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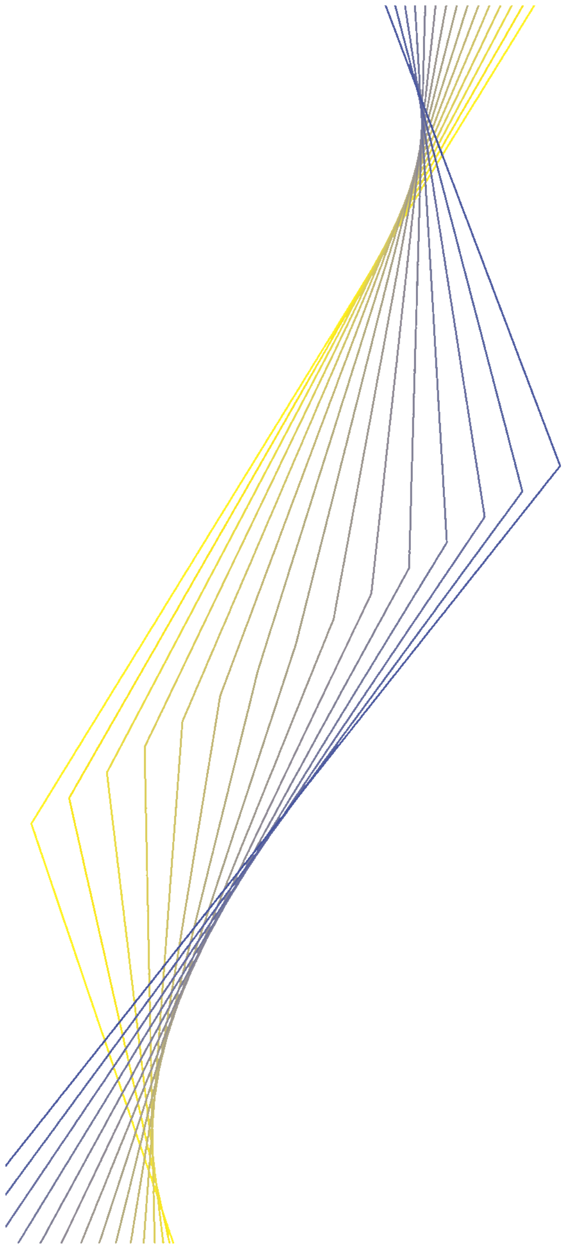

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USING MONEY MARKET RATES TO ASSESS THE ALTERNATIVES OF FIXED VS. VARIABLE RATE TENDERS: THE LESSON FROM 1989-1998 DATA FOR GERMANY[1]

BY MICHELE MANNA[2]

October 2002

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Abstract

This paper uses the variability of money market rates to compare the conduct of the central bank's key market operation as a fixed-rate tender (FRT) or a variable-rate tender (VRT). Nowadays, leading central banks generally use FRTs or other approaches (e.g. target rates) which yield step changes in the policy rate, as opposed to the more piecemeal, but also more noisy changes resulting from the VRT rate. Given the central bankers' preference for stable money market conditions, FRTs should thus remain associated with lower market variability. In fact, daily data for the German overnight and three-month rates from 1989 to 1998, when the Bundesbank alternated FRTs and VRTs, indicate that the average variability of money market rates is broadly the same under the two tender procedures. A small model shows that this finding holds true under rather general conditions, and is not only a feature of the experience in Germany.

Key words: central bank tender procedures; money market rates; key policy rate; daily data; monetary policy.

JEL-classification: E4, E5, G2, N2.

Non-technical summary

This paper addresses the issue of the conduct by the central bank of its main open market operation in the form of either a fixed-rate tender (FRT) or a variable-rate tender (VRT). The starting point of the analysis is the difference between the streams of policy signals released by the two tender procedures. Under the FRT, the tender rate may remain unchanged for prolonged period of times, and when it is changed, changes are generally by round and non-negligible amounts, e.g. 25 or 50 basis points (bp). Conversely, under the VRT, the rate resulting from each tender usually differs from the one of the previous operation, albeit the difference may well amount to only a few basis points (e.g. 2 to 3 bp).

Current practice among leading central banks points to a widespread use of FRTs or other signalling mechanisms which likewise yield changes in the key policy rate in steps, as opposed to the piecemeal, but also more noisy rate changes which are typical of VRTs. Given this preference and the fact that central bankers are usually keen on preserving fairly stable conditions in the money market, one could expect clear evidence pointing to a lower variability of money market rates under the FRT compared with the alternative tender procedure. In fact, the findings presented in this paper highlight the lack of any such systematic nexus.

The record of the Deutsche Bundesbank in the decade prior to the start of EMU provides an excellent (and almost unique) empirical basis for this research. This is because during that period, the German central bank alternated the FRT and VRT procedures in its weekly open market operation. In addition, it retained an effective autonomy in setting its domestic interest rates, given the role of the Deutsche Mark as the anchor of the European Rate Mechanism, and both its monetary policy strategy and operational framework remained broadly unchanged.

As a main result, the empirical analysis, conducted on daily data from 1989 to 1998, shows that the average variability of both the German overnight and the three-month rates is *not* statistically different under the two tender procedures. This result is confirmed by an econometric analysis conducted with a view to monitoring the patterns of those economic indicators which motivated the activities of the Deutsche Bundesbank, notably broad money growth and the consumers' price inflation, as well as the changes in the Lombard rate, recourse to fine-tuning operations and seasonal regularities.

This body of evidence should not be interpreted as lack of any proof in favour of FRTs. For example, a significant lowering of the market rate variability was observed from 1996 to 1998, when the Deutsche Bundesbank relied on FRTs. Moreover, at the peak of the 1992

EMS crisis, the German central bank flagged its intention to switch from a series of rate hikes to a new phase of rate cuts via the re-introduction of the FRTs; reasoning to the contrary, one could well argue that VRTs do not quite suit the scope for reversals in trend. In fairness, there still remains a degree of controversy over the period from to 1996 to 1998. This is because Germany did not experience, within the selected sample, a similar period of "quiet" macroeconomic conditions with the simultaneous use of VRTs. Consequently, it is difficult to rule out the possibility that in the last three years prior to the start of EMU a lowering of market rate variability may have been obtained anyway, irrespective of the tender procedure adopted. With regard to the experience of 1992, while this is certainly a relevant case study, caution should be exercised in drawing general conclusions from a single episode, which occurred under exceptional circumstances.

A small model for the overnight rate and a generic time deposit rate, with maturity spanning over two meetings of the monetary policy-making body, shows that the finding of no systematic difference in the amount of variability holds true under rather general conditions, and is not only a feature of the experience in Germany. For example, in order to achieve the same average day-to-day change in the overnight rate under the two tender procedures, the "noise" characterising the rate resulting from the VRT ought to be more than twice as loud as the loudest "noise" found in German records. More mixed results are obtained for time deposit rates, where neither of the two tender procedures seems to prevail.

In order to keep the derivation of the analytical results and the subsequent numerical exercises simple, a number of assumptions have been adopted within the model and, naturally, different results could hold when different assumptions are taken. For example, the instance whereby the disturbance associated to the VRT rate follows a non-normal distribution has not been fully explored. However, the range of results from the various numerical exercises is broad enough to suggest a rather sceptical view of the assertion that the variability of money market rates is necessarily lower under the FRT procedure.

A number of arguments may still explain the current consensus in favour of FRTs. For example, a big plus in this procedure is the more immediate measurability of the impact of each rate decision on financial markets. In addition, further light should be shed on issues such as the nexus between the two tender procedures in question and the transmission of the monetary policy signal to long-term rates. Or, on the link with the dynamics of the interest-rate setting process, including the game played within the monetary policy-making body. The results presented in this paper lend support, however, to the view that VRTs, as an alternative to FRTs, should not be rejected on the grounds of triggering higher variability in money market rates, where this is measured over a sufficiently long sample comprising different phases of the business cycle.

1 INTRODUCTION

This paper addresses the issue of the conduct by the central bank of its main open market operation in the form of either a fixed-rate tender (FRT) or a variable-rate tender (VRT).[1] The starting point of the analysis is the difference between the streams of policy signals released by the two tender procedures. Under the FRT, the tender rate may remain unchanged for prolonged period of times, and when it is changed, changes are generally by round and non-negligible amounts, e.g. 25 or 50 basis points (bp). Conversely, under the VRT, the rate resulting from each tender usually differs from the one of the previous operation, albeit the difference may well amount to only a few basis points (e.g. 2 to 3 bp).

The European Central Bank (ECB) applied an FRT to its weekly main open market operation since the start of Economic and Monetary Union (EMU) in January 1999 until June 2000. Thereafter, it has applied a VRT with pre-announcement of the minimum bid rate. The switch reflected operational concerns and, as flagged by the ECB, "the minimum bid rate is designed to play the role performed, until now, by the rate in fixed rate tenders.".[2] Overall, in the three years up to December 2001, the ECB changed its key policy rate 5 times by 50bp and 7 times by 25bp.

The researcher may thus be keen to take one step back in the past, and analyse the record of the Deutsche Bundesbank in the decade prior the start of EMU. During that time, the German central bank alternated the FRT and VRT procedures in its weekly open market operation. In addition, it retained an effective autonomy in setting its domestic interest rates, given the role of the Deutsche Mark as anchor of the European Rate Mechanism (ERM), and both its monetary policy strategy and operational framework remained broadly unchanged. Hence, these elements taken together indicate that the German data for the period 1989-1998 provide an excellent basis for the scope of this paper.

The signalling policies currently adopted by the US Fed and the Bank of England yield changes in steps comparable to those of an FRT. It is therefore of some interest to note that in the years 1999-2001 the US Fed changed its target Fed Fund rate 8 times by 25bp and 9 times by 50bp, while over the same period of time the Bank of England changed its repo rate 13 times by 25bp and 3 times by 50bp. Similarly, until the switch in March 2001 to a policy of targeting liquidity volumes, the Bank of Japan changed its target for the uncollateralised overnight call rate by effectively 10, 15 or 25 basis points.

In the implementation of the monetary policy, central banks usually steer their actions towards a reduction of the variability of short-term interest rates (Goodfriend, 1986), and they like to emphasize the results when they manage to do so.[3] Since, as put it by Haldane and Read (1999), "news about policy variables shows up in movements at the short end of the yield curve", and taking into consideration the aforementioned streams of policy signals, one ought to expect some systematic

[1] Throughout this paper and unless noted otherwise, reference is made to the VRT procedure without pre-announcement by the central bank of minimum/maximum bid rates.

[2] ECB press release on "Monetary policy decisions", dated 8 June 2000.

[3] A good example of this attitude is offered by the Deutsche Bundesbank (Monthly report, May 1994, p. 60) which in an analysis of its money market management pointed out that "Interest rate movements in the Germany day-to-day money market are marked by exceptionally high degree of steadiness by international standards".

nexus between the variability of money market interest rates and the tender procedures used by the central bank in its main open market operation. Notably, given the current preference for FRTs, it seems natural to expect that this tender procedure (or, more broadly, styles of "step" changes in the key policy rate) is normally associated with a lower variability.

Against this background, the paper is organised around the following three questions:

1. Which elements may explain the current consensus in favour of FRTs and conversely which could argue in favour of VRTs?
2. With reference to the experience of the Bundesbank in the decade prior to the start of EMU, did the variability of German money market rates tend to change systematically between FRT and VRT procedures?
3. Can the results found for Germany be generalised?

Laid down in the line of research followed in the paper, three preliminary remarks are in order. Firstly, irrespective of the way the central bank implements the rate changes, some variability of money market rates is expected to arise anyway. This is because part of the variability reflects non-policy related, market idiosyncrasies such as the limits imposed to trading by the credit lines (see Hamilton, 1996, for empirical evidence on this point for the US Fed Funds rate). From a different standpoint, it may be observed that although today there is a large consensus that transparency is the "right thing" in central banking, it is also accepted that full transparency is not necessarily best in policy making, nor it can always be achieved (see Duisenberg, 1999, and Padoa-Schioppa, 2000 for the view of central bankers on this point; Winkler, 2000, for a survey of what is transparency in monetary policy making). This brings about some unavoidable amount of news which, in turn, would trigger the variability of money market interest rates.

Secondly, in principle, the rate applied to the FRT could be changed by a few basis points at each operation, just as the VRT could yield the outcomes of, say, no change or change by 25bp. In practice, the patterns described at the beginning of this introduction are those which have prevailed in contemporary central banking. At the same time, it is fair to observe that a number of operational procedures have been devised by central banks (Borio, 1997, and BIS, 1999). Nonetheless the chosen settings should hopefully conveniently act as benchmarks against which other styles of implementation of rate changes may be assessed.

Thirdly, to define the boundaries of the current research, this paper does not examine the spillover of the variability of money market rates on the long-term part of the yield curve. Moreover, it also does not explore the issue of the optimal amount and distribution of such variability. Both these topics, while certainly worthy of an investigation, are beyond the scope of this paper, and may usefully set out an agenda for further research work in this field.

