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ABSTRACT

Interest Rate Setting by the ECB: Words and Deeds*

This Paper discusses interest rate setting by the ECB between 1999 and 2004. I develop from the Monthly Bulletins quantitative indicators of the Governing Council's assessment of inflation, economic activity, and M3 growth, and investigate their impact on its interest rate decisions. I also estimate reaction functions with ordered probit techniques, using the Monthly Bulletins to guide the choice of variables for the analysis. The results show that the ECB reacts strongly to economic sentiment indicators as measures of the state of the real economy. Furthermore, I find statistically significant reactions to inflation and M3 growth.

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1. Introduction

With the ECB – or, more correctly, its Governing Council – having conducted monetary policy since January 1999, it is timely to consider its interest rate setting behaviour. While a number of authors have sought to do so by estimating empirical reaction functions of the Taylor variety, these are subject to several potentially important shortcomings.

First and most obviously, because the euro was introduced so recently, some studies use data solely from before 1999 while others combine data from before and after the introduction of Economic and Monetary Union.[1] Since there was no single monetary policy maker in (what came to be) the euro area before 1999, reaction functions based on pre-1999 data do not provide clean estimates of the Governing Council's reaction function.

Second, many studies capture the stance of monetary policy by a short-term interbank rate, rather than the ECB's repo rate that serves as its main policy instrument.[2] This is, of course, also related to the fact that many studies use pre-1999 data, which necessitates the use of an interbank rate as a proxy for the policy rate. However, interbank rates are influenced by market expectations of future monetary policy that could impact on the results. For instance, if inflation rises market participants may expect monetary policy to be tightened. This would lead to an increase in interbank rates without policy being changed and, potentially, without policy makers having any intention of doing so. Thus, empirical reaction functions estimated on market determined interbank rates are in fact a convolution of the policy reaction function and market expectations thereof. It is therefore desirable to focus on the ECB's repo rate which only changes as a result of explicit policy decisions.

Third, empirical reaction functions, for the euro area and other economies, are typically estimated using OLS or some instrumental-variables technique. While this is

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[1] For instance, Gerlach and Schnabel (2000) investigate synthetic data for the euro area economy ending in 1998:4, that is, before EMU was established. Peersman and Smets (1998) estimate Taylor rules on data ending in December 1997 for an aggregate of five euro area economies.

[2] See, among others, Coenen and Wieland (2000), Fagan, Henry, and Mestre (2001) and Gerdesmeier and Roffia (2003).

appropriate when studying the determination of interbank rates, it is less attractive when policy rates are studied. The reason for this is that in most months policy makers do not in fact change interest rates. When they do, furthermore, they change them by discrete amounts, typically 0.25% or 0.50%. It is for this reason more appropriate to estimate ordered probit models that distinguish between months in which interest rates were raised, left unchanged, or reduced.

In addition to these shortcomings, there is a deeper issue whether econometric studies that focus solely on the ECB's deeds – its policy actions – are likely to be fully informative about the way the Governing Council sets interest rates. Empirical reaction functions link observations of interest rates with data on macroeconomic variables that the central bank is assumed to react to, which disregards the fact that policy makers' assessment of the information contained in these macroeconomic variables may vary over time. For instance, while central banks typically react to movements in headline inflation, the extent to which they do so may depend on whether they expect them to be temporary or permanent. A given change in the rate of inflation can therefore elicit a range of interest rate responses. To understand better the ECB's policy decisions, it is helpful to consider how the Governing Council interprets incoming data. It is possible to do so by studying its public statements regarding macroeconomic developments, that is, by also studying the words of the ECB.

The purpose of this paper is to extend the literature on empirical reaction functions in the euro area in two ways.

First, the paper exploits the information in statements made in the ECB's Monthly Bulletins to develop indicators capturing the Governing Council's assessment of inflation pressures, developments in real economic activity, and growth of M3. The paper studies how these qualitative measures evolve over time, what factors explain them, and how they are related to decisions to change the repo rate.

The Monthly Bulletins are also of interest because they help understand what variables the Governing Council responds to in conducting policy. For instance, empirical reaction functions estimated on euro area data typically use either a measure of the output gap constructed from data on real GDP or an index of industrial production to explore how the ECB responds to changes in real activity. However, the

statements in the Monthly Bulletins never refer to output gaps and suggest instead that the Governing Council attaches great weight to business and consumer confidence. For this reason the paper uses a measure of economic sentiment, constructed by the European Commission, in the econometric analysis.

Second, the paper studies the information in the ECB's statements and actions by estimating empirical interest rate reaction functions. To avoid mingling the data from the ECB and the pre-ECB periods, the sample period starts in February 1999 (to allow for a lag of the interest rate), when the responsibility for setting interest rates in the euro area was transferred to the ECB. Furthermore, changes in the repo rate are used as evidence of policy action and the reaction functions are estimated using ordered probit techniques. Finally, I use the indicator variables discussed above, before considering standard macroeconomic variables as regressors.

Two other, less novel, aspects of the paper warrant mentioning. While other studies have also focussed on the post-1998 data, these were based on shorter sample periods during which the great bulk of policy changes were in the same direction. By contrast, this paper is based on a sample that covers a sufficiently long time period to capture a full interest rate "cycle." This may render the results more reliable than those obtained from shorter samples. Furthermore, the paper uses monthly data. While this seems natural given the frequency by which interest rates in the euro area are changed, many studies use quarterly data, most likely because data on real GDP, which are required to estimate the output gap, are only available on a quarterly basis.

The rest of the paper is organised as follows. Section 2 discusses how the Editorials are used to construct the indicator variables, and what can be learned from them regarding the Governing Council's choice of information variables. Measures of economic "sentiment" figure prominently in the review of real economic developments in the Monthly Bulletin, in contrast to output gaps, which play an important role in empirical studies of monetary policy reaction functions. I demonstrate that, perhaps surprisingly, a measure of economic sentiment in the euro area compiled by the European Commission is strongly correlated with standard measures of the output gap about a year ahead.

Section 3 looks at the relationship between the indicator variables constructed from the Monthly Bulletins and formal measures of inflation, real economic activity, and

money growth. I find that while the indicator variable capturing the Governing Council's view of the outlook for activity is strongly correlated with several direct measures thereof, the indicator variables for inflation and money growth are much less closely tied to a range of inflation variables and the growth rate of M3. I present some simple empirical work that suggests that economic activity plays the dominant role in influencing the Governing Council's views of the outlook for inflation, its assessment of the current state of the economy and its interpretation of the inflationary implications of money growth. Interestingly, money growth also impacts on the Governing Council's outlook for inflation.

In Section 4 the analysis turns to the econometric work. I provide a selected review of the literature on empirical reaction functions for the euro area and discuss some econometric issues. I go on to estimate ordered probit models on the indicator variables constructed from the Monthly Bulletins and show that these are informative about interest rate decisions. Using data on inflation, real economic activity, and money growth, I show that the economic sentiment variable appears more closely tied to the Governing Council's interest rate decisions that other variables capturing real economic activity. Furthermore, headline inflation appears better able to explain interest rate changes than alternative inflation measures.

The main finding in this section, however, is that money growth is statistically significant in the reaction functions. Section 5 investigates more closely the role of money growth in interest rate setting. Interestingly, the results show that while money growth is not an important factor explaining repo rate changes under normal conditions, it plays a greater role in situations in which sentiment is strong.

Finally, Section 6 concludes.

2. Preliminaries

The econometric research that has been undertaken on interest rate setting by the ECB has focussed on estimating reaction functions. While such quantitative analysis is valuable, it disregards the potentially important fact that a central bank's response to, say, inflation does not only depend on the observed change in prices but also on policy makers' interpretation of the data. For instance, a central bank may choose not to react to an increase in inflation that is due to a depreciation of the exchange rate under the argument that this is a price level shock that only impacts temporarily on

inflation. By contrast, it may react strongly to an increase in inflation that is due to an increase in wage inflation, which may contain a more permanent element. To understand the ECB's interest rate setting it is therefore desirable also to consider qualitative information that captures the Governing Council's judgement about the outlook for inflation and economic activity, and its assessment of monetary developments.

To do so, I construct indicator variables of the Governing Council's view of the outlook of the economy by reading the Editorials of the Monthly Bulletin of the ECB in the period between January 1999 and June 2004. The reason for focussing on the Editorials, rather than the full report, is as follows. The Monthly Bulletins contain an exhaustive analysis of macroeconomic conditions in the euro area. While there is little doubt that the members of the Governing Council are in general agreement with that analysis, it is arguably best interpreted as expressing the views of the ECB's senior staff. By contrast, the Editorials, which constitute the first 2-3 pages of the reports, contain a short explanation for why interest rates were or were not changed in the previous month and frequently include a summary statement of the Governing Council's view of the economy. For instance, in June 1999 it states that *"...the Governing Council did not consider that recent monetary developments were indicative of future price pressures"* (page 5) and in January 2000 it notes that *"... recent data confirm the Governing Council's previous assessment regarding the outlook ..."* (page 6). For these reasons and given its prominence in the report, the Editorial must receive considerable scrutiny by the members of the Governing Council. In what follows I therefore rely on the Editorials to construct the indicator variables.

To proceed, I next discuss the construction of the indicator variables and review what can be learned from the Editorials about the Governing Council's views about the relative importance of alternative information variables. Since that analysis suggests that survey measures of economic "confidence" or "sentiment", rather than the output gap, play an important role in the ECB's conduct of policy, I explore whether these variables contain similar information.

2.1 Construction of the indicator variables

The discussion of the risks to price stability in the Editorials is structured in three parts. There is a discussion of (1) the behaviour of real activity, presumably because the Governing Council views this as an important determinant of future inflation, (2) recent inflation trends, and (3) monetary developments in the euro area. Using the Editorials, I construct indicator variables that are intended to capture the Governing Council's views of the "risks to price stability" arising from recent developments in economy activity, realised inflation, and M3 growth. While there is little evidence that central banks react to monetary growth (in the narrow sense that money growth is typically insignificant in empirical reaction functions), the ECB has emphasised the importance of M3 growth for its policy decisions. It is therefore particularly interesting to explore if information about the Governing Council's assessment of money growth helps us to understand policy changes.

