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APPLICATION OF FUNDAMENTAL MODELS TO MONEY AND EXCHANGE RATE MARKETS

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Abstract

The present paper addresses the issue of fundamental determinants of US and Euro area government bonds interest rate levels, yield curve spreads and G3 foreign exchange rates. The author aims to find whether there exist any fundamental indicators that would allow one to register some "equilibrium level" on the markets.

As a baseline for modelling interest rate and yield curve spreads, the conventional IS-LM framework, and for modelling exchange rates, the standard monetary model of exchange rates were chosen. The estimated models cover 10-year government bonds interest rate levels and 2-year-10-year yield curve spreads in the US and Germany, and the USD/EUR and USD/JPY exchange rates.

The results indicate that the fundamental indicators can give relatively accurate estimates of the equilibrium value *ex post*, but *ex ante* model estimates may lag behind the actual market cycle turning points.

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Comments welcome

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APPENDIXES

Introduction

This paper is a small introductory overview of the first steps made on the way to building a working set of fundamental and technical applications that could be helpful in the investment decisions made by a conservative investor who invests its funds only in the government bond markets of the G3 countries (the United States, Euro area and Japan). An example set of such conservative investors could include central banks, governments and conservative pension funds.

For an investor investing its funds on global bond markets, the return in short-medium term is determined by the following factors:

- Fluctuations of government bond interest rates. If the interest rates fall, then the prices of bonds (and also the wealth of the investor) will rise and vice versa — if interest rates rise, then the prices of bonds will fall. Therefore the return of an investment can be increased by holding the funds on relatively longer maturities during the periods of falling interest rates and relatively shorter maturities during the periods of rising interest rates. Also advantage can be taken of the relative movement of interest rates (rise in one region relative to another, rise in one maturity sector relative to another etc) if properly predicted.
- Fluctuations of exchange rates. Although some conservative investors prefer to hedge all exchange rate risk, correctly predicting the movement of exchange rates can be a source of additional return.

The present paper addresses the issue of fundamental determinants of interest rate levels and foreign exchange rates. The purpose of the paper is to determine whether there exist any fundamental indicators that would allow us to determine some

"equilibrium level" on the markets. If an "equilibrium level" could be determined, then the deviations from this level would tell us that there is a bigger probability of the markets moving towards the equilibrium (and not the opposite way), thus enabling the investor to increase his/her return over time[1].

The paper falls into three sections. The first one describes briefly the theoretical baselines of the models, in the second section the models are estimated and in the third section their performance is tested. The models cover the movements of the US and Germany's 10-year government bond interest rates, the movements of yield curve spreads (between 10-year and 2-year interest rates) and the movements of the USD/EUR and USD/JPY exchange rates. The estimation results in sections 2 and 3.1 are given for the period when the models were estimated for the first time — ending between quarters Q3/2001 — Q1/2002, depending on the model. The real-life performance of the models after that period is discussed in section 3.2.

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[1] One can argue that at present the financial markets are so efficient that the increase of investors' return based on models estimated on publicly available macro data is not possible. However, many big international investment banks claim that they have investment models that enable them to earn additional returns relative to their benchmark in interest and exchange rate markets. Therefore the author concludes that the task is at least worth tackling.

1.   Theoretical basis

1.1. Theoretical basis for modelling long-term interest rates

As a theoretical basis for modelling 10-year interest rates the conventional IS-LM framework was used[2], where the LM equation expresses the relationship between the real money supply, income level and real interest rates:

$$m - p = \alpha y - \beta r$$

Rearranging and writing the real interest rate as nominal interest rate minus inflation expectations, we get:

$$i = E(\pi) - \frac{1}{\beta}(m - p) + \frac{\alpha}{\beta} y \text{ , where}$$

(all variables except the interest rate are in logarithms):

y – real income,
$E(\pi)$ – inflation expectations,
m – money supply,
p – price level,
i – nominal interest rate.

This theoretical basis (or its modifications/elements) has also been used in other studies that focus on modelling long-term interest rates, for instance, Hatzius (1999) used it for modelling the US 30-year T-bond interest rate, and Ilmanen (1999) for modelling the German 10-year interest rate. However, both models are already outdated to be used without re-estimation.

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[2] An alternative idea that was tested was the loanable funds equilibrium model (see for instance Caporale and Williams 1998 p 13) that included also the government's deficit (as an indicator of the supply of government bonds) and debt to GDP ratio (as a proxy for the default risk). However, during estimation, the government's deficit turned out to be statistically insignificant and in the context of government bonds of the USA and Germany, the author assumed that default risk can be left aside.

1.2. Theoretical basis for modelling exchange rate

As a theoretical basis the standard monetary model of exchange rate (Frankel, Rose p 1691–1692) was chosen. According to that, the nominal exchange rate is calculated by the following equation:

$$e_t = (p - p^*)_t = (m - m^*)_t - \beta(y - y^*)_t + \alpha(i - i^*)_t + \varepsilon,$$

where

e_t – log (price of foreign currency in domestic currency),
p – log (price level),
m – log (money supply),
y – log (real income),
i – nominal interest rate,
* denotes a foreign country.

According to previous research, the given model has had very little predictive power in short and medium term (*ibid,* p 1708), working somewhat better in a longer horizon. The reason is the huge amount of speculative positions in foreign exchange markets, which cause relatively large random speculative movements. Using data on quarterly averages (as is the case with the present paper) should, however, eliminate those disturbances, making it possible to capture the long-term effect of macroeconomic variables.

1.3. Theoretical basis for modelling the spread between short and long term interest rates[3]

The movements of **yield curve spread** are influenced by two factors — the movement of long-term interest rates and the movement of short-term interest rates. The theoretical basis for modelling the movements of long-term interest rates is presented in section 1.1. The movement of short-term interest rates is effected mainly by the (expectations of) political decisions about the base interest rate. Therefore also the base interest rate should be added as a negative factor (a decline in the base interest rate means that the spread will rise, *ceteris paribus*) into the model[4].

The approach where the yield curve spread is modelled by means of determinants of long-term interest rates, with short-term interest rates added as an additional exogenous variable, has been used before. For instance, Ilmanen *et al* (2000) used it to forecast the monthly return for a duration-neutral position between Germany's 1–3-year bond index and 7–10-year bond index, while Goldman, Sachs & Co (1997) used it for modelling the US 2–30 yield curve spread. However, the model estimated by Ilmanen *et al* was not meant for estimating the equilibrium value for the yield curve spread (this is the goal of the present

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[3] Alternative approach to make a model that could be useful in yield curve trades would be to model not only the spread but also the shape of the whole yield curve, using three parametres – the level, slope and curvature of the yield curve. A model by Diebold and Li (2002) is an example of such an approach. For simplicity, only the spread is modelled in the present article.

[4] The given approach is also consistent with the expectations hypothesis of the term structure of interest rates. Other theories explaining the differences between short- and long term interest rates (for instance, liquidity preference theory and market segmentation theory) were left aside, because it is relatively difficult to get time series about investors' liquidity preferences or about the supply and demand of loanable funds in different sectors of the yield curve.

paper) and some explanatory variables used by Goldman, Sachs & Co (e.g. budget deficit) turned highly insignificant in the subsequent years.

