Do Fundamentals Matter for the D-Mark/Euro – Dollar? A Regime Switching Approach

Michael Frömmel, University of Hannover, Germany
Ronald MacDonald, University of Strathclyde, UK
Lukas Menkhoff, University of Hannover, Germany

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Abstract:
In this paper we demonstrate that there is evidence of an unstable and nonlinear relationship between fundamentals and exchange rates. Modeling this time-varying nature of the importance of fundamentals in a Markov switching framework substantially improves the fit of the real interest rate differential model and leads to parameter estimates, which in one regime are in line with theoretical expectations and allow us to draw reasonable conclusions on the influence of fundamentals on exchange rate dynamics. Factors which prove to be closely related to regime switches are short term interest rate, inflation differentials and differences in economic growth. Therefore fundamentals do not only matter for the exchange rate *within* each regime, but are also related to the switches *between* the regimes.

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Corresponding author: Lukas Menkhoff, Department of Economics, University of Hannover, Königsworther Platz 1, D-30167 Hannover, Germany, menkhoff@gif.uni-hannover.de

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1 Introduction

Although it has become something of a stylized fact that traditional, fundamentals-based, exchange rate models do not perform well either on an in-sample or out-of-sample context (recent proponents of this view are Frankel and Rose, 1995 and Sarno and Taylor, 2002), there is now a sufficient body of accumulated evidence to warrant some optimism about the fundamentals-based exchange rate behavior (see for example MacDonald (1999, 2004). This renewed optimism about modeling exchange rates in terms of fundamentals motivates us in this paper to explore a new approach to exchange rate modeling. In particular, we take the real interest differential monetary (RID) model of Frankel (1979) and add a regime switching process for the underlying fundamentals. We demonstrate that this extension considerably improves the fit of this fundamentals-based exchange rate model.

Exchange rates are often regarded as moving accidentally because no permanent forces can be detected. As a focal point of earlier market microstructural research, FX dealers have attracted much attention. They seem to act on a minute-by-minute basis and this does not really fit in with the notion of a longer term impact of fundamentals. Moreover, the global turnover in foreign exchange is high and is certainly much higher than can be explained by international trade alone (BIS, 2002). This paper does not debate these well-known facts but argues that a role for fundamentals is shown to exist once one moves from structural models with constant coefficients, to models with time-varying coefficients. A small but expanding literature has illustrated the usefulness of a time-varying coefficients approach (see, for example, Wolff, 1987, Schinasi and Swamy, 1989, Frydman and Goldberg, 2001, De Grauwe and Vansteenkiste, 2001).

We contribute to this literature by modifying the RID model with a Markov switching process in the underlying fundamentals. This approach is closest in spirit to Frydman and Goldberg (2001), who test a cointegration relationship in the context of a monetary exchange rate model for structural breaks, and to De Grauwe and Vansteenkiste (2001) who rely on a broad set of fundamentals but not on a precisely determined fundamental model. In this paper we go beyond the content of a companion paper (Frömmel, MacDonald and Menkhoff, 2002) by utilizing a longer time period, including the first years since the introduction of the Euro. Moreover, we are keen here to explore the role played by interest rates, and to this end we present a variant of the baseline model in which the role of interest rates is brought into sharp relief.

The paper is organized as follows: Section 2 reviews the relevant exchange rate literature and places our contribution in the context of this literature. Section 3 presents empirical evidence in favor of a fundamental model with time-varying coefficients. A concrete modeling technique is proposed and applied to the D-Mark/Euro–Dollar exchange rate in Section 4. Section 5 proposes some economic rationale to the regimes identified. Section 6 concludes.

2 Motivation from exchange rate modeling

Jeffrey Frankel (1979) extended the workhorse of exchange rate modeling, namely the monetary model, by differentiating the impact on the exchange rate of short and long term interest rates. The flex price monetary model translates national money demand functions to the international level and thereby assumes that higher interest rates reflect lower money demand. Therefore higher domestic interest rates are related to an increase of the price of foreign currency, the exchange rate. This view contrasts starkly with the Mundell-Fleming-Dornbusch model, where higher interest rates generate capital inflows which appreciate the home currency, i.e. decrease the exchange rate. The latter effect is usually motivated in terms of the effect of a liquidity impulse in the presence of sticky prices.

A possible way of understanding these contradictory views builds on the distinction of the Fisher equation, that the nominal interest rate can be divided into real interest and expected inflation components. From this point of view, the flex price monetary model stresses the importance of inflation on interest rates and then on exchange rates, whereas the sticky price Mundell-Fleming-Dornbusch view neglects inflation and stresses the real interest rate, or liquidity, component of nominal interest changes. We interpret the Frankel model as an empirically driven approach which attempts to pick up this distinction in interest rate determination. The standard Frankel reduced form is:

$$e_t = \alpha \cdot (m_t - m_t^*) + \beta \cdot (y_t - y_t^*) + \gamma \cdot (i_t^s - i_t^{s*}) + \delta \cdot (i_t^l - i_t^{l*}) \quad (1)$$

where the short term interest rates, i^s, are designed to capture liquidity, or real effects while the long term rates, i^l, are designed to capture expected inflation effects. The pragmatic approach to exchange rate modeling of Frankel received considerable empirical support for the early part of the post Bretton Woods period (see, for example, MacDonald, 1988) but less so for the more recent part of the floating rate period (see MacDonald, 2004). Clearly one reason for this is that there were too many other influences "disturbing" and contaminating the real-interest / exchange rate relationship. Indeed, this instability in exchange rate modeling reappears again and again in the literature and emerges as a kind of stylized fact (see recently Faust, Rogers and Wright, 2003). A possible way to address this instability is to distinguish different states of exchange rates. In the most simple variant of this, there is one state where Frankel's RID model holds and a second one where other influences dominate. This is exactly what motivates our choice of a regime switching approach.

