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Anticipation and Surprises in Central Bank Interest Rate Policy

The Case of the Bundesbank

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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 applied to estimate the response of euro–deutsche mark interest rates to adjustments in the Bundesbank's Lombard and discount rates. [JEL E43, E47]

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 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 both to define the range within which it manages short-term interbank rates through on-going open market operations, and to signal its 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. It is therefore important that policymakers be able to predict the market response to such changes. Yet market participants have an incentive to anticipate policy shifts, and insofar as they succeed, market prices should largely adjust in advance of the implementation of a

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change. Therefore, predicting the market response to changes in official rates requires that these changes be decomposed into their anticipated and unanticipated components. Such a decomposition may reveal what aspects of a change in official rates influence expectations over different time horizons, and whether the central bank can achieve different ends depending on the nature and degree of forewarning that 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 simply 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 to 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 United States 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 ordinary least squares (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 and others (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. However, there may be many occasions when market participants attach some probability to a change occurring in the near future. Market participants' expectations are unobserved, but information concerning them ought to be contained in market prices. In these circumstances, 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 an appropriate 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.[1] Attention focuses here on the relationship between interbank rates and the interest rates on the two standing facilities of the Deutsche Bundesbank, namely the Lombard and discount rates, but the technique could be applied to other financial market prices and other central bank rates (such as that on repurchase operations) and official rates in other countries.[2]

I. The Bundesbank's Monetary Instruments and Operating Procedures

The Bundesbank has long maintained both a Lombard and a discount facility (for details see Deutsche Bundesbank, 1994).[3] At the Lombard facility banks may obtain very short-term liquidity at relatively high interest rates, and at the discount facility banks may obtain a limited amount of funds for up to three months at a lower interest rate. The Bundesbank also conducts regular repurchase operations ("Pensionsgeschäfte"), which are currently 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.

Since 1985, repurchase operations have been the Bundesbank's main vehicle for active liquidity management and the control of short-term money market interest rates. Nonetheless, weight is still attached to the "official rates" at the discount and Lombard facilities. Changes in these official rates are viewed, by the Bundesbank and others, as signals of its policy stance:

[1] This paper is an extension of Hardy (1996), which 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.

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

[3] 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.

"Interest rate policy longer-run adjustment provides longer-run guidelines for interest rates in the money and credit markets. This applies particularly to changes in the discount and Lombard rates" (Deutsche Bundesbank, 1995, p. 97). The spread between the Lombard and discount rates effectively forms a band or corridor within which short-term money market rates fluctuate.[4] However, the constraint is not rigid because borrowing at these facilities are not perfect substitutes for interbank borrowing. In particular, access to the discount facility is limited by quota, and in practice banks are reluctant to make very heavy and frequent use of Lombard loans, which "should be extended only to bridge temporary liquidity needs and only if the size and maturity . . . seems appropriate and warranted" (Deutsche Bundesbank, 1994, p. 102).

The discount and Lombard rates are reviewed by the Bundesbank Council in its morning meetings every other Thursday, and decisions on any change are announced that afternoon or early the next morning.[5] Meetings are normally preceded by public discussion of the Bundesbank's likely actions. Changes have tended to be rare (with only 33 during the period 1985–95), with long periods of no change being interspersed with series of small changes all in one direction spaced over several years. 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.