2.   Empirical estimation

2.1. Functional form and steps in estimation

Prior to estimation, the problem whether to use monthly or quarterly data was analyzed. Quarterly data were chosen for two reasons. Firstly, one of the main explanatory variables in the equations — the real GDP — is available only on a quarterly basis and secondly, it turned out that the monthly data had too much noise that obstructed proper estimation. As the quarterly data too had noise that could not be captured by fundamentals, then the series were additionally smoothed by means of the Henderson filter[5]. The whole process can be seen in Figure 1.
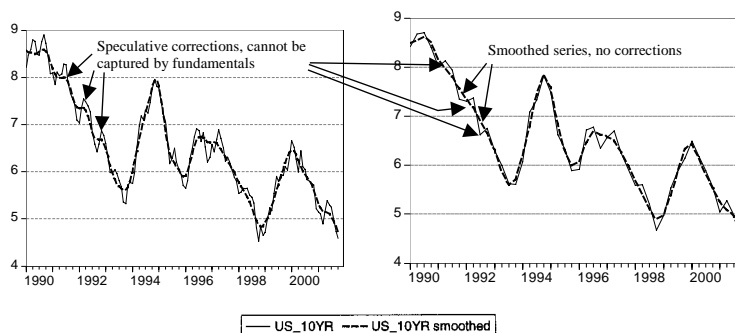

Figure 1. Smoothed and unsmoothed monthly and quarterly series of the US 10-year interest rate

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[5] Here the exception was the spread between the US 2- and 10-year interest rates that gave better results while estimated without smoothing.

Such a procedure allowed us to estimate the relationship bet-ween the cycles of different variables without possible disturbances caused by noise[6]. When using the estimated equations in forecasting, random errors were added during simulations, using the properties of noise eliminated during smoothing. Where possible, equations were estimated using vector error correction model specification. If such an approach gave unsatisfactory results, then the equations were estimated on differences. In cases where the coefficients of the parameters were not stable over time, the Kalman filter was used in estimation.

2.2. Estimation of the US 10-year government bond rate

The starting point for the estimation was the conventional IS-LM model described in section 1.1. The data from Bloomberg were used; higher frequency data were transformed into quarterly averages. In the course of the estimation, the following was discovered:

- At the beginning of 1995 there was a major break in the relationship between the interest rate and explanatory variab-les. Therefore only the data from Q1 1995 and later were used.
- No statistically significant long-term relationship between the levels was discovered. So the estimation was made on first differences.
- Different measures of money supply were not significant if used together with inflation. Nor were there any statistically good leading indicators available for money supply. There-fore money supply was not included in the analysis.

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[6] The elimination of noise has also a negative effect — without noise, the unit root, autocorrelation and other statistical tests cannot give accurate results any more. This fact has to be taken into account when interpreting the results.

- As the RGDP growth lagged behind the interest rate movements, the index of leading indicators that led movements in interest rates for one quarter was used instead[7].
- Forming statistically significant price expectations was rather difficult. Simple adaptive expectations did not give good results. Weighting together Consensus forecasts of CPI inflation and market expectations (calculated as the spread between the 10-year and 3 month interest rates[8]) gave better though also not completely satisfactory results. So also the actual inflation was used.

The final equation turned out as follows, its statistical properties are shown in Appendix 1 and notations in Appendix 5:

d(US_10YR_TC)=0.103*d(LEADING_US_4Q_TC$_{t-1}$)+
1.339*(0.3*CPI_NEXT1QDIF_F_TC$_{t-1}$+
0.3*d(SPREAD_US_TC$_{t-1}$)+0.4*d(CPI_US_4Q_TC)) - 0.058.

The constant can be interpreted as a decline in interest rate if price and real GDP growth expectations do not change, because of a decline in the uncertainty of future economic developments. The parameters of the equation have been relatively stable since the beginning of the year 2000.

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[7] Instead of the composite leading index, some studies have used separate leading indicators of economic activity. For instance, Ilmanen (1997) used relative stock market performance in modelling the US-Germany's 10-year interest rate spread. However, in the present article, a broader composite leading index was preferred.

[8] This spread was found by data mining from different combinations of short- and long term interest rates. The idea to test interest rate spread as a measure of market inflation expectations is based on the expectations hypothesis of the term structure of interest rates and various studies on leading indicators of the business cycle. Although besides the studies supporting the view of interest rate spread being an indicator of market expectations of inflation, there are also theories that put it in doubt (for the discussion of this problem and exact quotations see eg Newman et al 1992, p 817), the spread between 3-month and 10-year interest rates behaved statistically significantly in the given case.

2.3. Estimation of Germany's 10-year government bond rate

The basis for estimating the equation for Germany's 10-year government bond interest rate was the same as in the case of the USA. In the course of the estimation of the conventional equation, the following specifics were additionally discovered:

- High dependence on the US 10-year interest rates was revealed, the movements in the US 10-year rate explain about 50% of the movements in Germany's 10-year rate. The Granger causality test (presented in Appendix 2) too supports the given relationship[9].
- The variables of the whole Euro area had a better explanatory power than the variables of Germany.

The final equation ran as follows (statistical tests in Appendix 3, notations in Appendix 5):

$d(GER\_10YR\_TC) = 0.82*(0.3*d(SPREAD\_EMU\_TC_{t-1})+ .7*d(CPI\_EMU\_4Q\_TC)) + 0.49*d(US\_10YR\_TC) + 0.05*d(LEADING\_GER\_4Q\_TC_{t-2})$

Historically, this equation gave relatively good results, but *ex ante* it underestimated the actual interest rates during and shortly after the bear/bull market turning point in Q4 2001 and Q1 2002. In order to find a more precise equation, the following specification based on the Kalman filter was also estimated (statistical properties and dynamics of state variables in Appendix 4, notations in Appendix 5):

$d(GER\_10YR\_TC) = C1*(0.5*d(SPREAD\_EMU\_TC_{t-1})+ 0.5*d(CPI\_EMU\_4Q\_TC)) + C2*d(US\_10YR\_TC) + C3*d(LEADING\_GER\_4Q\_TC_{t-2})+[var=0.0001]$

$@state\ c1=c1_{t-1}+[var=0.001]$
$@state\ c2=c2_{t-1}+[var=0.00001]$
$@state\ c3=c3_{t-1}+[var=0.00002]$

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[9] However, the given relationship is not very robust. If we test the causality from the year 1994, then we get the opposite result – German interest rates Granger cause movements in US interest rates.

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This specification gave somewhat better forecasts for the given quarters (see Figure 2):
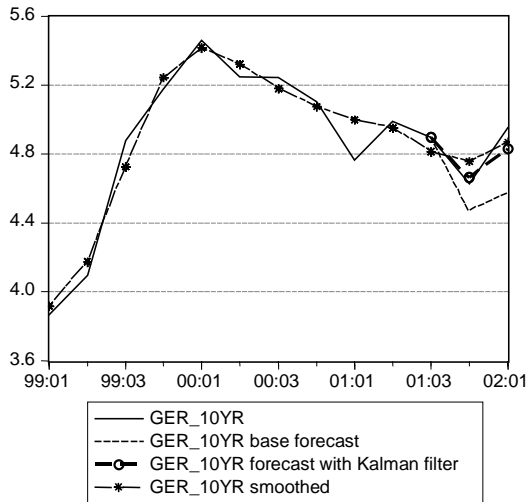
Figure 2. GER 10-year interest rate forecast for Q4, 2001 and Q1, 2002 with both equations.

As the difference between *ex ante* forecast results did not disappear in the next quarters either, the conventional approach was left aside in modelling Germany's 10-year interest rate. Instead, the equation based on the Kalman filter was used.

2.4. Estimation of the USD/EUR exchange rate

The estimation was carried out in accordance with the theoretical model described in section 1.2 and the methodology given in section 2.1. The following variables were used (data source: Bloomberg, data from Jan 1, 1989, if not indicated otherwise):

- Exchange rate: Daily exchange rate, price of 1 EUR (before Jan. 1, 1999 XEU) in USDs.
- Price level: Monthly CPI index. In the Euro area, the data were available from Jan 1996.
- Money supply: Monthly M1, M2 and M3.
- Real income: Real GDP. In the Euro area, the data were available from Q1 1991. The data were not converted into the same currency, as we are interested in the relative dynamics of the real GDP of the two countries, not in the absolute value.
- Interest rates: Daily statistics of 3-month, 2-year and 10-year nominal interest rates of government bonds. As the time series of the EMU interest rates were very short (from 1 Jan. 1999), the German interest rates were used instead.

