, on September 15th in 2000, the ECB raised the first time its key interest rate. Nevertheless, financial markets evaluated this as a weak act and sentiment in the euro dropped even further. Though, it seems puzzling, why we do not reveal such an effect in the US-dollar equation. However, the ppp-deviation term proves to be most pronounced in the US-dollar dispersion among the three models, why this variable presumably absorbs this effect.

The model for the JP-yen differs slightly from the others as can be seen from Table 7. Regarding the long-term relations, dispersion in the JP-yen reacts positively if the ppp-deviation decreases or when the risk premium increases, which is in line with the two other models. However, the influence of the extrapolation term on expectation heterogeneity turns out being different. Heterogeneity in the JP-yen error-corrects to a second cointegration relation, in which the risk premium depends positively on the extrapolative term and on the ppp-deviation. Considering both cointegration relations, the effect arising from the ppp-deviation term on expectation heterogeneity appears somewhat ambiguous. One may speculate whether this ambiguity result from the particular monetary policy in Japan. It is known that the Bank of Japan holds deliberately the JP-yen weak against other currencies via extremely low interest rates as well as exchange rate interventions (see e.g. Frenkel, Pierdzioch and Stadtmann, 2004, Ito and Yabu, 2004), which could potentially affect the respective risk premium.

Despite certain particularities of the three models, we emphasize that the baseline structure remains: we find that the C&F variables and the risk premium show expected impacts on heterogeneity in exchange rate expectations. To check for robustness, we consolidate the unrestricted VEC models in order to obtain the parsimonious specifications. In sum, we confirm that dispersion's error-correction remains unchanged, regarding all three models; likewise holds extrapolation's positive influence on dispersion in the short run.[19]

5 Conclusions

Exchange rate dynamics have not been well understood for the last 30 years. We know that traditional models with representative agents fail seriously when confronted with real-

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[18] At this time (and still today), the GB-pound constitutes the only one currency of the three examined in this work, which is believed to join the euro somewhere along the way.

[19] We do not present related results to conserve space, though they will be provided upon request.

world data. Thus, it does not surprise that simulation results, generated by models based on heterogeneity, better fit stylized facts of foreign exchange markets. However, several heterogeneous agent models, which have been recently built, belong to the chartist-fundamentalist approach and share a few strong implications on agents' behavior. In sum, our paper contributes empirical analyzes of the determinants of heterogeneity in exchange rate expectations and in particular, examines the validity of the C&F approach from a different perspective.

We take advantage of our comparatively long dataset, covering 15 years exchange rate expectations. By calculating dispersion, i.e. our measure of heterogeneity in exchange rate expectations, we can analyze its potential determinants suggested by the exchange rate literature. We find that influences arising from fundamentalists' and chartists' behavior are most useful to explain heterogeneity, which is in line with the C&F approach.

Considering the long-term effects on heterogeneity, it decreases when the exchange rate is farther away from its fundamental equilibrium; according to the C&F approach, because professionals then tend more and more to anticipate exchange rate's mean-reversion towards equilibrium. In addition, a stronger change in the exchange rate increases heterogeneity; according to the C&F approach that is because a shift of opinion then occurs from dominating fundamentalists to the minority group of chartists.[20] Finally, we reveal a positive impact arising from the risk premium, which we associate with noise trader risk. Considering alternatively the latter variable capturing information uncertainty, we see this less justified, since we do not find any influence arising from further fundamentals or related volatilities.

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[20] In Section 1 we already discussed the common dominance of fundamentalism in middle-term expectations.

References

Alfarano, Simone and Thomas Lux (2006), A noise trader model as a generator of apparent power laws and long memory, *Macroeconomic Dynamics*, forthcoming.

Bacchetta, Philippe and Eric van Wincoop (2006a), Can information heterogeneity explain the exchange rate determination puzzle?, *American Economic Review*, 96: 552-76.

Bacchetta, Philippe and Eric van Wincoop (2006b), Incomplete information processing: a solution to the forward discount puzzle, CEPR discussion papers, 96: 552-76.

Bams, Dennis, Kim Walkowiak and Christian C. Wolff (2004), More evidence on the dollar risk premium in the foreign exchange market, *Journal of International Money and Finance*, 23: 271-82.

Boswijk, H. Peter, Cars H. Hommes and Sebastiano Manzan (2007), Behavioral heterogeneity in stock prices, *Journal of Economic Dynamics & Control*, forthcoming.

Brock, William A. and Cars H. Hommes (1998), Heterogeneous beliefs and routes to chaos in a simple asset pricing model, *Journal of Economic Dynamics & Control*, 22: 1235-74.

Capistrán, Carlos and Allan Timmermann (2006), Disagreement and biases in inflation expectations, UCSD working paper.

Carlson, John A. and Michael Parkin (1975), Inflation expectations, *Economica*, 42: 123-38.

Cavaglia, Stefano M., Willem F. Verschoor and Christian C. Wolff (1994), On the biasedness of forwards foreign exchange rate: irrationality of risk premia?, *Journal of Business*, 67: 321-43.

