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Anticipation and Surprises in Central Bank Interest Rate Policy: The Case of the Bundesbank

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Abstract

Market reaction to a change in official interest rates will depend on the extent to which the change is anticipated, and on how it is interpreted as a signal of future policy. In this paper, a technique is developed to separate the anticipated and unanticipated components of such changes and is applied to estimate the response of Euro-deutsch mark interest rates to adjustments in the Bundesbank's Lombard and discount rates. The results shed light on the efficiency of this market and on the scope for policy signaling by the central bank.

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SUMMARY

In most industrial and some developing countries, the central bank determines and announces "official" interest rates both to define the range within which it manages short-term interbank rates and to signal its short- to medium-term policy stance. Policymakers must be able to predict the market response to a change in official interest rates, so as to ensure that the desired monetary policy impulse is transmitted to the economy.

Market prices and especially interest rates will reflect participants' expectations about the central bank's future policy stance—in particular, expectations about the timing and magnitude of increases and decreases in official interest rates. In this paper, a technique is developed to use this and other available information to estimate the extent to which market participants can foresee such changes and to what extent the changes come as surprises.

The technique is applied to study changes in the rates applied at the Deutsche Bundesbank's Lombard and discount facilities during 1985-95, when these rates played a prominent role in the coordination of monetary policy among European central banks. These estimates are then used to gauge how far the market response depends on the degree of anticipation. The reaction of market rates (especially but not exclusively for maturities between one month and one year) to changes in official rates was found to have been sharp but of moderate magnitude. The effect is strongest when the change is unexpected, but the anticipated component also influenced market rates in the days leading up to a decision.

Market prices and especially interest rates will reflect participants' expectations about the central bank's future policy stance—in particular, expectations about the timing and magnitude of increases and decreases in official interest rates. In this paper a technique is developed to use this and other available information to estimate the extent to which market participants can foresee such changes, and to what extent the changes come as surprises. The technique is applied to study changes in the rates applied at the Deutsche Bundesbank's Lombard and discount facilities during 1985-95, when these rates played a prominent role in the coordination of monetary policy among European central banks. These estimates are then used to gauge how far the market response depends on the degree of anticipation. The reaction of market rates (especially but not exclusively for maturities between one month and one year) to changes in official rates was found to have been sharp but of moderate magnitude. The effect is strongest when the change is unexpected, but the anticipated component also influenced market rates in the days leading up to a decision.

I. Introduction

Government officials, financial market participants and agents in the economy at large attach importance to official central bank interest rates. What are termed official rates typically comprise the rates applied at one or more central bank standing facilities and in some cases that at which the central bank operates a regular tender. In most industrialized countries, as in a number of developing countries, the central bank determines these rates in order both to define the range within which it manages short-term interbank rates through on-going open market operations, and to signal its short- to medium-term policy stance (see Borio (1997) for a recent survey). A change in official rates can thus affect expectations that are reflected in longer-term interest rates and other financial market prices, and hence initiate the monetary policy transmission process. Therefore policymakers need to be able to predict the market response to such changes, and if possible manage this response by explaining its actions. Yet market participants have an incentive to anticipate policy shifts, and insofar as they succeed, market prices should adjust in advance of the implementation of a change. Estimation of the reaction to a change in official rates, decomposed into its anticipated and unanticipated components, can be regarded as a test of market efficiency, and of whether the central bank can achieve different ends depending on the nature and degree of forewarning has been given of the change. These considerations were the motivation for this paper.

A number of past studies have looked at the impact effect of changes in official interest rates by the U.S. Federal Reserve (for instance Lombra and Torto, 1977; Thornton,1986 and 1994; Cook and Hahn, 1988 and 1989; and Radecki and Reinhart, 1994), the Bank of England (Dale, 1993), the Bank of Canada (Paquet and Pérez, 1995), and recently the Deutsche Bundesbank (Nautz, 1995; Hardy, 1996). In most such studies the change in money market rates on the days surrounding a change in an official rate is regressed on the change itself. However, changes in market rates ought largely to reflect changes in expectations, based presumably on new information, so it is important to distinguish between the anticipated and unanticipated actions by the central bank. These studies also usually limit their focus on the relatively rare instances when central bank rates were actually changed and neglect occasions when a change was thought possible but did not materialize.

One common approach to identifying anticipated changes in official rates, suitable for the U.S. and followed by Smirlock and Yawitz (1985) and subsequently others, is to categorize the changes as either "policy" and therefore unanticipated, or "technical" and anticipated, on the basis of published explanations of the central bank's actions. Even if the necessarily somewhat subjective evaluations are accepted, it may be inappropriate to regard actions as falling exclusively into one or other category. Roley and Troll (1984) use OLS estimation to predict changes in the U.S. discount rate, but they do not take into account the censored nature of the sample and achieve very low explanatory power. Skinner and Zettelmeyer (1997) resort to the assumption that the change in the three month interbank rate is a good proxy for the unanticipated policy change. Favero *et al.* (1996) calculate implicit forward rates, which they use in conjunction with the assumptions that the pure expectational model of the term structure holds and that the overnight rate is that controlled by the authorities to estimate market expectations of policy changes and reactions to surprises. The statistical properties of these estimates are obscure, in part because the errors cannot be taken to be symmetrically distributed: even when, say, some reduction in official rates is deemed very likely, the probability of a zero change remains positive.

Assessment of the effect of anticipated and unanticipated changes in official interest rates must start from a recognition that realized changes are discrete and relatively rare events, while making use of the information contained in market prices. Therefore, a limited dependent variable technique is appropriate to the estimation of the probabilities attached by market participants to an increase or decrease in official rates, and the expected magnitude of the change. In this paper such a technique is developed and applied, and indeed one of the aims of the paper is to examine how financial market variables reflect (short-run) expectations about central bank policy.[2] Attention focuses here on changes in the interest rates on the two standing facilities of the Deutsche Bundesbank, namely the Lombard and discount rates, as periodically decided by the Bundesbank Council, but the technique could be applied to changes in other rates (such as that on repurchase operations) and official rates in other countries.[3] Section II explains the technique (which is set out more fully in the Appendix), and Section III describes the institutional setting and the data. In Section IV the anticipated and unanticipated components of the changes are estimated and their separate effects assessed. Section V concludes.

II. Model Specification and Estimation

Early studies of the market reaction to changes in official interest rates relied on a simple specification linking changes in market interest rates to realized changes in official rates, of the form

$$(r_{\tau'} - r_{\tau}) = b_0 + b_1 \Delta s_t + e_{\tau'}, \qquad (1)$$

[2] This paper is an extension of Hardy (1996), which though concentrates more on the reaction of a wide variety of interest rates and exchange rates to overall changes in the Bundesbank's Lombard, discount, and repurchase rates, and does not examine closely which variables reflect market expectations.