II. Model Specification and Estimation

Official Rates and the Term Structure

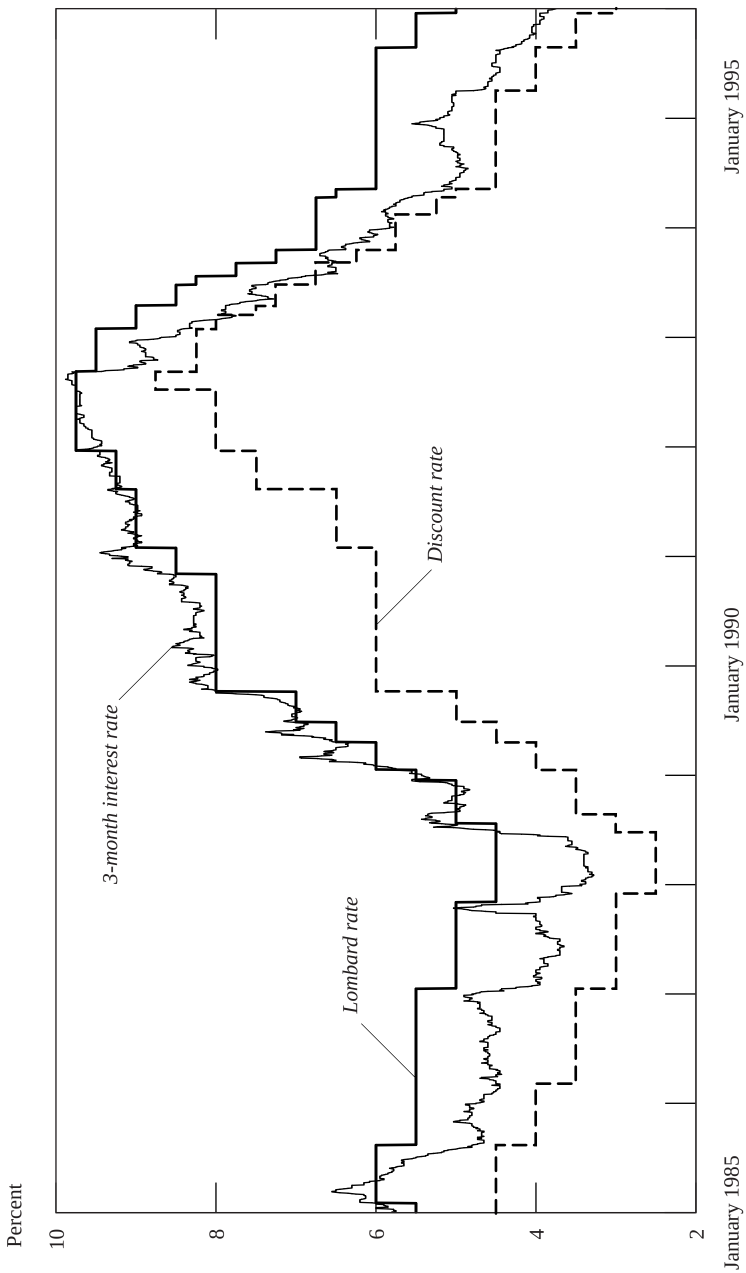
How would one expect market rates to react to a change in official interest rates or information about a forthcoming change? To obtain an intuition, suppose that on each day τ, $\tau = 0, 1, 2, \ldots$ the central bank announces an

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

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. Similarly, 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 there is significant expectation of a revaluation.

[5] There were 266 Bundesbank Council meetings during the period 1985–95, which will form the sample period. 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.

Figure 1. *Lombard, Discount, and Market Interest Rates*



official interest rate s_τ that exactly determines the current overnight interbank interest rate, which will be denoted $r(1)_\tau$. The interest rate on interbank loans of longer maturity M is assumed to be determined simply by the expected average of the overnight rates over that time span, which equals the expected average level of the official rate:

$$r(M)_\tau = \frac{1}{M} E\left(\sum_{i=\tau}^{\tau+M-1} s_i \middle| \Omega_\tau \right), \tag{1}$$

where the information set available to market participants at time τ is represented by Ω_τ, and E is the expectations operator.

If at date $\tau = 1$ the central bank unexpectedly increases the official rate by an amount Δs and this change is believed to be permanent, all market rates should immediately increase by the same amount. If the change is expected to last for one period only, then the overnight rate $r(1)_1$ should increase by Δs from period $\tau = 0$ to $\tau = 1$, but the change in the M-period rate should be only $\Delta s(1/M)$. If instead the central bank announces at $\tau = 1$ that it will increase its official rate permanently by Δs at $\tau = 2$, then the M-period rate should increase by $\Delta s(M - 1)/M$ from $\tau = 0$ to $\tau = 1$, and a further $\Delta s(1/M)$ from $\tau = 1$ to $\tau = 2$, when the anticipated change is realized. The overnight rate will increase first in period $\tau = 2$, but then by the full amount Δs. It is easy to construct other scenarios where the change in the official rate is more or less anticipated and expected to be more or less permanent.