The indicator variables can take five values: -2, -1 0, 1 and 2. A separate Appendix, which is available on request, provides summary statements drawn from the Editorials to illustrate how the indicator variables were coded.[3] The value of zero should be interpreted as the Editorial suggesting that the Governing Council believes that given the current level of the repo rate, a change in the level of interest rates is not warranted. To understand this better, it is helpful to consider some concrete examples. For instance, the Editorial in the first Monthly Bulletin in January 1999 states that *"on balance, the evidence suggests that there are no indications of significant upward or downward pressures on price developments…"* and goes on to argue that *"Overall … the outlook for price developments can be regarded as being broadly balanced."* Since the Editorial more generally suggests that the Governing Council viewed inflation over 12 months as stable at the then current rate of 0.9%, the assessment of price pressures is coded as 0.

The value –1 indicates that the Editorial suggests that the behaviour of the variable may warrant a relaxation of the policy, that is, the current level of the repo rate is too high. For instance, the April 1999 Monthly Bulletin notes that *"many projections for*

[3] It should be emphasised that the coding was done by reading the full Editorials and that the statements in the Appendix only serve to provide a brief background to the coding.

inflation rates in the euro area have been revised downwards recently." Moreover, the Editorial states that *"downward pressure on inflation stems from the current economic situation."* Since this and the overall reading of the Editorial suggests that the Governing Council's assessment of price pressures had changed and the Governing Council had become more concerned that inflation might fall too low, the inflation indicator is coded as –1.

The value –2 is used when the Governing Council appears increasingly persuaded that the behaviour of the variable in question warrants a cut in interest rates. Consider, for instance, the Governing Council's assessment of real economic activity in early 1999. In January 1999 the Editorial discusses *"expectations of a slowdown in the growth of economic activity in the short term"* (coded as –1) and in February it notes that *"while there are indications of a slowdown in real GDP growth, the extent and duration of such a weakening of economic activity remain a matter of uncertainty"* (also coded as –1). By contrast, in the March issue the tone had sharpened, as it had become clearer to the Governing Council that real economic activity was indeed slowing and that it was doing so more rapidly than it had anticipated earlier. This is indicated by the phrasing *"recent information on indicators of economic activity ... provided evidence of a sizeable slowdown in the fourth quarter of 1998"* and *"the deterioration of confidence has continued into 1999."* For these reasons I code this as –2. The values +1 and +2 are applied in cases in which in the Governing Council appears to be somewhat or strongly concerned that developments in inflation, real economic activity, or M3 growth warrant a tightening of policy.

In interpreting these indicator variables it should be emphasised that they are intended to capture the Governing Council's assessment whether some variable suggests that a change in policy is warranted, which does not necessarily map into the actual behaviour of some macroeconomic aggregate in an obvious or unique way. Thus, while one expects these indicators to be correlated with more objective measures of inflation, economic activity, and money growth, one would not necessarily expect the correlations to be large. Indeed, the rationale for using the indicators is that macroeconomic data may not be fully informative about the Governing Council's view of the economy, which suggests that the correlations are not too high.

In Section 3 below I plot the indicator variables and discuss how they relate to macroeconomic data.

2.2 The Governing Council's choice of information variables

A further reason why it is helpful to read the Editorials is that they provide information about how the Governing Council views the economic environment, which is helpful in choosing variables for the econometric analysis conducted below. Four points deserve special attention.

First, while data on price and monetary developments are available with little delay, national accounts data are released with long lags and are subject to revisions. Indeed, comments in the Editorials on the behaviour of real GDP typically refer to developments that occurred several quarters ago. For instance, in discussing Eurostat's first estimate of real GDP growth in the fourth quarter of 2003, the March 2004 Editorial states: *"These data confirm that a gradual recovery in economic activity in the euro area took place in the second half of 2003. More recent indicators, including those from business and consumer surveys, point to a moderate economic growth also in early 2004."* This suggests that estimates of output gaps, which are typically used in empirical reaction functions, are unlikely to play much of a role in actual interest rate setting (although, of course, they may be highly significant in empirical reaction functions).[4] However, and as is clear from the quote above, in discussing recent developments in real economic activity, the Editorials refer to indications coming from a wide variety of sources, and frequently comment on measures of consumer and business confidence. For this reason I use an Economic Sentiment Indicator, developed by the European Commission, in the econometric analysis below, which is available with a very short time lag.[5] Several other measures of real economic activity are also considered.

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[4] Orphanides (2001) shows that estimates of empirical reaction functions for the Federal Reserve are highly sensitive to the choice of ex post or real-time data.

[5] The economic sentiment index pertains to euro area. It is based on surveys of firms and consumers conducted at the national level. The data sample is very large: for the EU it is based on a sample of 68,000 firms and 27,000 consumers. The monthly surveys are carried out in the first two weeks of the month (for a limited number of items a quarterly survey is done). The sentiment indicator attaches a weight of 40% to the industrial confidence indicator, 20% to the consumer confidence indicator, 20% to the construction confidence indicator and 20% to the retail trade confidence indicator. The sentiment indicator takes values close to 100, I subtract 100 from it in order to facilitate the graphical presentation. For more information about the index, see:
http://europa.eu.int/comm/economy_finance/indicators/business_consumer_surveys/userguide_en.pdf
The data can be downloaded from:
http://europa.eu.int/comm/economy_finance/indicators/business_consumer_surveys/bcsseries_en.htm

Second, while the ECB has not adopted any measure of core inflation, the Editorials often discuss the behaviour of HICP inflation excluding energy and unprocessed food prices. I therefore use the data and the CPI weights provided in the statistical section of the Monthly Bulletins to construct this measure of inflation, which, for simplicity, I refer to as "core" inflation in what follows. Since the discussion in the Editorials focusses on the annual change in prices, headline and core inflation are measured over twelve months in the discussion below.

Third, as is readily apparent from the Editorials, the Governing Council sets monetary policy in a forward-looking manner. This is evidenced by, for instance, the fact that policy decisions are discussed in the context of the Governing Council's view of "the outlook for price stability." This makes it desirable to use measures of expected future economic conditions in estimating reaction functions. For this reason I consider measures of expected inflation and real GDP growth over the coming 12 months, computed using data tabulated in The Economist.[6] It should be noted that in a perfectly credible monetary policy regime, the expected rate of inflation would always equal the targeted level, which in the ECB's case can be interpreted to be somewhere in the range of 1.5-2%. If so, interest rate changes would be difficult to explain given inflation expectations.

Fourth, while the Monthly Bulletins suggest that money and credit growth both are important in the Governing Council's thinking about policy, the official position of the ECB is that M3 growth is the single most important indicator of monetary developments. I therefore concentrate on this variable in the econometric analysis. Since the Editorials suggest that the Governing Council's deliberation focusses on the three-month moving average of the annual rate of money growth, this definition is used in the empirical analysis below.

As an aside it is interesting to note that the Editorials highlight how pervasive the uncertainty about the state of the economy is. They typically list the main factors suggesting that inflation may be rising or economic conditions strengthening, and

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[6] The Economist provides data on expected inflation and real GDP growth for the current and the next year. The expected rates of inflation rate and real economic growth are computed as weighted averages of the expected rates for this and next year.

continue by reviewing the considerations that indicate the opposite. Moreover, the commentaries suggest that the Governing Council may over- or underpredict some aspect of the economy for several months. Overall this points to uncertainty about the state of the economy as a major factor why interest rate smoothing occurs.[7]

2.3 Economic Sentiment Indicator

As noted above, the Governing Council makes frequent references to indicators of economic sentiment in its discussion of real economic conditions. Estimates of the output gap, by contrast, do not appear to play any role in the analysis because real GDP data are reported with long lags and are subject to large revisions. Since the empirical literature on central bank reaction functions, following Taylor (1993), sees the output gap as playing a primary role in interest rate decisions, I next seek to understand the relationship between the economic sentiment indicator and output gaps.

To do so, I compute two estimates of the output gap, using quarterly real GDP data for the euro area for the period 1991:1 to 2004:1. The first of these is calculated using the Hodrick-Prescott filter, setting the smoothing parameter equal to 1600. The second estimate is obtained by applying a band-pass filter, extracting the information in the frequency band corresponding to a periodicity of between 16 and 32 quarters, to the level of the logarithm of real GDP. Since the output gaps are measured in percentage points, I define the sentiment as the percentage deviation from its mean in the sample period.[8]

Figure 1 contains a time series plot of the sentiment indicator and the output gap series. Since the series have different amplitudes, I normalise them to have zero mean and unit variance. A notable aspect of the figure is that sentiment and the output gaps evolve over time in much the same way, except for a brief period in 1997-98. For instance, they all point to a trough in economic activity in 1993 and to a peak in 2000. Sentiment can thus be thought of as a rapidly available indicator of the output gap. To

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[7] By interest rate smoothing I mean the fact the lagged interest rate typically is highly significant in empirical reaction functions.

[8] That is, I use $100 \times \log(s/s^*)$, where s denotes the sentiment indicator, and s^* its mean. The quarterly data on sentiment are obtained by using the data point for the first month of the quarter.

shed more light on information content of sentiment, Figure 2 contains cross-correlations between the current level of sentiment and past and future levels of the two output gaps, together with a 95% confidence band. The figure shows that sentiment is negatively correlated with past output gaps, but positively correlated with the current output gap and strongly so with future output gaps. Overall, the two figures indicate that sentiment provides a forecast of the output gap three or four quarters ahead. Since the sentiment data are available with a very short lag and are not revised, these findings suggest that it makes good sense for the Governing Council to use sentiment as a forward-looking indicator of real activity.

3. A look at the data

In this section I review the indicator variables constructed from the Editorials and macroeconomic data on inflation, real economic activity, and money growth. The purpose of this analysis is to understand how closely the indicator variables are related to more objective measures of the state of the economy. The indicator variables are available in Table 1.

3.1 Inflation

It is useful to start by considering the Governing Council's assessment of inflation. Figure 3 contains plots of the inflation indicator together with realised and expected future inflation constructed from the data published by The Economist.[9] The 2% upper limit of the ECB's definition of price stability is also indicated.