3 Further motivation for the RID from survey-based evidence

In this section we consider some further evidence which is supportive to the RID model. In particular in Section 3.1 we present evidence from survey data questionnaires which favors the RID. In Section 3.2 we update the relations between fundamentals and the D-Mark/Euro–Dollar rate in the vein of Meese (1990).

3.1 Evidence from questionnaire surveys

The use of any fundamental exchange rate model will be much more convincing if market participants themselves say that they rely on this kind of information. Whereas traditional exchange rate theory always assumed only economic (or political) fundamentals could influence practitioners thinking, the microstructure research of the 1990s showed the limited reach of this approach. In fact, technical analysis has, since the 1980s, been a hard rival in conquering practitioners time tables and in recent years has revealed that flow analysis has to be taken seriously as another source of information. However, summarizing the results from earlier studies, Figure 1 shows what role fundamental analysis played ten years ago and that they still play an important part in professionals reasoning today. Although it has lost importance over time, fundamental analysis is still important for FX dealers and even dominates the calculus of the rising fund managers.

When it comes to the kind of fundamentals that are taken into account by FX dealers, the prominent position of interest rates – reflecting its prominence in exchange rate modeling – is beyond doubt. As an example for their relative importance, Figure 2 shows the agreement on (the change in) interest rate difference in comparison to other fundamentals that were named by professionals. Both interest rate items clearly rank above other fundamentals. One can recognize, moreover, the important positioning of the other variables of the monetary model: business indicators as well labor market figures represent the "income" variable, whereas growth in money as well as inflation represent the "money" variable. Note, moreover, that further variables rank far behind, cautiously indicating that indeed the monetary model's variables are in the mind of market participants.

Finally, earlier research has demonstrated the importance of forecasting horizons for the way how professionals think about exchange rates. Fundamentals are considered more at longer horizons. So, it is interesting to see whether interest rates matter at horizons of all lengths. Figure 3 shows the importance given to interest rates as a source of information for FX dealers and international fund managers, grouped by the typical forecasting horizon of professionals. It is found that the positive relation of horizon and the fundamental variable "interest rate" also shows up here but that interest rates do matter even for short term oriented professionals.

Overall, these survey findings demonstrate that FX dealers and fund managers consider several sources of information but that fundamentals should not be neglected in this respect. Among the many fundamentals, interest rates are of special importance. We take this as a cautious indication for the potential usefulness of our approach which relies on fundamentals and on interest rates in particular.

3.2 Evidence on the relation of fundamentals and the US Dollar

Meese (1990) reported for the first 14 years of the post Bretton Woods regime that relationships between fundamentals as well as between fundamentals and exchange rates are often hard to rationalize. We take up his notion and re-examine the relation between the fundamental variables and the exchange rate considered here. Due to the focus of the present research, it seems most interesting to compare relations over several sub-periods. These sub-periods are chosen according to the major fundamental shocks in either the US or Germany. A first period would thus be formed until the year 1980 when the second oil price shock happened and the Federal Reserve changed its policy towards a strong anti-inflationary stance. The next structural break could be the year 1990, marking German unification. A third event is the introduction of the Euro at the turn of 1998/99. These break points define four sub-periods.

Table 1 gives the coefficients of rank correlation for fundamentals of the RID model with the D-Mark/Euro-US Dollar rate for these sub-periods. It is found that the sign of the coefficients for the total sample only conforms to expectations of the monetary model for the income differential. Moreover, the sign of coefficients over time is unstable for all four variables of the RID model. This can be seen as another clear motivation for applying exchange rate models with varying coefficients.

Turning to the behavior of the short and long term interest differential over the whole 30 year period, Figure 4 gives a picture using monthly data. The exchange rate is expressed as a 12-month change, i.e. the variable that is to be explained later. The interest rate differentials are expressed as US rates minus German rates. As is well-known from term structure theory, both interest rate differentials move largely in the same direction. In addition, it can be recognized that a widening of the interest rate gap in favor of the US Dollar tends to appreciate this currency. The relations are of course not as tight as we would like to have them but the importance of interest rates seems to shine through even in this illustrative figure.

In summary, there is evidence from questionnaire surveys, as well from preliminary relations of fundamentals with the US Dollar, that substantiate the main claim made in this paper: fundamentals matter for exchange rates and interest rates are of particular importance, but relations are not stable over time and hint at a non-linear relationship. This is in line with other empirical works (e.g. So, 2001). In this context De Grauwe (2000) stresses the importance of changing beliefs of the market participants.