The remainder of the paper is organised as follows. Section 2 briefly surveys the rate signalling mechanisms adopted by some leading central banks. Section 3 presents an analysis of daily data for the German money market in 1989 through to 1998. Section 4 focuses on the corresponding econometric analysis. Section 5 illustrates a model for the money market. Finally, section 6 concludes the paper.

2 A BRIEF SURVEY OF RATE SIGNALLING MECHANISMS

Table 1 summarises the signalling mechanisms adopted by the central banks of France, Germany, Italy (before the start of EMU), Japan, United Kingdom, USA and the ECB (the table including footnotes is an abridged version of table 5.1 in Borio, 1997, except for the column referring to the ECB).

Table 1

SIGNALLING MECHANISMS: INTEREST RATE SIGNALS [1]

	France [2]	Germany [2]	Italy [2]	ECB	Japan	United Kingdom	USA
Announcement of target					[3]	[4]	*
Regular tender	*	*	*[5]	*[6]		*[4]	
▪ Fixed rate	*	*[7]		*[8]			
▪ Variable rate		*[7]	*[5]	*[9]		*[4]	
Other market operations	*						
Standing facilities	*	*	*	*	*		
Other						*[10]	

Notes:
[1] Except for the column referring to the ECB, this table and associated footnotes have been reproduced from Table 5.1, Borio (1997). [2] Prior to start of EMU on 1 January 1999. [3] Since July 1995, explicit indications about the desired average level of the overnight rate. [4] Following the introduction of the new monetary framework in the autumn of 1992, the Bank of England began to announce changes in official rates, applying in particular to the daily eligible bills variable rate tenders (stop rate). [5] Weak signals via VRT with pre-announced quantities; speed of reserve accumulation (published daily) underlines the signal. [6] Main refinancing operation, carried out weekly with two-week maturity. [7] Switch to FRT to strengthen the signal. [8] From January 1999 until the tender settled on 21 June 2000. [9] VRT with pre-announced minimum bid rate as from the tender settled on 28 June 2000. [10] Until the introduction of the new monetary framework, 2.30pm lending: when instituted, this replaced the usual 2.45pm lending facility, and was done at a longer maturity than overnight (typically one week).

The survey shows that while some central banks rely on a single key interest rate, seemingly other central banks put emphasis on more than one rate at the same time. An example of the former group is the US Fed with its target Fed Funds rate. Conversely, in its press releases on interest rate decisions, the ECB refers routinely to the rate applied to its weekly main refinancing operation as well as to the rates of the two standing facilities (the deposit and the marginal lending facility). In practice, in the latter group the different rates have generally moved in parallel, so that de facto a single policy signal is released. Exceptions to this rule, i.e. the fact that a central bank changes its key rates by different amounts at the same point in time, often owe to circumstances of severe external pressures, usually originated in the exchange-rate market. This was the case, for example, of the Banque de France which during the French Franc exchange-rate crisis of summer 1993 kept unchanged the tender rate, while it raised markedly the rate applied to the five-to-ten-day standing facility.

As a second finding, the Banque de France and Banca d'Italia used to make recourse to the FRT and VRT respectively, while the Bundesbank and the ECB (have) used both types of tender procedures. (For the sake of completeness, looking at the key rate, the US Fed, the Bank of England and the Bank of Japan have relied on targeting systems, and have changed accordingly their key policy rate in discrete steps.) Taking into account that from a policy signalling point of view the ECB has effectively never forsaken the FRT, it follows that within this survey the Deutsche Bundesbank is the only central bank which relied on both types of tender procedures to release its key monetary policy signal.[4] Quite luckily for the researcher, the conditions under which this central bank operated –autonomy in setting the domestic interest rates; broad stability of monetary policy framework and strategy at least throughout the decade ending with the start of EMU in January 1999– allow a meaningful comparison between the variability of money market rates under the two tender procedures.

This notable exception notwithstanding, which arguments may explain the current practice in favour of FRTs (or other stepwise approaches)? In terms of operational implications, the main aspects of the problem are well known. As put it by the Deutsche Bundesbank (Monthly Report, May 1994, pp. 59-74), the VRT gives market players a "say" in the open market operations while the FRT provides an "unequivocal form of interest rate leadership". An example of what this could mean in practice is offered by the change in phase which occurred in Autumn 1992, when at the peak of the EMS crisis the German central bank signalled the switch from the previous series of hikes to a periods of cuts by resuming the FRT (Chart 3 below).

The assessment of the two tender procedures may be conducted also against the broader context of the debate on interest rate smoothing, Huizinga and Eijffinger (1999) argue that "central bankers gain credibility by having a reputation for maintaining the same policy stance for some time" and that to do so, they should "restrain themselves from fine-tuning policy in response to news as it arrives". From this standpoint, while in theory the rate resulting from the VRT might remain constant for a period of time, arguably the FRT is a better-designed procedure to cater for the steadiness of the central bank's rate.

The (current application of) FRTs could be regarded also as a pragmatic intermediate solution. According to some scholars, today's central banking action leads to "too little, too late" changes of the key policy rate. To quote one authoritative supporter of this view, Goodhart (1996, pages 31-32) argues that "the exact rationale for smoothing, wishing to limit the size of interest rate jumps in any

[4] The Bundesbank (Monthly Report, May 1994, p. 62) flagged that the rate of its regular weekly tender was the "operational key rate", while the Lombard rate and the discount rate "are key rates as well".

period, has never been clearly spelt out [..] By the same token, frequent reversals in the direction of interest rate changes, which should, perhaps, be bigger on average than in the past, possibly connected with revisions to future forecasts, should not be regarded as a sign of the authorities' failure, but as a sign of their success". From this viewpoint, today's style of application of the FRTs based on a sequence of changes each by up to 50bp within the same phase of the business cycle could be seen as a compromise between the bigger changes (with limited smoothing) advocated by, inter alia, Goodhart and the very small changes (and high degree of smoothing) which a VRT tends to yield.

The current practice could also reflect a game theory type of argument. In a context where the interest rate setting process is not a one-(wo)man decision, it is probably easier to gather a majority in the monetary policy making body around relatively few and "large" interest rate changes, rather than seeking at each meeting an agreement over a change of a few basis points.

If anything, against this background there seems to be a paucity of arguments in favour of the pattern of rate changes supported by a VRT, at least in the case where the central bank conducts its monetary policy in an autonomous way. One possible line of argumentation is that whilst the central bank may have taken a decision on the order of magnitude of the rate change to be implemented over the very-near future (e.g. 50bp within the next two months), it may prefer nonetheless to release this signal in a piecemeal way to test the reaction of financial markets, also in the light of the uncertainties surrounding the impact of a shock on the economy. In doing that, the central bank may broaden its information set and adapt the pace at which the rate change is implemented. A different line of thought could be based on the "open mouth approach" marketed by Guthrie and Wright (1999) and elaborated on the basis of the monetary policy framework which the Reserve Bank of New Zealand used to apply until March 1999. In a nutshell, the intuition behind this approach is that a transparent central bank may teach agents to deliver the appropriate market rates, which would require in turn the submission of appropriate bids at the VRT, without the need to take any explicit action, bar verbal utterances (the "open mouth approach"), at least under normal circumstances. The ultimate goal of this game, if played successfully, would be the enhancement of the central bank's credibility.

Taking all these arguments together, it could be argued that the FRT is the standard, while the VRT is a viable alternative when the central bank is not in the position of releasing a strong interest rate signal. In this light, so goes the common wisdom, the increase in variability of money market rates would be the "price" paid for the use of the latter, non-standard procedure.

3 ANALYSIS OF GERMAN'S DATA FOR THE YEARS 1989-1998

3.1 The data

The bulk of the empirical analysis is carried out on monthly indicators of the variability of a) overnight and three-month interest rates on unsecured interbank deposits denominated in Deutsche

Mark (see also section 5.2.3 below on the choice of these two rates) and of b) the Deutsche Bundesbank's tender rate. The sample runs from January 1989 to December 1998. The starting date was chosen with a view to striking a balance between the need for broad homogeneity of the monetary policy strategy and operational framework adopted by Deutsche Bundesbank –which points to a relatively short sample– and the need to avail of enough variety of phases of the business cycle within the sample, and thus different conditions of action for the central bank –which points to the opposite need of a relatively long sample. In this respect, 1989 was broadly the time when the phase of rise in interest rates which eventually led to the ERM crisis of 1992 started, and happened to be also the first full year after base money had been dismissed a high-profile role in the conduct of monetary policy by the German central bank (Pösö and Stracca, 2001). The end-date was set by the start of EMU.

{CHART 1 ABOUT HERE}

The indicators of variability of the overnight (VOVN) and three-month interest rates (V3M) are calculated as average of the respective day-to-day changes, taken in absolute value, occurring during each reserve maintenance period, which in Germany coincided with the calendar month. As an important technical correction, the monthly indicator of the overnight rate variability is derived from a series of daily observations which does not include the end-of-maintenance period days.[5] The variability of the overnight rate on those days reflects a well-known technical factor –banks are no longer in the position of transferring to the future the imbalance between the availability of funds and the reserve requirements, and at an aggregated level any excess in the demand for funds tends to trigger sharp rises or falls (depending on the sign of the excess demand) in the resulting market overnight rate[6]– and accounts for more than half of the total variability of the month.[7] This component of technical variability, which can easily be identified –as a rule, it does not arise before the execution of the last open market operation of the period–, could have otherwise hidden the policy-related patterns. Unsurprisingly, no large end-of-period component of the variability is observed in the case of the three-month interest rate.

{CHART 2 ABOUT HERE}

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5 In the monetary framework adopted by the Deutsche Bundesbank, the end of the reserve maintenance period may be defined as the period spanning from (and including) the last Wednesday (day of the week of settlement of the weekly open market operation) of the period until the last day of the period.

6 Perez-Quiros and Rodriguez (2000) show that the upward spikes were more frequent than downward spikes as a reflection of the asymmetry of the Deutsche Bundesbank's operational framework where no deposit facility counterbalanced the function played by the Lombard loans.

7 The average day-to-day absolute change in the overnight rate over the selected sample was 9.9bp when all observations are included and 4.3bp when the end-of-maintenance-period observations are excluded. For the three-month interest rate, the average figures are 1.5bp and 1.4bp respectively. Some of the fits presented in Section 4 were replicated also using an indicator of variability of the overnight rate based on the entire series of daily observations, with no significant differences.

To derive the monthly indicator of the variability in tender rates (VOLTR), first a series of the rates applied to the weekly open market operations was compiled using the marginal rate in case of VRTs and the applied rate in case of FRTs (Chart 3); on those weeks when the Deutsche Bundesbank launched more than one tender, the tender with the shortest maturity was considered.[8] Incidentally, it is remarkable the degree of smoothness of the resulting series on those periods when the Deutsche Bundesbank offered VRTs; a successful action of moral suasion by this central bank aimed at having banks submitting only "behaved" bids may account for such a striking result. At an aggregate level, this regularity suggests that German banks could forecast the marginal rate of the VRT quite accurately.

{CHART 3 ABOUT HERE}

The monthly indicator VOLTR was subsequently derived as average of the changes, taken in absolute value, between each observation of the series of tender rates and the next within each month.

{CHART 4 ABOUT HERE}

3.2 Descriptive statistics

Overall, the sample was formed by 10 years of monthly observations, i.e. 120 data points. The Deutsche Bundesbank offered only FRTs in 54 (45%) months, only VRTs in 48 (40%) months and both types of tender within the same month in the remaining 18 (15%) months. In the following, these months are referred to as "FRT months", "VRT months" and "mixed months" respectively, with intuitive meaning.

The variability of both selected market rates, as measured by the indicators described above, was on average lower in FRT months than in VRT months: 3.7bp and 4.3bp respectively for the overnight rate; 1.0bp and 1.6bp respectively for the three-month rate (Table 2). The resulting difference (0.6bp for both interest rates) amounts however to around one fifth of the standard deviation for the overnight

8 This was the tender conveying the policy message. The tender with longer maturity had, as put it by the Deutsche Bundesbank (Monthly Report, May 1994, p. 64), only a role of "double-decker" in the provision of liquidity. Note that until 12 December 1990, the Bundesbank did not announce explicitly a marginal interest rate for variable rate tenders. During that period the marginal rate is here identified with the lower bound of the range of allotment rates.

rate and less than one standard deviation for the three-month interest rate, and is therefore *not* significant by conventional statistical standards.[9]

Table 2

OVERNIGHT AND THREE-MONTH DEUTSCHE MARK INTEREST RATES: DESCRIPTIVE STATISTICS OF MONTHLY VARIABILITY 1989 –1998

(absolute day-to-day change in basis points)

	Average	Median	Standard deviation
	Overnight interest rate [1]		
FRT months [2]	3.7	2.4	3.5
VRT months [3]	4.3	3.4	2.5
Mixed months [4]	6.1	5.3	3.5
Total	4.3	3.2	3.1
	Three-month interest rate		
FRT months [2]	1.0	0.6	0.8
VRT months [3]	1.6	1.3	1.3
Mixed months [4]	2.5	2.3	1.0
Total	1.5	1.1	1.1

Notes
[1] Excluding observations falling between the last Wednesday (day of the week of settlement of the Deutsche Bundesbank's weekly open market operation) of the month and the end of the month (reserve maintenance period). [2] Months when the Deutsche Bundesbank ran its weekly open market operation always as FRT. [3] Months when the Deutsche Bundesbank ran its weekly open market operation always as VRT. [4] Months when the Deutsche Bundesbank ran its weekly open market operation using both tender procedures.

