Essays on Central Bank Forecasting

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Introduction

> I've just picked up a fault in the AE35 unit. It's going to go 100% failure in 72 hours. [...] The 9000 series is [...], by any practical definition of the words, foolproof and incapable of error.
>
> —HAL 9000 in Stanley Kubrick's 2001: A Space Odyssey

The ultimate goal of today's monetary policy makers around the world is to maintain price stability. Modern central banks mostly have refined this goal to keeping inflation on a well-defined target value, or, in case of deviation, bringing inflation back to target. Often, monetary policy makers have the additional pursuit of stabilizing output around potential output. To control these target variables inflation and output growth, a central bank sets the level of its control variable, which usually is some short-term interest rate. Lags in monetary policy transmission, however, complicate the issue, such that a change in interest rates affects inflation and output growth with considerable delay only. Thus, to set interest rates properly, central banks typically consider future values of inflation and output growth when casting the level of the key interest rate. Since these future values are unknown, central banks engage in forecasting to make informed monetary policy decisions in a best possible way.

Different from the science fiction example quoted above, forecasts in the real world are inherently subject to uncertainty. While in earlier times, central banks had a clear emphasis on point forecasts, they have by now recognized that assessments of future uncertainties and risks to the economy are valuable information in their own rights. Today, monetary policy makers employ human capital, computer power and sophisticated models extensively to cope with keeping the standard of publishing forecasts for inflation and output growth in company of an explicit quantification of the respective forecast uncertainties and their potential asymmetries, mostly by publishing entire density forecasts. Moreover, central bankers have contributed to the public understanding of matters by visualizing possible future inflation and output growth values and their uncertainty ranges in form of the well-known fan charts.

A number of questions can come up when considering the intricate and also delicate task for a central bank to making statements concerning likely future developments of the economy. Specifically, it is important to understand why and how central banks communicate their forecasts, and what these central bank forecasts ought to convey besides pure figures. Therefore this thesis aims at providing answers to four specific questions related to the informational and political dimensions of density forecasts and fan charts. This is accomplished by questioning, first, the information content of macroeconomic risk forecasts, second, the construction principles of fan charts, third, the implication of conditioning assumptions for forecast accuracy of point and density forecasts and, fourth, the overall usability of uncertainty and risks forecasts for monetary policy decisions.

Chapter one deals with the information contained in macroeconomic risk forecasts, which are hardly studied in the literature, given that central banks have only since fairly recently been engaged in the quantification of future asymmetries of forecast uncertainty. Many central banks have started providing assessments of the uncertainty surrounding point forecasts and, in addition, a large share of these banks also issues statements about the probability of future outturns lying above or below the point forecasts. Hence, these monetary policy makers are explicit about the asymmetry of the forecast density.

When studying central bank statements, the term 'risk' generally appears, usually in form of phrases like 'the overall risks', 'the balance of risks', or simply 'the risks' to a certain variable. A typical example is a statement as made by the Board of Governors of the Federal Reserve System (2008, p. 41), saying that "Most participants viewed the risks to their projections for GDP growth as weighted to the downside." Such statements thus apparently often refer to the entire set of single risks that have been identified and weighted by their perceived probabilities of materialization as well as their potential impact, while a single risk is usually understood as a possible future event whose occurrence would lead to outturns markedly different from the point forecasts. Hence, statements as shown above are supposed to contain information about the asymmetry of the forecast density.

Forecasting a phenomenon related to third moments, however, is an extremely challenging task, which might be illustrated by the fact that many central banks simply base their assessment of forecast uncertainty, i.e. a phenomenon related to second moments and therefore generally easier to assess, on past forecast errors, see for instance Deutsche Bundesbank (2010, pp. 34-36) for an overview. This is due to the lack of models which can accomplish this task, as explained by Wallis (1989). If forecasting uncertainty appropriately is already difficult, and central banks nonetheless engage in risk forecasting despite the difficulties encountered, it is important to find out how successful these risk forecasts are and whether there is a systematic connection between risk forecasts and mode forecast errors.

This question is investigated using risk forecasts for inflation published by the Bank of England and the Sveriges Riksbank. If there is a systematic connection, given the point forecast is a mode forecast, upside [downside] risks should on average be followed by outturns that are greater [less] than the point forecasts. Moreover, the magnitude of the mode forecast error should on average correspond to the magnitude of the suitably defined forecast risk. If this is the case, the risk forecasts can be considered optimal, or rather, partially optimal in the sense of Diebold and Lopez (1996). If there is no systematic connection, i.e. if the risk forecasts do not help to predict the mode forecast errors, the risk forecasts are uninformative.

It turns out that there is considerable evidence against the optimality of risk forecasts, at least for the Bank of England. For both the Bank of England and the Sveriges Riksbank, no robust evidence is found that risk forecasts have the intended information content. Hence, it seems that there is no systematic connection between risk forecasts and mode forecast errors.

Nonetheless, central banks continue to cast assessments of risks into density forecasts, and chapter two investigates further the reasons why. Results from density forecasting are often depicted as graphs of the central projection and potentially asymmetric uncertainty intervals surrounding this projection, known as fan charts. While potentially asymmetric fan charts are a well established device for monetary policy makers to communicate a baseline and its uncertainties, there exists an oddity regarding their construction. Usually, central bank fan charts are not generated by a model. Blix and Sellin (1999, pp.2-3) describe for the Sveriges Riksbank that “The traditional statistical approach to producing uncertainty intervals would involve [...] constructing a model intended for inflation forecasts. [...] The Riksbank, however, does not use the approach [...].” It is documented, for instance by Britton, Fisher, and Whitley (1998, p.32) for the Bank of England, that fan charts are rather the result of a forecasting process where the “central tendency for inflation [...], the degree of uncertainty [...] and the balance of risks” are to be evaluated. Further examples of central banks that follow this practice include the Magyar Nemzeti Bank, the Banco Central do Brazil and the Banco Central de Chile.

If central bank fan charts are not resulting from a model, the question arises how width and skewness of these graphical devices are set. More generally speaking, what determines the shape of central bank fan charts? Reasons for macroeconomic risk forecasting, which is closely related to skewed densities and asymmetric fan charts, are collected by Knüppel and Schultefrankenfeld (2012) and include non-linearities, frozen-forecast issues, biases in recent forecast errors, expert expectations about future asymmetries of shocks or simply from central bank communication strategies.

An important reason for risk forecasting that virtually summarizes the aforementioned ones is disagreement in decision-making. Disagreement in decision-making within institutions, in particular in the form of disagreement and dissenting views in monetary policy committees, plays a prominent role, since forecasting and monetary policy decisions are usually the concern of several decision-makers in a decision-making body of a central bank. In committees such as the Monetary Policy Committee of the Bank of England, the Policy Board of the Bank of Japan, the Federal Open Market Committee at the Federal Reserve System and the Governing Council of the European Central Bank, several members vote on an interest rate proposal made by the chairman to raise, maintain or lower the key interest rate. If at the end of the voting procedure a proposal has attained the majority of the member votes, the aggregate interest rate decision is achieved. In a second round, the committee then has usually to agree on an aggregate inflation projection that consistent with this interest rate decision.

Typically, committee members form their interest vote on the basis that inflation in two years ahead has to be on target. If there are minority views that do not agree with the interest rate decision, these minority voters probably do not agree with the aggregate projection, as they may consider future inflation unlikely to hit the target given the aggregate interest rate decision. If views of the decision-making body as a whole are represented by fan charts, then it seems reasonable that dissenting views on monetary policy have an effect on the shape of central bank inflation fan charts.

Although no individual inflation forecasts are available, the Bank of England, the Magyar Nemzeti Bank and the Sveriges Riksbank are the only central banks that make attributed interest rate voting records as well as the entire forecast densities published in their inflation reports available. Hence, the individual paths of interest rates for the committee members can be determined. This dataset allows to investigate if there is a systematic connection between the degree of disagreement about monetary policy committee decisions on the level of the policy instrument and risks and uncertainties to forecasts of the target variable inflation, as published in the subsequent monetary policy reports. Disagreement is found to translate into wider fan charts in case of the Hungarian national bank. For the Bank of England and the Sveriges Riksbank, there is statistical evidence that disagreement on the level of interest rates can fairly well explain the skewness of forecast inflation fan charts. This prepares ground for the argument that dissenting views in monetary policy committees voting on central banks' level of the policy instrument are a significant determinant of the shape of forecast inflation fan charts.

After having addressed the relationship between disagreement on interest rates and density forecasts, chapter three takes a different perspective and asks if certain assumptions about the future path of interest rates affect the predictive accuracy of mean and density forecasts of central banks. For the forecasts of variables central banks intend to control, the policy variable, i.e. the short-term interest rate set by the central bank, plays a special role. According to Galí (2011), in practice one can basically distinguish three approaches. Firstly, forecasts can be conditioned on a constant interest-rate assumption, such that the interest rate is assumed to remain at the level it had attained at the time the forecast was made. This so-called CIR approach was pursued, for example, by the ECB until 2006 and the Sveriges Riksbank until the end of 2005. Secondly, the expectations of market participants can serve as a conditioning assumption about the interest rate path. The so-called ME approach is current practice at, for example, the Bank of Japan and the ECB. Market expectations are usually derived from the term structure of interest rates. Finally, a central bank can issue unconditional forecasts for its target variables by using its own expectations about the interest rate path. The CBE approach, as it is called, has been adopted, for instance, by the Norges Bank, the Riksbank and the Federal Reserve System. The Fed's December 2011 FOMC statement contributed to drawing the attention of economists to the topic of interest rate assumptions when announcing that "participants agreed that adding their projections of the target federal funds rate to the economic projections already provided in the SEP [Summary of Economic Projections] would help the public better understand the Committee's monetary policy decisions".

Among academics, there seems to be a clear ranking of the three approaches in terms of their suitability for central bank forecasts. Galí (2011), Svensson (2006) and Woodford (2005) advocate the approach of central bank expectations, i.e. prefer unconditional forecasts. Galí (2011) shows that it is possible to construct different forecasts conditional on one given nominal interest rate path, thus calling into question any conditioning assumptions about interest rates, and a similar point is raised by Woodford (2005). Overall, in the theoretical literature, it is evident that the CBE approach is supposed to yield the highest forecast accuracy. This property serves as one of the main reasons for preferring the CBE approach over conditional forecasts. For instance, Galí (2011, p.539) states that "it is not clear why the central bank would want to base its projections on a rule other than the actual rule it follows for, among other things, in that case the projections would also correspond to the best unconditional forecasts". Svensson (2006) also resorts to the potential gains in forecast accuracy when advocating the CBE approach. The literature does not provide comparably clear ideas concerning the relative forecast accuracy of the ME approach with respect to the

CIR approach. However, it seems plausible that the ME approach should perform better unless the policy rate is best described by a random walk.

A large share of central banks, however, does not base its forecasts on its own interest rate expectations, probably also to circumvent potential communication issues. Goodhart (2009), for instance, finds that using the central bank's expectations of the interest rate could be misunderstood as a commitment. Therefore, an interest rate path derived from market expectations is "a brilliant compromise" (Goodhart 2009, p. 94) between the potential lack of credibility of a constant rate assumption and the problems associated with publishing a path of future interest rates expected by the central bank. However, there are also central banks, for instance the Swiss National Bank, that use the constant interest rate assumption, whose merits are described in Goodhart (2001). Several empirical aspects related to interest rate assumptions are investigated in Andersson and Hofmann (2009), for instance that if a central bank is transparent and committed to maintaining price stability, the behavior of key variables like inflation expectations and long-term bond yields does not seem to be affected by the type of interest-rate assumption. In contrast to that, Winkelmann (2010) finds that using the CBE approach instead of the ME approach leads to better private-sector forecasts of longer-term interest rates.

The effects of the interest rate assumptions is assessed by testing for differences in forecast accuracy, since forecast accuracy is one the main reasons given in the academic literature for preferring the CBE approach. Moreover, forecast accuracy is related to central bank communication and the banks' ability to steer market expectations for interest rates, inflation, and growth, and, thus, financial variables like bond yields, if the precision of central bank information varies with the conditioning assumption. Hence, forecast accuracy may also to detect if any of the three forecasting approaches yields improvements in monetary policy, such that central banks may better control macroeconomic volatility. To this extent, interest rate, inflation forecast and real GDP data from the Bank of England and the Banco Central do Brazil are exploited in order to assess the impact of the various interest rate assumptions on forecast accuracy. Results show that there is no significant difference in the predictive accuracy of competing forecast made conditional on different interest rate assumption. Thus, the theoretical ranking of the CBE, ME and CIR approaches cannot be confirmed empirically on the basis of data from the two central banks.

Finally, chapter four asks how central banks utilize information from their own forecasts of their target variables, in particular so from uncertainty and risk forecasts of these, when deciding on monetary policy. Monetary policy makers, such as the Bank of England, Sveriges Riksbank, Banco de Portugal, or Magyar Nemzeti Bank, to name but a few, publish entire probability distributions of the forecast variables inflation and output growth and thereby explicitly quantify forecast uncertainty. Forecasting entire densities is not an end in itself. If monetary policy decisions are made subject to economic prospects, it seems reasonable that uncertainty about these prospects may have an influence on the decisions.

Forecast-based rules encompass the lags of monetary policy transmission, and the forecast data are already conditioned on the relevant information set on future economic developments, see Batini and Haldane (1999). Thus, forecast-based rules can be a fairly precise and yet compact tool for characterizing historical monetary policy decisions, as shown by Kuttner (2004) who evaluates forecast-based rules for New Zealand, Sweden, the United Kingdom, and the United States. Similarly, Goodhart (2005) presents estimates of a forecast-based Bank of England's Monetary Policy Committee reaction function and emphasizes the Committee's high degree of forward-looking with respect to inflation. Besley, Meads, and Surico (2008) analyze the role of heterogeneity among the board members of the bank's committee in a forecast-based rule setting. Gorter et al. (2008, 2009) provide evidence for the performance of interest rate rules for the European Central Bank, based on expectations data constructed from Consensus Economics forecasts. Orphanides and Wieland (2008) explain the Federal Open Market Committee decisions by its own projections for inflation and unemployment.