4 Regime switching model

4.1 The Markov switching approach

For analyzing the time-varying influence of interest rates on exchange rate movements we rely on the Markov switching model, which we subsequently describe (for a more detailed discussion see Hamilton, 1994, chapter 22, Kim and Nelson, 1999, chapter 4). In this model the conditional distribution of the mean depends on the value of a non-observable state variable s_t, which in our case may take two values (1 and 2). The model extends Frankel's (1979) original RID model by allowing the constant and the coefficients for the short and long term interest rates to switch, depending on the value of the state variable. The coefficients on the money stock and income differentials are, by contrast, kept constant across regimes[1]. Furthermore, we rely on one year changes in the variables. This is due to the observation that purchasing power parity, which is a substantial element of Frankel's model, does hold for differences rather than for levels. Furthermore this approach reduces noise in the observations and avoids seasonal effects in the data.

The mean equation for the return of the exchange rate is as follows:

$$\Delta e_t = \omega_{s_t} + \alpha \cdot (\Delta m_t - \Delta m_t^*) + \beta \cdot (\Delta y_t - \Delta y_t^*) + \gamma_{s_t} \cdot (\Delta i_t^s - \Delta i_t^{s*}) + \delta_{s_t} \cdot (\Delta i_t^l - \Delta i_t^{l*}) + \varepsilon_t \qquad (2)$$

where Δ denotes the one year percentage change in the respective variable and ε_t is Gaussian white noise. The coefficients ω_{s_t}, γ_{s_t} and δ_{s_t} depend on the state variable s_t, which may take the values one or two. If the values of s_t were known, that is if we knew the dates of structural breaks, the model would be nothing more than a simple dummy variable model. However, as the outcomes of s_t cannot be directly observed, it is assumed to follow a first order Markov chain. This underlying process is governed by the transition probabilities $p_{ij}=Pr(s_t=j \mid s_{t-1}=i)$, $i \in \{1,2\}$.

By estimating the coefficients one has to make inferences about the values of s_t. As a result of the estimation procedure (see Kim and Nelson, 1994, for further details) we obtain the probability of being in state 1 in period t conditional on the *information up to period t*. This probability is referred to as the filter probability. Based on the filter probability and the matrix of transition probabilities p_{ij} we can then calculate (Kim, 1994) the probability of being in state 1 in period t conditional on the *information in the whole data set*, the smoothed probability. As this paper focuses on understanding the role interest rates play in exchange rate determination rather than on forecasting exchange rates[2], we use all available information and rely on

[1] If all coefficients are allowed to switch, Wald- and LR-tests indicate that the difference in the coefficients for money and income are not significant. Therefore the unrestricted model does not outperform the restricted one.

forecasting exchange rates[2], we use all available information and rely on smoothed probabilities. However, the results between the two approaches do not differ substantially.

4.2 Earlier findings

Applications of the Markov switching model to exchange rates started with models which excluded fundamentals. Engel and Hamilton (1990) and Engel (1994) use a Markov switching model, in which the conditional distribution of quarterly exchange rate returns simultaneously switches in both, mean and variance. Both works find long swings in the data but stress the poor out-of-sample forecasting performance of the Markov switching model. Later studies separate the switches in mean and variance either by using two distinctive state variables for mean and variance each (Dewachter, 1997) or by using a Markov switching model with four states differing in mean or variance (Bollen, Gray and Whaley, 1998, Dewachter, 2001). Again, regime switches seem to capture some major dynamics that characterize exchange rate behavior, although the structures may be varying over time.

In comparison to these purely time-series oriented approaches, there are few works incorporating fundamentals in a Markov switching model of exchange rates. Marsh (2000) applies a Markov switching model for daily exchange rate changes, including interest rate differentials as the only fundamental variable. The performance of this model is poor, probably due to the comparatively high frequency of the data. De Grauwe and Vansteenkiste (2001) use a broader set of fundamentals (money stock, inflation rates and long term interest rates) to explain monthly exchange rates of several high and low inflation countries. They detect regime switches for high inflation countries, but far less for low inflation countries. In contrast, Frömmel, MacDonald and Menkhoff (2002) find evidence for regime switching coefficients by applying a monetary exchange rate model to monthly data of the three most heavily traded exchange rates. They come to the conclusion that the Markov switching model is able to capture the movements of these rates much better than a linear model, although the out-of-sample forecasting performance again is poor.

[2] The model does not significantly outperform competing models in forecasting. Obviously there are important other forces besides the fundamentals captured in the models, which are driving the exchange rate in the shorter run.

The evidence for a regime switching monetary model is supported by Frydman and Goldberg (2001), who test a monetary exchange rate model for the Deutsche Mark/US Dollar exchange rate for structural breaks. They do not incorporate the regime switches in the model but estimate a cointegration relationship between the exchange rate and the fundamentals for each subsample. The position of those breaks is roughly the same as in Frömmel, MacDonald and Menkhoff (2002).

Summing up so far, there exist a few studies on exchange rates and fundamentals incorporating regime switches. They tend to focus on the detection of regime switches rather than on the role of fundamentals. Our paper adds to this literature by focusing on the forces driving the regime switches; that is, the question of whether the different regimes may be characterized by some specific circumstances.

