Oesterreichische Nationalbank

Working Paper 94

What Do German Short-Term Interest Rates Tell Us About Future Inflation?

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Imprint: Responsibility according to Austrian media law: Guenther Thonabauer, Secretariat of the Board of Executive Directors, Oesterreichische Nationalbank
Published and printed by Oesterreichische Nationalbank, Wien.
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Editorial

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December 31, 2004

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Abstract:

We empirically assess the predictive power of short-term interest rates and term spreads for future inflation in Germany. Based on a multivariate term structure framework, we construct a vector error forecasting equation for inflation forecasts of up to two years. The results of the alternative error correction reveal that the level of the short-term interest rates conveys much more information on future inflation than the yield curve spreads. In particular, the one-month and three-month nominal interest rates seem to be informative on future inflation at a two-year horizon.

The views expressed are those of the author and do not necessarily represent those of the Oesterreichische Nationalbank. The author thanks an anonymous referee, Benedikt Braumann, Heinz Herrmann, Helene Schuberth and in particular Peter Brandner for helpful comments and suggestions.

1 Introduction

Using the yield curve for monetary policy purposes has a long tradition in central banking. It has long been recognized that the yield curve incorporates information on economic agents expectations about future inflation and other economic variables, like interest rates, output, exchange rates, etc. Empirical research on the information content of the yield curve was sparked off in the U.S. at the beginning of the 1990s, when Manuel Johnson, vice-governor of the Federal Reserve System, announced that the term structure was one of three indicators to gauge whether monetary policy was expansionary or not. Since then, a bulk of empirical papers analysed the predicitve content of yield curve movements in the U.S. and other countries.[1] Term structure movements have been found to forecast changes in inflation pretty well in one period in one country, but the empirical evidence is not straightforward, for a thorough review of the literature on the role of asset prices for forecasting inflation (and output) see Stock and Watson (2003).

[1] Mishkin (1988, 1990a, 1990b, 1990c, 1991, 1992) and Jorion and Mishkin (1991) found that in the US, the longer-maturity term spreads provide substantial information about future inflation whereas the shorter-maturity term spreads for maturities of six months or less provides more information on the term structure of real interest rates. Other papers during the 1990s evaluated the information content of the German yield curve, see for instance Hesse and Roth (1992), Davis and Fagan (1997), Gerlach (1995), Wolters (1998), Schich (1999), Jochum and Kirchgässner (1999) and Hansen (2001). Jochum and Kirchgässner (1999), for instance, find no evidence, Hanson (2001), in contrast, some evidence on the usefulness of term spreads to predict future inflation. In two recent contributions, Estrella and Mishkin (1997) and Berg and Bergeijk (2001) explore the inflation forecasting properties of the term structure for the Eurosystem. Estrella and Mishkin (1997) argue that the yield curve has significant predictive power for real activity and inflation, with horizons of one to two years for real activity and more than two years for inflation. Berk and Bergijk (2001), on the contrary, conclude that considerable care should be taken in using the yield curve as an information variable for monetary policy decisions. The study of Estrella and Mishkin (1997) is a cross-country analysis covering France, Germany, Italy, the U.K. and the U.S.A. from 1973 to 1995, whereas Berk and Bergijk (2001) take a broader set of 12 OECD countries plus euro area-wide equivalents from 1970 to 1998. Stock and Watson (2003) analyse quarterly data on 43 variables from seven countries (Canada, France, Germany, Italy, Japan, the United Kingdom and the United States). According to their findings, first, there is stronger evidence on the usefulness of asset prices to forecast output growth than inflation. In another recent paper, Forni, Hallin, Lippi and Reichlin (2003) use a large dataset of 447 monthly macroeconomic time series of the main Euro area countries to simulate out-of-sample predictions of the Euro area industrial production and the harmonized inflation index and to evaluate the forecasting power of financial variables. Forni et al. (2003) find that multivariate methods outperform univariate methods, with financial variables helping to forecast inflation at a one-, three-, six- and twelve-month horizon. Berk (1998) provides a comprehensive survey.

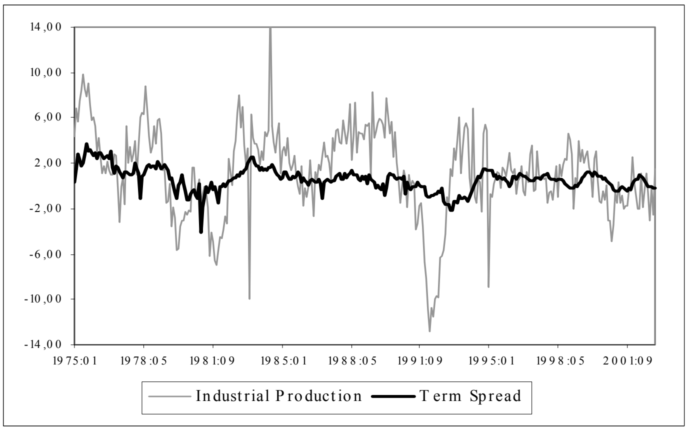

Figure 1: The term spread and industrial production in Germany one year ahead (1975:01 - 2002:12)

A related strand in the literature investigates the information content of the yield curve for future economic activity, thereby showing that in particular in Germany, the term structure strongly predicts real activity[2], see Figure 1 for expositional purposes.

In this paper, we empirically assess the predictive power of the German yield curve for future inflation from January 1975 to December 2002. As opposed to former contributions to the literature, which primarily evaluate the relationship between interest rate spreads and inflation rates for medium- and long-term horizons (1 to 10 years), we focus on short-term horizons between 1 and 24 months.[3] Also in contrast to previous work on the German yield curve, we test for structural breaks in the real interest rate time series. Basically, we follow the framework of Tzavalis and Wickens (1996), applied in their empirical work on U.S. interest rate and inflation data.

[2] Plosser and Rouwenhorst (1994), Davis and Hendry (1994), Davis and Fagan (1997), Smets and Tsatsaronis (1997) and Estrella and Mishkin (1997).

[3] The maximum horizon of 24 months is also chosen because monetary policy measures are typically assumed to affect the real economy with a lag of six months or two years, or somewhere in-between, see for instance Duisenberg (1999).

The forecasting error correction equation is based on multivariate cointegration analyses including the term spread and short-term interest rates[4] with the short-run dynamic adjustment of the term structure as additional information.

The paper is organized as follows: Chapter 2 outlines the theoretical framework of the m-period Fisher equation. Chapter 3 describes the data including tests on structural breaks in the real interest rate series. Chapter 4 presents empirical tests on the Fisher equation. Chapter 5 displays new evidence on the Mishkin equation. Chapter 6 covers the error correction forecasting equation and Chapter 7 concludes.

2 Future inflation and the term structure

The derivation of a formal relationship between inflation and the term structure is based on two building blocks, the one-period Fisher equation and the Rational Expectations Hypothesis of the Term Structure (REHTS). The intuition is straightforward. Nominal interest rates are—according to the Fisher equation—composed of at least two components, the ex-ante real interest rate and the expected rate of inflation. A comparison of current nominal with expected future interest rates should give some indication on the future path of inflation if certain assumptions are met: constancy of real interest rates, perfect substitutability between assets of different maturities and the validity of the expectations theory of the term structure.[5]

[4]Kozicki (1998) and Estrella and Mishkin (1997) argue that the term spread incorporates information on future inflation since inflation responds to monetary policy action and the yield curve spread is an indication of the monetary policy stance. Changes of the key monetary policy interest rates usually spread along the entire yield curve, however in a non-uniform way. Short-term interest rates are predominantly affected by liquidity conditions in the credit markets, long-term rates mainly by inflation expectations and ex-ante long-term real interest rates. If, for instance, the central bank raises interest rates and the monetary policy tightening is regarded as credible, tighter money market conditions are mitigated at the long end of the yield curve by reduced inflation expectations. As a result, long-term rates generally mount less than short-term rates, the yield curve flattens and the term spread decreases. Vice versa, a lowering of interest rates should lead to an increase in the spread, the monetary policy stance has been loosened, real activity will speed up and inflation accelerate in the future. Other indicators measuring the monetary policy stance include key monetary policy rates, short-term nominal and real interest rates and monetary aggregates. In comparison with yield curve spreads, short-term interest rates are more accurate and less noisy measures, since—in particular—longer-term spreads are frequently influenced by fluctuations in risk premiums.

[5]In case any of these assumptions is violated, the interpretation of term structure movements would be more complex and the value of term spread variations as an indicator

According to the Fisher equation, the nominal 1-period interest rate $R_{(t)}$ is given by:

$$R_{(t)} = rr_{(t)} + E_{(t)}\pi_{(t,1)} \tag{1}$$

where $rr_{(t)}$ is the one-period ex-ante real interest rate and $E_{(t)}\pi_{(t,1)}$ the expected inflation at time t for the period $(t+1)$.[6] In other words, the nominal interest rate at time t is the sum of the ex-ante real interest rate and the expected rate of inflation from t to $(t+m)$. The other building block, the REHTS, maintains that, after adjustment for risk, the expected return from holding a bond for one period that has m-periods to maturity is the same as holding a one-period bond plus a term premium $\phi_{(t,m)}$. For zero coupon bonds, the REHTS can be written as:

$$mR_{(t,m)} = (m-1)\, E_t R_{(t+1,m-1)} + R_{t,1} + \phi_{(t,m)} \tag{2}$$

Solving forward equation (2) gives for $R_{(t,m)}$ the yield to maturity of a bond with m periods to maturity at time t:

$$R_{(t,m)} = \frac{1}{m}\sum_{i=0}^{m-1} E_t R_{(t+i)} + \frac{1}{m}\sum_{i=0}^{m-1} E_t \phi_{(t+i,m-1)} \tag{3}$$

Substituting $R_{(t+i)} = rr_{(t+i)} + E_{(t+i)}\pi_{(t+i+1)}$ into equation (3) yields the following m-period Fisher equation:[7]

$$R_{(t,m)} = \frac{1}{m}\sum_{i=0}^{m-1} E_t rr_{(t+i)} + \frac{1}{m}\sum_{i=0}^{m-1} E_t \pi_{(t+i+1)} + \frac{1}{m}\sum_{i=0}^{m-1} E_t \phi_{(t+i,m-1)} \tag{4}$$

Rewriting equation (4) yields:

$$R_{(t,m)} = E_{(t)} rr_{(t,m)} + E_{(t)}\pi_{(t,m)} + \phi_{(t,m)} \tag{5}$$

where $rr_{(t,m)} = \frac{1}{m}\sum\limits_{i=0}^{m-1} rr_{(t+i)}$ is the average ex-ante real interest rate over the current and next $(m-1)$ periods, $\pi_{(t,m)}$ is the average inflation rate over the next m-periods and $\phi_{(t,m)}$ is the average risk premium on an m-period bond until maturity.

for future inflation reduced, see Davis and Fagan (1997).