The variables were transformed into quarterly frequency, averaging the observations of higher frequencies. Then the given series were seasonally adjusted by the Census X12 method and smoothed with the Henderson filter. First the relationship of the exchange rate was tested individually against all different factors of the model[10] (price level difference, money supply difference, real GDP difference, nominal interest rate difference). The results are presented in Table 1:

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[10] As the noise and seasonal components were eliminated from the series (leaving only trend and cycle components), no unit root tests were performed before estimation because of questionable interpretability of the results.

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Table 1

Results of the analysis

Factor	R^2	Lead(+)/lag(-)	Significant from
p-p*	Relationship contrary to theory, 1996:1 – 2001:3		
m-m* (M1)	0.65	0	1989:1
M2	Relationship contrary to theory		
M3			
y-y*	0.57	–2	1991:3
i-i* (3m)	No relationship individually		
i-i* (2y)	Relationship contrary to theory		
i-i* (10y)	Relationship contrary to theory		

From the results of the analysis we can conclude that the exchange rate has no relationship with price level difference, therefore the exchange rate was modelled, using the M1 and real income differences. Also short-term interest rates became significant if used together with M1 and real GDP.

The final equation was estimated in the error-correction form, using ordinary OLS, and turned out as follows:

dlog(EUR_USD_TC)=-0.08(log(EUR_USD_TC$_{t-1}$)-
0.88*(log(M1_US_TC$_{t-1}$)-log(M1_EMU_TC$_{t-1}$))+
0.07*(log(RGDP_US_TC$_{t-3}$)-log(RGDP_EMU_TC$_{t-3}$))-
0.02*(3MR_US_TC$_{t-3}$-3MR_GER_TC$_{t-3}$))+
1.2*dlog(EUR_USD_TC$_{t-1}$)-0.6*dlog(EUR_USD_TC$_{t-2}$)*

Notations are presented in Appendix 5; the cointegration test is presented in Appendix 6 and the statistical properties of the estimated equation in Appendix 7. According to the equation, only lagged or present exogenous variables are needed in order to forecast next quarters' change in exchange rate. This enables one to minimize the risk of inaccurate predictions of exogenous variables in practical forecasting.

2.5. **Estimation of the USD/JPY exchange rate**

The estimation of the equation for the USD/JPY exchange rate followed the previously estimated USD/EUR exchange rate equation. The following specifics were discovered:

- Unlike the conventional exchange rate representation for the USD/EUR exchange rate (x USD for 1 EUR), the conventional representation for the USD/JPY exchange rate is reverse (x JPY for 1 USD). Therefore also the explanatory variables were used in the reverse order.
- The difference between real economic growths of the two countries was statistically significant as a short-term explanatory variable, unlike the USD/EUR equation, where it was in the long-term part.
- Due to data availability, 6-month interest rates were used instead of 3-month rates.

The estimated equation was (notations in Appendix 5 and statistical tests in Appendix 8):

dlog(USD_JPY_TC)=-0.19*(log(USD_JPY_TC$_{t-1}$)-0.01*(JP_6MR_TC$_{t-1}$-US_6MR_TC$_{t-1}$)-0.23*(log(M1_JP_TC$_{t-1}$)-log(M1_US_TC$_{t-1}$))-5.17)+1.29*dlog(USD_JPY_TC$_{t-1}$)-0.86*dlog(USD_JPY_TC$_{t-2}$)+0.54*dlog(USD_JPY_TC$_{t-3}$)-1.03*d(log(RGDP_JP_TC$_{t-1}$)-log(RGDP_US_TC$_{t-1}$))

The equation shows that the USD/JPY exchange rate has a long-run relationship with the difference between short-term interest rates and money supply in both countries. In a short run, also the difference in real economic growth has an effect.

2.6. **Estimation of the spread between US 10- and 2-year interest rates**

The estimation was carried out using the theoretical framework for modelling nominal interest rates with the FED base interest rate added in order to better capture the dynamics of the 2-year

rate. In the course of the estimation, the following specifics were discovered:

- The time series of the spread was quite stable, hence no smoothing was necessary.
- Real GDP and CPI growth rates could not be estimated within one equation. A better result having been obtained with CPI, real GDP was left out of the equation.
- The present level of the spread turned out to be very important, as the spread has a strong tendency to move towards the historic average level. Therefore also the deviation on average of three last quarter's spreads from the historic average (0.77) was added as an explanatory variable.

The final equation was as follows (statistical tests in Appendix 9, notations in Appendix 5):

d(SREAD_US_10YR_US_2YR)=-0.43*d(FED_RATE)-0.07*((SPREAD_US_10YR_US_2YR$_{t-1}$ + SPREAD_US_10YR_US_2YR$_{t-2}$+ SPREAD_US_10YR_US_2YR$_{t-3}$)/3-0.8)+ 0.1*d(CPI_US_4Q)

According to the equation, the spread between US 10- and 2-year interest rates is determined by three explanatory variables. 1 bp change in base interest rate affects the spread 0.4 bp in the opposite direction, a 1% increase in inflation has a 10 bp positive effect on the spread, and the spread has a tendency to move towards its historically average value, which is ab. 80 bp.

2.7. Estimation of the spread between Germany's 10- and 2-year interest rates

The estimation procedure of the equation for the spread between Germany's 10-year and 2-year interest rates was similar to the previous (US) case. The only difference was that the spread time series in Germany was much more volatile than in the US, therefore the series were smoothed before estimation.

Also the US 10-year interest rate that was a rather significant factor in modelling Germany's 10-year interest rate, appeared to be insignificant in modelling the yield curve spread.

The final equation was the following (statistical tests in Appendix 10, notations in Appendix 5):

d(SPREAD_GER_10YR_GER_2YR_TC)=-0.96*d(ECB_RATE_TC)+0.62*d(CPI_EMU_4Q_TC$_{t-1}$)-0.07*(SPREAD_GER_10_GER_2YR_TC$_{t-1}$-0.63).

According to this equation, the spread between Germany's 10- and 2-year interest rates is influenced by the base ECB interest rate, inflation, and the previous deviation of the spread from its equilibrium value (0.63).

3. Statistical performance of the models and equations

3.1. Ex post performance

The interest rate equations were estimated to every quarter between Q4 1997 and Q3 2001. After that two equations were put together into one model and then the next quarter's interest rate was predicted. In order to test first the performance of the model, real future values for exogenous values were used[11]. The results and statistics of fit are shown in Figure 2 and Table 2.

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[11] Forecasts using forecasts of exogenous variables available in each time period instead of real exogenous variables were also made, giving somewhat worse, but still satisfactory results.
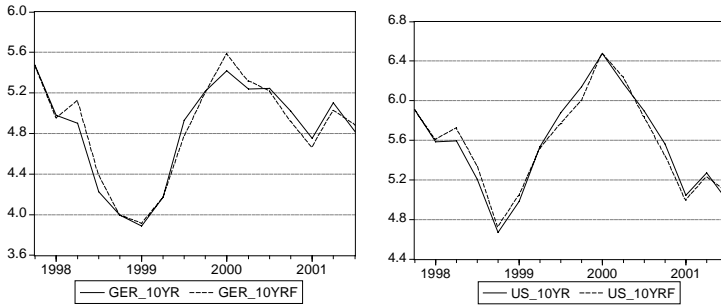
Figure 3. US and Germany's 10-year interest rate and 1 quarter model forecasts.