[3] A number of countries besides Germany share the approach of using two official rates to form a corridor for short-term rates; a consensus has emerged that the future European Central Bank will also have two standing facilities.

where $(r_{\tau'} - r_\tau)$ is the change in market interest rates between (the morning of) day τ and some other day τ', Δs_t is the change in official rates announced on date t, and $e_{\tau'}$ is an error term.[4] The results of estimating such an equation provide an indication of the total effect of a typical change in official rates. However, the scope for interpreting the results is limited because no distinction is made between anticipated and unanticipated changes in official rates, and the evolution of expectations around the date of a change is not tracked. Therefore, one cannot necessarily say anything about market efficiency, or the possibility of the central bank influencing the reaction by giving explicit or implicit forewarnings of its actions and *ex post* explanations.

The hypothesis that financial prices are influenced by official rates, combined with some version of the expectations theory, suggests that market interest rates on any day should be a function of expectations of their own future value conditional on information available on that day, the current official rates, and possibly other factors.[5] If financial markets are informationally efficient, changes in rates should reflect news events, such as the signal of a shift in policy stance imparted by an unexpected change in official rates or a public statement on the central bank's policy stance. The reaction to what had been foreseen should be minimal. This differential response to anticipated and unanticipated events may be represented by the equation

$$(r_{\tau'} - r_\tau) = b_0 + b_1 E(\Delta s_t \mid \Omega_\tau) + b_2[E(\Delta s_t \mid \Omega_{\tau'}) - E(\Delta s_t \mid \Omega_\tau)] + e_{\tau'}, \quad (2)$$

which is the main regression specification used here. The information set available to market participants at time τ is represented by Ω_τ, and E is the expectations operator. The immediate reaction of market rates to a change in official rates is given by the change from $\tau = t$ to $\tau' = t + 1$. For $\tau, \tau' < t$ the equation is meant to capture the effect of shifting expectations as information is released in the days prior to a possible change in central bank rates. This information might include for example economic data relevant to predicting the policy reaction and also statements from officials. For $\tau' > t$ market participants are assumed to have learnt the actual change in official rates, so $[E(\Delta s_t \mid \Omega_{\tau'}) - E(\Delta s_t \mid \Omega_\tau)] = [\Delta s_t - E(\Delta s_t \mid \Omega_\tau)]$, that is, the unanticipated component of the realized change; the equation is then meant to capture the effect of learning by market participants as they reflect on the central bank's announcement of a change and pronouncements thereafter, and thereby assess the likely persistence of the change.

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[4] Instead of interest rates, the exchange rate or a stock price index could be used to estimate the reaction in those markets.

[5] Consider a simple linearized version of the expectations theory, whereby at time t the interest rate $r_{M,t}$ for maturity M equals the average of expected spot interest rates $r_{1,t+i}$, $i = 0, 1, \ldots$ between t and $t+M-1$ conditional on available information Ω_t. The M-period rate will change by an amount equal to only one $(1/M)$th of a realized change in the spot rate caused, say, by a change in the official rate, unless expected rates also change. The more permanent the change in the spot rate is expected to be, the larger the reaction of the longer term rate.

One would expect $b_0 = 0$. The first null hypothesis to be tested is whether $b_1 = 0$, that is, whether expected changes in central bank rates do not change market rates. In addition, the magnitude of the coefficient b_2 should reflect the market's interpretation of policy signals sent through the unexpected component of changes in official interest rates and other innovations in expectations. For example, a large estimate of b_2 for changes in rates on long-term assets from $\tau = t$ to $\tau' = t + 1$ could indicate that an increase in official rates is viewed as the start of a long period of higher interest rates. A large estimate of of b_2 for changes in market rates in the days before a possible change in official rates (that is, when $\tau, \tau' < t$) could indicate that shifts in expectations are important, and that the central bank can influence market rates strongly by releasing information on its intentions during this period.

In the work that follows the logarithms of interest rates are used instead of levels. This somewhat unusual specification was chosen to respect the restriction that interest rates cannot become negative, and the supposition that an interest rate change from, say, 3 to 3.5 percent might be more important for the economy at large than one from 8 to 8.5.[6] The equations were also estimated using a simple linear specification and the results were not qualitatively different from those reported below.

Expectations and surprises are not observed, but under the assumption of rational expectations the realized decisions of the central bank should differ from expectations about them by no more than an uncorrelated, zero-mean error term. An instrumental variables technique, implemented through multi-stage regressions, can be used to deal with this "error-in variables" problem. The explanatory variables used in the initial stages need not reflect all available information perfectly, nor need financial markets be informationally fully efficient for this procedure to be valid, because the errors in the estimates of expectations will be orthogonal to other error terms by construction. Moreover, since changes in the central bank rates are discrete events, the dependent variable comes from a truncated sample, which demands application of nonlinear estimation techniques (see Maddala, 1983 for a survey). These procedures have recently been applied to study an analogous problem concerning expected realignments of exchange rate bands (see Edin and Vredin, 1993; and also Bertola and Svensson, 1993). In the case of German official rates the task is simplified by the fact that changes in the Lombard and discount rates occur only after Bundesbank Council meetings, the dates of which are known; the probability of a change on other days is zero. An extra difficulty, compared with the study of most exchange rate realignments, is that both increases and decreases must be considered.

Estimation proceeds in three stages (see the Appendix for details). First an "ordered probit" model of changes in official rates is estimated by maximum likelihood, where the dependent variable can be thought of as a pair of dummy variables that identify when

[6] The absolute level of interest rates and spreads may be of primary importance to financial market participants such as commercial banks.

official rates were increased, decreased or left unchanged following a Bundesbank Council meetings.[7] Candidate righthand-side variables are those that may contain relevant information to the formulation of market participants' beliefs about the probability of the central bank increasing or decreasing official rates and are known at the time, or that reflect these beliefs. The results of this stage may themselves be of interest insofar as they suggest what variables indicate market sentiment and reveal a pattern in central bank behavior.

The fitted values from the first stage are treated as the market's assessment of the probabilities of a forthcoming increase or decrease in official rates. In the second stage the estimated probabilities are appropriately combined with other candidate informational variables (with compatible dating) in a linear regression to generate a forecast of the magnitude of the any change. The additional informational variables, or instruments, are meant to capture market expectations concerning the path of interest rates in the coming months and perceptions of the intentions of the Bundesbank.

The series of fitted values from the second stage regression are taken as a proxy for the expected magnitude of any movement in official rates, and the unanticipated component is simply the difference between the estimated market expectation and the realized change.[8] In the third stage the log change in market rates is regressed on the estimates of the anticipated and unanticipated log changes in official rates, as in equation (2). The resulting coefficient estimates can be shown to be unbiased, and that of b_2 to be efficient.

III. Institutional Setting and Data Sources

The Bundesbank has long maintained both a Lombard and a discount facility (for details see Deutsche Bundesbank, 1995).[9] At the Lombard facility banks may obtain short-term liquidity at relatively high interest rates, and at the discount facility banks may obtain a limited amount of funds at a lower interest rate. The spread between the Lombard and discount rates effectively forms a band or corridor within which short-term money market rates fluctuate, but the constraint is not rigid because borrowing at these facilities are not perfect substitutes for interbank borrowing. The Bundesbank also conducts regular repurchase operations ("Pensionsgeschäfte"), which since 1985 have been the main

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[7] All estimation was performed using TSP Version 4.2.