[6] Occasionally an inflation risk premium, the premium of holding nominal rather than real assets, is included into the Fisher equation, see for instance Evans and Wachtel (1993).

[7] The m-period Fisher equation also incorporates a supplementary term, the term or liquidity premium $\phi_{(t,m)}$. In contrast to the inflation premium, the liquidity premium is found to have considerable influence on the term structure, see Evans and Lewis (1994).

Equation (5) patently shows why the term spread should help to predict future inflation: Subtracting an n-period bond $R_{(t,n)}$ from an m-period bond $R_{(t,m)}$ gives the following equation:

$$\begin{aligned} R_{(t,m)} - R_{(t,n)} &= E_{(t)}\left(rr_{(t,m)} - rr_{(t,n)}\right) + E_{(t)}\left(\pi_{(t,m)} - \pi_{(t,n)}\right) + \\ &\quad + \left(\phi_{(t,m)} - \phi_{(t,n)}\right) \end{aligned} \tag{6}$$

The term spread $R_{(t,m)} - R_{(t,n)}$ incorporates information on the direction of expected real interest rate changes $E_{(t)}\left(rr_{(t,m)} - rr_{(t,n)}\right)$, the direction of expected inflation changes $E_{(t)}\left(\pi_{(t,m)} - \pi_{(t,n)}\right)$ and term premium changes $\phi_{(t,m)} - \phi_{(t,n)}$. If term spread fluctuations are dominated by variations in expected inflation, then the term spread may help to assess the direction of future inflation changes.

3 Inflation and interest rate data

German inflation data for the period from January 1975 to December 2002 are monthly observations of the Consumer Price Index (CPI), taken from the International Financial Statistics (IFS). M-period inflation rates are calculated as log differences for 1, 3, 6, 12 and 24 months. The one-month inflation rate, for instance, is given by $\pi_{(t,1)} = \ln(CPI_{(t+1)}) - \ln(CPI_{(t)})$. The five m-period inflation rate series $\left(\pi_{(t,1)}, \pi_{(t,3)}, \pi_{(t,6)}, \pi_{(t,12)}, \pi_{(t,24)}\right)$ are shown in Figure 3 Interest rates $R_{(t,m)}$ are end-of-month observations of Deutsche Mark (DEM) rates, taken from the London Interbank market and provided by the BIS data base. The maturity ranges from 1 to 24 months, see Figure 4. Ex-post real interest rates $rr_{(t,m)}$, calculated for instance for one month as $rr_{(t,1)} = R_{(t,1)} - \pi_{(t,1)}$, are shown in Figure 5.

Augmented Dickey-Fuller (ADF) tests for the nominal interest rates $R_{(t,m)}$, CPI series $\pi_{(t,m)}$ and real interest rates $rr_{(t,m)}$, based on lag length 12, are displayed in Table 1. The results of the ADF tests suggest that $R_{(t,m)}$ and $\pi_{(t,m)}$ are non-stationary, $rr_{(t,m)}$—in particular for $m = 1, 3$—is, however, stationary.

Table 1: ADF-tests (The 5% critical value is -2.87.)

$R_{(t,1)}$	-2.73	$\pi_{(t,1)}$	-2.55	$rr_{(t,1)}$	-3.10
$R_{(t,3)}$	-2.72	$\pi_{(t,3)}$	-2.43	$rr_{(t,3)}$	-3.18
$R_{(t,6)}$	-2.48	$\pi_{(t,6)}$	-1.84	$rr_{(t,6)}$	-2.83
$R_{(t,12)}$	-2.32	$\pi_{(t,12)}$	-1.83	$rr_{(t,12)}$	-2.82
$R_{(t,24)}$	-1.91	$\pi_{(t,24)}$	-2.12	$rr_{(t,24)}$	-2.77

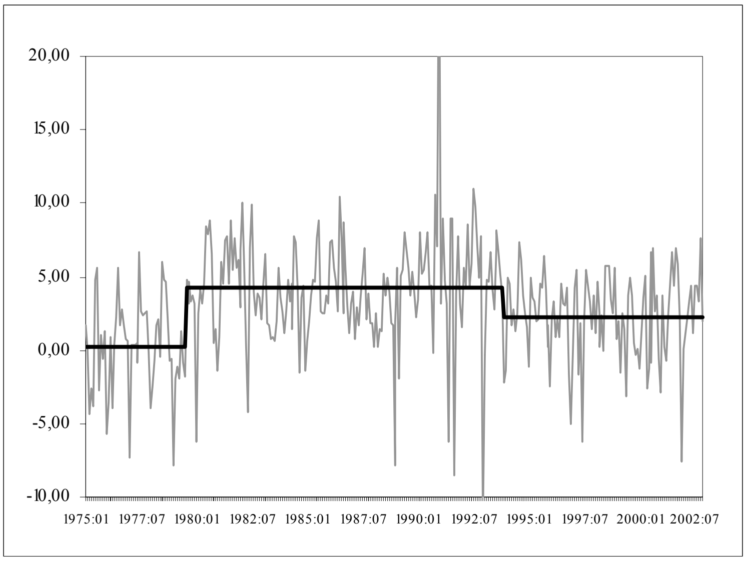

Figure 2: German ex-post real interest rate (1975:01 - 2002:12)

Empirical analyses on the information content of the German yield curve, cited in the introduction, were generally undertaken without accounting for possible structural breaks in the real interest rate time series. Visual inspection, however, suggests that different regimes may have prevailed, see Figure 2: a period with low real interest rates from 1975 to 1979, a period with high real interest rates from 1980 to 1993—as a result of the second oil price shock, high international real interest rates, expansionary fiscal policy in the first half of the eighties, German reunification and increased inflation risk premia— and a period with decreasing real interest rates from 1993 onwards, mainly as result of a decline in nominal interest rates. In order to control for structural breaks that would possibly need to be considered in the empirical analyses, we apply a set of different tests, developed by Bai and Perron (1998, 2001 and 2003).[8] The test procedures, all of which are intended to detect multiple structural break points in the mean of the series at unknown points, are based on the following multiple linear regression model with m breaks ($m + 1$ regimes), see Bai and Perron (2003):

[8] We thank Pierre Perron and Jushan Bai for providing the GAUSS code via the Internet.

$$y_t = x_t^{'}\beta + z_t^{'}\delta_j + u_t \tag{7}$$

with $t = T_{j-1+1}, ...T_j$ for $j = 1, ..., m+1$; y_t is the observed independent variable at time t; $x_t(p \text{ x } 1)$ and $z_t(q \text{ x } 1)$ are vectors of covariates; β and δ_j $(j = 1, ..., m+1)$ are the corresponding vectors of coefficients. The method rests upon the principle of global minimizers of the sum of squared residuals and consistently determines the number of break points over all possible partitions. The break points $(T_i, ..., T_m)$ are explicitly treated as unknown. In our model, there is only one constant as regressor $(z_t = 1)$.[9] The maximum number of breaks allowed for is five $(m = 5)$. Detailed results are presented in Table 2.

In order to determine the number of breaks, we first apply a $supWald$ type test ($supF_t(k)$ test) for the null hypothesis of no change $(m = 0)$ versus the alternative of $m = k$ breaks. All five $supF_t(k)$ tests are significant for k between 1 and 5, which indicates that at least one break is present.

We further apply double maximum tests, the $UDmaxF_t(M, q)$ and $WDmaxF_t(M, q)$, where the null hypotheses of no structural breaks $(m = 0)$ are tested against an unknown number of breaks given some upper bound M. The test statistics are both significant at a 5% level, confirming the results of the $supF_t(k)$ tests.

We next apply the $supF_t(l + 1/l)$ test to check for the existence of the number of (l) breaks against the alternative of $(l + 1)$ changes. The model with (l) breaks is rejected in favor of the model with $(l + 1)$ breaks if the overall minimum value of the sum of squared residuals from the $(l + 1)$ breaks model is sufficiently smaller than the sum of squared residuals from the (l) breaks model. The $supF_T(2/1)$ test has a value of 14.43, which is significant at a 5% level whereas the $supF_T(3/2)$ has a value of 3.52, which is not significant. According to the $supF_t(l+1/l)$ test, two breaks are present.

Moreover, we employ model selection procedures by using the modified Schwarz criterion of Liu et al. (1997) and the BIC criterion and—in addition—a sequential method based on the application of the $supF_t(l+1/l)$ test. The modified Schwarz criterion and the sequential $supF_t(l + 1/l)$ test produce two breaks, the BIC criterion only one.[10]

[9] This model specification is identical to the model Bai and Perron applied in their empirical analysis on the U.S. ex-post real interest rate, see Bai and Perron (2003, p.16).

[10] In case, the various tests produce different numbers of breaks, Bai and Perron (2001) suggest that the preferred strategy is to primarily follow the results of the $supF(l + 1/l)$ test. The results of the sequential procedure are ranked second and the results of the information criterion driven model selection third.

In determining the number of breaks, we follow the suggestions of Bai and Perron (2001); the two estimated break dates are found to be in June 1979 and November 1993, see Figure 2, page 6.[11]

Summary statistics are presented in Tables 3a - 3c. Means and variances on inflation rates, term spreads and interest rates are shown in Table 3a. Correlation coefficients measuring the correlation between inflation rates and term spreads and between inflation and interest rates are displayed in Table 3b. There seems to be no correlation between inflation rates and term spreads; inflation and real interest rates are negatively, inflation and nominal interest rates—in contrast—are positively correlated. Table 3c reports autocorrelation coefficients of the five inflation rate series. At a one-month lag, inflation rates are highly persistent. This is not surprising, because the annualized inflation rates are calculated over the previous m-months and hence subsequent monthly inflation rates incorporate an $(m-1)$ overlap. At a 12- and 24-month lag, autocorrelation coefficients are considerably smaller.