Table 2

Statistical fit of the forecast interest rate

	US_10YR	GER_10YR
Root Mean Squared Error	0.08524	0.10703
Mean Absolute Error	0.07357	0.08228
Mean Abs. Percent Error	1.34299	1.68864
Mean Error	0.00320	0.01507
Mean Percent Error	0.11322	0.33091
Theil Inequality Coefficient	0.00767	0.01109
Bias proportion	0.00141	0.01983
Variance proportion	0.09246	0.00519
Covariance proportion	0.90613	0.97498

From the figure and the table of statistics we can conclude that statistically the model works relatively well.

The USD/EUR exchange rate equation was estimated from Q4 1991 until every quarter between Q4 1994 and Q3 2001. After the estimation 1-quarter predictions were made, after which the actual data series was compared to the quarter-by-quarter predicted series. The results and statistics of fit are shown in Figure 3 and Table 3.
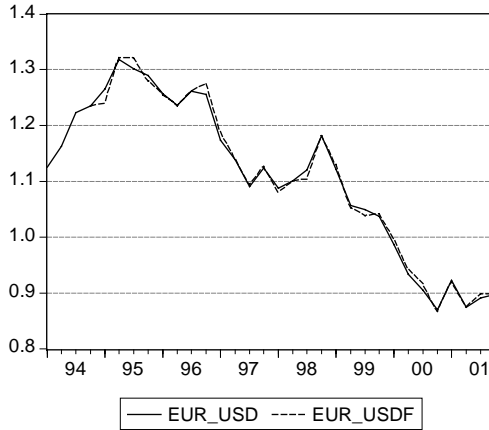
Figure 4. EUR/USD exchange rate and 1-quarter forecast rate.

Table 3

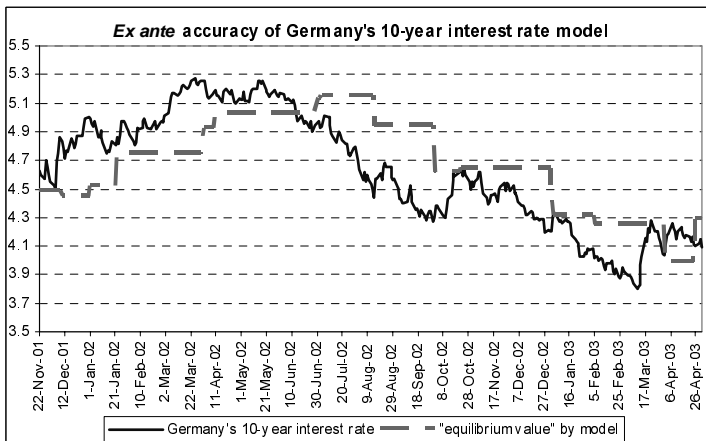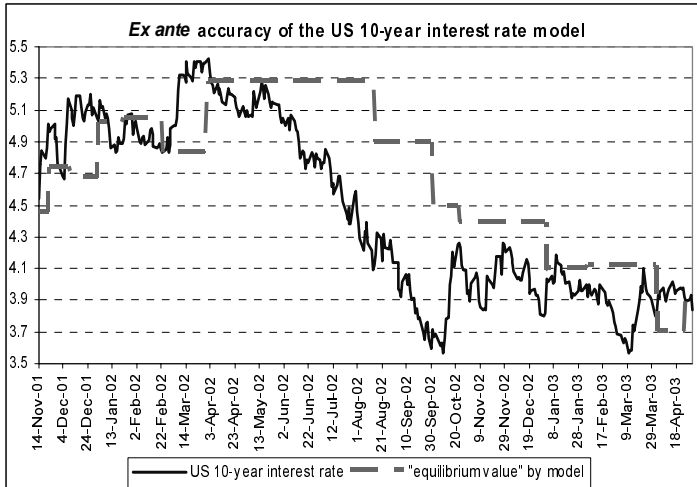**Statistical fit of the forecast exchange rate**

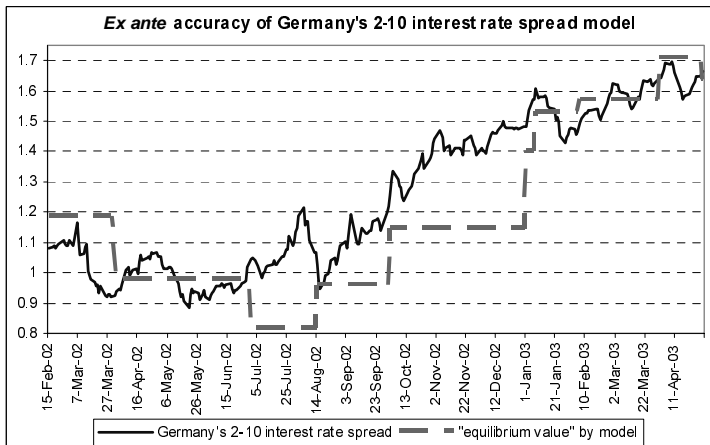|	
Root Mean Squared Error	0.00988
Mean Absolute Error	0.00722
Mean Abs. Percent Error	0.64429
Mean Error	0.00137
Mean Percent Error	0.13560
Theil Inequality Coefficient	0.00446
Bias proportion	0.01925
Variance proportion	0.00065
Covariance proportion	0.98010

From the figure and statistics we can conclude that the predictive power of the equation in the past was relatively good.

The *ex post* tests of yield curve spread equations and the USD/JPY exchange rate equation gave similar, acceptable results and are not presented here.

3.2. Ex ante performance

The *ex ante* forecasting accuracy of the models in real-life testing is shown in Figure 4. In each figure the actual time series is shown with running the most recent estimation of the equilibrium level by the model. The line of the model estimation changes at each point the forecast was changed (due to additional data availability) or when the quarter changed.

Ex ante accuracy of US 2-10 interest rate spread model

Ex ante accuracy of Germany's 2-10 interest rate spread model

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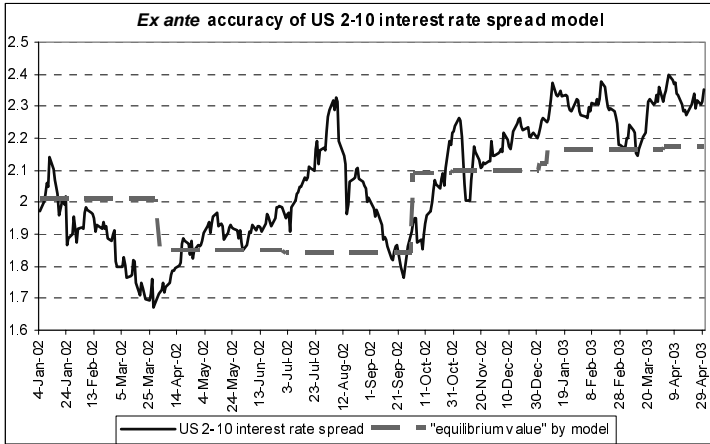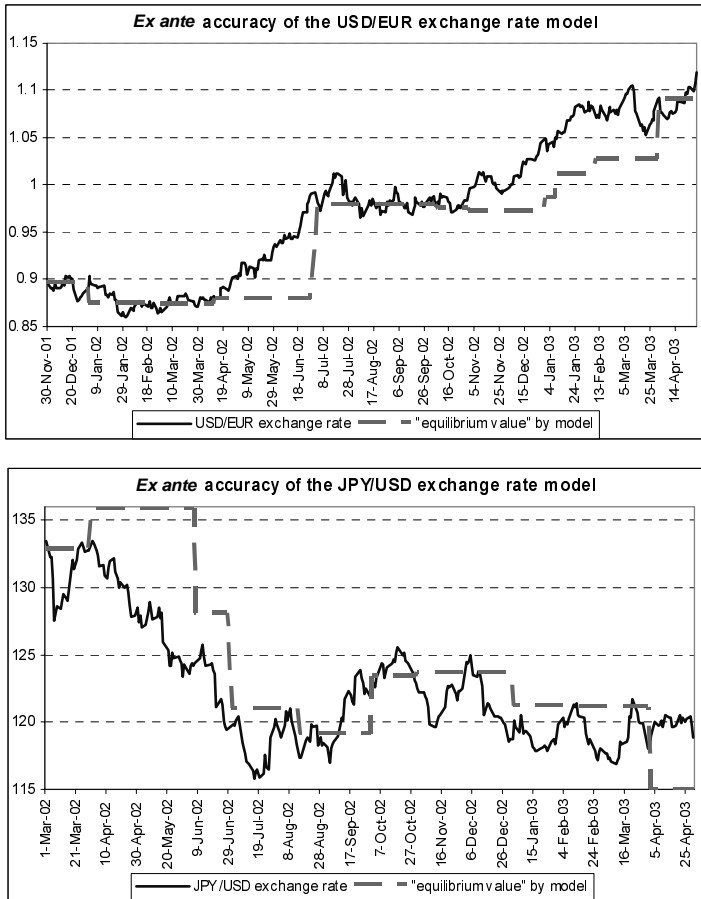
Figure 5. *Ex ante* accuracy of the estimated models