Studies in particular of Bhattacharjee and Holly (2010), Kim and Nelson (2006) and Martin and Milas (2005a, 2005b, 2006, 2009) have considered the impact of uncertainty on interest rate decisions and find either intensified or attenuated reactions. Yet, the uncertainty measures used in these studies do not reflect the measure of uncertainty that the institution under study was facing when making the monetary policy decision. To account for that lack, chapter four shows how to recover the exact forecast standard deviations for inflation and for output growth directly from the forecast densities which are published by the Bank of England between 1997Q4 and 2009Q4, following a recipe of Wallis (2004). These forecast standard deviations originally associated with the forecast location parameters reflect the genuine and thus relevant measure of uncertainty about future economic developments which the Monetary Policy Committee has available at the time the interest rate decision is made. Uncertainty measures are incorporated directly in forecast-based interest rate reaction functions in order to estimate the strength and the direction of the impact of forecast uncertainty on the Monetary Policy Committee's interest rate responses to forecast deviations of inflation from target and output growth from long-run mean.

Since the Bank of England emphasizes its use of the two-piece normal distribution, potential asymmetries in forecast uncertainty have to be taken into consideration. Forecast uncertainty is asymmetric when an average of likely alternative outcomes for one variable is seen to exceed or to fall short of the central projection for that variable. The Monetary Policy Committee defines such a difference between mean and mode forecast as forecast risk to the central projection. Hence, to control for these risks, the exact forecast Pearson mode skewness for inflation and for output growth, is included into the regression models. Results show that forecast inflation uncertainty has a very strong and intensifying effect on interest rate reactions. In contrast, forecast output growth uncertainty has an attenuating effect on the interest rate decision response. Forecast upward risks to inflation contribute to the intensifying effect of forecast inflation uncertainty. Forecast risks for inflation have a direct effect on interest rate decisions, in particular when the central projection for inflation is close to target. Interestingly, the bank's inhouse uncertainty and risk measures seem to be exhaustive, as insignificant results obtained from using direct uncertainty and risk measures constructed from the density forecasts of the bank's Survey of External Forecasters show.

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Chapter 1

How Informative Are Central Bank Assessments of Macroeconomic Risks?

Abstract: Many central banks publish regular assessments of the magnitude and balance of risks to the macroeconomic outlook. In this paper, we analyze the statistical properties of the inflation risk assessments that have been published by the Bank of England and the Sveriges Riksbank. In each case, we find no significant evidence of any systematic connection between the ex ante risk assessments and the ex post forecast errors at horizons from zero to eight quarters. These results illustrate the difficult challenges in making accurate real-time assessments of temporal changes in the distribution of forecast errors.

Keywords: Forecast Evaluation, Risk Forecasts, Inflation Forecasts

JEL-Codes: E37, C12, C53

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Knüppel, M. and Schultefrankenfeld, G., 2012, How informative are central bank assessments of macroeconomic risks?, International Journal of Central Banking 8(3), 87-139.

1.1 Introduction

> "If Banks routinely report risk assessments, then those assessments should be systematically evaluated, just as the accuracy of Banks' inflation forecasts are evaluated. [...] If such an analysis finds no systematic connection between risk assessments and forecast errors, then the value of the risk assessments is called into question."
>
> — Eric Leeper (2003, p.16)[1]

Today, most major central banks publish point forecasts for macroeconomic variables that play an important role in the monetary policy decision-making process. Moreover, many central banks also provide an assessment of the uncertainty surrounding these forecasts. In addition to this information, a large share of central banks issues statements about the probability of future outturns lying above or below the point forecasts, i.e. about the asymmetry of the forecast density. In these statements, the term 'risk' generally appears. A single risk to the forecast is usually understood to be a possible future event whose occurrence would lead to outturns that differ markedly from the point forecasts. Statements about 'the overall risks', 'the balance of risks', or simply 'the risks' to a certain variable then apparently often refer to the entire set of single risks that have been identified and weighted by their perceived probabilities of materialization as well as their potential impact. These statements are supposed to contain information about the asymmetry of the forecast density. For example, a typical statement of this kind can read "Most participants viewed the risks to their projections for GDP growth as weighted to the downside."[2] We will further elaborate on central bank's use of the term 'risk' below.

Determining the asymmetry of a forecast density, i.e. forecasting a phenomenon related to third moments is certainly an extremely challenging task. This might be illustrated by the fact that many central banks simply base their assessment of forecast uncertainty, i.e. a phenomenon related to second moments and therefore generally easier to assess, on past forecast errors.[3] This is due to the lack of models which can accomplish this task, as explained by Wallis (1989). However, if it is so difficult to forecast the uncertainty surrounding an institution's forecast appropriately, it is questionable whether risks can be forecast in a reasonable manner. Given that so many institutions engage in risk forecasting despite the difficulties encountered, it is important and interesting to find out how successful these risk forecasts are.

[1] In a footnote, Eric Leeper thanks Stefan Palmqvist for making this suggestion.

[2] See Board of Governors of the Federal Reserve System (2008, p.41). Henceforth, we will refer to the Board of Governors of the Federal Reserve System simply as the Federal Reserve.

[3] See Deutsche Bundesbank (2010, pp.34-36) for an overview.

In this paper, we concentrate on risk forecasts for inflation published by the Bank of England (henceforth BoE) and the Sveriges Riksbank (henceforth Riksbank) due to data availability. To the best of our knowledge, there have hardly been any investigations of risk forecasts in the literature. For the BoE, which has the longest risk forecasting record, risk forecasts have at best been evaluated in the context of investigations of the entire forecast density. For instance, Wallis (2003, p.165) states that "the excessive concern with upside risk was not justified over the period considered." In a comprehensive study of the BoE's density forecasts, Mitchell and Hall (2005) note that the null hypothesis of equal density forecast accuracy for the BoE's asymmetric and the corresponding symmetric forecast densities could not be rejected. Both studies focus on one-year-ahead inflation forecasts.[4]

While these results already hint at the existence of problems with the risk forecasts, it still remains to be analyzed whether there is a systematic connection between the BoE's risk forecasts and its forecast errors. If there is a systematic connection, and if the point forecast is a mode forecast, then upside [downside] risks should on average be followed by outturns that are greater [less] than the point forecasts. Moreover, the magnitude of the mode forecast error should on average correspond to the magnitude of the (suitably defined) forecast risk. If this is the case, the risk forecasts can be considered optimal.[5] If there is no systematic connection, i.e. if the risk forecasts do not help to predict the mode forecast errors, the risk forecasts are uninformative.

The analysis in this study is performed in the context of tests for forecast optimality similar to those of Mincer and Zarnowitz (1969). It turns out that there is considerable evidence against the optimality of risk forecasts, at least for the BoE. For both central banks under study, we fail to find robust evidence that risk forecasts have the intended information content. Put differently, it seems that there is no systematic connection between risk forecasts and mode forecast errors.

The outline of the paper is as follows. We present a survey of current risk-forecasting practices at several central banks in Section 2. In Section 3, we give an overview of our forecast data set. In Section 4, we explain the methodology used, and Section 5 follows with a detailed analysis of the risk forecasts of the BoE and the Riksbank with respect to optimality and informativeness. In Section 6, we briefly address reasons for risk forecasting in light of the apparent lack of information content found in Section 5. Section 7 concludes.

[4] Wallis (2003) does not find major problems when studying the inflation nowcasts.

[5] To be more precise, they would at least be considered partially optimal in the sense of Diebold and Rudebusch (1996). The concept of optimality used in this paper will become clear in Section 1.4.

1.2 An Overview of Risk Forecasting

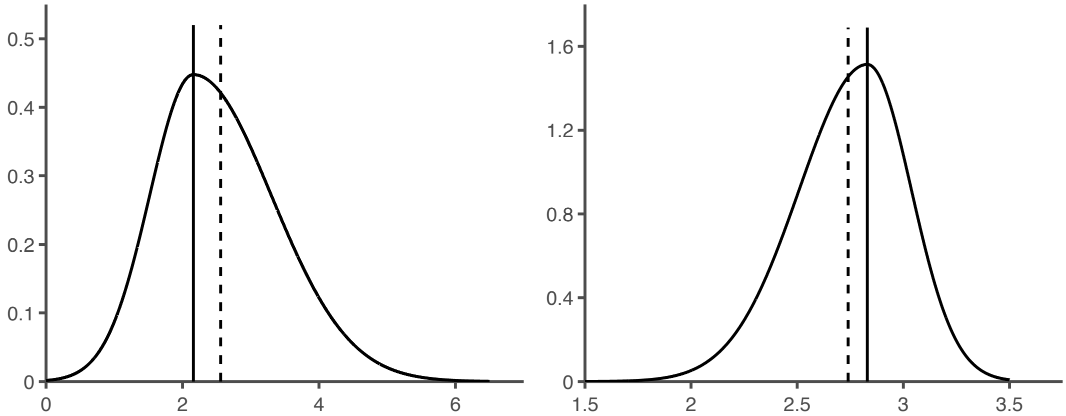
Although the term 'risk' is used in many forecasting-related central bank publications, there is no unique definition of its meaning. In the New Palgrave Dictionary of Economics, Machina and Rothschild (2008) state that "A situation is said to involve 'risk' if the randomness facing an economic agent presents itself in the form of exogenously specified or scientifically calculable objective probabilities, as with gambles based on a roulette wheel or a pair of dice." However, the term 'risk' as used by central banks often refers to important events with a rather uncertain probability of occurrence, like a large change in oil prices or in exchange rates. A different interpretation of the term 'risk' is provided by Kilian and Manganelli (2007), who link the risks to the preferences of central bankers. This might be a valid interpretation with respect to several statements made by the Federal Reserve during a certain period. It is not adequate, though, for the current risk forecasts of the Federal Reserve and many other central banks, among others those whose data are investigated in this study.

Many central banks devote a kind of stand-alone publication such as a box, a chapter, or an article to their respective definitions of risk. An example-based yet precise definition is given by the BoE in Britton, Fisher, and Whitley (1998, pp.32-33).[6] According to the BoE, a risk is given by an uncertain and important event not taken into account in the central view, where the central view, i.e. the point forecast, corresponds to the mode of the forecast density. In contrast to the definition of Machina and Rothschild (2008), the probability of the event is not exogenously specified or scientifically calculable, and in contrast to the interpretation of Kilian and Manganelli (2007), the risk is unrelated to the preferences of the central bank. The balance of risks refers to the probabilities of the events mentioned producing values above or below the point forecast. The balance of risks is thus directly related to the skewness of the forecast density, which, in the case of the BoE, is measured as the difference between the mean and the mode of the forecast density. In Figure 1.1, two asymmetric forecast densities from the BoE are displayed.

The fact that the mode (and not the mean) of the forecast density serves as the BoE's point forecast appears surprising, since aiming at the mode is associated with a rather im-

[6] It reads: "In deciding upon central assumptions and risks across key components of the forecast, it may become clear that the risks are unbalanced. A good example of this is the effect of 'windfall' gains to consumers from the conversion of several building societies to banks in 1997. Uncertainty about the pace at which the windfalls would be spent represented a risk to the forecast of consumer spending. The Bank's theoretical analysis suggested that only a small proportion of these gains would be spent in the first year, and correspondingly took this as a central view. In the Bank's judgment, the risks were much greater that actual expenditure would be in excess of the central forecast assumption than that it would be less. This was an upside risk to the forecast during most of 1997. In order to produce the fan chart, only one number is needed to summarise the degree of skewness (the balance of risks). Just as with the central view and the degree of uncertainty, there is more than one possible choice of parameter. The Bank's analysis focuses on the difference between the mean and the mode of the forecast distribution to be presented in the Report. This difference is of interest as a summary statistic of the balance of risks."

Figure 1.1: Two of the Bank of England's density forecasts for inflation



Note: The forecast in the left-hand panel, made in the second quarter of 2002 for the first quarter of 2004, implies an upward risk, where the mean (dashed vertical line) exceeds the mode (solid vertical line). The forecast in the right-hand panel, made in the second quarter of 1998 for the same quarter, implies a downward risk, with the mean (dashed vertical line) falling short of the mode (solid vertical line).

plausible all-or-nothing loss function of the policy maker.[7] Interestingly, however, nearly all of the central banks we consider in this study as listed in Table 1.1 specifically indicate that their point forecasts are mode forecasts.[8]

Definitions of risk similar to the one used by the BoE can be found in the publications of other central banks. The Riksbank (1998, p.36) writes that "[...] two aspects of the forecast distribution are assessed subjectively: whether the uncertainty in the forecast differs from the historical uncertainty [...], and whether the risk of forecasting errors is symmetric, upside or downside. In the absence of information to the contrary, the risk is assumed to be symmetric. [...] A skewed uncertainty (a difference between the upside and downside risks in the assessment of a particular variable, e.g. imports) affects the distribution of the inflation forecast by the amount of the variable's weight in the macro model. Skew is measured as the difference between the mean value and the most probable value (the mode of the distribution)." Again, the mode forecast serves as the point forecast. Further details concerning the forecasts of the Riksbank can be found in Blix and Sellin (1999). However, the Riksbank changed its forecasting procedure in 2007. Since then, it has only published symmetric forecast densities and has not mentioned the balance of risks, but just scenarios and risks. The Riksbank (2009, p.22) now states that "The forecasts in the main scenario show the path which the Riksbank expects the economy to take and is a weighted consideration of various conceivable

[7] See Wallis (1999) for a discussion.

[8] From Table 1.1, only the Bank of Israel and the Swiss National Bank do not explicitly characterize the meaning of their point forecasts. Moreover, the Bank of Japan and the Federal Reserve do not produce unified forecasts but instead publish summary statistics and histograms of modal forecasts from individual policy makers. The European Central Bank only publishes forecast ranges.

development paths (scenarios) and risks"; therefore, its main forecast currently seems to be a mean forecast. The Norges Bank appears to use the same approach.

Other central banks have followed the path set out by the BoE and the Riksbank. For example, the Magyar Nemzeti Bank (2004, p.108) writes that "The method that we follow in preparing fan charts broadly corresponds to that of the Bank of England, and the same holds true for the Swedish method".