[8] By construction the expected and unexpected components are mutually orthogonal. Except for the need to estimate the probabilities of a change in official rates, the procedure is similar to instrumental variables estimation implemented through two-stage least squares. It would be possible to estimate all stages jointly, but the properties of such estimates would be less straighforward to establish.

[9] In the past the Bundesbank operated various other, specialized facilities, but the rates offered on them were not generally regarded as indicative of the policy stance. The phrase "official rates" will be reserved for the Lombard and discount rates.

instrument for the implementation of monetary policy, and which at present are implemented through a tender every Wednesday. In addition, the Bundesbank occasionally organizes *ad hoc* "Schnelltender" repurchase operations, and has in the past issued securities to absorb liquidity.[10]

The discount and Lombard rates are reviewed by the Bundesbank Council in its morning meetings every other Thursday, and decisions are announced that afternoon or early the next morning.[11] Changes have tended to be rare (with only thirty three during the period 1985-1995), with long periods of no change being interspersed with series of small changes all in one direction. There were, however, 266 Bundesbank Council meetings during this period for which data are available, and these are the observations that will be used for estimation (the periods t in equation (2)). Official rates are always changed in multiples of 1/4 percentage point, and often the Lombard and discount rates are moved together. The width of the spread between the two rates varies but is typically about 2 percentage points. These characteristics of evolution of the Lombard and discount rates are apparent from Figure 1, which also illustrates the path of one typical money-market rate.

Daily data were taken from Bundesbank publications on the Lombard, discount repurchase rates; rates on Euro-DM deposit with maturities of 1 day, and of 1, 3, 6, 12, and 24 months; Frankfurt money market rates for 1 day and 1, 3, 6, and 12 month maturity interbank loans, from January 1985 through January 1996 or as far back as available.[12] The dates of Bundesbank Council meetings were obtained and changes in market rates over

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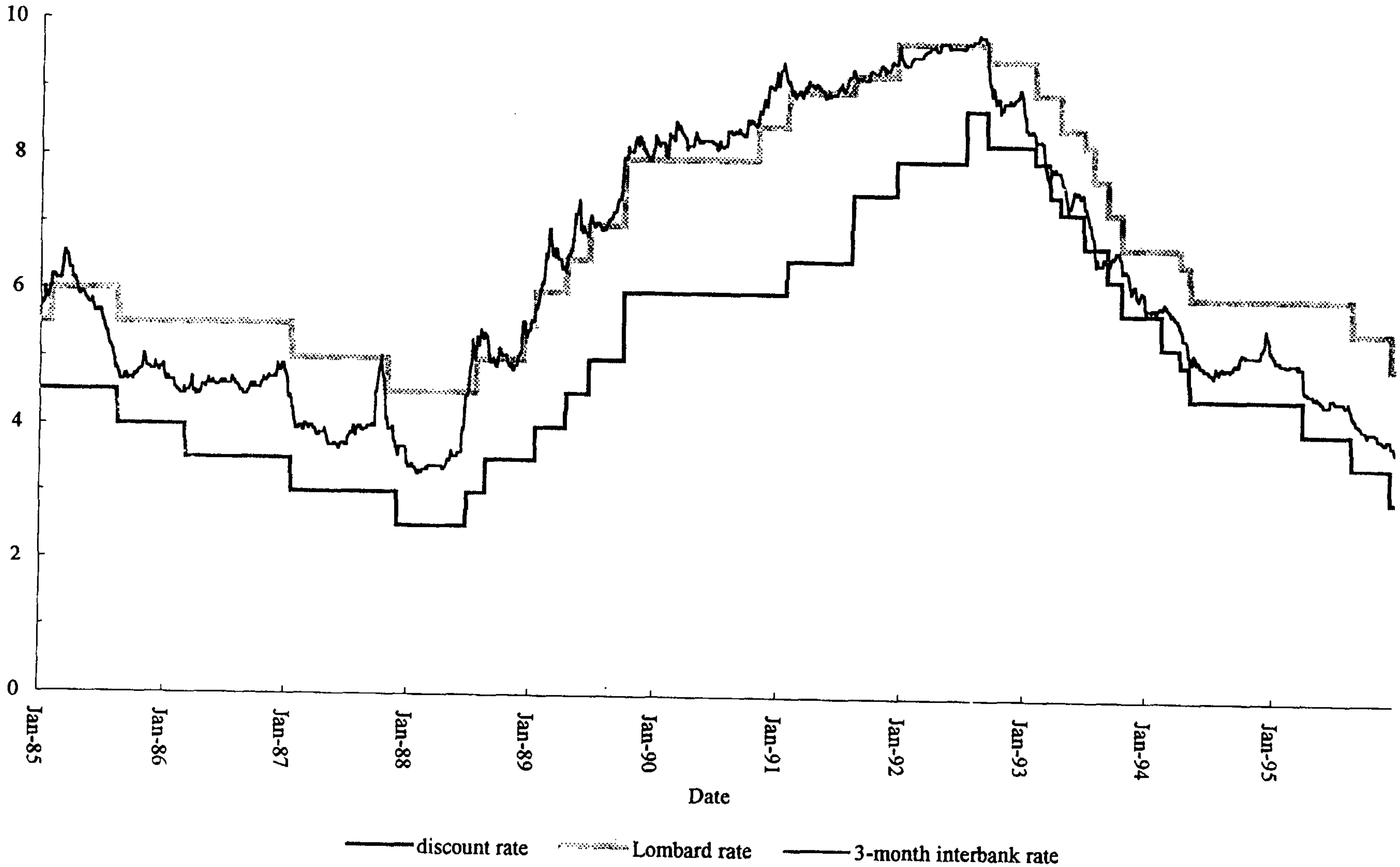
[10] There is an analogy with an exchange rate floating within an adjustable band. The Bundesbank steers rates within the interest rate corridor with its repurchase operations, much as a central bank can steer the exchange rate within a band with intramarginal intervention. Typically the market rate must get quite close to one or the other edge of the band before is there significant expectation of a revaluation.

[11] Occasionally the meetings are held on other days of the week or are missed due to holidays. The dates of meetings are published in advance. Bundesbank Council meetings immediately preceded all changes in official rates.

[12] Hardy (1996) provides evidence that the reaction of market rates to changes in the Lombard and discount was significantly different in the period before 1985 when open market operations were much less important.