This illustrative model shows that if a change in official rates is expected to be relatively permanent, then the reaction of longer-term market rates will be relatively large. Longer-term rates should also react more to news about future changes in official rates, and their movements in the period leading up to a possible change should reflect the accumulation of information on the central bank's intentions. Longer-term rates should react correspondingly less to the realization of anticipated events; the immediate, one-day response of longer-term rates should be caused almost entirely by the unforeseen component of a change in official rates. This differential response to anticipated and unanticipated events may be represented by the equation

$$\begin{aligned} &\left[r(M)_{\tau'} - r(M)_\tau \right] \\ &= b_0 + b_1 E\left(\Delta s_t \middle| \Omega_\tau\right) + b_2 \left[E\left(\Delta s_t \middle| \Omega_{\tau'}\right) - E\left(\Delta s_t \middle| \Omega_\tau\right)\right] + e_{\tau'}, \end{aligned} \tag{2}$$

where $[r(M)_{\tau'} - r(M)_\tau]$ is the change in the M-period market interest rates between (the morning of) day τ and some other day τ'; Δs_t is the change in official rates announced during a particular day $\tau = t$; and $e_{\tau'}$ is an error term. 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 before 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 learned 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. Equation (2) is the main regression specification used in this paper.

According to the illustrative model, one would expect $b_0 = 0$. One would also expect that b_1 will be very small for longer maturities. Thus, expected changes in central bank rates should not significantly affect market rates except for very short maturities. 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 the unexpected component of an increase in official rates is viewed as the start of a long period of higher interest rates. A large estimate of b_2 for changes in market rates in the days before a possible change in official rates (that is, when τ, $\tau' < t$) 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. The magnitudes of both b_1 and b_2 should vary with the difference between τ and τ' and their relationship to time t when the official rates are changed. The greater the difference $(\tau' - \tau)$, the longer market prices have to incorporate news, so generally one would expect b_2, the coefficient on the unanticipated change, to increase.

Under the institutional arrangements established by the Bundesbank (see above), these qualitative relationships should still hold, but may be weakened. The Lombard and discount rates do not exactly determine market interest rates at any maturity, first because these bounds on market rates are not usually binding, and second because banks cannot freely and without limit arbitrage between these facilities and the money market. Furthermore, banks must meet reserve requirements as an average of daily positions, and therefore have considerable flexibility in managing their short-term liquidity. Hence, for example, they may try to build up their liquidity positions when they anticipate that interest rates will rise in the near future. Then even the overnight rate will be strongly influenced by expected future rates, and the simple term structure model that was posited may not hold. All these factors would tend to decrease the market reaction to changes in official rates and especially to anticipated changes.

Estimation

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 multistage 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. The dependent variable can be thought of as a set of dummy variables that identify when official rates were increased, decreased, or left unchanged following a Bundesbank Council meeting. Candidate right-hand 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 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. The unanticipated component is simply the difference between the estimated market expectation and the realized change.[6]

In the third stage, the change in market rates is regressed on the estimates of the anticipated and unanticipated 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.

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.[7] The equations were also estimated using a simple linear specification and the results were not qualitatively different from those reported below.

Data Sources

Daily data were taken from Bundesbank publications on the Lombard and discount repurchase rates, rates on euro–deutsche mark deposits with maturities of 1 day, and of 1, 3, 6, 12, and 24 months, and 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.[8] The dates of Bundesbank Council meetings were obtained and changes in market rates over surrounding days calculated. In particular, the changes from four days before a meeting to the day of a meeting or five days afterward ($\tau = t - 4$ 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 time spans 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 eurocurrency 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

[6] 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 straightforward to establish.

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

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

recorded on Thursday and those recorded on Friday. Therefore, the corresponding information sets are dated $\tau = t - 4$ and $\tau = t$.[9]

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

Overall Response to Changes in Official Rates

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[10]

$$\left[r(M)_{\tau'} - r(M)_{\tau}\right] = b_0 + b_1 \Delta s_t + e_{\tau'}. \tag{3}$$

In the estimates reported here, the dependent variable is the log change in the euro–deutsche mark interest rate with maturities between 1 day and 24 months.[11] As mentioned above, the discount and Lombard rates are often moved together, which makes it 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.[12]

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 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

[9] 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.