4 Estimating the long-run m-period Fisher equation

After having determined the long-run properties of $R_{(t,m)}$, $\pi_{(t,m)}$ and $rr_{(t,m)}$ and assuming that risk premiums $\phi_{(t,m)}$ are stationary, we can interprete the m-period Fisher equation (5) as the following cointegrating relationship:

$$\pi_{(t,m)} = \alpha + \beta R_{(t,m)} + e_{(t,m)} \tag{8}$$

with the coefficient β equal to 1 and the error term $e_{(t,m)}$ being stationary. To test for cointegration, we first apply the two-step Engle and Granger (1987) procedure and then estimate a vector error correction model, using the method of Johansen (1988).

Detailed estimation results of the cointegrating regressions are presented in Table 4(a)—without regime dummies—and 4(b)—with dummies. The estimations without regime dummies show highly significant β-coefficients,

[11] Estrella, Rodrigues and Schich (2003) analyse the information content of the German yield curve for the period from January 1967 to December 1998. They conduct various stability tests and find a structural break in March 1979, four years after the Bundesbank has adopted a monetary aggregate targeting in October 1974. Von Hagen (1998) characterized the period until 1978 as experimental, since the announced targets were regularly missed.

although different from 1. The estimated values are around 0.4. The adjusted R^2 increases with maturity, ranging from 0.09 for 1 month to 0.29 for 24 months. The residuals for 1, 3 and 6 months are stationary, however with high serial correlation. There are also ARCH effects in the residuals, which increase substantially at longer maturities.

We next include the three regime dummies in the equations. The dummy variables are mostly significant for all five horizons. The β-coefficients are substantially higher (around 0.6), yet still different from 1. The adjusted R^2 has increased, ranging from 0.14 for 1 month to 0.48 for 24 months. Serial correlation and heteroscedasticity have decreased, but are still present.

In a different approach, we estimate the following vector error correction model (VECM):

$$\Gamma(L)\Delta x_{(t)} = Ax_{(t-1)} + \omega_{(t)} \tag{9}$$

where $x_{(t)}$ is the (2 x 1) vector $(R_{(t,m)}, \pi_{(t,m)})$ of $I(1)$ variables. If the m-period Fisher equation holds, then the matrix A is equal to (γ, α'), with $\alpha'=$ $(-1{,}1)$ being the cointegrating vector. The results of the cointegration tests and likelihood ratio tests are shown in Table 5(a)—without dummies—and 5(b)—with dummies. Cointegration is found for all five horizons regardless of whether or not dummy variables are included in the estimations. In testing the $(-1{,}1)$ restriction without dummies, the likelihood ratio statistic indicates that the long-run m-period Fisher equation does not hold, see Table 5(a)II. When dummies are included, the likelihood ratio statistic provides support for the 1-month, the 12- and 24-month Fisher equation, see Table 5(b)II.[12] To sum up the bivariate cointegration tests (cointegrating regressions and VECM), the estimations of m-period Fisher equations provide mixed results with, however, clear evidence in favor of the 1-month and 12-month horizons.

5 Forecasting inflation from the long run m-period Fisher equation

As already described in Chapter 2, subtracting an n-period from an m-period Fisher equation yields the inflation forecasting equation (6), see page 5.

[12] Empirical results are highly sensitive to the number of lags. On the basis of the Schwarz information criterion, we chose the lag order of 1.

When assuming rational expectations $E_{(t)}\pi_{(t,m)} = \pi_{(t,m)} + \varepsilon_{(t,m)}$, equation (6) can be rearranged as follows:

$$\pi_{(t,m)} - \pi_{(t,n)} = \alpha_{m,n} + \beta_{m,n}\left(R_{(t,m)} - R_{(t,n)}\right) + \eta_{(t,m)} \tag{10}$$

The error term $\eta_{(t,m)} = \varepsilon_{(t,n)} - \varepsilon_{(t,m)}$ captures variations in expected real interest rates $E_{(t)}\left(rr_{(t,m)} - rr_{(t,n)}\right)$ and risk premiums $\phi_{(t,m)} - \phi_{(t,n)}$. Since $\eta_{(t,m)}$ is not directly observable, the appropriate modeling of $\eta_{(t,m)}$ is therefore of considerable importance. Tzavalis and Wickens (1996, p. 115) argue that the usefulness of equation (10) as an inflation forecasting equation is largely dependent on a successful modeling of the error term.

OLS estimation results of equation (10), including the regime dummies, are presented in Table 6a. Spreads are calculated for various periods, 1 versus 3 months (1/3), 1 versus 6 (1/6), 1 versus 12 (1/12), 3 versus 6 (3/6), 3 versus 12 (3/12), 6 versus 12 months (6/12) and 1, 3, 6, 12 versus 24 months, respectively (1/24, 3/24, 6/24, 12/24). The coefficients of the three dummy variables are highly significant. The adjusted R^2 is low, increasing slightly with longer maturities. The β-coefficients are, although mostly statistically significant, different from 1 and with the exception of the 1/3- and 6/24-month spread negative. Standard errors are, however, biased and the residuals are serially correlated and heteroscedastic.[13] In order to deal with the high serial correlation and heteroscedasticity, the error term $\eta_{(t,m)}$ is modeled as a moving average (MA) process. The MA terms should help to cope with expected changes in real interest rates, changes in risk premiums and inflation innovations, which are otherwise not considered. The results of the NLLS estimations are reported in Table 6b. The estimated β-coefficients predominantly show a positive sign, but are still statistically insignificant. The adjusted R^2 has substantially increased, which is due to the high significance of the MA terms. Serial correlation and ARCH effects in the residuals have decreased considerably.

To sum up, predicting inflation by subtracting an n-period from an m-period Fisher equation and estimating with OLS is obviously subject to misspecification. Including MA-terms in the error term and estimation with NLLS helps to deal with serial correlation and heteroscedasticity but does not largely improve the ability of equation (10) to forecast future inflation. This conclusion for German data is in line with the empirical findings of Tzavalis and Wickens (1996) for U.S. data.

[13] One reason for the weak performance of equation (10) may also be the downward bias of the estimated β-coefficients, which may be due to the correlation between the term structure spread and the error term, see e.g. Fama, 1984b.

6 Inflation forecasting from an error correction model of the term structure

In the previous section we argued that the ability to forecast inflation on the basis of equation (10) is heavily influenced by the modeling of the error term, which is intended to capture real interest rate changes, risk premiums variations and inflation innovations. One alternative to more thoroughly exploit the information of the term structure is, on the one hand, to use the dynamic adjustment of the term structure as additional information and, on the other hand, to include all interest rates in the model and not only those that are used in equation (10) for each forecasting horizon.

We estimate the following multivariate model:

$$\Gamma(L)\Delta x_{(t)} = \delta_1 D_1 + \delta_2 D_2 + \delta_3 D_3 + A x_{(t-1)} + \omega_{(t)} \tag{11}$$

where $x_{(t)}$ contains the 1-month, 3-month, 6-month, 12-month and 24–month interest rates $(R_{(1,t)}, R_{(3,t)}, R_{(6,t)}, R_{(12,t)}, R_{(24,t)})$ and the 1-month inflation rate $(\pi_{(t,1)})$. The results of the estimations—carried out with lag 1—are displayed in Table 7a. LR tests (λ_{max}- and λ_{trace}-tests) reveal that there are five cointegrating equations. Imposing the restrictions (1,-1,0,0,0,0), (1,0,-1,0,0,0), (1,0,0,-1,0,0), (1,0,0,0,-1,0) and (1,0,0,0,0,-1) show that the five cointegrating vectors can be represented by the 1,3-; 1,6-; 1,12- and 1,24-month term spreads and the 1-month real interest rate.[14] To check for robustness, we estimate equation (11) with the 3-month inflation rate $\pi_{(t,3)}$ instead of $\pi_{(t,1)}$. The results remain qualitatively unchanged, see Table 7b.

On the basis of the multivariate cointegration analysis, we estimate a VEC forecasting equation for an m-period change in inflation $\Delta\pi_{(t,m)}$. The equation for the expected change in inflation $\Delta\pi_{(t,m)}$ consists of the three regime shift dummies D_1, D_2, D_3, short-run dynamics $\Delta\pi_{(t,1)}, \Delta R_{(t,1)}$, the cointegrating vectors $(R_{(t,m)} - R_{(t,n)}), (R_{(t,1)} - \pi_{(t,1)})$ and a moving average component $v_{(n,t)}$ of innovations $\epsilon(t)$, $v_{(t,m)} = \eta(L)\ \epsilon(t)$.

$$\begin{aligned} \Delta\pi_{(t,m)} \quad = \quad & D_1\delta_1 + D_2\delta_2 + D_3\delta_3 + \gamma_1\Delta\pi_{(t,1)} + \gamma_2\Delta R_{(t,1)} + \\ & +\gamma_3\Delta R_{(t,m)} + \beta_1\left[R_{(t,m)} - R_{(t,n)}\right] + \beta_2\left[R_{(t,1)} - \pi_{(t,1)}\right] + v_{(t,m)} \end{aligned} \tag{12}$$

Inflation forecasts cover the periods from 1 to 3 (1/3), 1 to 6 (1/6), 1 to 12 (1/12) and 1 to 24 months (1/24). The estimation results are presented in

[14] LR tests of the estimations, undertaken without dummies, show that neither of these vectors spans the cointegration space.

Table 8a.[15] Diagnostic tests do not show any misspecification. 8a(I) displays the results of OLS and 8b(II) the results of NLLS estimations. The OLS and NLLS estimation results show that the term spread is only significant at the shortest maturity (3 months). For all other forecast horizons (6, 12 and 24 months), the term spread is not significant. The 1-month real interest rate, however, is highly significant with a positive sign for all forecasting periods, which however contradicts the results of the correlation analysis, where we find a negative correlation between inflation and real interest rates.

To check for robustness, we undertake the same kind of analysis with the 3-month real interest rate, see Table 8b. Similar results for the term spread and the real interest rate coefficients suggest that the short-term real interest rate contains far more information on future inflation than the term spreads. This empirical finding is perfectly in line with the results for the U.S. data, obtained by Tzavalis and Wickens (1996). Tzavalis and Wickens (1996) give a possible economic interpretation, arguing that because of sticky prices monetary shocks have real effects in the short run and nominal effects in the long run, which compensates ex post for the initial short-term real effects. Another explanation would be that a positive sign of the estimated coefficient of the real rate reflects correlation between the real interest rate and the current inflation component of the dependent variable, see Kozicki (1998).