Coming to the distribution of the monthly indicators of variability of the two selected money market rates (Table 3), this is markedly skewed to the left (low values) for the overnight rate under the FRT and to the right in mixed months, while a more even distribution prevails under the VRT. The breakdown into the upper tenth points however to the fact that while *high amounts* of variability are, on average, more frequent under the VRT procedure, the opposite holds when only *very high amounts* are considered. Similar distributions prevail also in the case of the three-month interest rates, with the notable exception though that the FRT procedure does not yield more frequent, in relative terms, occurrences of very high amounts of variability.

[9] "Mixed months" were characterised by higher average variability (see Table 2) and shorter duration (on average 1.4 months in a row compared to 7.7 and 4.4 months for the FRT and VRT months respectively). These findings characterize the mixed months as the point of juncture between prolonged phases of recourse to FRTs and VRTs.

Table 3

OVERNIGHT AND THREE-MONTH DEUTSCHE MARK INTEREST RATES: DISTRIBUTION OF MONTHLY VARIABILITY 1989 –1998

(number of occurrences and percentage; absolute day-to-day change in basis points)

	Lower third	Mid third	Upper third		Total
				o.w. upper tenth	
Overnight rate					
	< 2.4 b.p.	2.4 to 4.9 b.p.	> 4.9 b.p.	> 8.5 b.p.	
FRT months	27 (50%)	15 (28%)	12 (22%)	7 (13%)	54 (100%)
VRT months	13 (27%)	17 (35%)	18 (38%)	2 (4%)	48 (100%)
Mixed months	1 (6%)	7 (39%)	10 (56%)	3 (17%)	18 (100%)
Total	41 (34%)	39 (33%)	40 (33%)	12 (10%)	120 (100%)
Three-month interest rate					
	< 0.7 b.p.	0.7 to 1.7 b.p.	> 1.7 b.p.	> 3.1 b.p.	
FRT months	29 (54%)	16 (30%)	9 (17%)	2 (4%)	54 (100%)
VRT months	12 (25%)	20 (42%)	16 (33%)	6 (13%)	48 (100%)
Mixed months	0 (0%)	4 (22%)	14 (78%)	4 (22%)	18 (100%)
Total	41 (34%)	39 (33%)	40 (33%)	12 (10%)	120 (100%)

Note:
The thresholds shown in the table are chosen so as to have (bar rounding) one third each of the total number of months in the "Lower third", "Mid third" and "Upper third", and one-tenth in the "Upper tenth". See also notes at the bottom of Table 2.

4 THE ECONOMETRIC ANALYSIS

4.1 The general problem

Arguably, the findings just described should be assessed also in the light of the timing of the changes in the tender rate. FRT months, which account for more than half of the sample, are associated to only one tenth of the total tender rate change implemented by the Deutsche Bundesbank in 1989 through 1998.[10] Since times of change should naturally be associated with more uncertainty, the above descriptive statistics may not provide a fair representation, since different results (i.e. a comparatively lower variability under the VRT) could be derived if developments in external conditions are taken in due account.

To this end, a number of fits were run to test the relationship between the volatility of market interest rates, the variability of tender rates, and the patterns of those macroeconomic variables which led the

[10] With reference to the monthly indicator VOLTR, 53% of the rate changes were implemented in VRT months, 36% in mixed months and only 11% in FRT months.

action of the German central bank. Once more, for all fits the sample is January 1989 trough December 1998, for a total of 120 monthly observations. The baseline models used in the fits are:

$$VOVN_t = \beta_0 + \beta_1 * VOLTR_t + \beta_2 * DUMFIX_t + \beta_3 * ECO1_{t-k} + \beta_4 * ECO2_{t-k} + \ldots + \beta_n * DEC_t + \varepsilon_t^{OVN} \quad k \geq 0 \qquad [1]$$

and

$$V3M_t = \gamma_0 + \gamma_1 * VOLTR_t + \gamma_2 * DUMFIX_t + \gamma_3 * ECO1_{t-k} + \gamma_4 * ECO2_{t-k} + \ldots + \gamma_n * DEC_t + \varepsilon_t^{3M} \quad k \geq 0 \qquad [2]$$

for the overnight and three-month interest rates respectively, where DUMFIX is a dummy variable which takes value 1 when on month t the central bank offered only FRTs and 0 otherwise, ECO1, ECO2, etc. are relevant (possibly lagged) macro-economic variables, and VOVN, V3M and VOLTR are as described above. The existence of window dressing behaviour towards the year-end suggested fitting also a seasonal dummy for the month of December (DEC), while ε_t^{OVN} and ε_t^{3M} are random shocks i.i.d.~N(0, σ^2). Finally, fits have been run with and without a variable measuring the change, taken in absolute value, of the Bundesbank's Lombard rate at end month (D_LOMB).

Our test is whether the estimates of the parameters β_2 and γ_2 are statistically different from zero.

4.2 Some methodological notes

Inflation and monetary growth series. The Deutsche Bundesbank used to announce an official target range for the growth rate of M3.[11] In fact, in the academic literature the claim that the German central bank was truly a money targeter, and not actually an inflation targeter, is disputed. In a well-known paper, Bernanke and Mihov (1997) analyse the policy choices of the Bundesbank from 1969 to 1995 and conclude that "although the Bundesbank uses money growth as an important informational variable and operating guide, and despite its protestations to the contrary, it seems to be better characterised as an inflation targeter than as a monetary targeter". In the light of this dispute, measures of both money growth and price consumer's inflation were tried. Moreover, lacking any obvious a priori on what is the appropriate measures of uncertainty surrounding money growth and/or inflation (e.g. whether to measure inflation uncertainty on the basis of a 3-term or 6-term moving standard deviation), a number of indicators were tested and the final selection was carried out using the Schwarz Information Criterion.

Conduct of the fits. The dependent variables VOVN and V3M take by construction only non-negative values. It follows that the fit of [1] and [2] ought to consider ex ante this constraint or, at least, ex post one should check that the fit provides meaningful (positive) results. In our case, the latter approach

[11] Defined as currency in circulation, sight deposits, time deposits with maturity up to four years and saving deposits at statutory notice held by domestic non-banks at domestic banks.

sufficed as the fitted values of the dependent variable turned out to be always positive (see, for example, Chart 5 below).

In addition, the plot of the two dependent variables (Chart 2) suggests the presence of heteroscedasticity, and therefore the need for an appropriate method of fit. Fits were thus conducted using OLS with White's correction for heteroscedatistity and GARCH models of various orders. (Some of the OLS fits were run using Ridge correction; see footnote 17.) The two approaches led to similar qualitative results in terms of the role of the two tender procedures.

Moreover, it was pointed out to us that the key result of same (in statistical terms) average variability might have reflected the fact that, at least on some occasions, the Deutsche Bundesbank would have associated the offer of VRTs with the execution of additional fine-tuning operations to check the otherwise higher market rate variability. This was controlled by adding a variable for the number of fine-tuning operations on each month (NFTOPS).[12]

As a further remark, the results presented above show that "mixed months" were markedly different from both FRT and VRT months, suggesting the possibility to use a second dummy variable to allow differentiating the three types of months. In practice, this turned out to be not feasible due to multi-collinearity. Values of the variable DUMFIX taking value 0 comprise therefore both "VRT months" and "mixed months".

Finally, besides its standard econometric role, the constant plays here a specific economic role and can be described as the sum of two unobserved components of the variability of the money market rates: 1) the market idiosyncrasies described by Hamilton (1996) and 2) the "cost" of some unavoidable amount of news in releasing the monetary policy signal predicted by Haldane and Read (1999).[13]

Monthly or weekly measures of variability? Fits can meaningfully be conducted using a sample of either weekly or monthly observations. Weekly observations allow a direct use of raw data, and avoid the occurrence of "mixed" periods. Conversely, monthly observations allow the use of macroeconomic variables such as rates of growth of monetary aggregates and inflation. In addition, they avoid the need for taking care of the intra-maintenance period patterns of volatility. On balance, the latter type of sample appears to be more advantageous and is here used in the presentation. Fits have however been carried out also using weekly observations, with no changes in the final outcome.

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[12] We are grateful to participants to an internal ECB seminar for raising this point. Given the heterogeneity of fine-tuning operations carried out by the Deutsche Bundesbank, the number of such operations per month appears to be the only sensible summary statistics to be used in the context of the fits.

[13] In the econometric exercise the dummy variable measures the difference in variability between the state '1', the FRT months, and the state '0', the VRT and mixed months. It follows that under this specification the constant can also capture the variability associated with the VRT and the mixed months.

4.3 Results of the fits

Results of the most meaningful OLS and GARCH fits of models [1] and [2] are presented in tables 4 and 5 respectively.[14] In the following presentation, fits will be referred to as 'OVN_1a', 'OVN_2a', 'OVN_3a', 'OVN_4a', 'OVN_1b', 'OVN_2b', 'OVN_3b' where the 'a' in the code indicates the recourse to OLS, while the 'b' the use of a GARCH model. Equivalent codes are used for the three-month (3M) rate.

Amongst the "economic" variables ECO, the most convincing results were obtained using series referred to inflation, in particular a six-term moving standard deviation of the consumer's price inflation (SD_INF) and the expectation of the inflation level rate six-month ahead (EXPINF). A number of indicators referred to M3 growth rates were also tried, but none of them turned out to be highly significant. Incidentally, this result matches the thesis put forward by Bernanke and Mihov (1997). It is worth noting the negative sign of the estimate of SD_INF, which suggests that markets expected some action by the Deutsche Bundesbank (hence, more rate variability) when the inflation outlook was less uncertain. This could signal in turn a risk-averse attitude by this central bank in taking its rate decisions. Besides these two variables, also the change in the IFO index, D_IFO, appears as economic variable in tables 4 and 5.

Overall, the quality of the results is satisfactory, and the structure of the residuals looks reasonably "white noise". The explanatory power of the fits, as measured by the R^2, is close to 30% for the overnight interest rate and is generally between 50% and 60% for the three-month rate, a difference which reflects, in turn, the more "behaved" character of the three-month interest rate when compared with the overnight interest rate (Chart 2). The assessment of the explanatory power of the models ought to take into account also the fact that the dependent variable is not the level of the rates, but its variability, i.e. an indicator with more limited autoregressive component. Moreover, an indicator measuring the daily pattern of the liquidity supply, which might have contributed to the fits, especially those of the overnight rate, was not compiled due to the lack of relevant data.

Fits are presented (with two exceptions) in the version without the variable for the Lombard rate (D_LOMB), since while this variable generally shows the expected positive sign, it turned out to be not significant in any of the fits.

[14] Results of additional fits, not shown in the paper, are available from the author on request.

Table 4

VARIABILITY OF THE DEUTSCHE MARK OVERNIGHT RATE: SELECTED FITS (dependent variable: $VOVN_t$; sample January 1989 – December 1998: 120 monthly observations)							
Variable	Fit						
	OVN_1a	OVN_2a	OVN_3a	OVN_4a	OVN_1b	OVN_2b	OVN_3b
Constant	1.91 (1.19)	2.26 (1.19)	4.81*** (0.47)		1.96 (1.18)	1.97*** (0.75)	4.84*** (0.30)
$VOLTR_t$	0.22*** (0.08)	0.18* (0.09)	0.08 (0.09)	0.003 (0.002)	0.15** (0.07)	0.14 (0.07)	0.07 (0.06)
$DUMFIX_t$	0.26 (0.79)	0.22 (0.78)			-0.18 (0.66)	-0.78 (0.50)	
$DUMFIX96_t$			-3.37*** (0.48)	-0.09*** (0.02)			-3.16*** (0.34)
$EXPINF_{t-1}$	1.42*** (0.40)	1.21*** (0.39)		0.003 (0.01)	1.30*** (0.31)	1.02*** (0.24)	
D_IFO_t			0.18** (0.07)				0.19*** (0.06)
SD_INF_{t-1}	-8.00*** (1.70)	-8.27*** (1.78)		-0.14*** (0.04)	-7.24*** (2.20)	-4.14*** (1.55)	
D_LOMB_t			0.99 (1.58)			0.21 (0.21)	
$NFTOPS_t$		0.35 (0.27)				0.21 (0.21)	
DEC_t	1.82* (0.89)	1.82* (0.91)	1.46 (0.83)	0.05* (0.02)	1.35 (0.71)	1.39** (0.60)	1.66** (0.70)
Method of estimation	OLS-White	OLS-White	OLS-White	OLS-Ridge	GARCH (2)	GARCH (2)	GARCH (2)
R^2	0.28	0.30	0.34	0.37	0.25	0.22	0.33
F-statistics	8.85***	7.82***	11.41***	13.21***	3.57***	2.42***	5.95***
D-W test	1.79	1.76	1.88	1.96	1.70	1.64	1.85
Breusch-Godfrey test	0.72	0.89	0.63	0.87	n.a.	n.a.	n.a.
ARCH test	1.24	1.39	0.91	0.51	0.34	0.08	0.26

Notes:

Standard errors are reported between parentheses. Symbols *,**,*** indicate that estimates exceed the relevant 95%,97.5%,99% critical value of the t-statistics for OLS fits and z-statistics for GARCH fits. Methods of estimation: 'OLS-White': OLS with White heteroskedasticity-consistent standard error covariance matrix; 'OLS-Ridge': OLS with Ridge regressor correction; GARCH(2): GARCH of order 2. The Breusch-Godfrey is a test for rather general forms of serial correlation which can be described by a model ARMA(p,q), with p and q not higher than 2 in the chosen specification. The ARCH test is a Lagrange multiplier test for autoregressive conditional heteroskedasticity, of order 1 in the chosen specification. No constant term appears among the results of fit OVN_4a since the Ridge procedure is based on the preliminary transformation of the original variables into deviations from the mean. Variables: $VOVN_t$: average of the day-to-day changes in absolute value of the DEM overnight rate in month t excluding end-of-month observations; $VOLTR_t$: average of the changes in absolute value of the Deutsche Bundesbank's tender rates executed in month t; $DUMFIX_t$: dummy variable that takes value 1 if on month t the Deutsche Bundesbank offered only FRTs and 0 otherwise; $DUMFIX96_t$: as $DUMFIX_t$, but it may take value 1 only in 1996-1998; $EXPINF_t$: level of the consumption inflation rate expected to prevail in month t+6; SD_INF_{t-1}: six-month moving standard deviation (over period ending in month t-1) of consumption inflation rate; D_IFO_t: change in IFO index in month t; D_LOMB_t: change (in absolute value) between level of the Lombard rate at end-month t and end-month t-1; $NFTOPS_t$: number of fine-tuning operations conducted by the Deutsche Bundesbank in month t; DEC_t: dummy variable that takes value 1 in December.

