The Performance of the Euribor Futures Market: Efficiency and the Impact of ECB Policy Announcements

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Bonn, May 19, 2003

Abstract

The hypothesis that futures rates are unbiased and efficient predictors of future spot interest rates has been one of the most controversial topics in the empirical literature on market efficiency. The first part of this article concentrates on the question of whether the hypothesis that rates are unbiased holds for the 3-month Euribor futures market. The empirical analysis differs from usually applied tests in its employment of a panel estimation approach, which enables the use of all daily futures rates from December 1998 to December 2001.

The second part of this article analyzes the impact of ECB monetary policy news on the volatility and the prediction error of the Euribor futures rates. As interest rate futures are regarded as the market's expectations of future interest rates, the day-to-day volatility of the Euribor futures rates can be used to draw conclusions as to whether ECB monetary policy decisions are fully anticipated by market participants. The analysis of the change of the prediction error between two days serves the detection whether the ECB monetary announcements improves or worsens in general the interest rate forecast.

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1 Introduction

Financial markets are a main part of the transmission channel of the European Central Bank's (ECB) monetary policy. Since expectations about future key interest rates determine current market interest rates, it is important for an effective and smooth monetary policy that interest rate expectations are in line with the central bank's policy intentions. The degree of interest rate predictability can, therefore, be seen as an indicator of the clarity of communication between the ECB and the financial markets and the effectiveness of monetary policy implementation.

In this paper, we analyse two aspects of predictability of interest rates in the European Monetary Union (EMU). The first is the efficiency of Euribor interest rate futures markets. An interest rate future is a futures contract with a three-months interbank deposit as the underlying asset. The implied futures rate, which can be derived from the quoted price of the futures contract, is a predictor of the Euribor interbank interest rate prevailing at the time of maturity. Accordingly to the efficient market hypothesis (EMH), Euribor futures rates should be unbiased predictors of the rates prevailing at the time of maturity, and they should contain all information the market has about these rates.

The second aspect we investigate is the effect of policy announcements by the European Central Bank (ECB) on the volatility of Euribor futures rates. If policy announcements increase the volatility of futures rates, these announcements must have caused market participants to revise their interest rate expectations, i.e., they must have contained some surprise. This would imply that the central bank did not fully succeed in a smooth management of information regarding its monetary policy.

Our paper is the first investigating of the performance of the Euribor market. It is of special interest, because the start of EMU has led to the emergence of new financial markets in Europe. By using data starting at the time when trading in Euribor futures contracts first began in December 1998, we can check whether the market was efficient from the beginning or whether and how the ECB's information management changed over time.

As it turns out, the Euribor futures show to be unbiased and informational efficient. That result supports the view that the policy decisions of the ECB have been on average predictable and by and large the communication strategy with the market has worked surprisingly well for a relatively new institution.

The analysis of the interday volatility of the futures rates provides evidence that the futures rates' average volatility is significantly higher on Governing Council meetings days than on non-Council Thursdays or any other day of the week. Additionally, the Governing Council meetings are found to have on average a higher informational content than e.g. the release of information published by the Monthly Bulletin. However, a closer look on the futures rates changes at Governing Council days shows that while some ECB policy decisions were anticipated correctly by the money market participants, some other decisions constituted as a surprise.

The paper proceeds as follows. Section 2 describes how unbiasedness and efficiency of futures markets is defined. Section 3 presents the in the literature usually applied empirical tests for unbiasedness and efficiency and employs an alternative test procedure using a panel estimation approach. In section 4 the data we use for the estimation is briefly introduced, and in section 5 a detailed model specification of the panel model is given. Section 6 discusses the test results of the efficiency test. The impact of ECB monetary policy decisions on the day-volatility and the absolute prediction error of the Euribor futures rates are described in section 7, and section 8 concludes.

2 The Efficiency of Interest Rate Futures Markets

2.1 The 3-months Euribor Futures Markets

A futures contract is a binding agreement between two parties to make a particular exchange on a specified date t in the future. Thus, in a futures contract there exists a time lag between the agreement to trade at a certain price and the execution of the trade. The Euribor futures is a futures contract with a Euribor deposit as the underlying asset. Since 1 January 1999, the Euribor (European Interbank Offered Rate) has been used as the European money market reference rate for the unsecured market. 1-month and 3-month Euribor futures have been traded on the derivatives market since December 1998. The 3-month Euribor future is a contract to engage in a three month loan or deposit of a face value of 1.000.000 Euro. The futures price is quoted on a daily basis for the delivery months March, June, September and December, in each case for the 3rd Wednesday of that month. The last trading day of a futures contract is always two exchange trading days prior to the relevant settlement day.

The implied futures rate, $f_{i,t}$, is derived from the quoted price by subtracting the latter from 100.[1] Here, i is the settlement period of the contract and t is the time when the contract matures, i.e., the contract is concluded at $t - i$. In theory the futures rates $f_{i,t}$ are regarded as predictors of futures spot interest rates at time t, which is denoted by r_t. The specific relation between the futures prices and the expected future spot prices relies on exploiting the efficient market hypothesis (EMH), which is described in the next section.

2.2 The Efficient Markets Hypothesis (EMH)

The efficient markets hypothesis (EMH) is a central proposition of finance for over thirty years. Fama (1970) summarizes the idea saying that a market is called efficient, when prices fully reflect all available information. Market participants rapidly incorporate all relevant information in the determination of prices or returns. Thus, the only reason for prices, P_t, to change between time t and $t+1$ is the arrival of 'news' or unanticipated events. Since 'news' are by definition random, efficiency implies that forecast errors are unpredictable on the basis of any information Ω_t that was available at the time the forecast was made. The latter effect is often referred to as the *rational expectations* element of the EMH and may be represented by:

$$P_{t+1} = E_t(P_{t+1}|\Omega_t) + \epsilon_{t+1}, \tag{1}$$

where ϵ_{t+1} denotes a random forecast error which is expected to be zero. In that sense, efficiency with respect to an information set Ω_t implies that it is impossible to make superior profits by trading on the basis of this information. With risk-neutral investors efficiency therefore requires zero profits. The implication of efficiency is that the forecast of a financial price, $E_t(P_{t+1}|\Omega_t)$ is unbiased, which means that on average, the expected price equals the actual price. An other way to describe market efficiency is the so called *orthogonality condition*, which uses the fact that the forecast error should be on average zero and uncorrelated with the information contained in Ω_t:

$$E_t(\epsilon_{t+1}|\Omega_t) = E_t(P_{t+1} - E_t(P_{t+1}|\Omega_t)|\Omega_t) = 0. \tag{2}$$

It should be stressed here that the EMH is a *joint hypothesis* assuming that agents do not make systematic forecast errors, and that they know the expected market

[1] see e.g. Krehbiel/Adkins (1994).

equilibrium prices or expected equilibrium returns. That fact makes it difficult for researchers of the EMH to distinguish whether a rejection of the hypothesis is due to the irrationality of market particicants or to a misspecification of the equilibrium returns.

Depending on the definitions of the information set Ω_t, that is taken into account when determining financial prices or returns, one distinguishes between the following forms of efficiency:[2]

- *Strong-form efficiency*: The information set Ω_t includes all information known to any market participant (private information).
- *Semistrong-form efficiency*: The information Ω_t set consists of all information known to all market participants (publicly available information).
- *Weak-form efficiency*: The information set Ω_t includes only the history of prices or returns themselves.

One can summarize that market efficiency requires that agents are able to process available information and form rational expectations in accordance to equation (1)[3].

2.3 Efficiency of the Futures Market

Futures rates are widely accepted to express the market's expectations about future interest rates.[4] Let r_t be the spot interest rate at time t and $f_{i,t}$ the futures rate at time $t-i$ for the futures contract that expires at time t. Under risk neutrality, the market drives the futures rate into equality with the expected interest rate at

[2]see Campbell et al. (1967), p. 22.

[3]The latter requirement is a very strong assumption and is often criticised in the literature. In the recent literature about behavioural finance, it is stressed that the efficient markets hypothesis (EHM) does not live or die by investors rationality. Shleifer (2001) claims, that market efficiency is still achieved when the trades of the irrational investors are random and therefore cancel each other out without effecting prices, determined by the rational investors, or when investors are irrational in similar ways and are met in the market by rational arbitrageurs who eliminate their influence on prices. But there is no doubt that the efficient market hypothesis is only valid if the main part of market participants behave rational. In the following when one talks about rational behaviour of market participants, the reader should keep in mind that this assumption does not require strict rationality of all market participants.