Cheung, Yin-Wong, Menzie D. Chinn and Antonio Garcia Pascual (2005), Empirical exchange rate models of the nineties: are any fit to survive?, *Journal of International Money and Finance*, 24: 1150-75.

Cheung, Yin-Wong and Yuk-Pang Wong (2000), A survey of market practitioners' views on exchange rate dynamics, *Journal of International Economics*, 51: 401-19.

Cheung, Yin-Wong and Menzie D. Chinn (2001), Currency traders and exchange rate dynamics: a survey of the US market, *Journal of International Money and Finance*, 34: 439-71.

Chiarella, Carl, Roberto Dieci and Xue-Zhong He (2007), Heterogeneous expectations and speculative behaviour in a dynamic multi-asset framework, *Journal of Economic Dynamics & Control*, forthcoming.

De Grauwe, Paul and Marianna Grimaldi (2005), Heterogeneity of agents, transactions costs and the exchange rate, *Journal of Economic Dynamics & Control*, 29: 691-719.

De Grauwe, Paul and Marianna Grimaldi (2006), Exchange rate puzzles: a tale of switching attractors, *European Economic Review*, 50: 1-33.

Flood, Robert P. and Andrew K. Rose (1996), Fixes: of the forward discount puzzle, *Review of Economics and Statistics*, 128: 748-52.

Frankel, Jeffrey A. and Kenneth A. Froot (1990), Chartists, fundamentalists and the demand for dollars, in: Anthony S. Courakis and Mark P. Taylor (eds.), *Private behaviour and government policy in interdependent economies*, Oxford: Clarendon Press, 73-126.

Frankel, Jeffrey A. and Kenneth A. Froot (1990a), Chartists, fundamentalists, and trading in the foreign exchange market, *American Economic Review*, 80: 181-85.

Frankel, Jeffrey A. and Andrew K. Rose (1995), Empirical research on nominal exchange rates, in: G. Grossmann and K. Rogoff (eds.), *Handbook of International Economics*, Vol. III (Amsterdam et al.: North-Holland): 1689-729.

Frenkel, Michael, Christian Pierdzioch and Georg Stadtmann (2004), The accuracy of press reports regarding the foreign exchange interventions of the Bank of Japan, *Journal of International Financial Markets, Institutions and Money,* 14: 25-36.

Froot, Kenneth A. and Jeffrey A. Frankel (1989), Forward Discount Bias: Is it an exchange risk premium?, *Quarterly Journal of Economics*, 104: 139-61.

Gehrig, Thomas and Lukas Menkhoff (2004), The use of flow analysis in foreign exchange: exploratory evidence, *Journal of International Money and Finance*, 23: 573-94.

Goodman, Stephen H. (1979), Foreign exchange rate forecasting techniques: implications for business and policy, *Journal of Finance*, 34: 415-427.

Hau, H., Rey, H. (2006), Exchange rates, stock prices, and capital flows, *Review of Financial Studies*, 9: 273–317.

Ito, Takatoshi (1990), Foreign exchange rate expectations: micro survey data, *American Economic Review*, 80(3): 434-49.

Ito, Takatoshi and Tomoyoshi Yabu (2004), What prompts Japan to intervene in the forex market? A new approach to a reaction function, NBER Working Paper, 10456.

Jeanne, Olivier and Andrew K. Rose (2002), Noise trading and exchange rate regimes, *Quarterly Journal of Economics*, 117: 537-69.

Johansen, Sören (1995), *Likelihood-based inference in cointegrated vector auto-regressive models*, Oxford: Oxford University Press.

Johansen, Sören (2006), Cointegration: an overview, in: Terence C. Mills and Kerry Patterson (eds.), *Palgrave Handbook of Econometrics: Volume 1, Econometric Theory*, Basingstoke: Palgrave Macmillan: 540-77.

Kilian, Lothian and Mark P. Taylor (2003), Why is it so difficult to beat the random walk forecast of exchange rates?, Journal of International Economics, 60: 85-107.

MacDonald, Ronald (1999), Exchange rates: do fundamentals matter?, *Economic Journal*, 109: 673-91.

MacDonald, Ronald (2000), Expectations formation and risk in three financial markets: surveying what the surveys say, *Journal of Economic Surveys*, 14: 69-100.

Mankiw, N. Gregory and Ricardo Reis (2002), Sticky information versus sticky prices: a proposal to replace the new Keynesian Phillips curve, *Quarterly Journal of Economics*, 117: 1295-328.

Mankiw, N. Gregory, Ricardo Reis and Justin Wolfers (2003), Disagreement about inflation expectations, in: Gertler and Rogoff (eds.), *NBER Macroeconomics Annual 2003*, Cambridge: MIT Press, 257-68.

Manzan, Sebastiano and Frank Westerhoff (2005), Representativeness of news and exchange rate dynamics, *Journal of Economic Dynamics & Controls*, 29: 677-89.