4.3 New results

Our sample consists of monthly data from the IMF's International Financial Statistics database. These are, besides the exchange rate of the Deutsche Mark respective the Euro against the US Dollar, the money stock M2, seasonally adjusted industrial production as a proxy for income, the federal funds rate (US) and the money market rate (Germany) as a short term interest rate and government bond yields as long term interest rate[3]. All series are available for the whole period from 1973 to 2003, with exception of the money stock. This series ends with the introduction of the Euro in January 1999 and was extended using the German share of European money stock M2 in the Deutsche Bundesbank's time series database. The whole series has then been corrected for structural breaks due to German reunification and a different calculation of money stock by the Bundesbank before and after January 2002 (currency in circulation is no longer included in money stock). There are several ways to deal with such effects. Following Weber (1996) we treat the breaks as a one time shift and correct the series of money stock for this. For industrial production we do not detect a structural break and therefore do not adjust the series. This may be justified by the low level of industrial production in the former German Democratic Republic after reunification.

[3] The codes of the series are as follows: 134.RF.ZF (exchange rate); 111.39MBC and 134.39MBC (money), 111.66...CZF and 134.66...CZF (industrial production), 111.60B...ZF and 134.60B...ZF (short term interest rate); 111.61...ZF and 134.61...ZF (government bond yield).

One would expect that the coefficient on money (α) is positive and large (which means close to one) whereas the sign of the coefficient on income (β) should be negative and about -0.5. The influence of interest rates seems to be more interesting: in the RID framework γ (short term) is expected to be negative, whereas δ (long term) is expected to be positive (for a discussion of the signs see Frankel, 1979).

Frankel's RID has been estimated in its original form and in the Markov switching specification from equation (2). The estimation results are given in Table 2. The first three columns on the left show estimation results for the whole period from 1974 to 2003. It is noteworthy that the sign on the coefficient for the money stock is wrong for the constant coefficient RID model. This is in line with most empirical work. Although Frankel's (1979) initial results favored the RID model, the results broke down when the period was extended beyond 1978 (see, inter alia, Backus, 1984, MacDonald, 1988, Papell, 1997). In contrast, the coefficient is correctly signed (although not significant) in the RID model with Markov switching coefficients. The estimation for β (the coefficient on income) performs much better for both models, being highly significant and close to the expected value. The results for the interest rates are again remarkably different across the models: the constant coefficient model shows estimations which are contradictory to Frankel's model as they are all wrongly-signed. However, if the coefficients are allowed to switch, we find signs which are in accordance with the expected values from the RID in one regime (subsequently referred to as regime 1) and equal the results from the constant coefficient estimations in the other regime (regime 2). It should be noted that the regimes are highly persistent. The probability of remaining in the current regime are 0.954 (regime 1) and 0.953 (regime 2), which means that the expected durations of the regimes are between 21 and 22 months.

It is of interest to know how the models perform when the sample is split into a pre-EMU sample (1974-1998, 300 observations) and a post-EMU sample (1999-2003, 52 observations). Unfortunately, the latter sample is comparatively short, so we do not apply the regime switching model, which requires estimation of 13 coefficients. For the pre-EMU sample the results are even more in favor of the regime switching approach. The coefficient for money stock becomes significant (at the 10 per cent level). This may reflect that the German share in the European money stock is less important for the EUR/USD rate than the German money stock was before 1998 for the former DEM/USD rate. The other coefficients remain remarkably stable.

The constant coefficient model does not show any improvement for any subperiod. Furthermore, the estimation seems to be much less stable than those for the regime switching model and for all subperiods the regime switching model tracks the data better than the linear model, showing much lower errors. Table 2 gives the results for the mean average error and the root mean squared error in the respective rows. The average error of the RID model with regime switching coefficients is only about half of the error of the conventional RID model.

5 Characteristics of regimes

The Markov switching model has clearly revealed that there are two regimes which differ with respect to the signs of fundamentals. In order to interpret the fundamental variables and, in particular, the impact from interest rates it seems useful to switch from growth rates to levels where feasible. Figure 4 above provides another justification to analyze the difference in interest rates. Moreover, Frankel (1979) suggested that the inflation environment should play a role in the sense that higher inflation would reduce the appropriateness of his RID model. Thus the difference in inflation rates is also considered.

Taking these variables as explanatory variables in order to characterize regime 1 and regime 2 of the Markov switching RID (see Table 2) requires a logit regression approach. Table 3 gives the coefficients of the full model 1, whereas model 2 considers only the statistically significant variables. Both models are not significantly different, as the LR test shows.

A first insight is the negative sign of the inflation variable, confirming Frankel's suggestion. The higher the inflation differential, i.e. normally the more the US inflation is greater than the German inflation, the less does the RID model (regime 1) apply to the data (see also Figure 5). Second, it is only the short term interest rate that has a positive sign and thus directly reflects the RID model: accordingly, high US money market rates favor the US Dollar. Third, the last significant fundamental variable, the growth in income, has a negative sign. That is, high US growth rates do not fit the RID model, possibly due to the fact that high growth causes higher longer term interest but less so because of heavy inflation concerns but more due to increasing real interest rates. This is a scenario not covered by the RID model.

We cautiously conclude that some economic rationale may be underlying the pure statistical identification of two regimes. Focusing on interest rates, regime 1 – the RID model – fits primarily to the classic Mundell-Fleming-Dornbusch case where higher short term interest rates appreciate a currency. The importance of this scenario is also highlighted by simulations in Carlson and Osler (2003) which intend to capture portfolio flows by a calculus being based on short term interest rates. Regime 2, however, the "non-fundamental" regime which does not fit any monetary model may be driven by high growth which, in turn, increases longer term interest rates. The central argument would be that these increasing rates are not caused by "pure" inflation fears but by improved investment opportunities. The latter might be reflected by capital inflows in the stock market (see Hau and Rey, 2002).