[4]see European Central Bank (2001), p. 28.

time t: $E_{t-i}(r_t) = f_{i,t}$. On the other hand, if investors are risk-avers, they will require a positive risk premium for holding a futures position and futures rates are systematically bigger than the expected future spot rates: $E_{t-1}(r_t) < f_{i,t}$. The situation is known as *normal backwardation*.[5]

Furthermore, informational efficiency of futures markets implies that the forecasts of future spot interest rates made e.g. at time $t-i$, the futures rate $f_{i,t}$, are determined by market participants, who use all available and relevant information of the information set Ω_{t-i}. Accordingly, a futures market is said to be efficient with respect to some information set Ω_t, if futures prices or rates do not move when this information is revealed.[6] Taking everything together with reference to equation (1) and (2) the relation between spot and futures rates can be summarized by the following equation:

$$r_t = \alpha_i + f_{i,t} + \epsilon_t, \tag{3}$$

where $t \in \{1, \ldots, T\}$, $i \in \{1, \cdots, N\}$, α_i denotes a time-varying risk premium and ϵ_t a random error term. Thus, if $\alpha = 0$, the futures rate is an unbiased estimator of the spot interest rate.

The ability of futures markets to predict subsequent spot interest rates is discussed by many articles. The empirical evidence is mixed, and varies for different markets. Cole et al. (1991) and Krueger and Kuttner (1996) examine the forecasting power of treasury bill futures. They provide evidence that the treasury bill futures rates are efficient and unbiased. In contrast, Cole and Reichenstein (1994) and Krehbiel and Adkins (1994) show that the federal funds futures rates and the Eurodollar futures rates seem to be efficient but incorporate a positive risk premium since they are upward biased. The unbiasedness hypothesis in these papers was assessed on a time series dimension by regressing the observed spot interest rate on a previous period futures rate and by testing whether the intercept is not significantly different from zero and the slope coefficient not significantly different from one. In order to avoid overlapping data, these authors used for the estimations only one futures rate of each futures contract, which required a sufficient long time horizon of observed data.

[5] compare Keynes (1930).

[6] compare Campbell et al. (1997), pp.20 ff.

3 A statistical test for Informational Efficiency

3.1 An Overview of conventional tests

The standard way in the literature to test an interest rate futures market for unbiasedness is to run a regression of the form:[7]

$$r_t = \alpha_i + \beta_i f_{i,t} + \epsilon_{it}, \tag{4}$$

where the forecast horizon, expressed by i, is assumed to be fixed. Accordingly, the time series of futures rates consists of only one futures rate quoted before every futures settlement date contract.[8] The futures market is called unbiased, if one cannot reject the null hypothesis $H_0 : \alpha = 0, \beta = 1$. The futures market is called biased, if the null- hypothesis is rejected. A significant constant term α in (4) might reflect a constant risk premium, and a significant deviation of β from one might reflect a time varying or risk premium, irrationality or both.

Efficiency of a futures market implies additionally that the futures rates reflect all information in the set Ω_{t-i}. Researchers like e.g. Cuthbertson (1996) and Dunis and Keller (1995) analyse efficiency by testing whether any variable in the information set Ω_{t-i} has a significant impact in equation (4):

$$r_t = \alpha_i + \beta_i f_{i,t} + \gamma_i X_{it} + \epsilon_{it}, \tag{5}$$

where X_{it} is a column vector of variables assumed to be contained in the information set Ω_{t-i} and is γ a row vector of parameters. If the interest rate futures market is efficient, γ should not be significantly different from zero. Another implication of the EMH is that the error term ϵ_t has to show no serial correlation. Serial correlation in the error terms would give evidence that past prediction errors have a predictable effect on the current forecast error ϵ_t.

3.2 A Panel Data Approach

As mentioned in the previous subsection, most studies examining the unbiasedness and efficiency of futures markets assume that the time to expiration of the futures

[7]compare e.g. Cole, Impson and Reichenstein (1991), Krehbiel and Adkins (1994), Cole and Reichenstein (1994), Krueger and Kuttner (1996).

[8]e.g. Cole, Impson and Reichenstein (1991) examined the forecast power of one-quarter ahead futures, so that $i = 91$; Carlson, McIntire and Thomson (1995) tested the performance for one-month ahead ($i = 30$) till five-month ahead federal funds futures ($i = 155$).

contract, i, is fixed, while the time of expiration, t, is changing. This test requires a relatively long time horizon with a sufficiently large number of observed futures contracts to get reliable estimation results. Since Euribor futures have only been traded since December 1998, Euribor time series are short. One way to overcome this problem is to exploit the fact that futures prices are quoted on a daily basis, and to use all daily futures rate for testing for unbiasedness and efficiency. This means that the parameter i, denoting the forecast horizon of the futures rate, is no longer fixed.

Using daily quoted futures rates for the estimation of equation (5) creates two new problems. The first is the fact that the data are overlapping. Assume two dates, date A with a forecast horizon of i days and day B with a forecast horizon of $i-1$ (see figure (1)). For the pricing of the futures rate at A, the information set Ω_A was available, and respectively for the one at B, Ω_B. We have that the information set at A is a subset of the information set in B, thus $\Omega_A \subset \Omega_B$. This leads to a dependence between observations, and, therefore, to inconsistent estimates if one does not correct for it. The second is that it seems to be problematic to assume a constant risk premium α that is independent of the forecast horizon i.[9] It is likely that the risk premium asked by investors, if any, increases with the time to maturity i of the futures contract.

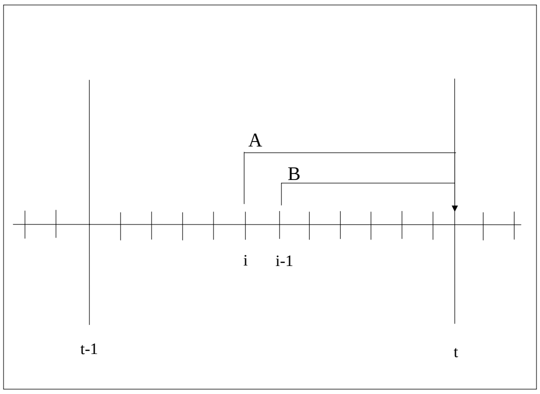

Figure 1: Overlapping Data

One can solve these two problems by resorting to a panel estimation. This

[9]Fama (1984) claimed that the size of a risk-premium for holding a futures position depends on the number of days to maturity i.

method was also proposed by Dunis and Keller (1995), who performed an efficiency test for different currency option markets. The use of panel regressions to test for unbiasedness and efficiency of futures or forward markets seems to be new in the literature.

We construct the panel by grouping the daily futures rates according to their time to expiration, which is depict in figure 2. Taking all futures rates with a forecast horizon of one to N days, we have N groups with T observations each. We apply a panel estimation procedure by taking the time to expiration i as the cross-sectional dimension and the futures contract's settlement date t as the time-dimension.

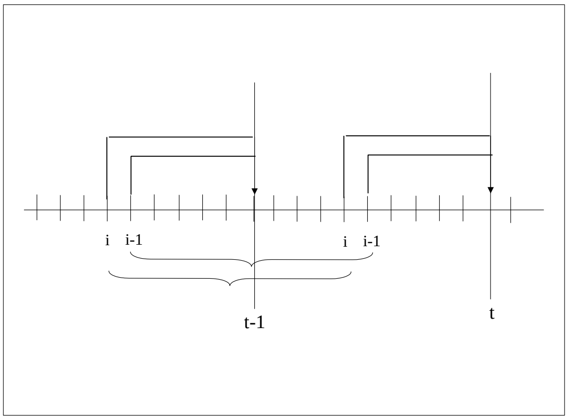

Figure 2: Grouping of the Data According to the time to Maturity i

Following Baltagi (1995)[10], a necessary condition for poolability, is that in terms of the equations (4) and (5) the groups are homogenoeous in the slopes in all cross-sectional regressions, i.e., $\beta_i = \beta$ and $\gamma_i = \gamma$ for all i. If one cannot reject this hypothesis, the data can be pooled across the i, the time to maturity.

If poolability is accepted, equation (5) can be transformed into the following panel structures:

$$r_t = \alpha_i + \beta f_{i,t} + \gamma X_{i,t} + \epsilon_{i,t} \tag{6}$$

where the index $t = 1, 2, ...T$ numbers the futures contracts - $t = 1$ would refer for example to the contracts expiring in March 1999 - and $i = 1, 2, ..., N$ is the index for the number of days before contract maturity. The null hypothesis for efficiency

[10]compare pp.47.

and unbiasedness is described by $H_0 : \alpha_i = 0, \beta = 1, \gamma = 0$ and ϵ_{it} to be serially uncorrelated.

4 Data Description

The Euribor futures contract data used in this study are provided by LIFFE (London International Financial Futures and Options Exchange). Our data sample covers daily closing rates of 3-months Euribor futures rates of the futures contracts that settle in between March 1999 and March 2002, a total of 13 settlement days. We use all futures rates with a forecast horizon of up to six months to delivery for every futures contract. The first futures rate in our data sample was priced on 15 December 1998 and the last on 18 March 2002.

Figures (3)-(8) plots this data, where the futures rates and the corresponding interest rates are grouped according to different forecast horizons. As one can see, the Euribor futures rates are in general close to the spot rates, especially near to the settlement date, and one observes for all contracts small positive and negative differences. A period with a negative deviation, where the futures rates underforecast the spot rate is observed for the March 2000 and the June 2000 contract. The opposite happened for the December 2000 contract, where the futures rates overpredicted the spot interest rates. The periods with strong biases suggest that the decline or increase in the Euribor rate was to some extent unanticipated.