In another paper, Neiss and Nelson (2001) examine the indicator properties of what they call the " natural real interest rate" and the "real interest rate gap" for future inflation, using a dynamic stochastic general equilibrium model.[16] According to their work, the behavior of the real interest rate is a reasonable approximation of the behavior of the real interest rate gap, with the correlation between these two series being relatively high and the volatility roughly the same. In the empirical analysis of quarterly UK data from 1980 to 1999, the authors find a negative correlation between inflation and the real interest rate. They also conclude that within their model framework, a real interest rate gap series could provide useful auxiliary information in evaluating the monetary policy stance and the prospects for future inflation. Forecasting inflation from controlling for movements in the natural real rate, however, may possibly not reap great benefits since the empirical variation in the natural rate appears to be quite small.

[15] When estimating equation (12), the three regime shift dummies are incorporated into the 1-month real interest rate, iie. the real interest rate is regressed on the dummies and the residual series is used as a proxy for the real interest rate.

[16] The "real interest rate gap" ist the spread between the actual and the "natural real interest rate".

As a final step, we replace the short-term real interest rate $R_{(t,m)} - \pi_{(t,m)}$ in equation (12) with the short-term nominal interest rate $R_{(t,m)}$ and run NLLS regressions. The estimation results are shown in Table 9a(I) for the one-month nominal interest rate $R_{(t,1)}$ and 9b(II) for the three-month nominal interest rate $R_{(t,3)}$.[17] At the 3-, 6- and 12-month horizon, the term spread and the nominal interest rates provide no information on future inflation. At the 24-month horizon, however, the coefficients of the nominal short-term interest rates are statistically significant, however—contrary to the results of the real interst rate series—with a negative sign, indicating that a rise in short-term nominal rates leads to a reduction in the 24-month inflation rate and vice versa. A possible interpretation for the predicitive power of the short-term nominal interest rate for future inflation at a 24-month horizon is that the short-term nominal interest rate may provide a cleaner measure for the monetary policy stance than short-term real interest rates or the term spreads.

7 Summary and conclusions

In this paper, we empirically assess the predictive power of short-term interest rates and term spreads of up to 24 months for future inflation in Germany. The period under review is January 1975 to December 2002. Our analysis is based on a one-period Fisher equation and the Rational Expectations Theory of the Term Structure. Both building blocks are used to derive an m-period Fisher equation. Bivariate cointegration tests lend some support to the validity of the long-run Fisher equation, at least for the 1-month and 12-month horizons. Structural breaks in the short-term real interest rate series are found in 1979 and 1993.

By subtracting an n-period Fisher equation from an m-period Fisher equation, a simple (n, m)-period Fisher forecasting equation in the tradition of Mishkin is estimated. The results show that the term spreads have no information content on future inflation. In addition, various tests on the regression residuals indicate that the simple spread equations might be subject to misspecification. The assumptions on constant real interest rates and risk premiums are violated.

[17] The three regime dummies are regressed on the nominal interest rate series; the resulting series is found to be stationary.

In line with Tzavalis and Wickens (1996), an alternative vector error forecasting equation is constructed in a multivariate term structure framework. Inflation forecasts are estimated with term spreads from 1 to 3, 1 to 6, 1 to 12 and 1 to 24 months. Multivariate cointegration tests show that there are five cointegrating vectors, which can be represented by four term spreads and the one- (or three-) month real interest rate. The results of the alternative error correction reveal that the level of the short-term interest rates conveys a lot more information on future inflation than the yield curve spreads. In particular, the one-month and three-month nominal interest rates seem to be informative on future inflation at a two-year horizon.

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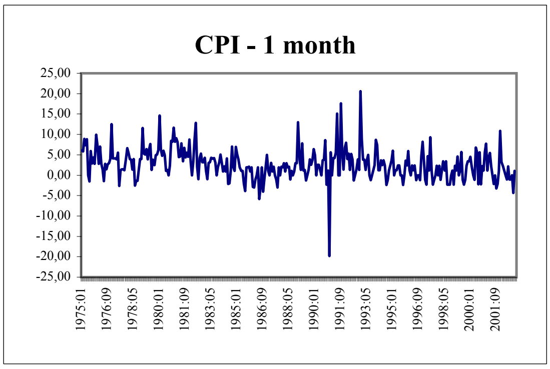
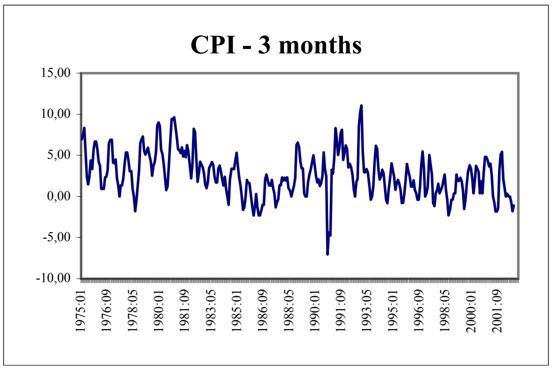
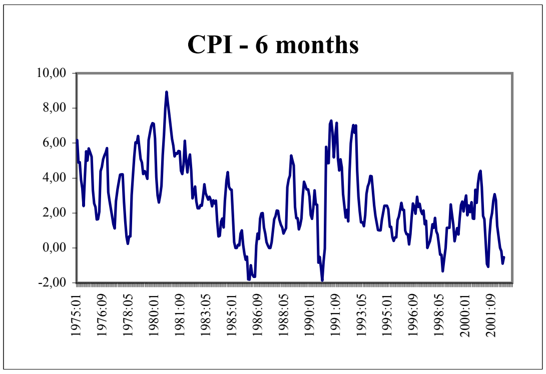
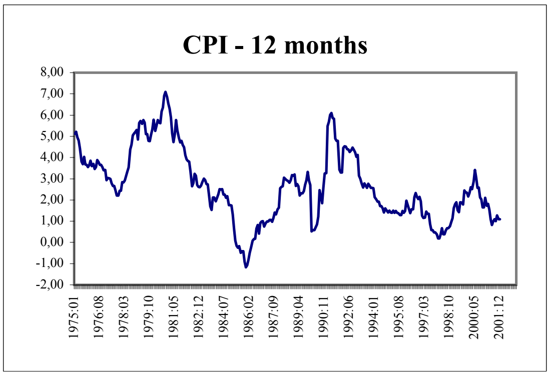
Figure 3: German CPI (1975:01 - 2002:12)









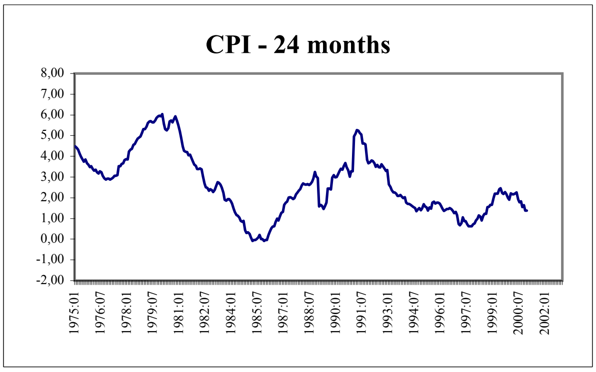


Figure 4: German nominal interest rates (1975:01 - 2002:12)

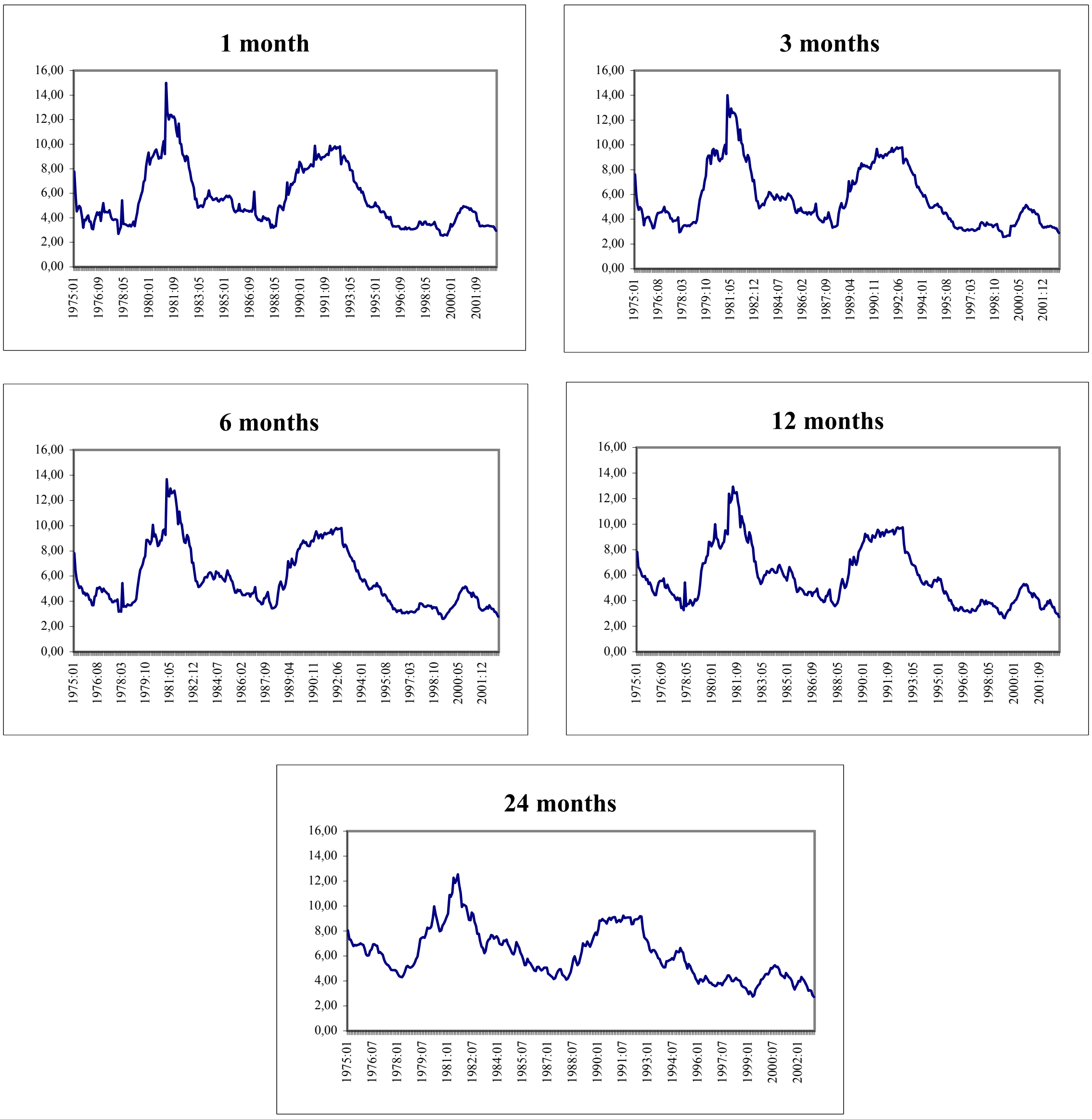


Figure 5: German ex-post real interest rates (1975:01 - 2002:12)