[10] All estimation was performed using TSP Version 4.2 econometric software.

[11] 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 from the Frankfurt stock market, and interest rates outside Germany (see Hardy, 1996, for related results).

[12] 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.

Table 1. *Reaction of Euro–Deutsche Mark 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[a]	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[b]	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[b]	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[c]	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[d]	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[e]	0.1221	2.258	0.0082	0.211	0.2380	6.683
	(0.0637)*	0.0226	(0.0445)	0.0158	(0.0712)**	0.0251

Notes: OLS estimation of $[r(M)_{\tau'} - r(M)_{\tau}] = b_0 + b_1\Delta s_t + e_{\tau'}$. Estimated coefficient b_1, standard errors in parentheses, percentage R^2, and equation standard error reported. Two asterisks indicate significance at 1 percent; one asterisk indicates significance at 5 percent; a plus sign indicates significance at 10 percent.

[a] Number of observations = 266.
[b] 241 observations.
[c] 205 observations.
[d] 189 observations.
[e] 163 observations.

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–deutsche mark deposits was reportedly not very active during the sample period, which may explain the slow responsiveness of these rates to changes in official rates.

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 toward the new level. However, these rates are to some extent 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 in the appropriate direction. Therefore, the convergence of short-term rates to one or the 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).[13] The difference of logarithms was chosen over levels to capture a nonlinear 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 a way 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, 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 this paper could 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

[13] The one-month interbank rate, the repurchase rate, and the three-month euro–deutsche mark rate were found to be about equally good instruments.

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

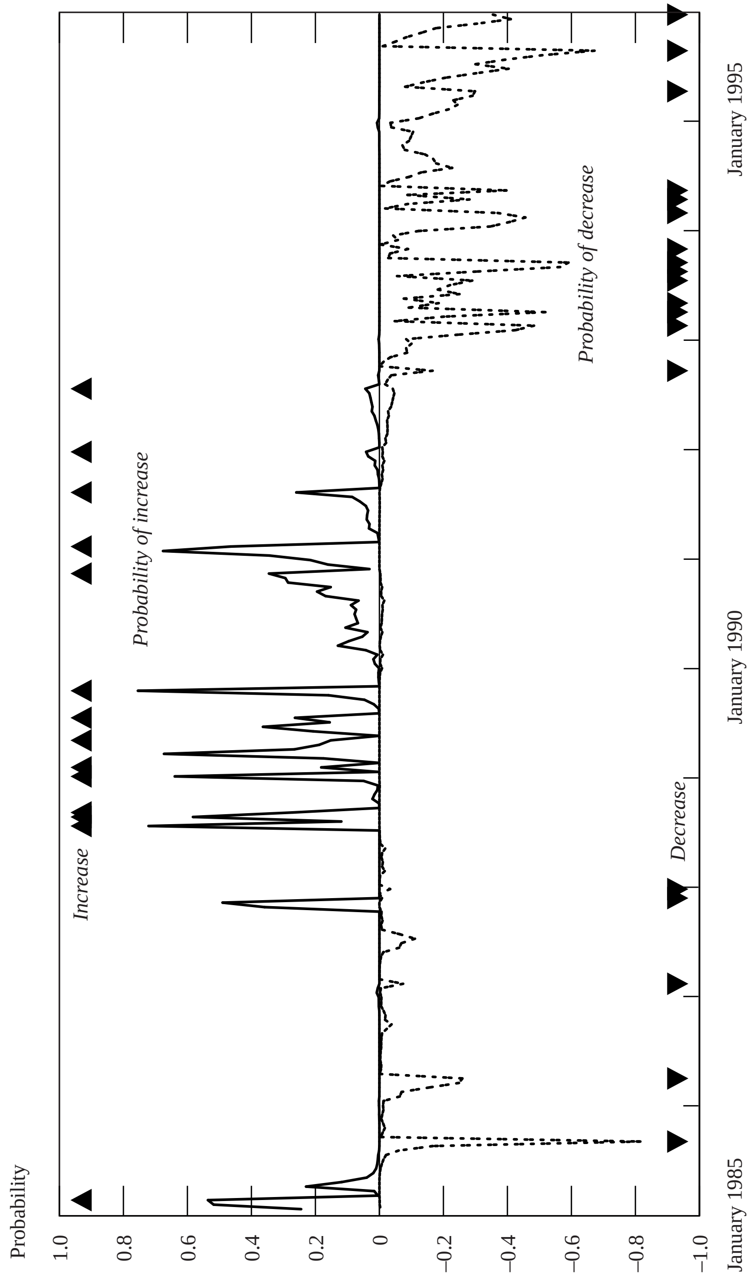
	Based on information at time $t-4$	Based on information at time t
	Probability of a decrease	
Constant	–1.9834	–2.6990
	(0.7140)**	(0.9032)**
ln(*R*3*M*/*DISC*)	–8.5210	–10.1404
	(1.8471)**	(2.1240)**
ln(*R*3*M*/*LOMB*)	–4.5854	–6.3617
	(2.2454)*	(2.3889)*
ln*LCHG*	2.3293	3.6356
	(1.7478)	(1.9451)+
ln*LAPS*	0.3307	0.4765
	(0.1708)+	(0.2110)*
	Probability of an increase	
Constant	–4.5474	–5.4543
	(1.4123)**	(1.7854)**
ln(*R*3*M*/*DISC*)	4.4717	3.2692
	(2.2091)*	(2.4761)
ln(*R*3*M*/*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