Figure 1. Lombard, discount, and market interest rates



surrounding days calculated. In particular the changes from four days before to the day of a meeting or five days afterwards ($\tau = t - 4$ to $\tau' = t$ or $\tau' = t + 5$, respectively), and from the day of a meeting to the next day ($\tau = t$ to $\tau' = t + 1$) will be reported; these timespans cover from one working week before Bundesbank Council meetings to one week thereafter. Data are generally recorded at 1:00 p.m. in Frankfurt except for the Euro-currency deposit rates, which are measured at 10.00 a.m. by the BIS. Thus, a change in an official rate announced on a Thursday afternoon or Friday morning ought to act as a "surprise" affecting the difference between market prices recorded on Thursday and those recorded on Friday. Therefore the corresponding information sets are dated $\tau = t - 4$ and $\tau = t$.[13]

IV. Anticipated and Unanticipated Changes in Official Rates and Market Response

A. Overall Response to Changes in Official Rates

In order to provide a benchmark with which to compare the effects of anticipated and unanticipated changes in official rates, changes in market rates were simply regressed on the total changes in official rates using the specification given in equation (1). In the estimates reported here the dependent variable is the log change in the Euro-deutschmark interest rate with maturities between 1 day and 24 months.[14] As mentioned above, the discount and Lombard rates are often moved together, which makes it is difficult given the sample to distinguish the possibly different effects of changes in the two rates. Therefore the average of the Lombard and discount rates is used as the explanatory variable.[15]

Results are presented in Table 1. The constant term was always insignificantly different from zero and is not reported. The estimates of the parameter b_1 suggest that the announcement of a change in official rates (at the end of day t) usually had a highly

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[13] Estimates were performed for changes across a number of other time spans and based on other information sets, including information lagged one day. The results corroborated those reported here.

[14] Similar results were obtained in estimates for Frankfurt interbank interest rates. The technique has also been applied to estimate the effect of changes in the Lombard and discount rates on yields on German government securities, implied forward rates, exchange rates, the DAX share price index, and interest rates outside Germany (see Hardy, 1996 for related results).

[15] An alternative would be the average when the rates are moved together, and the change in the Lombard or discount rate when one or the other alone was changed. Estimation results did not differ qualitatively when this construct was used as the explanatory variable.

significant effect on market rates for all maturities below two years. However, (anticipation of) such a change usually had a larger total effect over the days leading up to Bundesbank Council meetings (from t - 4 to t). Almost no effect is observed in the days following a decision, as indicated by the fact that the estimates of b_1 for the change in market rates from t - 4 to t + 5 are all almost equal to the sum of the respective estimates for t - 4 to t, and t to t + 1; the former. However, the change in market rates from t - 4 to t + 5 tends to be marginally less than the sum of previous changes, suggesting that rates tend to revert slightly after the announcement.

The announcement day effect is nearly the same for interest rates of all maturities, but over longer time spans (from t - 4 to t or t + 5) the effect tends to decrease with maturity. The market for 2-year Euro-DM deposits was reportedly not very active during the sample period, which may explain the slow responsiveness of these rates to changes in official rates.

B. Estimated Probabilities of Changes in Official Rates

Estimation of the anticipated and unanticipated components of changes in official rates and their separate effects on market rates can now proceed along the lines laid out in Section II. The first step is to estimate the probabilities of a change in official rates, for which purpose suitable explanatory or informational variables need to be found. These variables must represent information relevant to the prediction of the Bundesbank's actions that is publicly available at the appropriate point in time. One consideration is that when a change in official rates is expected, money market interest rates should tend to move in advance towards the new level, but they are constrained by the operation of the standing facilities where the old rates still apply. Moreover the Bundesbank tends to lead up to changes in the Lombard or discount rate with changes in the repurchase rate, which in turn steers money market rates. Therefore the convergence of short-term rates to one or other boundary of the interest rate "band" may indicate that a corresponding shift in the band is expected. Another consideration is that the Bundesbank has tended to change official rates in "runs" of small changes fairly close together, so a change in one direction should make another in the same direction more likely. For the same reason also the time elapsed since the last change may be informative.

After some experimentation it was found that the differences between the three month interbank rate and the discount rate and the Lombard rate, all in logarithms, were useful as informational variables to capture market sentiment concerning the likelihood of an official rate change (denoted by ln(R3M/DISC) and ln(R3M/LOMB), respectively).[16] The difference

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[16] The one month interbank rate, the repurchase rate, and the three-month Euro-DM rate were found to be about equally good instruments.

Table 1. Reaction of Euro-DM Rates to Changes in Official Rates

	Change from $t-4$ to t		Change from t to $t+1$		Change from $t-4$ to $t+5$	
	b_1	R^2 s.e.	b_1	R^2 s.e.	b_1	R^2 s.e.
1 day [1]	0.3266	3.651	0.1035	1.217	0.4415	2.213
	(0.1035) **	0.0464	(0.0574) +	0.0257	(0.1810) **	0.0811
1 month [2]	0.2472	7.639	0.1243	8.248	0.3059	6.582
	(0.0556) **	0.0242	(0.0268) **	0.0116	(0.0746) **	0.0324
3 months [2]	0.2378	9.807	0.1000	5.035	0.3066	7.148
	(0.0466) **	0.0203	(0.0281) **	0.0122	(0.0715) **	0.0310
6 months [3]	0.1903	6.868	0.0980	7.322	0.2390	4.867
	(0.0493) **	0.0203	(0.0245) **	0.0101	(0.0744) **	0.0305
12 months [4]	0.1302	3.283	0.0951	4.802	0.2338	4.877
	(0.0518) *	0.0206	(0.0310) **	0.0123	(0.0757) **	0.0301
24 months [5]	0.1221	2.258	0.0082	0.211	0.2380	6.683
	(0.0637) *	0.0226	(0.0445)	0.0158	(0.0712) **	0.0251

OLS estimation of $(r_{\tau'} - r_{\tau}) = b_0 + b_1\Delta s_t + e_{\tau'}$. Estimated coefficient b_1, standard errors in parentheses, percentage R^2, and standard error reported. (1) Number of observations = 266. (2) 241 observations. (3) 205 observations. (4) 189 observations. (5) 163 observations.

of logarithms were preferred to levels in order to capture a non-linear phenomenon, namely, that short term market rates (and the repurchase rate) can fluctuate in a middle range between the discount and Lombard rates without signifying expectations of a change in the band. The logarithm of the last change in the average official interest rate (ln(LCHG)), and the logarithm of the time in days elapsed since the last change (ln(LAPS)) were included as means to represent the tendency for rate changes to be positively serially correlated but spaced some weeks or months apart. Several other financial variables, for example, some capturing the slope of the term structure, were deleted from the list of informational variables because their influence did not seem to be robust enough to warrant the loss of parsimony. In principle macroeconomic variables, such as price and money supply developments, could also have been used as informational variables. It is, however, difficult to determine exactly when these data became available, and insofar as they influence the expectations of market participants, prices should already reflect the information. An extension of the paper would consider the information contained in exchange rates and, were they available, quantity variables such as the stock of lending at the Lombard and discount windows. Variables observed at time t were used as instruments for the change from t to $t + 1$; the same variables dated $t - 4$ were used as instruments for the change from $t - 4$ to t or $t + 5$.

The results of the first stage estimation are presented in Table 2 and illustrated in Figure 2, which depicts the estimated probabilities at each date t of an increase or a decrease in official rates, (the latter shown as a negative number), and occasions when rates were in fact changed. The results seem plausible. For prolonged periods no change is expected. Expectations of an increase or decrease in rates tend to build up from one Council meeting to the next, peaking on the occasion of a realized change, and then falling to near zero.[17] On only a few occasions did a rate change came as a complete surprise or a firmly expected change fail to materialize (the probability attached to a rise in rates in 1987 is due to turbulence following the stock market collapse of that year).