The Editorials suggest that the concerns the Governing Council expressed about declining inflation in the spring of 1999 before the interest cut in April, soon gave way to worries that inflation risks had increased. This coincided with rising headline and expected future inflation. In late 2000 and in early 2001 the Governing Council viewed inflation risks as having become more balanced, despite the fact that headline inflation was generally above 2%. However, that judgement looked appropriate as headline and expected future inflation declined during the later part of 2001. With both rising towards the end of the year and in early 2002, the Governing Council

indicated again concerns in the Editorials in the middle of 2002 as expected inflation started to rise towards the 2% level. But with inflation staying just above, and expected inflation just below, 2%, the Governing Council soon again judged the risks as more balanced, and maintained that judgement until June 2004 when the sample ends. In Figure 4 I plot the inflation indicator together with core inflation and the difference between headline and core inflation. Note that the inflation indicator does not appear to be strongly tied to either of these variables.

The above analysis of the Governing Council's assessments suggests that realised inflation and the ECB's judgement of the outlook for price stability may be quite different at times. However, since the ECB also reacts to other variables, I postpone a discussion of what to infer from this for the moment.

3.2 Real economic activity

While the overriding objective of the ECB is to ensure price stability, the Editorials contain frequent statements about developments in real economic activity, presumably because it impacts on the rate of inflation with a lag. Figure 5 shows the indicator variable together the sentiment indicator (scaled by 0.1 for comparison purposes) and the expected real GDP growth in the coming twelve months constructed from data published by The Economist. The figure shows a striking correlation between the indicator and the sentiment and expected GDP growth series (the correlation is in both cases 0.81). Furthermore, the correlation between the sentiment and expected output growth is even higher at 0.94, which further supports the view that sentiment captures expected future growth in the economy.

In Figure 6 I plot the indicator variable together with the growth rate of industrial production over twelve months, and EuroCOIN, a monthly real-time indicator of euro area business cycles published by the CEPR.[10] Since the industrial production data are subject to some month-to-month volatility, I use a three-month moving average, which appears to be the ECB's standard "filter" to reduce volatility, of the series. This figure also shows a relatively tight link between the Governing Council's assessment

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[9] Alesina et al. (2001) and Begg et al. (2001) used data from The Economist to compute measures of expected future inflation, but not output (as is done below).

of real economic activity and the industrial production and the EuroCOIN indicator, although the correlations are lower than in the previous figure.[11]

Again I emphasise that real GDP growth and the output gap are not included in the analysis since the Editorials suggest that these variables do not play much of a role in the Governing Council's assessment of inflation risks. Real GDP growth serves mainly to provide ex post assessments of judgements about activity made by the Governing Council some quarters earlier.

3.3 Money growth

Since the ECB has repeatedly stated that it attaches a prominent role to money in conducting monetary policy, I turn to its interpretation of movements in M3 growth. Figure 7 contains a plot of the indicator variable for money together with (a three-month average of) M3 growth over twelve months. For clarity, the 4.5% "reference value" for money growth that the ECB has announced is also indicated. The figure suggests that while the Governing Council viewed money growth as indicating risks to price stability between mid-1999 and late 2000, it has subsequently not done so, except during a brief period in 2002, despite the fact that money growth has exceeded the reference value since early 2001. As is clear from its statements in the Editorials, the reason for this is, effectively, that the rapid increase in money growth has been interpreted as largely reflecting increases in the demand for money that did not generate inflation risks.

3.4 The determinants of the indicators

The indicators are intended to summarise the Governing Council's views of the outlook for inflation and real economic activity, and its interpretation of the information in money growth. As is clear from the figures reviewed above, the different indicators, in particular those for inflation and money growth, evolve in similar ways over time. This suggests that they may in fact be driven by the same factors. To explore this issue in an informal way, I regress the indicator variables on

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[10] See www.cepr.org/data/EuroCOIN for more information.

[11] Interestingly, estimated cross-correlations for both this and longer sample periods show that the EuroCOIN indicator leads the other measures of real economic activity.

the lagged value of inflation, sentiment (as a measure of the output gap), and M3 growth. Since these regressions are subject to serial correlation and heteroscedasticity, I assume first-order autoregressive errors and compute standard errors using the White approach. The results, in Table 2, show that the sentiment variable and the autoregressive coefficient for the errors are significant in all equations. Apart from past money growth in the equation for the inflation indicator, no other variable is significant.

These results appear compatible with the following interpretation. First, and as argued by a number of authors, the Governing Council's assessments of the outlook for inflation and economic activity react strongly to movements in economic activity, presumably because it sees a rise in activity as signalling rising inflation. Furthermore and provided that inflation is under control, the Governing Council no doubt seeks to stabilise the real economy. Second, money growth impacts on the outlook for inflation, as suggested by the adoption of the two-pillar framework. Third, the assessment of money growth depends on economic activity. One reason for this may be that while money growth has been above the 4.5% reference value during most of the period studied, the Governing Council is mainly concerned about money growth when it coincides with strong activity.

3.5 Repo rate

Finally, Figure 8 shows the repo rate in the sample period. Figures 3 to 6 suggest that the interest rate reduction in the spring of 1999 was due to the Governing Council coming to the view that activity was slowing and inflation pressures receding. This was followed from summer onwards by an economic expansion that the Governing Council interpreted as generating upside risks to price stability, and it consequently raised the repo rate. This process halted in the middle of 2000, and during 2001 activity slowed and the Governing Council's assessment of inflation risks turned increasingly benign, which led to a series of cuts in interest rates. In late 2001, however, as sentiment started to improve, the Governing Council took a more neutral view of the implications for inflation and kept interest rates constant. Interestingly, the growth of industrial production and the expectations of future economic growth only started to recover some months later. During 2002, the resumption of growth soon gave way to a worsening sentiment and downward revisions of expected future

growth which led the Governing Council to conclude that the downward risks to price stability had risen.

Overall, it is possible to account for the rises in interest rates in 1999-2000 by appealing to inflationary pressures and rapid real economic growth, and the reduction in 2001-2003 by considering the weakness in real economic activity in a situation in which headline inflation fluctuated around 2%. This raises the question of what role the Governing Council's views of money growth played for its interest rate decisions. As a preliminary to the analysis below, it should be noted that the inflation and money growth indicators differed in only five of the 66 months between January 1999 and June 2004. This suggests that it will be difficult to distinguish between their relative importance.

3.6 Conclusions

The above analysis suggests a number of conclusions that have a bearing on the econometric work that follows.

First, the link between realised and expected future inflation rates on the one hand and the Governing Council's outlook for inflation on the other is not close. As suggested earlier, this is likely because inflation is a backward-looking variable while monetary policy is inherently forward looking. Furthermore, it seems likely that the ECB's analysis of future inflation, which is conditional on the current level of interest rates, is at times quite different from private sector inflation forecasts, which are unconditional.

Second, there are strong correlations between data on, and the Governing Council's assessment of, real economic activity.

Third, the relationship between money growth and interest rates appears complex. Since the Governing Council has repeatedly stated that it attaches importance to monetary developments as an indicator of "risks to price stability", one would perhaps have expected that high money growth would have been associated with high or rising interest rates. Figures 7 and 8 suggest that the opposite is the case: periods of above-average interest rates are associated with money growth below average and vice versa. No doubt, this observation is one reason why many observers have questioned

the ECB's repeated statements that it does, in fact, pay attention to money growth in setting interest rates.

However, the ECB's claim that money growth plays an important role in its interest rate decisions presumably means that, conditional on the information embedded in inflation and economic activity, it reacts to money growth. If so, the bivariate relationship between money growth and the repo rate provides little evidence on the issue whether the ECB responds to money growth. Multivariate reaction functions, in which inflation and real activity are included in the analysis, are likely to be more informative.

4. Interest rate setting by the ECB

4.1 Estimates in the literature

The Taylor rule, which was initially proposed by Taylor (1993) as a device to understand monetary policy in the United States in the late 1980s and early 1990s, has been applied to data from the euro area by large number of authors. While it goes beyond the goals of this paper to summarise these contributions in detail, it is useful to distinguish between five branches of the literature.

The first of these use the Taylor rule, or empirical reaction functions of the Taylor-rule form, to study the behaviour of short-term interest rates before the introduction of monetary union and a single monetary policy (e.g., Gerlach and Schnabel (2000) and Peersman and Smets (1999)). The goal in these papers is to form a view as to how the ECB might conduct policy.

A second strand of papers estimates reaction functions using data from before and after the establishment of the euro area. Gerdesmeier and Roffia (2003) provide an exhaustive series of empirical estimates of reaction functions for interest rates in the euro area, using data for the 1985 - 2002 period.[12] Surico (2003) estimates reaction functions that allow for asymmetric policy responses and produce evidence suggesting that interest rates have responded more strongly to output contractions than to expansions in the 1997-2002 period. Gerlach-Kristen (2003) demonstrates that

"level" estimates of reaction functions display parameter instability and forecast poorly out of sample. By contrast, reaction functions specified in error-correction form are not subject to these problems.[13]

Third, a number of authors estimate empirical reaction functions in order to close and simulate econometric models of the euro area. For instance, such reaction functions are incorporated in the ECB's area-wide model of the euro area (see Fagan et al. (2001)) and are used by Coenen and Wieland (2000) and Clausen and Hayo (2002). The dynamic stochastic general equilibrium model presented by Smets and Wouters (2002) also comprises a version of the empirical reaction function.[14] Since these papers focus more on understanding the euro area economy than interest rate setting by the ECB, these authors typically study data from before and after the introduction of monetary union.

While interesting, the papers reviewed above do not focus solely on the period after the ECB started to conduct monetary policy and, consequently, provide little evidence on interest rate setting by the ECB.

The fourth strand of the literature uses the Taylor rule to understand the ECB's interest rate setting. For instance, see the reports in the CEPR series on "Monitoring the European Central Bank" (see Begg et al. (1998, 2002), Alesina et al. (2001) and Favero et al. (2000)) and Faust et al. (2001). These studies were written before sufficient data were available to estimate a reaction function solely for the ECB period, and use calibrated reaction functions, or reaction functions estimated for the Bundesbank and the Federal Reserve, to understand the ECB's monetary policy.