The Federal Reserve (2008, p.45) explains that the members of the Board of Governors and the presidents of the Federal Reserve Banks "provide judgements as to whether the risks to their projections are weighted to the upside, downside, or are broadly balanced. That is, participants judge whether each variable is more likely to be above or below their projections of the most likely outcome". Hence, in contrast to the approaches mentioned so far, the risk assessments are only qualitative (naming upside, downside, or broadly balanced risks) and not quantitative. This means that there is no number attached to the risk forecasts; only the direction of the risk is given. The same applies to the risk forecasts of the European Central Bank (henceforth ECB). For example, the ECB (2010, p.6) states that "In the Governing Council's assessment, the risks to this improved economic outlook are slightly tilted to the downside".[9]

Several other central banks also link the overall forecast risks to the asymmetry of the forecast density, among them the Bank of Canada, the Banco Central de Chile, the Banco de España, the Bank of Japan, the Banco de Portugal, the Deutsche Bundesbank, and the International Monetary Fund (henceforth IMF).[10] Details concerning the corresponding references are provided below.

We also found central banks which regularly report their assessments of individual risks but which do not always mention the balance of these risks. For example, the Reserve Bank of Australia (2008, p.68) states that "Risks to these forecasts can be identified in both directions. A further deterioration in the outlook for global growth would be the main source of downside risk to the forecasts for domestic activity". Another example is the Swiss National Bank (2010a, p.40), which declares that "The biggest risk for the global economy is the continued increase in tension on financial markets [...]. At the same time, there are upside risks for the global economy [...]". In both cases, no overall assessment of risks follows. Yet

[9]However, the ECB often also mentions "risks to price stability", where the term 'risks' instead appears to refer to the possibility that the ECB might not achieve its "aim of keeping inflation rates below, but close to, 2% over the medium term" (ECB, 2010, p. 6). In this case, the risks are apparently unrelated to the asymmetry of a forecast density. Note that the risks to price stability can also be asymmetric, as described in the statements: "The information that has become available [...] has confirmed that [...] upside risks to price stability over the medium term prevail" (ECB, 2008, p.5). Yet this asymmetry supposedly just refers to the probability of observing inflation rates above 2% over the medium term being larger than 50%, and is therefore also unrelated to the asymmetry of forecast densities.

[10]The IMF is an intergovernmental organization, but we consider it here because its interpretation of risk forecasts is identical to that used by most central banks.

Table 1.1: Central bank assessments of macroeconomic balances of risks

Central Bank	**Type of Assessment**	**Assessment of Inflation Risk**	**Assessment of Real Risk**	**Publication of Fan Charts**
Bank of Canada	quantitative	yes	no	asymmetric
Banco Central de Chile	quantitative	yes	yes	asymmetric
Bank of England	quantitative	yes	yes	asymmetric
Banco de España	qualitative	yes	yes	symmetric
Bank of Israel	qualitative	yes	no	symmetric
Bank of Japan	quantitative	yes	yes	none
Banco de Portugal	quantitative	yes	yes	asymmetric
Board of Governors of the Federal Reserve System	qualitative	yes	yes	none
Deutsche Bundesbank	qualitative	yes	yes	symmetric
European Central Bank	qualitative	yes	yes	none
International Monetary Fund	quantitative	yes	yes	asymmetric
Magyar Nemzeti Bank	quantitative	yes	yes	asymmetric
Norges Bank	none	no	no	symmetric
Reserve Bank of Australia	qualitative	yes	yes	none
Reserve Bank of New Zealand	qualitative	yes	yes	none
Sveriges Riksbank (2007 - present)	none	no	no	symmetric
Sveriges Riksbank (1999 - 2006)	quantitative	yes	no	asymmetric
Swiss National Bank	qualitative	yes	yes	none

sometimes such an assessment is made by these central banks.[11] The Reserve Bank of New Zealand behaves similarly to the two aforementioned central banks, making clear statements concerning the overall risks on some occasions and mentioning only individual risks on others. The same applies to the Bank of Israel.

In Table 1.1, we present an overview of the risk forecasting practices of several central banks. Of course, this table only reflects the current situation, and the approaches to risk forecasting might change over time, as in the case of the Riksbank. Moreover, in some cases we have not been able to discover statements concerning the balance of risks, but it is not impossible that these exist.[12] All central banks shown in the table regularly discuss risks to their forecasts.[13] Furthermore, as mentioned above, almost all of these central banks use the mode forecast as their central forecast.

All central banks shown in the table which make precise statements concerning the meaning of the balance of risks use at least one of the following definitions. If the balance of risks for a certain variable is tilted to the upside, this means that the expected value of that variable exceeds the most likely value (i.e. the point forecast which is identical to the mode forecast), that the probability of an outturn above the point forecast is more likely than an outturn below, or that the forecast density is positively skewed.[14] Thus balance-of-risks statements are supposed to contain information about the potential asymmetry of the forecast density.

It should be noted that, for many asymmetric distributions, the above-mentioned inequalities $E[Y] > mode(Y)$, $P(y > mode\,(Y)) > P(y < mode\,(Y))$, and $E[(Y - E[Y])^3] > 0$ imply each other.[15] This holds, for example, in case of the two-piece normal distribution used by the BoE, the Magyar Nemzeti Bank, the IMF and the Riksbank (until 2006) for their asymmetric fan charts.[16] Therefore, potential differences in the technical definitions of the balance of risks are probably irrelevant in actual practice.

It is perfectly possible for a central bank to consider the balance of risks to be asymmetric and nevertheless publish symmetric fan charts, as in the case of the Deutsche Bundesbank, the Banco de España, or the Bank of Israel. This could be due to the fact that these central banks, like many others, assess the balance of risks in a qualitative manner only. Asymmetric fan charts tend to be used if quantitative risk assessments are produced. The Banco de

[11] For example, the Swiss National Bank (2010b, p.26) claims that “At present, the upside and downside risks are relatively balanced” for output growth.

[12] We corresponded with members of several central banks in order to minimize the possibility of certain definitions having slipped our attention.

[13] Table 1.6 in Appendix A.1 lists where these discussions can be found.

[14] In Appendix A.1, we provide the references on which several of the statements made above and Table 1.1 are based.

[15] The same applies to the reversed inequalities $E[Y] < mode(Y)$, $P(y > mode\,(Y)) < P(y < mode\,(Y))$ and $E[(Y - E[Y])^3] < 0$. $E[Y]$ denotes the expectation of Y and $P\,(A)$ the probability of event A.

[16] We will elaborate on this distribution below.

Portugal and the Riksbank (1999-2006) are the only central banks which also release figures measuring the risk of the forecast density in their main publications.[17] The Banco de Portugal shows the probabilities of an outturn below the central projection. The Riksbank (1999-2006) publishes the values of the mode and the mean of the forecast density.

Reading through central bank publications, it seems that risks to inflation or other aggregates are commonly identified via risks to variables that determine these aggregates. For example, an upward risk to inflation might be caused by an upward risk to oil prices, to the value-added tax (henceforth VAT) rate or by a risk of the domestic currency depreciating. Thus, in order to correctly forecast the risks to inflation, one has to forecast the risks to these determinants. Actually, the process of risk forecasting could be thought of as a three-step process. In the first step, those determinants which are subject to forecast risks have to be identified. In the second step, these risks must be quantified, and in the third step, their impact on the aggregate of interest has to be calculated.

All of these steps appear extremely demanding. The first step requires the identification of variables whose most likely future paths (represented by the mode forecast) differ from their expected future paths (represented by the mean forecast). This might be possible for fiscal variables like the VAT rate, where one could imagine that a certain rate is likely, but that an alternative rate is being discussed by the government at the time the forecast is made. For variables like oil prices and exchange rates, however, this task is very challenging. The subsequent quantification of the identified risks appears fairly difficult as well. Elekdag and Kannan (2009) propose methods for accomplishing this task which can be applied to certain variables. However, their empirical performance is not evaluated. Apparently, most central banks rely on judgement for identifying as well as quantifying risks. Yet even if the risks to determinants are correctly identified and quantified, assessing their impact on the aggregate of interest is no trivial matter, as explained in Pinheiro and Esteves (2010).

To summarize, all central banks considered discuss risks to their forecasts, and many of them also assess the balance of these risks. The balance of risks is supposed to contain information about the asymmetry of the forecast density. The published point forecast corresponds to the mode of the forecast density for almost all central banks. In the following, the term 'risk forecast' will refer to the balance-of-risks forecast, i.e. to a potentially asymmetric forecast density. It will thus not denote the assessment of certain individual risks without the evaluation of their overall effect on the forecast variable of interest.

[17] Figures for the BoE's and the Magyar Nemzeti Bank's density forecasts can be downloaded from the respective websites.

1.3 Data

1.3.1 Data Sources

The risk forecasting record of most central banks is very limited. As explained in Knüppel and Schultefrankenfeld (2011), inference concerning risk forecasts tends to be easier with quantitative than with qualitative risk forecasts. Therefore, we focus on data sources where quantitative risk forecasts are available. The first quantitative risk forecast that we are aware of was published by the BoE in its Inflation Report from February 1996 for inflation.[18] As mentioned before, the Riksbank issued quantitative risk assessments from 1999 to 2006. Our subsequent analysis will be restricted to the risk forecasts of these two central banks, because the quantitative risk forecasts of the other institutions shown in Table 1.1 are (still) unsuitable for evaluation purposes.[19]

The BoE and the Riksbank use the two-piece normal distribution (henceforth *tpn*-distribution) as described, for example, in Wallis (2004, p.66). Our analysis utilizes the BoE's forecasts for inflation, based on the assumption that the future official Bank Rate, i.e. the interest rate paid on commercial bank reserves, follows a path implied by market interest rates.[20] In line with Elder, Kapetanios, Taylor, and Yates (2005), for the purpose of forecast evaluations we consider this assumption more adequate than that of a constant official Bank Rate. The forecast and inflation data range from the first quarter of 1998 (henceforth 1998Q1) - the first time the aforementioned interest assumption was used - to 2010Q2. Each of the BoE's quarterly projections covers the current and the subsequent 8 quarters. For some forecasts, mean and mode forecast coincide, which results in a risk forecast equal to zero. This means that the risks to the inflation forecast are balanced.[21] The BoE publishes several parameters of the forecast densities that allow a straightforward calculation of the Pearson mode skewness which will serve as our risk measure. The Pearson mode skewness of a density is defined as the mean-mode difference divided by the standard deviation.

[18] According to the numerical parameters that can be downloaded at `http://www.bankofengland.co.uk/publications/inflationreport/irprobab.htm`, the skewness of the forecast density then differed from zero for the first time.

[19] The Banco de Portugal started to publish quantitative risk forecasts in December 2003, but these are annual forecasts, which means that only very few observations are available. The IMF and the Bank of Japan only release annual risk forecasts, too. The Bank of Canada and the Banco de Chile do not publish data which allow a calculation of their quantitative forecast risks. Finally, the quantitative risk forecasting record of the Magyar Nemzeti Bank dates back to its Inflation Report from November 2002, and its forecasts have a quarterly frequency. However, the magnitudes of the asymmetries we backed out from its density forecast data are far too small for reliable inference about risk forecast optimality and informativeness. The asymmetries were backed out in a similar way as described for the Riksbank in Appendix A.2.2. Further details are available upon request.

[20] Until 2003, the BoE used to forecast the inflation of the All Items Retail Price Index excluding mortgage interest payments (RPIX). Since 2004, it has forecast CPI inflation.

[21] The BoE also publishes risk forecasts for GDP. We do not study these forecasts here, since the analysis of GDP risk forecasts would be more complicated due to the effects of data revisions. Such revisions play a substantial role for the assessment of the BoE's GDP forecasts, as noted by Elder et al. (2005).

Our forecast data set from the Riksbank starts in December 1999, when the data used to produce the fan charts of the respective Inflation Report were made publicly available on the Riksbank's website for the first time.[22] The last asymmetric fan chart appeared in October 2006. From 1999 to 2005, there were always four Inflation Reports per year, namely in February/March/April, May/June, October, and December. Like the Riksbank, we will refer to these as the Inflation Reports y:1, y:2, y:3, and y:4, respectively, where 'y' stands for the year. There was no Inflation Report 2006:4, and since 2007, the fan charts of the Monetary Policy Reports, which succeeded the Inflation Reports, have always been symmetric. Therefore, our data sample covers the forecasts from the Inflation Reports from 1999:4 to 2006:3.[23]

A potential drawback of the data from the Riksbank is given by the constant interest rate assumption underlying the forecasts in the Inflation Reports 1999:4 to 2005:2, i.e. it was assumed that the interest rates do not change during the forecasting period, but remain on the level they had attained at the time the forecast was produced. Starting with the Inflation Report 2005:3, the forecasts have been conditioned on interest rates expected by market participants.[24]

In the case of a constant interest rate assumption, it might be difficult to assess the optimality of risk forecasts, at least for larger horizons. For example, if the constant interest rate assumption leads to inflation forecasts that exceed the target at the relevant policy horizon, the policy maker is likely to raise the policy rate to dampen inflation. Thus, the inflation forecast error mainly depends on the point forecast for inflation, and only to a very limited extent on the risk forecast.[25] For short horizons, however, testing for risk forecast optimality should be possible even with a constant interest rate assumption for two reasons. Firstly, a constant interest rate assumption is probably a good approximation to the behavior of interest rates in the short run. Secondly, inflation responds to changes in the interest rate only with a certain delay. Therefore, in case of the Riksbank, we will only consider risk forecasts for up to four quarters ahead.

The Riksbank forecasts two monthly inflation measures, where we decide to focus on CPI inflation only. From the available 24 forecast horizons, we use every third monthly forecast for up to four quarters ahead. We are therefore left with 5 forecast horizons, always with one observation per quarter.[26] The shortest forecast horizon is chosen such that it

[22] See `http://www.riksbank.se/templates/DocumentList.aspx?id=5031`.