The estimated parameters are largely as expected (due to the estimation procedure separate parameters are estimated for interest rate increases and decreases). When the three-months interbank rate is close to the discount rate (so ln (R3M/DISC) is small or negative) a decrease in official rates is likely, and when it is close to the Lombard rate (so ln(R3M/LOMB) is large) an increase is likely. When the interbank rate is far from either official rate, neither an increase nor a decrease is likely; therefore ln(R3M/LOMB) is significant in explaining the occurrence of reduction in official rates, and ln(R3M/DISC) is

[17] Estimated probabilities of exchange rate realignments, as reported in the articles cited, tend to display a similar pattern of asymmetric peaks.

Figure 2. Estimated probabilities of changes in official rates

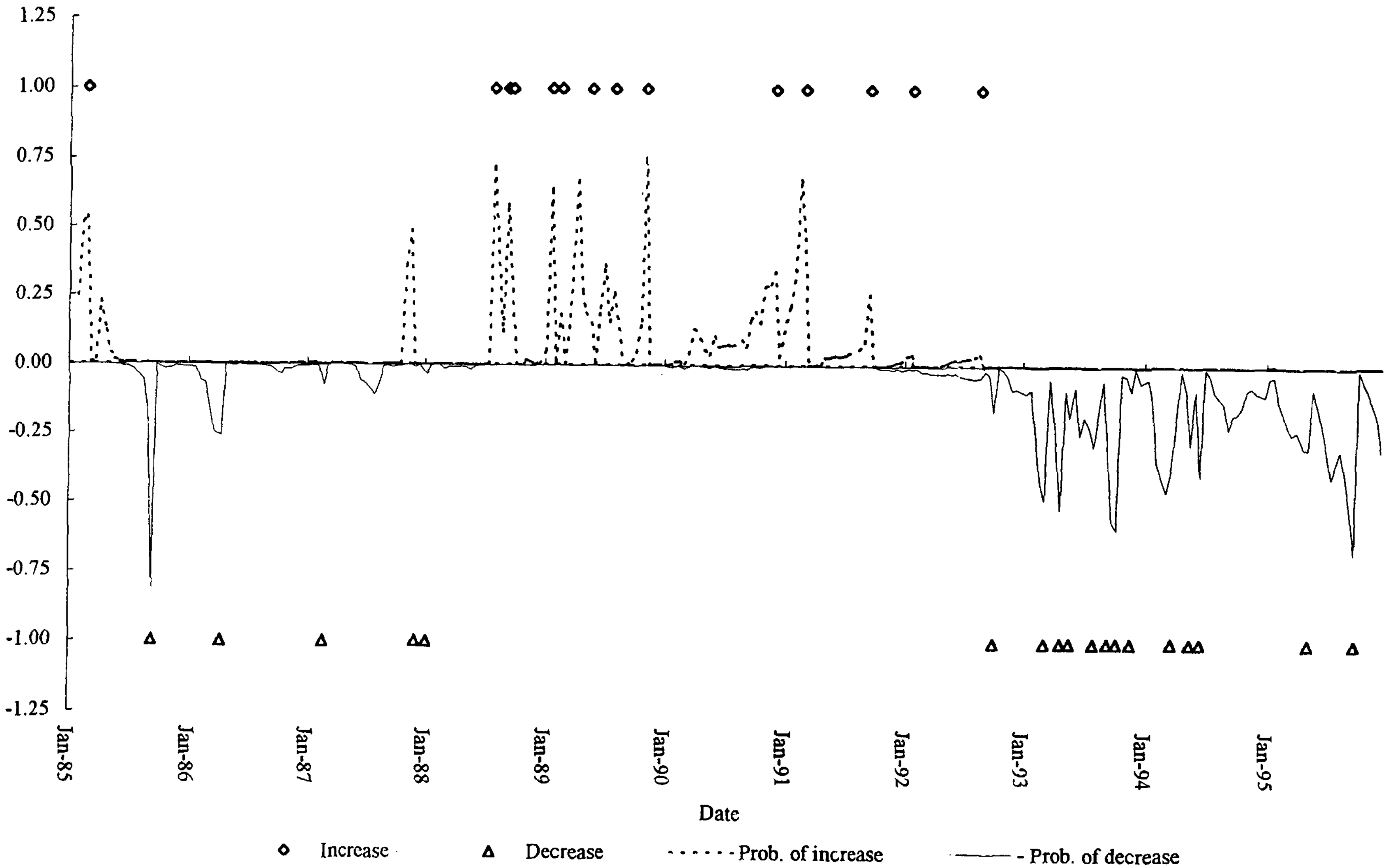

Table 2. Estimation of the Probability of Changes in Official Rates

	Based on information at time *t* - 4	Based on information at time *t*
	Probability of a decrease	
Constant	-1.9834	-2.6990
	(0.7140) **	(0.9032) **
ln(R3M/DISC)	-8.5210	-10.1404
	(1.8471) **	(2.1240) **
ln(R3M/LOMB)	-4.5854	-6.3617
	(2.2454) *	(2.3889) *
ln(LCHG)	2.3293	3.6356
	(1.7478)	(1.9451) +
ln(LAPS)	0.3307	0.4765
	(0.1708) +	(0.2110) *
	Probability of an increase	
Constant	-4.5474)	-5.4543
	(1.4123) **	(1.7854) **
ln(R3M/DISC)	4.4717	3.2692
	(2.2091) *	(2.4761)
ln(R3M/LOMB)	10.7469	17.0490
	(4.5526) *	(5.8442) **
ln(LCHG)	-2.5418	-4.1598
	(1.6970)	(1.8999) *
ln(LAPS)	0.4222	0.6711
	(0.2079) *	(0.2700) *
Log likelihood	-81.3872	-72.1383

Based on 266 observations. Estimated standard errors in parentheses. **: significant at 1 percent; *: significant at 5 percent; +: significant at 10 percent.

significant in explaining increases. The sign of changes in official rates tends to be persistent, especially for increases, and the likelihood of a change increases with the time elapsed since the last change but at a declining rate. The predictions made using the information set available at time t - 4 are not as reliable as those that can be made with the information set available at time t, but estimated parameters are similar in sign and only slightly less significance. The qualitative results are not very sensitive to the inclusion or exclusion of particular informational variables, or to the use of lagged data (i.e. observations dated τ-1 instead of those dated τ, where $\tau = t$ or t - 4). The results were also qualitatively unaffected when a dummy variable was included to capture the "surprising" interest rate reductions in 1987, or when only post-1987 data were included in the sample.