Notes: Based on 266 observations. Estimated standard errors in parentheses. Two asterisks indicate significance at 1 percent; one asterisk indicates significance at 5 percent; a plus sign indicates significance at 10 percent.

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.[14] On only a few occasions did a rate change come 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).

[14] 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*



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-month interbank rate is close to the discount rate (so ln(*R*3*M*/*DISC*) is small or negative) a decrease in official rates is likely. When it is close to the Lombard rate (so ln(*R*3*M*/*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(*R*3*M*/*LOMB*) is significant in explaining the occurrence of reduction in official rates and ln(*R*3*M*/*DISC*) is 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 significant. 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 $\tau - 1$ 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.

Estimated Magnitude of Changes in Official Rates

In the second stage the magnitude of the expected change is estimated. The dependent variable is the actual change in official rates (if any). To account for the discrete nature of the dependent variable, the constant and the right-hand 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.[15]

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

[15] 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 the necessary data for this were unavailable.

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

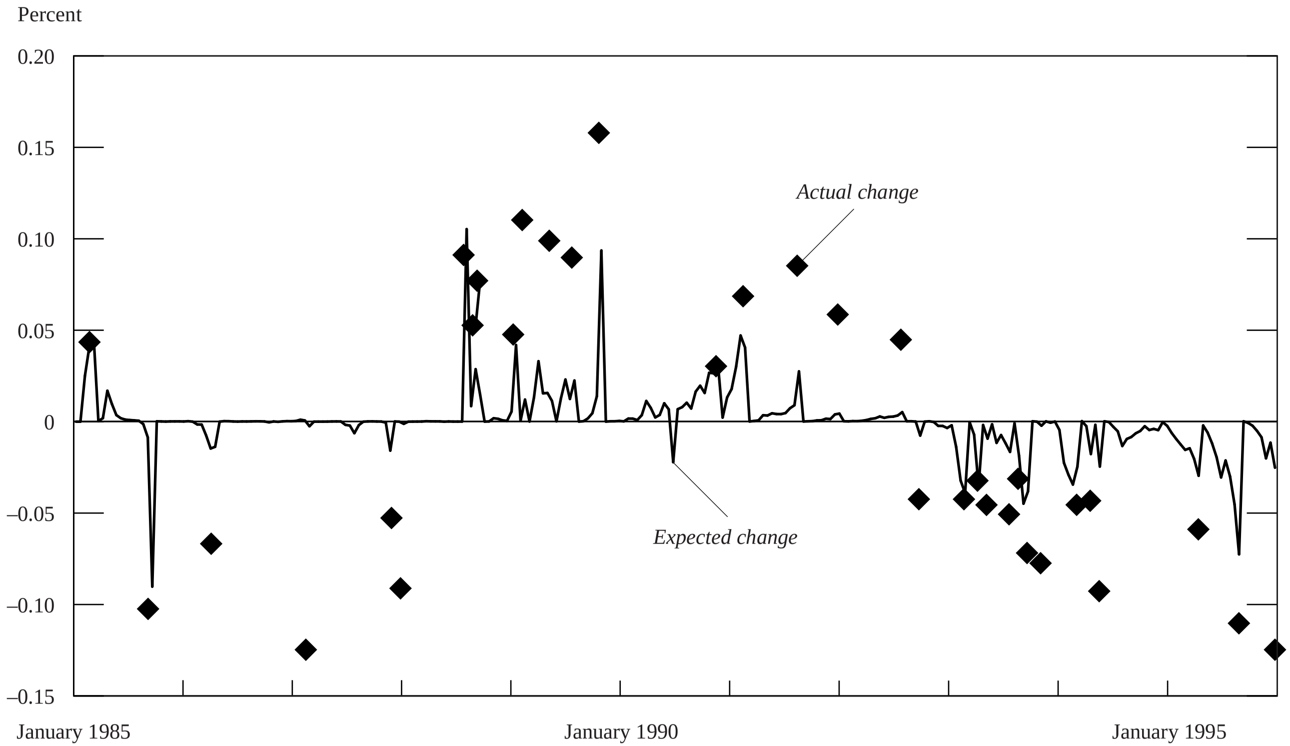
	Based on information at time $t - 4$	Based on information at time t
$W1$	–0.1568	–0.1333
	(0.0522)**	(0.0298)**
$W1 \cdot \ln(R1D/R3M)$	0.1918	0.2033
	(0.3512)	(0.1738)
$X1$	0.0697	0.0579
	(0.0393)+	(0.0258)*
$W3$	0.1208	0.1330
	(0.0848)	(0.0455)**
$W3 \cdot \ln(R1D/R3M)$	0.3586	0.6331
	(0.1876)+	(0.1813)**
$X3$	0.0007	–0.0025
	(0.0526)	(0.0433)
Standard error of regression	0.0234	0.0218
R^2	0.2907	0.3851
$\bar{R}^2$	0.2770	0.3733