Manzan, Sebastiano and Frank Westerhoff (2007), Heterogeneous expectations, exchange rate dynamics and predictability, *Journal of Economic Behavior and Organization*, forthcoming.

Mark, Nelson C. and Yangru Wu (1998), Rethinking deviations from uncovered interest parity: the role of covariance risk and noise, *Economic Journal*, 108: 1686-706.

Meese, Richard A. (1990), Currency fluctuations in the post-Bretton Woods era, *Journal of Economic Perspectives*, 4: 117-34.

Meese, Richard A. and Kenneth Rogoff (1983), Empirical exchange rate models of the seventies, *Journal of International Economics*, 14: 3-24.

Menkhoff, Lukas (1998), The noise trading approach - questionnaire evidence from foreign exchange, *Journal of International Money and Finance*, 17: 547-64.

Menkhoff, Lukas, Rafael Rebitzky and Michael Schröder (2007), Do Dollar forecasters believe too much in PPP?, *Applied Economics*, forthcoming.

Menkhoff, Lukas and Mark P. Taylor (2007), The obstinate passion of foreign exchange professionals: technical analysis, *Journal of Economic Literature*, forthcoming.

Nielsen, Heino B. (2004), Cointegration analysis in the presence of outliers, *Econometrics Journal*, 7: 249-71.

Olson, Dennis, (2004), Have trading rule profits in the currency market declined over time?, *Journal of Banking and Finance*, 28: 85-105.

Osler, Carol (2003), Currency Orders and Exchange-Rate Dynamics: Explaining the Success of Technical Analysis, *Journal of Finance*, 58: 1791-819.

Reis, Ricardo (2007), Inattentive consumers, *Journal of Monetary Economics*, 53: 1761-800.

Sarno, Lucio and Mark P. Taylor (2002), *The economics of exchange rates*, Cambridge et al.: Cambridge University Press.

Sims, Chris (2003), Implications of rational inattention, *Journal of Monetary Economics*, 50: 665-90.

TABLE 1 Descriptive statistics of consensus expectations

	US-dollar		GB-pound		JP-yen	
	cons.	disp.	cons.	disp.	cons.	disp.
mean	1.133	0.070	0.718	0.042	1.319	0.043
std.	0.120	0.017	0.065	0.011	0.136	0.009
25%-q.	1.049	0.058	0.671	0.035	1.231	0.036
75%-q.	1.225	0.078	0.762	0.047	1.402	0.048
min.	0.881	0.043	0.628	0.024	0.975	0.028
max.	1.369	0.132	0.877	0.086	1.696	0.080

Notes: The data series are based upon corresponding six months expectations data from December 1991 until August 2006. All series relate above-mentioned currencies to the D-mark until December 1998 and thereafter to the euro. The variables are abbreviated as follows: aggregated point forecast – i.e. consensus (cons.) and dispersion (disp.). Using the method of Carlson and Parkin (1975) to derive aggregate point expectations requires two assumptions. First, each individual forecast is based upon a subjective probability distribution concerning the outcome of this forecast. However, applying the logistic distribution did not change qualitatively the results. Second, the corresponding means of the individual probability distributions follow-up a normal distribution, which can be justified via the Central-Limit Theorem. Furthermore, we choose a symmetric scaling of three percent, which displays a threshold. Hence, forecasters perceive noticeable changes in the exchange rate, if the latter proves being three percent or more. Based upon a particular survey, the participants of the ZEW Financial Market Survey were asked to reveal the individual thresholds associated with their different forecasts. Nevertheless, choosing other thresholds – around three percent – did not reveal qualitatively different results.

TABLE 2 Univariate OLS-regressions of dispersion

	US-dollar	GB-pound	JP-yen
extrapol.	-0.006	-0.006	0.000
|extrapol.|	0.100	0.067	0.092
[split: $^{(+)}$, $^{(-)}$]	[0.062, 0.145]	[0.094, 0.045]	[0.078, 0.098]
ppp-dev.	0.018	0.059	0.522
|ppp-dev.|	0.029	0.059	0.550
[split: $^{(+)}$, $^{(-)}$]	[0.014, 0.032]	[n.a., 0.059]	[0.626, -0.016]
risk	0.113	0.299	0.476
|risk|	0.436	0.468	0.512
[split: $^{(+)}$, $^{(-)}$]	[0.534, 0.259]	[-0.000, 0.565]	[0.044, 0.534]
vola.	0.124	0.242	0.236

Notes: The regressions are calculated upon monthly data, covering December 1991 until August 2006. Dispersion series are based upon accordant six months expectations, whereas above-mentioned currencies are related to the D-mark until December 1998 and thereafter against the euro. The numbers document adjusted R-squares of univariate OLS-regressions, in which dispersion is calculated on the displayed variable next to a constant. We do not show corresponding probability values, since we solely focus on the explained variances of dispersion. The variables are abbreviated as follows: Current 1-months exchange rate extrapolation (extrapol.), regressive term – i.e. difference between the actual exchange rate and its fair value based upon relative ppp using CPI – (ppp-dev.), risk premia – i.e. the expected (consensus) exchange rate change minus the relative bond rate (risk) and exchange rate volatility – i.e. corresponding 1-month standard-deviation – (vola.). Notice, that strokes indicate that the respective variable appears in absolute measure. Moreover, splits separate the observations upon the signs of the respective variable, such that adjusted R-squares are calculated separately for positive and negative values.