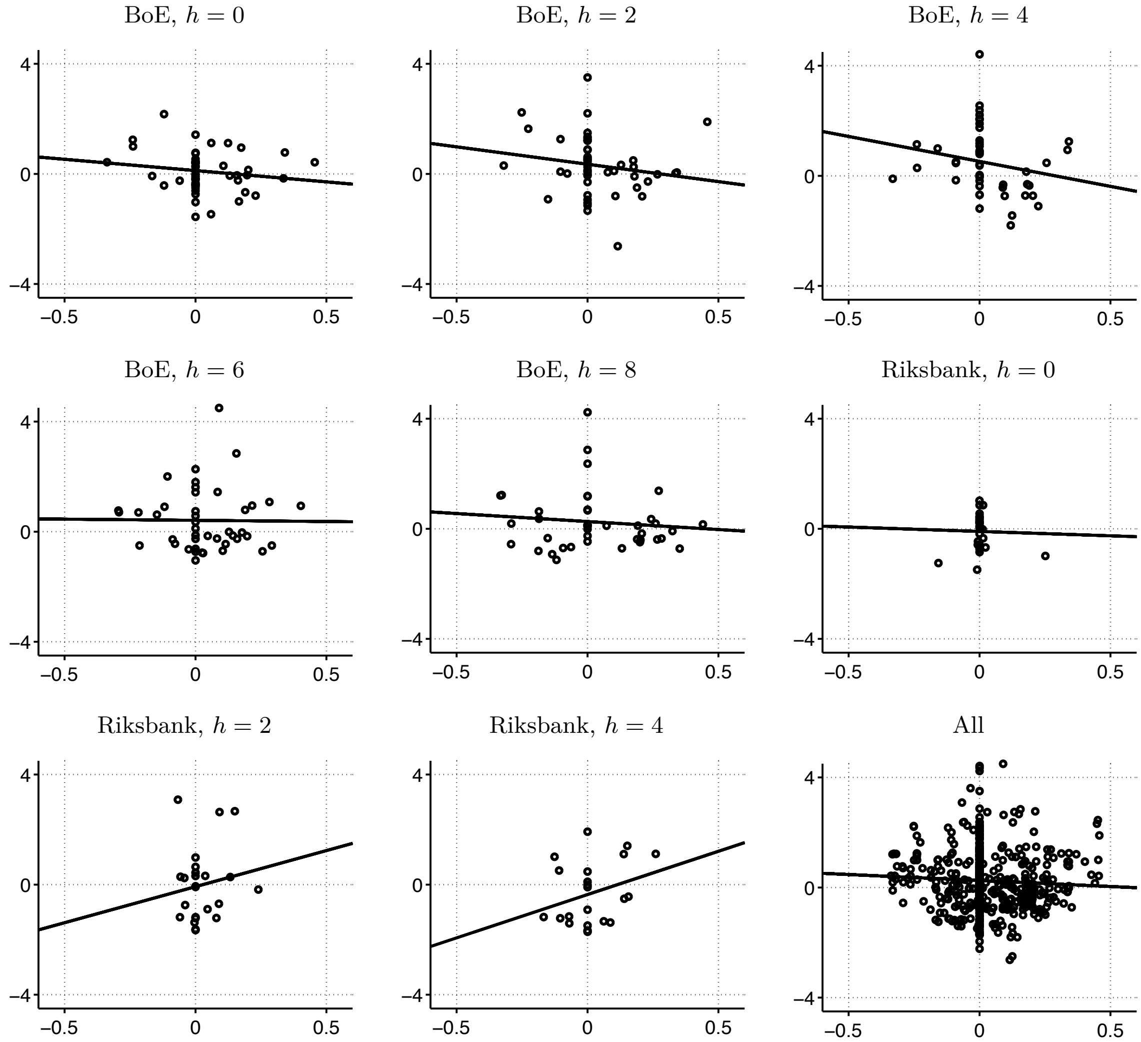
[23] Unfortunately, the forecast data from the Inflation Report 2000:1 are not available, which means that our sample contains only 27 instead of 28 forecasts.

[24] See Sveriges Riksbank (2005, p.57).

[25] Only if the central inflation forecast implies that inflation will be close to target, could the inflation forecast error be well predicted by the risk forecast if the risk forecast is optimal.

[26] Using all monthly forecasts yields practically no additional insights, since the monthly risk forecasts are quantitatively very similar for adjacent forecast horizons, and the forecast errors of adjacent horizons are often similar, too. Moreover, the results can be compared more easily to those for the BoE using every third monthly

Figure 1.2: Scatter plots for the Bank of England and the Sveriges Riksbank



Note: The forecast Pearson mode skewness is shown on the X-axis, the scaled forecast error of the mode on the Y-axis. The lower right-hand panel is a scatter plot of all data of the Bank of England for $h = 0, 2, 4, 6, 8$ and of the Sveriges Riksbank for $h = 0, 2, 4$.

contains a forecast for the month of the publication of the Inflation Report, meaning that this forecast is actually a nowcast. Thus, we consider the Riksbank's 0-, 3-, 6-, 9-, and 12-month-ahead forecasts. In contrast to the BoE, the Riksbank only published the mode of the forecast density and the values of several quantiles. From these data and the corresponding statements in the Inflation Reports, we carefully back out the parameters which permit calculation of the Pearson mode skewness of the forecast densities. Details are provided in Appendix A.2.2.

forecast only.

Table 1.2: Summary statistics for forecast data of the Bank of England and the Sveriges Riksbank

h	0	2	4	6	8
	Bank of England				
	Sample average				
$\hat{m}_{t+h\|t}$	2.35	2.23	2.06	2.03	2.14
$\hat{\mu}_{t+h\|t} - \hat{m}_{t+h\|t}$	0.01	0.03	0.03	0.04	0.04
$\hat{\sigma}^2_{t+h\|t}$	0.08	0.29	0.43	0.58	0.77
	Interquartile range				
$\hat{m}_{t+h\|t}$	0.71	0.48	0.58	0.52	0.47
$\hat{\mu}_{t+h\|t} - \hat{m}_{t+h\|t}$	0.03	0.07	0.09	0.11	0.20
$\hat{\sigma}^2_{t+h\|t}$	0.05	0.14	0.16	0.24	0.42
	Sveriges Riksbank				
	Sample average				
$\hat{m}_{t+h\|t}$	1.44	1.46	1.71		
$\hat{\mu}_{t+h\|t} - \hat{m}_{t+h\|t}$	0.00	0.01	0.02		
$\hat{\sigma}^2_{t+h\|t}$	0.09	0.24	0.54		
	Interquartile range				
$\hat{m}_{t+h\|t}$	1.52	0.85	0.67		
$\hat{\mu}_{t+h\|t} - \hat{m}_{t+h\|t}$	0.00	0.03	0.09		
$\hat{\sigma}^2_{t+h\|t}$	0.01	0.02	0.05		

Note: The sample size equals $T = 50$ for the Bank of England and $T = 27$ for the Sveriges Riksbank.

The risk forecasts of the BoE and the Riksbank as measured by the Pearson mode skewness of the forecast densities are displayed in Tables 1.7 and 1.8 in Appendix A.2 for all forecast horizons. For ease of exposition, in the following we focus on the results for even horizons, i.e. BoE results for $h = 0, 2, 4, 6, 8$ and Riksbank results for $h = 0, 2, 4$.[27] No major insights are lost by leaving the odd horizons aside.

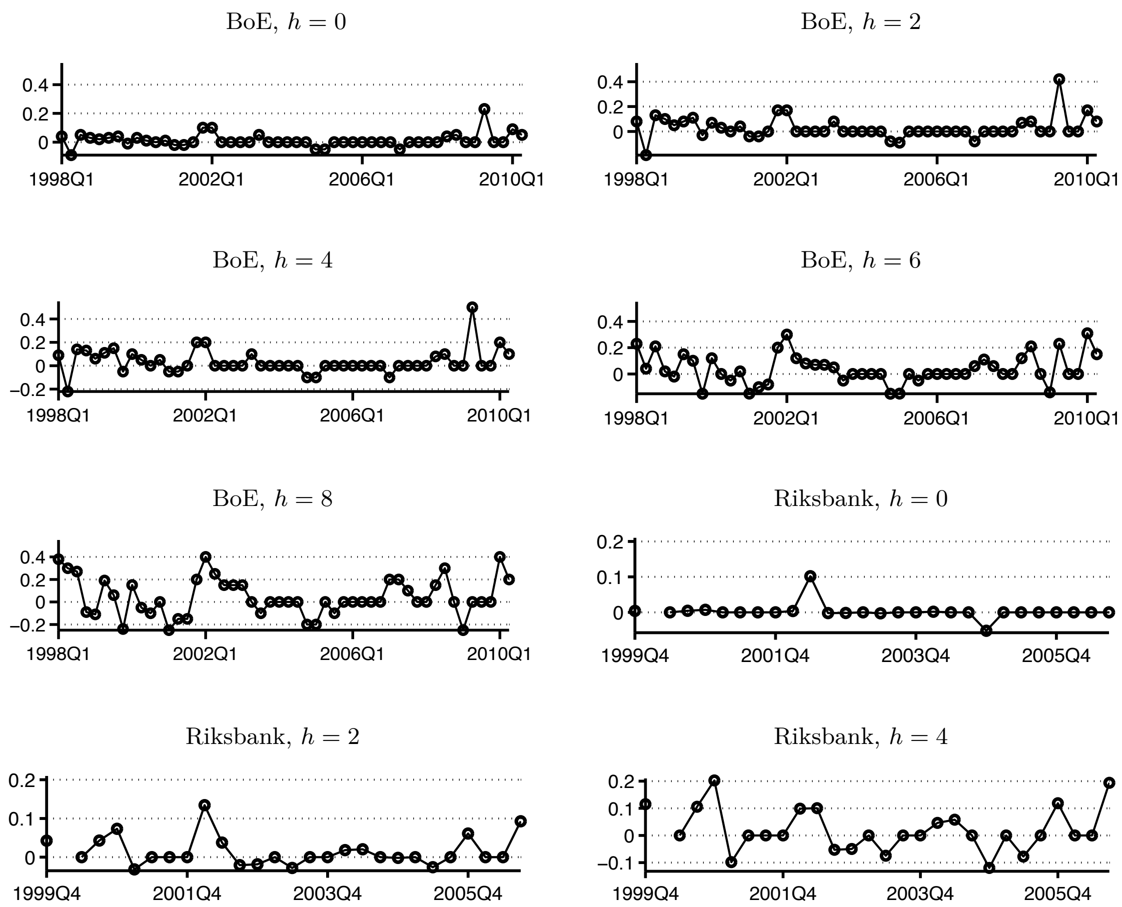
1.3.2 Summary Statistics

Before turning to the empirical tests, it is useful to take a brief look at the forecast risks and the associated realized risks used in this study. The forecast risk, measured by the Pearson mode skewness, is defined as $(\hat{\mu}_{t+h|t} - \hat{m}_{t+h|t})/\hat{\sigma}_{t+h|t}$, where $\hat{\mu}_{t+h|t}$ is the mean forecast for period $t + h$ made in period t, $\hat{m}_{t+h|t}$ is the corresponding mode forecast, and $\hat{\sigma}_{t+h|t}$ is the corresponding forecast of the standard deviation.[28] Our measure of realized risk is given by the scaled mode forecast error, i.e. by $(y_{t+h} - \hat{m}_{t+h|t})/\hat{\sigma}_{t+h|t}$, where y_{t+h} is the realization of

[27] These quarterly horizons correspond to the the Riksbank's 0-, 6-, and 12-month-ahead forecasts, respectively.

[28] Further explanations concerning the use of the Pearson mode skewness follow in Section 1.4 and computational details are provided in Appendix A.2.1.

Figure 1.3: Plots of the differences between the mean forecast and the mode forecast for the Bank of England and the Sveriges Riksbank



the forecast variable in period $t+h$. Figure 1.2 shows horizon-specific scatter plots of forecast and realized risks for the BoE and the Riksbank. The lower right-hand panel contains all data from the previous plots summarized in a single scatter plot. The largest forecast risks equal about 0.5, the smallest about -0.3. The realized risks, i.e. the scaled mode forecast errors, range from about -2.6 to about 4.5. For a large number of periods, the risks were actually forecast to be balanced.

If the risk forecasts are optimal, most points in the scatter plots should be located in the first and third quadrant. If the risk forecasts are not informative, the points should spread broadly evenly above and below the zero-line.[29] Thus, the regression lines in all BoE data plots in Figure 1.2 rather suggest a lack of information content, because they are not

[29] Of course, if the risk forecasts are not unbiased, the points would simply be shifted away from the zero-line.

upward-sloping. In contrast, the regression lines for $h = 2$ and $h = 4$ for the Riksbank are upward-sloping, but the scatter plots indicate that there is considerable uncertainty about these slopes. Finally, the line computed for the entire sample of risk forecasts is slightly downward-sloping.

In Table 1.3.2, we provide summary statistics for the forecast data of the BoE and the Riksbank. While the sample averages of the difference between mean and mode forecasts increase with the forecast horizon, they remain very close to zero. The sample averages of the forecast variance grow substantially with the horizon, indicating the increasing forecast uncertainty. While the interquartile ranges for the forecasts of mean-mode differences and variances also increase with the forecast horizon, for the mode forecasts they do not. The latter finding is, of course, due to the fact that the long-run inflation point forecasts tend to be close to the inflation target.

Figure 1.3 shows the differences between mean and mode forecasts. It reveals that serial correlation in these differences seems to be fairly contained. In contrast, there are pronounced correlations across horizons.[30]

1.3.3 Bias Tests

As explained in Knüppel and Schultefrankenfeld (2011), when applying the framework of regression-based tests for forecast optimality as proposed by Mincer and Zarnowitz (1969) to risk forecasts, estimates of the intercept and the slope coefficient might be biased since the forecast data used to construct the Pearson mode skewness might themselves be biased.