As the figures indicate, the models have done a relatively good job in estimating the equilibrium value, although in some episodes the estimations of the models have lagged behind the actual data series. But as all the models enable us to get a relatively accurate prediction of the next quarter's average already ab 1 month before the end of the quarter, the actual lag is less than that shown in the figures.

CONCLUSIONS

The present paper tests the conventional theoretical baselines (the IS-LM model and standard monetary model of exchange rate) in estimating the equilibrium level on money and exchange rate markets. The goal was to determine whether the models based on those theories would allow us to determine some "equilibrium level" on the markets. If the "equilibrium level" could be determined, then the deviations from that level would tell us that there is a bigger probability of markets moving towards the equilibrium (and not the opposite way), thereby enabling the investor investing in those markets to increase one's return over time. From the analysis, the following conclusions were drawn:

- The given theoretical baselines (the IS-LM model and standard monetary model of exchange rate) give reasonable results in modelling the US and Euro area interest rates, interest rate spreads and exchange rates between the USD and EUR, and the USD and JPY.
- However, these models become effective only in relatively long horizons and cannot capture random market disturbances. Therefore different models had to be estimated on quarterly data, in some cases even quarterly data had to be additionally smoothed.
- The estimated models of interest rate and exchange rate gave good statistical results in *ex post* tests but in some episodes lagged behind the actual market cycle turning points according to the *ex ante* test results.

These results indicate that it is possible to determine the fundamental "equilibrium value" in money and exchange rate markets and that big deviations from this value are mostly

followed by a successive move towards the equilibrium. However, as some deviations can be relatively long-lasting and also the "equilibrium value" can lag behind the actual market moves, then for those models to be useful in increasing the investors' return over time, they have to be combined with some shorter-time technical indicators.

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Appendixes

Statistical properties of the US 10-year interest rate equation

Statistical properties

Dependent Variable: d(US_10YR_TC)
Method: Least Squares
Sample: 1995:3 2001:3
Included observations: 25

Variable	Coefficient	Std. Error	t-Statistic	Prob.
d(LEADING_US_4Q_ TC$_{t-1}$)	0.102959	0.043648	2.358838	0.0276
0.3*CPI_NEXT1QDIF_ F_TC$_{t1}$+0.3*d(SPREAD _US_TC$_{t1}$)+0.4*d(CPI_ US_4Q_TC)	1.339279	0.173836	7.704276	0.0000
C	-0.058285	0.022466	-2.594327	0.0166
R-squared	0.854648	Mean dependent var		-0.073711
Adjusted R-squared	0.841434	S.D. dependent var		0.281573
S.E. of regression	0.112123	Akaike info criterion		-1.426267
Sum squared resid	0.276576	Schwarz criterion		-1.280002
Log likelihood	20.82834	F-statistic		64.67827
Durbin-Watson stat	1.246578	Prob(F-statistic)		0.000000

Graph of actual, fitted and residual series
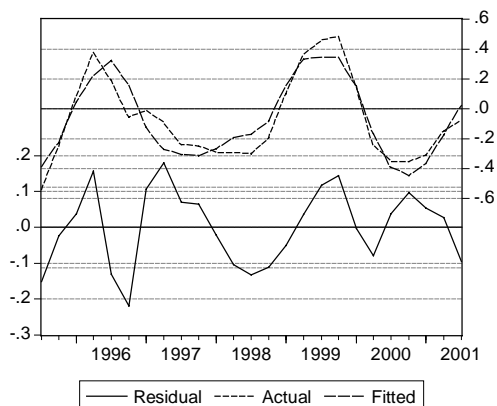
Recursive estimates of the coefficients
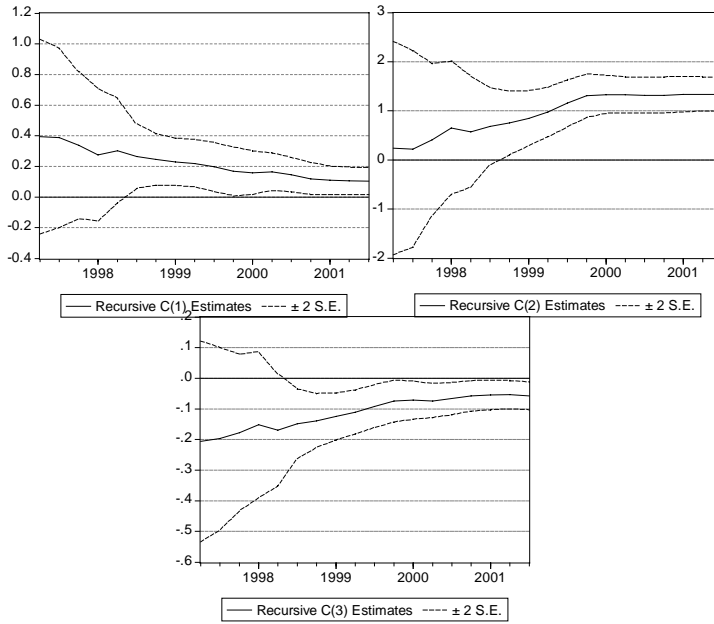
Appendix 2

**Granger causality test of the US and Germany's
10-year interest rates**

Pairwise Granger Causality Tests

Sample: 1997:01 2002:10

Lags: 1

Null Hypothesis:	Obs	F-Statistic	Probability
US_10YR does not Granger Cause GER_10YR	58	6.64212	0.01267
GER_10YR does not Granger Cause US_10YR		0.21754	0.64276

Statistical properties of Germany's 10-year interest rate equation

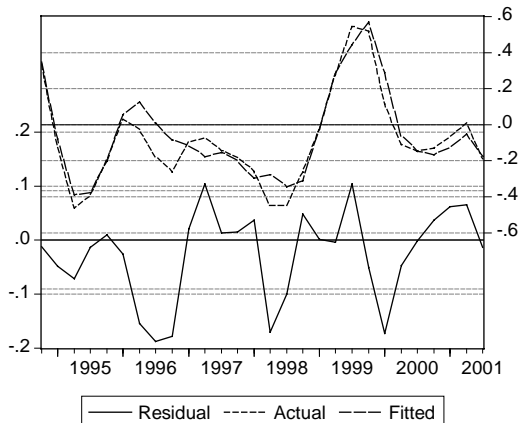Statistical properties

Dependent Variable: D (GER_10YR_TC)
Method: Least Squares
Sample: 1994:2 2001:3
Included observations: 30