5 Estimating the Performance of the Euribor Futures

5.1 The Panel Design

With 13 different futures contracts and a forecast horizon of the futures rates from one and 183 days, we have $t = 1, \ldots, 13$ and $i = 1, ..., 183$. This yields 131 cross sections with 13 observations, after excluding all missing observations due to weekends.[11] It seems intuitive that the forecasting performance diminishes as the time to

[11] we will not test futures rates with a larger time distance to the contract maturity, because we would lose too many observations, due to the fact that the 3-month Euribor future is traded only

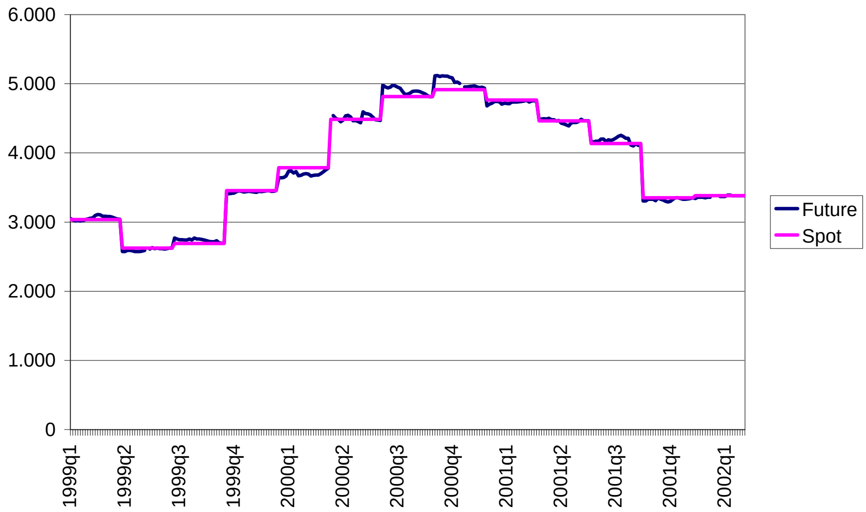

Figure 3: Futures with one-month horizon

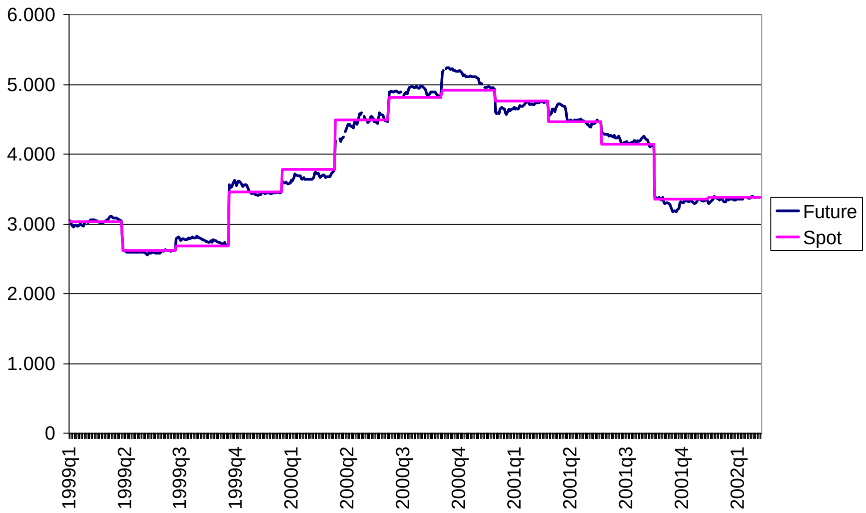

Figure 4: Futures with two-month horizon

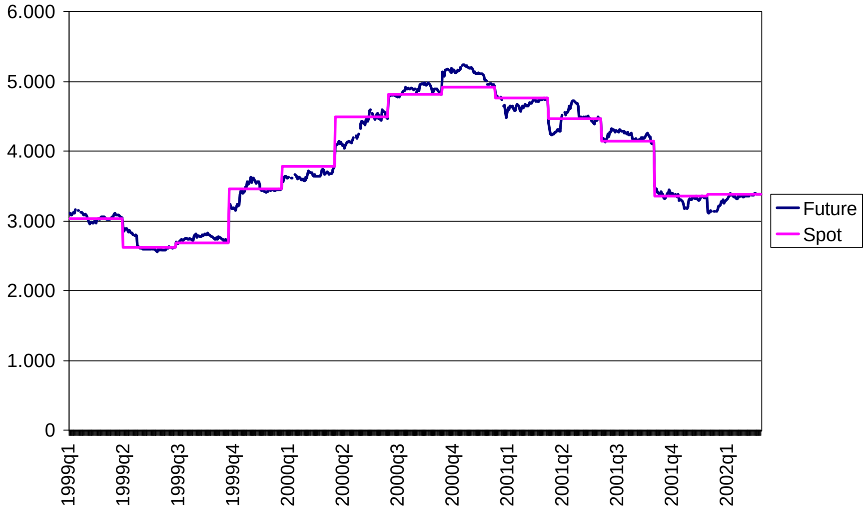

Figure 5: Futures with three-month horizon

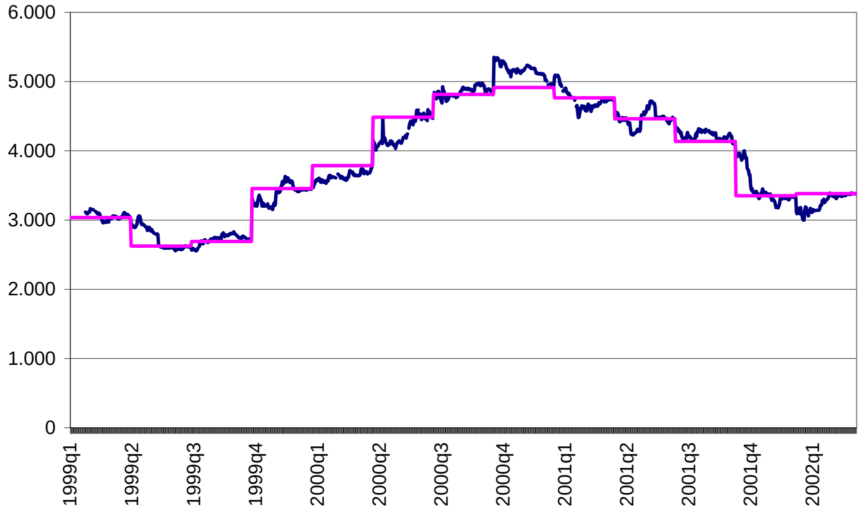

Figure 6: Futures with four-month horizon

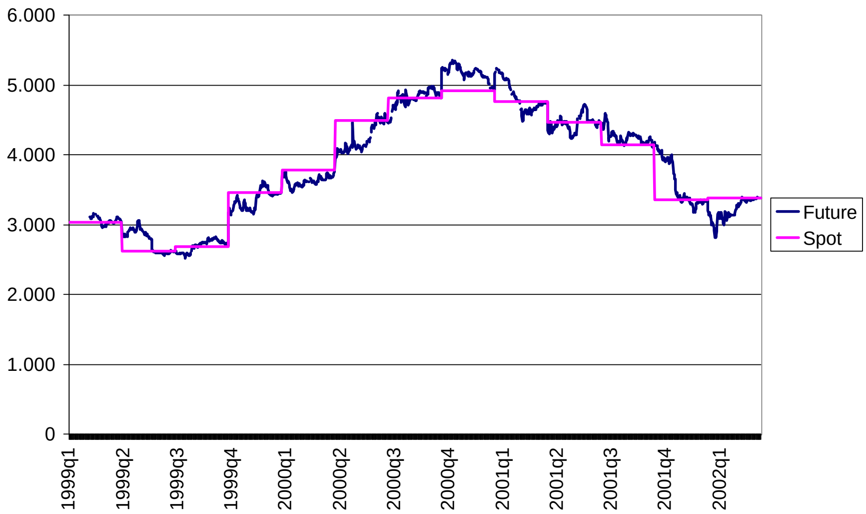

Figure 7: Futures with five-month horizon

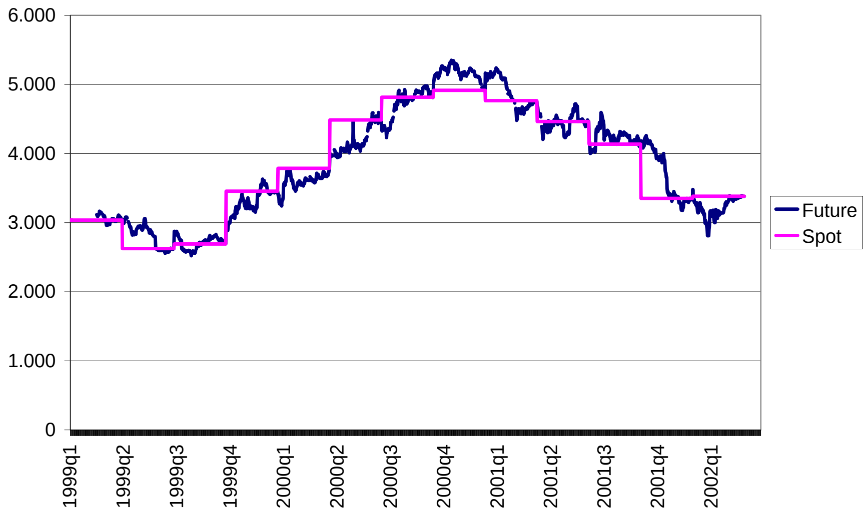

Figure 8: Futures with six-month horizon

expiration of the futures rates i increases. For this and other reasons, the result of the efficiency and unbiasedness tests may depend on the length of the forecast period. Therefore, we will perform the tests for different forecasting horizons: one-month-horizon ($N = \{1, \ldots, 31\}$), two-months-horizon ($N = \{1, \ldots, 61\}$), three-months-horizon ($N = \{1, \ldots, 91\}$), four-months-horizon ($N = \{1, \ldots, 122\}$), five-months-horizon ($N = \{1, \ldots, 153\}$) and finally six-months-horizon ($N = \{1, \ldots, 183\}$).