Testing for a bias of the mean forecasts is interesting in itself. In addition, if the mean forecast $\hat{\mu}_{t+h|t}$ is biased, the squared forecast error of the mean, $\left(y_{t+h} - \hat{\mu}_{t+h|t}\right)^2$, is unlikely to be a good measure for the variance of inflation realization y_{t+h}. Therefore, it is useful to test whether an estimate of the intercept c in the equation

$$y_{t+h} - \hat{\mu}_{t+h|t} = c + \varepsilon_{t+h} \tag{1.1}$$

is equal to zero. If the true variances, and hence the true standard deviations σ_{t+h} are, on average, smaller than $\hat{\sigma}_{t+h|t}$, estimates of intercept and slope in a Mincer-Zarnowitz-type regression for risk forecasts are biased towards zero.[31] Conversely, if σ_{t+h} is larger than $\hat{\sigma}_{t+h|t}$, the estimates of intercept and slope are biased away from zero. Thus, it is important to test for unbiasedness of the volatility forecasts, too. Analogously to above, in the equation

$$\left(y_{t+h} - \hat{\mu}_{t+h|t}\right)^2 - \hat{\sigma}^2_{t+h|t} = c + \varepsilon_{t+h}, \tag{1.2}$$

[30]This can also be seen in Tables 1.7 and 1.8.

[31]The corresponding regression equation (1.3) can be found in the following section.

Table 1.3: Tests for bias of forecast mean and forecast variance

h	0	2	4	6	8
	Bank of England				
T	50	48	46	44	42
mean	0.02	0.14	0.27	0.25	0.11
	(0.02)	(0.12)	(0.26)	(0.30)	(0.28)
variance	-0.05	0.13	0.38	0.24	0.01
	(0.03)	(0.11)	(0.32)	(0.38)	(0.39)
	Sveriges Riksbank				
T	27	27	27		
mean	-0.04	-0.01	-0.24		
	(0.04)	(0.19)	(0.29)		
variance	-0.05^{**}	0.13	0.02		
	(0.01)	(0.17)	(0.16)		

Note: Figures in parentheses are Newey-West (1987) standard errors. The sample size is denoted by T. One asterik indicates significance at the 5% level, two asteriks indicate significance at the 1% level.

we conduct a test for the null that $c = 0$.[32] In both equations (1.1) and (1.2), ε_{t+h} denotes a zero-mean error term which is potentially subject to serial correlation. We address this issue by using Newey-West (1987) standard errors and prewhitening as suggested by Andrews and Monahan (1992). The truncation lags are chosen based on the procedure of Andrews (1991). For the above and all other tests in this study, we employ the conventional significance level of 5%.

The results in Table 1.3 show that all mean forecasts and all but one of the volatility forecasts are unbiased. The Riksbank's variance nowcast is an exception, showing a significant overprediction of volatility.

1.4 Methodology

The evaluation of risk forecasts will be based on tests for risk forecast optimality and informativeness as discussed in Knüppel and Schultefrankenfeld (2011). In order to conduct such tests, a measure for the asymmetry of the forecast density has to be selected. Knüppel and Schultefrankenfeld (2011) find that the above-mentioned Pearson mode skewness is strongly preferable to the standard third-moment based skewness, because the latter implies a very low power of the tests. As briefly stated above, the Pearson mode skewness of a random

[32] We also conducted bias tests for the mode forecast (under the potentially restrictive assumption of balanced risks on average) and the average balance of forecast risks. In both cases we could not reject the null of no bias for any forecast horizon.

variable Y is given by $\left(E\left[Y\right]-m\right)/\sigma$, where $E\left[Y\right]$ is the expectation, m is the mode, and σ is the standard deviation of Y.

Given a forecast horizon h, risk forecasts can be evaluated using the OLS regression equation

$$\frac{y_{t+h}-\hat{m}_{t+h|t}}{\hat{\sigma}_{t+h|t}}=\alpha+\beta\frac{\hat{\mu}_{t+h|t}-\hat{m}_{t+h|t}}{\hat{\sigma}_{t+h|t}}+\varepsilon_{t+h},\quad t+h=1,2,\ldots,T, \tag{1.3}$$

where the error term ε_{t+h} has an expectation of zero, and intercept α and slope β are the coefficients to be estimated. T denotes the sample size.

As stated above, the term $(\hat{\mu}_{t+h|t}-\hat{m}_{t+h|t})/\hat{\sigma}_{t+h|t}$ on the right-hand side is simply the risk forecast for period $t+h$, made in period t, where risk is measured by the Pearson mode skewness. On the left-hand side, $(y_{t+h}-\hat{m}_{t+h|t})/\hat{\sigma}_{t+h|t}$ is the measure of realized risk, being equal to the scaled mode forecast error. It would be preferable to use $(y_{t+h}-m_{t+h|t})/\sigma_{t+h|t}$ as the measure of realized risk, where $m_{t+h|t}$ and $\sigma_{t+h|t}$ are the true values of mode and standard deviation of the forecast variable in period $t+h$, conditional on information available to the forecaster in period t, but these quantities are, of course, unknown. However, as long as $\hat{m}_{t+h|t}$ and $\hat{\sigma}_{t+h|t}$ are unbiased forecasts of $m_{t+h|t}$ and $\sigma_{t+h|t}$, no major complications arise.

If $\hat{m}_{t+h|t}$ is biased, $\hat{\alpha}$, the estimate of the intercept α, will be biased as well, but the slope β will continue to be estimated consistently by $\hat{\beta}$.[33] If $\hat{\sigma}_{t+h|t}$ is biased, $\hat{\beta}$ will also be biased.

Assuming that $\hat{m}_{t+h|t}$ and $\hat{\sigma}_{t+h|t}$ are unbiased, it should not be possible to reject the joint hypothesis $\alpha=0$, $\beta=1$ if the risk forecasts are optimal, resembling the hypothesis for mean forecast optimality used by Mincer and Zarnowitz (1969). However, potential biases of $\hat{m}_{t+h|t}$ and $\hat{\sigma}_{t+h|t}$ suggest a slightly different approach. Knüppel and Schultefrankenfeld (2011) recommend checking for a potential bias of $\hat{\sigma}_{t+h|t}$ first, and focusing on the single hypothesis $\beta=1$ due to its robustness with respect to biased mode forecasts. A complementing test of $\alpha=0$ can be useful, but a rejection does not necessarily imply non-optimality of the risk forecasts, since it could be caused by biased mode forecasts.

If the risk forecasts contain useful information, one should expect a rejection of the hypothesis $\beta=0$. If the test does not reject this hypothesis, there is no statistical evidence against a lack of information content. In view of the excerpt from Leeper (2003) cited at the beginning of this paper, this test, which checks for a systematic connection between forecast risks and realized risks, could actually be considered the most important one.

Although the tests have a much greater power if the Pearson mode skewness is used instead of the standard skewness as the measure of asymmetry, their power can still be

[33] In the remainder of the paper, a hat over a character always denotes the estimate or the forecast of the corresponding parameter. Whether the object is a forecast or an estimate will be clear from the context.

expected to be fairly low in our empirical application.[34] This is due to several reasons. Firstly, our samples of risk forecasts are rather small. Moreover, the magnitude of the forecast risks is, at best, moderate. The smaller these magnitudes are, however, the more difficult the inference about β becomes. In addition, the fact that $m_{t+h|t}$ and $\sigma_{t+h|t}$ are unknown also contributes to the tests' low power, even if $\hat{m}_{t+h|t}$ and $\hat{\sigma}_{t+h|t}$ are unbiased forecasts. Finally, the potential serial correlation of the error terms also reduces power.

In order to alleviate these problems, in this analysis the quantitative risk forecasts will be investigated in a panel setup, where all forecast horizons are analyzed simultaneously and where, in addition to the serial correlation, the cross-correlation of the error terms is taken into account. The cross-correlation is caused by the fact that, for example, if y_t is far from its unconditional mean, it is very likely that the realized risks, i.e. the scaled mode forecast errors associated with y_t are large for all but the short forecast horizons. For the panel estimation, we use the approach described in Greene (1997, p.687). This approach can also be applied to unbalanced panels, which allows us to use all of the BoE's risk forecast data. In a first step, the Prais-Winsten transformation is employed to remove autocorrelation. Then the transformed data are analyzed using the seemingly unrelated regressions model.[35]

As described above, many central banks do not publish quantitative, but only qualitative risk forecasts, giving assessments about the direction of the forecast risk. It is therefore important to evaluate direction-of-risk forecasts as well, even if the corresponding tests can be expected to suffer from lower power than those for the quantitative risk forecasts.[36] The evaluation here is based on the categorical variables q_{t+h} and $\hat{q}_{t+h|t}$, determined by the quantitative risk forecasts and realizations, where q_{t+h} is related to the direction of the realized risk by

$$q_{t+h|t} = \begin{cases} 1 & \text{if } y_{t+h} > \hat{m}_{t+h|t} \\ 0 & \text{if } y_{t+h} < \hat{m}_{t+h|t} \\ na & \text{if } \hat{\mu}_{t+h|t} = \hat{m}_{t+h|t} \end{cases}, \quad (1.4)$$

[34]Using standard skewness, the forecast risk would be given by $E\left[\left(Y_{t+h|t} - \hat{\mu}_{t+h|t}\right)^3\right] / \hat{\sigma}^3_{t+h|t}$ and the proxy for the realized risk by $\left(y_{t+h} - \hat{\mu}_{t+h|t}\right)^3 / \hat{\sigma}^3_{t+h|t}$. $E\left[\left(Y_{t+h|t} - \hat{\mu}_{t+h|t}\right)^3\right]$ would be calculated based on the forecast density of the random variable $Y_{t+h|t}$.

[35]Note that there is a minor error in the formula (15-57) by Greene (1997, p.687). For the construction of the final covariance matrix of the errors, the covariance matrices of $AR(1)$-processes as defined in formula (13-10) are required. When estimating the covariances of the errors, we make use of the entire unbalanced sample in case of the BoE. This approach is commonly attributed to Wilks (1932). Note that this approach does not necessarily produce a positive-semidefinite covariance matrix. Using only the balanced sample for the covariance estimation leaves the results virtually unchanged.

[36]However, tests based on direction-of-risk forecasts might be more reliable in the event of outliers or severe problems with the forecasts of σ_{t+h}.

and $\hat{q}_{t+h|t}$ is related to the direction of the forecast risk by

$$\hat{q}_{t+h|t} = \begin{cases} 1 & \text{if } \hat{\mu}_{t+h|t} > \hat{m}_{t+h|t} \\ 0 & \text{if } \hat{\mu}_{t+h|t} < \hat{m}_{t+h|t} \\ na & \text{if } \hat{\mu}_{t+h|t} = \hat{m}_{t+h|t} \end{cases}, \tag{1.5}$$

where na denotes a missing value which will be excluded from the analysis. Then, if $q_{t+h|t} = \hat{q}_{t+h|t}$, the direction-of-risk forecast is successful, and if $q_{t+h|t} \neq \hat{q}_{t+h|t}$, it is not.

In order to construct variables without missing values, we use the transformations

$$\begin{aligned} \mathbf{q}_h^N &= \mathbf{A}_h \mathbf{q}_h^T, \\ \hat{\mathbf{q}}_h^N &= \mathbf{A}_h \hat{\mathbf{q}}_h^T, \end{aligned} \tag{1.6}$$

where the vector $\mathbf{q}_h^T$ is given by $\mathbf{q}_h^T = \left(q_{1+h|1}, q_{2+h|2}, \ldots, q_{T+h|T}\right)'$, the vector $\hat{\mathbf{q}}_{t+h|t}$ is given by $\hat{\mathbf{q}}_{t+h|t} = \left(\hat{q}_{1+h|1}, \hat{q}_{2+h|2}, \ldots, \hat{q}_{T+h|T}\right)'$ and $\mathbf{A}_h$ is a known $(N \times T)$ selection matrix consisting of 1's and 0's, and with $N \leq T$. $\mathbf{A}_h$ is chosen such that the vectors $\mathbf{q}_h^N$ and $\hat{\mathbf{q}}_h^N$ do not contain missing values.[37]

Denoting the elements of $\mathbf{q}_h^N$ and $\hat{\mathbf{q}}_h^N$ by $q_{n+h|n}$ and $\hat{q}_{n+h|n}$, respectively, with $n = 1, 2, \ldots, N$, we test for the optimality of the direction-of-risk forecasts based on the regression

$$q_{n+h|n} = \alpha_q + \beta_q \hat{q}_{n+h|n} + \varepsilon_{n+h}. \tag{1.7}$$

Optimal risk forecasts neither imply $\beta_q = 1$ nor $\alpha_q = 0$, as explained in Knüppel and Schultefrankenfeld (2011). However, a necessary condition for forecast optimality is given by the inequality $\beta_q > 0$. While a test of this inequality should not reject in the case of optimal forecasts, the hypothesis $\beta_q = 0$ should be rejected. The hypothesis $\beta_q = 0$ implies that the direction-of-risk forecasts are not informative.[38]

1.5 Analysis of Risk Assessments

1.5.1 Quantitative Assessments

In Table 1.4, the results of the tests for risk forecast optimality are shown for the even forecast horizons of both central banks, respectively. Note that the Riksbank forecast unbalanced risks only in about half of its forecasts. The same holds for the BoE for nowcasts and forecasts

[37] If there are no missing values, $\mathbf{A}_h$ is a $(T \times T)$ identity matrix. If, for example, only the risk forecast for the first forecast of horizon h is balanced, i.e. in the case $\hat{\mu}_{1+h|1} = \hat{m}_{1+h|1}$, N equals $T - 1$ and $\mathbf{A}_h$ is given by $\mathbf{A}_h = [\mathbf{0}_N \;\; \mathbf{I}_N]$, where $\mathbf{0}_N$ denotes an $(N \times 1)$ vector of 0's and $\mathbf{I}_N$ denotes the $(N \times N)$ identity matrix.

[38] In principle, tests based on the binomial distribution could be used for direction-of-risk forecasts, but the potential serial correlation of ε_{n+h} renders the regression-based approach presented here more appealing for our investigations.

up to one year ahead. For longer forecast horizons, the share of unbalanced risk forecasts equals about two-thirds. Interestingly, the estimates of β are negative for horizons $h = 0, 4, 6$ in the case of the BoE, while the Riksbank's slope coefficients are all positive. The standard errors for the slope are often smaller for longer horizons than for shorter ones. This is due to the fact that the cross-correlations of the error terms are especially pronounced for longer forecast horizons.