Variable	Coefficient	Std. Error	T-Statistic	Prob.
0.3*D (SPREAD_EMU_ TC $_{t-1}$)+0.7*D (CPI_EMU _4Q_TC)	0.822527	0.125423	6.558016	0.0000
D (US_10YR_ TC)	0.491797	0.059774	8.227546	0.0000
D (LEADING_ GER_4Q_TC $_{t-2}$)	0.050150	0.020359	2.463231	0.0204
R-squared	0.911241	Mean dependent var		-0.046788
Adjusted R-squared	0.904666	S.D. dependent var		0.292362
S.E. of regression	0.090270	Akaike info criterion		-1.877380
Sum squared resid	0.220015	Schwarz criterion		-1.737260
Log likelihood	31.16069	Durbin-Watson stat		1.144584

Graph of actual, fitted and residual series

Recursive estimates of the coefficients
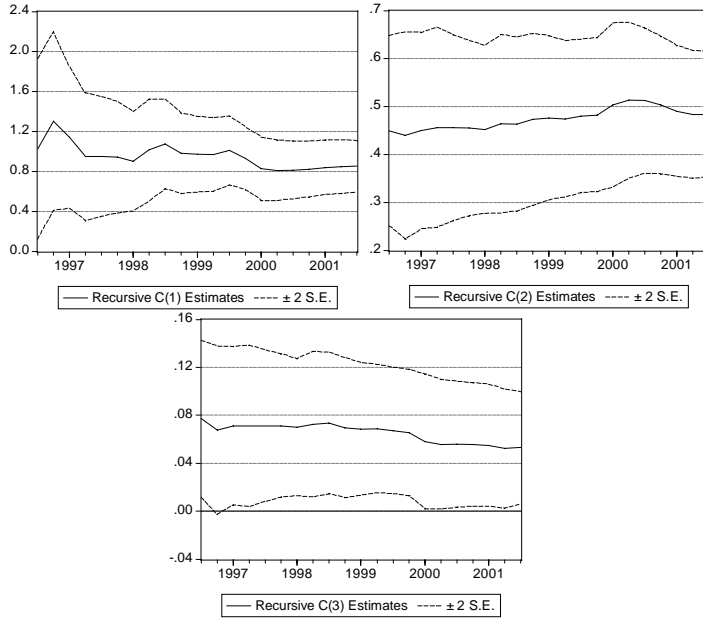
**Estimation of the German 10-year interest rate by means
of the Kalman filter**

Statistical properties

Sspace: KALMAN_GER10YR
Method: Kalman filter
Included observations: 29

	Final State	Root MSE	z-Statistic	Prob.
C1	0.249513	0.081621	3.056956	0.0022
C2	0.337375	0.016173	20.86092	0.0000
C3	0.049059	0.007666	6.399285	0.0000
Log likelihood	-629.5826	Akaike info criterion		43.41949
Parameters	0	Schwarz criterion		43.41949
Diffuse priors	3	Hannan-Quinn criter.		43.41949

Graphs of estimated state series
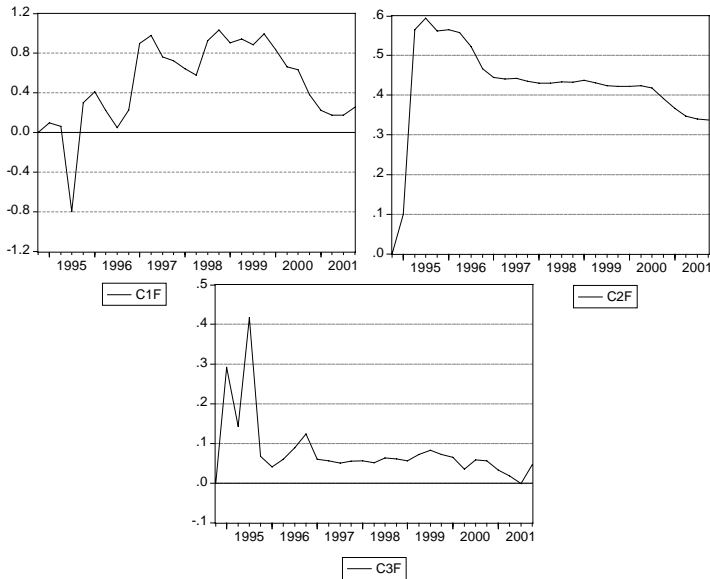
Actual and 1-period-ahead forecasted series and their residual
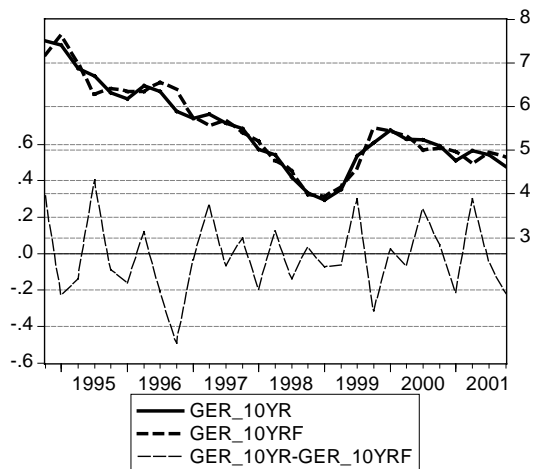
Appendix 5
Notations

<u>Endogenous variables:</u>

EUR_USD	Price of 1 EUR in USD
JPY_USD	Price of 1 USD in JPY
SPREAD_…	Spread between two interest rates
US_2YR	Generic interest rate of US 2-year Government Bonds
US_10YR	Generic interest rate of US 10-year Government Bonds

<u>Exogenous variables:</u>

3MR	3-month interest rate
CPI	Consumer price index
CPI_NEXT1QDIF_F	Consensus forecast of the change in US CPI yearly inflation in the next quarter compared to the present one
ECB_RATE	ECB base interest rate, before 1999 Germany's base interest rate
FED_RATE	FED base interest rate
GDP	Nominal GDP
LEADING	leading indicator (index)
M1	Money supply M1
RGDP	Real GDP
SPREAD	Spread between 10-year and 3-month interest rates

<u>Suffixes:</u>

_4Q	4-quarter index
_EMU	Variable of the Euro area
_GER	Variable of Germany
_JP	Variable of Japan
_Q	1-quarter index
_TC	Seasonally adjusted and smoothed series
_TCA	Annualized seasonally adjusted and smoothed series
_US	Variable of the United States

Appendix 6

Cointegration test of the USD/EUR exchange rate equation

Sample (adjusted): 1991:4 2001:4

Included observations: 41 after adjusting endpoints

Trend assumption: No deterministic trend

Series: log(EUR_USD_TC) log(M1_US_TC)-log(M1_EMU_TC) log(RGDP_US_TC$_{t-2}$)-log(RGDP_EMU_TC$_{t-2}$) US_3MTBILL_TC$_{t-2}$-GER3MR_TC$_{t-2}$

Exogenous series: d(log(EUR_USD_TC$_{t-1}$)) d(log(EUR_USD_TC$_{t-2}$))

Warning: Critical values assume no exogenous series

Lags interval (in first differences): No lags

Unrestricted Cointegration Rank Test

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	5 Percent Critical Value	1 Percent Critical Value
None **	0.879209	153.4805	39.89	45.58
At most 1 **	0.598932	66.81904	24.31	29.75
At most 2 **	0.511182	29.36042	12.53	16.31
At most 3	0.000342	0.014032	3.84	6.51