By contrast, the fifth and last strand of the literature, including Breuss (2002), Hayo (2003), Galí et al. (2004), Hofmann and Hayo (2004), Neumann (2001 and 2002) and Ullrich (2003), uses data from January 1999 onwards to provide estimates of the Governing Council's reaction function. These authors typically use the overnight rate

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[12] They also estimate one model on the sample 1999:01-2002:02.

[13] She also follows Kozicki and Tinsley (2001a and b) and extracts an estimate of long-run inflation expectations from the term-structure of interest rates, and shows that this is significant in the reaction function.

[14] However, the output gap is in this model measured by the wedge between the actual and the flexible price level of output, which is more attractive from a theoretical perspective, rather than by more traditional measures of the gap.

to capture policy, headline HICP inflation as the relevant measure of price pressures, and employ an output gap constructed by applying the Hodrick-Prescott filter to industrial production data. One common finding in this literature is that the ECB appears to react strongly to movements in real economic activity, or, as (Neumann, 2001, p. 14) puts is, "*... ECB's monetary policy is not just guided by the price stability objective but to a considerable degree also tries to stabilise the business cycle.*"

The present study is related to three of these papers. Heinemann and Hüfner (2004) estimate reaction functions for the period January 1999 – April 2002 and reaction functions using both traditional methods and ordered probit techniques, distinguishing between months in which the Governing Council increases, leaves unchanged and cuts interest rates. Galí et al. (2004) also estimate ordered probit models for changes in the ECB's repo rate. Carstensen (2003) estimates ordered probit equations for the level of the repo rate, and finds strong responses to output and weak responses to inflation. Interestingly, his results show that a range of measures of money growth, money gaps, and monetary overhangs are significant in the reaction functions.

4.2 Estimation issues and the model

Since the Governing Council leaves the repo rate unchanged in most months, it is inappropriate to fit the model using OLS. Below I therefore follow the approach in the three studies discussed above and estimate ordered probit models.[15] As is shown in Table 3, the repo rate was changed on fifteen occasions in the sample period: it was raised seven times and cut eight times. On eight occasions the change was ±0.25%, and on eight occasions it was ±0.50%. Interestingly, while increases tended to be small, cuts tended to be large. It is too early to tell, however, whether this represents any asymmetry in the Governing Council's behaviour.

Below I make a distinction between "small" and "large" changes in interest rates. The dependent variable takes the value 2 (1) in the months in which the repo rate was raised by 0.5% (0.25%), zero in the months it was left unchanged and –1 (–2) in the

[15] Kim et al. (2004) estimate logit functions for interest rate decisions by the Bank of England.

months in which it was reduced by 0.25% (0.50%). The resulting indicator for the repo rate is available in Table 1.

Before turning to the empirical work, it is useful to consider the underpinnings for the estimated equation and some econometric issues. Let i_t denote the repo rate, and i_t^{opt} the Governing Council's view of the "optimal" repo rate, at time t. These may differ because of the practice of the ECB and most other central banks of setting interest rates at discrete levels, typically 0.25% apart. Let π_t, y_t and μ_t denote (some measure of) inflation, real economic activity, and money growth. Consider next the following expression for the optimal level for the interest rate:

$$(1) \qquad i_t^{opt} = \alpha_\pi \pi_t + \alpha_y y_t + \alpha_\mu \mu_t$$

where all parameters are positive.[16] Next, allow for gradual adjustment of the actual interest rate as in Judd and Rudebusch (1998):[17]

$$(2) \qquad i_t - i_{t-1} = \beta_0 \left(i_t^{opt} - i_{t-1} \right) + \beta_1 \Delta i_{t-1} + e_t$$

where the constant is omitted and e_t is a residual. This can be rearranged as:

$$(3) \qquad i_t - i_{t-1} = \alpha^T x_t + e_t$$

where $x_t^T = \left[\pi_t \quad y_t \quad \mu_t \quad i_{t-1} \quad \Delta i_{t-1} \right]$, $\alpha^T = \left[\alpha_\pi \beta_0 \quad \alpha_y \beta_0 \quad \alpha_\mu \beta_0 \quad -\beta_0 \quad \beta_1 \right]$. Thus, the equation states that the desired change of the repo rate depends on the level of inflation, economic activity and money growth, relative to the lagged level of the repo rate.

This reaction function must be modified, however, to incorporate the fact that the ECB sets interest rates in steps. To do so, we view equation (3) as an expression for the desired change in the interest rate, $i_t^* - i_{t-1}$. Note that this formulation differs from the dynamic probit models estimated by Eichengreen et al. (1985) and Davutyan and Parke (1995), who assume that (in our notation) $i_t^* - i_{t-1}^* = \alpha^T x_t + e_t$. This alternative

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[16] Svensson (1997) presents a simple model in which the optimal interest rate depends on the state of the economy, as measured by the output gap, and the deviation of inflation from the central bank's target or objective and thus provides some theoretical foundations for the Taylor rule. Equation (1), which should be seen as a generalisation of that rule, however, lacks such foundations.

specification implies that the optimal value of the current interest rate can be written as $i_t^* = \alpha^T \sum_{\tau=1}^{t} x_\tau + \sum_{\tau=1}^{t} e_\tau + i_0^*$. Since the desired interest rate depends on the path of the driving variables and past errors, this model is more difficult to handle in applied work.

Since the Governing Council changed the repo rate by 0.25% or 0.50% (in absolute value) in the sample period, only five policy outcomes are observed:

$$
\begin{aligned}
&\Delta i_t = -0.50\% && \text{if } i_t^* - i_{t-1} \le \gamma_1 \\
&\Delta i_t = -0.25\% && \text{if } \gamma_1 < i_t^* - i_{t-1} \le \gamma_2 \\
(3)\qquad &\Delta i_t = 0 && \text{if } \gamma_2 < i_t^* - i_{t-1} \le \gamma_3 \\
&\Delta i_t = +0.25\% && \text{if } \gamma_3 < i_t^* - i_{t-1} \le \gamma_4 \\
&\Delta i_t = +0.50\% && \text{if } \gamma_4 < i_t^* - i_{t-1}
\end{aligned}
$$

It is useful to define the function that takes the value 1 if the j:th of these outcomes is observed, $1\{i_t^* - i_{t-1} = j\}$, where j = 0 if $i_t^* - i_{t-1} \le \gamma_1$, j = 1 if $\gamma_1 < i_t^* - i_{t-1} \le \gamma_2$, … and j = 4 if $\gamma_4 < i_t^* - i_{t-1}$.

The actual change in the repo rate depends on the desired change, relative to the limit points given by the γ_i:s, that are estimated jointly together with the α vector.

In the ordered probit model, the probabilities are given by:[18]

$$\Pr(\Delta i_t = -0.50\%) = \Phi\left(\frac{\gamma_1 - \alpha^T x_t}{\sigma}\right)$$

$$\Pr(\Delta i_t = -0.25\%) = \Phi\left(\frac{\gamma_2 - \alpha^T x_t}{\sigma}\right) - \Phi\left(\frac{\gamma_1 - \alpha^T x_t}{\sigma}\right)$$

[17] See also Dueker (1999).
[18] The discussion here follows Ruud (2000).

(4) $$\Pr(\Delta i_t = 0) = \Phi\left(\frac{\gamma_3 - \alpha^T x_t}{\sigma}\right) - \Phi\left(\frac{\gamma_2 - \alpha^T x_t}{\sigma}\right)$$

$$\Pr(\Delta i_t = +0.25\%) = \Phi\left(\frac{\gamma_4 - \alpha^T x_t}{\sigma}\right) - \Phi\left(\frac{\gamma_3 - \alpha^T x_t}{\sigma}\right)$$

$$\Pr(\Delta i_t = +0.50\%) = 1 - \Phi\left(\frac{\gamma_4 - \alpha^T x_t}{\sigma}\right)$$

where Φ is the cumulative distribution for a standard normal variable. It is assumed that $\gamma_0 = -\infty$ and $\gamma_5 = +\infty$. The average log-likelihood function equals:

(5) $$E_T\left[\sum_{j=0}^{4} 1\{\Delta i_t = j\} \log\left[\Phi\left(\frac{\gamma_{1+j} - \alpha^T x_t}{\sigma}\right) - \Phi\left(\frac{\gamma_j - \alpha^T x_t}{\sigma}\right)\right]\right]$$

Before estimating the model it is useful to consider the terms in $\Phi(\bullet)$:

$$\frac{\gamma_j - \alpha^T x_t}{\sigma} = \frac{\gamma_j - \alpha_0}{\sigma} - \frac{\gamma_j - \alpha_1 x_{1,t}}{\sigma} - \ldots - \frac{\gamma_j - \alpha_k x_{k,t}}{\sigma}$$

From here it follows that the limit points are not identified separately from the constant, α_0, and the model is therefore estimated without a constant (since including one simply changes all the limit points equally much). Furthermore, the parameters are identified up to some factor of proportionality, $1/\sigma$. It is therefore convenient to introduce the normalisation $\sigma = 1$.

To interpret the results below, it is useful to study more formally the impact on the probabilities of changes in x_t. To do so, consider the derivatives of the first, last and one of the "intermediate" probabilities, for instance, the probability of no change in the interest rate. Dropping time subscripts, these are **Error! Not a valid link.**given by:

(6a) $$\frac{\partial \Phi\left[\gamma_1 - \alpha^T x\right]}{\partial x} = -\phi\left[\gamma_1 - \alpha^T x\right]\alpha$$

(6b) $$\frac{\partial\left[1 - \Phi\left[\gamma_4 - \alpha^T x\right]\right]}{\partial x} = \phi\left[\gamma_4 - \alpha^T x\right]\alpha$$

(6c) $$\frac{\partial\left[\Phi\left[\gamma_3 - \alpha^T x\right] - \Phi\left[\gamma_2 - \alpha^T x\right]\right]}{\partial x} = \left[\phi\left[\gamma_3 - \alpha^T x\right] - \phi\left[\gamma_2 - \alpha^T x\right]\right]\alpha$$

where $\phi(\bullet)$ denotes the density corresponding to a standard normal.