We focus on weak-form efficiency. For the efficiency test described by equation (6), we include the variables r_{t-1}, $f_{i,t-1}$ and the forecast innovation[12] $f_{i,t} - f_{i-1,t}$ into the panel regressions and test for their significance. The resulting panel equations are the following:

$$r_t = \alpha_i + \beta f_{i,t} + \epsilon_{i,t}, \tag{7}$$

$$r_t = \alpha_i + \beta f_{i,t} + \gamma_1 r_{t-1} + \epsilon_{i,t}, \tag{8}$$

$$r_t = \alpha_i + \beta f_{i,t} + \gamma_2 f_{i,t-1} + \epsilon_{i,t} \tag{9}$$

$$r_t = \alpha_i + \beta f_{i,t} + \gamma_3 (f_{i,t} - f_{i-1,t}) + \epsilon_{i,t}, \tag{10}$$

Before estimating these panel regressions we check the condition for poolability, i.e., that the coefficients in the panel regression are the same for every cross section. As one assumes any coefficient of the information set Ω_{t-i} to be insignificant, it is sufficient to establish poolability by using only equation (7) and to test whether the β coefficients are the same for every individual cross-sections. Chow (1960) proposes a simple F-test to test for the hypothesis. The test results do not reject poolability.

Next, we test whether there are significant individual effects in the sense that $\alpha_i \neq \alpha_j$ for $i \neq j$. The presence of individual effects would point to a time varying risk-premium, and would require corrections of the covariance matrix or the use of a fixed- or random effects model in order to get unbiased and consistent estimates of

since December 1998.

[12]Since the forecast errors of $f_{i-1,t}$ and $f_{i,t}$ overlap, the only new information for the investor between these two days is the innovation or the difference between these two futures rates.

the coefficients.[13] To test for individual effects, we used again a Chow test.[14] With p-values not lower than $0,99$, the Chow test does not reject the non-existence of individual effects for all panel regressions and futures rates with different forecasting horizons (see detailed test results in table 11 in the Appendix). As a result one can say that the risk premium in this data set is time invariant.

In order to get consistent and efficient estimates, one has to test and, if present, to correct for heteroscedasticity. In panel data heteroscadasticity can be present across cross-sections i and across the time dimension t. In the case of panel heteroscedasticity, the variance of the error process in our case differs depending on the days to maturity i. It is likely that the errors in the panel model show this kind of heteroskedasticity, because one might expect e.g. that the interest rate prediction three months before the contract expiring day will show higher variability than only one week before, because of greater uncertainty. Figure 9, in which the root mean squared error in dependence of the days to maturity is depicted, confirms this presumption. The increasing graph shows that the predictive accuracy diminishes as the contract horizon is extended.

In order to test formally for homoskedasticity across panels, a Lagrange Multiplier test is used to test for a common variance.[15] Since the LM statistic for all panel regressions are significantly bigger than the 5 percent critical value, the test rejects the null hypothesis of homoskedasticity in all groups of futures interest rates (see detailed test results in table 11 in the Appendix).

Next, we test for heteroscedasticity across time, i.e. a variance of the error process depending on the index t. We perform a White test, with the result that one cannot reject the null hypothesis of homoscedasticity for all panel regressions and futures rates with different forecasting horizons.

Our data structure suggest further the presence of contemporaneous correla-

[13]With the presence of individual effects e.g., the estimation of equation (9) would turn out to be a dynamic panel model, which would require more complex GMM estimation techniques. The topic of estimating dynamic panel models has been the focus of many recent theoretical and simulation papers (see for example, Arellano and Bond [1991], Arellano and Bover (1993), Kiviet (1995) and Ahn and Schmidt(1995)) Many solutions to overcome the problem of biased and inconsistent estimators due to correlation of the error term with the lagged dependent variable have been already presented. See e.g. Sevestre and Trognon (1985) for the magnitude of this asymptotic bias in dynamic error component models.

[14]see Baltagi (1995), p.12.

[15]compare Greene (2000), p. 596ff.

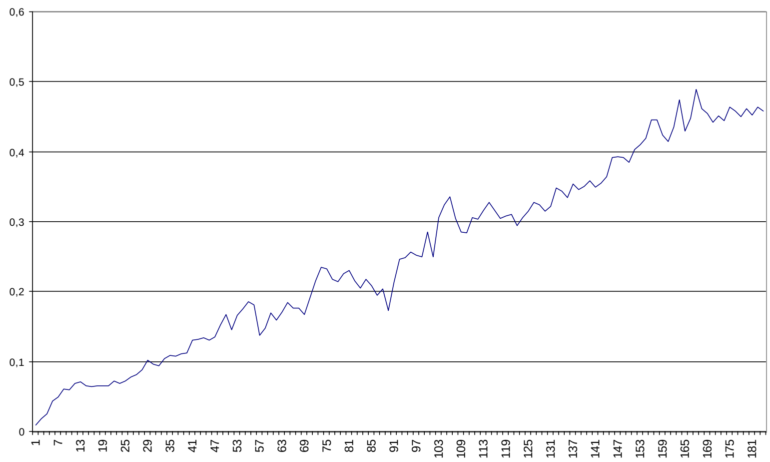

Figure 9: The Root Mean Squared Error of Euribor Futures from Spot Interest Rates

tion.[16] If a futures rate has a positive prediction error i days before contract maturity, it is likely that the futures price will show a similar prediction error j days before maturity, where $j = [i - n, i + n]$ and n denotes a sufficiently small time distance to this specific day. Such a contemporaneous correlation goes along with the elements $E_t(\epsilon_{it}\epsilon_{jt})$ being non-zero, where $E_t(\epsilon_{it}\epsilon_{jt})$ differs among pairs of units but not by time, i.e. $E_t(\epsilon_{it}\epsilon_{jt}) = E_{t'}(\epsilon_{it'}\epsilon_{jt'})$, $t \neq t'$. In order to test for contemporaneous correlation we performed a Breusch-Pagan LM test. With very large X^2 statistics for all panel regressions we can reject, as assumed, at every significance level the null-hypothesis of no cross-sectional correlation (see detailed test results in table 11 in the Appendix).

Additionally, there are two reasons, why one should test and control, if present, for serial correlation in the error process. The first reason is that serial correlation in cross sectional data needs for corrections in order to get unbiased and efficient estimates of standard errors. The second reason is that the presence of serial correlation contradicts against one criteria of informational efficiency.[17] Accordingly, we will test for first-order serial correlation, in which case the error process follows the

[16]Which means that large errors for unit i at time t are often accompanied by large errors for unit j at time t.

[17]compare Section 3.1.

structure:

$$\epsilon_{i,t} = \rho\epsilon_{i,t-1} + \nu_{i,t} \tag{11}$$

where the $\nu_{i,t}$'s are mean-zero variables independently distributed across time. Some analysts impose the additional assumption that the degree of correlation may differ between the units, so that we have to impose ρ_i instead of ρ. Beck and Katz (1995) argued that it is better to assume a common autoregressive process, because if one assumes poolability, it makes no sense to assume varying correlation coefficients.[18] The null hypothesis for no serial correlation is $\rho = 0$ against the alternative $|\rho| < 1$. Table (1) and table 11 in the Appendix summarize the LM test results for all equations and forecast horizons. In all regressions we cannot reject the null hypothesis of no serial correlation at least at a significance level of one percent.