TABLE 3 Multivariate OLS-regressions of dispersion

	US-dollar	**GB-pound**	**JP-yen**
const.	0.027***	0.026	0.015***
disp. $_{(-1)}$	0.423***	0.655***	0.488***
|ppp-dev.|	-0.033***	-0.004	0.023***
|risk|	0.229***	0.059**	0.076***
|extrapol.|	0.249***	0.078	0.089***
vola.	0.024	0.187	-0.006
adj. R^2	0.641	0.746	0.755

Notes: The regressions are calculated upon monthly data, covering December 1991 until August 2006 by using Newey-West standard errors. Dispersion series are based upon accordant six months expectations, whereas above-mentioned currencies are related to the D-mark until December 1998 and thereafter against the euro. The variables are abbreviated as follows: constant (const.), lagged dispersion (disp. $_{(-1)}$), regressive term – i.e. difference between the actual exchange rate and its fair value based upon relative ppp using CPI – (ppp-dev.), risk premia – i.e. the expected (consensus) exchange rate change minus the relative bond rate (risk), current exchange rate extrapolation (extrapol.) and exchange rate volatility – i.e. corresponding 1-month standard-deviation – (vola.). Notice, that strokes indicate that the respective variable appears in absolute measure. Sticking to exchange rate volatility is solely appertained, to underlie the irrelevance of exchange rate volatility. Without the latter, R^2's remain obviously nearly the same but besides, the other regressors do not change in a meaningful way. Asterisks refer to the level of significance: *, **, *** to ten, five and one percent.

TABLE 4 Cointegration rank determination (Trace tests)

		rank three	rank two	rank one	rank zero
US-dollar	LR-test	-	2.973	17.010	52.788***
	[prob. value]	[n.a.]	[0.833]	[0.385]	[0.003]
	LR-test #	-	2.879	16.655	51.446***
	[prob. value] #	[n.a.]	[0.844]	[0.410]	[0.005]
GB-pound	LR-test	-	2.570	9.378	60.420***
	[prob. value]	[n.a.]	[0.880]	[0.916]	[0.000]
	LR-test #	-	2.416	9.053	58.961***
	[prob. value] #	[n.a.]	[0.896]	[0.929]	[0.001]
JP-yen	LR-test	-	6.705	46.968***	94.519***
	[prob. value]	[n.a.]	[0.353]	[0.000]	[0.000]
	LR-test #	-	6.361	45.663***	94.519***
	[prob. value] #	[n.a.]	[0.390]	[0.000]	[0.000]

Notes: The underlying VEC models are estimated using the Maximum Likelihood-method (ML-method), covering 177 monthly observations, from December 1991 to August 2006. The likelihood-ratio-tests and the probability values marked with a hash are the Bartlett-corrected LR-tests and p-values, necessary to consider sample-size effects on the power of the rank determination. Asterisks refer to the level of significance: *, **, *** to ten, five and one percent. It figures out, that solely considering the US-dollar and the GB-pound, in each case one long-term relation underlies the data, since higher-order LR-tests do not reject the null hypothesis of one less unit-root. Contrary to the others, the JP-yen reveals two long-term relations.

TABLE 5 The unrestricted VEC model for the US-dollar

cointegration equation:

	disp. $_{(-1)}$		**risk** $_{(-1)}$	**ppp-dev.** $_{(-1)}$	**extrapol.** $_{(-1)}$	**const.**
$\beta'_{(1)}$	1.000	=	0.298	-0.066	0.710	0.048

error-correction equations:

	Δdisp.	**Δrisk**	**Δppp-dev.**
$\alpha_{(1)}$	-0.421^{***}	-0.114	-0.309^{**}
[t-value]	[-5.310]	[-1.096]	[-2.041]
$\Delta disp._{(-1)}$	-0.123	-0.021	0.190
[t-value]	[-1.318]	[-0.175]	[1.061]
$\Delta risk_{(-1)}$	0.030	0.002	-0.411^{***}
[t-value]	[0.388]	[0.022]	[-2.828]
$\Delta ppp\text{-}dev_{(-1)}$	0.053	0.041	0.264^{***}
[t-value]	[1.372]	[0.818]	[3.582]
$\Delta extrapol._{(0)}$	0.309^{***}	0.130^{**}	0.015
[t-value]	[6.718]	[2.163]	[0.166]
$\Delta extrapol._{(-1)}$	-0.018	-0.078	-0.060
[t-value]	[-0.341]	[-1.129]	[-0.589]
adj. R^2	0.289	0.030	0.131
sum $resid^2$	0.021	0.037	0.078

Notes: The VEC model is estimated using the ML-method. The sample contains 177 monthly observations, from December 1991 to August 2006. The variables are calculated in absolute values and are abbreviated as follows: Dispersion (disp.), risk premium (risk), regressive term (ppp-dev.) – i.e. current exchange rate minus fair value upon the relative ppp concept using CPI data – as well as 1-month exchange rate extrapolation (extrapol.). Based upon calculated t-values, corresponding cointegration parameters are highly significant. Nevertheless, since latter test-statistics are not valid, they just provide roughly indications about the significances, why we do not represent them. The log-likelihood of the system yields 2264.205. Asterisks refer to regressors' level of significance in the short-term relations: *, **, *** to ten, five and one percent.

