



# Market Reaction to Changes in German Official Interest Rates

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# **Kurzfristige Marktreaktionen auf Änderungen der deutschen Notenbankzinsen**

## **Zusammenfassung**

Änderungen der Notenbankzinsen sind in Deutschland wie in allen anderen westlichen Industrieländern das zentrale Instrument der Geldpolitik. Sie stellen den ersten Schritt im monetären Transmissionsprozeß dar. Die wichtigsten Notenbankzinsen sind in Deutschland der Pensionsatz, der Lombard- und der Diskontsatz. In dieser Arbeit werden die unmittelbaren Marktreaktionen auf Änderungen der Leitzinsen untersucht. Dabei interessiert vor allem, welche Signalwirkungen von Notenbankzinsänderungen auf die Marktzinssätze aller Fristigkeiten und auf andere finanzielle Preise ausgehen. Insbesondere werden die Reaktionen der Geldmarktzinsen, der Rendite öffentlicher Wertpapiere, der impliziten Terminalsätze, der Wechselkurse, der ausländischen Zinssätze und schließlich der Aktienkurse im unmittelbaren Umfeld von Änderungen der Leitzinssätze beobachtet.

Das Papier unterscheidet zwei Perioden. Vor 1985 haben die Pensionsgeschäfte der Bundesbank eine vergleichsweise unbedeutende Rolle gespielt. In dieser Zeit haben Änderungen der Lombard- und Diskontsätze sehr starke Reaktionen bei den Marktsätzen ausgelöst. Nach 1985 haben die Pensionsgeschäfte der Bundesbank die zentrale Bedeutung für die Geldpolitik übernommen. Die Marktzinsen haben sich dementsprechend im Umfeld von Diskont- und Lombardsatzänderungen weniger ausgeprägt verändert. Dennoch bestand weiterhin ein signifikanter Zusammenhang.

Der direkte Einfluß der Notenbankzinsänderungen auf die Zinsen von Anlagen mit einer Laufzeit von mehr als einem Jahr nimmt mit der Fristigkeit deutlich ab; die Ergebnisse für die Terminalsätze weisen sogar darauf hin, daß hier negative Beziehungen bestehen, d. h. daß z. B. eine Erhöhung der Lombard- und Diskontsätze Erwartungen auf niedrigere Zinsen in der Zukunft auslöst. Die Wechselkursreaktionen auf Notenbankzinsänderungen sind insgesamt wenig ausgeprägt. Dagegen enthalten deutsche Leitzinsänderungen wichtige Informationen über die Zinsentwicklung in anderen Ländern. Dies deutet auf die Koordination der Geld- und Wechselkurspolitik in Europa hin.

In einem weiteren Abschnitt wird ein Verfahren entwickelt, um die Markterwartungen über anstehende Änderungen bei den Lombard- und Diskontsätzen zu schätzen. Dieses Verfahren soll es erlauben, zwischen den Marktreaktionen auf erwartete und unerwartete

Notenbankzinsänderungen zu unterscheiden. Entsprechend der Theorie hatte diese - nach diesem Verfahren ermittelte - unvorhergesehene Änderung der Notenbankzinsen einen größeren Einfluß auf die Marktpreise. Das gilt insbesondere bezüglich der Wechselkurse und der Aktienpreise. Allerdings zeigt sich, daß auch erwartete Änderungen der Notenbankzinsen Wirkungen auf die Marktpreise haben. Dies legt den Schluß nahe, daß tatsächliche Notenbankzinsänderungen eine Signalwirkung haben, die durch andere Aktionen der Geldpolitik nicht zu ersetzen sind.

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# Market Reaction to Changes in German Official Interest Rates \*

## I. Introduction

Central banks in most industrialised countries announce official interest rates. These rates are normally those at which the central bank provides or accepts liquidity from commercial banks, either at a standing facility or through periodic auctions. Often the volume of transactions conducted at official interest rates is relatively small, and modern central banks implement monetary policy primarily through open market operations, which offer more flexibility, precision and discretion in the management of bank liquidity and short term market interest rates. Yet official rates are retained, primarily because of their role as signals of the central bank's intentions. Official rates are seen by both market participants and central bank officials as indicators of the central bank's operational target range for money market rates, and thus for interest rates in the economy generally.<sup>1</sup> The signalling effect may be reinforced when, as in Germany, the official Lombard and discount rates are changed relatively infrequently and accompanied by much public discussion, and when due to their role in the operation of standing facilities they serve as more or less tight bounds on short-term money market rates.

The empirical question remains whether central banks are justified in their belief that changes in official rates have a strong signalling effect in addition to that achievable through by public announcements, changes in open market rates, and demonstrated past policy rules. In particular, in a typical market economy monetary policy impulses are transmitted to the economy generally, and thus to broad money growth and inflation, in large part through changes in longer term interest rates and associated changes in expected inflation and real interest rates over the medium term. Therefore one may wish to evaluate the reaction of longer term market-determined interest rates to changes in the very short

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\* I should like to thank H. Herrmann, O. Issing, J. Reckwert, S. Schich, K.-H. Tödter and participants at a seminar at the Deutsche Bundesbank for their helpful comments. All views expressed and all remaining errors are my own.

<sup>1</sup> For clarity, the term, 'official rates' will be reserved here for the rates announced from time to time by the central bank, specifically those on standing facilities, as distinct from the rates prevailing in open market operations, which may nonetheless have an 'official' character.

term rates controlled by the authorities. Changes in official rates could affect other financial market prices, such as share indexes and exchange rates, which may play a role in the transmission process or otherwise be of concern to the authorities. Further one may ask what quantifiable factors affect the strength and interpretation of the signal. Since many central banks, including the Bundesbank, maintain two official rates to serve effectively as the upper and lower bounds on certain money market rates, one may also ask whether market reactions to changes in the two bounds are similar, and whether the reaction to coordinated changes is especially great. The effect of changes in the official interest rates may be compared to that of changes in the rate determined through open market operations. Indeed, the open market repurchase rate is often termed in Germany the "dritte Leitzinsatz", the third leading or indicator rate.

However, there are strong incentives for participants in financial markets to anticipate economic developments in general and central bank actions in particular. It follows that changes in market rates may largely reflect changes in expectations, based presumably on new information (the argument applies *a fortiori* to exchange rates and share prices). Under rational expectations and on condition that the central bank has a stable objective function and no informational advantage, changes in official rates will be fully anticipated and the reaction of market rates to their implementation will be minimal. Central banks indeed often facilitate such anticipation by providing press releases, periodicals, etc. explaining the policy stance, and by leading up to changes in official rates with partial adjustments to the rates determined in open market operations. A change in official rates that comes as a 'surprise' and signals an enduring shift in the level of interest rates will have an especially strong effect. Thus, 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, or at least of whether the central bank can send different signals depending on the degree to which forewarning has been given of the change.

These considerations have motivated a number of studies of the impact effect of official rate changes by the U.S. Federal Reserve (Lombra and Torto, 1977, Roley and Troll, 1984, Smirlock 1985, Thornton, 1986 and 1994, Cook and Hahn, 1988 and 1989, May, 1992, Radecki and Reinhart, 1994, Garfinkel and Thornton, 1995), the Bank of England (Dale, 1993), and the Bank of Canada (Paquet and Pérez, 1995). Normally in these studies changes in money market rates on the days surrounding a change in an official rate are regressed on that change, possibly with allowance made for other factors that might have come into play such as the central bank's published explanations of its actions. The effects of the anticipated and unanticipated components of the change are generally not



distinguished explicitly.<sup>2</sup> Except for Paquet and Pérez, the studies cited do not examine market reaction to high frequency open market operations. Some general conclusions reached are that changes in official rates in these countries did affect market rates, but to a limited degree that declines along the term structure; that the magnitude of the effects depended importantly on the central bank's operating rule and in particular on the weight it was believed to attach to smoothing interest rates; and that the market could rapidly but not immediately distinguish between 'technical,' corrective adjustments and shifts in the policy stance. Some of these results may be special to the U.S. and Great Britain with their particular set of instruments and financial market institutions, and histories of relatively volatile interest rates.

This study is believed to be the first to apply this approach to evaluating monetary policy instruments in Germany.<sup>3</sup> The effectiveness of the Bundesbank's various monetary policy instruments may be of wider relevance if they become the model for those used by the planned European Central Bank. The reaction of various interest rates, implied forward rates, exchange rates, and share prices to both changes in the official Lombard and discount rates and changes in the repurchase rate will be examined. This study also develops a technique to separate anticipated and unanticipated changes in official rates and estimate their different effects.

The Deutsche Bundesbank announces Lombard and discount rates.<sup>4</sup> The Lombard rate is that at which commercial banks can obtain liquidity at short notice by pledging Government paper and bills of exchange ("Wechsel"). Typically the Lombard facility is used at the end of the month to make up any aggregate shortfall in required reserve. The Lombard rate serves as an approximate upper bound on very short term money market rates. The discount rate is that at which commercial banks can rediscount securities at the Bundesbank for three months; this rate is intentionally kept below prevailing market rates

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<sup>2</sup> Changes in the U.S. discount rate that are deemed 'technical' on the basis of the Federal Reserve Board's explanations of its actions are interpreted by Smirlock and Yawitz as having been anticipated by market participants. They and Roley and Troll estimate simple equations predicting changes in the U.S. discount rate, but do not take into account the truncated nature of the sample and achieve very low explanatory power.

<sup>3</sup> Nautz, 1995, looks just at the reaction of the overnight rate to changes in the repurchase rate. There have been studies using monthly data of the effect of official rate changes on retail lending and deposit rates (for example Deutsche Bundesbank, 1991, and, for an international comparison, Borio and Fritz, 1995, and Cottarelli and Kouralis, 1994).

<sup>4</sup> In the past the Bundesbank operated various other, specialised facilities, but the rates offered on them were not generally regarded as indicative of the policy stance (for details see Deutsche Bundesbank, 1995).

and access is subject to ceilings. The spread between the Lombard and discount rates varies but is typically about two percentage points. These official rates are determined by the Bundesbank Council in its morning meetings every other Thursday, with any change being announced that afternoon or early the next morning.<sup>5</sup> Changes have tended to be rare (averaging two or three per year), with long periods of no change being interspersed with series of small changes all in one direction.

The Bundesbank also conducts weekly repurchase operations ("Pensionsgeschäfte"), which since 1985 have been the main instrument for the implementation of monetary policy. Through these operations commercial banks obtain liquidity for two weeks on the basis of securities. Allocation is determined either through an interest rate tender or a quantity tender. The former are conducted as discriminatory price ("American") auctions and multiple bids are allowed, but the quantity allocated is not pre-announced, whereas in the latter the Bundesbank announces the rate in advance.<sup>6</sup> Repurchase operations are normally announced on Tuesdays mornings, commercial banks have until late afternoon to submit bids, and the results are released mid-morning Wednesday. Typically the Bundesbank alternates only infrequently between rate and quantity tenders, and the interest rate pre-announced at quantity tenders tends to be constant for extended periods.<sup>7</sup>

The remainder of the paper examines how market prices responded to the Bundesbank's actions in raising or lowering its official Lombard and discount rates, and its variation of the rate obtained in repurchase operations. Section II explains the methodology and data in more detail. The total response to changes in official rates are reported in Sections III, and in Section IV the anticipated and unanticipated components of the changes are estimated and their separate effects assessed. The market response to changes in the repurchase rate is considered in Section V. Section VI concludes.

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<sup>5</sup> 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.

<sup>6</sup> There have been a number of minor variations in repurchase operations since 1985, with the general tendency towards shorter maturities and more frequent operations. On occasion uniform price ("Dutch") auction procedures with an announced minimum rate have been used (see Deutsche Bundesbank, 1995).

<sup>7</sup> In addition the Bundesbank can organise an *ad hoc* "Schnelltender" at short notice if it wishes to provide banks with liquidity for a few days to meet an unexpected disturbance, and has on occasion issued securities to absorb liquidity.