Table 5

VARIABILITY OF THE DEUTSCHE MARK THREE-MONTH RATE: SELECTED FITS (dependent variable: $V3M_t$; sample January 1989 – December 1998: 120 monthly observations)							
Variable	Fit						
	3M_1a	3M_2a	3M_3a	3M_4a	3M_1b	3M_2b	3M_3b
Constant	0.13* (0.06)	0.15** (0.06)	0.21*** (0.02)		0.04 (0.03)	0.06 (0.03)	0.18*** (0.02)
$VOLTR_t$	0.04*** (0.01)	0.04*** (0.01)	0.04*** (0.006)	0.01*** (0.001)	0.03*** (0.004)	0.03*** (0.003)	0.03*** (0.003)
$DUMFIX_t$	-0.01 (0.04)	-0.01 (0.04)			0.02 (0.03)	0.04 (0.03)	
$DUMFIX96_t$			-0.12*** (0.03)	-0.05*** (0.02)			-0.09*** (0.02)
$EXPINF_{t-1}$	0.04* (0.02)	0.02 (0.02)		-0.004 (0.01)	0.07*** (0.01)	0.05*** (0.01)	
D_IFO_t			0.01** (0.004)				0.003 (0.003)
$SDINF_{t-1}$	-0.22*** (0.08)	-0.24*** (0.08)		-0.03 (0.04)	-0.29*** (0.06)	-0.30*** (0.07)	
D_LOMB_t			0.01 (0.12)			0.21 (0.21)	
$NFTOPS_t$		0.02 (0.02)				0.04*** (0.01)	
DEC_t	0.12 (0.06)	0.12 (0.06)	0.10 (0.06)	0.04*** (0.02)	0.12*** (0.02)	0.09*** (0.03)	0.12*** (0.02)
Method of estimation	OLS-White	OLS-White	OLS-White	OLS-Ridge	Garch (2,2)	Garch (2,2)	Garch (2,2)
R^2	0.54	0.55	0.58	0.57	0.48	0.51	0.55
F-statistics	26.51***	22.98***	31.74***	30.4***	9.78***	10.23***	15.08***
D-W test	1.96	1.90	1.99	2.00	1.53	1.63	1.87
Breusch-Godfrey test	2.14	1.84	1.60	2.05	n.a.	n.a.	n.a.
ARCH test	2.15	4.14*	1.66	2.41	0.08	0.20	1.61

Notes:
$V3M_t$: average of the day-to-day changes taken in absolute value of the three-month rate in month t. See also notes at the bottom of Table 4.

An example of actual and fitted values for fit OVN_1a is presented below.

{CHART 5 ABOUT HERE}

The variable measuring the recourse to fine-tuning operations (NFTOPS) enters the fits with positive sign and has generally no significant impact. This should not be taken as lack of effectiveness. The point is that these operations were mostly aimed at offsetting occasional large imbalances in the liquidity supply, and were not used (at least not as a main purpose) as a tool conducive to smooth interest rate signals.[15] Finally, as expected, some evidence of regular end-of-year pattern is found.

Coming to the key result of the analysis, after a first round of fits ('1a', '2a', '1b' and '2b'), the estimate of the coefficient of DUMFIX turned out to be *not* different from zero across the board. This confirms the finding of the descriptive statistics of no significant difference in the average amount of variability of the selected money market rates depending on whether the Deutsche Bundesbank relied on FRTs or not. The robustness of this result is enhanced by the way the variable DUMFIX was compiled, since this takes value 0 on both "VRT months" and "mixed months", where the latter group of months has been singled out above as months of enhanced variability.[16]

The analysis of the residuals suggested however to try additional variants of [1] and [2]. With reference to fit OVN_2a, the CUSUM test indicates the possibility of a structural break at the beginning of 1996 (see Chart 6), a finding which was confirmed by a Chow test: the probability associated with the null of no structural break on December 1995 is virtually nil. Similar pattern is found for the three-month rate.

{CHART 6 ABOUT HERE)

In the light of the observed distribution of FRTs within the sample, this finding could reflect the fact that prior to 1996, the Deutsche Bundesbank did not offer FRTs for prolonged period of times, while from 1996 to 1998 it relied without interruptions on this tender procedure. This suggested to replace the dummy variable DUMFIX with another variable (DUMFIX96) which took value 1 only on those months in 1996 through 1998 when the Bundesbank offered FRTs, and 0 in all earlier periods, irrespective of the tender procedure adopted.[17] As a result, the quality of the estimates increases, as indicated by the CUSUM test as well as the values of R^2 and the statistics F for fit OVN_3a.

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15 We are grateful to H. Asche, Deutsche Bundesbank, for clarifying words on this point.

16 Fits '2b' have been carried out also using a dummy variable which takes value 1 in VRT months and 0 elsewhere (i.e. in FRT and mixed months). Both in the case of the overnight rate and the three month rate, the estimate of the coefficient of this dummy variable takes a positive sign, confirming a certain increase of the variability in VRT months. However, once more, this increase is not significantly different from zero (the probabilities of the z-statistics are 0.297 in the fit for the overnight rate and 0.500 in the fit for the three-month rate).

17 After the substitution of DUMFIX with DUMFIX96, fits could not be replicated in an exact way due to multicollinearity. In particular, the correlation between DUMFIX96 and EXPINF was –0.64. Two alternative routes were followed to deal with this problem. Firstly, the IFO index and the rate of growth of industrial production were tried as instruments for the series of expectations of inflation. Secondly, fit '1a' was re-estimated using the ridge technique, as developed by Hoerl, Kennard, and Baldwin (1975) based on the preliminary standardisation of the regressor variables, as suggested by Judge *et al*. (1988).

{CHART 7 ABOUT HERE)

Quite interestingly, irrespective of the specific method of estimation and variables used, the estimate of the coefficient of DUMFIX96 was negative and this time significantly different from zero (see fits '3a', '4a' and '3b'). DUMFIX96 seems therefore to encompass those "FRT months" which in terms of the distribution described by Table 3 were clustered in the lower tail, while skipping the occurrences of very high variability which tilted even the overall balance of the average variability under the two tender procedures.

A possible reading of this result is that eventually FRTs fulfil the expected (by common wisdom) stabilisation of market rate variability. Some conditions seem to be needed however to obtain this result. In particular, the experience in Germany in the last years prior to the start of EMU indicates a need for a steady recourse to the instrument and few interest rate changes, i.e. a monetary policy of steady hands to use the words of the Deutsche Bundesbank. It is fair to flag however that those years were characterised also by highly stable macroeconomic conditions, at least with respect to consumer's price inflation (Chart 8). Consequently, it is difficult to prove whether the low market rate variability which occurred at the time the German central bank privileged the recourse to FRTs was a matter of causality or, rather, correlation. In other words, it may well be argued that similar results could have been obtained had the Deutsche Bundesbank insisted in the years 1996 – 1998 on VRTs. In fact, unfortunately, we miss, as ultimate acid test, a period within the sample when the recourse to VRTs took place in a context of "quiet" macroeconomic conditions.

{CHART 8 ABOUT HERE)

5 THE MODEL

5.1 The basic framework

Can the above results be generalised? Under which conditions would the variability of money market rates be systematically lower under FRTs? To shed light on these issues, we present here a simple model of the day-to-day variability of money market rates. A few "stylised facts" ease the design of the model and reduce the number of potential options for consideration.

1) Market participants are virtually certain about the sign of the change, if any, in the FRT rate. This owes to the central banks' habit of staying on hold for relatively long periods on occasion of switches from a sequence of hikes to one of cuts (or viceversa). For example, for the ECB in 1999

through 2001, the average period of time between two rate changes of opposite sign was 7.4 months, compared to an average of 2.0 months between two "change" decisions with same sign.[18]

2) Under the FRT there exists however uncertainty on the amount of the rate change. As noted in section 1, current practice of the ECB is to implement changes in steps by either 25 or 50 bp. Between 1989 and 1998, the Bundesbank changed the FRT rate by 10 / 25 / 30 / 35 basis points.

3) To date, the ECB has always taken a 'no change' decision after a 'change' decision at the previous meeting of its Governing Council. Same the Bundesbank did, again in 1989 through to 1998. Broadening the sample, consecutive changes have however been implemented by the US Fed and the Bank of England.[19]

4) The pattern of the VRT rate can be fit fairly accurately by a linear trend. Using German's data for the three longest sequences of use of VRTs, fits of the model $R_t = \alpha + \beta \times t + \varepsilon_t$ –where R_t is the VRT rate at time t, t goes from 1 to N (number of observations in the sample) and ε_t is a random disturbance– yield the following results:

Table 6

VRTs in Germany: Fits of $R_t = \alpha + \beta * (t / 100)$					
estimates		R^2	s.e. of fit (# of bp)	Sample	No. of obs.
α	β				
6.5***	1.9***	0.95	7	5/6/91 – 9/9/92	57
7.3***	0.8***	0.89	3	3/1/90 – 2/11/90	40
10.7***	–2.0***	0.85	9	12/4/95 – 13/12/95	36

Notes:
OLS fits. Symbols *** indicates that estimates exceed the relevant 99% critical value of the t-statistics.

5) A mild version of fact 1) applies to the VRTs. The noise which surrounds the outcome of this tender procedure leaves some room for immediate reversals. Such room may be limited however: the frequency of the outcome $(r_t - r_{t-1}) \times (r_{t-1} - r_{t-2}) < 0$ was less than 4% in the Bundesbank's record, and no trend reversals are observed (Chart 3). It follows that under the VRT there may be no uncertainty at least on the trend followed by the resulting tender rate.

[18] For the US Fed, in 1996 to 2001 the lapse between two rate changes of opposite sign was 11.1 months, compared to only 1.5 months between two rate changes with same sign. For the Bank of England, June 1997 through to December 2001, the corresponding statistics are 6.2 and 1.8 months respectively.

[19] This difference seems to owe to the various frequencies of the meetings of the monetary policy body. When measured in terms of time, the interval between each 'change' decision and the next (irrespective of the sign of the changes) is close to three months both at the ECB, US Fed and Bank of England.

5.2 The assumptions used in the model

5.2.1 Defining the short-term horizon

The short-term horizon is here defined as the period during which the key policy rate (the tender rate) may take different levels depending on the tender procedure adopted by the central bank, while, conversely, over the medium-term the level of the key policy rate is assumed not to change with the tender procedure. This assumption is embedded in market expectations as follows:

$$E_t\,(R_{t+k}\ /\ \text{fixed rate tender}) = E_t\,(R_{t+k}\ /\ \text{variable rate tender}) \qquad [3a]$$

where R is the central bank's tender rate, the subscript denotes the time, $E_t(X)$ is the mathematical expectation of variable X elaborated by market participants on the basis of information available on day t, and t+k defines the medium term from the point of view of day t, where the information set is updated after each tender operation.