Notes: Based on 266 observations. Estimated standard errors in parentheses. Two asterisks indicate significance at 1 percent; one asterisk indicates significance at 5 percent; a plus sign indicates significance at 10 percent.

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, P percentage points, and this expectation will be built into the level of three-month rates. 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 P percentage points so as to anticipate the change, and the term structure will flatten. If the central bank is expected to effect the adjustment only slowly, then overnight rates will move less than P; the term structure will be relatively steep. Hence, the closer the overnight rate is to the three-month rate, the larger the change in official rates expected in the next few days. 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 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

Figure 3. *Estimated Forecasts of Changes in Official Rates*



rates lie in such a narrow range. Again, the results are not very sensitive to the exact specification of the informational variable or to changes in sample size.

IV. 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 are used as explanatory variables in OLS estimation of equation (2), the results of which are shown in Table 4.

It is clear from Table 4 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, possibly because borrowing at the discount facility is typically for a term of at least several weeks and thus a relatively close substitute for one-month interbank borrowing. 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 with 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.

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 much larger than when the reaction is measured starting on day t.[16] The Bundesbank normally seems 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

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

Table 4. *Reaction of Euro–Deutsche Mark 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[a]	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[b]	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[b]	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[c]	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[d]	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[e]	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

Note: OLS estimation of $[r(M)_{\tau'} - r(M)_{\tau}] = b_0 + b_1 E(\Delta s_t | \Omega_{\tau}) + b_2[E(\Delta s_t | \Omega_{\tau'}) - E(\Delta s_t | \Omega_{\tau})] + e_{\tau'}$. Estimated coefficients b_1 and b_2, estimated standard errors in parentheses, percentage R^2, and equation standard error reported. Two asterisks indicate significance at 1 percent; one asterisk indicates significance at 5 percent.

[a] Number of observations = 266.
[b] 241 observations.
[c] 205 observations.
[d] 189 observations.
[e] 163 observations.

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 less 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 the longest maturity rates, the estimated coefficient is significantly larger than that on the unanticipated change.[17] Several (not mutually exclusive) explanations for this result can be suggested.

As explained in Section II, the operation of the standing facilities themselves may in large part 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. 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 will 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.