## II. Model specification and data

The aim is to assess the market reaction to changes in the official Lombard and discount rates, and the repurchase rate. Yet the hypothesis that financial prices are influenced by official rates, combined with some version of the expectations theory, suggests that the 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. The estimation procedure has to take into account this sensitivity to informational events in order to isolate the signalling effect of a change in official interest rates from the impact of other 'news'.<sup>8</sup> One must also recognise the possibility that the central bank's decision to adjust official rates will be determined in part by the same external factors that influence market rates (say, recent data on inflation trends). These considerations suggest that attention should concentrate on the change in market rates around the date of changes in official rates. In particular, the basic regression specification will take the form

$$(r_{\tau'} - r_{\tau}) = b_0 + b_1(s_{\tau+1} - s_{\tau}) + \varepsilon_{\tau'}, \quad (1)$$

where  $r_{\tau}$  is the logarithm of a market interest rate (or exchange rate or stock price index) on day  $\tau$  and  $r_{\tau'}$  is its level on another date  $\tau'$ ,  $s_{\tau}$  is the logarithm of the official interest rate or the repurchase rate, and  $\varepsilon_{\tau'}$  is an error term.<sup>9</sup> The explanatory variable in most reported regressions is based on the average of the discount and Lombard rates, or, in Section V, the cut-off rate obtained in the current repurchase operation (whether a rate or a quantity

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<sup>8</sup> Consider a simple version of the expectations theory, whereby the interest rate  $r_{M,t}$  for maturity  $M$  at time  $t$  equals the average of expected spot interest rates between  $t$  and  $t+M-1$  conditional on available information  $\Omega_t$ :

$$r_{M,t} = \frac{1}{M} \sum_{i=0}^{M-1} E(r_{1,t+i} | \Omega_t).$$

Then the change in the  $M$ -period rate from  $t-1$  to  $t$  will equal  $(1/M)$  multiplied by the overall realised change in the spot rate caused, say, by a change in the official rate, and  $(M-1)/M$  multiplied by the change in expectations. The more permanent the change in the spot rate, the larger the reaction of the longer term rate.

<sup>9</sup> This is similar to the specification used in the literature cited above.

tender).<sup>10</sup> One would expect  $b_0 = 0$ . The null hypothesis to be tested is whether  $b_1 = 0$ , that is, whether market rates are unaffected by changes in central bank rates.<sup>11</sup>

The somewhat unusual specification of logarithms of interest rates was chosen in part to respect the restriction that interest rates cannot become negative and the fact that an interest rate change from, say, 3 to 3.5 percent ought to be much more important for the economy at large than one from 8 to 8.5, and in part to facilitate comparison with results in some of the studies cited above.<sup>12</sup> The qualitative results do not differ in important ways if a linear specification is used, but the fit can then be improved significantly by the inclusion of quadratic terms.

Date 't' denotes a time immediately before a change in the official or repurchase rates. Estimates were performed for  $\tau$  lying between  $t-2$  and  $t+2$ ; thus, under this specification only the reactions of market rates on dates surrounding realised changes in central bank rates are examined. The immediate reaction of market rates is given by the change from  $t$  to  $t+1$ . For  $\tau < t$  the equation is meant to capture the effect of shifting expectations as information is released in the days prior to a change in central bank rates. For  $\tau > t$  the equation is meant to capture the effect of learning by market participants as they reflect on the Bundesbank's actions and pronouncements so as to assess the likely persistence of the change. The movement of market prices from one day to the next may contain a good deal of extraneous variation; a clearer impression of the total market reaction to a change in official rates, which may be of primary concern to policymakers, might be obtained by considering the total response from several days before to several days after the event.

For  $\tau \geq t$  the right-hand-side variable is certainly pre-determined, so estimation can proceed using straightforward means. Due to the timing of decision making and data recording, changes in the Lombard and discount rate are also effectively pre-determined in relation to the change in market rates from  $t-1$  to  $t$ . Moreover it seems implausible that the Bundesbank Council is influenced by movements in market rates in the day or two before

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<sup>10</sup> An alternative to the average of the changes in the Lombard and discount rates would be that average when the rates were moved together, the change in the Lombard rate when it alone was changed, and likewise the change in the discount rate when it alone was changed. Estimation results did not differ qualitatively when this alternative explanatory variable was used.

<sup>11</sup> Strictly speaking, specification (1) is only appropriate if the interest rate follows a random walk. However, any 'mean-revision' process should plausibly have a negligible effect on daily rate changes, and the estimate of  $b_1$  will be unbiased if the change in official rates comes as an orthogonal 'surprise'.

<sup>12</sup> The absolute level of interest rates and spreads may be of primary importance to financial market participants such as commercial banks.

deciding on a change the Lombard or discount rates that is meant to signal medium term intentions and can normally be effected only every two weeks. Therefore it will be assumed that the changes in official rates are independent of the error term for all  $\tau \geq t-2$ . With regard to the repurchase rate, the Bundesbank enjoys great flexibility in the conduct of these operations, and has available other instruments to deal with exceptional interest rate movements (i.e. the "Schnelltender"). Therefore it will be (provisionally) assumed that any feedback from movements in market rates from  $t-2$  onwards to the announced repurchase rate in quantity tenders or the cut-off rate in rate tenders can be neglected.<sup>13</sup>

Various factors might be thought to influence the reaction of market rates to changes in official rates and could be captured in an extended specification:

- Changes in the discount and Lombard rates might send different signals, and the coordinated use of policy instruments and their relative levels might be interpreted as being of special importance;
- likewise one may wish to estimate whether the signal broadcast by repurchase operations depends on the type of tender used or on whether the Bundesbank has switched tender type;
- official rates tend to be changed in 'runs' of small changes fairly close together, so changes in official rates after a prolonged period of stability or which otherwise may represent the start of a new policy direction may have an especially large impact: may have an especially large impact. The lagged change in official rates or rates on repurchase operations may be significant if market participants wait for changes to be confirmed by repetition before adjusting expectations fully;
- large changes may convey a stronger signal, or the central bank's decision to move official rates might be regarded as significant independent of the magnitudes involved, so possible non-linearities should be investigated. Increases and decreases in official rates could have different effects.

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<sup>13</sup> However, the maximum and average rates at which the repurchase operations are conducted are determined by the bids of the commercial banks, and so are likely to be heavily influenced by current market rates. Therefore only the cut-off rate will be considered.

- since the Bundesbank tends to lead up to changes in the Lombard or discount rate with changes in the repurchase rate, markets may react strongly when the repurchase rate approaches one or other bound of the interest rate corridor.

Daily data were taken from the Bundesbank's own database on Lombard and discount rates; Frankfurt money market rates for 1 day and 1, 3, 6, and 12 month maturity interbank loans; the exchange rate of the Deutschemark against the U.S. dollar, Japanese yen, and most European currencies; and the Dax share price index, from the January 2 1975 through January 2 1996 or as far back as available. In addition daily data from January 1985 onwards was obtained on rates on repurchase operations (differentiated between rate and quantity tenders); the term structure of yields on Government securities, as calculated by the Bundesbank for maturities of 24, 36, 60, 84 and 120 months; rates from the BIS on three month Euro-currency deposits for the U.S. dollar, Japanese yen and most European currencies; and Euro-DM deposits with maturities of 1 day and 1, 3, 6, 12, and 24 months as far back as they were available. The government securities yields are constructed series, with properties dependent in part on the method used in their construction, in particular assumptions about the form of the yield curve and the treatment of coupons; results based on these series therefore need to be treated with caution. Figure 1 shows the evolution of official rates and one typical money market rate since 1985. Lastly, the exact dates of Bundesbank Council meetings (that is, the occasions when official rates might be changed) since 1985 were obtained.

Data are generally recorded at 1 p.m. in Frankfurt.<sup>14</sup> 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.

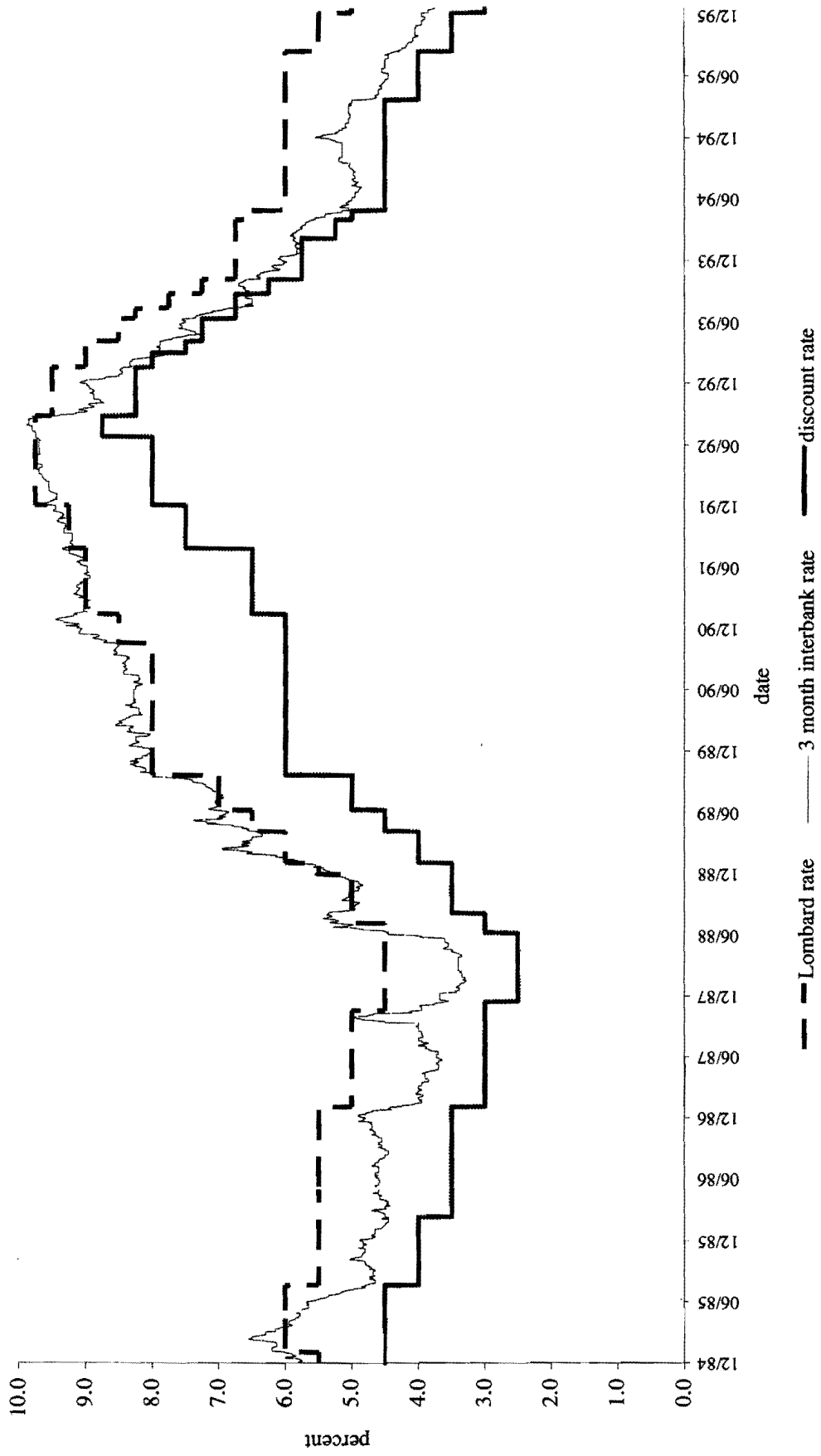
Estimation and testing using these data is complicated by a number of factors.<sup>15</sup> First, the Bundesbank changed its approach to using its instruments in 1985, since when repurchase operations have been emphasised. Coincidentally, a number of important data series were available only from around that time. Second, changes in official rates are rare events, with only twenty two between 1975 and 1984 and thirty three during 1985-1995. With such a

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<sup>14</sup> The only exceptions are the Dax index, which is recorded around 2.00 p.m., and the Euro-currency deposit rates, which are measured at 10.00 a.m. by the BIS.

<sup>15</sup> All estimation was performed using TSP Version 4.2.

**Figure 1.**  
**Official interest rates and interbank rates, 1985-1995.**



small sample one cannot rely on asymptotic results or include a large number of explanatory variables, and tests may lack power. Changes in the repurchase rate from one quantity tenders to the next are also rare, with only eleven examples since 1985.<sup>16</sup> Third, there appears to be multicollinearity between several of the possible explanatory variables, primarily because changes in official rates tend to be of equal magnitude (normally 1/4 or 1/2 percentage point) and official rates are often moved together, so the power of tests may be further reduced. In addition, several series of residuals seem to contain outliers or displayed heteroskedasticity or excess kurtosis.

In response to these difficulties the sample was split in 1985. The OLS results were supplemented with a sign test, which should be relatively robust. The sign test was carried out by assigning a counting variable a value of unity if the dependent variable was of the same sign as the explanatory variable, zero if they were of opposite signs, and 1/2 if either was zero. The sum of the counting variable should have an approximately binomial distribution under the null hypothesis that the variables are unrelated; the binomial approaches the normal distribution fairly rapidly as the size of the sample increases. The reported sign test statistics are normalised to have mean zero and variance 1, so they may be regarded as following an approximately standard normal distribution. Furthermore the regressions using the realised changes in the Lombard and discount rates were reestimated including a number of dummies to remove the effect of outliers. In the regressions based on anticipated and unanticipated changes in official rates and those on repurchase rates, where a large number of degrees of freedom were available, the estimated standard errors were corrected for heteroskedasticity using the procedure from White (1980).