6 Conclusions

This paper examines the influence of interest rates on the exchange rate of the Deutsche Mark respective the Euro against the US Dollar. We do this using a version of Frankel's (1979) real interest differential model, in which the influence of interest rates on the exchange rate is allowed to change over time. The approach is motivated by theoretical considerations as well as by empirical findings. The choice of a regime switching model stems from the failure of the traditional monetary model to detect stable relationships between fundamentals, especially interest rates, and exchange rates across different sub-samples. However, questionnaire surveys indicate that interest rates do play a dominant role in professionals' decision making process.

We find that the real interest differential model does indeed perform much better when the coefficients for the interest rates are allowed to switch. There is one regime which shows correctly signed coefficients with respect to Frankel's RID, whereas the other regime shows an inverted relationship between interest rates and exchange rates. In contrast, the RID without regime switching does not show estimations which are consistent with theory.

Based on the clear-cut assignment of periods to the regimes we are then able to analyze the influence of fundamentals on the regimes. Our results show a close relationship between (short term) interest rates and inflation on the one hand and the regimes identified by the Markov switching model on the other hand. By contrast, the impact of differences in money stock and long term interest rates on the regime is weak.

Summing up, our findings support the view of a highly nonlinear and complex formation of exchange rates (Mahavan and Wagner, 1999) and lead to the following conclusions. First, there is evidence of an unstable and nonlinear relationship between fundamentals and exchange rates. Secondly, modeling this time-varying nature of the importance of fundamentals in a Markov switching framework substantially improves the fit of the RID model and leads to parameter estimates which are in one regime in line with those theoretically expected, and allow us to draw reasonable conclusions on the influence of fundamentals on exchange rate dynamics. Third, there are mainly three factors, which are closely related to regime switches: short term interest rate, inflation differentials and differences in economic growth. The money stock and long term interest rates on the other hand do not play any substantial role. According to our results Frankel's approach seems to be most appealing in an environment of low differences in inflation and growth, going ahead with a large difference in short term interest rates. Therefore fundamentals do not only matter for the exchange rate *within* each regime, but are also related to the switches *between* the regimes.

In sum, it seems that nonlinear modeling of exchange rates is able to improve our understanding of exchange rate determination.

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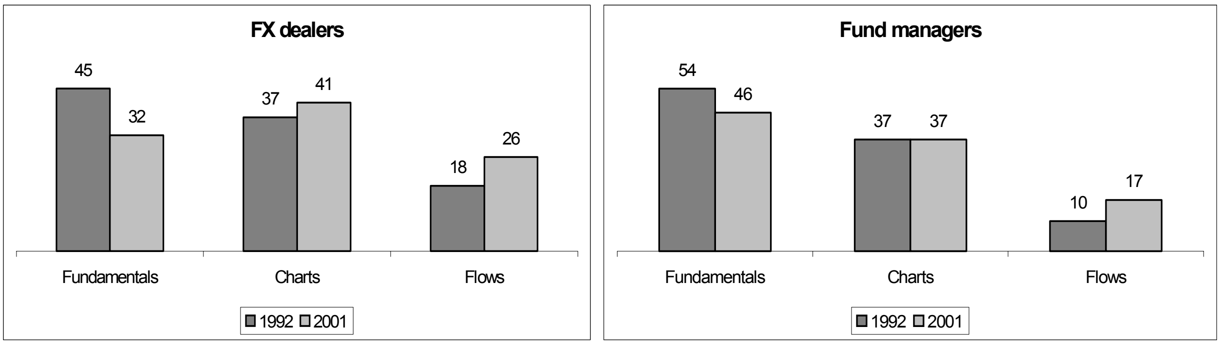
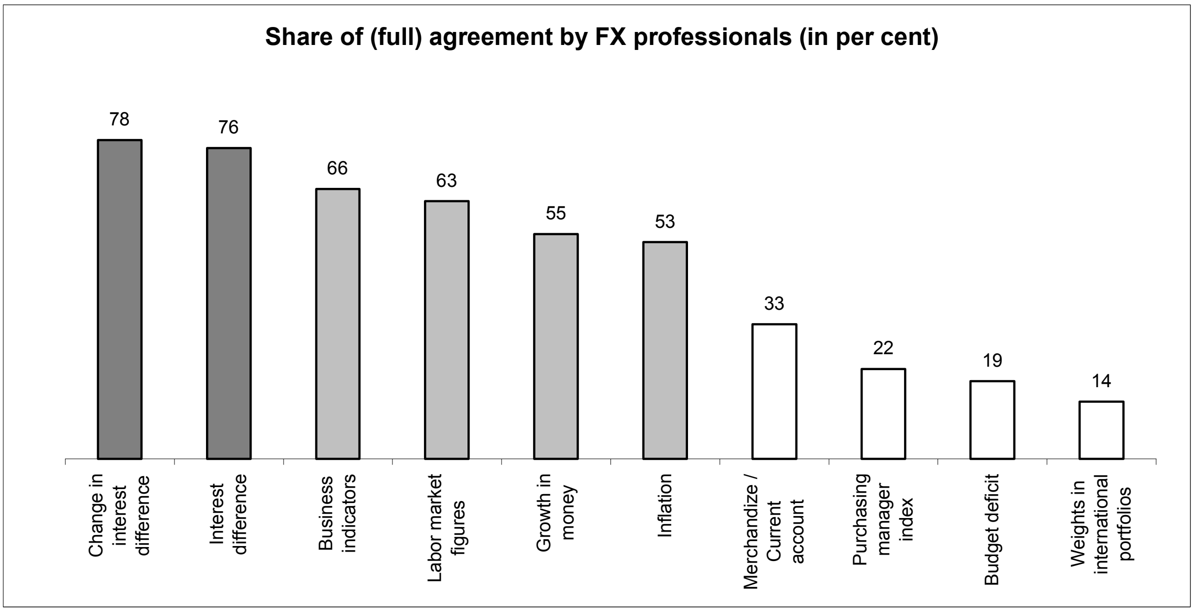
FIGURE 1. The relative importance of fundamental information (in per cent) for the year 1992 and 2001 respectively.