Broadly speaking, the assumption that the level of the key central bank's policy rate does not depend on technicalities such as the tender procedure –with the possible exception of the short term– seems to be a *fait accompli* in monetary policy making. We did not manage to very find explicit quotes in this sense. However, reasoning to the contrary, central banks' analyses and academic research alike hardly phrase the debate on the appropriate monetary policy stance in the terms of such technical aspects.[20]

5.2.2 The main open market operation

The central bank is assumed to refinance the banking system by means of a regular open market operation with two-day maturity carried out and settled at the beginning of the second day of a two-day reserve maintenance period, before the trading session in the market starts. This schedule allows introducing the crucial distinction between the market trading which takes place *before* and *after* respectively the last (only) open market operation of the reserve maintenance period. The former is dominated by the market *expectation* of the rate applied to this operation, while the latter type of trading, taking place towards the end of the reserve maintenance period, is driven by the *realised* rate of the last tender and by imbalances between the available liquidity supply and the reserve requirements. (Bindseil and Seitz, 2001, discuss the role of end-maintenance period days on the equilibrium level of the overnight rate.)

The main open market operation is carried out either as an FRT or as a VRT. Given an objective of total rate change for short-term, under the FRT the objective is fulfilled by the central bank through a sequence of steps of size S (e.g. 25bp or 50bp). Conversely, under the VRT, the central bank steers the resulting rate along a liner a trend, bar random fluctuations.

[20] Underlying this statement there is also today's consensus that the conduct of monetary policy should be oriented towards the medium term.

5.2.3 *Institutional settings of the money market*

Banks are assumed to be perfect-competitors, rationale, risk-neutral agents which take their trading decisions with a view to minimizing the cost of reserve holdings over the entire two-day reserve maintenance period.[21]

Without hopefully much loss of generality, the central bank is assumed to control the liquidity supply in a deterministic way. It follows that the rate applied to the single open market operation carried out each reserve maintenance period drives the cost of liquidity for the banking system over the entire period.[22]

While there exists an entire spectrum of money market rates, market practitioners and economists alike often focus on two pivotal interest rates: the overnight rate and a time deposit rate such as the three-month interbank rate. Emphasis is put here on the fact that these two rates have convenient maturities in the sense that these are respectively shorter and longer than the usual interval of time –from two to six weeks– between each meeting of the central bank's interest-setting body and the next. For example, the ECB's Governing Council normally meets every two weeks, the US Fed's Federal Open Market Committee meets approximately every 1½ months, the Bank of England's Monetary Policy Committee once every month, and, finally, the Monetary Policy Meetings of the Bank of Japan are held with a frequency of at least once per month.[23] It follows that the two selected rates are crucially different insofar one reflects a single interest rate decision by the policy makers, while the other reflects a chain of such decisions. As a further relevant difference, while the overnight rate spans within one maintenance period, a time deposit rate such as the three-month rate spans over more than one period.

The focus is maintained here in the model which assumes that banks exchange funds in the money market at the overnight (one-day) and at the three-day maturity. For simplicity's sake, the latter maturity is chosen because it is the shortest maturity which spans over more than one central bank's interest rate decision (the interest-rate setting process follows the two-day frequency of the regular open market operations), and over more than one maintenance period. The term expectation hypothesis with no risk premia is also assumed to hold.

Finally, to introduce a piece of notation, days are numbered as 1, 2, 3, 4,…, where days 1 and 2 are the first and second day respectively of the first reserve maintenance period, days 3 and 4 are the first and

[21] The reserve requirement is verified on the basis of the average of daily holdings. No carry-over of excess or deficit reserves to the following reserve maintenance period is allowed.

[22] In practice, the central bank does not control the liquidity supply in a deterministic way because autonomous factors are subject to random shocks. These typically trigger some modest noise in the pattern of money market rates during most of the reserve maintenance period and possibly large fluctuations on the last days of the period. Both types of volatility are deemed to be unrelated to the interest rate policy pursued by the central bank. Hence the assumption made in the text should be neutral as regards the final comparison between the money market rates variability under the two tender procedures.

[23] The schedule of the meetings of these central banks is available on the internet at the websites www.ecb.int, www.federalreserve.gov, www.bankofengland.co.uk, www.boj.or.jp/en (English version) respectively.

second day of the second reserve maintenance period, etc.. Day 0 is the day before day 1, and thus the second day of a maintenance period.

5.3 Developing the model

5.3.1 Day-to-day change of money market rates

The assumptions of risk neutrality and profit maximisation imply the equality ex ante of the overnight (OVN) rates prevailing during the reserve maintenance period[24]

$$OVN_t = E_t\,(OVN_{t+1}) \qquad \text{for } t = 1, 3, \dots \qquad [4]$$

while owing to the deterministic control of liquidity by the central bank, on the second and last day of each reserve maintenance period the overnight rate coincides with the rate of the outstanding central bank operation

$$OVN_t = R_t \qquad \text{for } t = 2, 4, \dots \qquad [5]$$

For days 1 and 2 it is straightforward to derive

$$OVN_1 = E_1\,(R_2) \qquad [6a]$$

$$OVN_2 = R_2 \qquad [6b]$$

Coming to the time-deposit (TD) rate, from the assumption on the term expectation hypothesis it follows:

$$TD_t = [OVN_t + E_t(OVN_{t+1}) + E_t(OVN_{t+2})] / 3 \qquad \text{for } t = 1, 2,.. \qquad [7]$$

Elementary algebra yields:

$$TD_1 = [OVN_1 + E_1(OVN_2) + E_1(OVN_3)] / 3 = [2\,E_1(R_2) + E_1(R_4)] / 3 \qquad [8a]$$

$$TD_2 = [OVN_2 + E_2(OVN_3) + E_2(OVN_4)] / 3 = [R_2 + 2\,E_2(R_4)] / 3 \qquad [8b]$$

The absolute change[25] from day 1 to day 2 of the overnight and time deposit rates can now straightforwardly be derived:

$$|OVN_2 - OVN_1| = |R_2 - E_1\,(R_2)| \qquad [9]$$

$$|TD_2 - TD_1| = |R_2 - 2\,E_1(R_2) + 2\,E_2(R_4) - E_1(R_4)| / 3 \qquad [10]$$

Results [9] and [10] are the thrust of the model and in the following our attention will thus be focused on the derivation of expressions for R_2, $E_1\,(R_2)$, $E_2(R_4)$ and $E_1(R_4)$.

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24 The martingale pattern which the overnight rate should follow within each reserve maintenance period in a world void of frictions is a well-known theoretical result, see Campbell (1987) and Hamilton (1996).

25 The solution where signed values are taken is trivial (equal to nil on average for the overnight rate).

A first insight offered by [9] and [10] is that day 4 (more precisely, the fourth day after day 0) is the latest point in time of relevance for our analysis and can thus be considered as effectively starting the medium-term horizon; day 0 is the starting point of the analysis when the system is in equilibrium.

Following the "stylised facts" no. 1 and 5 (see section 5.1) which point to one-sided expectations, the market expectation of the total rate change between day 0 and day 4 is assumed to be positive with no loss of generality. Accordingly, [3a] can be rewritten as:

$$0 \leq E_0 [R_4 / FRT] - R_0 = E_0 [R_4 / VRT] - R_0 \qquad [3b]$$

or equivalently

$$0 \leq E_1 [R_4 / FRT] - R_0 = E_1 [R_4 / VRT] - R_0 \qquad [3c]$$

since the information set used by market to participants to form expectations and available on day 1 is the same as of day 0 (it changes on day 2 after the execution of the tender operation).

Under the FRT, the rate change may equal any of n+1, with n finite, realisations of which one is the 'no change' decision. In formulating their expectations, market associate a probability to the realisation of each state S_i (i=0,…,n) on occasion of the operation conducted on day j (j=2,4). Probabilities are conditional, insofar they depend on the outcome of the previous tender[26]; in particular, the probabilities associated to the outcomes on day 4 depend on the outcome of day 2. We use the symbols $\omega_{i,2}$ and $\omega_{i,4/2}$ to denote the probability associated to the state *i* on day 2 and day 4 respectively:[27]

$$E_1 [R_4 / FRT] = R_0 + \sum_{i=0}^{n} \omega_{i,2} S_i + \sum_{i=0}^{n} \omega_{i,4/2} S_i \text{ with } \sum_{i=0}^{n} \omega_{i,2} = \sum_{i=0}^{n} \omega_{i,4/2} = 1 \text{ and } \omega_{i,j} \in [0,1] \text{ for each } \{i,j\} \qquad [11]$$

Taking as a reference the 1999-2001 record of the ECB, the model is presented below for the case n = 2, with $S_0 = 0$, $S_1 = 25$bp and $S_2 = 50$bp, or with slightly more general notation, $S_0 = 0$, $S_1 = \Delta$ and $S_2 = 2\,\Delta$. This preserves the uncertainty on the amount of the rate change, if any, in accordance, with the 'fact' no. 2, while keeping the analytical presentation hopefully streamlined.

5.3.2 Derivation of results for the overnight rate

Taking a truncated version of [11], the expectation for the tender rate on day 2 can be written

$$E_1 (R_2 / FRT) = R_0 + \omega_{1,2} \Delta + 2\, \omega_{2,2} \Delta = R_0 + (\omega_{1,2} + 2\, \omega_{2,2}) \Delta \qquad [12]$$

[26] The fact that probabilities are conditional is well illustrated by the "stylised fact" no. 3 where it is pointed out that, to date, the ECB has always taken a 'no change' decision after a 'change' decision.

[27] We do not need to characterize explicitly the dependency of the outcome of the tender executed on day 2 on the result of the previous operation given the assumption of day 0 as the starting equilibrium state.

It follows[28]

– if $R_2 = R_0$ $\Rightarrow OVN_2 - OVN_1 = R_0 - R_0 - (\omega_{1,2} + 2\,\omega_{2,2})\,\Delta = -(\omega_{1,2} + 2\,\omega_{2,2})\,\Delta$ [13a]

– if $R_2 = R_0 + \Delta$ $\Rightarrow OVN_2 - OVN_1 = R_0 + \Delta - R_0 - (\omega_{1,2} + 2\,\omega_{2,2})\,\Delta = (1 - \omega_{1,2} - 2\,\omega_{2,2})\,\Delta$ [13b]

– if $R_2 = R_0 + 2\,\Delta$ $\Rightarrow OVN_2 - OVN_1 = R_0 + 2\,\Delta - R_0 - (\omega_{1,2} + 2\,\omega_{2,2})\,\Delta = (2 - \omega_{1,2} - 2\,\omega_{2,2})\,\Delta$ [13c]

Finally, taking absolute values, the difference $OVN_2 - OVN_1$ over the three possible outcomes of R_2 is[29]

$$\left|OVN_2 - OVN_1\right| = 2\,\omega_{2,2} \times [2 - \omega_{1,2} - 2\,\omega_{2,2}]\,\Delta \qquad \text{if } \omega_{1,2} + 2\,\omega_{2,2} \geq 1 \qquad [14a]$$

$$= 2\,[\omega_{1,2} + 2\,\omega_{2,2} - 3\,\omega_{1,2}\,\omega_{2,2} - (\omega_{1,2})^2 - 2\,(\omega_{2,2})^2]\,\Delta \qquad \text{if } \omega_{1,2} + 2\,\omega_{2,2} < 1 \qquad [14b]$$

For example, if markets expect with probability $\omega_{2,2} = 1$ that a hike by 2 times Δ will be implemented and this change is delivered, using [14a] the overnight rate stays constant from day 1 to day 2, reflecting the full anticipation of the rate increase by the central bank. If the relative frequencies observed in 1999 through 2001 for the ECB are taken as probabilities, i.e. $\omega_{1,2} = 0.097$ and $\omega_{2,2} = 0.069$, and Δ equals 25bp, $\left|OVN_2 - OVN_1\right|$ equals 9.8bp using [14b]. Searching over all suitable pairs $\{\omega_{1,2}, \omega_{2,2}\}$ with step 0.01, the average of $\left|OVN_2 - OVN_1\right|$ can be worked out equal to 19.6bp when $\Delta = 25$bp, while the corresponding standard deviation is 8.6bp.[30]

Coming to the case of VRTs, building on the model $R_t = \alpha + \beta \times t + \varepsilon_t$ presented under the "stylised fact" No. 4, for t = 2 it holds

$$(R_2 / VRT) = \alpha + 2\,\beta + \varepsilon_2 \qquad [15]$$

from which it follows

$$E_1\,(R_2 / VRT) = \alpha + 2\,\beta \qquad [16]$$

Substituting [15] and [16] in [9], it is immediate to derive

$$\left|OVN_2 - OVN_1\right| = \left|\varepsilon_2\right| \qquad [17]$$

So far, no explicit assumptions have been made regarding the distribution of the disturbance ε. As a baseline scenario, we will adopt the assumption of normal distribution with mean 0 and variance σ^2.

[28] To ease the presentation, the specification FRT or VRT is omitted when there should be no doubts to which tender procedure the rate R refers.