For both the BoE and the Riksbank, we cannot reject the null that the estimated intercept $\hat{\alpha}$ is equal to zero at the 5% level. This means that there is no significant bias issue for any forecast horizon. In the case of the BoE, the p-values for the single null of optimality, i.e. for tests of $\beta = 1$, indicate rejections for all horizons but $h = 8$. The results of the joint null hypothesis of risk forecast optimality $\alpha = 0$, $\beta = 1$, which are not reported in the table, tend to confirm this finding, with rejections for all forecast horizons except $h = 0$ and $h = 8$. The hypothesis of no information content is only rejected for the horizons $h = 4$ and $h = 8$, as shown by the p-values for informativeness. However, $\hat{\beta}$ is negative for $h = 4$, which means that this rejection does not appear very plausible, because it would imply an adverse informative value. For the Riksbank, the estimation uncertainty turns out to be very large, so that no hypothesis about the slope β can be rejected. Put differently, we cannot make clear statements with respect to the hypotheses of informativeness and of optimality, because the confidence intervals for the slope β contain zero and unity likewise.

The results for the BoE strongly indicate that its risk forecasts are not optimal, and that there is no systematic connection between realized risks and forecast risks. The only potential exception is the forecast horizon $h = 8$. However, it does not appear too convincing that the properties of the risk forecasts just for the horizon $h = 8$ should be so different from the other horizons.[39]

Moreover, a horizon-specific regression yields a negative estimate of β for $h = 8$, as also suggested by Figure 1.2. Based on this estimate and its Newey-West standard error, one would reject the optimality hypothesis, $\beta = 1$, but not the hypothesis of no informativeness, $\beta = 0$.[40] The results for $h = 8$ are therefore rather unclear. The results for the Riksbank do not provide evidence against the hypothesis that risk forecasts and realized risks are unrelated at all forecast horizons. However, this result could also be caused by the small sample size, which strongly hampers inference.[41]

[39] For the neighboring horizon $h = 7$, the estimated slope $\hat{\beta}$ equals 0.1 with a standard error of 0.2, which means that the null of optimality is rejected, while the null of non-informativeness is not. The same results are obtained for all other odd horizons except for $h = 5$, where, as in case of $h = 4$, $\hat{\beta}$ is significantly negative.

[40] The horizon-specific estimate for β equals -0.46, its standard error being 0.62. It should be mentioned that for no other forecast horizon do the panel setup and the separate analysis of each horizon give such contradictory results, i.e. for no other forecast horizon, including the odd horizons not reported here, is one of the hypotheses $\beta = 0$ or $\beta = 1$ rejected in one setup, and the other hypothesis rejected in the other setup. The same applies to the results for the Riksbank. In general, the standard errors are, of course, considerably larger when each horizon is analyzed separately, which makes inference rather difficult.

[41] We also ran an estimation with the very restrictive assumption that intercept α and slope β are identical,

Table 1.4: Panel-based tests for bias, informativeness and optimality of quantitative risk forecasts of the Bank of England and the Sveriges Riksbank

h	0	2	4	6	8
	Bank of England				
T	50	48	46	44	42
N	24	22	22	30	28
	coefficient estimates				
intercept	0.09	0.19	0.33	0.24	-0.09
	(0.10)	(0.17)	(0.18)	(0.19)	(0.18)
slope	-0.45	0.13	-0.52	-0.30	0.71
	(0.61)	(0.26)	(0.21)	(0.26)	(0.21)
	p-values				
bias	0.376	0.253	0.066	0.209	0.621
informativeness	0.465	0.619	0.017	0.267	0.002
optimality	0.021	0.002	0.000	0.000	0.173
	Sveriges Riksbank				
T	27	27	27		
N	13	15	15		
	coefficient estimates				
intercept	-0.09	-0.07	-0.31		
	(0.13)	(0.38)	(0.31)		
slope	1.08	1.64	0.47		
	(1.68)	(2.02)	(1.05)		
	p-values				
bias	0.513	0.855	0.336		
informativeness	0.529	0.425	0.656		
optimality	0.965	0.755	0.618		

Note: Figures in parentheses are standard errors. T denotes the sample size. N denotes the number of forecasts with unbalanced risks. The row 'bias' refers to tests for $\alpha = 0$, 'informativeness' to tests for $\beta = 0$, and 'optimality' to tests for $\beta = 1$ in equation (1.3).

1.5.2 Direction-of-Risk Assessments

Since we are not aware of approaches for analyzing categorical data with potentially autocorrelated residuals in a panel setup, in the following analysis each forecast horizon is investigated separately. The results of the analysis of direction-of-risk forecasts are reported in Table 1.5. When recoding the data according to equations (1.4) and (1.5), and selecting only observations with corresponding non-zero risk forecasts according to (1.6), we are left with, at most, 30 observations per forecast horizon. The estimates for the intercept α_q are unrelated to forecast optimality and only reported for information. Note that, according to Pesaran and Timmermann (2006), the problem of autocorrelation of the error terms in equations with

respectively, across all horizons. Even in this case, no hypothesis of interest can be rejected.

Table 1.5: Tests for informativeness and optimality of direction-of-risk forecasts of the Bank of England and the Sveriges Riksbank

h	0	2	4	6	8
	Bank of England				
N	24	22	22	30	28
	coefficient estimates				
intercept	0.57	0.86	0.71	0.60	0.42
	(0.15)	(0.11)	(0.17)	(0.11)	(0.16)
slope	-0.10	-0.32	-0.38	-0.25	0.02
	(0.18)	(0.19)	(0.24)	(0.12)	(0.20)
	p-values				
informativeness	0.571	0.104	0.126	0.039	0.919
optimality	0.286	0.052	0.063	0.020	0.541
	Sveriges Riksbank				
N	13	15	15		
	coefficient estimates				
intercept	0.33	0.50	0.33		
	(0.20)	(0.19)	(0.20)		
slope	0.10	0.06	0.11		
	(0.34)	(0.26)	(0.18)		
	p-values				
informativeness	0.787	0.832	0.549		
optimality	0.606	0.584	0.726		

Note: Figures in parentheses are Newey-West (1987) standard errors. N denotes the sample size, being equal to the number of forecasts with unbalanced risks. The row 'informativeness' refers to tests for $\beta = 0$, and 'optimality' to tests for $\beta > 0$ in equation (1.7).

categorical data like equation (1.7) can be addressed using Newey-West standard errors.[42] The estimates for β_q are negative in the case of the BoE except for $h = 8$, and positive in the case of the Riksbank. For the Riksbank, again, none of the null hypotheses can be rejected. For the BoE forecasts, a rejection of the hypothesis $\beta_q > 0$ occurs for $h = 6$, suggesting that the respective risk forecasts cannot be optimal. At the same time, the null of no information content must be rejected. This result, however, does not seem very plausible due to the negative sign of the slope. For all other horizons, i.e for $h = 0, 2, 4, 8$, the p-values for the test for informativeness substantially exceed 0.05. Hence, there is no evidence against a lack of information content in the BoE's direction-of-risk forecasts at these horizons. Although the null of risk forecast optimality is not rejected for $h = 2$ and $h = 4$, it should be noted that the respective p-values hardly exceed 5%.[43]

[42] Since Pesaran and Timmermann (2006) do not address the possibility of prewithening, we do not use it here. Apart from that, we employ the same approach as for the bias tests in Section 1.3.

[43] Moreover, for the horizons $h = 1$ and $h = 3$ not reported in the table, the null of risk forecast optimality is rejected.

Interestingly, the best risk forecast performance in the case of the BoE is again observed for $h = 8$. However, even for this horizon only 50% of the direction-of-risk forecasts were successful, which means that the qualitative risk forecast performance rather tends to support the hypothesis of no information content for this horizon.

1.5.3 Summary of Empirical Results

Summing up the results for quantitative and direction-of-risk forecasts, for the BoE there is strong evidence against the optimality of risk forecasts for almost all forecast horizons. In contrast, there is no conclusive evidence against the hypothesis that risk forecasts and realized risks are unrelated at all forecast horizons. The latter result also holds for the Riksbank. Yet the results for the Riksbank are subject to great uncertainty, because with only 7 years of data an evaluation of macroeconomic risk forecasts can be extremely difficult.

Given the number of central banks which engage in risk forecasting and the resources which are devoted to it, the fact that risk forecasts and realized risks seem to lack a systematic connection might appear surprising. However, taking into account the often rather poor performance of macroeconomic forecasts even for first moments, i.e. point forecasts, except for short forecast horizons, it does not seem too implausible for macroeconomic forecasts of third moments to be unsuccessful.

1.6 Reconsidering the Rationale for Risk Assessments

In light of the results of the previous section, it is interesting to consider some of the reasons that are commonly mentioned in order to explain why macroeconomic risk forecasts are made.

The IMF (2008, pp.42-43) offers four reasons for potential asymmetries of forecast densities. Firstly, non-linearities such as capacity constraints or the zero-lower bound for interest rates might result in asymmetric forecast densities. Given the apparent lack of informativeness as shown by the evaluation results for the quantitative risk forecasts and the direction-of-risk forecasts, non-linearities either seemed to play no role in the samples under study, or the forecasters' understanding of these non-linearities is too limited to lead to successful risk forecasts. For example, while the zero lower bound for the policy rate is a popular motivation for asymmetric forecast densities, one could ask whether the effects of quantitative easing might not counteract the zero-lower-bound problem in such a way that the forecast density is actually close to symmetric even if the policy rate is at a very low level.

Secondly, the figures of the central forecast might already be fixed when sudden large changes in important variables such as oil prices or exchange rates occur. Due to time constraints it might be infeasible to calculate a new central forecast and to adapt the often extensive explanatory notes that come with the central forecast. Nonetheless, it might be possible to adapt the asymmetry of the forecast density to reflect the new information. However, if risk forecasts were used to incorporate last-minute information into the forecast densities without having to change the central forecast, the risk forecast accuracy ought to have been higher than it was above, in particular at very short forecast horizons. So at least for the BoE and the Riksbank, it can be stated without much doubt that this reason for issuing risk forecasts does not matter.

Thirdly, forecasts are often based on 'technical' assumptions, in many cases concerning exogenous variables. For example, exchange rates are commonly assumed to remain constant for all forecast horizons. If such an assumption is used for institutional reasons but the forecaster believes that the domestic currency will appreciate soon, the asymmetry of the forecast density can be employed to allow for this view. However, if 'technical' assumptions are used in the forecasting processes of the BoE and the Riksbank, and risk forecasts are used as an attempt to improve upon the forecast accuracy implied by these assumptions, it seems that such an improvement is infeasible. Coming back to the example of constant exchange rates, the difficulties in beating the random-walk forecast are actually well-known.[44]

The fourth reason concerns the possibility of biased forecasts. If recent forecast errors appear to be biased, maybe owing to an undetected structural change, the forecaster might refrain from shifting the current central forecast. Instead, he might be inclined to issue an asymmetric forecast density in order to account for the potential bias. Such an attempted bias correction using risk forecasts has either not been carried out by the BoE and the Riksbank, or was carried out but did not work as intended. However, it is not possible to assess the individual probability of these two explanations based on the results of the optimality tests.

In addition to the reasons mentioned by the IMF, experts' expectations about asymmetric shocks might be a further motivation for risk forecasting. For example, a forecaster could simply believe that, in a certain situation, positive shocks are more likely than negative shocks.[45] The asymmetry of future shocks is apparently often assumed in the forecasts of central banks, but our results suggest that such assumptions might not be justified. Actually, the BoE gives some narrative support to this supposition. Referring to inflationary developments from 1997 to 1999, the BoE states that "In general, the modal inflation forecast has been closer to actual outturns than the mean projection. This is because the MPC judged

[44]See, for instance, Meese and Rogoff (1983).

[45]Actually, this reason for risk forecasts is very common in the publications of central banks. Two examples read: "Risks to this [inflation] outlook are fully confirmed to lie on the upside. These risks include the possibility of further rises in oil and agricultural prices, as well as of unanticipated increases in administered prices and indirect taxes", (ECB, 2007, p.55), and "The balance of risks to the inflation outlook, relative to the central projection, lies on the upside, as the prospect of a faster exchange rate depreciation and the associated adjustment to the level of import prices is the dominant influence", (BoE, 2002, p.49). It is unlikely that non-linear forecasting models are the motivations for assuming unbalanced risks in oil and agricultural prices or exchange rates. Moreover, the BoE apparently made no technical assumption with respect to exchange rates. Instead, the forecasters simply seem to anticipate an asymmetry of future shocks.

the risks to the central projection to be on the upside, largely because of the risk that the sterling exchange rate might depreciate sharply. Up to 2000 Q2 this did not occur; indeed, the exchange rate tended to be higher than the central assumption", (Bank of England, 2000, pp.63-64).

Furthermore, minority views may lead to asymmetric forecast densities. In institutions where several decision makers have to agree on a single central forecast, as, for instance, the board members of the BoE have to, a minority of the decision makers may not agree with the central forecast decided upon by the majority. The view of the minority then can be accommodated by the asymmetry of the forecast density. If this is actually the case, the results shown above suggest that such minority views do not help to produce more accurate forecasts.

Finally, risk forecasts could also be employed as a (subtle) communication device. For example, if the forecasts of an inflation-targeting central bank are made conditional on future interest rates as expected by market participants, it is rather unlikely that the inflation forecast will deviate strongly from the target at the relevant policy horizon. If there were a strong deviation, this might cause market participants to believe that either the policy of the central bank has changed, or that the central bank's assessment of the economic conditions strongly differs from their own assessment. Both possibilities are not very attractive for a central bank that seeks to be transparent and predictable. In order to signal the possibility of an unexpected increase in the policy rate, a central bank might therefore prefer to forecast an inflation rate that is only slightly above target and to add upward risks to this forecast. By doing so, the central bank's central forecast is basically in line with the forecasts of the market participants. At the same time, the central bank makes it clear that these forecasts are subject to uncertainty, and that the materialization of certain risks considered to be likely by the central bank would require a policy response different to the one expected by the market. As the probabilities of these risks materializing will change over time, the market participants will adapt their interest rate expectations accordingly. However, Rasche and Thornton (2002) investigate the balance-of-risks statements of the Federal Reserve and find that these do not appear to be a crucial factor in the market expectations concerning the Fed Funds Rate.[46] The likelihood of the possibility that risk forecasts are being used as a communication device cannot be evaluated based on our risk forecast evaluation. However, if risk forecasts are used in this way, they should be positively correlated with the (small) deviations of the inflation forecasts from the target. However, for neither the BoE nor the Riksbank do we find evidence of positive correlations.[47]

[46] However, the balance-of-risks statements supposedly had a different interpretation during that period. They were rather related to a loss-function as suggested by Kilian and Manganelli (2007) than to asymmetries of forecast densities.