TABLE 6 The unrestricted VEC model for the GB-pound

cointegration equation:

	disp. $_{(-1)}$		**risk** $_{(-1)}$	**ppp-dev.** $_{(-1)}$	**extrapol.** $_{(-1)}$	**const.**
$\beta'_{(1)}$	1.000	=	0.237	-0.014	0.582	0.073

error-correction equations:

	Δdisp.	**Δrisk**	**Δppp-dev.**
$\alpha_{(1)}$	-0.275***	0.132**	-0.349*
[t-value]	[-5.629]	[2.265]	[-1.747]
$\Delta disp._{(-1)}$	-0.017	0.195**	0.674**
[t-value]	[-0.261]	[2.521]	[2.539]
$\Delta risk_{(-1)}$	0.011	-0.134*	-0.197
[t-value]	[0.186]	[-1.819]	[-0.780]
$\Delta ppp\text{-}dev._{(-1)}$	-0.036**	0.043**	0.170**
[t-value]	[-1.998]	[2.029]	[2.329]
$\Delta extrapol._{(0)}$	0.155***	0.033	0.440***
[t-value]	[6.011]	[1.068]	[4.174]
$\Delta extrapol._{(-1)}$	-0.006	0.027	0.193*
[t-value]	[-0.206]	[0.817]	[1.709]
$\Delta du0009_{(0)}$	0.017***	-0.001	0.004
[t-value]	[3.829]	[-0.181]	[0.224]
$\Delta du9812_{(0)}$	0.036***	-0.003	0.020
[t-value]	[7.828]	[-0.573]	[1.089]
adj. R^2	0.408	0.093	0.111
sum $resid^2$	0.003	0.005	0.058

Notes: The VEC-model is estimated using the ML-method. The sample contains 177 monthly observations, from December 1991 to August 2006. The variables are calculated in absolute values and are abbreviated as follows: Dispersion (disp.), risk premium (risk), regressive term (ppp-dev.) – i.e. current exchange rate minus fair value upon the relative ppp concept using CPI data – as well as 1-month exchange rate extrapolation (extrapol.). Moreover, specification tests showed the necessity to implement a mean-shift dummy in September 2000 (du0009) and a permanent-intervention dummy in December 1998. Based upon calculated t-values, corresponding cointegration parameters are highly significant. Nevertheless, since latter test-statistics are not valid, they just provide roughly indications about the significances, why we do not represent them. The log-likelihood of the system yields 2579.982. Asterisks refer to regressors' level of significance in the short-term relations: *, **, *** to ten, five and one percent.

TABLE 7 The unrestricted VEC model for the JP-yen

cointegration equation:

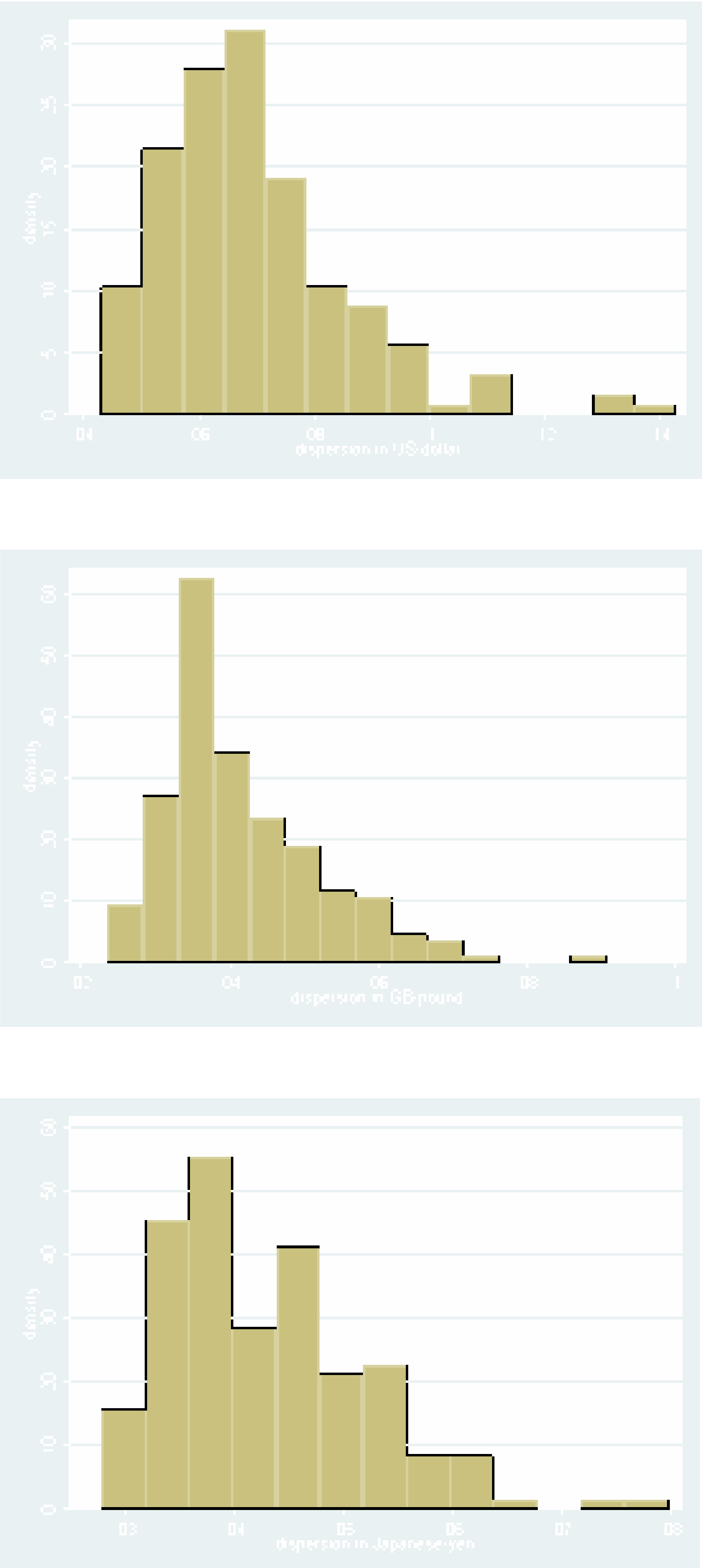
	disp. $_{(-1)}$		risk $_{(-1)}$		ppp-dev. $_{(-1)}$	extrapol. $_{(-1)}$	const.
$\beta'_{(1)}$	1.000	=	0.400		-0.032	n.a.	0.033
$\beta'_{(2)}$	n.a.		1.000	=	0.224	0.660	-0.012

error-correction equations:

	Δdisp.	Δrisk	Δppp-dev.
$\alpha_{(1)}$	-0.450***	-0.234**	0.640
[t-value]	[-6.422]	[-2.566]	[1.476]
$\alpha_{(2)}$	-0.136***	-0.217***	0.091
[t-value]	[-5.315]	[-6.534]	[0.576]
Δdisp. $_{(-1)}$	0.020	0.221**	-0.397
[t-value]	[0.272]	[2.288]	[-0.864]
Δrisk $_{(-1)}$	0.047	-0.107	-0.942***
[t-value]	[0.857]	[-1.479]	[-2.751]
Δppp-dev. $_{(-1)}$	-0.001	-0.006	0.037
[t-value]	[-0.082]	[-0.329]	[0.449]
Δextrapol. $_{(0)}$	0.081***	0.084***	-0.060
[t-value]	[5.103]	[4.048]	-[0.613]
Δextrapol. $_{(-1)}$	-0.011	-0.046**	-0.024
[t-value]	[-0.630]	[-2.104]	[-0.230]
Δdu0009 $_{(0)}$	0.023***	0.000	0.065**
[t-value]	[5.060]	[0.028]	[2.377]
adj. R^2	0.364	0.265	0.070
sum resid^2	0.003	0.006	0.123