*(**) denotes rejection of the hypothesis at the 5%(1%) level

Trace test indicates 3 cointegrating equation(s) at both 5% and 1% levels

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	5 Percent Critical Value	1 Percent Critical Value
None **	0.879209	86.66147	23.80	28.82
At most 1 **	0.598932	37.45862	17.89	22.99
At most 2 **	0.511182	29.34639	11.44	15.69
At most 3	0.000342	0.014032	3.84	6.51

*(**) denotes rejection of the hypothesis at the 5%(1%) level

Max-eigenvalue test indicates 3 cointegrating equation(s) at both 5% and 1% levels

Statistical properties of the USD/EUR exchange rate equation

Statistical properties

Dependent Variable: d(log(EUR_USD_TC))
Method: Least Squares
Sample (adjusted): 1991:4 2001:3
Included observations: 40 after adjusting endpoints
Convergence achieved after 5 iterations
d(log(EUR_USD_TC)) = C(1)*(log(EUR_USD_TC$_{t-1}$)+C(21)*(log(M1_US_TC$_{t-1}$)-log(M1_EMU_TC$_{t-1}$))
+C(22)*(log(RGDP_US_TC$_{t-3}$)-log(RGDP_EMU_TC$_{t-3}$))
+C(23)*(US_3MTBILL_TC$_{t-3}$-GER3MR_TC$_{t-3}$)) + C(4)
*d(log(EUR_USD_TC$_{t-1}$)) +C(5)*d(log(EUR_USD_TC$_{t-2}$))

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.078230	0.036624	-2.136052	0.0400
C(21)	-0.881572	0.212435	-4.149845	0.0002
C(22)	0.067887	0.010583	6.414383	0.0000
C(23)	-0.020192	0.012282	-1.644051	0.1094
C(4)	1.203161	0.106354	11.31276	0.0000
C(5)	-0.617336	0.111487	-5.537307	0.0000
R-squared	0.848142	Mean dependent var.		-0.007340
Adjusted R-squared	0.825810	S.D. dependent var.		0.024260
S.E. of regression	0.010125	Akaike info criterion		-6.210116
Sum squared resid	0.003486	Schwarz criterion		-5.956784
Log likelihood	130.2023	Durbin-Watson stat		1.776617

Graph of the actual, fitted and residual series
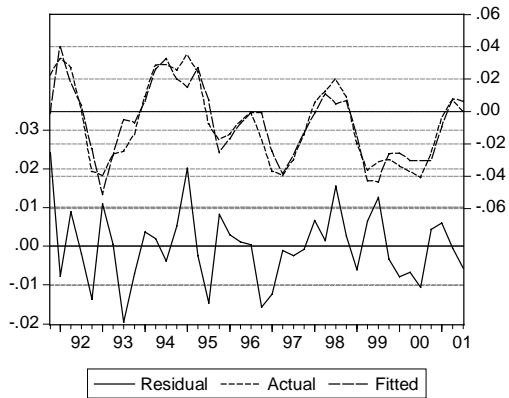
Statistical properties of the USD/JPY exchange rate equation

Cointegration test

Sample(adjusted): 1992:4 2002:1

Included observations: 38 after adjusting endpoints

Trend assumption: No deterministic trend (restricted constant)

Series: USD_JPY_TC JP_6MR_TC-US_6MTBILL_TC M1_JP_TC-M1_US_TC

Exogenous series: $dlog$(USD_JPY_TC$_{t-1}$) $dlog$(USD_JPY_TC$_{t-2}$) $dlog$(USD_JPY_TC$_{t-3}$) d(log(RGDP_JP_TC$_{t-1}$)-log(RGDP_US_TC$_{t-1}$))

Warning: Critical values assume no exogenous series

Lags interval (in first differences): No lags

Unrestricted Cointegration Rank Test

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	5 Percent Critical Value	1 Percent Critical Value
None **	0.840090	116.0856	34.91	41.07
At most 1 **	0.498457	46.42612	19.96	24.60
At most 2 **	0.412380	20.20364	9.24	12.97

*(**) denotes rejection of the hypothesis at the 5%(1%) level

Trace test indicates 3 cointegrating equation(s) at both 5% and 1% levels

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	5 Percent Critical Value	1 Percent Critical Value
None **	0.840090	69.65947	22.00	26.81
At most 1 **	0.498457	26.22248	15.67	20.20
At most 2 **	0.412380	20.20364	9.24	12.97

*(**) denotes rejection of the hypothesis at the 5%(1%) level

Max-eigenvalue test indicates 3 cointegrating equation(s) at both 5% and 1% levels

Statistical tests

Dependent Variable: $dlog$(USD_JPY_TC)
Method: Least Squares
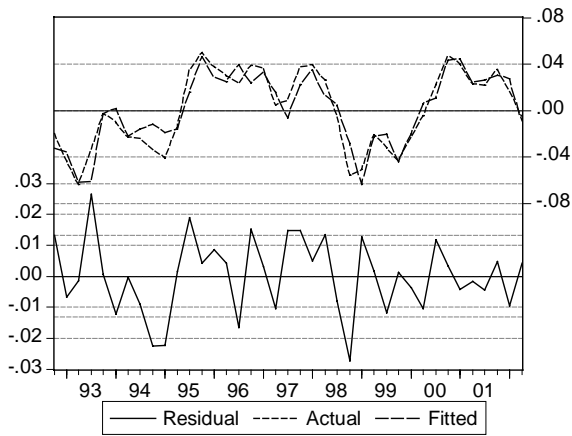Sample(adjusted): 1992:4 2002:2
Included observations: 39 after adjusting endpoints
Convergence achieved after 1 iteration

$dlog$(USD_JPY_TC)=C(1)*(log(USD_JPY_TC$_{t-1}$)+C(11)*(JP_6MR_TC$_{t-1}$-US_6MTBILL_TC$_{t-1}$)+C(12)*(log(M1_JP_TC$_{t-1}$)-log(M1_US_TC$_{t-1}$))+C(13)+ C(2)*$dlog$(USD_JPY_TC$_{t-1}$)+C(3)*$dlog$(USD_JPY_TC$_{t-2}$)+ C(4)*$dlog$(USD_JPY_TC$_{t-3}$)+C(5)*d(log(RGDP_JP_TC$_{t-1}$)- log(RGDP_US_TC$_{t-1}$))

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.187220	0.044811	-4.178027	0.0002
C(11)	-0.015526	0.008802	-1.763923	0.0876
C(12)	-0.244297	0.058515	-4.174924	0.0002
C(13)	-5.206750	0.125225	-41.57904	0.0000
C(2)	1.395583	0.143435	9.729740	0.0000
C(3)	-0.939466	0.187252	-5.017109	0.0000
C(4)	0.547026	0.131972	4.145014	0.0002
C(5)	-1.183691	0.503385	-2.351463	0.0252
R-squared	0.867688	Mean dependent var.		0.000448
Adjusted R-squared	0.837811	S.D. dependent var.		0.032973
S.E. of regression	0.013279	Akaike info criterion		-5.624545
Sum squared resid.	0.005467	Schwarz criterion		-5.283301
Log likelihood	117.6786	Durbin-Watson stat.		1.877873