C. Estimated Magnitude of Changes in Official Rates

In the second stage the magnitude of the expected change is to be estimated. The dependent variable is the actual change in official rates (if any). In order to account for the discrete nature of the dependent variable, the constant and the righthand-side informational variable(s) are multiplied by the estimated probability of a reduction or increase in official rates (termed *W1* and *W3*, respectively), and the value of the density functions (*X1* and *X3*) are also included as explanatory variables. Candidate informational variables were suggested by the consideration that market interest rates should depend on both the actual and the expected future level of official rates. Therefore the slope of the term structure could contain relevant information. In particular, the difference in the (log) overnight and three month interbank rates was chosen.[18]

Estimation results are presented in Table 3, and Figure 3 shows that the equation yields estimates of expected changes (based on information available on day t) that are of plausible amplitude and variability. The interpretation of the positive coefficient on the ln(R1D/R3M) term may be as follows: market participants may have a sense of the trend in interest rates, so that they believe that in the next few months rates are likely to change by, say, N percentage points, and this expectation will be built into the level of three-months rates.

[18] Rudebusch (1995) contains a discussion of the relationship between the term structure and central bank interest rate policy. It might have been preferable to use, say, the difference between the 7-day and the 1 or 3 month rates, but data were unavailable.

Figure 3. Estimated forecasts of changes in official rates

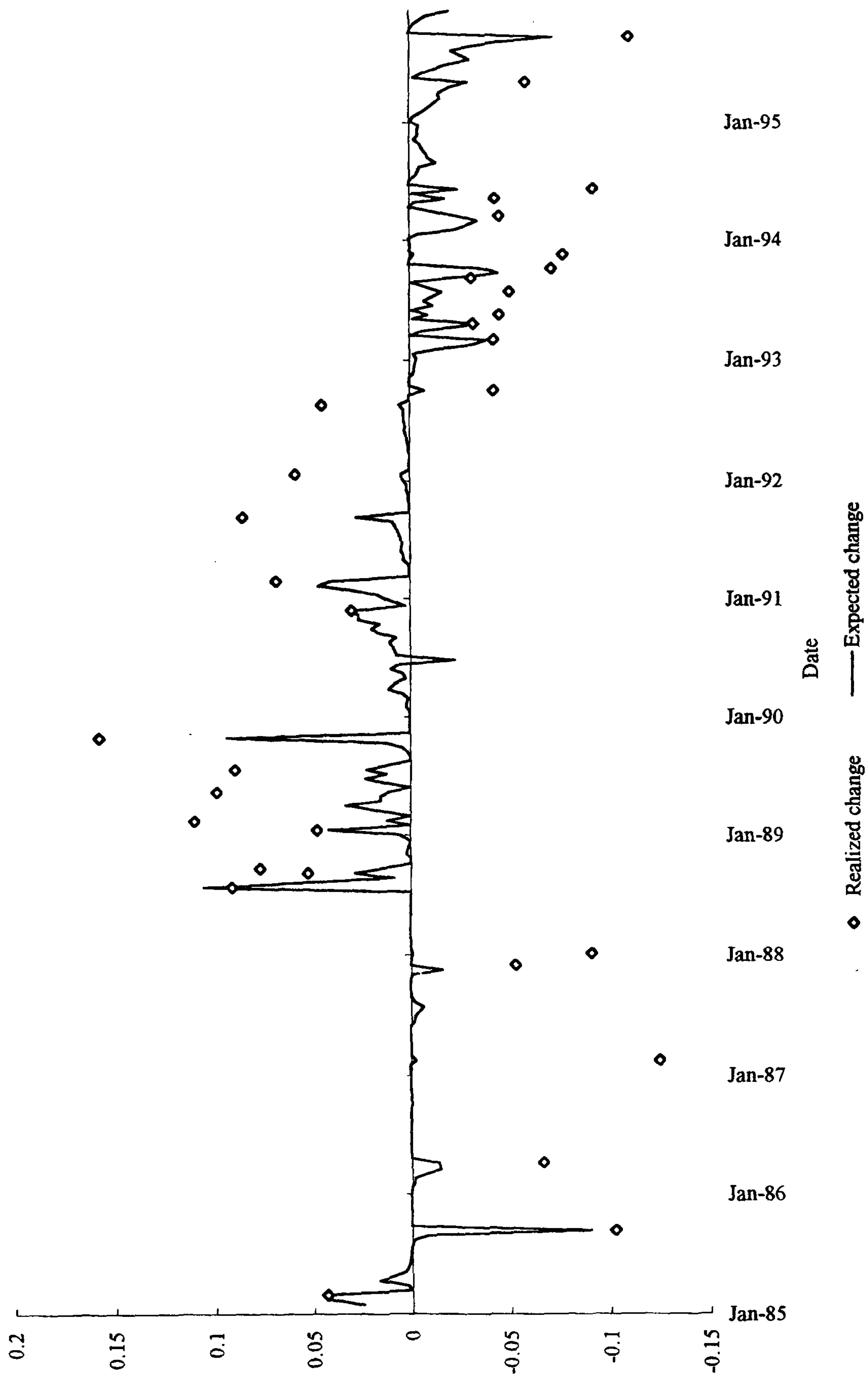

Table 3. Estimation of the Expected Magnitude of Changes in Official Rates

	Based on information at time *t* - 4	Based on information at time *t*
W1	-0.1568	-0.1333
	(0.0522) **	(0.0298) **
*W1**ln(R1D/R3M)	0.1918	0.2033
	(0.3512)	(0.1738)
X1	0.0697	0.0579
	(0.0393) +	(0.0258) *
W3	0.1208	0.1330
	(0.0848)	(0.0455) **
*W3**ln(R1D/R3M)	0.3586	0.6331
	(0.1876) +	(0.1813) **
X3	0.0007	-0.0025
	(0.0526)	(0.0433)
s.e. of regression	0.0234	0.0218
R^2	0.2907	0.3851
[illegible]	0.2770	0.3733

Based on 266 observations. Estimated standard errors in parentheses. **: significant at 1 percent; *: significant at 5 percent; +: significant at 10 percent.

If they believe that the central bank intends to "front load" this move in rates with a big change in the near future, very short-term money market rates will move approximately *N* percentage points so as to anticipate the change; the term structure will flatten. If the central bank is expected to effect the adjustment only slowly then overnight rates will move less than *N* and the term structure will be relatively steep. Hence the larger is the overnight rate relative to the three-months rate, the larger the change in official rates expected. In addition, the Bundesbank may have intervened through its repurchase tenders or other open market operations preceding a change in the Lombard or discount rates so as to ensure that very short-term rates do not jump too abruptly when the change is announced. The effect again would be to flatten the yield curve in advance of large changes.

It was difficult to find other variables that performed reliably as informational variables, perhaps because the magnitudes of changes in official rates lie in such a narrow range. Again the results are not very sensitive to the exact specification of the informational variable, or changes in sample size.

D. Estimated Reaction to Anticipated and Unanticipated Changes in Official Rates

Finally the estimated expected and unexpected components of the change in Lombard and discount rates taken from the second stage were used as explanatory variables in OLS estimation of equation (2), the results of which are shown in Table 4.