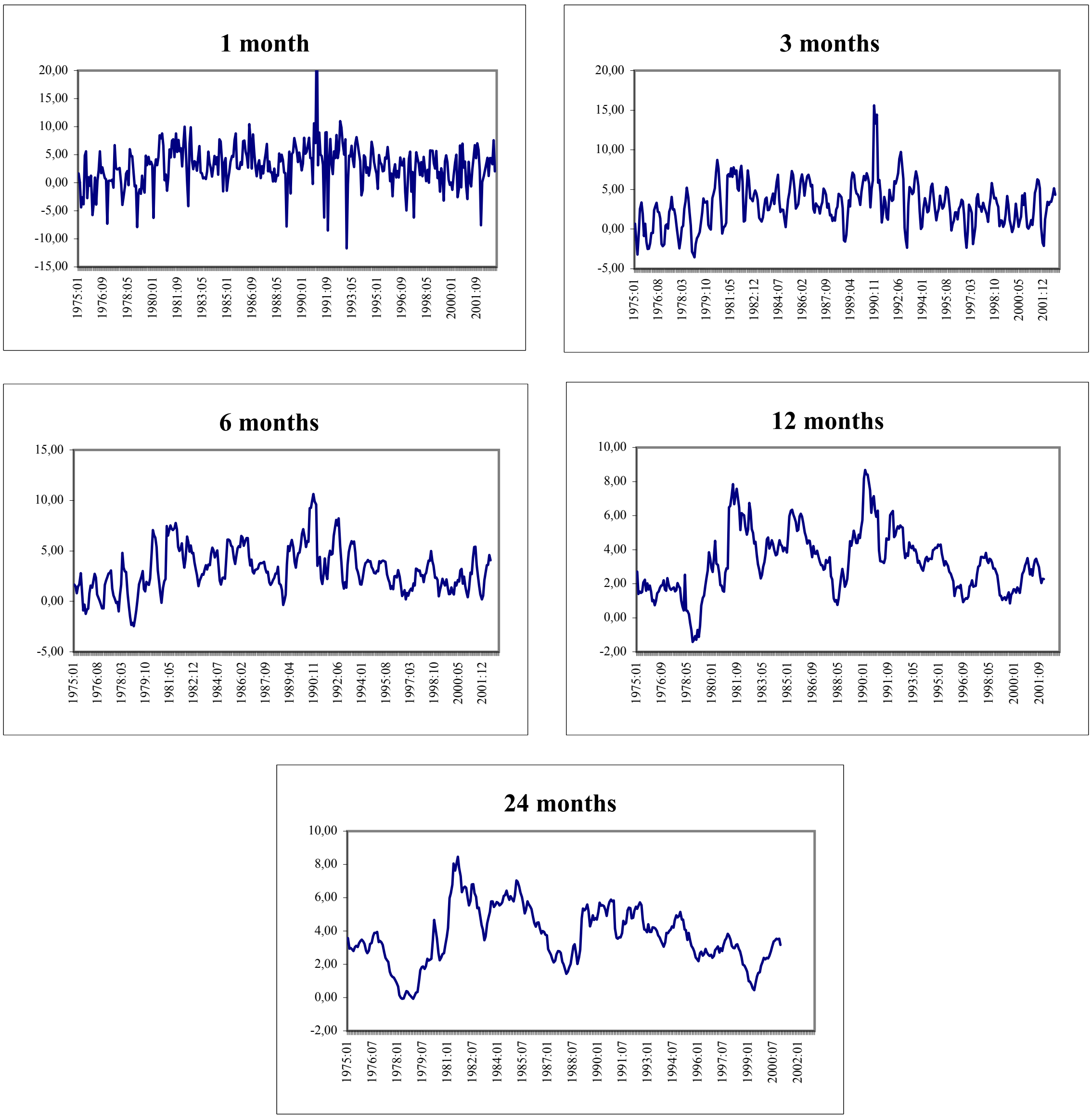


Table 2: Bai - Perron-Test, German ex-post real interest rate 1975:01 - 2002:12

Tests[1]

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	UDmax	WDmax
24.06*	17.66*	12.10*	9.16*	7.26*	24.06*	24.06*
SupF(2/1)	SupF(3/2)	SupF(4/3)	SupF(5/4)			
14.43*	3.52	0.84	0.08			

Number of breaks selected[2]

Sequential	2
LWZ	2
BIC	1

Estimates with two breaks[3]

δ_1	δ_2	δ_3	T_1	T_2
0.21	4.19	2.29	79:06	93:11
(0.59)	(0.36)	(0.33)	(77:12-80:08)	(90:11-00:01)

[1] In line with Bai and Perron (2003), the $\sup F_T(k)$ tests and the reported standard errors and confidence intervals allow for serial correlation in the disturbances. The heteroscedasticity and autocorrelation consistent covariance matrix is constructed following Andrews and Monohan (1992) by using a quadratic kernel with automatic bandwith selection based on an AR(1) approximation. The residuals are pre-withened by using a VAR(1).

[2] We use a 5% size for the sequential test $\sup F_T(l+1/l)$.

[3] The standard errors (robust to serial correlation) for δ_1, δ_2, δ_3 and the 95% confidence intervals for T_1 and T_2 are given in parentheses.

* Significant at a 5% level.

Table 3a: Summary statistics 1 (means and variances)

	German nominal interest rates							
	Total period[1)]		Period 1[2)]		Period 2[3)]		Period 3[4)]	
	mean	variance	mean	variance	mean	variance	mean	variance
1 month	5.58	5,81	4.13	0.77	7.13	5.62	3.84	0.73
3 months	5.65	5,83	4.23	0.75	7.22	5.55	3.86	0.70
6 months	5,74	5.60	4.55	0.84	7.27	5.26	3.89	0.65
12 months	5,83	5.11	4.94	1.03	7.26	4.76	4.00	0.70
24 months	6,16	4.10	5.97	0.97	7.37	3.55	4.32	0.77

	German real interest rates							
	Total period		Period 1		Period 2		Period 3	
	mean	variance	mean	variance	mean	variance	mean	variance
1 month	2.94	14.55	0.22	10.13	4.20	15.78	2.30	8.32
3 months	3.03	7.74	0.39	4.84	4.25	7.36	2.38	3.50
6 months	3.15	5.03	0.82	2.67	4.30	4.53	2.42	1.54
12 months	3.27	3.45	1.10	1.15	4.36	2.65	2.54	0.90
24 months	3.69	3.01	2.01	1.90	4.59	2.34	2.92	1.05

	German CPI							
	Total period		Period 1		Period 2		Period 3	
	mean	variance	mean	variance	mean	variance	mean	variance
1 month	2.64	14.21	3.91	10.95	2.93	17.44	1.55	8.74
3 months	2.64	7.27	3.84	5.70	2.97	8.76	1.50	3.54
6 months	2.64	4.52	3.73	2.81	2.97	5.72	1.51	1.37
12 months	2.65	2.82	3.84	1.03	2.90	3.53	1.53	0.43
24 months	2.64	2.29	3.96	0.74	2.78	2.62	1.53	0.22

	German yield curve spreads							
	Total period		Period 1		Period 2		Period 3	
	mean	variance	mean	variance	mean	variance	mean	variance
1-3 months	0.07	0.06	0.10	0.13	0.09	0.06	0.02	0.02
1-6 months	0.16	0.13	0.42	0.14	0.14	0.16	0.05	0.05
1-12 months	0.25	0.37	0.81	0.37	0.13	0.40	0.17	0.14
1-24 months	0.58	1.04	1.84	0.75	0.24	0.99	0.48	0.30

1) 1975:01 - 2002:12
2) 1975:01 - 1979:06
3) 1979:07 - 1993:11
4) 1993:12 - 2002:12

Table 3b: Summary statistics 2 (correlation coefficients)

Inflation rate	*Term spread (in months)*			
(in months)	1/3	1/6	1/12	1/24
3	0.06	-0.01	-0.10	-0.12
6	0.11	0.02	-0.08	0.13
12	0.11	0.05	-0.04	0.13
24	0.10	0.09	0.00	-0.09

Inflation rate	*Real interest rate (in months)*				
(in months)	1	3	6	12	24
1	0.29	0.39	0.48	0.55	0.47
3	0.29	0.40	0.49	0.56	0.49
6	0.29	0.40	0.50	0.57	0.50
12	0.29	0.40	0.50	0.58	0.51
24	0.30	0.42	0.50	0.60	0.54

Inflation rate	*Nominal interest rate (in months)*				
(in months)	1	3	6	12	24
1	-0.79	-0.43	-0.20	-0.08	-0.08
3	-0.40	-0.60	-0.34	-0.11	-0.11
6	-0.17	-0.32	-0.41	-0.14	-0.13
12	-0.05	-0.08	-0.11	-0.20	-0.19
24	0.02	0.00	-0.02	-0.09	-0.25

Table 3c: Summary statistics 3 (inflation autocorrelations)

Inflation rate	*Autocorrelation lag (months)*		
(in months)	1	12	24
1	0.31	0.36	0.13
3	0.80	0.47	0.21
6	0.90	0.51	0.24
12	0.97	0.59	0.31
24	0.99	0.77	0.42

Table 4: OLS estimates of the long-run *m* -period Fisher equation

(a) Without dummies

Model: $\pi_{(t,m)} = \delta_0 + \beta R_{(t,m)} + e_{(t,m)}$

Period(m)	1 month	3 months	6 months	12 months	24 months
δ_0	0.01 (0.50)	0.03 (0.11)	0.01 (0.03)	0.05 (0.25)	0.05 (0.22)
β	0.47 (5.77)*	0.46 (8.23)*	0.45 (10.62)*	0.44 (13.05)*	0.41 (11.23)*
R^{2bar}	0.09	0.17	0.25	0.34	0.29
ADF(4)	-8.17	-7.21	-7.05	-3.39	-2.41
LM(1)	19.96	455.58	1,004.17	3,215.35	7,315.05
LM(12)	5.37	79.62	152.27	273.77	647.69
ARCH(1)	0.03	141.28	592.72	1,759.77	5,772.54
N(2)	827.54	28.97	0.69	2.36	9.12