Graph of the actual, fitted and residual series

Appendix 9
Statistical properties of the US yield curve spread equation

Statistical properties

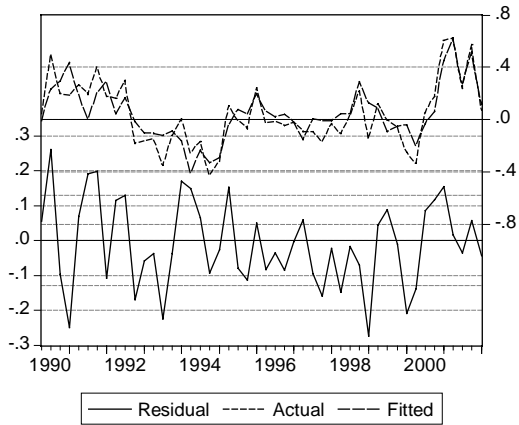Dependent Variable: d(SPREAD_US_10YR_US_2YR)
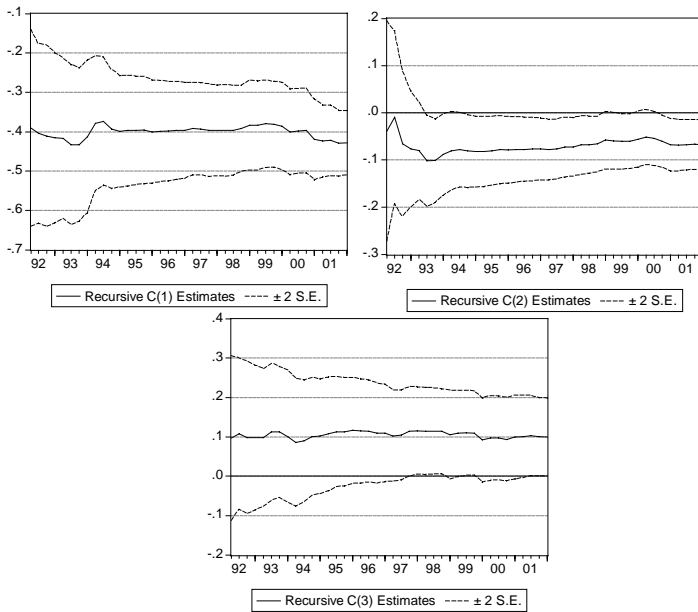Method: Least Squares
Sample (adjusted): 1990:2 2001:4
Included observations: 47 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
d(FED_RATE)	-0.429966	0.041612	-10.33280	0.0000
(SPREAD_US_10YR_US_2YR$_{t-1}$+SPREAD_US_10YR_US_2YR$_{t-2}$+SPREAD_US_10YR_US_2YR$_{t-3}$)/3-0.76627	-0.067070	0.026548	-2.526396	0.0152
d(CPI_US_4Q)	0.100530	0.049880	2.015438	0.0500
R-squared	0.739216	Mean dependent var		0.038834
Adjusted R-squared	0.727362	S.D. dependent var		0.248264
S.E. of regression	0.129630	Akaike info criterion		-1.186560
Sum squared resid	0.739376	Schwarz criterion		-1.068466
Log likelihood	30.88417	Durbin-Watson stat		1.646654

Graph of the actual, fitted and residual series

Recursive estimates of the coefficients

Appendix 10
Statistical tests of Germany's yield curve spread equation

Statistical properties

Dependent Variable: d(SPREAD_GER_10YR_2YR_TC)
Method: Least Squares
Sample (adjusted): 1994:2 2002:1
Included observations: 32 after adjusting endpoints
Convergence achieved after 3 iterations
d(SPREAD_GER_10YR_GER_2YR_TC)=C(1)*
d(ECB_RATE_TC)+C(2)d(CPI_EMU_4Q_TC$_{t-1}$)+C(3)(SPREAD_GER_10YR_GER_2YR_TC$_{t-1}$-C(4))

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.955764	0.084184	-11.35329	0.0000
C(2)	0.617954	0.125328	4.930682	0.0000
C(3)	-0.070239	0.027480	-2.556018	0.0163
C(4)	0.626689	0.364140	1.721011	0.0963
R-squared	0.843636	Mean dependent var.		0.012779
Adjusted R-squared	0.826882	S.D. dependent var.		0.236925
S.E. of regression	0.098578	Akaike info criterion		-1.679459
Sum squared resid.	0.272096	Schwarz criterion		-1.496242
Log likelihood	30.87134	Durbin-Watson stat.		0.715993

Graph of the actual, fitted and residual series
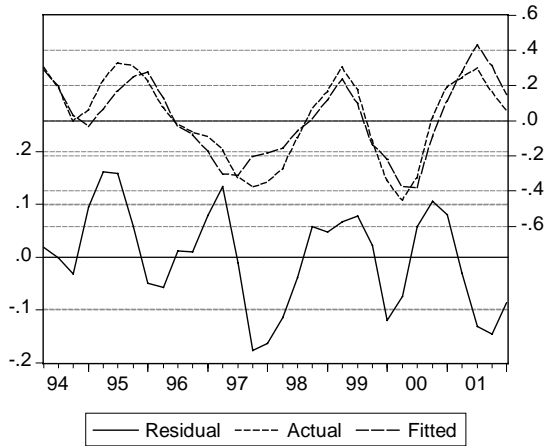
Recursive estimates of the coefficients
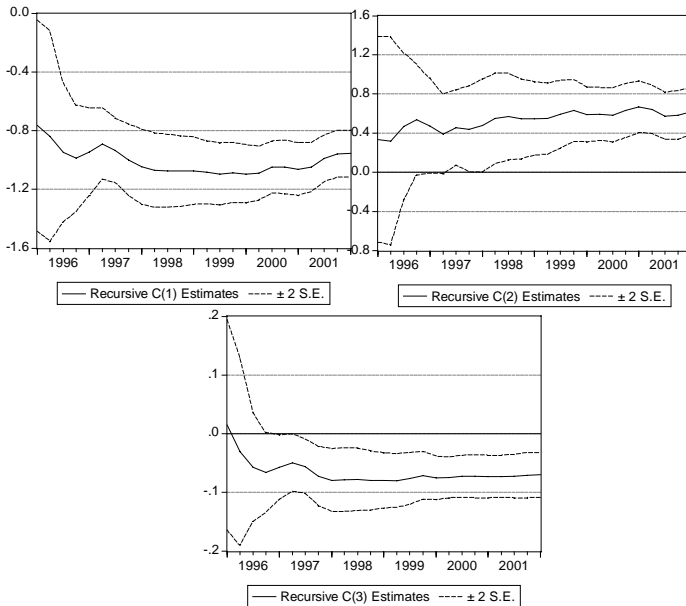
KOKKUVÕTE

Fundamentaalmudelite kasutamisest raha- ja valuutaturgudel

Käesoleva artikli eesmärgiks on uurida fundamentaalnäitajatel baseeruvate ökonomeetriliste mudelite kasutamisvõimalust USA ja Euroala pikaajaliste valitsusvõlakirjade intressitaseme, intressikõvera järskuse ning G3 valuutaturu tasakaalulise taseme määratlemisel.

Teoreetilise baasina kasutatakse intressitasemete mudelil konventsionaalset IS-LM raamistikku ning valuutakursimudelil standardset vahetuskursi monetaarmudelit. Mudelid hinnatakse kvartaalsel andmestikul, kasutades kvartali keskmisi väärtusi. Endogeenseteks näitajateks on USA ja Saksamaa 10-aastase valitsusvõlakirja intressimäär, 2- ja 10-aastaste valitsusvõlakirjade intressimäärade vahe ning USD/EUR ja USD/JPY vahetuskurss.

Hindamise tulemusel jõutakse järeldusele, et hindamisperioodi siseselt on konventsionaalsete fundamentaalseoste abil võimalik suhteliselt täpselt kirjeldada intressitasemete, intressikõvera järskuse ja valuutakursside liikumisi. Hindamisperioodi välisel (*ex ante*) testimisel aga oli mitmeid perioode, kus mudelijärgne "tasakaalutase" jäi tegelikust turuliikumisest trendi pöördepunktides maha. Seega praktilisel investeerimisel kasutamiseks tuleks fundamentaalnäitajatel baseeruvaid mudeleid kombineerida teiste, lühemaajalisi trende püüdvate (näiteks tehniliste) mudelitega.