It is clear from the table that only the unanticipated component of the change in official rates has a systematic positive effect on market rates between day t and day $t + 1$. The estimated coefficients on the "surprise" component are consistently significantly different from zero, albeit relatively small, and are almost the same for all maturities up to about one year. This stability could indicate that market participants interpret a surprise change in official rates as signaling a policy shift that will persist over this time horizon. The overnight rate, which displays much more volatility than the other series, reacts slightly less than the one-month rate, as one would expect given that the closest substitute to borrowing from the standing facilities is an interbank loan of at least several weeks' maturity. The two year rate, which is determined in what is reportedly a rather thin market and for which fewer observations are available, seems again to react more sluggishly. The reaction to the anticipated component of the change is always close to zero and sometimes even negative. These results can be compared to those obtained when the change in official rates is not decomposed into its anticipated and unanticipated parts (reported in Table 1). The unanticipated change is found to affect market rates more strongly than does the total change, and decomposing the change yields notably higher explanatory power, as indicated by the R^2 statistics.

Table 4. Reaction of Euro-DM Rates to Anticipated and Unanticipated Changes in Official Rates

Dependent variable (by maturity)	Change from t - 4 to t			Change from t to t + 1			Change from t - 4 to t + 5		
	Anticipated change	Unanticipated change	R^2 s.e.	Anticipated change	Unanticipated change	R^2 s.e.	Anticipated change	Unanticipated change	R^2 s.e.
1 day [1]	0.2809	1.8119	10.426	0.0173	0.1876	1.747	0.1408	0.5645	2.626
	(0.1876)	(0.3447) **	0.0448	(0.0924)	(0.0732) *	0.0257	(0.3379)	(0.2153) *	0.0811
1 month [2]	0.2607	1.2176	17.265	-0.0482	0.2176	16.509	0.0547	0.3957	8.200
	(0.1021) *	(0.1836) **	0.0229	(0.0438)	(0.0320) **	0.0111	(0.1432)	(0.0861) **	0.0322
3 months [2]	0.2481	1.0045	16.975	-0.0005	0.1544	7.677	0.1067	0.3781	8.256
	(0.0868) **	(0.1561) **	0.0195	(0.0475)	(0.0347) **	0.0121	(0.1378)	(0.0827) **	0.0309
6 months [3]	0.2080	0.6950	10.592	0.0123	0.1548	10.746	0.1206	0.2874	5.371
	(0.0890) *	(0.1600) **	0.0199	(0.0391)	(0.0309) **	0.0099	(0.1365)	(0.0878) **	0.0305
12 months [4]	0.2146	0.3634	5.090	-0.0005	0.1621	8.098	0.1741	0.2606	5.022
	(0.0997) *	(0.1740) *	0.0204	(0.0480)	(0.0400) **	0.0121	(0.1355)	(0.0911) *	0.0301
24 months [5]	0.3916	0.0740	7.749	-0.0641	0.0542	1.026	0.3703	0.1769	7.739
	(0.1075) **	(0.2582)	0.0220	(0.0720)	(0.0572)	0.0158	(0.1221) **	(0.0845) *	0.0774

OLS estimation of $(r_{\tau'} - r_\tau) = b_0 + b_1 E(\Delta s_t|\Omega_\tau) + b_2[E(\Delta s_t|\Omega_{\tau'}) - E(\Delta s_t|\Omega_\tau)] + e_{\tau'}$. Estimated coefficients b_1 and b_2, estimated standard errors in parentheses, and percentage R^2 reported. (1) Number of observations = 266. (2) 241 observations. (3) 205 observations. (4) 189 observations. (5) 163 observations.

The results for the change in market rates from $t - 4$ to t are in some ways quite different from those for the change from t to $t + 1$. The advance reaction to shifts in expectations about movements in official rates is generally very much larger than when the reaction is measured starting on day t.[19] The Bundesbank seems normally to give considerable forewarning of its decisions whether or not to adjust the Lombard or discount rates, and this news is clearly given considerable weight by market participants. Perhaps news that becomes available in the days leading up to Bundesbank Council meetings is considered especially relevant to forecasting the policy stance over the longer term; it is during this period that the Bundesbank may be signaling how large and permanent a shift in interest rates it envisages. The "news" contained in the announcement on day t of the precise magnitude of a change in official rates may be of lessor relevance. The reaction to the evolution of expectations before day t is more pronounced for shorter maturities.

Equally remarkable is the magnitude and significance of the estimated coefficients on the anticipated component of changes in the Lombard and discount rates. For longest maturity the estimated coefficient is significantly larger than that on the unanticipated change.[20] Several (not mutually exclusive) explanations for this result can be suggested. It could simply be that the Euro-DM market is not perfectly efficient, so anticipated changes in official rates are not fully discounted in advance. A related possibility is that, when a change in official rates is deemed likely, participants adopt a "wait and see" approach and activity in these markets dries up. The recorded prices may then not represent those at which most agents are willing to trade and so they fail to reflect expectations. These two hypothesis are perhaps most plausible for the longer maturities, where indeed the effect of anticipated changes is greatest.

It might also be asserted that the instrumental variables technique in fact uses more information than was available to market participants: for each observation the prediction of the change in official rates is based not only on individual data that were publicly available at the time, but also on parameters in the auxiliary regressions that are estimated from the full sample up the end of 1995. The technique may therefore identify as anticipated what was in fact a "surprise" to market participants. The estimated coefficient b_1 will be biased downward

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[19] However, the changes in estimated expectations are mostly fairly small.

[20] Estimates were run for the change from $t - n$ to $t + 1$, with various values of n between 0 and 10. The effect of the anticipated component is larger, the larger is n (the longer the time interval).

and b_2 biased upward.[21] This argument cannot though account for why the phenomenon is much more pronounced for changes in market rates from $t - 4$ to t than for changes from t to $t + 1$.

The operation of the standing facilities themselves may largely account for the gradual reaction of market prices to expected changes in the rates charged on these facilities. At each point in time the current Lombard and discount rates constrain short-term money market rates from above and below, respectively, although the constraint is not absolute because arbitrage is not possible and access is limited. When a large change in official rates is expected in the near future, short-term market rates will "hit" one or other boundary of the interest rate band and therefore not necessarily move all the way to the new expected level until the change is realized. The effect on short-term rates of the Lombard and discount rate bounds may then be transmitted along the yield curve. As the date of the expected change approaches, uncertainty about the magnitude of the change and the advantage of bringing forward or delaying a transaction decreases, so the effectiveness of the boundaries should diminish.

The separation of the anticipated and unanticipated components of changes in official rates has increased considerably the explanatory power of the estimates for this time horizon; the relevant R^2 statistics are up to 10 percentage points higher in Table 4 than in Table 1. The estimated coefficients on the total change are less than those on the unanticipated component for all maturities less then two years, and also less than those on the anticipated component for longer maturities.

Table 4 also shows that the estimated coefficients for the reaction from $t - 4$ to $t + 5$ are approximately equal to or below the average of those for the reaction from $t - 4$ to t and from t to $t + 1$. Hence it seems that almost the full reaction to the realized unexpected change occurs on the day of change itself, so there is little sign that the markets need several days to "digest" the news or rely on ex post explanations by the Bundesbank. These results suggest that the market is in this regard informationally efficient.