[29] If $R_2=R_0$ then $\left|OVN_2–OVN_1\right|=(\omega_{1,2}+2\omega_{2,2})\Delta$; if $R_2=R_0+2\Delta$ then $\left|OVN_2–OVN_1\right|=(2–\omega_{1,2}–2\omega_{2,2})\Delta$; if $R_2=R_0+\Delta$ then $\left|OVN_2–OVN_1\right|=(1–\omega_{1,2}–2\omega_{2,2})\Delta$ if $\omega_{1,2}+2\omega_{2,2}<1$ and $\left|OVN_2–OVN_1\right|=(–1+\omega_{1,2}+2\omega_{2,2})\Delta$ otherwise. It follows that if $\omega_{1,2}+2\omega_{2,2}\geq 1$, $\left|OVN_2–OVN_1\right|=[\omega_{1,2}(–1+\omega_{1,2}+2\omega_{2,2})+\omega_{2,2}(2–\omega_{1,2}–2\omega_{2,2})+(1–\omega_{1,2}–2\omega_{2,2})(\omega_{1,2}+2\omega_{2,2})]$ which using simple algebra yields result [14a]. A corresponding procedure yields [14b].

[30] A four-step procedure yields these numerical results. First, as both $\omega_{1,2}$ and $\omega_{2,2}$ are defined over the closed interval [0,1], for the step 0.01, a matrix corresponding to the 101^2 combinations of the sequence {0, 0.01, 0.02, …, 1) can be derived. Second, all combinations which do not meet the constraint $(\omega_{1,2}+\omega_{2,2}) \leq 1$ are discarded. Third, for each suitable pair $\{\omega_{1,2},$

For this distribution, it is fairly straightforward to derive the moments of the absolute value $|\varepsilon|$, the mean and the standard deviation of which are $2\,\phi(0)\,\sigma$ and $\{1 - 4\times[\phi(0)]^2\}\sigma^2$ respectively, where $\phi(.)$ is the probability density function of a standard normal distribution (see annex 1). In the Bundesbank's record, σ ranged from 3bp to 9bp (see Table 6). If, say, $\sigma = 3$bp, $|OVN_2 - OVN_1|$ equals 2.4bp, and the corresponding standard deviation is 3.3bp. Table 7 presents the results obtained so far using [14a] and [14b], for the FRT and [17] for the VRT.

Table 7

Moments of $|OVN_2 - OVN_1|$ (number of basis points)			
		Average	Standard deviation
FRT		19.6	8.6
VRT	$\sigma = 3$	2.4	1.8
	$\sigma = 9$	7.2	5.4
	$\sigma = 24$	19.1	14.5

To recapitulate, if the distribution of the noise ε lies within the historical record of the Bundesbank, i.e. $\sigma \in$ [3bp, 9bp], on average the VRT yields a substantially smaller day-to-day change in the overnight rate. Alternatively, to obtain under the VRT an average day-to-day change comparable to the FRT, the standard deviation σ ought to be equal to 24bp, which is a quite large, and unusual amount of noise for a VRT.

What if the disturbance ε follows a non-normal distribution?[31] Computational difficulties –the fact that, to the best of our knowledge, there is no easy way to calculate the moments of the distribution of $|\varepsilon|$ for ε with tails fatter than normal– hampered a full investigation of this case. The following can be observed however. Given a distribution with probability density function $\phi^*(.)$ and "fat" tails, the inequality $\phi^*(0) < \phi(0)$ should hold, so that for given σ numerical results for the mean of $|\varepsilon_2|$ may be even lower than those presented in table 7 for the VRT (if a result of the type $2\phi(0)\sigma$ holds). The opposite result should (unsurprisingly) hold for the standard deviation. This should add scepticism, if anything, as regards the assertion that the variability of money market rates is always higher under VRTs.

$\omega_{2,2}\}$ the value of $|OVN_2 - OVN_1|$ is worked out using [14a] or [14b] as appropriate. Fourth, descriptive statistics (mean, standard deviation) are derived over the sample formed by the results of the previous step.

[31] I am indebted to an anonymous referee for helping highlighting this issue. Noted that the assumption of normality applies here to the residuals and not to the tender rate directly, due consideration should be given to the often-found result in the empirical literature that financial variables have "fat" tails.

5.3.3 Derivation of results for the time-deposit rate

Starting from the FRT, result [11] can be rewritten as

$$E_1 (R_4 / FRT) - R_0 = \omega_{1,2}\,\Delta + \omega_{2,2}\,(2\Delta) + \omega_{1,4/2}\,\Delta + \omega_{2,4/2}\,(2\Delta) = (\omega_{1,2} + 2\,\omega_{2,2} + \omega_{1,4/2} + 2\,\omega_{2,4/2})\,\Delta \qquad [18]$$

As argued above, the probabilities $\omega_{1,4/2}$ and $\omega_{2,4/2}$ are conditional on the outcome of the tender on day 2. Drawing from the a limited generalisation of the "stylised fact" No. 3, we assume as a baseline scenario:

– if $R_2 = R_0 \quad \Rightarrow \quad \omega_{1,4/2} = \omega_{1,2}$ and $\omega_{2,4/2} = \omega_{2,2}$ [19a]

– if $R_2 = R_0 + \Delta \quad \Rightarrow \quad \omega_{1,4/2} \in [0,1]$ and $\omega_{2,4/2} = 0$ [19b]

– if $R_2 = R_0 + 2\,\Delta \quad \Rightarrow \quad \omega_{1,4/2} = \omega_{2,4/2} = 0$ [19c]

where [19a] says that if on day 2 no change is implemented, the distribution of markets' expectations which prevailed with respect to day 2 applies again unchanged to day 4; [19c] says that if a change by 2 times Δ is implemented on day 2, no further changes will be expected on day 4, while [19b] relaxes this assumption in case of a change by Δ, insofar it allows the possibility of a further change by Δ.[32]

Note that taken together these assumptions imply a change in the FRT rate from day 0 to day 4 comprised between 0 and 50 bp.

Using some simple algebra, [19a] – [19c] allow the derivation of expressions for $E_2(R_4)$ and $E_1(R_4)$. In turn, using the above results $E_1(R_2)$, explicit expressions for result [10] can be derived. While these steps are conceptually simple, the resulting expressions are fairly long and of limited interest per se, and are therefore presented in Annex 2.

What are of interest instead are the corresponding numerical results. These are presented in table 8 for $\omega_{1,4/2} = \omega_{1,2}$, $\omega_{1,4/2} = 0.5\,\omega_{1,2}$ and $\omega_{1,4/2} = (1+\omega_{1,2})/2$, where the latter two cases correspond to $\omega_{1,4/2}$ being the middle point between 0 and $\omega_{1,2}$ and between $\omega_{1,2}$ and 1 respectively. This should cater for a range broad enough of possible options, and implicitly provide a test of sensitiveness of the results of the model to changes in the underlying assumptions.

Coming to the VRT, building on [15]

$$E_1 (R_4 / VRT) = \alpha + 4\,\beta \qquad [20]$$

and

$$R_2 - R_0 = 2\beta + \varepsilon_2 \qquad [21]$$

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[32] If one followed the ECB's and Bundesbank's record strictly, $\omega_{1,4/2}$ ought to be nil in [19b].

where R_0 equals α, i.e. no disturbance exists in the steady state of time 0. Since markets expectations adjust to the new information, the expected increase from time 2 to time 4 equals the right hand-side of [21]:

$$E_2 (R_4) - R_2 = 2\beta + \varepsilon_2 \qquad [22a]$$

from which using [15]

$$E_2 (R_4) = \alpha + 4\beta + 2\,\varepsilon_2 \qquad [22b]$$

In turn, the substitution of [15], [16], [20] and [22] in [10] yields

$$\left| TD_2 - TD_1 \right| = \left| 2/3\,\beta + 5/3\,\varepsilon_2 \right| \qquad [23]$$

To derive numerical results for [23], we need some assumptions for ε_2 – already done above – and for β. Since this parameter controls the speed of change in the VRT rate, to make the numerical results for FRTs and VRTs comparable and close the model, we assume that also under the latter procedure the increase between time 0 and time 4 of the tender rate is comprised between 0 and 50bp, bar random fluctuations.

$$0 \le E_1 (R_4 / VRT) - R_0 = \alpha + 4\beta - \alpha \le 50 \qquad [24]$$

so that

$$0 \le \beta \le 12.5 \qquad [25]$$

Numerical results for [10] under the two tender procedures are shown in Table 8; analytical expressions for the average and the variance of [23] are presented in Annex 1.

Table 8

Moments of $\left| TD_2 - TD_1 \right|$
(number of basis points)

			Average	standard deviation
FRT	$\omega_{1,4/2} = \omega_{1,2}$		10.9	2.8
	$\omega_{1,4/2} = 0.5\ \omega_{1,2}$		10.8	2.8
	$\omega_{1,4/2} = (1- \omega_{1,2})/2$		10.4	3.3
VRT	$\sigma = 3$	$\beta = 0$	4.0	1.8
		$\beta = 12.5$	8.9	2.7
	$\sigma = 9$	$\beta = 0$	12.0	5.4
		$\beta = 12.5$	15.5	6.4

Admittedly, further analytical solutions could be devised by playing with the various assumptions. Again, the chosen settings should however hopefully act as convenient benchmarks against which such solutions can be assessed. With respect to the numerical results, Table 8 shows that already within the range of σ resulting from the Bundesbank's record, the average amount of variability can be lower under either of the two tender procedures. It follows that no conclusion pointing to the dominance (in the sense of delivering lower money market rate variability) of one or the other tender procedure seems to be warranted.

6 CONCLUDING REMARKS

This paper has examined the issue of the conduct by the central bank of its main open market operation via either a fixed-rate tender or a variable-rate tender procedure. The variability of money market rates which remains associated with each of the two tender procedures has been used as metric for comparison. In particular, the focus is on the overnight and the three-month deposit rates, which, besides their well-established role in market analyses, play a convenient analytical role given that the associated market expectations cover respectively one and a number of decisions of the monetary policy making body (as well as one and a number of reserve maintenance periods).

Current practice points to a widespread use of FRTs and other signalling mechanisms which likewise yield changes in the key policy rate in steps, as opposed to the piecemeal, but also more noisy rate changes which are typical of VRTs. Given this preference and the fact that central banks are usually keen on preserving fairly stable conditions in the money market, one could expect clear evidence pointing to a lower variability of money market rates under the FRT, as regards the alternative tender procedure. In fact, the findings presented in this paper highlight the lack of any such systematic nexus.

The paper has first presented some empirical results drawn from the experience in Germany in the decade prior to the start of EMU, i.e. in 1989 through 1998. This country was chosen because, as an almost unique setting, its central bank alternated over time the two tender procedures under examination and retained autonomy in setting the domestic interest rates. As a main result, while the average variability of the German overnight and three-month rates was lower in those months when the Deutsche Bundesbank offered only fixed-rate tenders than when it offered only variable-rate tenders, the difference turns out to be *not* statistically significant.

This result was confirmed also by an econometric analysis where we controlled for the patterns of those economic indicators which led the action of the Deutsche Bundesbank, notably broad money growth and the consumers' price inflation, as well as for the changes in the Lombard rate, recourse to fine-tuning operations and seasonal regularities.

Subsequently, the paper has presented a small model of the variability within the reserve maintenance period of the overnight rate and of a generic time deposit rate with maturity longer than the interval between two interest rate decisions. The model draws on a limited generalisation of the ECB's and Bundesbank's records. (Admittedly, not the only potential solution.) As a main finding, it suggests that the aforementioned main result should not be seen only as a feature of the experience in Germany, but may hold true under quite general conditions. For example, to achieve same average day-to-day change in the overnight rate under the two tender procedures, the noise characterising the rate resulting from the VRT ought to be more than twice as loud as the loudest one found in German records. More mixed results are obtained for the case of time deposit rates, where neither of the two tender procedures seems to prevail.

This body of evidence should not be interpreted as lack of any proof in favour of fixed-rate tenders. For example, the econometric analysis highlights a significant lowering of the market rate variability when only the FRTs offered from 1996 to 1998, rather than over the entire sample, are considered. This was also (approximately) the time when the Deutsche Bundesbank emphasised its preference for a "monetary policy of steady hands", to mean a style of implementation of monetary policy characterised by a great amount of stability and few and predictable interest rate changes. It is also of some relevance the fact that in autumn 1992, at the peak of the EMS crisis, the Deutsche Bundesbank flagged its intention to switch from a series of rate hikes to a new phase of rate cuts via the re-introduction of the fixed-rate tenders. (Using the words of this central bank, the rate of the FRT had an "unequivocal form of interest rate leadership".) Reasoning to the contrary, one could well argue that VRTs do not quite suit the scope for reversals in the trend.

In fairness, there still remains a degree of controversy over the period from 1996 to 1998. This is because Germany did not experience, within the selected sample, a similar period of broadly "quiet" macro-economic conditions and simultaneous use of variable-rate tenders. In other words, it is difficult to rule out the possibility that in the last three years prior to the start of EMU a lowering of market rate variability would have been obtained anyway, irrespective of the tender procedure adopted. With regard to the experience of 1992, while this is certainly a relevant case study, a word of caution should be exercised in drawing general conclusions from a single episode, which occurred under rather exceptional circumstances.

In order to keep the derivation of the analytical results and the subsequent numerical exercises simple, a number of assumptions have been adopted and, naturally, different results could hold when different assumptions are taken. For example, the instance whereby the disturbance associated to the VRT rate follows a non-normal distribution has not been fully explored. However, the range of results from the various numerical exercises is broad enough to suggest a rather sceptical view of the assertion that the variability of money market rates is necessarily lower under the FRT procedure.