### **III. Market reaction to changes in the Lombard and discount rates**

Table 1 presents OLS estimates of the simple specification given by equation (1) for the period 1975-1985 relating the log change in market interest rates to the average of the log changes in the Lombard and discount rates, on the days surrounding a change in official rates and summed from two days before to three afterwards.<sup>17</sup>

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<sup>16</sup> There were, however, 472 repurchase tenders during this period and 266 Bundesbank Council meetings for which data are available.

<sup>17</sup> The constant term was always insignificantly different from zero and is not reported to save space.



**Table 1.**  
**Reaction of market rates to changes in official rates, 1975-1984.**

Dependent variable	Change from t-1 to t			Change from t to t+1			Change from t+1 to t+2			Change from t-2 to t+3		
	Coefficient estimate (t statistic)	R <sup>2</sup> (%)	sign test	Coefficient estimate (t statistic)	R <sup>2</sup> (%)	sign test	Coefficient estimate (t statistic)	R <sup>2</sup> (%)	sign test	Coefficient estimate (t statistic)	R <sup>2</sup> (%)	sign test
<b>Interbank rates</b>												
<b>1 day</b>	0.0027 (0.0402)	0.000	-1.877	1.1103 (4.3149) **	48.211	4.379	0.0303 (0.5876)	1.697	-2.294	0.9979 (3.0330) **	21.505	3.128
<b>1 month</b>	0.1700 (1.2674)	7.434	-1.706	0.4212 (5.9966) **	34.260	3.128	0.0139 (0.4658)	1.073	-1.877	0.4625 (4.2659) **	47.641	2.668
<b>3 months</b>	0.0336 (1.8665) +	14.834	-3.545	0.3472 (3.9489) **	43.811	2.294	0.0148 (0.6590)	2.215	-2.294	0.4103 (4.6271) **	51.704	3.1277
<b>Exchange rates</b>												
<b>USD</b>	-0.0066 (-0.8012)	0.031	-0.209	0.0052 (0.5467)	1.473	-0.626	0.0032 (0.3008)	0.451	0.209	0.0069 (0.2846)	0.403	-0.626
<b>GBP</b>	-0.0093 (-1.3240)	8.059	-1.043	0.0135 (2.6570) *	26.093	-0.209	0.0107 (1.2326)	7.060	0.209	0.0097 (0.4415)	0.097	-0.626
<b>FRF</b>	0.0007 (0.0938)	0.044	-1.043	0.0057 (2.0776) +	17.751	-0.626	-0.0050 (-0.1361)	0.097	-0.209	0.0341 (1.5304)	12.484	-0.209
<b>JPY</b>	0.0010 (0.1771)	0.157	-0.209	-0.0024 (-0.2706)	0.365	-1.460	0.0184 (2.0393) +	17.214	0.209	-0.0002 (-0.0091)	0.000	0.209
<b>DAX index</b>	-0.0062 (-0.6063)	1.805	0.626	-0.0108 (-0.7040)	2.418	-1.043	-0.0022 (-0.1292)	0.023	0.626	-0.0276 (-0.6621)	2.145	-0.626

OLS estimation of  $(r(\tau)-r(\tau)) = b_0 + b_1(s(t+1)-s(t)) + \varepsilon(\tau)$ . Estimated coefficient  $b_1$  and t-statistic in parentheses, percentage  $R^2$  and sign test statistic reported. Number of observations = 22. Here and in subsequent tables a cross next to a t statistic denotes significance at the 10 percent level at least, an asterisk denotes at least 5 percent significance, and two asterisks at least 1 percent significance.

The results for this period before emphasis was placed on repurchase operations show a relatively large effect of changes in official interest rates on market prices. The estimated coefficients on money market interest rates differ significantly from zero and are always positive. The elasticity of the reaction of the overnight rate is near unity because institutional features tied that rate very closely to the Lombard rate (see Bundesbank, 1995). The magnitude of the reaction declines steeply with increasing maturity but remains sizeable (at least for the limited range for which data are available). Little anticipation of changes in the preceding days was found, nor gradual adjustment afterwards. During this earlier period changes in official rates also affected share prices negatively, as one would expect, but the estimated coefficients are insignificantly different from zero. The effect on

exchange rates was more ambiguous, with significant positive coefficients in some instances but little cumulative impact; the sign tests suggest that there was no relationship.

Table 2 below reports results for the second period starting in 1985. The reaction of market interest rates remains positive and is economically significant, but much smaller than in the earlier period; the estimated elasticity is at most 25 percent. Presumably market and official rates do not get out of line with each other because three quarters of the adjustment is anticipated well in advance or achieved later (perhaps because of the Bundesbank's repurchase rate policy). The maximum effect is seen on the day of change itself. Money market rates move significantly between  $t-1$  and  $t$  in advance of changes in official rates, presumably because economic agents can use publicly available data and Bundesbank statements to discern when a shift is imminent. However, there is little further movement afterwards, indicating perhaps that a change in official rates gives an unambiguous signal that does not need to be supplemented with later verbal explanations.<sup>18</sup> It would seem that the shift in emphasis to repurchase operations in 1985 greatly reduced the impact effect of realised changes in official rates, first because the tight institutional link between the Lombard rate and the overnight money rate was severed, and second perhaps because the Bundesbank's management of its repurchase rate has reduced the 'surprise' element.<sup>19</sup>

As illustrated in Figure 2, the effect is strongest for overnight and one month money market interest rates, but declines only slightly as maturity increases up to 12 months.<sup>20</sup> Thereafter the estimated effect declines markedly, with only a very small elasticity for maturities beyond three years. These results are corroborated by the sign test statistics and by the results for rates on Euro-DM deposits with maturities up to two years, which are available upon request.

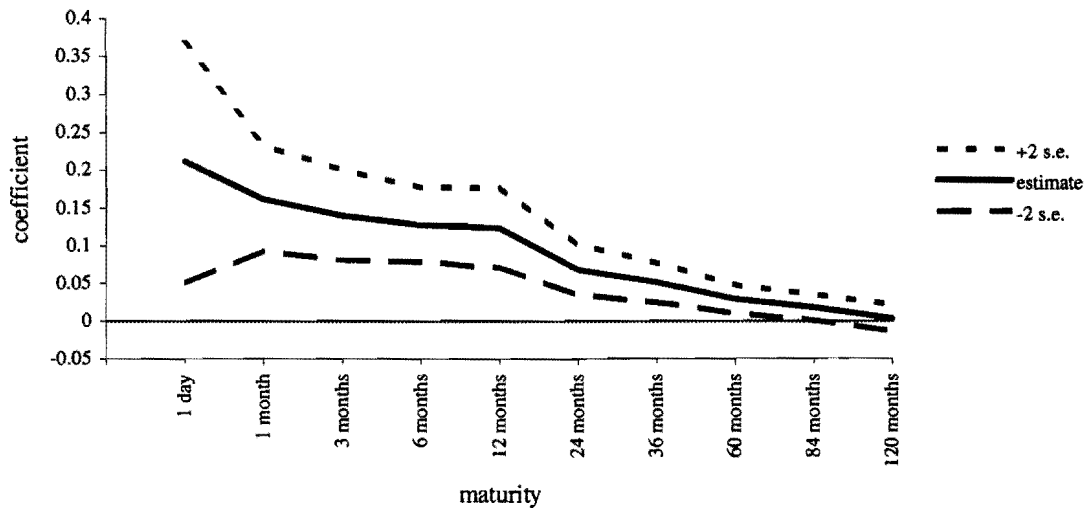
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<sup>18</sup> The effect on from day  $t-2$  to  $t-1$  and from  $t+2$  to  $t+3$  were usually insignificantly different from zero.

<sup>19</sup> As a measure of the robustness of the procedure used here, the regressions were repeated using changes in market rates on all working days during the sample period and on days surrounding Bundesbank Council meetings. The estimated coefficients were never statistically significantly different and were often almost unaffected; if the mean change in market interest rates were exactly zero, the estimates would be identical to those presented here.

<sup>20</sup> The regressions for the overnight rate include four dummy variables to filter out the effect of outliers. When these dummies are excluded the estimated coefficient becomes small and insignificant. The estimated coefficients on the dummies remained highly significant when other candidate explanatory variables were included in the regression (see below). Inclusion of dummies for outliers has little effect on the estimated coefficients for other maturities.

**Figure 2.**  
**Estimated reaction from t to t+1 to changes in average official rates, 1985-1995**



The results for implied forward rates clarify the relationship between the time horizon and the effect of changes in official rates.<sup>21</sup> The estimated coefficient is highest for the 1 month/3 months forward rate implicit in interbank money market rates but remains significantly positive and stable for forward rates up to one year ahead. The response of implied forward bond yields declines rapidly with maturity, and from the third year ahead the reaction becomes negative, in one instance even marginally significantly so. The implication could be that, when the Bundesbank raises rates, it not only induces expectations of higher interest rates in the near future but also convince market participants that rates will eventually fall to below their initial level, either because inflation will be lower or because real interest rates will decline.

Despite an extensive specification search few other variables were found to have significant and consistent additional explanatory power. To save space results are not reported, but they are available from the author. The logarithm of the number of days since the last change in official rates, multiplied by the sign of the change, seemed to explain the

<sup>21</sup> The implicit forward rate  ${}_t f_{t2}$  from period  $t1$  to  $t2$  as used here is defined by

$$1 + {}_t f_{t2} = (1 + r_{t2})^{t2/(t2-t1)} (1 + r_{t1})^{-t1/(t2-t1)}$$

where  $r_{t1}$  and  $r_{t2}$  are the yields currently available on securities with those maturities. The calculated rates may diverge from 'true' forward rates due to the treatment of coupons in the estimation of yields.

**Table 2. Reaction of market rates to changes in official rates, 1985-1995.**

Dependent variable	Change from t-1 to t			Change from t to t+1			Change from t+1 to t+2			Change from t-2 to t+3		
	Coefficient estimate (t statistic)	R <sup>2</sup> (%)	sign test	Coefficient estimate (t statistic)	R <sup>2</sup> (%)	sign test	Coefficient estimate (t statistic)	R <sup>2</sup> (%)	sign test	Coefficient estimate (t statistic)	R <sup>2</sup> (%)	sign test
<b>Spot interbank rates</b>												
1 day †	0.1158 (1.9392) +	20.895	1.393	0.2107 (2.6544) *	52.867	1.567	-0.0529 (-1.2573)	92.976	-0.696	0.2530 (2.0532) *	58.570	2.089
1 month	0.0561 (2.6657) *	18.648	2.263	0.1622 (4.6593) **	41.187	2.785	-0.0101 (-0.7274)	1.678	0.696	0.2480 (4.7596) **	42.222	3.482
3 months	0.0370 (1.8438) +	9.883	1.915	0.1408 (4.7585) **	42.211	3.656	0.0126 (0.8606)	2.333	0.870	0.2221 (4.5676) **	40.227	3.308
6 months	0.0379 (1.7772) +	9.247	1.393	0.1282 (5.2092) **	46.678	3.482	0.0055 (0.4817)	0.743	1.219	0.2071 (4.1200) **	35.382	3.482
12 months	0.0349 (1.5989)	7.618	1.393	0.1248 (4.6909) **	41.513	3.308	-0.0001 (-0.0091)	0.000	0.174	0.2036 (3.9153) *	33.088	3.830
<b>Spot government bond rates</b>												
24 months	0.0249 (1.8918) +	10.350	2.089	0.0684 (4.0522) **	34.627	2.959	0.0224 (1.0408)	3.376	1.044	0.1328 (2.6930) *	18.959	2.785
36 months	0.0183 (1.4215)	6.119	1.045	0.0512 (3.8702) **	32.576	2.785	0.0152 (0.8221)	2.134	0.348	0.0883 (1.9267) +	10.695	1.915
60 months	0.0086 (0.6830)	1.483	0.000	0.0289 (3.1253) **	23.959	1.393	0.0111 (0.6738)	1.444	0.696	0.0322 (0.7563)	1.812	0.696
84 months	0.0058 (0.4868)	0.759	-0.522	0.0179 (2.1095) *	12.553	0.174	0.0060 (0.3769)	0.456	0.522	0.0058 (0.1397)	0.063	-0.174
120 months	0.0040 (0.3629)	0.423	-0.522	0.0036 (0.4021)	0.519	-1.393	0.0091 (0.5903)	1.112	0.348	-0.0119 (-0.3014)	0.292	-0.696
<b>Forward interbank rates</b>												
1f3	0.0276 (1.1553)	4.125	0.870	0.1302 (4.0846) **	34.988	2.785	0.0234 (1.3233)	5.347	1.219	0.2094 (3.9201) **	33.142	3.200
3f6	0.0389 (1.6252)	7.851	2.600	0.1157 (3.8614) **	32.477	3.307	-0.0013 (-0.0893)	0.026	0.522	0.1924 (3.3312) **	26.361	3.482
6f12	0.0324 (1.3290)	5.391	1.044	0.1208 (3.5573) **	28.988	2.785	-0.0026 (-0.0055)	0.227	0.522	0.2003 (3.4386) **	27.611	3.656
<b>Forward government bond rates</b>												
24f36	0.0067 (0.4840)	0.750	0.174	0.0213 (2.1100) *	12.558	1.741	0.0017 (0.1027)	0.034	-0.174	0.0091 (0.2019)	0.131	0.174
36f60	-0.0038 (-0.2880)	0.267	-1.044	-0.0016 (-0.1536)	0.076	-1.915	0.0062 (0.3934)	0.497	0.870	-0.0435 (-1.0405)	3.371	-1.219
60f84	-0.0005 (-0.0461)	0.000	-1.219	-0.0070 (-0.5941)	1.126	-1.567	-0.0065 (-0.4040)	0.524	0.174	-0.0538 (-1.2574)	4.853	-1.567
84f120	0.0004 (0.0389)	0.000	-0.522	-0.0264 (-1.7970) +	9.434	-2.611	0.0156 (0.9876)	3.050	-0.174	-0.0503 (-1.3201)	5.322	-3.482