IV. Conclusion

The official interest rates applied at central bank standing facilities serve as bounds and guideposts for short-term money market rates. The relationship between market rates and these bound is therefore an important indicator of market sentiment concerning the probability of a forthcoming shift in the interest rate "band" and the central bank's operational target range for short-term money market rates over the coming period. This and other available information can be used to estimate the extent to which market participants

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[21] In principle it would be possible to mitigate this difficulty by using a recursive estimation technique, which, however, would exhaust many degrees of freedom, and perhaps make use of too little information at the start of the available sample.

can foresee the timing and magnitude of changes in the central bank's official interest rates and to what extent the changes come as a surprise. In this article such estimates are generated for changes in the rates applied at the Bundesbank's Lombard and discount facilities, and then used to gauge how far the market response depends on the degree of anticipation. The reaction of market rates (especially but not exclusively for maturities between one month and one year) to unexpected changes in official rates was found to have been sharp but of moderate magnitude. In addition, the accrual of information as the central bank signals its intentions in advance of a change in official rates strongly influences market rates. However, the anticipated component is shown to influence market interest rates in the days leading up to a decision. The Bundesbank has relied primarily on open market operations in the implementation of policy since 1985, but even a largely anticipated change in official interest rates on standing facilities can still be effective in confirming and clarifying the public's understanding of a shift in the policy stance.

Estimation of Anticipated and Unanticipated Changes in Official Rates

The behavior of the Lombard and discount rates can be treated as an instance of an ordered response, limited dependent variable model: if certain conditions obtain, then one or both official rates increase in relatively large steps; if other conditions obtain they decrease; and under intermediary conditions they remain unchanged. The standard ordered response model will be generalized to allow the explanatory variables to affect the probability of an increase or a decrease in different ways, and then used to predict the magnitude of any change (see Heckman, 1974; and Maddala, 1983, pages 46-49 and Chapter 8). The predictions and the residuals are then taken as the anticipated and unanticipated components of the changes in official rates, respectively.

Let the dummy *d1* take the value of 1 when an official rate decreases, and zero otherwise. Similarly, let *d2* equal 1 only when rates are unchanged, and let *d3* equal 1 only when rates are increased. It is assumed that there exists a set of explanatory variables ***Z*** which predict the direction of changes in official rates, and another (possibly coincidental or overlapping) set of explanatory variables ***X*** which predict through some linear equation the magnitude of the change. The average log change in official rates will be denoted by y.[22] The scheme can be summarized as follows:

$$\text{if } \gamma_1'\boldsymbol{Z}+u<0 \qquad d1=1,\ d2=d3=0 \qquad y=\beta_1'\boldsymbol{X}+u_1 \tag{A1}$$

$$\text{if } \gamma_1'\boldsymbol{Z}+u>0>\gamma_3'Z+u \qquad d2=1,\ d1=d3=0 \qquad y=0$$

$$\text{if } \gamma_3'\boldsymbol{Z}+u>0 \qquad d3=1,\ d1=d2=0 \qquad y=\beta_3'\boldsymbol{X}+u_3$$

where γ_1, γ_3, β_1 and β_3 are parameters to be estimated, and u, u_1 and u_3 are correlated, homoskedastic random variables with a joint normal distribution.[23] The variable u is standardized to have mean zero and variance 1. Let f and F will denote the density function and the cumulative distribution function of the standard normal, respectively. With n observations indexed by i, and recalling that $1 - F(w) = F(-w)$, the likelihood function can be written as

$$L = \prod_{i=1}^{n} F(-g_1'Z_i)^{d1}\left[1 - F(-g_1 Z_i) - F(g_3'Z_i)\right]^{d2} F(g_3'Z_i)^{d3} \tag{A2}$$

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[22] Time subscripts are omitted where no ambiguity results. The instrumental variables in ***X*** and ***Z*** must be known before y is realized.

[23] The conditions $\gamma_1'\boldsymbol{Z}+u<0$ and $\gamma_3'\boldsymbol{Z}+u>0$ should not be fulfilled simultaneously. The method used here does not impose this constraint, but in the application no difficulties result.

The first stage of the regression procedure consists of maximizing the logarithm of (A2) with respect to the parameters g_i, $i = 1, 2, 3$. Starting values can be obtained by first estimating standard probit models for *d1* and *d3* separately. To estimate the predicted magnitude of changes in official rates, note that

$$E(y_i) = \text{Prob}(y_i{<}0)\cdot E(y_i \mid y_i{<}0) + \text{Prob}(y_i{=}0)\cdot E(y_i \mid y_i{=}0) + \text{Prob}(y_i{>}0)\cdot E(y_i \mid y_i{>}0),$$

which can be shown based on (A1) to imply that

$$E(y_i) = F(-\gamma_1{}'Z_i)\cdot\beta_1{}'X_i + f(-\gamma_1{}'Z_i)\cdot\sigma_{1u} + F(\gamma_3{}'Z_i)\cdot\beta_3{}'X_i + f(\gamma_3{}'Z_i)\cdot\sigma_{3u}\,. \qquad \text{(A3)}$$

In the second stage estimates of β_1, β_3, σ_{1u} and σ_{3u} are obtained by replacing $E(y_i)$ in (A3) with the realized value of y_i and then applying OLS, where use is made of the estimates of γ_1 and γ_3 obtained in the first stage. The standard errors are heteroskedastic, but the estimated standard errors can be corrected using the procedure from White (1980). Homoskedasticity had to be assumed in (A1) so that σ_{1u} and σ_{3u} can be taken to be constants.

The predicted value .. from the second stage regression (A3) is treated as the expected change $E(\Delta s_t \mid \Omega_\tau)$, and the residual ($y_i$ - ..) is the unexpected component, which by construction is orthogonal to the fitted value and the instruments.[24] The two are then used to estimate equation (2) in the specification

$$(r_{\tau'} - r_\tau) = b_0 + b_1 \,..\, + b_2(y_i - ..\,) + e_{\tau'}\,. \qquad \text{(A4)}$$

Pagan (1984) and McAleer and McKenze (1991) discuss the properties of regression output with such constructed regressors. Under reasonable conditions the OLS coefficient estimates are unbiased, and that of b_2 will be efficient. The OLS t-statistic on the estimate of b_1 may be biased upwards by an amount that varies positively with the product of $(b_2)^2$ and the variance o f the residuals from the auxiliary regression (A3 here), and negatively with the variance of the residuals from the regression of interest (A4). The estimate of b_2 was at most 1.8 and often much smaller (mostly in the range 0.15 to 0.4); the estimated variances of both the auxiliary regression and equation (A4) applied to imterest rates were about $4\text{x}10^{-4}$ (see Tables 3 and 4, respectively). Therefore the bias is likely to be small relative to the t-statistics achieved.

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[24] When estimating the effect of changes in expectations, as between day t - 4 and day t, the "surprise" term is the difference between the expectations based on the two information sets.

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