(b) With dummies

Model: $\pi_{(t,m)} = \delta_1 D_1 + \delta_2 D_2 + \delta_3 D_3 + \beta R_{(t,m)} + e_{(t,m)}$

Period(m)	1 month	3 months	6 months	12 months	24 months
δ_1	1.14 (1.77)	1.16 (2.67)*	1.01 (3.10)*	1.11 (4.63)*	1.31 (4.67)*
δ_2	-1.85 (-2.32)*	-1.62 (3.01)*	-1.35 (-3.39)*	-1.11 (-3.95)*	-0.49 (-1.61)
δ_3	1.03 (-1.96)	-0.96 (-2.72)*	-0.83 (-3.15)*	-0.72 (-3.78)*	-0.44 (-2.09)*
β	0.67 (6.36)*	0.63 (9.03)*	0.59 (11.41)*	0.55 (14.96)*	0.44 (11.10)*
R^{2bar}	0.14	0.27	0.38	0.54	0.48
ADF(4)	-9.09	-8.71	-8.85	-4.08	-2.96
LM(1)	11.64	364.81	755.09	1,901.58	4,534.81
LM(12)	4.24	65.69	122.08	161.30	392.78
ARCH(1)	0.04	125.31	474.54	1,036.40	2,047.80
N(2)	1,179.18	63.54	4.32	7.90	9.20

The numbers in parentheses are standard *t* -ratios.

The 5% critical value for the cointegration test is -3.60 (MacKinnon, 1991).

LM*(p)* is the Lagrange multiplier test for pth-order serial correlation.

ARCH(1) is the Lagrange multiplier test for conditional heteroscedasticity.

N(2) is the Jarque-Bera test for normality.

* Significant at a 5% level.

Table 5: Bivariate cointegration analysis

(a) Without dummies

Model: $\Gamma(L)\Delta x_{(t)} = \delta_0 + Ax_{(t-1)} + \omega_{(t)},\ \ x_{(t)}' = \{R_{(t,m)}, \pi_{(t,m)}\}$

I. Rank tests

Period(m)	1 mo		3 mo		6 mo		12 mo		24 mo	
Eigenvalues	λ_1	λ_2	λ_1	λ_2	λ_1	λ_2	λ_1	λ_2	λ_1	λ_2
	0.27	0.01	0.21	0.01	0.11	0.01	0.06	0.01	0.06	0.01
LR tests	λ_{trace}	λ_{max}	λ_{trace}	λ_{max}	λ_{trace}	λ_{max}	λ_{trace}	λ_{max}	λ_{trace}	λ_{max}
r = 0	107.37	104.82	81.10	78.94	41.38	39.09	21.47	19.64	21.25	19.35
r = 1	2.55	2.55	2.16	2.16	2.28	2.28	1.83	1.83	1.89	1.89

II. Estimates of the cointegrating vector and tests of the restriction (-1,1)

Period(m)	1 mo	3 mo	6 mo	12 mo	24 mo
(β_1,β_2)	(-1, 2.03)	(-1, 1.98)	(-1, 1.88)	(-1, 1.48)	(-1, 1.14)
LR statistic	18.17	18.31	10.60	13.98	12.20

(b) With dummies

Model: $\Gamma(L)\Delta x_{(t)} = \delta_1 D_1 + \delta_2 D_2 + \delta_3 D_3 + Ax_{(t-1)} + \omega_{(t)},\ \ x_{(t)}' = \{R_{(t,m)}, \pi_{(t,m)}\}$

I. Rank tests

Period(m)	1 mo		3 mo		6 mo		12 mo		24 mo	
Eigenvalues	λ_1	λ_2	λ_1	λ_2	λ_1	λ_2	λ_1	λ_2	λ_1	λ_2
	0.30	0.02	0.24	0.02	0.14	0.02	0.10	0.02	0.10	0.02
LR tests	λ_{trace}	λ_{max}	λ_{trace}	λ_{max}	λ_{trace}	λ_{max}	λ_{trace}	λ_{max}	λ_{trace}	λ_{max}
r = 0	128.07	121.75	98.57	93.09	55.11	50.15	38.49	32.01	37.65	32.32
r = 1	6.32	6.32	5.47	5.47	4.96	4.96	6.48	6.48	5.33	5.33

II. Estimates of the cointegrating vector and tests of the restriction (-1,1)

Period(m)	1 mo	3 mo	6 mo	12 mo	24 mo
(β_1,β_2)	(-1, 1.36)	(-1, 1.38)	(-1, 1.34)	(-1, 1.17)	(-1, 1.13)
LR statistic	3.81	6.37	4.41	0.09	2.12

The cointegrating vector has been normalized on R(t,m).

The 5% critical values for the λtrace test ($r = 0$, $r \le 1$) are {19.96, 9.24}.

The 5% critical values for the λmax test ($r = 0$, $r \le 1$) are {15.67, 9.24}.

Table 6a: OLS estimates of the *m* -period Fisher inflation forecasting equation

Model: $\pi_{(t,m)} - \pi_{(t,n)} = \delta_1 D_1 + \delta_2 D_2 + \delta_3 D_3 + \beta[R_{(t,m)} - R_{(t,n)}] + e_{(t,m)}$

Period (n,m)	(1,3)		(1,6)		(1,12)		(3,6)		(3,12)	
δ_1	0.62	(9.19)*	1.58	(11.85)*	3.83	(17.69)*	1.01	(10.07)*	3.29	(16.59)*
δ_2	0.48	(12.61)*	1.25	(17.96)*	2.70	(25.59)*	0.76	(15.55)*	2.18	(23.77)*
δ_3	0.23	(5.01)*	0.62	(7.14)*	1.45	(10.32)*	0.37	(5.94)*	1.20	(9.66*
β	0.13	(1.16)	-0.12	(-0.86)	-0.40	(-2.93)*	-0.34	(-2.11)*	-0.57	(3.68)*
R^{2bar}	0.07		0.12		0.24		0.09		0.22	
ADF(4)	-6.73		-6.69		-2.93		-6.60		-3.92	
DW	0.67		0.24		0.10		0.44		0.15	
LM(1)	252.70		1,091.10		3,104.88		499.04		1,831.60	
LM(12)	46.38		151.68		279.25		78.02		206.47	
ARCH(1)	75.35		486.29		1,584.61		150.72		1,046.71	
N(2)	172.12		375.51		526.75		14.11		2.88	
CH	0.69		0.57		0.43		0.76		0.59	

Period (n,m)	(6,12)		(1,24)		(3,24)		(6,24)		(12,24)	
δ_1	2.23	(14.46)*	9.41	(22.21)*	9.13	(22.67)*	7.94	(22.86)*	5.35	(21.47)*
δ_2	1.41	(19.24)*	5.55	(30.66)*	5.01	(30.68)*	4.20	(29.42)*	2.79	(26.96)*
δ_3	0.80	(7.98)*	3.51	(13.06)*	3.35	(13.57)*	2.92	(13.33)*	1.96	(12.40)*
β	-0.66	(3.18)*	-0.98	(6.46)*	-1.24	(-7.72)*	1.33	(-7.95)*	-1.23	(-7.46)*
R^{2bar}	0.18		0.36		0.39		0.39		0.36	
ADF(4)	-6.45		-2.60		-2.77		-3.13		-3.78	
DW	0.23		0.09		0.11		0.12		0.15	
LM(1)	1,105.49		3,212.15		2,718.38		2,303.63		1,766.73	
LM(12)	167.66		263.42		224.85		190.20		155.18	
ARCH(1)	541.59		1,313.83		892.29		899.38		969.91	
N(2)	11.24		172.12		375.51		526.75		14.11	
CH	0.71		0.44		0.54		0.62		0.48	

The numbers in parentheses are standard *t* -ratios.

δ_1, δ_2 δ_3 are the coefficients of the regime dummies.

LM*(p)* is the Lagrange multiplier test for pth-order serial correlation

ARCH(1) is the Lagrange multiplier test for conditional heteroscedasticity.

N(2) is the Jarque-Bera test for normality.

CH is the Chow test for structural stability, known as predictive failure test, based on observations of the last three years.

* Significant at a 5% level.

Table 6b: NLLS estimates of the *m* -period Fisher inflation forecasting equation

Model: $\pi_{(t,m)} - \pi_{(t,n)} = \delta_1 D_1 + \delta_2 D_2 + \delta_3 D_3 + \beta[R_{(t,m)} - R_{(t,n)}] + \sum_{i=0,k}\theta_i\varepsilon_{(t-i)}$

Period (n,m)	(1,3)		(1,6)		(1,12)		(3,6)		(3,12)	
δ_1	0.56	(7.08)*	1.08	(7.59)*	2.62	(11.14)*	0.70	(6.96)*	2.07	(9.41)*
δ_2	0.48	(9.46)*	1.12	(10.25)*	2.77	(17.06)*	0.64	(8.55)*	1.92	(10.51)*
δ_3	0.30	(4.67)*	0.91	(7.47)*	1.50	(7.59)*	0.59	(6.87)*	1.89	(9.56)*
β	0.00	(-0.32)	0.00	(0.25)	0.04	(1.12)	0.00	(-0.15)	0.00	(-0.05)
θ_1	1.21	(22.50)*	1.24	(23.07)*	1.15	(27.31)*	1.26	(22.50)*	1.34	(36.00)*
θ_2	0.23	(4.37)*	1.26	(-22.87)*	1.25	(33.94)*	1.38	(15.42)*	1.81	(39.11)*
θ_3	-		1.23	(22.11)*	1.23	(33.20)*	0.43	(3.77)*	1.56	(22.69)*
θ_4	-		1.22	(22.71)*	1.20	(32.29)*	0.17	(1.96)	1.23	(26.87)*
θ_5	-		-0.25	(4.74)*	0.63	(14.72)*	0.03	(0.71)	0.73	(19.57)*
R^{2bar}	0.64		0.89		0.93		0.79		0.91	
ADF(4)	-7.08		-6.82		-4.00		-7.03		5.29	
DW	1.95		1.94		1.86		1.97		1.99	
LM(1)	3.36		3.14		3.42		4.37		0.00	
LM(12)	3.90		3.86		13.69		4.43		13.58	
ARCH(1)	0.02		0.10		1.69		0.96		3.31	
N(2)	43.30		1.55		7.00		6.72		7.54	
CH	0.77		0.72		0.65		0.80		0.97	