**Table 2 (continued). Reaction of market rates to changes in official rates, 1985-1995.**

Dependent variable	Change from t-1 to t			Change from t to t+1			Change from t+1 to t+2			Change from t-2 to t+3		
	Coefficient estimate (t statistic)	R <sup>2</sup> (%)	sign test	Coefficient estimate (t statistic)	R <sup>2</sup> (%)	sign test	Coefficient estimate (t statistic)	R <sup>2</sup> (%)	sign test	Coefficient estimate (t statistic)	R <sup>2</sup> (%)	sign test
<b>Exchange rates</b>												
<b>BEF</b>	0.0010 (0.5072)	0.823	0.174	-0.0071 (-0.7941)	1.994	0.000	0.0031 (0.3592)	0.415	0.174	-0.0026 (-0.2025)	.132	-0.174
<b>FRF</b>	-0.0054 (-1.9058) +	10.487	-1.915	-0.0013 (-0.1925)	0.119	0.870	0.0038 (0.3826)	0.470	0.174	-0.0023 (-0.1744)	0.098	-0.696
<b>GBP</b>	-0.0144 (-1.5569)	7.252	-2.437	-0.0056 (-0.5204)	0.866	-1.219	-0.0182 (-1.4261)	6.157	-0.348	-0.0418 (-1.3232)	5.346	-0.522
<b>ITL</b>	-0.0029 (-0.1874)	0.113	-1.393	0.0021 (0.1716)	0.095	0.770	0.0131 (1.1057)	3.794	-0.174	0.0187 (0.4330)	.601	-0.522
<b>JPY</b>	-0.0215 (-1.4570)	6.409	-0.522	-0.0058 (-0.3153)	0.320	-0.348	0.0105 (0.5466)	0.955	0.174	-0.0262 (-0.6872)	1.501	-0.174
<b>USD</b>	0.0004 (0.0229)	0.002	0.174	0.0040 (0.2170)	0.152	1.219	-0.0068 (-0.2760)	0.245	-0.522	-0.0027 (-0.0580)	0.011	1.218
<b>Three-month Euro deposit rates</b>												
<b>BEF</b>	0.0640 (1.5695)	7.361	2.437	0.1778 (2.0670) *	12.113	2.785	0.0243 (0.6623)	1.395	0.522	0.3009 (2.5527) *	17.369	3.133
<b>DEM</b>	0.0603 (1.7721) +	9.198	1.044	0.0717 (1.6260)	7.859	1.393	-0.0187 (-0.6206)	1.227	-0.348	0.1498 (2.4022) *	15.693	3.482
<b>FRF</b>	0.0920 (1.9325) *	10.752	1.567	0.1802 (2.6116) *	18.034	2.959	0.0376 (0.4516)	0.654	0.000	0.3269 (3.8752) **	32.634	3.656
<b>GBP</b>	0.0188 (0.5470)	0.956	0.522	0.0982 (3.9846) **	33.870	2.785	-0.0011 (-0.0259)	0.002	0.000	0.1207 (2.2545) *	14.087	1.219
<b>ITL</b>	0.0828 (1.4605)	6.438	1.915	0.0992 (2.0582) *	12.022	2.785	0.0634 (1.5346)	7.060	0.522	0.2570 (3.0154) **	22.679	3.830
<b>JPY</b>	0.0948 (2.1485) *	12.961	0.870	0.0490 (0.7727)	1.890	-0.174	0.0489 (0.9432)	2.790	0.522	0.2305 (2.3250) *	14.848	0.174
<b>USD</b>	0.0121 (0.5560)	0.987	0.696	0.0090 (0.3372)	0.366	0.000	-0.0650 (-1.7603) +	9.087	-0.870	-0.0718 (-1.2695)	4.942	-0.348
<b>Dax index</b>	0.0041 (0.2023)	0.132	1.567	0.0061 (0.2176)	0.344	-0.174	-0.0075 (-0.1501)	0.073	1.567	0.0826 (0.8912)	2.498	1.567

OLS estimation of  $(r(\tau) - r(\tau)) = b_0 + b_1(s(t+1) - s(t)) + \varepsilon(\tau)$ . Estimated coefficient  $b_1$  and t-statistic in parentheses, percentage  $R^2$ , and sign test statistic reported. Number of observations = 33.

† Dummies for 6/3/86, 30/6/88, 28/7/88 and 25/8/88 included in estimated equation.

response of some market rates slightly better than the change itself, but the two variables are highly collinear. The response of market rates to negative changes in official rates seems to have been proportionately greater than that to positive changes on day  $t$  itself, but this tendency is not apparent on other days or overall from  $t-2$  to  $t+3$ .

No significant effects on exchange rates were found, although for the pound Sterling, the French and Belgian francs and the Japanese yen the signs of the coefficients were predominantly negative, that is, 'correct', and the sign test results suggest the presence of some relationship (especially an anticipatory movement in the rate between  $t-1$  and  $t$ ). The negligible reaction of exchange rates can be explained, at least in Europe, by the strong reaction of non-German interest rates to changes in the Bundesbank's official rates. The lower part of Table 2 shows that the rates available on three month Euro deposits denominated in French and Belgian franc, British pound Sterling and Italian lira moved by at least as much as rates on Deutschmark deposits.<sup>22</sup> Similarly strong results were found for rates on Austrian schilling, Danish krone, Spanish peseta, Irish pound and Netherlands guilder Euro deposits, with a somewhat weaker but still significant positive reaction on Danish crown and Swiss franc rates (results available upon request). Presumably the influence on rates in other European countries reflects the strength of policy co-ordination and the chosen exchange rate regime, under which changes in German official rates convey important information about concurrent or imminent changes in official rates throughout the continent.

Perhaps surprisingly, changes in official rates seem to have had no significant effect on share prices, and the coefficients have the 'wrong' sign (one would expect higher interest rates to reduce share prices). Possibly the share price index is too volatile a series for an effect to be extracted from the few observations.

A further question is whether changes in the Lombard and discount rates have different effects and whether a distinct signal is conveyed by simultaneous changes. However, the two official rates are often moved together, so there is limited evidence on which to base an answer.<sup>23</sup> The difficulty caused by this collinearity can be reduced by considering

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<sup>22</sup> The weak reaction of the Deutschmark exchange rates against the yen and the dollar remains to be explained. The sign test statistics confirm the intuition that interest rates in these currencies do not react to changes in German official rates.

<sup>23</sup> The sample period included eight occasions when the discount rate was changed and the Lombard rate left unchanged, and six occasions when the Lombard rate alone was changed. The mean change and mean absolute changes in the two variables are similar, as is the mean time between changes

separately the market reaction to changes in the Lombard rate alone, changes in the discount rate alone, and simultaneous changes. Market rates could react differently to the three sorts of changes in official rates if they convey different signals about the future course of interest rates and monetary policy generally. Formally, the null hypothesis to be tested is  $H_0: b_1 = b_3, b_2 = b_3$  in the equation

$$(r_{\tau'} - r_{\tau}) = b_0 + b_1[\Delta L_t/2 \mid \Delta D_t = 0] + b_2[\Delta D_t/2 \mid \Delta L_t = 0] \\ + b_3[(\Delta L_t + \Delta D_t)/2 \mid \Delta L_t, \Delta D_t \neq 0] + \varepsilon_{\tau'}. \quad (2)$$

The first explanatory variable  $[\Delta L_t/2 \mid \Delta D_t = 0]$  is the logarithmic change in the Lombard rate from day  $t$  to  $t+1$  on occasions when the discount rate was not changed, the second variable  $[\Delta D_t/2 \mid \Delta L_t = 0]$  is the logarithmic change in the discount rate when the Lombard rate was left unchanged, and the third term is the average change in official rates when they moved together. To test the null hypothesis, the modified specification

$$(r_{\tau'} - r_{\tau}) = b_0 + (b_1 - b_3)[\Delta L_t/2 \mid \Delta D_t = 0] + (b_2 - b_3)[\Delta D_t/2 \mid \Delta L_t = 0] \\ + b_3(\Delta L_t + \Delta D_t)/2 + \varepsilon_{\tau'}. \quad (2')$$

was estimated by OLS. Under  $H_0$  the estimated coefficients  $(b_1 - b_3)$  and  $(b_2 - b_3)$ , which capture the differential effect of Lombard and discount rate changes, should be insignificantly different from zero. The results are presented in Table 3, and some estimated coefficients are depicted in Figure 3.

Only the change in the average official interest rate seem to influence market rates on the day of the change itself; the estimated coefficients on the differential reaction to changes in the Lombard and discount rates are insignificantly different from zero. Results for implied forward rates and Euro-DM deposit rates (not reported to save space) were similar. However, Lombard rate changes seem to have a somewhat stronger influence on the days following a change, and, in some instances, on the preceding days. Perhaps the Bundesbank provides relatively little advance warning of changes in the Lombard rate, thus

**Table 3. Reaction of market rates to changes in the Lombard, discount, and average official rates, 1985-1995.**

Dependent variable	Change from t-1 to t				Change from t to t+1			
	Coefficient estimates (t statistics)			R <sup>2</sup> (%)	Coefficient estimates (t statistics)			R <sup>2</sup> (%)
	$\Delta L/2$	$\Delta D/2$	$(\Delta L+\Delta D)/2$		$\Delta L/2$	$\Delta D/2$	$(\Delta L+\Delta D)/2$	
<b>Interbank rates</b>								
1 day †	0.0763 (0.3372)	0.6513 (3.8170) **	0.0580 (1.0972)	50.051	0.4436 (1.2614)	-0.4289 (-1.6167)	0.2222 (2.7049) *	59.940
1 month	-0.0249 (-0.2670)	-0.0590 (-1.0516)	0.0680 (2.7802)	21.697	-0.0027 (-0.0173)	-0.0688 (-0.7344)	0.1745 (4.2705) **	42.269
3 months	0.1830 (2.1790) *	0.0058 (0.1146)	0.0247 (1.1219)	22.598	0.1197 (0.9203)	-0.0553 (-0.7067)	0.1431 (4.1892) **	45.066
6 months	0.2234 (2.5776) *	0.0041 (0.0779)	0.0234 (1.0278)	26.251	0.1574 (1.4808)	-0.0299 (-0.4668)	0.1237 (4.4310) **	51.055
12 months	0.2229 (2.5047) *	-0.0070 (-0.1305)	0.0224 (0.9565)	24.406	0.1297 (1.1186)	-0.0536 (-0.7676)	0.1262 (4.1447) **	45.382
<b>Government bond rates</b>								
24 months	0.0530 (0.9071)	-0.0046 (-0.1316)	0.0224 (1.4612)	12.982	0.0697 (0.9294)	0.0050 (0.1115)	0.0632 (3.2088) **	36.518
36 months	0.0329 (0.5709)	-0.0130 (-0.3754)	0.0186 (1.2278)	7.773	0.0567 (0.9685)	-0.0077 (-0.2193)	0.0490 (3.1868) **	34.922
60 months	0.0170 (0.3010)	-0.0090 (-0.2637)	0.0091 (0.6139)	2.090	0.0213 (0.5215)	-0.0245 (-0.9997)	0.0319 (2.9816) **	27.468
84 months	-0.0100 (-0.1881)	-0.0150 (-0.4682)	0.0090 (0.6453)	1.567	0.0116 (0.3150)	-0.0327 (-1.4812)	0.0229 (2.3763) *	19.302
120 months	-0.0189 (-0.3798)	-0.0071 (-0.2363)	0.0064 (0.4917)	1.046	0.0081 (0.2187)	-0.0499 (-2.2470) *	0.0118 (1.2219)	15.812