5.2 Estimation Results

For the estimating equations (7) to (10) we used the OLS estimator with panel corrected standard errors (PCSE) proposed by Beck and Kratz (1995) in order to take account of heteroskedasticity, contemporaneous correlation, and, if needed, serial correlation.[19]

Detailed estimation results are presented in tables (11) to (16) in the appendix, which are summarized in table 1. In only three out of 24 regressions the null hypothesis of efficiency and unbiasedness of the Euribor futures market must be rejected. The regression results of all other regressions show that we cannot reject the hypothesis. The three exceptions occured in the estimations of equation (10) with futures rates that have a forecast horizon longer than three months. In these regressions, the included variable $f_{i,t} - f_{i-1,t}$, which denotes the futures price innovation of the day before, turns out to be significant, which contradicts our hypothesis of efficiency.

Since our sample extends over the millenium change date, we wish to examine how the money market handled this event. The year 2000 (Y2K) changeover was

[18] They could additionally show by a series of Monte Carlo experiments, that the assumption of common serial correlation process leads to superior estimates of β even when the data are generated with diverse, unit-specific ρ_i.

[19] Beck and Katz (1995) showed that OLS with panel corrected standard errors is superior to alternative estimates like e.g. the feasible least squares estimator, because latter results in highly downward biased standard errors unless there are substantially more time periods (T) than there are cross-sectional units (N).

Table 1: **Summary of results of efficiency tests with overlapping data described by equations (7) to (10)**

		F-Test		
		$\alpha = 0,\ \beta = 1,\ \gamma = 0$	$\rho = 0$	**Conclusion**
Futures	Equ. (7)	Yes[a]	Yes[a]	Efficiency accepted
(1-31 days)	Equ. (8)	Yes[a]	Yes[a]	Efficiency accepted
	Equ. (9)	Yes[a]	Yes[a]	Efficiency accepted
	Equ. (10)	Yes[a]	Yes[a]	Efficiency accepted
Futures	Equ. (7)	Yes[a]	Yes[b]	Efficiency accepted
(1-61 days)	Equ. (8)	Yes[a]	Yes[a]	Efficiency accepted
	Equ. (9)	Yes[a]	Yes[a]	Efficiency accepted
	Equ. (10)	Yes[a]	Yes[b]	Efficiency accepted
Futures	Equ. (7)	Yes[a]	Yes[a]	Efficiency accepted
(1-91 days)	Equ. (8)	Yes[a]	Yes[a]	Efficiency accepted
	Equ. (9)	Yes[a]	Yes[a]	Efficiency accepted
	Equ. (10)	Yes[b]	Yes[a]	Efficiency accepted
Futures	Equ. (7)	Yes[a]	Yes[a]	Efficiency accepted
(1-122 days)	Equ. (8)	Yes[a]	Yes[b]	Efficiency accepted
	Equ. (9)	Yes[a]	Yes[b]	Efficiency accepted
	Equ. (10)	No	Yes[b]	**Efficiency rejected**
Futures	Equ. (7)	Yes[a]	Yes[a]	Efficiency accepted
(1-153 days)	Equ. (8)	Yes[a]	Yes[a]	Efficiency accepted
	Equ. (9)	Yes[a]	Yes[a]	Efficiency accepted
	Equ. (10)	No	Yes[a]	**Efficiency rejected**
Futures	Equ. (7)	Yes[a]	Yes[a]	Efficiency accepted
(1-183 days)	Equ. (8)	Yes[a]	Yes[a]	Efficiency accepted
	Equ. (9)	Yes[a]	Yes[a]	Efficiency accepted
	Equ. (10)	No	Yes[a]	**Efficiency rejected**

[a] Significant at a five percent level [b] Significant at a one percent level.

regarded as a particular risky episode for financial market participants, because it was feared that information technology system failures could cause shortages of liquidity. If market participants anticipated even with only a small probability that this liquidity shortage might occur, their expectations about future interest rates would rise. One can therefore assume that the futures rates priced in the year 1999 for a futures contract that matures in the early weeks of the year 2000 contained an additional risk premium, which we call the Y2K-effect. To capture and analyze the potential presence of such Y2K-effect, we add a Y2K dummy. Since we regard only futures rates with a forecast horizon up to six months, and we have quaterly futures contracts, our Y2K dummy consists of all futures rates of the March 2000 contract prices between the 13. September 1999 to the 07. January 2000.[20] If there is a Y2K effect, the coefficient on that dummy would be significant and we would assume it to be negative.

The Y2K dummy turns out to be insignificant in all regressions. From that we can conclude that market participants did not expect a shortage in liquidity that last until March 2000, the nearest futures contract settlement date of the Euribor contract after the millenium.

To summarize, the hypothesis that futures rates are good predictors of interest rates finds empirical support. With only three exceptions, the tests show that the futures rates with a forecast horizon up to six month are unbiased and efficient estimators of the relevant spot interest rates. They do not incorporate a significant risk premium. Only when the forecast horizon is longer than three months, market participants did not seem to incorporate immediately new information into their predictions that became available between $i-1$ and i.

6 The Impact of Monetary Policy News and Events

This section focuses on the reaction of the three-month Euribor futures rates on monetary policy decisions. This will allow us to draw conclusions of how well money market participants predict decisions of the Governing Council of the European Central Bank (ECB).

[20] After the first week of the year 2000 one can assume that this additional risk premium, if present, vanishes, since the investors could see that the 2000 changeover work without problems.

According to the efficient markets hypothesis (EMH), the three-month futures rate should only change between two days, if new information became available to money market participants that changes their expectations about future interest rates. As Poole and Rasche (2000) argue, the market should adjust to news, but not to the central bank's announcements of monetary policy decisions if the market is able to anticipate the systematic behavior of the central bank. The relation between financial price movements and information is often called the *announcement effect methodology.*[21] Most recent research dealing with announcement effects on financial prices focuses on the intraday volatility.[22] Some researchers also examine the impact of announcements and surprises on daily closing prices of financial assets or derivatives. Li and Engle (1998), for example, analyzed the impact of surprises in announcements on interday volatility persistence in the US treasury futures market and find strong asymmetric effects.

An interesting question we address in this section is whether market participants succeeded in forecasting the monetary policy decisions of the ECB, in the sense that futures rates' volatility is not significantly higher on policy announcements days than on other days.[23]. The answer indicates in how far the ECB monetary policy decisions were predictable, and in how far the market participants understand the central bank's policy intentions. Note that a futures rate correction at ECB council days does not necessarily mean that this interest rate decision was entirely surprising, or that the ECB's monetary policy is not understood by the financial market. Market participants might have expected an interest rate change by the ECB but they were wrong in the exact timing or size of that policy action.

Besides regarding this 'surprise effect', it is also interesting to focus on change

[21]This methodology was first developed by Wachtel and Young (1987), who have applied this announcement effect methodology to test for the effects of announced growing deficit on interest rates, see also Goodhart and O'Hara (1997) for an overview.

[22]e.g. Ederington and Lee (1993) analyzed transactions data on Eurodollar, Treasury Bond and Deutschemark futures to determine when market participants respond to 19 macroeconomic releases. They find that volatility is higher than normal for some 15 minutes after major releases and slightly higher for several hours on release days. Fleming and Remola (1997) analyzed the behavior of US T-Bonds to scheduled macroeconomic news announcement and found out that these announcements had a statistically significant impact upon trade volume and price changes.

[23]There are several papers addressing the same question for the US market. Krueger and Kuttner (1996), Kuttner (2001) and Poole and Rasche (2000) examined how well the markets are able to anticipate the Fed's monetary policy moves using Fed funds futures prices.

of the absolute prediction error between two days, $|(r_t - f_{i,t})| - |(r_t - f_{i-1,t})|$, in connection with the ECB monetary policy decisions. This may help to draw conclusions about whether ECB monetary decisions cause additional a 'confusion effect', in the sense that the forecast error increases. Alternatively, the central bank's policy devision could also help to improve the interest rate forecast in the sense that the prediction error decreases. For the analysis in this section, we take the closing rates of all nearby three-month Euribor futures between 1 January 1999 and 18 March 2002.

There are two main sources of information sent by the ECB. One is the news releases after Governing Council meetings. The Governing Council of the ECB is the main policy making entity and takes the main decisions of monetary policy for the Eurosystem. It is composed of 6 ECB Executive Board members and 12 governors of the national central banks of the countries who joint the third stage of Economic and Monetary Union (EMU). The Governing Council meets every two weeks (usually) on Thursdays, and their main focus are in particular interest rate decisions. The second source of information is the periodically released publications. Towards the end of each month the ECB publishes new figures on M3, and usually on the Thursday of the second week of each month it releases a Monthly Bulletin with a host of macroeconomic data and monetary analysis.[24] During our sample period 77 Governing Council meetings took place, including 12 ECB interest rate changes displayed in table 2, 34 releases of information about M3 figures, and 38 published Monthly Bulletin.

6.1 Intraweek Volatility of Euribor Futures Rates

In this section we discuss the intraweek volatility of the Euribor futures rates and analyze, whether any regularities can be observed that can be related to the institutional environment of the money market microstructure. Like e.g. Hartmann et al. (2001), we define volatility as the absolute change in the futures rate between two trading days multiplied by 100 to express all numbers in basis points, $\sigma_t = |f_{i,t} - f_{i-1,t}| * 100$.