Period (n,m)	(6,12)		(1,24)		(3,24)		(6,24)		(12,24)	
δ_1	1.56	(9.13)*	5.76	(14.65)*	5.53	(14.06)*	4.57	(13.01)*	3.07	(13.22)*
δ_2	1.26	(10.93)*	5.20	(19.90)*	4.76	(18.82)*	4.01	(17.21)*	2.70	(17.04)*
δ_3	1.10	(8.38)*	4.19	(12.27)*	3.66	(10.93)*	3.20	(10.46)*	2.03	(10.31)*
β	0.06	(1.19)	0.00	(-0.21)	-0.04	(-0.68)	0.00	(-0.03)	-0.02	(-0.48)
θ_1	1.09	(48.46)*	1.47	(29.63)*	1.44	(28.01)*	1.36	(29.86)*	1.23	(32.64)*
θ_2	1.11	(29.39)*	1.68	(23.27)*	1.62	(20.12)*	1.61	(23.62)*	1.26	(20.20)*
θ_3	1.03	(23.30)*	1.61	(20.72)*	1.43	(15.58)*	1.47	(19.02)*	1.15	(16.86)*
θ_4	0.94	(24.82)*	1.18	(16.34)*	0.97	(12.24)*	1.05	(15.49)*	0.89	(14.50)*
θ_5	0.90	(39.07)*	0.54	(10.73)*	0.47	(9.25)*	0.62	(13.43)*	0.75	(20.41)*
R^{2bar}	0.91		0.96		0.95		0.95		0.94	
ADF(4)	-6.33		-2.17		-2.59		-2.79		-3.73	
DW	1.58		1.58		1.60		1.66		1.70	
LM(1)	16.45		56.45		68.91		23.37		12.80	
LM(12)	5.47		25.66		21.83		20.93		15.44	
ARCH(1)	0.07		4.70		5.67		5.01		0.14	
N(2)	6.67		7.17		6.23		5.34		12.61	
CH	0.38		0.59		0.62		0.51		0.47	

The numbers in parentheses are standard t-ratios; δ1, δ2, δ3 are the coefficients of the regime dummies.
θ_1 to θ_5 are the coefficients of the MA terms. LM(p) is the Lagrange multiplier test for pth-order serial correlation.
ARCH(1) is the Lagrange multiplier test for conditional heteroscedasticity. N(2) is the Jarque-Bera test for normality.
CH is the Chow test for structural stability, known as predictive failure test, based on observations of the last three years.
* Significant at a 5% level.

Table 7a: Multivariate cointegration analysis

(a) Without dummies

Model: $\Gamma(L)\Delta x(t) = \delta_0 + Ax_{(t-1)} + \omega_{(t)}$

$x(t)' = \{R_{(t,1)}, R_{(t,3)}, R_{(t,6)}, R_{(t,12)}, R_{(t,24)}, \boldsymbol{\pi}_{(t,1)}\}$

(I) Rank tests

Eigenvalues	λ_1	λ_2	λ_3	λ_4	λ_5	λ_6
	0.49	0.42	0.32	0.18	0.03	0.01
LR tests	r = 0	r = 1	r = 2	r = 3	r = 4	r = 5
λ_{trace}	629.72	400.05	213.95	81.11	13.45	2.24
λ_{max}	229.66	186.10	132.84	67.66	11.20	2.24

(II) LR tests on structural relationships for $x(t)' = \{R_{(t,1)}, R_{(t,3)}, R_{(t,6)}, R_{(t,12)}, R_{(t,24)}, \boldsymbol{\pi}_{(t,1)}\}$

	$\{R_{(t,3)} - R_{(t,1)}\}$	$\{R_{(t,6)} - R_{(t,1)}\}$	$\{R_{(t,12)} - R_{(t,1)}\}$	$\{R_{(t,24)} - R_{(t,1)}\}$	$\{R_{(t,1)} - \pi_{(t,1)}\}$
LR statistics	-	-	-	-	-

(b) With dummies

Model: $\Gamma(L)\Delta x(t) = \delta_1 D_1 + \delta_2 D_2 + \delta_3 D_3 + Ax_{(t-1)} + \omega_{(t)}$

$x(t)' = \{R_{(t,1)}, R_{(t,3)}, R_{(t,6)}, R_{(t,12)}, R(t,24), \boldsymbol{\pi}_{(t,1)}\}$

(I) Rank tests

Eigenvalues	λ_1	λ_2	λ_3	λ_4	λ_5	λ_6
	0.52	0.44	0.34	0.19	0.06	0.01
LR tests	r = 0	r = 1	r = 2	r = 3	r = 4	r = 5
λ_{trace}	669.75	426.07	232.90	94.46	23.47	3.69
λ_{max}	243.67	193.17	138.44	70.98	19.78	3.69

(II) LR tests on structural relationships for $x(t)' = \{R_{(1,t)}, R_{(3,t)}, R_{(6,t)}, R_{(12,t)}, R_{(24,t)}, \boldsymbol{\pi}_{(t,1)}\}$

	$\{R_{(t,3)} - R_{(t,1)}\}$	$\{R_{(t,6)} - R_{(t,1)}\}$	$\{R_{(t,12)} - R_{(t,1)}\}$	$\{R_{(t,24)} - R_{(t,1)}\}$	$\{R_{(t,1)} - \pi_{(t,1)}\}$
LR statistics	3.31	0.98	0.27	0.05	2.91

Table 7b: Multivariate cointegration analysis

(a) Without dummies

Model: $\Gamma(L)\Delta x(t) = \delta_0 + Ax_{(t-1)} + \omega_{(t)}$

$x(t)' = \{R_{(t,1)}, R_{(t,3)}, R_{(t,6)}, R_{(t,12)}, R_{(t,24)}, \boldsymbol{\pi}_{(t,3)}\}$

(I) Rank tests

Eigenvalues	λ_1	λ_2	λ_3	λ_4	λ_5	λ_6
	0.49	0.35	0.20	0.12	0.07	0.01
LR tests	r = 0	r = 1	r = 2	r = 3	r = 4	r = 5
λ_{trace}	508.05	279.44	131.50	57.26	13.73	2.37
λ_{max}	228.61	147.93	74.24	43.53	11.36	2.37

(II) LR tests on structural relationships for $x(t)' = \{R_{(t,1)}, R_{(t,3)}, R_{(t,6)}, R_{(t,12)}, R_{(t,24)}, \boldsymbol{\pi}_{(t,3)}\}$

	$\{R_{(t,3)} - R_{(t,1)}\}$	$\{R_{(t,6)} - R_{(t,1)}\}$	$\{R_{(t,12)} - R_{(t,1)}\}$	$\{R_{(t,24)} - R_{(t,1)}\}$	$\{R_{(t,3)} - \pi_{(t,3)}\}$
LR statistics	-	-	-	-	-

(b) With dummies

Model: $\Gamma(L)\Delta x(t) = \delta_1 D_1 + \delta_2 D_2 + \delta_3 D_3 + Ax_{(t-1)} + \omega_{(t)}$

$x(t)' = \{R_{(t,1)}, R_{(t,3)}, R_{(t,6)}, R_{(t,12)}, R_{(t,24)}, \boldsymbol{\pi}_{(t,3)}\}$

(I) Rank tests

Eigenvalues	λ_1	λ_2	λ_3	λ_4	λ_5	λ_6
	0.52	0.36	0.21	0.13	0.06	0.01
LR tests	r = 0	r = 1	r = 2	r = 3	r = 4	r = 5
λ_{trace}	541.91	300.99	150.86	71.82	23.98	4.13
λ_{max}	240.91	150.12	79.05	47.84	19.84	4.13

(II) LR tests on structural relationships for $x(t)' = \{R_{(1,t)}, R_{(3,t)}, R_{(6,t)}, R_{(12,t)}, R_{(24,t)}, \boldsymbol{\pi}_{(t,3)}\}$

	$\{R_{(t,3)} - R_{(t,1)}\}$	$\{R_{(t,6)} - R_{(t,1)}\}$	$\{R_{(t,12)} - R_{(t,1)}\}$	$\{R_{(t,24)} - R_{(t,1)}\}$	$\{R_{(t,3)} - \pi_{(t,3)}\}$
LR statistics	3.54	1.03	0.27	0.06	2.85

Table 8a: Error correction forecasting equation

Model: $\Delta\pi_{(t,m)} = \delta_0 + \gamma_1\Delta\pi_{(t)} + \gamma_2\Delta R_{(t,1)} + \gamma_3\Delta R_{(t,m)} + \beta_1[R_{(t,m)} - R_{(t,1)}] +$
$+ \beta_2[R_{(t-1,1)} - \pi_{(t-1,1)}] + e_{(m,t)}$

(I) OLS estimates

Period (m)	3 mo	6 mo	12 mo	24 mo
δ_0	-0.07 (-1.13)	-0.04 (-1.13)	-0.01 (-1.08)	-0.01 (-1.83)
γ_1	0.03 (1.58)	0.00 (-0.15)	0.01 (2.53)*	0.00 (1.76)
γ_2	0.38 (1.30)	0.14 (1.23)	0.02 (0.61)	0.01 (0.95)
γ_3	-0.24 (-0.67)	0.00 (-0.02)	0.00 (-0.05)	-0.02 (-0.64)
β_1	0.90 (2.65)*	0.17 (1.75)	0.02 (0.95)	0.01 (1.77)
β_2	'0.30 (12.71)*	0.19 (15.94)*	0.04 (7.71)*	0.03 (10.13)*
R^{2bar}	0.48	0.55	0.30	0.40
ADF(4)	-8.75	-7.55	-7.06	-6.08
DW	1.57	1.53	1.53	1.35
LM(1)	15.89	17.87	18.11	34.63
LM(12)	4.29	3.46	2.31	5.71
ARCH(1)	0.00	0.02	0.01	0.01
N(2)	763.76	744.78	1,140.16	393.95
CH	0.79	0.75	0.80	0.81

(II) NLLS estimates ($e_{(m,t)} = \sum_{i=0,k} \theta_i \varepsilon_{(t-i)}$)