OLS estimation of  $(r(\tau)-r(\tau)) = b_0 + b_1[\Delta L/2 | \Delta D=0] + b_2[\Delta D/2 | \Delta L=0] + b_3(\Delta L+\Delta D)/2 + \varepsilon(\tau)$ . Estimated coefficients  $b_1$  and  $b_2$ , t-statistic in parentheses, percentage  $R^2$ , and sign test statistic reported. Number of observations = 33.  
 † Dummies for 6/3/86, 28/7/88 and 30/3/95 included in estimated equation.

increasing the 'surprise' element and the time needed to interpret the event. The cumulative effect over five days suggests that changes in the Lombard rate are especially important in determining money market rates in the three to twelve month range. These result may reflect a tendency for banks to regard Lombard credit as the marginal source of funds and

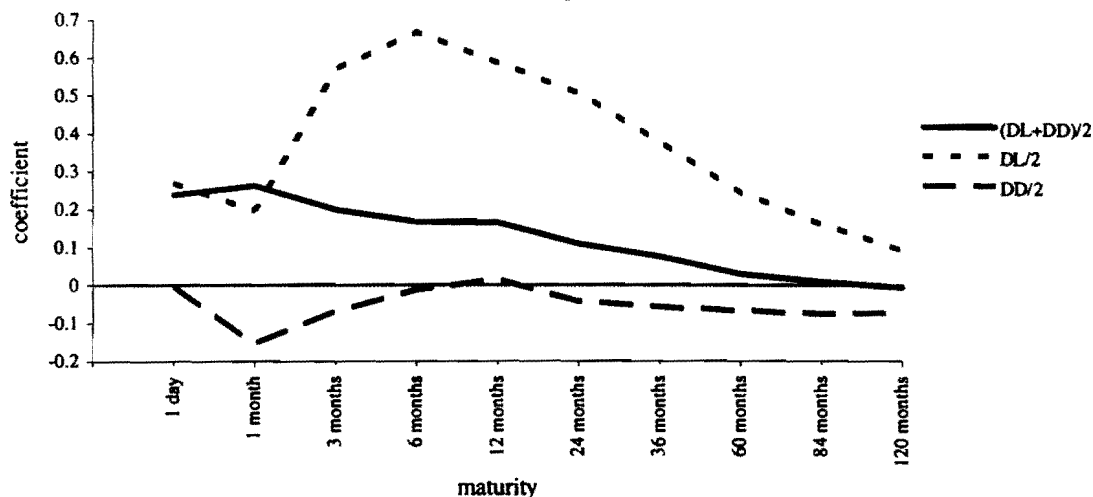


**Table 3 (Continued). Reaction of market rates to changes in the Lombard, discount, and average official rates, 1985-1995.**

Dependent variable	Change from t+1 to t+2				Change from t-2 to t+3			
	Coefficient estimates (t statistics)			R <sup>2</sup> (%)	Coefficient estimates (t statistics)			R <sup>2</sup> (%)
	$\Delta L/2$	$\Delta D/2$	$(\Delta L+\Delta D)/2$		$\Delta L/2$	$\Delta D/2$	$(\Delta L+\Delta D)/2$	
<b>Interbank rates</b>								
<b>1 day †</b>	-0.0401 (-0.2225)	-0.3334 (-2.4550) *	-0.0233 (-0.5530)	94.342	0.2695 (0.4605)	-0.0020 (-0.0044)	0.2387 (1.7460) +	58.920
<b>1 month</b>	0.0863 (1.6340)	-0.0896 (-2.8200) *	0.0003 (0.0227)	30.075	0.1962 (0.8674)	-0.1537 (-1.1288)	0.2628 (4.4236) **	46.415
<b>3 months</b>	0.1482 (2.5439) *	-0.0377 (-1.0744)	0.0101 (0.6591)	24.121	0.5699 (3.0121) **	-0.0681 (-0.5976)	0.1989 (4.0023) **	55.491
<b>6 months</b>	0.0886 (1.8070) +	0.0048 (0.1629)	-0.0008 (-0.0610)	10.791	0.6671 (3.5295) **	-0.0113 (-0.0990)	0.1679 (3.3821) **	55.059
<b>12 months</b>	0.1044 (1.7412) +	0.0093 (0.2565)	-0.0082 (-0.5203)	9.478	0.5853 (2.8186) **	0.0148 (0.1185)	0.1649 (3.0234) **	47.529
<b>Government bond rates</b>								
<b>24 months</b>	0.1995 (2.2395) *	-0.0141 (-0.2636)	0.0125 (0.5354)	18.255	0.5044 (2.5190) *	-0.0417 (-0.3459)	0.1090 (2.0717) *	34.239
<b>36 months</b>	0.1497 (1.9211) +	-0.0246 (-0.5246)	0.0103 (0.5030)	14.613	0.3788 (1.9658) +	-0.0562 (-0.4843)	0.0748 (1.4780)	22.368
<b>60 months</b>	0.1221 (1.7502) +	-0.0277 (-0.6591)	0.0084 (0.4592)	12.853	0.2440 (1.3222)	-0.0667 (-0.6007)	0.0288 (0.5946)	9.060
<b>84 months</b>	0.1103 (1.6353)	-0.0338 (-0.8328)	0.0051 (0.2890)	11.752	0.1626 (0.8837)	-0.0743 (-0.6703)	0.0088 (0.1829)	4.593
<b>120 months</b>	0.1060 (1.6053)	-0.0230 (-0.5778)	0.0066 (0.3803)	10.808	0.0925 (0.5263)	-0.0723 (-0.6834)	-0.0049 (-0.1068)	3.077

therefore as a closer substitute for market investments. However, the discount rate seems to have the greater, negative influence on long term bond rates (including forward rates) and on the exchange rate (not reported to save space), perhaps because discount rate changes are regarded as more permanent.

Figure 3.  
Estimated reaction from t-2 to t+3 to changes in the  
Lombard, discount, and average official rate, 1985-1995.



#### IV. Response to anticipated and unanticipated changes in official rates

There is good reason to suppose that interest rates and other financial asset prices determined in liquid and flexible markets should respond differently to events depending on the degree to which they are anticipated. Events that are not 'news' have already been discounted and are unlikely to have a major impact on prices. Therefore it is worthwhile distinguishing between foreseen and unforeseen changes in official rates. Furthermore, a central bank can decide how much information to give out in advance of a change in official rates; as a policy matter it is useful to know how strongly market rates for different maturities are likely to react depending on the degree of surprise achieved. This differential response may be captured in a regression specified as

$$(r_{\tau} - r_{\tau}) = b_0 + b_1 E((s_{t+1} - s_t) | \Omega_{\tau}) + b_2 UE((s_{t+1} - s_t) | \Omega_{\tau}) + \varepsilon_{\tau}, \quad (3)$$

where  $\Omega_{\tau}$  is the information set available to market participants at time  $\tau$ ,  $E$  is the expectations operator, and  $UE$  is an 'unexpected' operator, such that for some variable  $x_t$ ,  $UE(x_t | \Omega_{\tau}) = x_t - E(x_t | \Omega_{\tau})$ .

Since expectations and surprises are not observed, an instrumental variables technique is used in conjunction with an assumption of rational expectations to estimate this specification. It is possible to extend available econometric techniques to estimate market expectations of the timing and magnitude of changes in official rates, and thus also of the

extent to which the market is surprised by the central bank. Regression with limited dependent variables have received extensive and detailed examination (see Maddala, 1983, for a survey), and these procedures have recently been applied to study a somewhat analogous problem concerning expectations of exchange rate realignments (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 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 dummy variable that equals one if official rates were increased following a Bundesbank Council meeting, minus one if they were decreased, and zero otherwise.<sup>24</sup> Candidate explanatory variables are those known to market participants when forming their expectations, and which can plausibly be interpreted as incorporating market expectations about changes in official rates or elements of central bank behaviour. In particular, the differences between the three month interbank rate and the Lombard rate and the discount rate, and the change in the three month interbank rate since the last Bundesbank Council meeting, all in logarithms, were used as instruments to capture market sentiment concerning the likelihood of an official rate change.<sup>25</sup> Logarithms of the differences were used 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. Official rates are normally changed in a series of small steps all in one direction and spaced a few months apart. Therefore the time in days since the last change was included, in both levels and logarithms, a dummy indicating whether official rates were changed at the last Council meeting, and the logarithm of the last change in the average official interest rate were included as a means to represent this behaviour.<sup>26</sup> Variables observed on time  $t$  were used as instruments for the change from  $t$  to  $t+1$ , where  $t$  indexes the dates of Bundesbank Council meetings; the same variables dated  $t-2$  were used

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<sup>24</sup> Not enough observations of rate changes were available to estimate separate probabilities of Lombard rate, discount rate, and simultaneous increases or decreases.

<sup>25</sup> The one month interbank rate and the repurchase rate were found to be almost equally good instruments.

<sup>26</sup> Some macroeconomic variables, such as price and money supply developments, could also have been used as instruments. It is however difficult to determine to the day when these data became available.

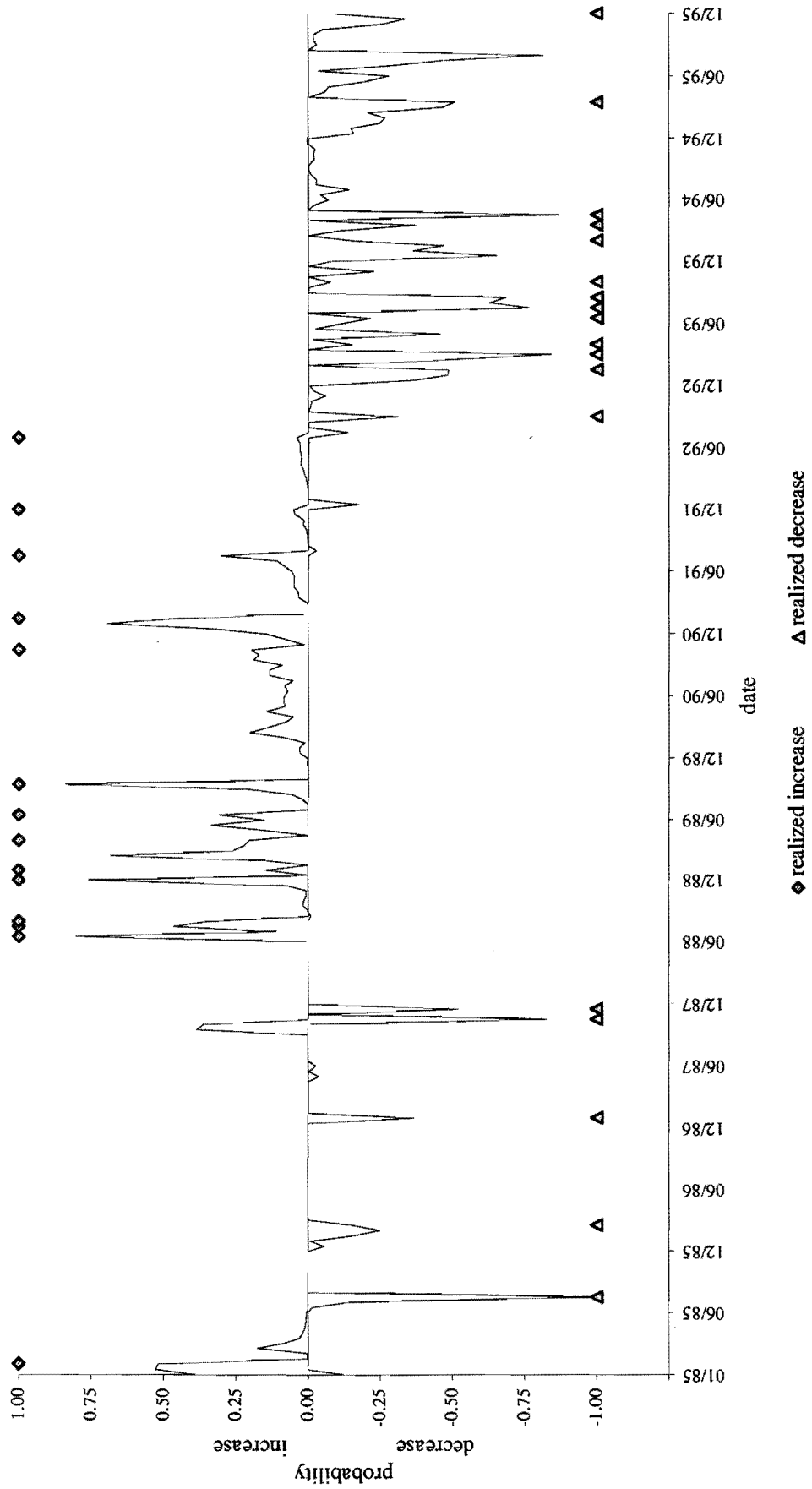
as instruments for the change from  $t-2$  to  $t+3$ . Figure 4 illustrates the estimated probabilities at each date  $t$  of an increase or a decrease in official rates, (the latter shown as a negative number), and occasions when rates were in fact changed; the model seems to fit the data well, with only a few occasions when a rate change came as a complete surprise or when a firmly expected change failed to materialise.