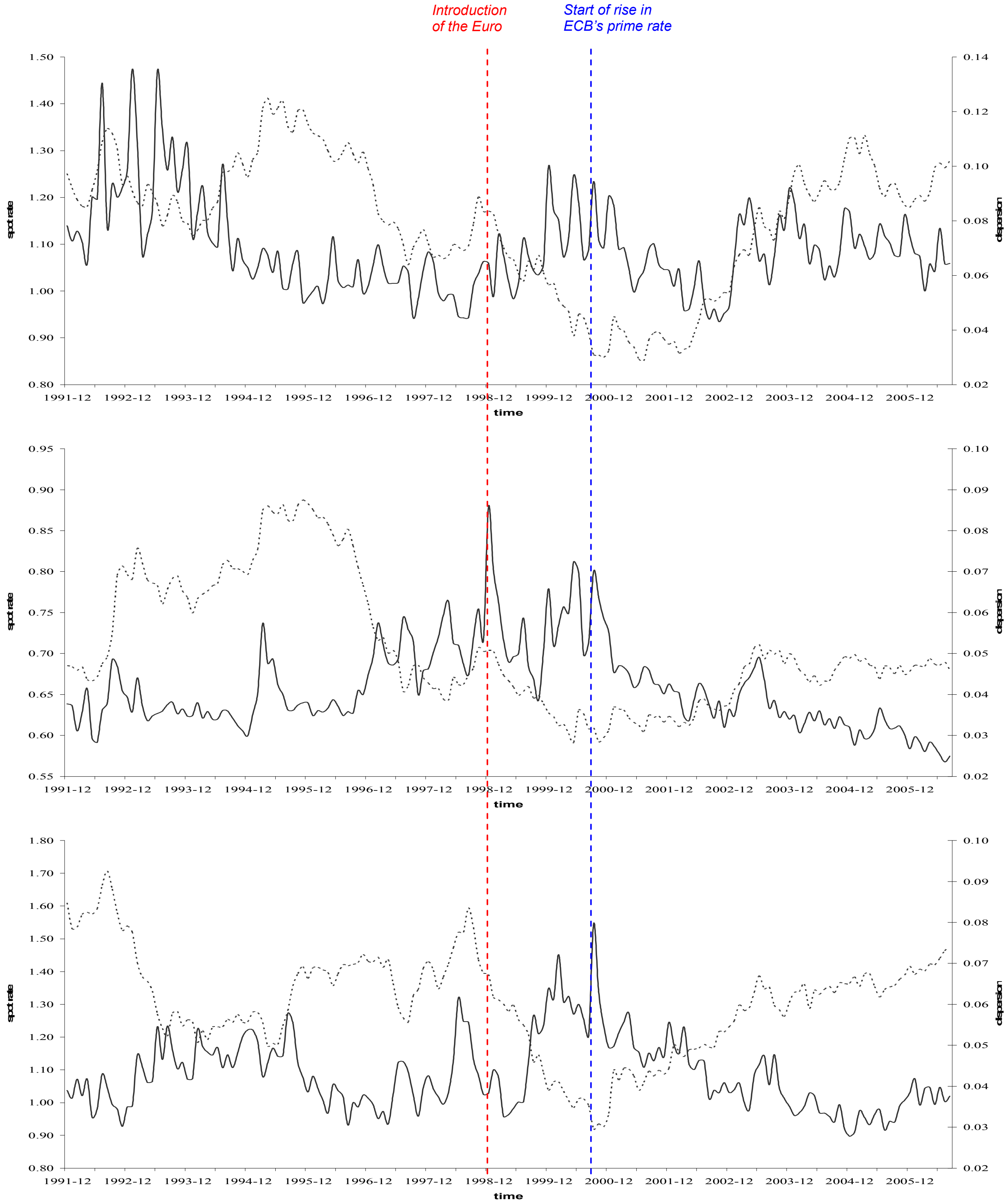
Notes: The VEC-model is estimated using the ML-method. The sample contains 177 monthly observations, from December 1991 to August 2006. The variables are calculated in absolute values and are abbreviated as follows: Dispersion (disp.), risk premium (risk), regressive term (ppp-dev.) – i.e. current exchange rate minus fair value upon the relative ppp concept using CPI data – as well as 1-month exchange rate extrapolation (extrapol.). Moreover, specification tests showed the necessity to implement a permanent-intervention dummy in September 2000 (du0009). Based upon calculated t-values, corresponding cointegration parameters are highly significant. Nevertheless, since latter test-statistics are not valid, they just provide roughly indications about the significances, why we do not represent them. The log-likelihood of the system yields 2468.597. Asterisks refer to regressors' level of significance in the short-term relations: *, **, *** to ten, five and one percent.

FIGURE 1 Histograms of dispersion in US-dollar, GB-pound and JP-yen



Notes: The dispersion series are based upon 6-month expectations data from Dec. 1991 until Aug. 2006. These histograms show the distribution of dispersion, when moving from top to down, in the euro/US-dollar, euro/GB-pound and euro/JP-yen (each with the D-Mark/- respectively).

FIGURE 2 Dispersion in US-dollar, GB-pound and JP-yen



Notes: The dispersion series are based upon 6-month expectations data from Dec. 1991 until Aug. 2006. The graphs show separately the time series of dispersion and related spot rates – moving from top to down – in the euro/US-dollar, euro/GB-pound and euro/JP-yen (each with the D-Mark/- respectively). Dashed horizontal lines represent spot rates, whereas solid lines show the corresponding dispersion series. Moreover, two dashed vertical lines represent the dummy events – i.e. the left related to December 1998 and the right to September 2000.

Appendix A

TABLE A1 Univariate unit-root tests

			test statistic	critical value (1%)	critical value (5%)	critical value (10%)
US-dollar disp.	ADF	level	-2.2822	-3.4712	-2.8794	-2.5764
		Δ	-7.9658***	-2.5786	-1.9427	-1.6115
	PP	level	-5.2598***	-3.4702	-2.8789	-2.5761
		Δ	-17.0691***	-2.5782	-1.9427	-1.6155
	KPSS	level	0.3783*	0.7390	0.4630	0.3470
		Δ	0.0291***	0.7390	0.4630	0.3470
GB-pound disp.	ADF	level	-2.0839	-3.4712	-2.8794	-2.5764
		Δ	-7.0425***	-2.5786	-1.9427	-1.6115
	PP	level	-3.6601***	-3.4702	-2.8789	-2.5761
		Δ	-15.5925***	-2.5782	-1.9427	-1.6155
	KPSS	level	0.3451	0.7390	0.4630	0.3470
		Δ	0.0626***	0.7390	0.4630	0.3470
JP-yen disp.	ADF	level	-2.1341	-3.4712	-2.8794	-2.5764
		Δ	-9.8842***	-2.5786	-1.9427	-1.6115
	PP	level	-3.8320***	-3.4702	-2.8789	-2.5761
		Δ	-16.3649***	-2.5782	-1.9427	-1.6155
	KPSS	level	0.1973	0.7390	0.4630	0.3470
		Δ	0.0364***	0.7390	0.4630	0.3470