These derivatives warrant three comments. First, note that the change in the probabilities depends on $\phi(\bullet)\alpha$. Thus, the vector of parameters, α, does not on its own indicate how sensitive the probabilities are to changes in the data vector, x_t. Second, the derivatives are given by the slope parameters times a term common to all derivatives of the probability in question. The ratio of the derivatives is therefore equal to the ratio of the slope parameters. Thus, if the ratio of the slope parameter for inflation to the parameter for the lagged repo rate is larger than unity (in absolute value), the probability is more sensitive to a one-percentage point change in inflation than to an identical change of the repo rate. Third, assuming that the elements of α are all positive, note that an increase in x_t unambiguously reduces the probability of the "lowest" outcome and increases the probability of the "highest" outcome. The impact on the probability of "intermediate" outcomes is, however, unclear. Thus, the signs of the parameters in the ordered probit models show whether an increase in the regressors makes it more or less likely that the Governing Council will cut or raise the repo rate by 0.50%. They will not on their own say anything, however, about how the probabilities that the Governing Council will alter interest rates by ±0.25% or leave monetary policy unaffected.

Below the estimates of the α vector are reported together with the value of the likelihood function. I also report the McFadden's likelihood ratio index, or the $\text{pseudo} - R^2$, which is given by:

$$\text{pseudo} - R^2 = 1 - \ln(L / L_0)$$

where L_0 is value of likelihood function when there are no time-varying regressors. Note that the $\text{pseudo} - R^2$, which ranges from 0 to 1, is related to a likelihood ratio test of the hypothesis that all slope parameters are zero, which is given by:

$$LR = -2\ln(L_0 / L).$$

Finally, I report the p-values from tests of the hypothesis of no first-order serial correlation in the residuals, constructed as suggested by Gourieroux et al. (1985, p. 326).

4.3 Estimates with indicator variables

Before estimating the reaction functions with macro economic data, it is of interest to estimate the model using the indicator variables developed above as regressors. Since these variables signal whether the Governing Council felt that, given the interest rate, the outlook for inflation or real economic activity, or realised M3 growth, warranted a change in interest rate, the lagged level of the repo rate is included in the equations. Furthermore, last month's policy decision may impact on the current decision. For instance, under interest rate smoothing, the coefficient on the lagged change of the repo rate should be positive. Alternatively, it could enter with a negative coefficient if an increase in interest rates last month reduces the probability of an increase this month. To explore this, the regressions incorporate the lagged change in the interest rate as an independent variable. There are thus five regressors in the probit model: the lagged repo rate, the lagged change in the repo rate, the indicator for inflation, the indicator for real economic activity, and the indicator for money growth.

Table 4 presents the estimates. To allow for the lagged change in the repo rate, the sample period starts in February 1999 and ends in June 2004. The first column reports results including all the indicator variables discussed above. Note that the parameter on the lagged repo rate is highly significant and negative, indicating that the probability of an increase in the interest rate depends negatively on the level of interest rates, which, in this sense, are mean reverting. Furthermore, the lagged change in the repo rate is highly significant and the parameter is negative. Thus, an increase in the repo rate last month reduces the probability of an increase this month.

The results show that the outlook for real economic activity has a positive and significant coefficient, indicating that better economic prospects make the Governing Council more likely to raise the repo rates. By contrast, the outlook for inflation and the assessment of money growth have positive parameters but are insignificant. However, since these evolve in a similar way over time, it is possible that the parameter estimates are subject to multicollinearity. I therefore drop the money growth indicator and reestimate the model. The results in the second column are similar to those in the first, except that the inflation indicator is significant at the 10% level and has a larger parameter than before. The pseudo r-squared falls trivially.

Next, the model is reestimated and the indicator for inflation is replaced with that for money. The coefficient on the money indicator is about as large and about as significant as the coefficient on the inflation indicator in the second column, and the other coefficient estimates remain similar. These results support the notion that the insignificance of money growth and inflation in the first column is due to multicollinearity.

While it is of interest to study the predictive ability of this model in greater detail, I defer that discussion until a competing model using macroeconomic variables as regressors has been developed. To summarise the results so far, Table 4 suggests that the Governing Council's interest rate decisions can be systematically tied to its assessment of economic conditions. Furthermore, the repo rate is mean reverting, and a change in interest rates last period reduces the likelihood of a similar change this period.

4.4 Estimates with macro variables

I next reestimate the ordered probit models using objective measures of inflation, real economic activity, and money growth as independent variables. There are two reasons why I do so. First, the indicator variables are at best crude measures of the Governing Council's views of the economy, which may explain why the significance of the inflation and money growth indicators is so low even when they are included individually. It is therefore of interest to contrast these results with estimates of the reaction function using macroeconomic data. Second, by doing so it is possible to form a view of what factors best capture the Governing Council's assessment of the outlook for inflation and the state of economic activity. For instance, how important is headline versus "core" inflation, or sentiment versus industrial production, in accounting for repo rate changes?

The models estimated below include the lagged level of, and change in, the repo rate, which were significant in the regressions in Table 4, as regressors. Since the Governing Council appears to focus on the three-month moving average of the annual growth rate of M3, this variable is also included among the independent variables. Moreover, I include the rate of HICP inflation, which the ECB's inflation objective is defined in terms of, and use the sentiment indicator since it appears frequently in the Editorials and since it is strongly correlated with the indicator variable for real

economic activity. Since the variables are reported with a time lag, the regressors are lagged by one month. Finally, in interpreting the results it should be kept in mind that the sample contains 65 observations and is thus quite small.

The results in the first column in Table 5 are encouraging in that all variables are significant at the five-percent level and have the expected signs. Thus, higher inflation, stronger sentiment, and faster money growth all increase the probability of a large interest rate increase and reduce the likelihood of a large cut. To get a sense of whether the "Taylor principle" holds, suppose that inflation rose one percentage point above its mean and ask how much higher the repo rate must be in order for the probability of an interest rate change to be unchanged. Since the parameter on inflation and the interest rate in column 1 in Table 5 are –1.24 and –1.00, this increase is given by –1.24/–1.00 = 1.24. While the Taylor principle thus held in the sample period, it should be noted that the hypothesis that the ratio is unity is not rejected ($p = 0.59$).

It is well established in the literature that the ECB appears to respond to inflation and real economic activity. However, with the exception of Carstensen (2003), who studies data from January 1999 onwards, I am not aware of any studies that find that money growth impacts on the ECB's interest rate setting. Indeed, it is commonly argued that the ECB does not react to money growth. Three considerations may explain why money growth is significant here and in the study by Carstensen. First, in both cases only data from the ECB period are used. Clearly, it is difficult to conduct any inference on what the Governing Council reacts to by using data from the period before the ECB was established. [19] Second, both studies use monthly, rather than quarterly, data. While using monthly data triples the number of observations, which increases the precision of the estimates, it also increases the amount of noise, which reduces precision. It may be that in this case the former effect dominates. Third, both studies use probit methods, which are inherently non-linear. Since it is plausible that the Governing Council's reactions to money growth depend also on the strength of

[19] Gerdesmeier and Roffia (2003) also find a significant coefficient on money growth, but this can not be attributed to the ECB since the sample starts in 1985.

inflation pressures and on economic sentiment, these models may do a better job in detecting policy responses to money growth.

One reaction to the significance of money growth is that it may be due to reverse causality. Changes in interest rates impact on the opportunity cost of holding money and therefore on money growth. Indeed, this is a major reason why it is difficult to interpret movements in money growth. The argument that the estimates are affected by reverse causality, however, implies that money growth should have a negative, not positive, sign in the model since a higher repo rate reduces money growth.[20]

4.5 Alternative estimates: real economic activity

Next I turn to the question whether other measures of economic activity and inflation are better able to account for changes of the repo rate. Rather than considering all possible variations of the different measures of economic activity and inflation, I first consider alternative measures of activity before turning to other concepts of inflation.

The second column in Table 5 reports results from estimation of the ordered probit model in column 1 using the growth rate of industrial production over twelve months instead of sentiment. The model in column 3 uses the EuroCOIN index and that in column 4 expected real GDP for the coming twelve months constructed from data tabulated in The Economist. While the different measures of economic activity are significant in all cases, which is evidence that the Governing Council responds strongly to changes in the outlook for growth, the $\text{pseudo} - \text{R}^2$ indicate that the fit is worse than when sentiment is used. This reduction in fit and the fact that different regressors are in many cases strongly correlated explains why the significance of the other variables declines, and why some parameter estimates change. For instance, when industrial production is used, no other variable is significant. From this I conclude that economic sentiment plays an import role in determining (or, at least, is strongly correlated with) the Governing Council's view of economic conditions.

[20] Interestingly, Ullrich (2003) reports a significant negative coefficient on money growth in reaction functions estimated on euro area data from January 1999 to August 2002.

4.6 Alternative estimates: inflation

As noted above, (my measure of) core inflation appears prominently in the discussion in the Editorials, as do prices of unprocessed food and energy. This raises the question whether the Governing Council responds equally strongly to these inflation measures, in which case headline inflation is the appropriate variable to include in the models. To explore this issue note that, by definition, headline inflation, π, can be written as an average of core inflation, π^c, the rate of change of energy prices, π^e, and the rate of change of unprocessed food prices, π^f (using the weights tabulated in the ECB's Monthly Bulletin):

$$\pi \equiv 0.842 \times \pi^c + 0.081 \times \pi^e + 0.077 \times \pi^f$$

The first column of Table 6 reports again the estimates using headline inflation. In the second column, headline inflation is decomposed into the three components (that is, $0.842 \times \pi^c$, $0.081 \times \pi^e$ and $0.077 \times \pi^f$). If the Governing Council reacts to headline inflation, it should not be possible to reject the hypothesis that the estimated parameters are all 1.24, that is, the parameter estimate for headline inflation in the first column. While the parameters on core inflation and the rate of change of energy prices are significant at the ten percent level, unprocessed food prices are highly insignificant. However, the hypothesis the parameters are equal to 1.24 is not rejected (p = 0.57) and I therefore conclude that the Governing Council reacts to headline inflation.

Estimating the model using the measure of expected inflation constructed using the data in The Economist yields the results in column 3. The pseudo $-R^2$ falls substantially and expected inflation is insignificant. The main conclusion is thus that the Governing Council seems to react to headline inflation in setting interest rates.