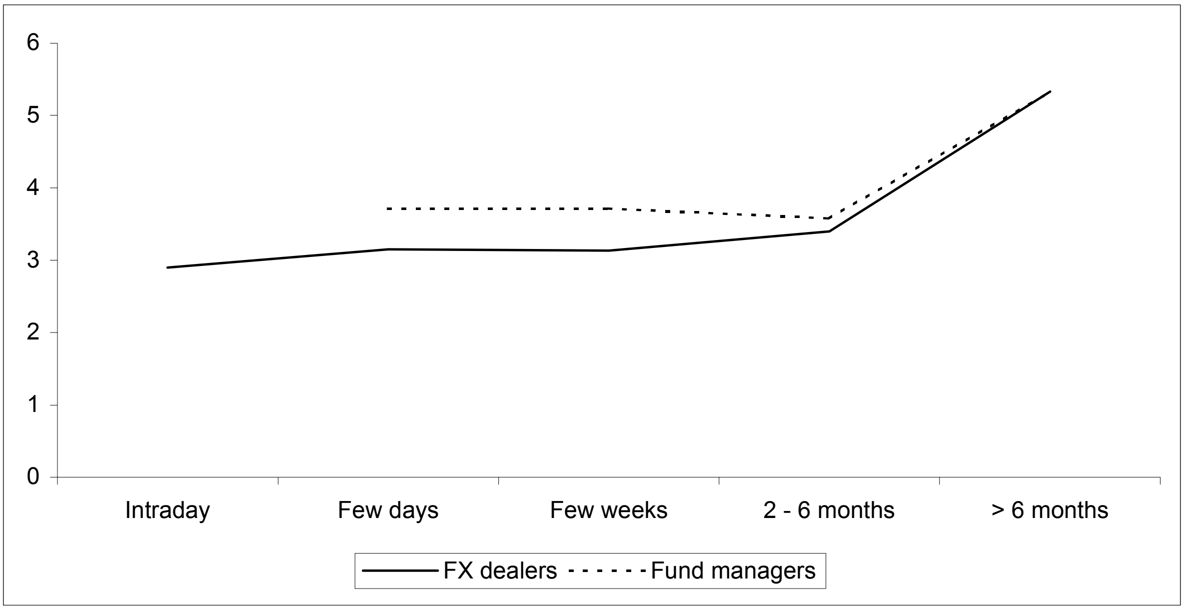
This figure presents answers on the following question: "Please evaluate the importance of the three following information types for your typical decision making, by distributing a total of 100 points. For information types which you do not use, please give 0 points. … Fundamentals (economic, political), … Technical analysis (charts, quantitative methods), … Flows (who is doing what, which customer orders are existing)."
The left bars are based on Menkhoff (1998), representing about 200 responses from Germany in 1992, the right bars are based on Gehrig and Menkhoff (2003), representing about 200 responses from Germany and Austria in 2001.

FIGURE 2. The importance of interest rates in relation to other fundamentals



This figure gives the share of the two answering categories with relatively full agreement on the following question: "Some regard the impact of the following economic factors on exchange rates (presently) as important. What is your opinion for each of these factors. Please give a mark between 'full agreement' and 'full disagreement' [6 categories]. [List of 10 fundamentals]."
The data are based on Menkhoff (1998), representing 168 responses from Germany in 1992 for these items.