In table 3 the simple average volatility across the different weekdays are listed. The overall average volatility of all trading days is about 1.87 basis points, and

[24] For a more detailed description of the functioning of the Eurosystem and monetary policy decisions in the euro area see Hartmann (2001).

Table 2: ECB interest rate changes between November 1999 and March 2002

Decision on	Deposit rate	MRO rate	Marg. lending rate
21 Jan 99	2.00	3.00	4.50
8 April 99	1.50	2.50	3.50
4 Nov 99	2.00	3.00	4.00
3 Feb 00	2.25	3.25	4.25
16 March 00	2.50	3.50	4.50
27 April 00	2.75	3.75	4.75
8 June 00	3.25	4.25	5.25
31 Aug 00	3.50	4.50	5.50
5 Oct 00	3.75	4.75	5.75
10 May 01	3.50	4.50	5.50
30 Aug 01	3.25	4.25	5.25
8 Nov 01	2.25	3.25	4.25

MRO=main refinancing operation.
The interest rate changes at the 4. January 99 are not included in this table, because it was already decided in December 1998.
Source: ECB

the single average volatilities on each day of the week lies between 1.46 and 2.26 basis points with Monday as the least volatile day and Thursday the most volatile weekday. In the second column of the table we examine the occurrences of "large" changes in expectations of market participants. We define "large" as an absolute daily change in the futures rate that exceeds ten basis points. All together there are seven large futures rate changes in the sample, of which three happened on a Thursday, and two each on a Wednesday and a Friday.

When regarding simple average volatilities, one ignores the potential influence of the time to contract expiration, on the futures rate volatility. Samuelson (1965) claims that volatility increases with a decreasing forecast horizon i.[25] Since the last trading day of the three-month Euribor futures contract is always a Monday, futures contracts traded e.g. on Wednesdays have forecast horizons that are 6 days longer than those traded on e.g. Mondays. If the time to maturity has an influence on the volatility of futures rates, this would result in a kind of heteroscedasticity. This can

[25]This phenomenon is called the Samuelson effect. Several authors showed that this effect is not present in the case of financial futures.

Table 3: Average Volatility and Frequency of ”‘large”’ Volatility of Euribor Futures Rates

	Average Volatility	Days with Volatility ≥ 10
Monday	1.46 [1.45]	0
Tuesday	1.79 [1.82]	0
Wednesday	1.88 [2.05]	2
Thursday	2.26 [2.54]	3
Friday	1.91 [2.23]	2
All days	1.86 [2.07]	7

Average standard deviations are reported in squared brackets. Volatility measures are multiplied by 100 to express basis points.

be tested and corrected by sorting the data by time to maturity and futures contract, and regressing the average volatilities on a constant and 'weekday-dummies' with an OLS estimation with panel corrected standard errors, proposed by Beck and Katz (1995), which corrects for panel-level heteroscedasticity and contemporaneous correlation. The estimation results are shown in table (4).

Table 4: Day- Average Volatilities with Corrections for Heteroscedasticity

Volatility	Coefficients
const.	1.46^{**} [0.11]
Tuesday	0.33 [0.21]
Wednesday	0.42^{*} [0.24]
Thursday	0.79^{**} [0.25]
Friday	0.45^{**} [0.20]
R^2	0.02
Obs.	801

The averages show identical figures like in table 3 but show smaller standard errors. The estimation results confirm our previous results. The average volatility is the highest on Thursdays and the lowest on Mondays.

6.2 Volatility and Governing Council Meetings

The higher volatility on Thursdays could be a general Thursday effect, or be caused by the informational content of Governing Council meetings and the release of the

Monthly Bulletin on Thursdays. In this section we explore this issue and analyse the impact of Governing Council meetings on the volatility of the Euribor Futures rates.

Figure 10 depicts the volatility of the futures rates on Council days. Meetings at which the ECB Council changed the interest rates are highlighted. The graph shoes that some Governing Council meetings had bigger effects on futures rate changes than others. On 15 out of 77 Governing Council days the futures rates changed by more than 4 basis points. Days with a high volatility of even more than 10 basis points are observed at the 08. June 2000, 04. January 2001, 11. April 2001 and the 10. May 2001. Half of these dates are days, when the ECB published an interest rate change. The market was surprised by these ECB policy decisions, either to change or not to change interest rates, and had to adapt their expectations about the future interest rates to the new economic environment.

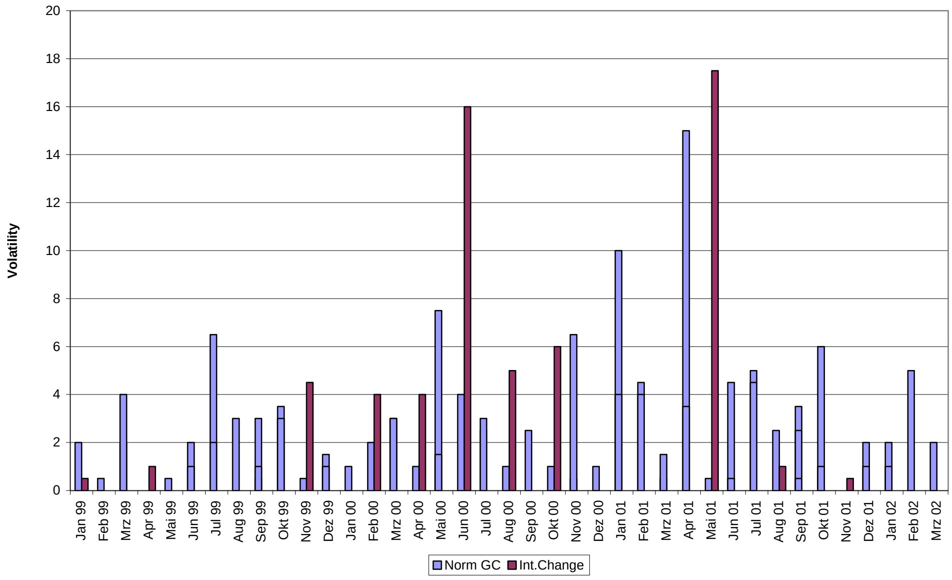

Figure 10: Volatility of Futures Rates at Governing Council Meetings

However, there are also Governing Council days with a low volatility of futures rates, where the financial market did not react heavily to monetary policy decisions. These policy decisions incorporated no new information and did not change the market's expectations. During the observed time period there were 33 out of 77

Governing Council days, where the volatility is low and under two basis points, which is roughly the average volatility at all days together. That means that the announcement effect of more than 40 percent of the Governing Council meetings has been small. Thus, these monetary policy decisions were widely in accordance with market participants' expectations about future interest rates.

Table 5 presents the average volatilities of the Euribor futures for non-Council Thursdays, Council days in general, Governing Council days with changes in interest rates, Governing Council days without changes in interest rates and Thursdays, when the Monthly Bulletin (MB) is published. Additionally, we listed again the number of days, where the absolute change of the Euribor futures rate exceeds 10 basis points.

Table 5: Effects of Monetary Policy Decisions and Announcements on Day-Volatility

	Obs.	Av. Volatility	Days with Vola.$\geq$ 10
Non-GC Thursdays	97	1.81 [1.86]	0
GC Days	77	2.95 [3.35]	4
GC with Int. rate Change	12	5.21 [5.71]	2
GC without Int.rate Change	65	2.54 [2.57]	0
Thursdays with MB release	38	1.95 [1.91]	0

Notes: Compare Table 2

Table 5 shows that the average volatility on Governing Council meetings is indeed higher than on non-Council Thursdays and on any other day of the week (compare table 3). This result holds for Governing Council meetings with and without announced interest rates changes. With an average volatility of more than 5 basis points, Governing Council meetings with announced monetary policy changes show the largest volatility in the table which is nearly three times larger than the average volatility on all days. The average volatility on Thursdays with a release of the Monthly Bulletin is not significantly larger than the average volatility. Out of the seven largest futures rate changes observed in our sample (compare table 3), four occurred at days with Governing Council meetings.

As one can interpret volatility as a measure of surprise, the high volatilities on Governing Council meetings indicate that on average the decisions of the European Central Bank Council, both to change and to keep the interest rates, were not fully anticipated by market participants. The results in table 6, where again the volatilities are corrected for heteroscedasticity, support these findings.[26]

[26]We excluded the a dummy for Governing Council meetings without interest rate changes from

Table 6: Effects of Monetary Policy Decisions and Announcements on Average Volatility with Correction for Heteroscedasticity

Volatility	Coefficients
const.	1.74** [0.14]
GC Days	0.79** [0.28]
GC with Int.rate Change	2.67** [0.84]
Thurdays with MB release	0.21 [0.41]
R^2	0.05
Obs.	801

Average standard deviations are reported in squared brackets. Volatilities are multiplied by 100 to express basis points.

There are several possible explanations of why some interest rate decisions seem to have surprised the market and it does not necessarily mean that the ECB has communicated its policy response inadequately. Issing (2001) argues that informational asymmetry between markets and the monetary authority may cause surprise effects of interest rate decisions. The monetary authority has some information at its disposal which market participants do not have. Furthermore he argues "that - even with the same information sets - the monetary authority and the financial markets may not share the same assessment of the economic, financial or monetary situation", which may lead to the central bank surprising markets with its policy moves.