4.7 Assessing the model

The results discussed above suggest that a specification in which sentiment, headline inflation, M3 growth, the repo rate, and the lagged change in the repo rate enter as regressors has the highest explanatory power of the models using macroeconomic variables. To explore this model further, I consider the actual versus predicted interest rate changes, both in the form of a contingency table and as time series plots. I also

compare the fit of this model with the model in Table 4 that uses the indicator variables as regressors.

Table 7 presents the actual and predicted outcomes from the model. There are 65 observations, of which 50 involve no change of the interest rate. Since a model with zero explanatory power would predict these correctly, it is more interesting to ask how well the model predicts the 15 interest rate changes that did occur. Interestingly, it correctly predicts the five large cuts in interest rates, but none of the three small cuts. Moreover, it predicts three of the five small increases, but none of the two large increases in rates. Overall, the model thus predicts eight of the fifteen policy changes. For comparison, the model using the indicator variables as regressors predicts correctly eleven of the fifteen interest rate changes (see Table 8).

To explore the model further, it is helpful to compare it to a simpler version that does not distinguish between small and large changes in the repo rate. Reestimating the model using a dependent variable that takes the value of –1 (+1) in months in which the ECB cut (raised) rates, and zero otherwise, yields very similar parameter estimates (and I therefore do no tabulate them). However, that simpler model correctly predicts five of the eight cuts in interest rates, and six of the seven increases. Overall it therefore appears that the model does predict the direction of interest rate changes, but that the fit deteriorates when it is asked to distinguish between small and large changes.

Figures 9 and 10 show the evolution over time of the fitted probabilities of interest rate changes. A comparison with Figure 8 indicates that the tightening in monetary policy in 2000-01 was associated with increases in the predicted probabilities of a tightening of monetary policy, and the cuts in late 2001 and late 2002 occurred in a period when the estimated probabilities of a relaxation of monetary policy were high. The cut in April 1999, which surprised financial markets, did not coincide with high estimated probabilities of a cut. The figures also show that the estimated probabilities for interest rate increases were quite high in late 2003, presumably because money growth was quite high, but rates were nevertheless kept steady.

It is also of interest to compare the model that uses macroeconomic variables as regressors with the model that uses the indicator variables. The highest likelihood value in Table 4 is –24.85 while the value for the preferred model in the first column

of Tables 5 and 6 is –36.29 (the corresponding pseudo $-R^2$:s are 0.55 and 0.34). Furthermore, and as noted above, the model using macroeconomic variables predicted eight of fifteen interest rate changes. By contrast and as is shown in Table 8, the model that uses indicator variables predicts eleven of fifteen changes.

Finally, it is interesting to test the two models directly against each other. One simple way to do so is to note that the estimated parameters times the values of the regressors can be thought of as a latent variable. I can therefore compare the models by computing these variables for the models in the first column of Tables 4 and 5 and by using them as regressors in an ordered probit regression for interest rate changes. The results show that the latent variable from the model using the indicators has a parameter close to unity and is highly significant, while the latent variable of the macro model is highly insignificant. Overall, these results suggest that the model using the indicator variables fits better than the model using macroeconomic variables. Of course, that may not be surprising, in particular since the Governing Council may "ratchet up the rhetoric" the months in which it changes rates.

5. Money growth

Next I turn to the question of the Governing Council's reaction to money growth. As noted above, the ratio of two parameters in an ordered probit model indicates the relative importance of the variables in influencing the probability of an interest rate change. Thus, since the parameter on headline inflation is about 1.2 and that on money growth about 0.9 (see the column 1 in Table 6), a one percentage point change in money growth has three quarters of the impact on the estimated probabilities of a one percentage point change in inflation.[21]

To get a better sense of the role of money growth in the ECB's interest rate setting, it is useful to calculate the probabilities of alternative policy changes as a function of the money growth rate. With five possible outcomes (-0.50%, -0.25%, 0, +0.25% and +0.50%), there are five different probabilities to calculate. Since the probabilities sum to unity, Figure 11 plots four of them as a function of money growth. Before considering the results it is important to recall that the probabilities depend on <u>all</u>

variables, and not only on money growth. To construct the plots, values for inflation, the repo rate, and sentiment must be assumed. Since the results below serve as benchmarks for the subsequent analysis, it is natural to assume that all variables are at their unconditional sample means and that there was no change in the repo rate last month.[22]

The estimated probabilities of a policy change are minimised at the average money growth rate in the sample, which was just above 6%. Faster money growth rates raise the probability of a 0.25% increase in the repo rate relatively quickly. As increasingly higher money growth rates are considered, the probability of a 0.50% increase in repo rates rises rapidly and the probability of a 0.25% increase starts to decline. This illustrates, as discussed above, the fact that the impact of the regressors on the probabilities of the "intermediate" outcomes is ambiguous.

The main finding in Figure 11 is that money growth rates below ten percent do not impact much on the likelihood of a tightening of monetary policy. This finding hinges on the assumption that the other variables are at their sample means, which, of course, makes a policy change unlikely. It is therefore of interest to study the impact of money growth on interest rate decisions in an environment in which a policy change is more likely, such as when sentiment, is strong. To do so, it is necessary to first make assumptions regarding inflation, sentiment and the repo rate. For the calculations to be informative, it is important that the scenarios considered are plausible given the observed relationships between the variables. Letting s denote sentiment, as a first step I obtain $E(\pi|s)$ and $E(i|s)$ by least-squares projection. I can then make assumptions regarding sentiment and use the implied values for inflation and the repo rate in the simulations.

Figure 12 contains a plot of the estimated probability of a 0.25% increase in interest rates for different rates of money growth. The probabilities are constructed under the assumption that sentiment is one standard deviation above its mean, or 8.5%, given which the most likely values for the repo rate and inflation are 3.6% and 1.9%, which I assume. For comparison purposes, the figure also contains the benchmark

[21] A test of the hypothesis that the parameters are equal yields p = 0.62.
[22] The sample means are: inflation, 2.0%; repo rate, 3.2%; and sentiment, 0.3%.

probabilities in Figure 11. The figure shows that the assumption of stronger sentiment shifts the probability-response curve to the left. For instance, while the probability of a small increase in the repo rate when money is growing by 6% is negligible when all variables are at their means, it is around 40% when sentiment is one standard deviation above its mean. Figure 13 contains the analogue curves for the case of a large increase in the repo rate. In this case the impact of a rise in sentiment by one standard deviation perhaps is even more striking. While the probability of a large tightening of monetary policy is essentially zero when the money growth rate is 7% and sentiment is at its mean, that probability is about 50% when sentiment is one standard deviation stronger.

The main conclusion of this analysis is that it appears that under "ordinary" conditions, when changes in monetary policy are unlikely, money growth has little impact on the probability of a policy change. When conditions are weaker or stronger, however, the role of money growth in interest rate setting is much greater.

6. Conclusions

The main conclusions of the analysis above are as follows.

First, measures of economic sentiment or confidence appear to play an important role in the ECB's policy decisions. They are frequently referred to in the Governing Council's discussion of the economy in the Editorials of the Monthly Bulletins and are statistically more significant than several other potential measures of real economic activity in the estimated reaction functions. The use of sentiment as a policy indicator seems sensible in light of the fact that it is strongly correlated with future output gaps and expectations of future real GDP growth. Furthermore, because of publication lags, the Governing Council uses real GDP data largely to assess how reasonable its past judgement of economic activity was. Output gaps thus appear to play no role in its thinking about the current state of the economy.

Second, interest rate changes are more closely tied to economic activity than to inflation and money growth. The reason for this seems to be that economic activity impacts on the Governing Council's assessment of the outlook for inflation. By contrast, it has interpreted movements in realised inflation as being largely temporary and thus as having little implication for future inflation. This has been the case even in situations in which inflation has exceeded the 2% level that constitutes the upper limit

of the ECB's definition of price stability. This interpretation is supported by the fact that expected inflation has been below, but close to, 2% in the period studied.[23]

Third, the "Taylor principle" appears satisfied in the sense that the (point) estimates suggest that the repo rate has to rise by more than one percentage point in order for a one percentage point rise in inflation to have no impact on the probability of an interest rate change. That said, I can not reject the hypothesis that the Governing Council has not raised the real interest rate in response to increases in inflation.

Fourth, the Governing Council reacts to M3 growth. The extent to which it does so, however, depends also on sentiment, inflation, and the level of the repo rate. In "good" times when inflation, sentiment, and the repo rate are at a normal level, the probability of a policy change is not very sensitive to money growth. In times in which there are greater risks of inflation, money growth has a much larger impact on the probability of interest rate changes.

[23] It should be recalled that expected inflation depends on the shocks that hit the economy and the public's perception of the ECB's ability to offset their impact on inflation.