The fitted values from the first stage are treated as the market's assessment of the probability of a forthcoming change in official rates. In the second stage the estimated probabilities are combined with other instruments (with compatible dating) in a linear regression to generate a forecast of the magnitude of the any change. The additional 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. They comprised the current three month and one year interbank rates and the most recent repurchase rate, the level of these variables following the most recent adjustment in official rates, and the three month interbank rate following the most recent Bundesbank Council meeting, all in logarithms; to capture possible non-linearities the change in the levels of the three month and one year interbank rates since the last adjustment in official rates were also included. The fitted value from the second stage regression is taken as a proxy for the market's expectation of movements in official rates, and the unanticipated component is simply the difference between the estimated market expectation and the realised change.

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 (3). Results are reported in Table 4. The dependent variable is either the change in market rates from  $t$  to  $t+1$  (where information at date  $t$  are used in the estimation of expected changes in official rates) or the change from  $t-2$  to  $t+3$  (where information at date  $t-2$  are used in the estimation of expected changes in official rates).

It is striking that the effect of unanticipated changes is much larger than that of anticipated changes, but the latter are often statistically different from zero. The estimated coefficients are again not very large in magnitude but still of economic significance. The one-day interbank rate reacts strongly to unanticipated changes, but hardly at all to anticipated changes. Other interbank rates react more to unanticipated than to anticipated changes, but the difference declines with maturity, and indeed the effect of anticipated changes is almost constant over the one to twelve month sections of the yield curve. The same pattern was found in estimates for implied forward rates, and was perhaps more pronounced in the

**Figure 4.**  
**Estimated probabilities of an increase or decrease in official rates,**  
**1985-1995.**



**Table 4. Reaction of market rates to anticipated and unanticipated changes in official rates, 1985-1995.**

Dependent variable	Change from t to t+1			Change from t-2 to t+3		
	Unanticipated change	Anticipated change	R <sup>2</sup> (%)	Unanticipated change	Anticipated change	R <sup>2</sup> (%)
	Coefficient (t statistic) (White' t statistic)	Coefficient (t statistic) (White' t statistic)		Coefficient (t statistic) (White' t statistic)	Coefficient (t statistic) (White' t statistic)	
<b>Interbank rates</b>						
1 day	0.1371 (0.6823) (0.8350)	0.0409 (0.2392) (0.3499)	0.198	0.3122 (1.3474) (1.7125) +	-0.0945 (-0.4373) (-0.4074)	0.757
1 month	0.2023 (5.3160) ** (4.2802) **	0.1366 (4.2166) ** (3.2999) **	14.901	0.3073 (4.1961) ** (4.5331) **	0.2013 (2.9472) ** (3.4968) **	9.088
3 months	0.1816 (6.3216) ** (4.4755) **	0.1160 (4.7441) ** (3.1251) **	19.197	0.2622 (4.3134) ** (4.3607) **	0.1958 (3.4549) ** (3.1422) **	10.403
6 months	0.1508 (6.3932) ** (4.4641) **	0.1136 (5.6594) ** (3.7710) **	21.707	0.2257 (3.7830) ** (3.7177) **	0.2001 (3.5967) ** (3.2031) **	9.386
12 months	0.1532 (6.0673) ** (4.6518) **	0.1096 (5.1040) ** (3.0712) **	19.295	0.2118 (3.5208) ** (3.3291) **	0.2103 (3.7489) ** (3.3786) **	9.137
<b>Government bond rates</b>						
24 months	0.0914 (3.8990) ** (3.8738) **	0.0592 (2.9676) ** (2.3695) *	8.367	0.1106 (1.8269) + (1.8886) +	0.1623 (2.8751) ** (2.9616) **	4.240
36 months	0.0695 (3.0674) ** (2.8889) *	0.0434 (2.2512) * (2.1309) *	5.218	0.0750 (1.3235) (1.4263)	0.1080 (2.0427) * (2.2421) *	2.211
60 months	0.0453 (2.0439) * (1.8839) +	0.0207 (1.0990) (1.2368)	2.007	0.0268 (0.4969) (0.5634)	0.0429 (0.8549) (0.9637)	0.372
84 months	0.0294 (1.3620) (1.1883)	0.0119 (0.6486) (0.7665)	0.858	0.0012 (0.0226) (0.0262)	0.0145 (0.2981) (0.3291)	0.034
120 months	0.0124 (0.5795) (0.4939)	-0.0023 (-0.1267) (-0.1583)	0.134	-0.0148 (-0.2944) (-0.3571)	-0.0063 (-0.1341) (-0.1493)	0.040

OLS estimation of  $(r(\tau) - r(\tau)) = b_0 + b_1E(s(t+1) - s(t)) + b_2UE(s(t+1) - s(t)) + \epsilon(\tau)$ . Estimated coefficients  $b_1$  and  $b_2$ , t-statistic and heteroskedasticity-consistent t-statistic in parentheses and percentage  $R^2$  reported. Number of observations = 266.

**Table 4 (Continued). Reaction of market rates to anticipated and unanticipated changes in official rates, 1985-1995.**

Dependent variable	Change from t to t+1			Change from t-2 to t+3		
	Unanticipated change	Anticipated change	R <sup>2</sup> (%)	Unanticipated change	Anticipated change	R <sup>2</sup> (%)
	Coefficient (t statistic) ( <i>'White'</i> t statistic)	Coefficient (t statistic) ( <i>'White'</i> t statistic)		Coefficient (t statistic) ( <i>'White'</i> t statistic)	Coefficient (t statistic) ( <i>'White'</i> t statistic)	
<b>Exchange rates</b>						
<b>USD</b>	-0.0163 (-0.6362) (-0.6123)	0.0229 (1.0511) (1.1347)	0.571	-0.0716 (-1.2795) (-1.1141)	0.0534 (1.0234) (1.1694)	1.014
<b>JPY</b>	-0.0020 (-0.0978) (-0.0954)	-0.0046 (-0.2575) (-0.2522)	0.029	-0.0849 (-1.9506) + (-1.6319)	0.0275 (0.6770) (0.6396)	1.601
<b>GBP</b>	-0.0124 (-0.7195) (-0.7607)	0.0003 (0.0193) (0.0190)	0.197	-0.0606 (-1.4980) (-1.3559)	-0.0247 (-0.6557) (-0.8368)	1.010
<b>FRF</b>	-0.0101 (-1.7801) + (-1.0869)	0.0048 (1.0000) (0.7132)	1.560	0.0017 (0.1565) (0.1106)	-0.0059 (-0.5925) (-0.5650)	0.143
<b>Dax index</b>	-0.0615 (-1.6210) (-1.8898) +	0.0612 (1.8957) + (1.9120) +	2.310	-0.0444 (-0.4981) (-0.5467)	0.2062 (2.4810) * (1.8403) +	2.384

behaviour of Euro-DM rates (results available upon request). The effect on day t of unanticipated changes in official rates on government bond yields tends to be about half as strong again as that of anticipated changes, but changes anticipated already on day t-2 are estimated to have had a stronger effect than the 'surprise' element.

These results are open to a number of interpretations. It could be that German interbank and government bond markets are not perfectly efficient, so anticipated changes in official rates are not fully discounted in advance, or that market participants at the time had less information than is used here. Another 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. In addition, market participants may regard an anticipated change in official rates, which typically the Bundesbank would have signalled through the public utterances of high officials, as representing an enduring shift

in the policy stance, whereas the unanticipated component may be regarded as a response to transitory disturbances. Hence the effect of unanticipated changes is concentrated in the short end of the term structure.

The separate expected and unexpected components have very different effects on share prices and exchange rates. Although the individual coefficients are not usually significant, unanticipated increases (decreases) in official rates lead to an appreciation (depreciation) of the DM against all currencies, including the U.S. dollar, whereas the anticipated change often has a small positive effect. An unanticipated increase in official rates does indeed depress share prices, but an anticipated increase has no or even the reverse effect. The results presented in Section III on the irrelevance of official rate changes for share prices and exchange rates may in large part be the result of ignoring the distinction between the expected and unexpected components of a change.

## **V. Market reaction to changes in the repurchase rate**

Changes in the official Lombard and discount rates are comparatively rare, and their timing and magnitude are in practice limited. The Bundesbank has more opportunities to change the rate at which it conducts its repurchase operations, which it can also alter in very small increments. There were 472 regular repurchase tenders between January 1985 and December 1995 for which data on (most) dependent variables are available. Approximately 60 percent were interest rate tenders and the rest quantity tenders; about one third of all operations involved some change in the rate.<sup>27</sup>

Estimates of the elasticities of market rates to changes in the repurchase rate based on the simplest specification given by equation (1) are presented in Table 5.<sup>28</sup> The greatest effect is on interbank deposit rates of maturities between one to six months, with a much diminished but still marginally positive effect even on the ten year bond yield. The estimated coefficients are still small in absolute terms but noticeably higher than those associated with changes in the two official rates, especially at longer maturities.

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<sup>27</sup> The dates of repurchase operations do not coincide with changes in official rates, so the separate treatment of reactions to the two types of events does not create a bias. However, announcements concerning forthcoming quantity tenders are usually made after Bundesbank Council meetings and may affect the interpretation of any concurrent change in Lombard and discount rates.

<sup>28</sup> Again constants are not reported to save space.



This tendency may arise because changes in the repurchase rate are more difficult to anticipate or are interpreted as a response to a temporary disturbance, while adjustments in official rates are often well signalled in advance and may represent part of a sustained effort to stabilise inflation and nominal interest rates. However, each change in the repurchase rate is usually very small (normally less than 10 basis points), which may not be strictly comparable to the 25 or 50 basis point changes in official rates.

The effect of repurchase rate changes is cumulative over the days surrounding the change, with rather more 'learning' after the change than was found in the response to changes in official rates. Whereas the latter are almost certain to represent enduring trends, the former may arise in response to transitory market pressures; economic agents may need time to gather new information and interpret the change in the Bundesbank's repurchase rate before forming definite expectations about the influence of a particular event on the future course of interest rates. The relatively large estimated anticipatory effect, especially on day  $t-2$  (not shown) could reflect the Bundesbank's reaction function if it accommodated short term interest movements to some degree; in interest rate tenders the Bundesbank may choose to set the cut-off rate not too far below the average bid. Given the Bundesbank's operating procedures, a more important explanation may be that significant 'news' relevant to predicting the Bundesbank's planned actions in each repurchase tender is received up to the morning of the tender, and market rates react accordingly; 'news' relevant to predicting changes in the two official rates accumulates more slowly over a longer period.

A perhaps surprising result is that changes in the repurchase rate have so little effect on the change in market rates from day  $t$  to  $t+1$ , when results are announced. The cause may lie in the institutional arrangements for the conduct of tenders, whereby a tender is announced on one morning and the results are declared mid-morning the next day. It is likely that little additional information is released during this hiatus, and financial markets are only open for two or three hours between the declaration of the results and the time when the Bundesbank records interest rates; most 'news' in the form, say, of Bundesbank releases, is obtained before or afterwards, when also there is time to formulate and disseminate interpretations.