[47] Depending on the forecast horizon and the central bank being analyzed, the correlation coefficients range from about -0.2 to 0.2. They are all insignificant.

1.7 Conclusion

Many central banks augment their point forecasts with assessments of the balance of risks. For virtually all of the central banks surveyed in this work, we actually find clear statements that the presence of unbalanced forecast risks corresponds to an asymmetry of forecast densities. Surprisingly, the point forecasts published almost always correspond to the modes of the forecast densities.

The risk forecasts are made and presented in a variety of ways. They can be quantitative as in the case of the BoE and the Riksbank, or qualitative, thus only indicating the direction of the balance of risks, as, for example, in the case of the Federal Reserve and the ECB. Risk forecasts can also be discussed without referring to the balance of risks, thereby just giving an idea of how the central forecast would change if a certain risk materialized. This is often the case, for instance, for the Reserve Banks of Australia and New Zealand. Apart from the verbal presentation of the (balance of) risks, balance-of-risks forecasts are frequently represented in potentially asymmetric fan charts.

Since the balance of risks is supposed to contain information about the asymmetries of the densities of the forecast variables, there should be a systematic connection between risk forecasts and realized risks, where the realized risks in our study correspond to the scaled mode forecast errors. Investigating the risk forecasts for inflation produced by the BoE and the Riksbank, we fail to find such a connection. While the results for the Riksbank could also be caused by the small sample size, the results for the BoE indicate relatively clearly that the risk forecasts do not provide the intended information. Instead, it seems that risk forecasts and forecast errors are unrelated. This holds for both quantitative forecasts and direction-of-risk forecasts. We therefore conclude that it seems questionable whether macroeconomic risk forecasts are meaningful.

If inflation is actually endogenous with respect to a central bank's risk forecast, then it could of course be that the estimation results presented are misleading. For instance, in case of an upward risk, economic agents could anticipate a risk of rising interest rates. In response to this risk, economic activity could be dampened, leading to lower demand and, consequently, to lower inflation. Then, even if the upward risk to inflation materialized, inflation could still be lower than forecast. However, if the endogeneity issue were empirically relevant, we would expect our estimated slope coefficients to decrease with the forecast horizon, because the endogeneity would tend to be less pronounced for shorter forecast horizons. Since there is no such decrease, the presence of an endogeneity problem appears unlikely. A deeper analysis of this issue, though, is left for future research.

However, two other caveats must also be mentioned. Firstly, the success of risk forecasts might depend on the variable under study. If, for example, output growth is best described by a regime-switching process as proposed by Hamilton (1989), it should be possible to issue informative risk forecasts for this variable. At least for short horizons, one would just have to forecast upward risks during recessions and downward risks during expansions. Secondly, if discrete random variables with few possible outcomes are an important determinant of the variable under study, risk forecasts could also perform well. One example might be a potential future change in the VAT rate and its effect on inflation. However, in such cases one might prefer to conduct scenario analyses, as the Riksbank has done since 2007. This has the additional advantage of clarifying the comovements between variables in the event of the risk materializing.

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Appendix

A.1 Central Bank Statements on Risk Forecasting

The following section cites the statements of central banks on which Section 1.2 and Table 1.1 are based. Table 1.6 contains the positions in these central banks' publications where their risk assessments can be found.

Bank of Canada

"The staff projection is an outlook for the economy's most likely path."[48]

"While the underlying macroeconomic risks to the projection are roughly balanced, the Bank judges that, as a consequence of operating at the effective lower bound, the overall risks to its inflation projection are tilted slightly to the downside", (Bank of Canada, 2009, p.27).

"Chart 23 and Chart 24 depict the 50 per cent and 90 per cent confidence bands for year-over-year core and total CPI inflation [...] In particular, they show the slight downward tilt to the confidence bands that results from monetary policy operating at the effective lower bound"[49], (Bank of Canada, 2009, p.26).

Banco Central de Chile

"Balance of risks: Evaluation of possible alternative scenarios to the baseline scenario used in projections (considered the most likely in the Monetary Policy Report) and their implications for future paths of output and inflation. The combined analysis of different sources of uncertainty to the baseline projection scenario are reflected in the balance of risks, which may be biased downward, upward or balanced, in terms of growth and inflation, as compared to the baseline scenario", (Banco Central de Chile, 2007, p.32).

"When the balance of risks around the central or modal projection slopes upward (positive bias), values above the modal projection are considered more likely to occur than values below it", (Banco Central de Chile, 2001, p.13).

Bank of England

"The central projection of inflation is then interpreted as being the 'mode' of the statistical distribution - it is the single most likely outcome based on current knowledge and judgment", (Britton et al., 1998, p.32).

"In order to produce the fan chart, only one number is needed to summarise the degree of skewness (the balance of risks). [...] The Bank's analysis focuses on the difference between

[48] See `http://www.bankofcanada.ca/en/monetary/monetary_decision3.html`.

[49] Note that this statement suggests that expected inflation is lower than the central projection of inflation. Moreover, it implies that the Bank of Canada produces quantitative risk forecasts.

the mean and the mode of the forecast distribution to be presented in the Report. This difference is of interest as a summary statistic of the balance of risks", (Britton et al., 1998, p.32).

"If the MPC believed there was a higher probability that inflation would be above the mode than below, then the area under the curve would be skewed to the right", (Bank of England, 2002, p.48).

Banco de España

"[...] These factors [...] suggest that the risks surrounding the output growth projections are on the low side. This means that downward deviations from the growth path of the central scenario of this report are considered more likely than upward ones", (Banco de España, 2008, p.4).

"[...] a central projection scenario is obtained [...]. This central scenario is considered the most likely", (Ortega, Burriel, Fernández, Ferraz, and Hurtado, 2007, p.19).

Bank of Israel

"Nonetheless, within the horizon of a year or more, the upside risks of inflation balance out with its downside risks", (Bank of Israel, 2008, p.26).

"The principal risk factor that could lead to the nonmaterialization of this forecast is the course of global developments", (Bank of Israel, 2010, p.36).

Bank of Japan

"Each Policy Board member submits his or her forecasts in the form of point estimates, the values to which he or she attaches the highest probability of realization [...] each Policy Board member also indicates, in the form of a probability distribution, the likelihood that upside or downside risks will materialize and cause divergence from the forecast value", (Bank of Japan, 2008, p.9).

"The probability distribution for the rate of real GDP growth in fiscal 2008 is skewed to the left. This suggests that Policy Board members consider the downside risks to be greater than the upside risks", (Bank of Japan, 2008, p.9).

Banco de Portugal

"Risks on economic activity are on the downside, particularly in 2011", (Banco de Portugal, 2010, p.10).

"According to the quantification of risks, the likelihood that GDP growth may fall below the present outlook stands at 54 per cent in 2010 and 63 per cent in 2011", (Banco de Portugal, 2010, p.18).

"The baseline point forecasts are interpreted as the mode of the joint distribution"[50], (Pinheiro and Esteves, 2010, p.1).

Board of Governors of the Federal Reserve System

"Participants also provide judgments as to whether the risks to their projections are weighted to the upside, downside, or are broadly balanced. That is, participants judge whether each variable is more likely to be above or below their projections of the most likely outcome", (Board of Governors of the Federal Reserve System, 2008, p.45).

"The projections now produced by FOMC participants are explicitly modal forecasts in that they represent participants' projections of the most likely outcome. Although participants provide qualitative assessments of whether the risks around their projections are weighted to one side or the other, we do not have quantitative estimates of any skew", (Reifschneider and Tulip, 2007, p.12).

"Most participants viewed the risks to their inflation projections as weighted to the upside. Recent sharp increases in energy and food prices and the passthrough of dollar depreciation into import prices could boost inflation in the near term by more than currently anticipated", (Board of Governors of the Federal Reserve System, 2008, p.41).

Deutsche Bundesbank

"It is generally assumed that uncertainties are distributed symmetrically around the most likely value, ie the baseline. Depending on the specific data situation and conditions, there may well be signs when the projections are produced that this will not be the case. Indeed, unlike in the historical patterns, there is often a skewed distribution. In this case, the terms upside or downside risks are used", (Deutsche Bundesbank, 2007, p.27).

European Central Bank

"Risks to the outlook for price developments are slightly tilted to the upside. They relate, in particular, to the evolution of energy and non-oil commodity prices. Furthermore, increases in indirect taxation and administered prices may be greater than currently expected", (European Central Bank, 2010, p.6).

"ECB/Eurosystem staff projections are presented in the form of ranges. The use of ranges acknowledges the inevitable uncertainty surrounding macroeconomic projections."[51]

[50]Note that this interpretation differs from those of most other central banks, which consider the marginal modes.

[51]See `www.ecb.int/pub/pdf/other/newprocedureforprojections200912en.pdf`.

Table 1.6: Publications of risk assessments by central banks

Central Bank	**Risk assessments published in**
Bank of Canada	Monetary Policy Report, Chapter “Risks to the outlook”
Banco Central de Chile	Monetary Policy Report, Chapter “Inflation scenarios”, Section “Risk scenarios”
Bank of England	Inflation Report, Chapter “Prospects for inflation”, Section “Key judgements and risk”
Banco de España	Economic Bulletin, Chapter “Spanish economic projections report”, Section “Risks to the projection” (Chapter appears semi-annually)
Bank of Israel	Inflation Report, Chapter “Update of the forecasts”, Section “Assessments regarding the development of inflation and the balance of its risks”
Bank of Japan	Outlook for Economic Activity and Prices, Figure “Risk balance charts” and Section “Upside and downside risks”
Banco de Portugal	Economic Bulletin, Chapter “Outlook for the Portuguese economy”, Section “Uncertainty and risks” (Chapter appears semi-annually)
Board of Governors of Federal Reserve System	Monetary Policy Report to the Congress, Chapter “Summary of economic projections”, Section “Uncertainty and risks”
Deutsche Bundesbank	Monthly Report, Chapter “Outlook for the German economy”, Section “Risk assessment” (Chapter appears semi-annually)
European Central Bank	Monthly Bulletin, “Editorial” and “The outlook for economic activity”
International Monetary Fund	World Economic Outlook, Chapter “Global prospects and policies”
Magyar Nemzeti Bank	Quarterly Report on inflation, Chapter “Inflation and real economy outlook”, Section “Inflation and growth risks”
Norges Bank	Monetary Policy Report, Chapter “Monetary policy assessments and strategy”, Section “Uncertainty surrounding the projections (scenario analyses)”
Reserve Bank of Australia	Statement on Monetary Policy, Chapter “Economic Outlook”, Section “Risks”
Reserve Bank of New Zealand	Monetary Policy Statement, Chapters “Overview and key policy judgements” and “International developments and outlook”
Sveriges Riksbank 2007-present	Monetary Policy Report, Chapter “Alternative scenarios and risks (scenario analyses)”
Sveriges Riksbank 1999-2006	Inflation Report, Chapter “Inflation assessment”, Section “Risk assessment”
Swiss National Bank	Quarterly Bulletin, Chapter “Monetary policy report”, Section “SNB inflation forecast”

International Monetary Fund

“[...] The IMF staff has presented risks to the WEO projections using a fan chart [...] The methodology for constructing the fan chart is similar to that originally developed by the Bank of England. The central forecast is represented as the mode, or the most likely outcome [...] The skewness of the distribution, or the relative size of the two pieces of the normal distribution, represents the balance of risks to the central forecast”, (International Monetary Fund, 2008, pp.41-42).

“In the case of the balance of risk being tilted to the downside [...] the expected probability of outcomes being below the central forecast exceeds 50 percent”, (International Monetary Fund, 2006, p.25).

Magyar Nemzeti Bank

“In order to plot the fan chart, the uncertainty distribution must be determined for each point in time on the projection horizon. [...] The mode of distribution is identical to the central projection. [...] In determining the skewness that indicates risk direction, the risk perception of the Economics Department prevails”, (Magyar Nemzeti Bank, 2004, p.107).

“The method that we follow in preparing fan charts broadly corresponds to that of the Bank of England, and the same holds true for the Swedish method”, (Magyar Nemzeti Bank, 2004, p.108).

“On the whole, our inflation forecast is apparently jeopardised by significant upward risks, which means that actual price increases will more likely exceed our expectations, rather than fall short of them”, (Magyar Nemzeti Bank, 2008, p.46).

Norges Bank

“There is also a risk that the global downturn will be deeper and more prolonged than expected. [...] Overall, the outlook and balance of risks suggest that the key policy rate should be gradually reduced further to a level of around 1% in the second half of 2009”, (Norges Bank, 2009, p.13).

Reserve Bank of Australia

“ [...] it would be a mistake to focus only on the point forecast; it makes much more sense to think of the central forecast as simply the modal point on the distribution of the possible outcomes, with a sequence of progressively less likely outcomes on either side. Nor is that distribution necessarily symmetric – it may be skewed one way or the other. [...] We do not use fan charts per se, but we do try to consider alternative scenarios to the central forecast.

We attempt to use the results of that process to articulate some sense of the balance of risks – both on the inflation outlook and on growth prospects – in the published statements."[52]

"As always, there are risks in both directions around the forecasts, although overall, these risks are viewed as evenly balanced", (Reserve Bank of Australia, 2010, p.57).

Reserve Bank of New Zealand

"[...] the central forecast is only one of a large number of potential outcomes for the economy, albeit the outcome that the Bank considers to be the most likely", (Conway, 2000, p.14).

"We continue to see the balance of risks to the central projection as being to the downside for activity and inflation", (Reserve Bank of New Zealand, 2009, p.4).

Sveriges Riksbank (2007-present)

"The forecasts in the main scenario show the path which the Riksbank expects the economy to take and is a weighted consideration of various conceivable development paths (scenarios) and risks. [*continued in footnote 11*] There are therefore no grounds to revise the main scenario afterwards in light of a certain specific risk. This approach was adopted previously in the Inflation Report", (Sveriges Riksbank, 2007, p.22).