To conclude, a number of arguments may still explain the current consensus in favour of fixed-rate tenders. For example, a big plus in this procedure is the more immediate measurability of the impact of each rate decision on financial markets. In addition, further light should be shed on issues such as the nexus between the two tender procedures in question and the transmission of the monetary policy signal to long-term rates. Or, on the link with the dynamics of the interest-rate setting process, including the game played within the monetary policy-making body. The results presented in this paper lend support however to the view that variable-rate tenders, as an alternative to fixed-rate tenders, should not be rejected on the grounds of triggering higher variability of money market rates, where this is measured over a sufficiently long sample comprising different phases of the business cycle.

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ANNEX 1

Following the presentation in Johnson and Kotz (1970), given a variable $X \sim N(0, \nu^2)$ and its linear transformation $(\alpha + \gamma X) \sim N(\alpha, \gamma^2 \nu^2)$, the absolute value $|\alpha + \gamma X|$ is also distributed normally with average

$$E\{|\alpha+\gamma X|\} = \alpha + \frac{\phi\left(\frac{\alpha}{\gamma\nu}\right)}{\Phi\left(\frac{\alpha}{\gamma\nu}\right)}\beta\nu \qquad [A.1]$$

and variance

$$V\{|\alpha+\gamma X|\} = \left\{1 - \frac{\left(\frac{\alpha}{\gamma\nu}\right)\phi\left(\frac{\alpha}{\gamma\nu}\right)}{\Phi\left(\frac{\alpha}{\gamma\nu}\right)} - \left[\frac{\phi\left(\frac{\alpha}{\gamma\nu}\right)}{\Phi\left(\frac{\alpha}{\gamma\nu}\right)}\right]^2\right\}\nu^2 \qquad [A.2]$$

where $\phi(.)$ is the probability density function of a standard normal distribution, and $\Phi(.)$ the corresponding cumulated function. It follows that given $\varepsilon \sim N(0, \sigma^2)$

$$E\{|\varepsilon|\} = 2\,\phi(0)\sigma \qquad [A.3]$$

$$V\{|\varepsilon|\} = \left[1 - 4\phi^2(0)\right]\sigma^2 \qquad [A.4]$$

and

$$E\{|\tfrac{2}{3}\beta + \tfrac{5}{3}\varepsilon|\} = \frac{2}{3}\beta + \frac{\phi\left(\frac{2\beta}{5\sigma}\right)}{\Phi\left(\frac{2\beta}{5\sigma}\right)}\frac{5}{3}\sigma \qquad [A.5]$$

$$v\{|\tfrac{2}{3}\beta + \tfrac{5}{3}\varepsilon|\} = \left\{1 - \frac{\frac{2\beta}{5\sigma}\phi\left(\frac{2\beta}{5\sigma}\right)}{\Phi\left(\frac{2\beta}{5\sigma}\right)} - \left[\frac{\phi\left(\frac{2\beta}{5\sigma}\right)}{\Phi\left(\frac{2\beta}{5\sigma}\right)}\right]^2\right\}\sigma^2 \qquad [A.6]$$

where $|OVN_2 - OVN_1| = |\varepsilon_2|$ and $|TD_2 - TD_1| = |\frac{2}{3}\beta + \frac{5}{3}\varepsilon_2|$.

ANNEX 2

For the FRTs, the following results hold:

$E_1(R_4) = R_0 + [2\,\omega_{1,2} + 4\,\omega_{2,2} - 3\,\omega_{1,2}\,\omega_{2,2} + \omega_{1,2}\,\omega_{1,4/2} - (\omega_{1,2})^2 - 2\,(\omega_{2,2})^2]\,\Delta$ [A.7]

and

$E_2(R_4) = R_0 + (\omega_{1,2} + 2\,\omega_{2,2})\,\Delta$ if $R_2 = R_0$ [A.8a]

$E_2(R_4) = R_0 + (1 + \omega_{1,4})\,\Delta$ if $R_2 = R_0 + \Delta$ [A.8b]

$E_2(R_4) = R_0 + 2\,\Delta$ if $R_2 = R_0 + 2\,\Delta$ [A.8c]

Substituting results [12], [A.7] and [A.8] in [10], it follows

if $R_2 = R_0$

$\Rightarrow \quad TD_2 - TD_1 = -\,[2\,\omega_{1,2} + 4\,\omega_{2,2} - 3\,\omega_{1,2}\,\omega_{2,2} + \omega_{1,2}\,\omega_{1,4/2} - (\omega_{1,2})^2 - 2\,(\omega_{2,2})^2]\,\Delta / 3$ [A.9a]

if $R_2 = R_0 + \Delta$

$\Rightarrow \quad TD_2 - TD_1 = [3 - 4\,\omega_{1,2} - 8\,\omega_{2,2} + 2\,\omega_{1,4/2} + 3\,\omega_{1,2}\,\omega_{2,2} - \omega_{1,2}\,w_{1,4/2} + (\omega_{1,2})^2 + 2\,(\omega_{2,2})^2]\,\Delta / 3$[A.9b]

if $R_2 = R_0 + 2\,\Delta$

$\Rightarrow \quad TD_2 - TD_1 = [6 - 4\,\omega_{1,2} - 8\,\omega_{2,2} + 3\,\omega_{1,2}\,\omega_{2,2} - \omega_{1,2}\,\omega_{1,4/2} + (\omega_{1,2})^2 + 2\,(\omega_{2,2})^2]\,\Delta / 3$ [A.9c]

where [A.9a] is always negative, [A.9c] is always positive, and [A.9b] can take either sign.

In the main text, numerical results are presented for the cases A) $\omega_{1,4/2} = \omega_{1,2}$, B) $\omega_{1,4/2} = 0.5\,\omega_{1,2}$ and C) $\omega_{1,4/2} = (1+\omega_{1,2})/2$, which correspond to:

A) if i) $\omega_{1,4/2} = \omega_{1,2}$ and ii) $TD_2 - TD_1 > 0$ when $R_2 = R_0 + \Delta$

$\Rightarrow \quad |TD_2 - TD_1| = [5\,\omega_{1,2} + 10\,\omega_{2,2} - 21\,\omega_{1,2}\,\omega_{2,2} - 4\,(\omega_{1,2})^2 - 14(\omega_{2,2})^2 + 6\,(\omega_{1,2})^2\,\omega_{2,2} + 10\,\omega_{1,2}$
$(\omega_{2,2})^2 + 4\,(\omega_{2,2})^3]\,\Delta / 3$ [A.10a]

if i) $\omega_{1,4/2} = \omega_{1,2}$ and ii) $TD_2 - TD_1 < 0$ when $R_2 = R_0 + \Delta$

$\Rightarrow \quad |TD_2 - TD_1| = [-\,\omega_{1,2} + 10\,\omega_{2,2} - 5\,\omega_{1,2}\,\omega_{2,2} - 14\,(\omega_{2,2})^2 + 6\,\omega_{1,2}\,(\omega_{2,2})^2 + 4\,(\omega_{2,2})^3]\,\Delta / 3$ [A.10b]

B) if i) $\omega_{1,4/2} = \omega_{1,2}/2$ and ii) $TD_2 - TD_1 > 0$ when $R_2 = R_0 + \Delta$

$\Rightarrow \quad |TD_2 - TD_1| = [5\,\omega_{1,2} + 10\,\omega_{2,2} - 21\,\omega_{1,2}\,\omega_{2,2} - 5.5\,(\omega_{1,2})^2 - 14\,(\omega_{2,2})^2 + 6.5\,(\omega_{1,2})^2\,\omega_{2,2} + 10\,\omega_{1,2}$
$(\omega_{2,2})^2 + 1.5\,(\omega_{1,2})^3 + 4\,(\omega_{2,2})^3]\,\Delta / 3$ [A.11a]

if i) $\omega_{1,4/2} = \omega_{1,2}/2$ and ii) $TD_2 - TD_1 < 0$ when $R_2 = R_0 + \Delta$

$\Rightarrow \quad |TD_2 - TD_1| = [-\,\omega_{1,2} + 10\,\omega_{2,2} - 5\,\omega_{1,2}\,\omega_{2,2} + 0.5\,(\omega_{1,2})^2 - 14\,(\omega_{2,2})^2 + 1.5\,(\omega_{1,2})^2\,\omega_{2,2} + 6\,\omega_{1,2}\,(\omega_{2,2})^2 + 4\,(\omega_{2,2})^3]\,\Delta / 3$ [A.11b]

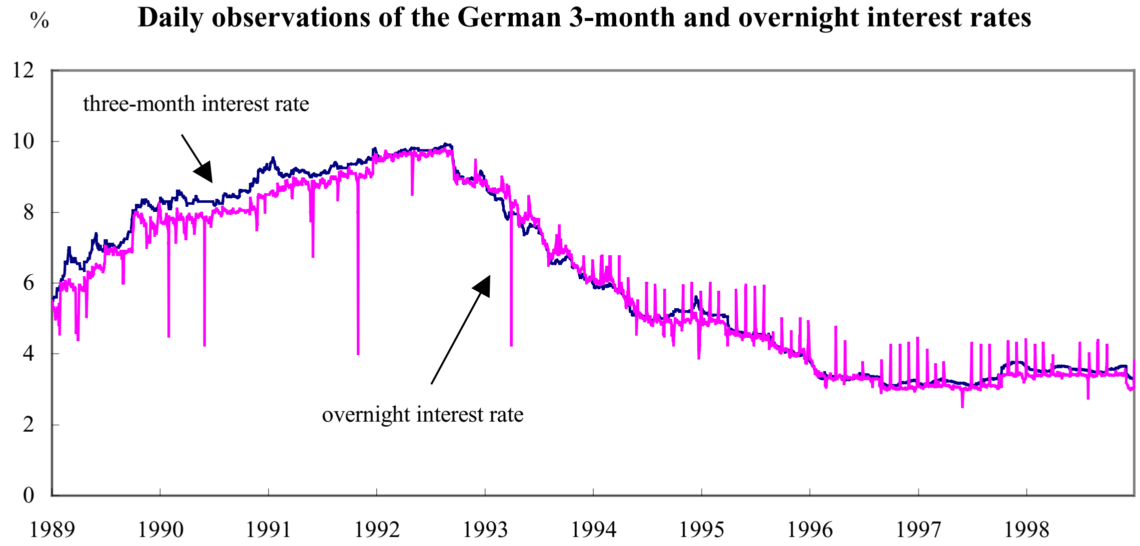
C) if i) $\omega_{1,4} = (1+\omega_{1,2})/2$ and ii) $TD_2 - TD_1 > 0$ when $R_2 = R_0 + \Delta$

$\Rightarrow \quad |TD_2 - TD_1| = [6.5\,\omega_{1,2} + 8\,\omega_{2,2} - 14\,\omega_{1,2}\,\omega_{2,2} - 6.5\,(\omega_{1,2})^2 - 12\,(\omega_{2,2})^2 + (\omega_{1,2})^2\,\omega_{2,2} + 6\,\omega_{1,2}\,(\omega_{2,2})^2 + 4\,(\omega_{2,2})^3]\,\Delta / 3$ [A.12a]

if i) $\omega_{1,4/2} = (1+\omega_{1,2})/2$ and ii) $TD_2 - TD_1 < 0$ when $R_2 = R_0 + \Delta$

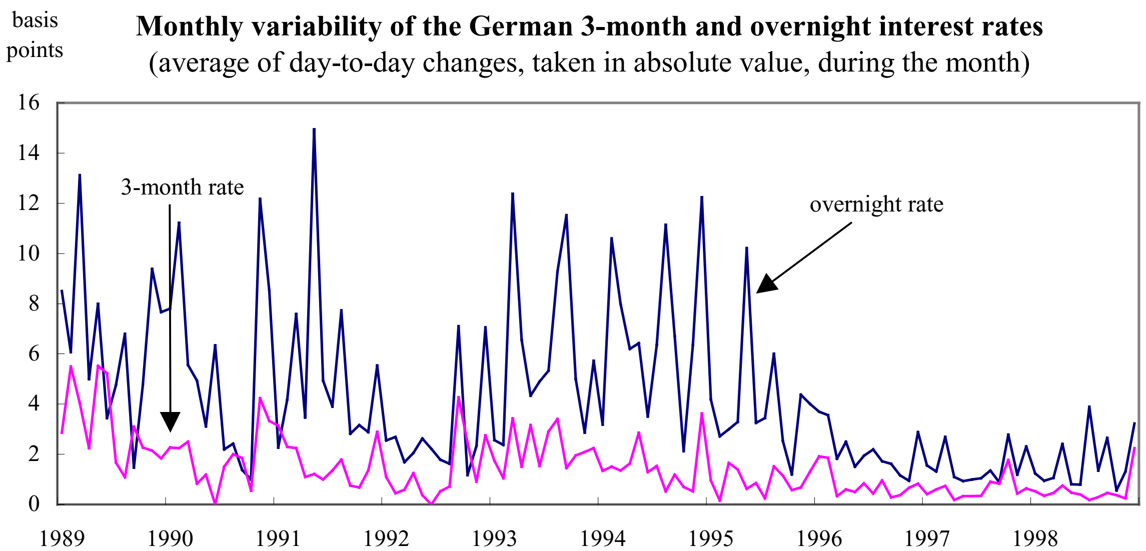
$\Rightarrow \quad |TD_2 - TD_1| = [-\,1.5\,\omega_{1,2} + 10\,\omega_{2,2} - 6\,\omega_{1,2}\,\omega_{2,2} + 0.5\,(\omega_{1,2})^2 - 14\,(\omega_{2,2})^2 + (\omega_{1,2})^2\,\omega_{2,2} + 6\,\omega_{1,2}\,(\omega_{2,2})^2 + 4\,(\omega_{2,2})^3]\,\Delta / 3$ [A.12b]