FIGURE 3. The importance of interest rates at different forecasting horizons



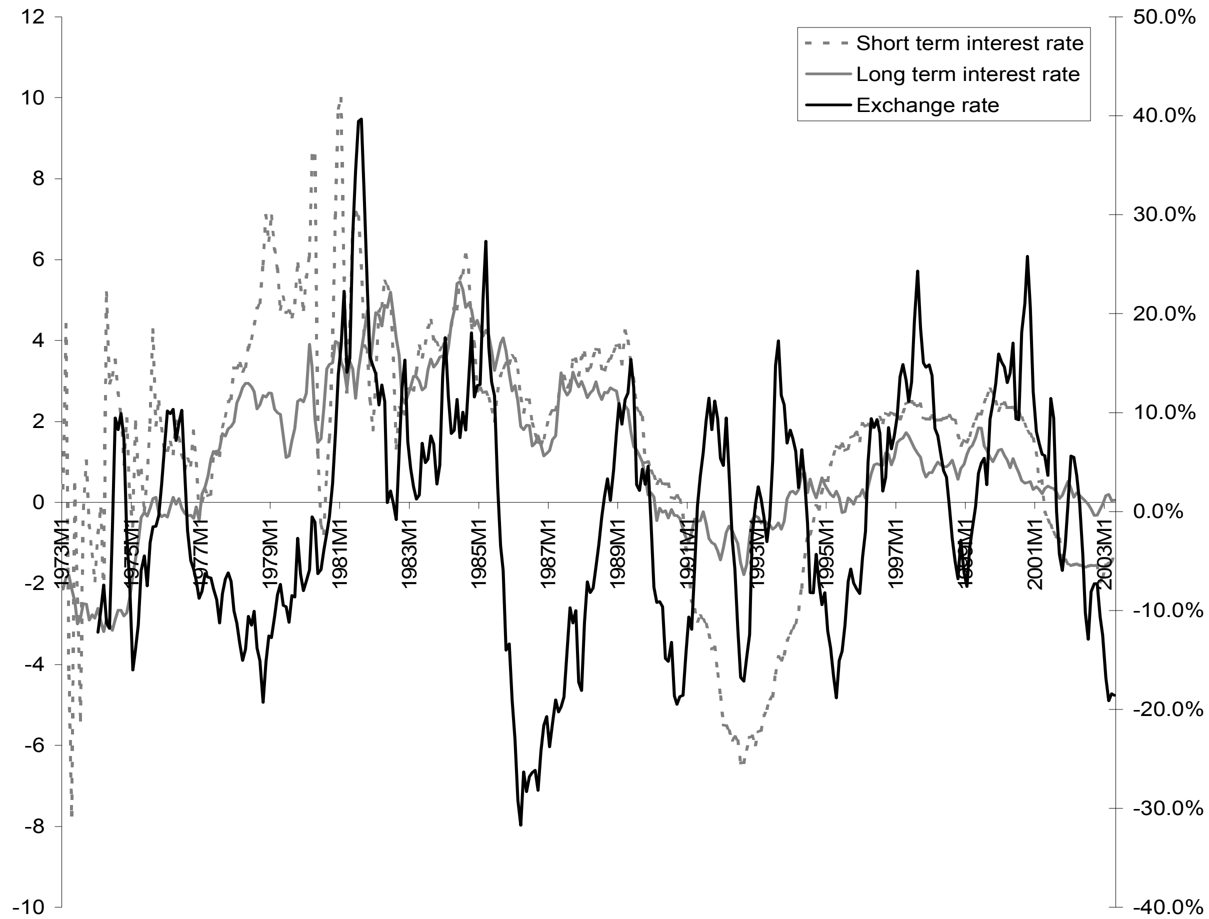
This figure firstly orders respondents according to their answer on the following question: "How far in advance do you take into account possible influences on the exchange rates when opening a position?" Then, secondly, the average answer on the following question is given: "How important is for your decision-making the 'level of money market rates' as source of information? [6 response categories from 1 for 'totally unimportant' to 6 for 'very important']."
There were no answers for 'fund managers' and 'intraday'.
The data are based on Gehrig and Menkhoff (2003), representing about 200 responses from Germany and Austria in 2001.

TABLE 1. Pearson coefficients of correlation between fundamentals and exchange rate

Fundamentals of the RID model	Expected sign	Time periods				
		1974 - 2003	1974 - 1980	1981 - 1990	1991 - 1998	1999 - 2003
$m_t - m_t^*$	> 0	-0.136** (0.011)	-0.485*** (0.000)	-0.200** (0.029)	0.037 (0.722)	-0.273** (0.050)
$y_t - y_t^*$	< 0	-0.115** (0.031)	0.130 (0.238)	-0.223** (0.014)	-0.111 (0.280)	0.220 (0.117)
$i_t^s - i_t^{s*}$	< 0	0.032 (0.545)	0.052 (0.641)	-0.114 (0.216)	0.231** (0.023)	-0.025 (0.858)
$i_t^l - i_t^{l*}$	> 0	-0.103* (0.053)	-0.023 (0.835)	-0.245*** (0.007)	-0.326*** (0.001)	0.000 (0.999)

Asterisks refer to level of significance, *: 10 per cent, **: 5 per cent, ***: 1 per cent, p-values in parentheses. The expected signs are according to Frankel (1979).

FIGURE 4. The relation between interest rate differential and the DEM/EUR-USD



The figure shows the percentage exchange rate changes over a period of 12 month each (bold line, right axis), the difference of long term interest rates between the US and Germany (thin line, left axis) and the difference of short term interest rates between the US and Germany (dotted line, left axis). The correlation of exchange rate changes and interest rate differentials are 0.215 (long term) and 0.137 (short term).