Notes: The actual unit-root test specifications depend on intercepts' and trend variables' significances – i.e. if one appears significant, then it is included as an additional regressor. We chose the integration of maximum twelve lagged differences. Appropriate lag-length selections in the Augmented Dickey-Fuller tests (ADF) are determined by the modified Akaike-procedure. In order to calculate the bandwidths for the Philips-Perron tests (PP) as well as for the Kwiatkowski-Phillips-Schmidt-Shin tests (KPS), we use Andrew's procedure, whereas Bartlett's kernel is chosen for the spectral estimations. Δ symbolizes the first difference of respective dispersion series. All tests are based upon 177 observations, containing observations from December 1991 to August 2006. Unit-root tests on respective differences in the level series clearly point to difference stationarity. Asterisks refer to the significance level: *: ten percent, **: five percent, ***: one percent.

TABLE A2 Misspecification tests for VEC models

	US-dollar		GB-pound		JP-yen	
tests for autocorrelation	X^2	[prob. value]	X^2	[prob. value]	X^2	[prob. value]
LM-test (1):	10.700	[0.297]	9.888	[0.360]	13.894	[0.126]
LM-test (2):	20.692**	[0.014]	1691	[0.995]	14.198	[0.115]
LM-test (3):	9.382	[0.403]	15.768	[0.072]	7.541	[0.581]
LM-test (4):	14.755*	[0.098]	5.546	[0.784]	11.237	[0.260]
LM-test (5):	9.001	[0.437]	16.030	[0.066]	7.343	[0.602]
test for normality						
LM-test (.):	25.591***	[0.000]	10.060**	[0.122]	22.995***	[0.001]
tests for ARCH						
LM-test (1):	48.789*	[0.076]	72.171	[0.000]	32.578	[0.632]
LM-test (2):	70.963	[0.512]	95.233***	[0.035]	99.153**	[0.019]

Notes: The underlying VEC-models are estimated using the ML-method, covering 177 monthly observations, from December 1991 to August 2006. The multivariate maximum-likelihood-test of order two shows some autocorrelation for the US-dollar (but up to order ten, no further autocorrelation exists). However, it seems noteworthy, that this traces back to residual correlation between dispersion's and risk premium's short-term relation. i.e. amounting to 0.662. Based on the parsimonious version of the model and correcting for related simultaneous effects, autocorrelation dies out. The test for normality reveals that the residuals do not follow closely a normal distribution. Accordant univariate tests reveal this is due to skewness and kurtosis in dispersion and the risk premium. Moreover, tests for ARCH-effects do not indicate heteroskedasticity in the data. However, results upon the Gaussian-likelihood are asymptotically robust to some types of deviations of the residuals from the Gaussian distribution – i.e. heteroskedasticity and non-normality (see, Johansen, 2006). Asterisks refer to the level of significance: *, **, *** to ten, five and one percent. However, accordant VEC estimations are shown in Table 5-7, where further details can be found in the notes.

TABLE A3 Multivariate LR-tests of unit-roots

		disp.	risk	ppp-dev.
US-dollar	rank one	10.526***	26.946***	27.326***
	[prob. value]	[0.005]	[0.000]	[0.000]
GB-pound	rank one	11.917***	38.982***	47.393***
	[prob. value]	[0.003]	[0.000]	[0.000]
JP-yen	rank one	25.393***	32.063***	34.042***
	[prob. value]	[0.000]	[0.000]	[0.000]
	rank two	19.7890***	29.334***	27.833***
	[prob. value]	[0.000]	[0.000]	[0.000]

Notes: The underlying VEC-models are estimated using the ML-method, covering 177 monthly observations, from December 1991 to August 2006. The variables are calculated in absolute values and are abbreviated as follows: Dispersion (disp.), risk premium (risk), regressive term (ppp-dev.) – i.e. current exchange rate minus fair value upon the relative ppp concept using CPI data – as well as 1-month exchange rate extrapolation (extrapol.).Included constants are restricted to the cointegration space. The numbers in brackets are corresponding probability values of the tests. Since the Trace tests in Table 4 reveal the ranks, separated for each exchange rate, we concentrate on respective likelihood-ratio-tests. Above results show clearly, that the uncovered long-term relations do not constitute a unit-root underlying one of the endogenous variables. Asterisks refer to the level of significance: *, **, *** to ten, five and one percent.