Chart 1



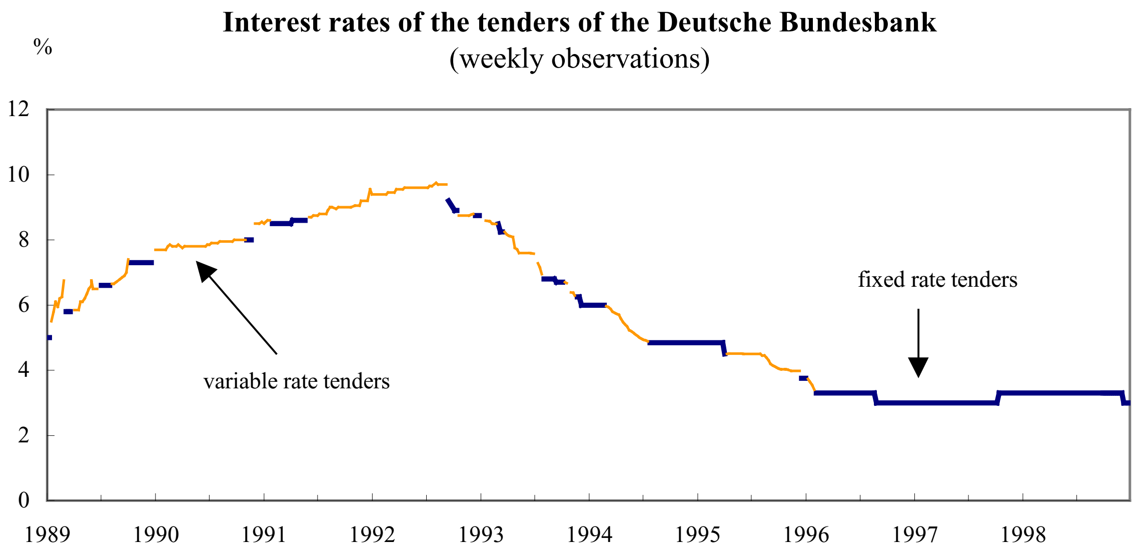
Source: BIS

Chart 2



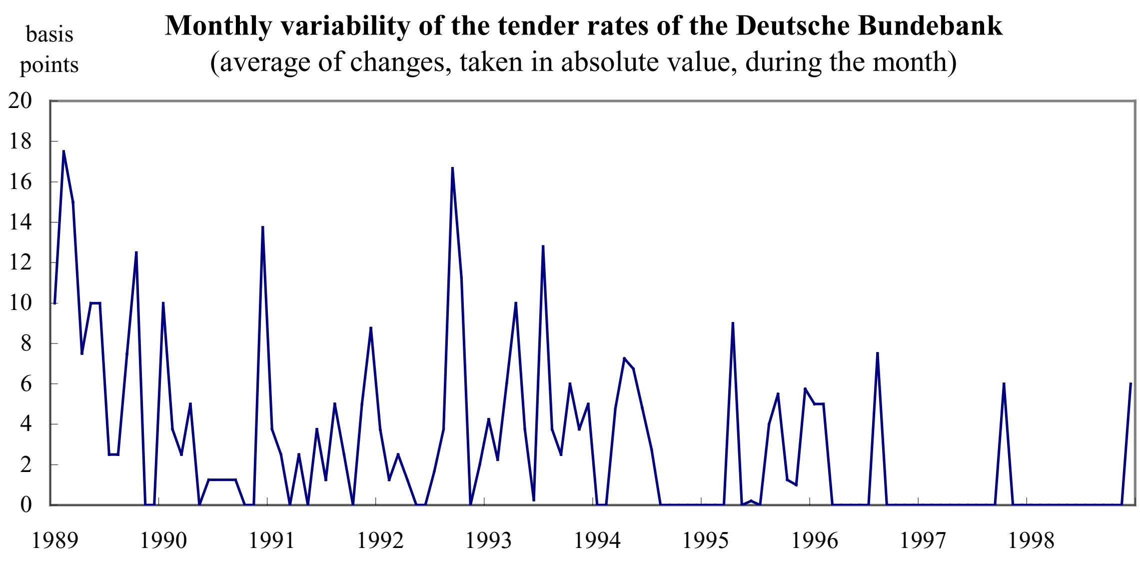
Source: BIS and author's calculations

Chart 3



Source: Deutsche Bundesbank and author's calculations

Chart 4



Source: Deutsche Bundesbank and author's calculations

Chart 5

Actual and fitted values of monthly indicator of overnight variability (fit OVN_1a)

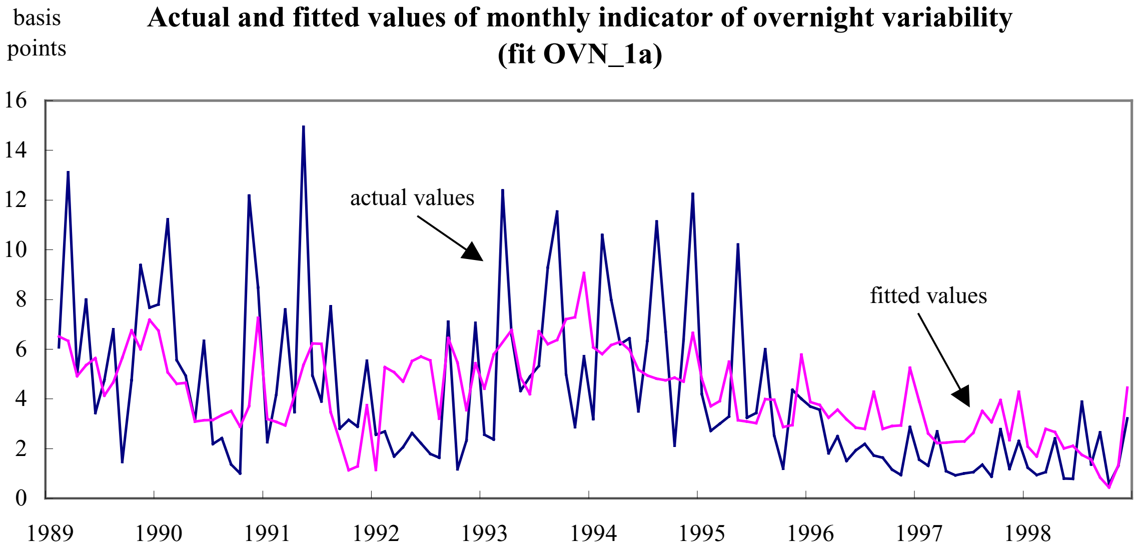


Chart 6

CUSUM test for fit OVN_2a

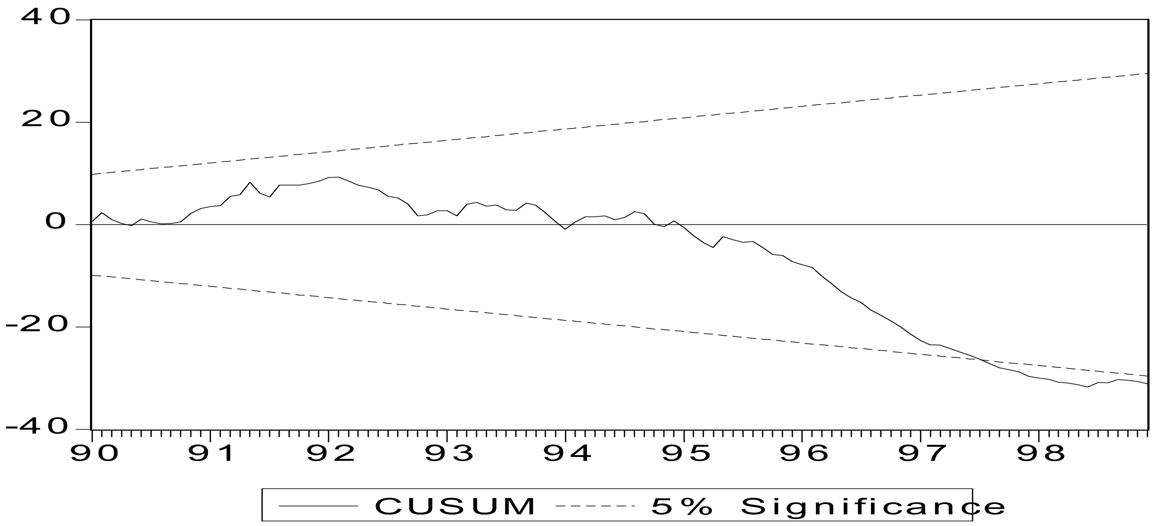


Chart 7

CUSUM test for fit OVN_3a

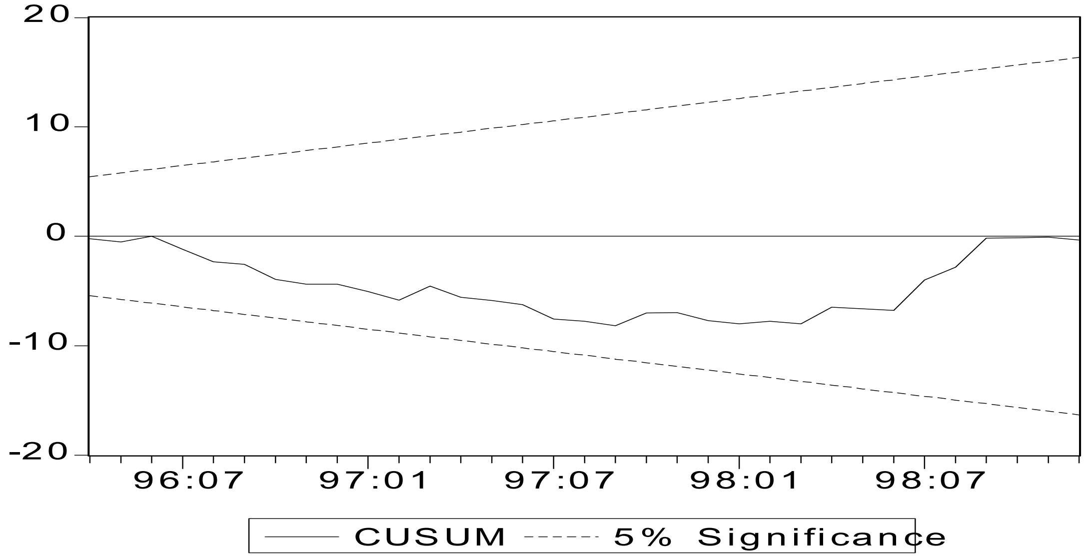
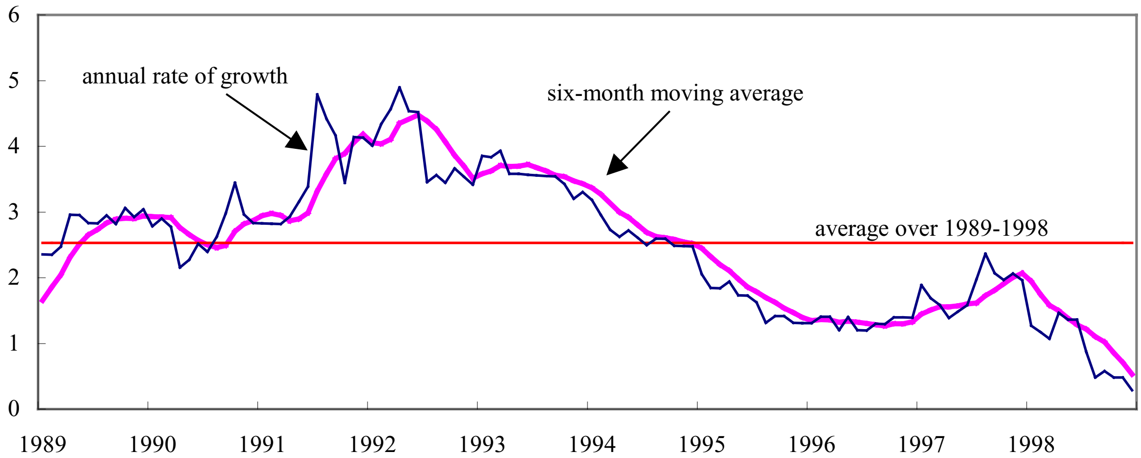


Chart 8

Germany's consumers price inflation
(annual rate of growth and six-month moving average)



Source: BIS and author's calculations

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