**Table 5. Reaction of market rates to changes in the repurchase rate, 1985-1995.**

Dependent variable	Change from t-1 to t		Change from t to t+1		Change from t to t+1		Change from t-2 to t+3	
	Coefficient (t statistic) (White' t statistic)	R <sup>2</sup> (%)	Coefficient (t statistic) (White' t statistic)	R <sup>2</sup> (%)	Coefficient (t statistic) (White' t statistic)	R <sup>2</sup> (%)	Coefficient (t statistic) (White' t statistic)	R <sup>2</sup> (%)
<b>Interbank rates</b>								
1 day	0.2098 (1.6434) (2.6547) **	0.571	0.0004 (0.0027) (0.0047)	0.1507	-0.0017 (-0.0243) (-0.0289)	0.000	0.2258 (1.2198) (0.9074)	0.316
1 month	0.1377 (5.6466) ** (2.5179) *	6.353	0.0331 (1.3544) (1.0307)	0.389	0.0754 (5.3880) ** (3.8613) **	5.817	0.3290 (6.1723) ** (3.9244) **	7.498
3 months	0.0954 (6.4225) ** (4.0722) *	8.068	0.0502 (3.1886) ** (1.8143) +	2.117	0.0531 (4.0710) ** (2.7997) *	3.406	0.3066 (7.3204) ** (5.0513) **	10.235
6 months	0.0968 (6.1511) ** (3.0518) *	7.450	0.0486 (3.2924) ** (2.0557) *	2.254	0.0703 (5.3528) ** (3.9166) *	5.746	0.3286 (8.0252) ** (5.5751) **	12.051
12 months	0.0802 (5.0200) ** (2.3349) *	5.089	0.0464 (3.0424) ** (1.7336) +	1.931	0.0428 (3.3744) ** (2.6291) *	2.365	0.2630 (6.1213) ** (4.0913) **	7.384
<b>Government bond rates</b>								
24 months	0.0328 (2.4306) * (2.0200) *	1.244	0.0629 (4.8133) ** (2.1662) *	4.698	0.0403 3.2283 ** 4.2175 **	2.169	0.2327 (5.7604) ** (5.1659) **	6.595
36 months †	0.0229 (1.6973) + (1.3351)	0.612	0.0439 (3.5763) ** (1.8940) +	2.655	0.0295 (2.2833) ** (2.8370) *	1.0971	0.1801 (4.6926) ** (4.7145) **	4.476
60 months †	0.0153 (1.0906) (0.8260)	0.253	0.0245 (1.9786) + (1.2724)	0.828	0.0136 (1.0053) (1.2306)	0.215	0.1205 (3.2015) ** (3.4832) **	2.134
84 months †	0.0073 (0.5123) (0.3614)	0.056	0.0172 (1.3874) (0.9857)	0.409	0.0109 (0.7995) (1.0140)	0.136	0.0864 (2.3448) * (2.6334) *	1.156
120 months †	0.0057 (0.3973) (0.2723)	0.034	0.0141 (1.0992) (0.7636)	0.257	0.0012 (0.0876) (0.1230)	0.002	0.0588 (1.6340) (1.8519) +	0.565

**Table 5 (Continued). Reaction of market rates to changes in the repurchase rate, 1985-1995.**

Dependent variable	Change from t-1 to t		Change from t to t+1		Change from t to t+1		Change from t-2 to t+3	
	Coefficient (t statistic) (White' t statistic)	R <sup>2</sup> (%)	Coefficient (t statistic) (White' t statistic)	R <sup>2</sup> (%)	Coefficient (t statistic) (White' t statistic)	R <sup>2</sup> (%)	Coefficient (t statistic) (White' t statistic)	R <sup>2</sup> (%)
<b>Exchange rates</b>								
<b>USD</b>	0.0052 (0.3062) (0.2714)	0.020	-0.0041 (-0.2371) (-0.2284)	0.012	0.0116 (0.6422) (0.5731)	0.088	0.0008 (0.0195) (0.0185)	0.000
<b>JPY</b>	-0.0097 (-0.6849) (-0.7253)	0.010	-0.0029 (-0.2098) (-0.2363)	0.009	-0.0006 (-0.0453) (-0.0499)	0.000	-0.0402 (-1.2395) (-1.5716)	0.326
<b>GBP</b>	0.0105 (1.0185) (1.2453)	0.220	-0.0192 (-1.6492) (-1.9131) +	0.575	0.0029 (0.3044) (0.2985)	0.020	0.0062 (0.2444) (0.3042)	0.013
<b>FRF</b>	0.0009 (0.2922) (0.3315)	0.018	-0.0059 (-1.5830) (-1.8156) +	0.530	-0.0021 (-0.6673) (-0.7450)	0.095	-0.0056 (-0.6048) (-0.8879)	0.078
<b>Dax index</b>	0.0221 (0.7703) (0.4288)	0.127	0.0197 (0.6917) (0.4746)	0.102	-0.0627 (-2.2325) * (-1.3361)	1.049	-0.0216 (-0.3329) (-0.2841)	0.024

OLS estimation of  $(r(\tau) - r(\tau)) = b_0 + b_1(s(t+1) - s(t)) + e(\tau)$ . Estimated coefficient  $b_1$ , t-statistic and heteroskedasticity-consistent t-statistics in parentheses and percentage R<sup>2</sup> reported. Number of observations = 472 unless otherwise indicated.

† Number of observations = 471.

Standard statistical tests and visual inspection of the residuals suggested the presence of heteroskedasticity or excess kurtosis even after the inclusion of other candidate explanatory variables. In particular short term rates displayed a number of outliers. However, the estimated coefficients on variables of interest were not significantly affected when appropriate dummy variables were included, and results of sign tests (not reported to save space) generally corroborated those obtained by OLS. Table 5 includes t-statistics based on White's (1980) heteroskedasticity-consistent covariance matrix estimator. They are mostly close to the conventional t-statistics but (with exceptions) somewhat smaller. There was no evidence for serial correlation.

In supplementary regressions (available on request) the effect of changes in the repurchase rate on forward rates was again found to be greater than that of changes in the Lombard and discount rates (except on the day of the change itself), and the estimated coefficient is only once negative. The implication could be that changes in the repurchase rate by themselves are believed to be less effective in controlling inflation than changes in the official rates,

and that therefore a rise in the repurchase rate is not closely associated with ultimately lower interest rates. Changes in the Bundesbank's repurchase rate were found to effect Euro-DM interest rates significantly, with a larger effect for maturities beyond 3 months than on rates for very short maturities.

A number of additional possible explanatory variables were included in the regressions (again results are available on request). The lagged change in the repurchase rate proved to be of considerable importance, which is surprising because this variable in itself does not convey new information which might alter expectations. Possibly market participants react especially strongly when they see confirmation that a trend is developing and that an individual change in the repurchase rate is not merely a response to a transitory disturbance. One implication could be that the Bundesbank can send a strong signal of a shift in its policy stance by changing its repurchase rate repeatedly in the same direction. As was found for changes in the official rates, the immediate response to decreases in the repurchase rate seems stronger than the response to increases, but this effect disappears when the response over several days is considered. No other additional explanatory variables were found to have a systematic effect.

The Dax share price index reacted negatively to increases in the repurchase rate, in contrast to its independence from overall changes in official rates. The repurchase rate also had an immediate influence on exchange rates similar to that of unanticipated changes in official rates; the estimated coefficients usually have the correct sign, sometimes marginally significantly so even when the covariance matrix estimator allows for heteroskedasticity.

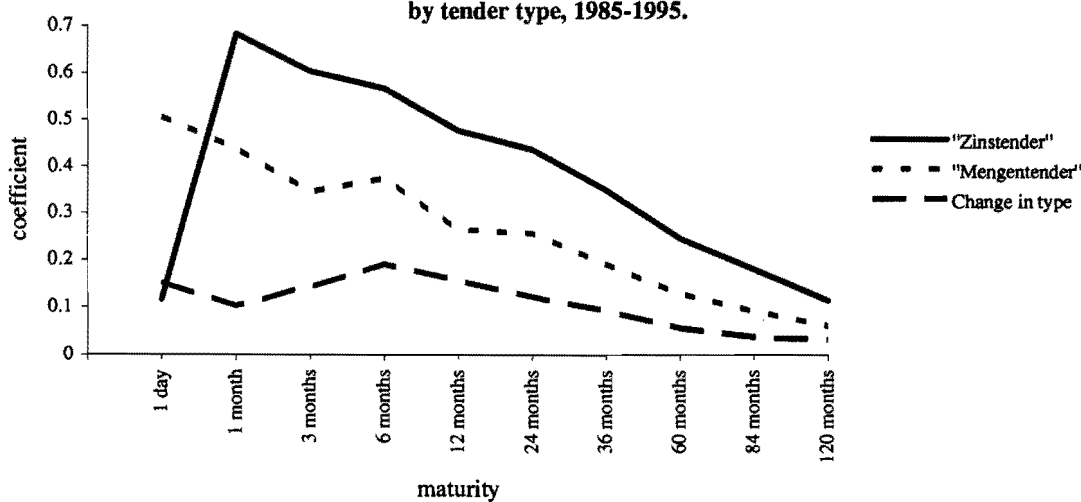
The Bundesbank occasionally switches between interest rate and quantity tenders to allocate its repurchase contracts. The signal transmitted by changes in the repurchase rate may depend on the type of tender conducted.<sup>29</sup> In Table 6 results for a regression of changes in interest rates on changes in the repurchase rate are shown, where 'DZ' denotes the (logarithmic) change in the repurchase rate from one interest rate 'Zinstender' to another; 'DM' denotes the change between subsequent 'Mengentenders'; and 'DMZ' denotes the rate change between a Mengen- and a Zinstender (or vice versa) when the Bundesbank switches tender type. Some of the estimated coefficients are depicted in Figure 5. On the

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<sup>29</sup> The signal may also depend on the type of interest rate tender used, in particular on whether a minimum bid was pre-announced, and the volume of bids and the proportion accepted. Nautz (1995) considers some of these issues in his examination of the reaction of the overnight money market rate.

day results are announced only repurchase rate changes produced by Zinstenders have a systematic positive effect on market rates; changes produced by quantity tenders are estimated to have even a negative effect. The cumulative effect from t-2 to t+3 is more balanced, with uniformly positive coefficients, but those relating to interest rate tenders are approximately one half larger in magnitude and often much more significant. This result supports the intuition that quantity tenders convey less information to the market because the interest rate is pre-announced and the market participants collectively already know the quantity bid. Changes in the repurchase rate that occur when the Bundesbank goes from a quantity to an interest rate may be regarded as largely technical rather than signalling a policy adjustment. In interest rate tenders the Bundesbank pre-announces nothing, so the results provide market participants with information about both the strength of demand and the Bundesbank's short term objectives.

**Figure 5.**  
**Estimated reaction from t-2 to t+3 to changes in the repurchase rate,**  
**by tender type, 1985-1995.**



**Table 6. Reaction of market rates to changes in the repurchase rate, by tender type, 1985-1995.**

Dependent variable	Change from t-1 to t				Change from t to t+1			
	DZ	DM	DMZ	R <sup>2</sup>	DZ	DM	DMZ	R <sup>2</sup>
	Coefficient (t statistic) (White' t statistic)	Coefficient (t statistic) (White' t statistic)	Coefficient (t statistic) (White' t statistic)	R <sup>2</sup> (%)	Coefficient (t statistic) (White' t statistic)	Coefficient (t statistic) (White' t statistic)	Coefficient (t statistic) (White' t statistic)	R <sup>2</sup> (%)
<b>Interbank rates</b>								
1 day	0.3172 (1.2493) (1.6957) +	0.0322 (0.1226) (0.5587)	0.2387 (1.3316) (1.9360) +	0.712	-0.0082 (-0.0297) (-0.0439)	-0.1794 (-0.6259) (-0.8638)	0.0881 (0.4509) (1.2829)	0.127
1 month	0.2990 (6.2946) ** (2.7094) *	0.1726 (3.5092) ** (1.4719)	0.0410 (1.2220) (0.6367)	10.250	0.1110 (2.2995) * (1.2789)	-0.0858 (-1.7175) + (-1.4733)	0.0495 (1.4544) (1.6174)	2.166
3 months	0.1541 (5.2415) ** (4.5607) **	0.0720 (2.3647) * (0.9363)	0.0770 (3.7110) ** (3.0091) **	9.109	0.1416 (4.5962) ** (3.1692) **	-0.0375 (-1.1748) (-0.6291)	0.0453 (2.0852) * (1.1431)	5.432
6 months	0.1591 (5.1113) ** (4.0375) **	0.0897 (2.7820) ** (1.1146)	0.0690 (3.1402) ** (1.4091)	8.554	0.1222 (4.2094) ** (3.5909) **	-0.0208 (-0.6934) (-0.3687)	0.0442 (2.1559) * (1.3083)	4.660
12 months	0.1255 (3.9619) ** (3.2230) **	0.0725 (2.2096) * (0.7842)	0.0611 (2.7315) ** (1.2075)	5.659	0.1284 (4.3347) ** (2.9877) **	-0.0694 (-2.2629) * (-1.3404)	0.0592 (2.8293) ** (1.6303)	6.391
<b>Government bond rates</b>								
24 months	0.0782 (2.9224) ** (2.7311) **	0.0114 (0.4116) (0.4943)	0.0201 (1.0652) (0.7613)	2.066	0.0980 (3.8022) ** (3.6661) **	-0.0035 (-0.1297) (-0.2308)	0.0762 (4.1884) ** (1.4266)	6.412
36 months †	0.0595 (2.2198) * (2.1740) *	0.0043 (0.1551) (0.1696)	0.0133 (0.7040) (0.4614)	1.156	0.0766 (3.1672) ** (3.3982) **	-0.0196 (-0.7822) (-1.8752) +	0.0570 (3.3389) ** (1.3601)	4.465
60 months †	0.0405 (1.4570) (1.6165)	-0.0055 (-0.1903) (-0.2412)	0.0123 (0.6261) (0.3746)	0.545	0.0504 (2.0587) * (2.2727) *	-0.0181 (-0.7141) (-1.2282)	0.0313 (1.8084) + (0.8992)	1.690
84 months †	0.0283 (0.9960) (1.1036)	-0.0053 (-0.1792) (-0.2023)	0.0027 (0.1346) (0.0746)	0.223	0.0365 (1.4805) (1.7837) +	-0.0246 (-0.9646) (-1.3584)	0.0271 (1.5568) (0.8833)	1.175
120 months †	0.0131 (0.4571) (0.5443)	-0.0025 (-0.0852) (-0.0884)	0.0059 (0.2902) (0.1565)	0.065	0.0282 (1.1070) (1.5431)	-0.0287 (-1.0889) (-1.4658)	0.0270 (1.5008) (0.8202)	0.990

OLS estimation of  $(r(\tau^t) - r(\tau)) = b_0 + b_1 DZ(t) + b_2 DM(t) + b_3 DMZ(t) + \varepsilon(\tau^t)$ . Estimated coefficient  $b_1$ ,  $b_2$  and  $b_3$ , t-statistic and heteroskedasticity-consistent t-statistics in parentheses, and percentage  $R^2$  reported. Number of observations = 472 unless otherwise indicated.