TABLE 2. The coefficients of the Markov switching RID (MS-RID) in comparison with the coefficients of a linear RID (RID) over different subperiods

	1974-2003			1974-1998			1998-2003
	MS-RID		RID	MS-RID		RID	RID
	s_t=1	s_t=2		s_t=1	s_t=2		
Constant	0.093***	-0.119***	-0.011	0.091***	-0.123***	-0.017**	-0.009
Money	0.032		-0.288**	0.126*		-0.193	-4.017***
Income	-0.538***		-0.415**	-0.538***		-0.483***	0.876
Interest rates							
Short term	-0.076***	0.037***	0.042**	-0.091***	0.028*	0.043**	-0.440***
Long term	0.228***	-0.098***	-0.069	0.181***	-0.082*	-0.096*	-0.071
p_{11}	0.954***		--	0.950***		--	--
p_{22}		0.953***	--		0.955***	--	--
MAE	0.050		0.099	0.051		0.099	0.078
RMSE	0.063		0.120	0.063		0.120	0.099

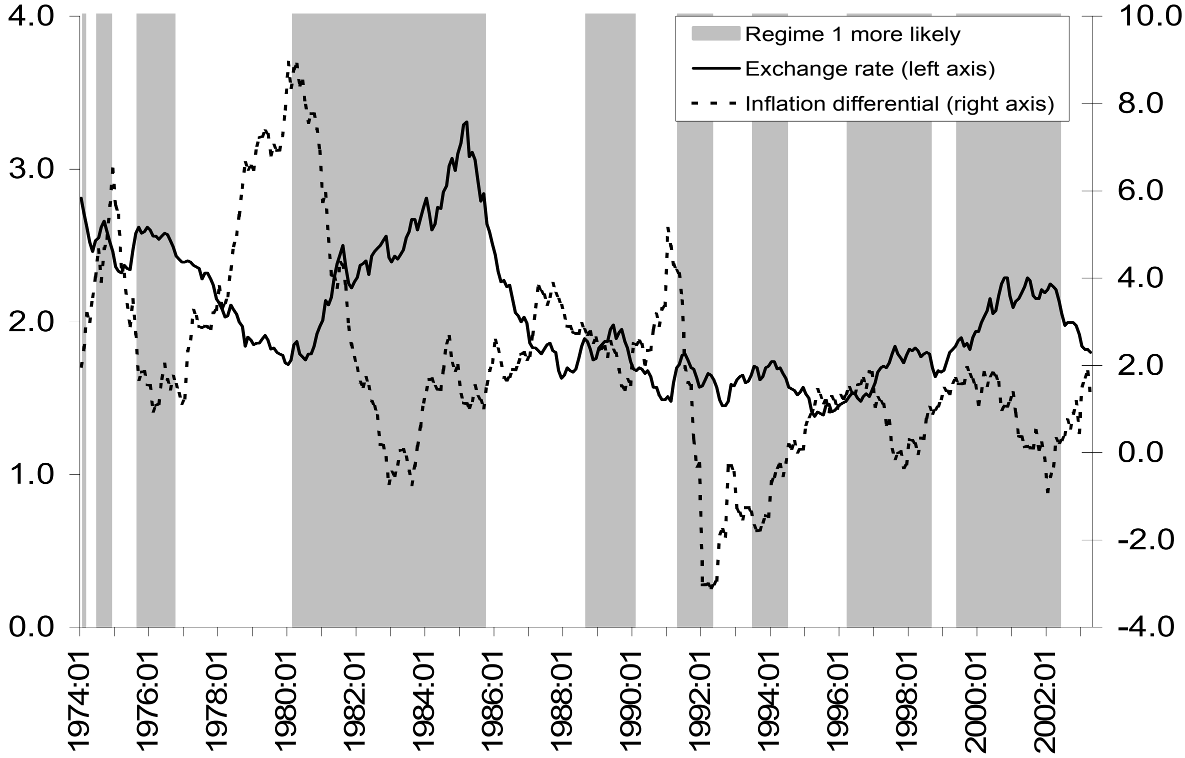
Due to the few observations the Markov switching RID could not be calculated for the period 1999-2003.
Asterisks refer to level of significance, *: 10 per cent, **: 5 per cent, ***: 1 per cent, p-values in parentheses. MAE means mean average error, RMSE root mean squared error.

TABLE 3. Estimation results of a logit regression analysis on regime

Difference in…	Model 1	Model 2
Growth of money stock	-0.248	--
Growth in income	-13.700***	-12.815***
Short term interest rate	0.389***	0.329***
Long term interest rate	-0.117	--
Inflation (CPI)	-0.626***	-0.557***
Constant	1.159***	0.961***
Observations regime = 0	160	160
Observations regime = 1	192	192
Loglikelihood	-205.858	-207.143
LR test		2.571 (p=0.277)
McFadden R^2	0.151	0.146

All differences are defined as US minus Germany, the dependent variable takes the value 1, if the Markov switching model is in favor of the RID and 0 otherwise. A positive coefficient means that high values of the respective variable increase the probability of being in the regime consistent with the RID.
Asterisks refer to level of significance, *: 10 per cent, **: 5 per cent, ***: 1 per cent, p-values in parentheses.

FIGURE 5. Regime inference and inflation differential



The figure shows the development of the DEM/USD exchange rate (beyond 1998 calculated from the USD/EUR rate; bold line, left axis) and the inflation differential (US increase of CPI minus German increase of CPI; dotted line, right axis). The shadowed areas mark the periods where regime 1, which is in favor of the RID model, is more likely than regime 2.