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Table 1
Indicator variables

Month	Inflation	Real Activity	Money	Policy
1999:01	0	-1	0	0
1999:02	0	-1	0	0
1999:03	0	-2	0	0
1999:04	-1	-2	0	-2
1999:05	0	-1	0	0
1999:06	0	-1	0	0
1999:07	0	0	0	0
1999:08	0	0	0	0
1999:09	1	1	1	0
1999:10	1	1	1	0
1999:11	1	1	1	2
1999:12	1	1	1	0
2000:01	1	1	1	0
2000:02	2	2	2	1
2000:03	2	2	2	1
2000:04	2	2	2	1
2000:05	2	2	2	0
2000:06	2	2	2	2
2000:07	2	2	2	0
2000:08	2	2	2	1
2000:09	2	2	2	0
2000:10	2	2	2	1
2000:11	1	1	1	0
2000:12	1	1	1	0
2001:01	1	1	1	0
2001:02	0	1	0	0
2001:03	0	1	0	0
2001:04	0	0	0	0
2001:05	0	0	-1	-1
2001:06	0	0	0	0
2001:07	0	0	0	0
2001:08	0	-1	0	-1
2001:09	0	-1	0	-2
2001:10	0	-1	0	0
2001:11	0	-2	0	-2
2001:12	0	-2	0	0
2002:01	0	-1	0	0
2002:02	0	0	0	0
2002:03	0	0	0	0
2002:04	0	0	0	0
2002:05	1	0	0	0
2002:06	1	0	0	0
2002:07	1	0	1	0
2002:08	0	0	1	0

2002:09	0	-1	0	0
2002:10	0	-1	0	0
2002:11	0	-1	0	0
2002:12	0	-1	0	-2
2003:01	0	-1	0	0
2003:02	0	-1	0	0
2003:03	0	-2	0	-1
2003:04	0	-2	0	0
2003:05	0	-1	0	0
2003:06	0	-2	0	-2
2003:07	0	-1	0	0
2003:08	0	-1	0	0
2003:09	0	0	0	0
2003:10	0	0	0	0
2003:11	0	0	0	0
2003:12	0	0	0	0
2004:01	0	0	0	0
2004:02	0	0	0	0
2004:03	0	0	0	0
2004:04	0	0	0	0
2004:05	0	0	0	0
2004:06	0	0	0	0

Table 2
OLS Regressions of Indicators on Macroeconomic Variables
1999:01 – 2004:06

	Inflation Indicator	Output Indicator	Money Growth Indicator
Sentiment	0.98	1.42	0.60
	[0.00]	[0.00]	[0.03]
Inflation	0.12	0.22	0.07
	[0.46]	[0.41]	[0.81]
M3 Growth	0.33	0.17	0.18
	[0.02]	[0.41]	[0.16]
Rho	0.70	0.72	0.78
	[0.00]	[0.00]	[0.00]
Adj. R-squared	0.81	0.86	0.78

Note: p-values in brackets, []. Standard errors computed using the White correction.

Table 3
Changes in repo rate
January 1999 – June 2004
(66 Observations)

	Small Change (0.25%)	Large Change (0.50%)	Subtotal
Increases	5	2	7
Cuts	3	5	8
Subtotal	8	7	Total: 15

Table 4
Ordered Probit Models
February 1999 – June 2004
(65 Observations)

Repo rate	-1.35	-1.38	-1.33
	[0.00]	[0.00]	[0.00]
Change in repo rate	-4.64	-4.56	-4.62
	[0.02]	[0.02]	[0.02]
Outlook for economic activity	1.89	1.81	2.04
	[0.00]	[0.00]	[0.00]
Outlook for inflation	0.70	1.32	
	[0.57]	[0.07]	
Assessment of money growth	0.59		1.02
	[0.54]		[0.07]
Log likelihood	-24.85	-25.04	-25.02
Pseudo r-squared	0.55	0.54	0.54
Serial correlation, p-value	0.12	0.12	0.11

Note: p-values in brackets [].

Table 5
Ordered Probit Models
February 1999 – June 2004
(65 Observations)

Repo rate	-1.00	-0.38	0.28	-1.12
	[0.03]	[0.24]	[0.50]	[0.01]
Change in repo rate	-3.22	-0.96	-3.13	-1.38
	[0.02]	[0.37]	[0.02]	[0.23]
Inflation	1.24	-0.03	0.35	0.92
	[0.05]	[0.95]	[0.46]	[0.08]
Sentiment	3.50			
	[0.00]			
Industrial production		0.31		
		[0.00]		
EuroCOIN			4.39	
			[0.00]	
Expected growth				2.64
				[0.00]
Money growth	0.90	-0.05	-0.05	0.20
	[0.02]	[0.81]	[0.85]	[0.45]
Log likelihood	-36.29	-46.05	-39.22	-40.52
Pseudo r-squared	0.34	0.16	0.29	0.26
Serial correlation, p-value	0.59	0.77	0.85	0.76

Note: p-values in brackets [].

Table 6
Ordered Probit Models
February 1999 – June 2004
(65 Observations)

Repo rate	-1.00	-0.74	-0.49
	[0.03]	[0.13]	[0.20]
Change in repo rate	-3.22	-3.99	-2.67
	[0.02]	[0.01]	[0.04]
Inflation	1.24		
	[0.05]		
Core inflation		2.20	
		[0.06]	
Energy		1.21	
		[0.10]	
Unprocessed food		-0.77	
		[0.61]	
Expected inflation			0.31
			[0.75]
Sentiment	3.50	3.86	2.96
	[0.00]	[0.00]	[0.00]
M3 growth	0.90	0.92	0.90
	[0.02]	[0.02]	[0.01]
Log likelihood	-36.29	-35.23	-38.52
Pseudo r-squared	0.34	0.36	0.30
Serial correlation, p-value	0.59	0.75	0.62

Note: p-values in brackets [].

Table 7

Actual and predicted interest rate changes
(Using model with macro variables in column 1 in Tables 4 and 5)

	Actual	Predicted	Error
Large cut	5	5	0
Small cut	3	0	3
No change	50	57	-7
Small rise	5	3	2
Large rise	2	0	2

Table 8

Actual and predicted interest rate changes
(Using model with indicators in column 1 in Table 3)

	Actual	Predicted	Error
Large cut	5	5	0
Small cut	3	0	3
No change	50	54	-4
Small rise	5	5	0
Large rise	2	1	1

Figure 1
Sentiment and Output Gaps
(Quarterly data; Normalised)

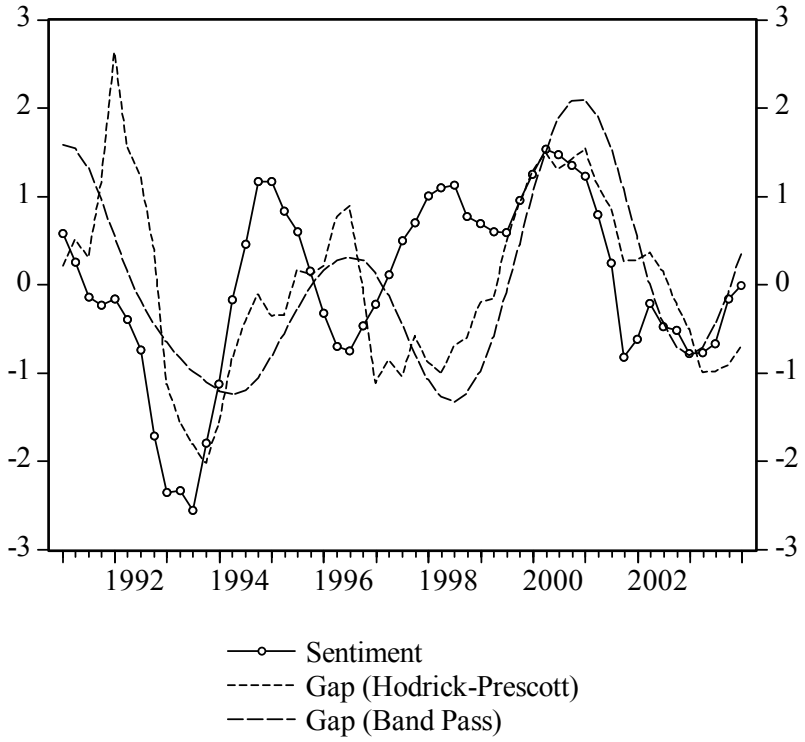

Figure 2
Cross-Correlations of Sentiment and Output Gaps
(Quarterly data; 95% Confidence Band)