6.3 Intraweek Volatility of the Prediction Error

The question we want address in this section is, whether the change of the absolute prediction error, $|(r_t - f_{i,t})| - |(r_t - f_{i-1,t})|$, varies between the different weekdays, and whether we can also find some policy announcement effects there. This analysis serves to answer the question whether ECB monetary policy decisions cause on average a decrease or an increase in the absolute prediction error.

Table 7 presents the average change of the absolute prediction error at every weekday. The figures show that on average the absolute forecast error decreased on Mondays, Tuesdays and Thursdays while it increased on Wednesdays and Fridays. These results have to be taken with caution since the resulting coefficients show big

the regressions since that dummy is highly correlated with the general Governing Council dummy standard errors indicating that there seems to be no significant positive or negative effect on any weekday.

Table 7: Average Absolute and Total Change in Prediction Error of Euribor Futures Rates

	Change in abs. Pred. Error
Monday	-0,13 [2.06]
Tuesday	-0,2 [2.56]
Wednesday	0.01 [2.79]
Thursday	-0.13 [3.4]
Friday	0.19 [2.93]
All days	-0.05 [2.79]

Average standard deviations are reported in squared brackets. Changes in the Prediction error are multiplied by 100 to express basis points.

Table 8 shows the estimation results with panel-corrected standard errors in order to correct for potential heteroskedasticity and correlation. The result coincide with the findings reported in table 7. None of the included dummies and also the constant shows a significant coefficient, which supports that we do not observe a systematic change of the absolute prediction error on any weekday. In that sense the prediction error on every weekday increases and decreases in absolute terms on average by the same amount.

Table 8: Average Prediction Error with Corrections for Heteroscedasticity

	Change in abs. Pred. Error
const.	0.02 [0.11]
Tuesday	-0.23 [0.21]
Wednesday	0.07 [0.21]
Thursday	-0.26 [0.21]
Friday	0.22 [0.19]
R^2	0.01
Obs.	801

6.4 Change in the Prediction Error and Governing Council Meetings

As we have seen in the previous sections, the average volatility of the Euribor futures rates was significantly higher on Governing Council days than on other weekdays, which indicates the news effect of ECB monetary policy decisions. In this section we want to investigate, whether the same can be observed for the average change of the absolute prediction error. If the news released on Governing Council days improved the market participants' prediction of interest rates, one might assume that the average change on these days has been negative.

Table 9: Effects of Monetary Policy Decisions and Announcements on Day-Change of the Prediction Error

	Change in abs. Pred. Error
GC-Days	-0.36 [4.47]
Non-GC Thursdays	-0.17 [2.59]
GC with Int. rate Change	0.38 [7.88]
Thursday with MB release	0.03 [2.75]

Notes: Compare Table 2

Figure 11 gives an overview about the change of the absolute prediction error on Governing Council and non-Council days. This figure shows seven outliers, where the absolute change of the forecast error exceeded ten basis points. Five of these outliers signal an improvement in the interest rate predictability. Three out of these seven outliers are observed on Governing Council days, two of them (the Council meetings at the 11.04.2001 and the 10.05.01) show a decrease and one (the Council meetings at the 04.01.2001) an increase in the prediction error. In general, the change of the prediction error on Council days shows to the same extent positive and negative values. Thus, from these findings one can conclude that the information released on Governing Council meetings did not always help the market participants to *improve* their interest rate forecasts.

Table 9 presents the average change of the absolute forecast error of the Euribor futures rates on non-council Thursdays, governing council days with and without interest rate changes, and days, when the Monthly Bulletin is released. The listed averages in that table are all very small and range between $-0,36$ basis points on Governing Council days and $0,38$ basis points on Governing Council days, when

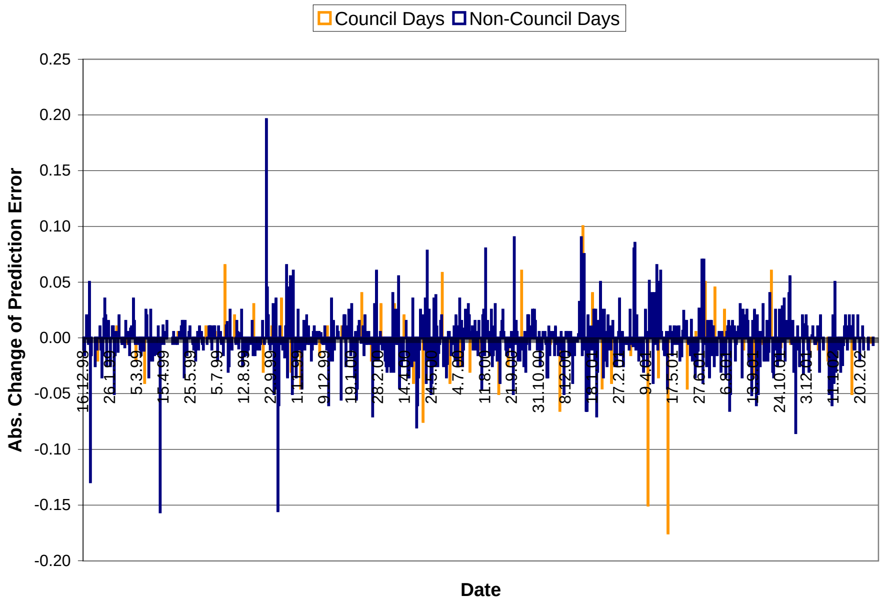

Figure 11: Total Change of the Prediction Error of Euribor Futures

an interest rate change was decided. In relation to these small average values we observe quite high standard errors indicating that there seems to be now significant increase or decrease of the prediction error on each of these specific days. That results is also supported by a panel corrected standard errors estimation to capture cross-sectional heteroscedasticity and correlation. The results of that estimation is illustrated in table 10.

Since none of the included dummies nor the constant show significant coefficients, we can conclude that we do not observe a systematic development of the forecast error of the Euribor futures rates, and that neither the information released on Governing Council meetings nor the information released by the publishing of the Monthly Bulletin had a significant increasing or decreasing effect on the forecast error. In that sense the ECB's monetary policy announcement caused no significant improvements of the interest rate predictability.

Table 10: Effects of Monetary Policy Decisions and Announcements on Day-Prediction Error with Correction for Heteroscedasticity

	Change in abs. Pred. Error
const.	0,03 [0,07]
GC	-0,22 [0,29]
Int. Change	-0,96 [0,88]
Month. Bulletin	0,06 [0,48]
R^2	0.01
Obs.	801

7 Conclusion

The first aim of this paper was to analyze the predicitive power of the three-month Euribor futures. We examined whether the Euribor futures rates are unbiased and efficient estimators of realized interest rates. We define efficiency as *informational efficiency* in the sense that the market participants should incorporate all available information into the pricing of the futures contract. Thus, past information should not help market participants to improve their forecast of future interest rates.

For the test of the unbiasedness and efficiency of the Euribor futures market we used daily quoted futures rates from December 1998 to March 2002. To avoid the problem of overlapping data and time-varying risk premia we performed a panel analysis, where we grouped the sample according to the time to expiration. The estimation results show that Euribor futures rates are unbiased and informationally efficient predictors of future spot interest rates. They do not incorporate any risk premium, and market participants form rational expectations in the sense that they use all available information for the pricing of the futures prices.

The second aim of this paper was to analyze the impact of the ECB Council's monetary policy decisions on the day-volatility of the Euribor futures rates and the change of the absolute prediction error. According to the Efficient Market Hypothesis the futures rates should only change between two days, when new information comes on the market. Thus, one can interprete the volatility of the futures rates at Governing Council meetings as a measure of surprise caused by the central bank's policy decision. If all decisions were anticipated in advance, the volatilty on Governing Council meetings should not be higher than on other days. The analysis of the change in the absolute forecast error on Governing Council days gives evidence, whether the central bank's policy decisions systematically improved or worsened the market participants ability to predict future interest rates.

The average volatlity of the Euribor futures rates on Governing Council Thursdays was nearly twice as large as on 'normal' Thursdays, and most of that extra volatility came from Governing Council meetings at which interest rate changes were adopted. A closer look at the futures rates changes at Governing Council days shows that while some ECB policy decisions were anticipated correctly by the money market participants, others constituted as a surprise. Thus, the timing of ECB's monetary decisions or the decisions themselves were not always fully anticipated by market participants.

The change in the absolute prediction error of the Euribor futures rates on Governing Council days was not significantly postive or negative and different compared to that on all other days. In that sense the ECB's policy decisions did not systematically cause the market participants to revise their interest rate predictions in an improving or worsening direction.

We can conclude that the unbiasedness and efficiency of the Euribor futures rates reflects a well functioning of the transmission process of the ECB's monetary policy. Market participants understand the policy decisions of the Central Bank and on average are able to predict them precisely. Nevertheless some Governing Council decisions still cause surprises leading market participants to revise their interest rate forecasts expressed by the futures rates. Thus, the ECB's information policy can be improved.