However, it could also be that the euro–deutsche mark market is not perfectly informationally 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 hypotheses are perhaps most plausible for the longer maturities, where indeed the effect of anticipated changes is greatest.

It might 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 to the

[17] 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 as n increases (i.e., the longer the time interval).

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 and b_2 biased upward.[18] This argument cannot, however, 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 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 slightly below the average of those for the reaction from $t - 4$ to t and from t to $t + 1$. While there may be some overshooting, it seems that almost the full reaction to the realized unexpected change occurs by the day of change itself; there is little sign that the markets need several days to "digest" the news or that they rely on explanations after the fact by the Bundesbank. In this regard the market may be fairly informationally efficient.

V. 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 bounds 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 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 paper, such estimates are generated for changes in the rates applied at the Bundesbank's Lombard and discount facilities. The estimates are 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

[18] 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.

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.

APPENDIX

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. It is then possible to go on to predict the magnitude of any positive or negative change (see Heckman, 1974; and Maddala, 1983, pp. 46–9 and Chapter 8). The predictions and the residuals are 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 $\boldsymbol{Z}$, which predict the direction of changes in official rates, and another (possibly coincidental or overlapping) set of explanatory variables $\boldsymbol{X}$, which predict through some linear equation the magnitude of the change. The average log change in official rates will be denoted by y.[19] The scheme can be summarized as follows:

$$\begin{array}{lll} \text{if } \gamma_1'\boldsymbol{Z} + u < 0 & d1 = 1,\ d2 = d3 = 0 & y = \beta_1'\boldsymbol{X} + u_1 \\ \text{if } \gamma_1'\boldsymbol{Z} + u > 0 > \gamma_3'\boldsymbol{Z} + u & d2 = 1,\ d1 = d3 = 0 & y = 0 \\ \text{if } \gamma_3'\boldsymbol{Z} + u > 0 & d3 = 1,\ d1 = d2 = 0 & y = \beta_3'\boldsymbol{X} + u_3, \end{array} \tag{A1}$$

where γ_1, γ_3, β_1, and β_3 are parameters to be estimated, and u, u_1, and u_3 are correlated, homoscedastic random variables with a joint normal distribution.[20] The

[19] Time subscripts are omitted where no ambiguity results. The instrumental variables in $\boldsymbol{X}$ and $\boldsymbol{Z}$ must be known before y is realized.

[20] 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.

variable u is standardized to have mean zero and variance of unity. Let f and F 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

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

The first stage of the regression procedure consists of maximizing the logarithm of equation (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

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

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

$$E(y_i) = F(-\gamma_1{}'\mathbf{Z}_i) \bullet \beta_1{}'\mathbf{X}_i + f(-\gamma_1{}'\mathbf{Z}_i) \bullet \sigma_{1u} + F(\gamma_3{}'\mathbf{Z}_i) \bullet \beta_3{}'\mathbf{X}_i + f(\gamma_3{}'\mathbf{Z}_i) \bullet \sigma_{3u}. \tag{A3}$$

In the second stage, estimates of β_1, β_3, σ_{1u}, and σ_{3u} are obtained by replacing $E(y_i)$ in equation (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 heteroscedastic, but the estimated standard errors can be corrected using the procedure from White (1980). Homoscedasticity had to be assumed in equation (A1) so σ_{1u} and σ_{3u} can be taken to be constants.

The predicted value $\hat{y}_i$ from the second-stage regression equation (A3) is treated as the expected change $E(\Delta s_t \mid \Omega_\tau)$. The residual $[y_i - \hat{y}_i]$ is the unexpected component, which by construction is orthogonal to the fitted value and the instruments.[21] The two are then used to estimate equation (2) in the specification

$$[r_{\tau'} - r_\tau] = b_0 + b_1\hat{y}_i + b_2[y_i - \hat{y}_i] + e_{\tau'}. \tag{A4}$$

Pagan (1984) and McAleer and McKenzie (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 upward by an amount that varies positively with the product of $(b_2)^2$ and the variance of the residuals from the auxiliary regression equation (A3 here), and negatively with the variance of the residuals from the regression of interest equation (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 interest rates were about 4×10^{-4} (see Tables 3 and 4, respectively). Therefore, the bias is likely to be small relative to the t-statistics achieved.

[21] 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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