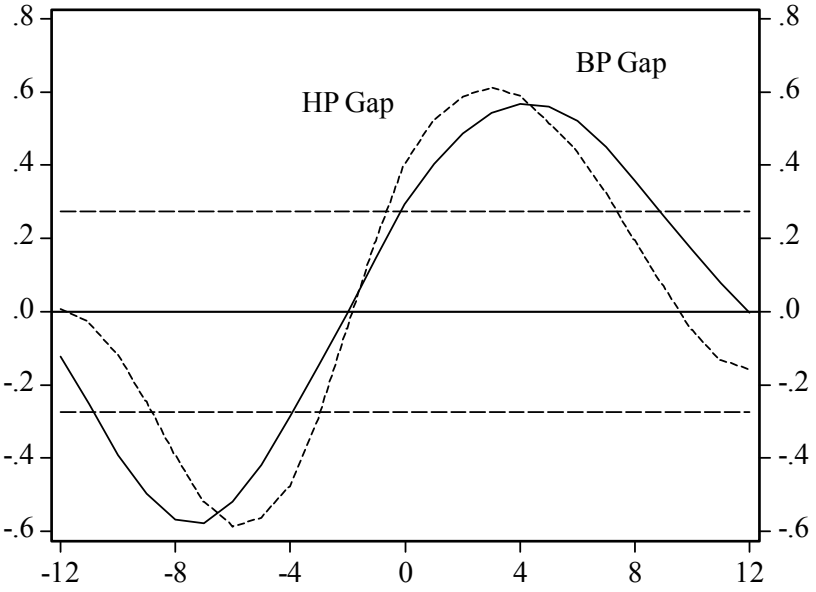

Figure 3
Alternative Inflation Measures 1

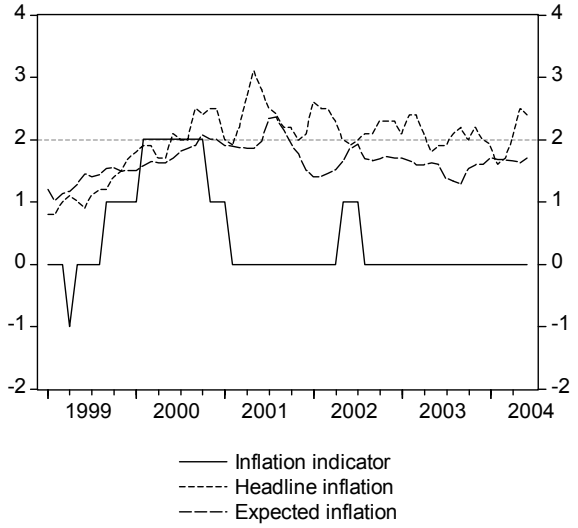

Figure 4
Alternative Inflation Measures 2

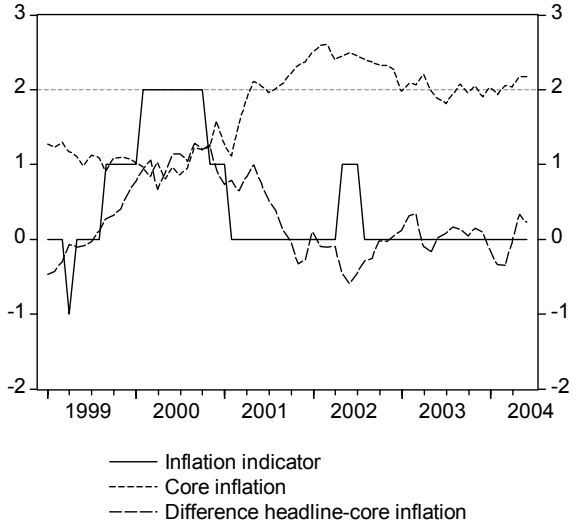

Figure 5
Alternative Measures of Real Economic Activity

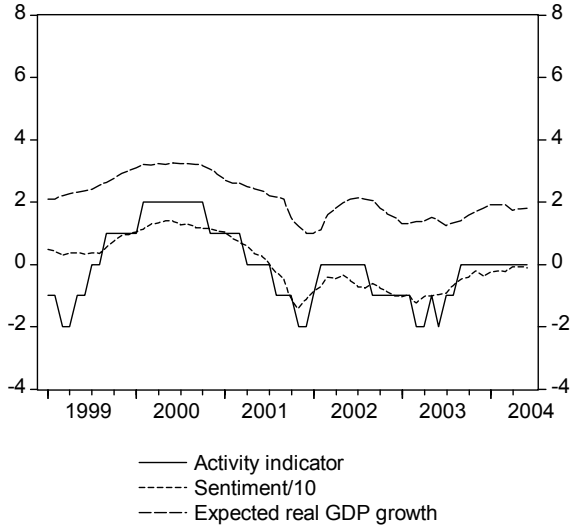

Figure 6
Alternative Measures of Real Economic Activity

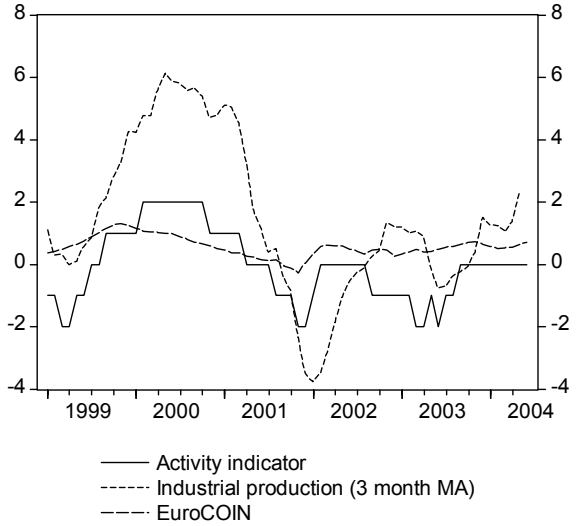

Figure 7
Alternative Measures of Money Growth

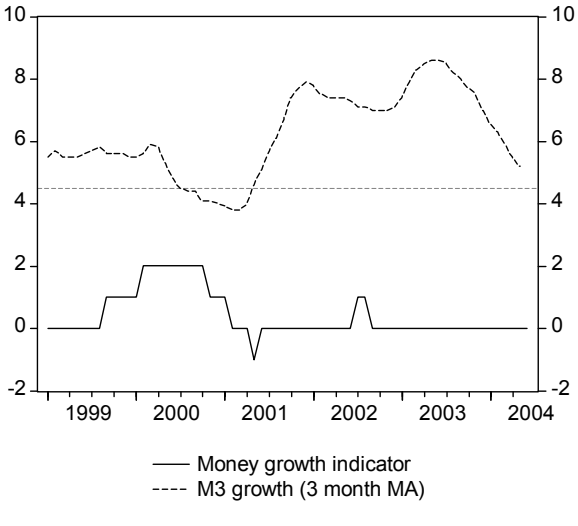

Figure 8
Repo Rate

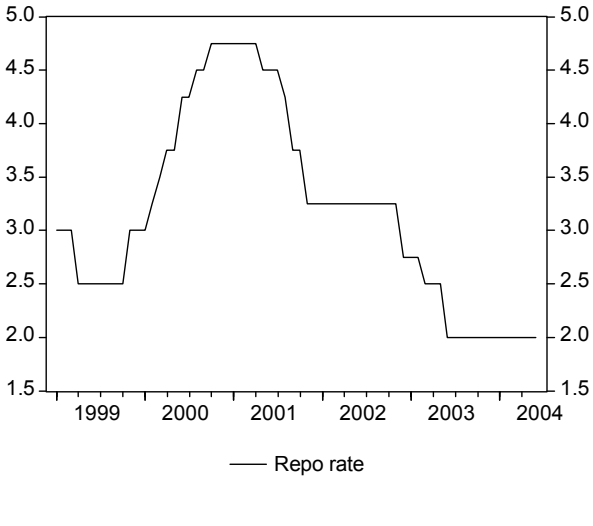

Figure 9
Estimated Probability of an Increase in Interest Rates

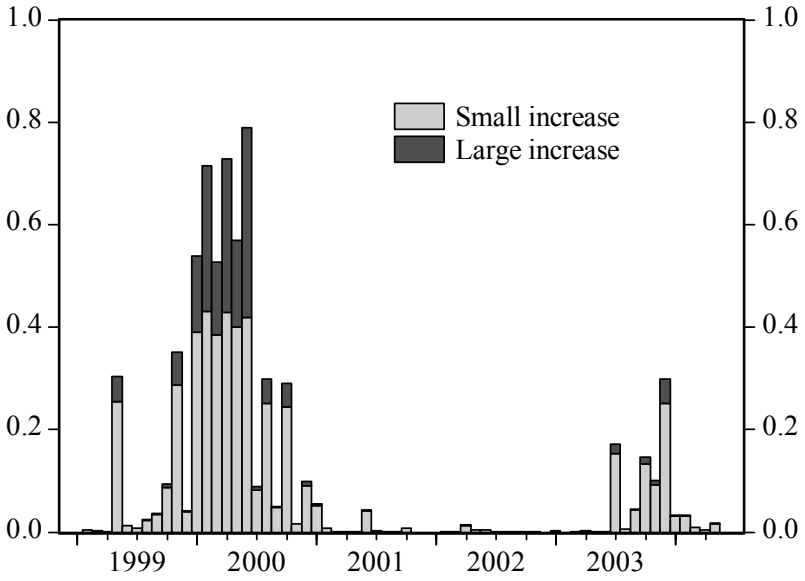

Figure 10
Estimated Probability of a Cut in Interest Rates

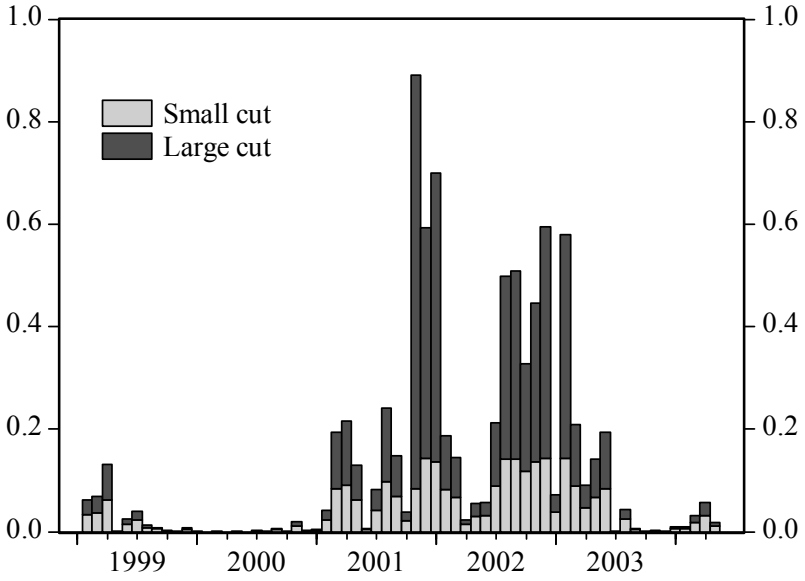

Figure 11
Probability of policy changes
(Variables evaluated at mean of sentiment)

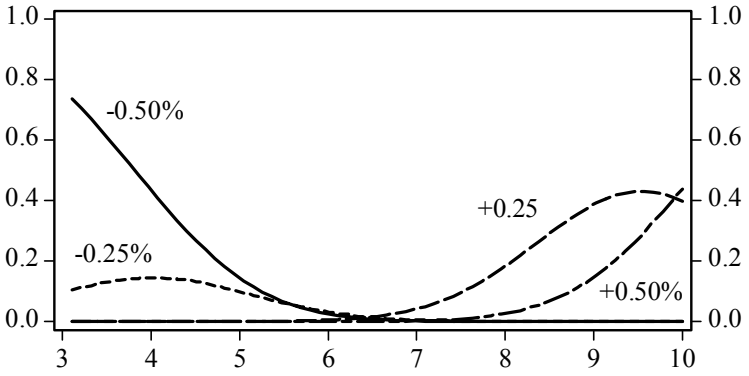

Figure 12
Probability of 0.25% interest rate increase
(Variables evaluated conditional on sentiment)

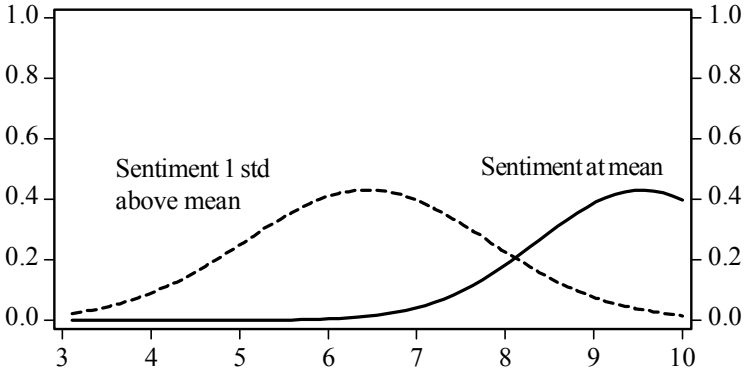

Figure 13
Probability of 0.50% interest rate increase
(Variables evaluated conditional on sentiment)