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A Appendix

Table 11: Test Statistics

		Indiv. Effects H_0: $\alpha_i = \alpha$	Hetero. across i H_0: $\sigma_{ii} = \sigma$	Contemp. Correl. H_0: $\sigma_{ij} = 0$	Serial Correl. H_0: $\rho = 0$
Futures	Equ. (7)	0.99	0.00	0.00	0.84
(1-31 days)	Equ. (8)	0.99	0.00	0.00	0.60
	Equ. (9)	0.99	0.00	0.00	0.91
	Equ. (10)	0.99	0.00	0.00	0.86
Futures	Equ. (7)	1.00	0.00	0.00	0.03
(1-61 days)	Equ. (8)	0.99	0.00	0.00	0.39
	Equ. (9)	0.99	0.00	0.00	0.84
	Equ. (10)	1.00	0.00	0.00	0.41
Futures	Equ. (7)	0.99	0.00	0.00	0.43
(1-91 days)	Equ. (8)	0.99	0.00	0.00	0.13
	Equ. (9)	0.99	0.00	0.00	0.08
	Equ. (10)	0.99	0.00	0.00	0.16
Futures	Equ. (7)	1.00	0.00	0.00	0.07
(1-122 days)	Equ. (8)	0.99	0.00	0.00	0.02
	Equ. (9)	1.00	0.00	0.00	0.01
	Equ. (10)	0.99	0.00	0.00	0.03
Futures	Equ. (7)	1.00	0.00	0.00	0.23
(1-153 days)	Equ. (8)	1.00	0.00	0.00	0.06
	Equ. (9)	1.00	0.00	0.00	0.13
	Equ. (10)	1.00	0.00	0.00	0.09
Futures	Equ. (7)	1.00	0.00	0.00	0.98
(1-183 days)	Equ. (8)	1.00	0.00	0.00	0.65
	Equ. (9)	1.00	0.00	0.00	0.37
	Equ. (10)	1.00	0.00	0.00	0.41

Figures in p-values.

Table 12: Estimation Results for Euribor Futures Rates with 1-month Forecast Horizon

	Independent Variables					Statistics				Coefficient test			F-test
Equ.	α	β	r_{t-1}	$f_{i,t-1}$	$f_{i,t}$-$f_{i-1,t}$	R^2	RMSE	NT	AR1	α	β	$\gamma_{1,2,3}$	
(10)	**0.09**	**0.97****				0.99	0.06	267	0.84	0.14	0.1		0.21
	0.06	0.02											
(11)	**0.10**	**0.95****	**0.02**			0.99	0.06	246	0.6	0.15	0.15	0.56	0.29
	0.07	0.03	0.03										
(12)	**0.11**	**0.96****		**0.02**		0.99	0.06	243	0.91	0.13	0.16	0.62	0.28
	0.07	0.03		0.03									
(13)	**0.09**	**0.97****			**0.00**	0.99	0.06	262	0.86	0.16	0.11	0.81	0.20
	0.07	0.02			0.02								

Standard errors in parentheses, R^2 is the proportion of the total variation in $r_{i,t}$ explaines by the regression, RMSE denotes the root mean squared error, NT is the number of observations. AR1 gives the p-values of a LM test for first-order autocorrelation, the individual coefficient tests are simple linear tests of coefficient restictions against the null hypothesis where α =0, β=1, $\gamma_{1,2,3}$=0, test results in p-values.

Table 13: Estimation Results for Euribor Futures Rates with 2-month Forecast Horizon

	Independent Variables					Statistics				Coefficient test			F-test
Equ.	α	β	r_{t-1}	$f_{i,t-1}$	$f_{i,t}$-$f_{i-1,t}$	R^2	RMSE	NT	AR1	α	β	$\gamma_{1,2,3}$	
(10)	**0.15**	**0.96****				0.98	0.1	548	0.03	0.15	0.1		0.21
	0.10	0.03											
(11)	**0.13**	**0.92****	**0.04**			0.98	0.1	505	0.39	0.26	0.11	0.4	0.29
	0.12	0.05	0.05										
(12)	**0.13**	**0.92****		**0.04**		0.98	0.1	497	0.84	0.24	0.11	0.39	0.29
	0.11	0.05		0.05									
(13)	**0.14**	**0.96****			**0.04**	0.99	0.09	538	0.41	0.15	0.11	0.22	0.05
	0.10	0.03			0.04								

See notes in bottom of table 12

Table 14: Estimation Results for Euribor Futures Rates with 3-month Forecast Horizon

	Independent Variables						Statistics				Coefficient test			F-test
Equ.	α	β	r_{t-1}	$f_{i,t-1}$	$f_{i,t}$-$f_{i-1,t}$	Y2K	R^2	RMSE	NT	AR1	α	β	$\gamma_{1,2,3}$	
(10)	**0.12**	**0.97****				**0.16**	0.97	0.13	814	0.43	0.3	0.28		0.56
	0.12	0.03				0.17								
(11)	**0.14**	**0.95**	**0.02**			**0.16**	0.97	0.13	753	0.13	0.32	0.39	0.76	0.71
	0.14	0.06	0.06			0.17								
(12)	**0.15**	**0.95****		**0.01**		**0.16**	0.97	0.13	730	0.08	0.25	0.39	0.86	0.66
	0.13	0.06		0.05		0.17								
(13)	**0.12**	**0.97**			**0.12***	**0.16**	0.97	0.13	792	0.16	0.3	0.29	0.01	0.01
	0.12	0.03			0.05	0.16								

See notes in bottom of table 12

Table 15: Estimation Results for Euribor Futures Rates with 4-month Forecast Horizon

	Independent Variables						Statistics				Coefficient test			F-test
Equ.	α	β	r_{t-1}	$f_{i,t-1}$	$f_{i,t}-f_{i-1,t}$	Y2K	R^2	RMSE	NT	AR1	α	β	$\gamma_{1,2,3}$	
(10)	**0.18**	**0.95****				**0.20**	0.95	0.17	1063	0.07	0.24	0.21		0.42
	0.15	0.04				0.21								
(11)	**0.20**	**0.96**	**-0.02**			**0.20**	0.95	0.17	1002	0.02	0.23	0.61	0.82	0.61
	0.17	0.07	0.07			0.21								
(12)	**0.28**	**0.96****		**-0.03**		**0.17**	0.95	0.16	955	0.01	0.07	0.52	0.62	0.32
	0.15	0.06		0.06		0.19								
(13)	**0.17**	**0.95****			**0.21****	**0.20**	0.95	0.17	1039	0.03	0.25	0.21	0	0
	0.15	0.04			0.06	0.21								

See notes in bottom of table 12

Table 16: Estimation Results for Euribor Futures Rates with 5-month Forecast Horizon

	Independent Variables						Statistics				Coefficient test			F-test
Equ.	α	β	r_{t-1}	$f_{i,t-1}$	$f_{i,t}-f_{i-1,t}$	Y2K	R^2	RMSE	NT	AR1	α	β	$\gamma_{1,2,3}$	
(10)	**0.26**	**0.93****				**0.19**	0.93	0.21	1334	0.23	0.19	0.15		0.32
	0.20	0.51				0.25								
(11)	**0.29**	**0.95****	**-0.03**			**0.18**	0.92	0.21	1273	0.06	0.18	0.57	0.77	0.49
	0.22	0.09	0.09			0.24								
(12)	**0.41**	**0.94****		**-0.05**		**0.14**	0.93	0.2	1198	0.13	0.04	0.48	0.55	0.21
	0.20	0.08		0.08		0.23								
(13)	**0.26**	**0.93****			**0.3****	**0.19**	0.93	0.21	1305	0.09	0.19	0.15	0	0
	0.20	0.05			0.09	0.25								

See notes in bottom of table 12

Table 17: Estimation Results for Euribor Futures Rates with 6-month Forecast Horizon

	Independent Variables						Statistics				Coefficient test			F-test
Equ.	α	β	r_{t-1}	$f_{i,t-1}$	$f_{i,t}-f_{i-1,t}$	Y2K	R^2	RMSE	NT	AR1	α	β	$\gamma_{1,2,3}$	
(10)	**0.29**	**0.92****				**0.23**	0.90	0.24	1582	0.98	0.22	0.18		0.38
	0.24	0.06				0.27								
(11)	**0.32**	**0.93****	**-0.01**			**0.22**	0.90	0.25	1521	0.65	0.23	0.51	0.9	0.57
	0.26	0.11	0.11			0.27								
(12)	**0.49**	**0.94****		**-0.06**		**0.17**	0.90	0.23	1413	0.37	0.04	0.51	0.51	0.22
	0.24	0.10		0.09		0.26								
(13)	**0.30**	**0.92****			**0.33****	**0.23**	0.90	0.24	1544	0.41	0.21	0.18	0	0
	0.24	0.09			0.11	0.28								

See notes in bottom of table 12