† Number of observations = 471.

**Table 6 (Continued). Reaction of market rates to changes in the repurchase rate, by tender type, 1985-1995.**

Dependent variable	Change from t+1 to t+2				Change from t-2 to t-3			
	DZ	DM	DMZ	R <sup>2</sup>	DZ	DM	DMZ	R <sup>2</sup>
	Coefficient (t statistic) ( 'White' t statistic)	Coefficient (t statistic) ( 'White' t statistic)	Coefficient (t statistic) ( 'White' t statistic)	(%)	Coefficient (t statistic) ( 'White' t statistic)	Coefficient (t statistic) ( 'White' t statistic)	Coefficient (t statistic) ( 'White' t statistic)	(%)
<b>Interbank rates</b>								
<b>1 day</b>	-0.0917 (-0.6781) (-0.6738)	0.2464 (1.7596) + (1.6166)	-0.0719 (-0.7531) (-1.5359)	0.874	0.1154 (0.3135) (0.2952)	0.5050 (1.3245) (1.6398)	0.1513 (0.5822) (0.3697)	0.466
<b>1 month</b>	0.0816 (2.9362) ** (2.3865) *	0.1081 (3.7566) ** (2.0235) *	0.0571 (2.9131) ** (2.4750) *	6.259	0.6832 (6.5905) ** (5.7193) **	0.4375 (4.0760) ** (2.1520) *	0.1021 (1.3950) (0.8445)	11.702
<b>3 months</b>	0.0982 (3.8097) ** (3.5426) **	0.0711 (2.6654) * (1.6575)	0.0222 (1.2202) (0.9677)	4.708	0.6024 (7.3916) ** (6.7787) **	0.3435 (4.0704) ** (2.0743) *	0.1419 (2.4667) * (2.0692) *	14.182
<b>6 months</b>	0.0910 (3.4835) ** (3.0849) **	0.0596 (2.2026) * (1.5614)	0.0650 (3.5249) ** (2.4569) *	5.920	0.5655 (7.0501) ** (6.4869) **	0.3722 (4.4802) ** (2.4101) *	0.1902 (3.3586) ** (2.2631) *	14.774
<b>12 months</b>	0.0725 (2.8820) ** (2.8907) **	0.0473 (1.8133) + (1.3698)	0.0259 (1.4555) (1.1091)	2.849	0.4758 (5.6194) ** (4.8417) **	0.2631 (3.0012) ** (1.6374)	0.1569 (2.6248) ** (1.6748)	9.218
<b>Government bond rates</b>								
<b>24 months</b>	0.0846 (3.4176) ** (3.9016) **	0.0230 (0.8977) (1.9305) +	0.0263 (1.5052) (1.7984) +	3.059	0.4356 (5.4789) ** (4.8121) **	0.2551 (3.0988) ** (3.3125) **	0.1211 (2.1574) * (1.8569) +	8.649
<b>36 months †</b>	0.0652 (2.5467) * (3.4464) **	0.0196 (0.7377) (1.2762)	0.0162 (0.8976) (0.9893)	1.648	0.3474 (4.5845) ** (4.3958) **	0.1907 (2.4296) * (3.1269) **	0.0918 (1.7162) + (1.6026)	6.003
<b>60 months †</b>	0.0405 (1.5104) (2.0772) *	-0.0000 (-0.0020) (-0.0025)	0.0065 (0.3410) (0.4181)	0.510	0.2443 (3.2742) ** (3.4358) **	0.1283 (1.6611) + (2.5096) *	0.0552 (1.0491) (1.0208)	3.024
<b>84 months †</b>	0.0313 (1.1602) (1.6806) +	-0.0029 (-0.1042) (-0.1257)	0.0070 (0.3693) (0.4889)	0.318	0.1795 (2.4530) * (2.7656) **	0.0915 (1.2078) (1.8735) +	0.0377 (0.7294) (0.7214)	1.683
<b>120 months †</b>	0.0189 (0.6993) (1.0571)	-0.0090 (-0.3240) (-0.4007)	-0.0029 (-0.1510) (-0.2360)	0.132	0.1131 (1.5808) (1.9475) +	0.0596 (0.8044) (1.2147)	0.0313 (0.6206) (0.6059)	0.750

## V. Conclusion

It has been shown that the immediate reaction of market interest rates and other financial market prices to changes in the Bundesbank's official Lombard and discount rates, that is, the rates applied at its standing facilities, and in the rate at which it conducts repurchase operations, is sharp but of moderate magnitude. It seems that the Bundesbank is indeed able to use these instruments to send definite signals affecting market participants' perceptions of the policy stance (especially but not exclusively over the subsequent year or so), and thus influence the level of rates all along the term structure. A change in official rates can even be interpreted as foretelling an opposite movement in interest rates in the longer term. The signalling effect is strongest when the change is unexpected, but, in a striking result, even the anticipated component is shown to influence market interest rates; a realised change in official rates seems to provide information that other sources such as public pronouncements on the policy stance cannot. Changes in the different official interest rates on standing facilities (the Lombard and discount rates in Germany) do not seem to send markedly different signals; interpretation may depend primarily on the central bank's public explanations of its actions. Furthermore, even unanticipated changes in official rates or changes in the repurchase rate had only moderate influence on German stock prices and the Deutschmark exchange rate.

It is interesting to compare the results reported in this paper to those obtained for other countries in the papers cited in the introduction. Most of the studies using data from the U.S. (especially for the period 1979-1982) and Dale for the U.K. find a somewhat larger reaction of money market rates with maturities up to 12 months, particularly on the day of change. Overall changes in official rates in Germany may have relatively small immediate impact (at least since 1985) because the Bundesbank may have given relatively unambiguous advance warnings; this interpretation is supported by the evidence that the reaction is highly concentrated on the day of announcement. Another, not exclusive, explanation could be that Germany's history of greater inflation and interest rates stability leads market participants to expect movements in interest movements to be temporary;<sup>30</sup> a rise in rates in the U.S. or the U.K. might more readily be viewed as a prelude to prolonged high inflation and nominal interest rates. Dale finds an additional effect from turning

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<sup>30</sup> Gerlach and Smets (1995) provide a similar explanations for the relatively poor performance of the expectations theory of the term structure using the U.S. data, and the predictability of German interest rates.



points, but corroborates that non-linearities or asymmetries do not seem important; similar results for the U.S. were found by Radecki and Reinhart.

Roley and Troll, Smirlock and Yawitz, Cook and Hahn and Thornton (1986) all illustrate using U.S. data the importance of the central bank's operating procedure in determining the market interest rate response; for Germany one obtains very different results for the period before 1985 when emphasis shifted to repurchase operations, and, less strikingly, for different types of repurchase tender. While Smirlock and Yawitz estimate that changes in U.S. official interest rate have a negative influence on forward rates similar to the tendency in Germany, Roley and Troll and Radecki and Reinhart find that the influence is insignificant or positive. Paquet and Pérez find that U.S. rates have a strong influence all along the term structure of Canadian interest rates. The German monetary authorities thus seem to enjoy a position akin to that of the U.S. Federal Reserve in the management of the respective domestic money markets, and changes in their official rates contain much information relevant to the determination of market rates throughout Europe. Smirlock and Yawitz and May estimate that changes in the U.S. discount rate have a significant negative effect on stock prices there, in contrast to the results for Germany presented here and newer evidence for the U.S. in Radecki and Reinhart .

In all countries, reaction to changes in official rates indicate how the central bank's intentions and credibility are perceived. Even when a central bank relies primarily on open market operations in the implementation of policy, as the Bundesbank has done since 1985, changes in official interest rates on standing facilities are still effective in confirming and reinforcing expectations derived from day to day trading, and thus in initialising a complex and perhaps protracted transmission process.

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## Appendix: Estimation of Anticipated and Unanticipated Changes in Official Rates

The behaviour 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. Techniques are available to assess under which conditions an ordered response variable will move in one or the other direction. The standard ordered response model will be generalised to allow the explanatory variables to affect the probability of an increase or a decrease in different ways (see Maddala 1983, pp. 46-49, and especially footnote 7), and then used to predict the magnitude of any change (see Heckman, 1974, and Maddala, 1983, 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  $d_1$  take the value of 1 when an official rate decreases, and zero otherwise. Similarly, let  $d_2$  equal 1 only when rates are unchanged, and let  $d_3$  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  $y$ .<sup>31</sup> The scheme can be summarised as follows:

$$\text{if } \gamma_1'Z + u < 0 \qquad d_1=1, d_2=d_3=0 \qquad y = \beta_1'X + u_1 \quad (A1)$$

$$\text{if } \gamma_1'Z + u > 0 > \gamma_3'Z + u \qquad d_2=1, d_1=d_3=0 \qquad y = 0$$

$$\text{if } \gamma_3'Z + u > 0 \qquad d_3=1, d_1=d_2=0 \qquad y = \beta_3'X + u_3$$

where  $\gamma_1$ ,  $\gamma_3$ ,  $\beta_1$  and  $\beta_3$  are parameters to be estimated, and  $u$ ,  $u_1$  and  $u_3$  are correlated random variables with a joint normal distribution.<sup>32</sup> The variable  $u$  is standardised to have mean zero and variance 1. Let  $f$  and  $F$  will denote the density function and the cumulative

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<sup>31</sup> Time subscripts are omitted where no ambiguity results. The instrumental variables in  $X$  and  $Z$  must be known before  $y$  is realized.

<sup>32</sup> The conditions  $\gamma_1'Z + u < 0$  and  $\gamma_3'Z + u > 0$  should not be fulfilled simultaneously. The method used here does not impose this constraint, but no difficulties seem to result.

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

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

the logarithm of which can readily be maximised. 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

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

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

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

Estimation of  $\beta_1$ ,  $\beta_3$ ,  $\sigma_{1u}$ , and  $\sigma_{3u}$  in (A3) can be carried out by OLS, but the standard errors are heteroskedastic. The approach adopted here is to estimate the equation by OLS and to correct the estimated standard errors using the procedure from White (1980). Homoskedasticity must be assumed in (A1) so that  $\sigma_{1u}$ , and  $\sigma_{3u}$  can be taken to be constants.

The predicted value  $\hat{y}_t$  is treated as the expected change, and the residual  $(y_t - \hat{y}_t)$  is the unexpected component, which by construction is orthogonal to the fitted value and the instruments. The two are then used to estimate equation (3) in the specification

$$(r_t' - r_t) = b_0 + b_1 \hat{y}_t + b_2 (y_t - \hat{y}_t) + \varepsilon_t' \quad (A4)$$

Pagan (1984, 1986) and McAleer and McKenzie (1991) discuss the properties of the regression output with such constructed regressors. Under reasonable conditions the OLS coefficient estimates are unbiased, and that of  $b_2$  will be efficient. The generated standard error of  $b_1$  may be biased by an amount that varies positively with the product of  $b_2^2$  and the variance of the auxiliary regression (A3 here), and negatively with the variance of the regression of interest (A4). The estimate of  $b_2$  was at most 0.3 and often an order of magnitude smaller; the estimated variance of the auxiliary regression was less than  $4 \times 10^{-4}$ , while the estimated variance of equation (A4) applied to interest rates was approximately  $3.5 \times 10^{-3}$ . Therefore the bias is likely to be at most 10 percent.

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