Period (m)	3 mo	6 mo	12 mo	24 mo
δ_0	-0.07 (-1.16)	-0.01 (-1.15)	-0.02 (-0.74)	-0.01 (-0.90)
γ_1	0.07 (0.75)	0.12 (13.37)*	0.01 (2.81)*	0.00 (2.12)*
γ_2	0.44 (1.50)	0.06 (1.27)	0.02 (0.54)	0.01 (0.47)
γ_3	-0.32 (-0.96)	0.07 (0.91)	-0.01 (-0.22)	-0.02 (-0.55)
β_1	0.90 (2.61)*	0.08 (1.24)	0.02 (0.68)	0.01 (0.73)
β_2	0.26 (3.17)*	0.06 (6.54)*	0.04 (6.92)*	0.03 (5.99)*
θ_1	0.22 (4.12)*	0.13 (3.29)*	0.21 (4.05)*	0.28 (3.69)*
θ_2	-0.16 (-0.53)	0.11 (3.30)*	0.12 (1.63)	0.17 (2.39)*
θ_3	-	0.11 (2.99)*	0.09 (1.11)	0.13 (1.43)
θ_4	-	-0.01 (-0.47)	0.04 (0.88)	0.09 (1.52)
θ_5	-	-0.85 (-21.21)*	0.03 (0.62)	0.07 (1.16)
R^{2bar}	0.50	0.59	0.34	0.47
ADF(4)	-8.69	-7.97	-8.08	-7.66
DW	2.00	1.88	2.01	2.01
LM(1)	0.10	3.13	2.34	1.22
LM(12)	2.87	2.07	0.76	2.26
ARCH(1)	0.04	0.05	0.76	2.15
N(2)	969.71	839.33	1,312.17	640.15
CH	0.80	0.81	0.83	0.75

The *t*-ratios are corrected for heteroscedasticity and serial correlation (Newey and West, 1987).
θ_1 to θ_5 are the coefficients of the MA terms, k = 2 for m = 3 and k = 5 for m = 6 and 12.
The three regime shift dummies are incorported into the real interest rate via regression
* Significant at a 5% level.

Table 8b: Error correction forecasting equation

Model: $\Delta\pi_{(t,m)} = \delta_0 + \gamma_1\Delta\pi_{(t)} + \gamma_2\Delta R_{(t,1)} + \gamma_3\Delta R_{(t,m)} + \beta_1[R_{(t,m)} - R_{(t,1)}] +$
$+ \beta_2[R_{(t-3,3)} - \pi_{(t,3)}] + e_{(t,m)}$

(I) OLS estimates

Period (m)	3 mo	6 mo	12 mo	24 mo
δ_0	-0.07 (-0.90)	-0.04 (-1.03)	-0.02 (-1.05)	-0.01 (-1.41)
γ_1	0.13 (7.08)*	0.06 (6.61)*	0.02 (6.79)*	0.01 (6.86)*
γ_2	0.21 (0.61)	0.01 (0.07)	0.00 (-0.03)	0.00 (-0.28)
γ_3	-0.20 (-0.50)	0.01 (0.05)	0.00 (-0.08)	-0.02 (-0.56)
β_1	0.76 (1.94)	0.22 (1.73)	0.03 (1.02)	0.01 (1.21)
β_2	0.23 (6.75)*	0.12 (6.41)*	0.02 (3.10)*	0.02 (4.43)*
R^{2bar}	0.32	0.30	0.20	0.26
ADF(4)	-10.54	-11.40	-7.18	-6.87
DW	1.63	1.45	1.50	1.35
LM(1)	11.87	29.14	21.00	37.01
LM(12)	12.79	15.38	3.92	4.96
ARCH(1)	2.24	1.75	0.14	1.13
N(2)	152.12	142.67	809.80	785.24
CH	0.79	0.88	0.69	0.73

(II) NLLS estimates ($e_{(m,t)} = \sum_{i=0,k} \theta_i \varepsilon_{(t-i)}$)

Period (m)	3 mo	6 mo	12 mo	24 mo
δ_0	-0.03 (-1.61)	-0.02 (-1.57)	-0.02 (-0.82)	-0.01 (-0.76)
γ_1	0.30 (41.47)*	0.16 (61.65)*	0.03 (8.60)*	0.02 (7.00)*
γ_2	0.12 (1.08)	0.07 (1.43)	0.00 (0.10)	-0.01 (-0.29)
γ_3	-0.05 (-0.39)	-0.08 (-1.36)	-0.01 (-0.25)	-0.02 (-0.57)
β_1	0.39 (2.16)*	0.08 (1.29)	0.03 (0.93)	0.01 (0.58)
β_2	0.09 (3.63)*	0.01 (1.12)	0.01 (1.83)	0.02 (1.76)
θ_1	0.14 (4.66)*	0.09 (4.44)*	0.25 (4.02)*	0.33 (3.70)*
θ_2	-0.84 (-26.89)*	0.09 (3.84)*	0.07 (1.03)	0.11 (1.71)
θ_3	-	0.05 (2.10)*	0.07 (0.89)	0.11 (1.17)
θ_4	-	0.03 (1.34)	0.01 (0.11)	0.05 (0.72)
θ_5	-	-0.91 (-41.42)*	0.03 (0.47)	0.01 (0.17)
R^{2bar}	0.50	0.54	0.24	0.33
ADF(4)	-8.20	-8.52	-7.98	7.86
DW	2.00	1.69	2.00	2.00
LM(1)	3.07	10.94	1.44	2.44
LM(12)	3.24	3.42	2.38	1.84
ARCH(1)	0.11	0.01	2.88	19.32
N(2)	889.51	635.69	872.18	700.25
CH	0.85	0.77	0.71	0.75

The *t*-ratios are corrected for heteroscedasticity and serial correlation (Newey and West, 1987).
θ_1 to θ_5 are the coefficients of the MA terms, k = 2 for m = 3 and k = 5 for m = 6 and 12.
The three regime shift dummies are incorported into the real interest rate via regression
* Significant at a 5% level.

Table 9: Error correction forecasting equation

Model: $\Delta\pi_{(t,m)} = \delta_0 + \gamma_1\Delta\pi_{(t)} + \gamma_2\Delta R_{(t,1)} + \gamma_3\Delta R_{(t,m)} + \beta_1[R_{(t,m)} - R_{(t,1)})] +$
$+ \beta_2[R_{(t,n)})] + e_{(t,m)}\,,\ e_{(t,m)} = \sum_{i=0,k}\theta_i\varepsilon_{(t-i)}$

(I) n=1

Period (m)	3 mo	6 mo	12 mo	24 mo
δ_0	-0.02 (-1.91)	-0.01 (-1.00)	-0.02 (-0.70)	0.00 (-0.31)
γ_1	0.32 (70.49)*	0.16 (72.88)*	0.03 (10.11)	0.02 (6.03)*
γ_2	0.00 (0.07)	0.01 (0.23)	0.01 (0.27)	0.00 (-0.36)
γ_3	0.02 (0.18)	0.00 (-0.06)	-0.02 (-0.55)	-0.02 (-0.61)
β_1	0.20 (1.40)	0.03 (0.50)	0.01 (0.48)	0.00 (-0.45)
β_2	0.00 (-0.56)	0.00 (-0.89)	-0.02 (-1.45)	-0.02 (-2.25)*
θ_1	0.06 (2.78)*	0.09 (3.20)*	0.26 (3.72)*	0.34 (3.82)*
θ_2	-0.93 (-42.15)*	0.09 (2.91)*	0.10 (1.47)	0.15 (2.21)*
θ_3	-	0.06 (2.29)*	0.09 (0.93)	0.15 (2.16)*
θ_4	-	0.04 (1.35)	0.00 (-0.01)	0.04 (0.76)
θ_5	-	-0.91 (-36.19)*	0.01 (0.20)	-0.01 (-0.17)
R^{2bar}	0.47	0.54	0.24	0.32
ADF(4)	-8.93	-8.67	-8.14	-8.01
DW	1.62	1.67	2.00	2.00
LM(1)	14.36	12.81	1.05	2.30
LM(12)	4.30	3.95	2.64	1.38
ARCH(1)	0.02	0.01	4.65	18.50
N(2)	731.02	605.78	808.64	1,068.70
CH	0.62	0.79	0.67	0.65

(II) n=3

Period (m)	3 mo	6 mo	12 mo	24 mo
δ_0	-0.02 (-1.91)	-0.01 (-1.00)	-0.01 (-0.69)	-0.01 (-0.32)
γ_1	0.32 (70.49)*	0.16 (72.88)*	0.03 (10.10)*	0.02 (6.04)*
γ_2	0.01 (0.07)	0.01 (0.23)	0.01 (0.26)	-0.01 (-0.37)
γ_3	0.02 (0.18)	0.00 (-0.06)	-0.02 (-0.54)	-0.02 (-0.61)
β_1	0.20 (1.40)	0.03 (0.50)	0.02 (0.47)	0.01 (-0.45)
β_2	0.00 (-0.56)	-0.01 (-0.89)	-0.02 (-1.44)	-0.02 (-2.25)*
θ_1	0.06 (2.77)*	0.09 (3.20)*	0.26 (3.72)*	0.34 (3.82)*
θ_2	-0.93 (-42.16)*	0.08 (2.91)*	0.10 (1.47)	0.15 (2.21)*
θ_3	-	0.06 (2.29)*	0.09 (0.92)	0.16 (2.17)*
θ_4	-	0.05 (1.35)	0.00 (-0.01)	0.05 (0.76)
θ_5	-	-0.91 (-36.19)*	0.04 (0.20)	-0.01 (-0.17)
R^{2bar}	0.47	0.59	0.24	0.32
ADF(4)	-8.93	-8.67	-8.13	-8.01
DW	1.62	1.67	2.00	2.00
LM(1)	14.36	12.81	1.05	2.30
LM(12)	4.30	3.95	2.63	1.38
ARCH(1)	0.02	0.01	4.64	18.50
N(2)	728.95	605.77	831.66	1,086.67
CH	0.61	0.79	0.67	0.65

The *t*-ratios are corrected for heteroscedasticity and serial correlation (Newey and West, 1987).
θ_1 to θ_5 are the coefficients of the MA terms, k = 2 for m = 3 and k = 5 for m = 6 and 12.
The three regime shift dummies are incorporated into the real interest rate via regression
* Significant at a 5% level.

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1) vergriffen (out of print)
2) In abgeänderter Form erschienen in Berichte und Studien Nr. 4/1990, S 74 ff
3) In abgeänderter Form erschienen in Berichte und Studien Nr. 4/1991, S 44 ff
4) In abgeänderter Form erschienen in Berichte und Studien Nr. 3/1991, S 39 ff
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