"The uncertainty bands for the forecasts for inflation and GDP growth are based on the Riksbank's historical forecast errors. [*continued in footnote 12*] This entails a change in the method used for designing the fan chart for inflation, which has previously been calculated using a weighted average of underlying risks. With the new method, the uncertainty bands are symmetrical", (Sveriges Riksbank, 2007, p.22).

Sveriges Riksbank (1999-2006)

"The distribution that is used as an approximation of the inflation forecast's distribution is known in statistical terminology as two-piece normal. [...] From Fig. B3 it will be seen that forecast inflation for the second quarter of 2000 carries a downside risk (the distribution in Fig. B3 is somewhat skewed to the left). The broken line is the inflation forecast in the main scenario (the mode)", (Sveriges Riksbank, 1998, pp.36-37).

"Skew is measured as the difference between the mean value and the most probable value (the mode of the distribution)", (Sveriges Riksbank, 1998, p.36).

"The overall assessment of different risks is that the probability of inflation being higher than in the main scenario is slightly greater than the probability of lower inflation", (Sveriges Riksbank, 2006, p.38).

[52] See http://www.rba.gov.au/speeches/2001/sp-ag-101001.html

Swiss National Bank

"[...] the higher inflation expectations and the possibility of second-round effects will keep inflation risks on the upside", (Swiss National Bank, 2008, p.13).

"Uncertainty about the future outlook for the global economy remains high, however, and downside risks predominate", (Swiss National Bank, 2010c, p.19).

A.2 Data Details

A.2.1 Bank of England

As mentioned in Section 1.3, the BoE and the Riksbank use the *tpn*-distibution. The density of a *tpn*-distributed variable Y is given by

$$f(y) = \begin{cases} A \exp\left(-\frac{(y-m)^2}{2\sigma_1^2}\right) & \text{if} \quad y \leq m \\ A \exp\left(-\frac{(y-m)^2}{2\sigma_2^2}\right) & \text{if} \quad y \geq m, \end{cases}$$

with $A = \frac{2}{\sqrt{2\pi}(\sigma_1+\sigma_2)}$ and m denoting the mode of the distribution. The more σ_1 differs from σ_2, the more asymmetric the distribution becomes. If σ_1 and σ_2 are identical, a normal distribution is obtained.

In order to determine the Pearson mode skewness, defined as the difference between the mean and the mode forecast, scaled by the forecast standard deviation, we have to calculate the variance, which is given by

$$\sigma^2 = \left(1 - \frac{2}{\pi}\right)(\sigma_2 - \sigma_1)^2 + \sigma_1\sigma_2.$$

For this calculation three parameters of the BoE's forecast densities are required, which can be downloaded directly from the bank's website.[53] These parameters are the mean μ, the mode m and an uncertainty measure ω. Following Wallis (2004), it is helpful to define

$$s = \frac{\mu - m}{\omega},$$

from which the quantity γ can be determined as

$$\gamma = sign(s)\sqrt{1 - 4\left(\frac{\sqrt{1+\pi s^2} - 1}{\pi s^2}\right)^2}.$$

[53] See http://www.bankofengland.co.uk/publications/inflationreport/irprobab.htm.

Table 1.7: Pearson mode skewness of forecast densities of the Bank of England

h	0	1	2	3	4	5	6	7	8
1998Q1	0.197	0.170	0.176	0.178	0.178	0.248	0.292	0.321	0.352
1998Q2	−0.338	−0.324	−0.320	−0.332	−0.332	−0.119	0.047	0.178	0.283
1998Q3	0.202	0.229	0.231	0.224	0.224	0.236	0.256	0.262	0.267
1998Q4	0.159	0.209	0.209	0.209	0.204	0.113	0.025	−0.034	−0.093
1999Q1	0.107	0.107	0.107	0.089	0.096	0.029	−0.026	−0.082	−0.118
1999Q2	0.166	0.166	0.189	0.166	0.182	0.195	0.197	0.199	0.207
1999Q3	0.230	0.272	0.267	0.265	0.256	0.206	0.143	0.103	0.073
1999Q4	−0.060	−0.108	−0.077	−0.080	−0.090	−0.132	−0.218	−0.272	−0.292
2000Q1	0.175	0.175	0.175	0.175	0.175	0.179	0.178	0.190	0.192
2000Q2	0.060	0.072	0.078	0.100	0.090	0.050	0.000	−0.040	−0.063
2000Q3	0	0	0	0	0	−0.034	−0.078	−0.114	−0.135
2000Q4	0.059	0.071	0.101	0.079	0.089	0.065	0.029	0.013	0
2001Q1	−0.120	−0.108	−0.103	−0.100	−0.090	−0.147	−0.214	−0.264	−0.291
2001Q2	−0.120	−0.108	−0.103	−0.080	−0.090	−0.116	−0.147	−0.172	−0.185
2001Q3	0	0	0	0	0	−0.050	−0.118	−0.159	−0.185
2001Q4	0.336	0.336	0.336	0.336	0.336	0.313	0.283	0.258	0.243
2002Q1	0.341	0.341	0.341	0.341	0.341	0.370	0.402	0.427	0.441
2002Q2	0	0	0	0	0	0.089	0.190	0.280	0.324
2002Q3	0	0	0	0	0	0.054	0.128	0.172	0.200
2002Q4	0	0	0	0	0	0.056	0.115	0.174	0.202
2003Q1	0	0	0	0	0	0.050	0.104	0.162	0.190
2003Q2	0.190	0.190	0.180	0.200	0.190	0.144	0.082	0.030	0.000
2003Q3	0	0	0	0	0	−0.038	−0.087	−0.128	−0.152
2003Q4	0	0	0	0	0	0	0	0	0
2004Q1	0	0	0	0	0	0	0	0	0
2004Q2	0	0	0	0	0	0	0	0	0
2004Q3	0	0	0	0	0	0	0	0	0
2004Q4	−0.240	−0.240	−0.226	−0.251	−0.240	−0.263	−0.292	−0.315	−0.328
2005Q1	−0.239	−0.239	−0.251	−0.250	−0.239	−0.264	−0.294	−0.319	−0.333
2005Q2	0	0	0	0	0	0	0	0	0
2005Q3	0	0	0	0	0	−0.047	−0.107	−0.158	−0.187
2005Q4	0	0	0	0	0	0	0	0	0
2006Q1	0	0	0	0	0	0	0	0	0
2006Q2	0	0	0	0	0	0	0	0	0
2006Q3	0	0	0	0	0	0	0	0	0
2006Q4	0	0	0	0	0	0	0	0	0
2007Q1	−0.165	−0.165	−0.151	−0.168	−0.160	−0.063	0.090	0.213	0.272
2007Q2	0	0	0	0	0	0.075	0.156	0.216	0.260
2007Q3	0	0	0	0	0	0.030	0.085	0.108	0.132
2007Q4	0	0	0	0	0	0	0	0	0
2008Q1	0	0	0	0	0	0	0	0	0
2008Q2	0.124	0.133	0.128	0.131	0.124	0.144	0.159	0.160	0.178
2008Q3	0.131	0.127	0.116	0.125	0.119	0.167	0.217	0.259	0.277
2008Q4	0	0	0	0	0	0	0	0	0
2009Q1	0	0	0	0	0	−0.059	−0.128	−0.179	−0.205
2009Q2	0.456	0.454	0.458	0.449	0.452	0.337	0.207	0.070	0
2009Q3	0	0	0	0	0	0	0	0	0
2009Q4	0	0	0	0	0	0	0	0	0
2010Q1	0.162	0.163	0.169	0.164	0.164	0.192	0.222	0.247	0.258
2010Q2	0.091	0.076	0.081	0.079	0.083	0.094	0.110	0.124	0.134

Note: The forecast horizon h is measured in quarters. A zero without a decimal point refers to the situation of exactly balanced forecast risks.

The standard deviations σ_1 and σ_2 can then be calculated as

$$\sigma_1 = \frac{\omega}{\sqrt{1+\gamma}}, \quad \sigma_2 = \frac{\omega}{\sqrt{1-\gamma}},$$

and can be inserted into the formula for the variance of the forecast density σ^2 given above. Then the Pearson mode skewness $(\mu - m)/\sigma$ can be determined. Its values are displayed in Table 1.7.

A.2.2 Sveriges Riksbank

There are two inflation fan charts in each Inflation Report we study. One chart refers to the price index CPI, the other to the price index UND1X.[54] We focus on the CPI only. Forecast values are given for the current month and the next 24 months. The values which are published are the central forecast (mode forecast) and the quantiles belonging to the 50%, 75% and 90% confidence intervals. Unlike the intervals published by the BoE, these intervals are symmetric around the median, as clarified by Blix and Sellin (2000, footnote 7).

In contrast to the BoE, the Riskbank does not publish the means and standard deviations of the *tpn*-distributions that underlie the fan charts.[55] Therefore, we first have to back out the parameters of these distributions in order to calculate their means and standard deviations. The precision of the parameter estimates of course depends on the precision of the published forecast values. For Inflation Reports 1999:4 to 2004:4 they are very precise, having fourteen decimal places. Then, for the Inflation Reports 2005:1 and 2005:2, the published values have two decimal places. Finally, the published values have only one decimal place for Inflation Reports 2005:3 to 2006:3. Surprisingly, the mode forecasts from Inflation Report 2004:4 also have only one decimal place. Hence, while backing out the exact parameter values is relatively easy until at least Inflation Report 2004:3, the estimates can be expected to be less precise for the following Inflation Reports due to the rounding of the forecast values.

Backing out the parameter values requires fitting a *tpn*-distribution to the modes and quantiles published. This fitting can either be carried out using a least squares criterion or a likelihood ratio criterion as shown by García and Manzanares (2007). For forecasts from Inflation Reports 1999:4 to 2004:4, the differences between the results obtained with both criterions are small in general. But especially when only 1 decimal place is used, the differences can become larger. In these cases, the likelihood ratio criterion gives more plausible results. For example, the skewness of the Riksbank's density forecasts published in a certain Inflation Report never changes sign from one forecast horizon to the next,[56] i.e. the skewness

[54] The index UND1X is defined as the CPI excluding household mortgage interest expenditure and the direct effects of changes in indirect taxes and subsidies.

[55] The fact that the Riksbank uses a *tpn*-distribution is stated in Sveriges Riksbank (1998, pp.36-37).

[56] This becomes clear when reading the chapters of the Inflation Reports that discuss the balance of risks.

Table 1.8: Pearson mode skewness of forecast densities of the Sveriges Riksbank

h	0	3	6	9	12	15	18	21
Dec 1999	0.014	0.053	0.089	0.124	0.157	0.140	0.124	0.107
Jun 2000	0	0	0	0	0	0.018	0.038	0.059
Oct 2000	0.014	0.054	0.092	0.127	0.152	0.159	0.165	0.172
Dec 2000	0.023	0.089	0.150	0.207	0.261	0.272	0.282	0.293
Mar 2001	−0.000	−0.035	−0.067	−0.098	−0.126	−0.114	−0.101	−0.089
May 2001	0	0	0	0	0	0	0	0
Oct 2001	0	0	0	0	0	0	0	0
Dec 2001	0	0	0	0	0	0	0	0
Mar 2002	0.012	0.244	0.240	0.110	0.139	0.125	0.111	0.097
Jun 2002	0.252	0.244	0.080	0.111	0.140	0.126	0.112	0.098
Oct 2002	−0.006	−0.025	−0.043	−0.059	−0.070	−0.073	−0.076	−0.079
Dec 2002	−0.006	−0.023	−0.040	−0.055	−0.070	−0.073	−0.077	−0.080
Mar 2003	0	0	0	0	0	0	0	0
Jun 2003	−0.009	−0.035	−0.059	−0.082	−0.104	−0.095	−0.086	−0.077
Oct 2003	0	0	0	0	0	0	0	0
Dec 2003	0	0	0	0	0	0	0	0
Apr 2004	0.006	0.022	0.037	0.052	0.062	0.067	0.071	0.076
May 2004	0.000	0.024	0.046	0.067	0.087	0.093	0.093	0.092
Oct 2004	0	0	0	0	0	0	0	0
Dec 2004	−0.157	0	−0.004	−0.096	−0.167	−0.160	−0.132	−0.100
Mar 2005	0	0	0	0	0	0	0	0
Jun 2005	−0.000	−0.038	−0.057	−0.086	−0.109	−0.092	−0.077	−0.055
Oct 2005	0	0	0	0	0	0	0	0
Dec 2005	0	0.120	0.133	0.206	0.166	0.221	0.163	0.084
Feb 2006	0	0	0	0	0	0	0	0
Jun 2006	0	0	0	0	0	0	0	0
Oct 2006	0	0.120	0.201	0.300	0.253	0.214	0.169	0.159

Note: The forecast horizon h is stated in months. A zero without a decimal point refers to the situation of exactly balanced forecast risks. Only the horizons $h \leq 12$ are used in the empirical analysis.

might switch between zero and positive, or between zero and negative, but not between positive and negative. Looking at the Inflation Report 2005:4, however, with the least squares criterion, the skewness for the 5-month-ahead forecast is negative, while it is positive for 4 and 6 months ahead. With the likelihood ratio criterion, the skewness is positive for 4, 5 and 6 months ahead. Therefore, we use the likelihood ratio criterion to back out the parameters and to calculate the skewness of the inflation forecasts.

The skewness obtained in this way is cross-checked with the statements in the Inflation Reports. If an Inflation Report states that risks are balanced, we set the skewness of the corresponding forecast densities to zero, even if the estimated parameters indicate a (small) non-zero skewness. We do this because the parameter estimation results, as explained above, can be affected by imprecise data. The Pearson mode skewness for the selected forecast horizons is displayed in Table 1.8.

Chapter 2

What determines the Shape of Inflation Fan Charts?

Abstract: To investigate potential determinants of the shape of forecast inflation fan charts, we analyze the historical interest rate voting patterns of the Bank of England's Monetary Policy Committee, the Magyar Nemzeti Bank's Monetary Council and the Sveriges Riksbank's Executive Board. We find that current disagreement about the level of interest rates translates into the asymmetry, but not the width of the subsequent forecast inflation fan charts of the Bank of England and of the Sveriges Riksbank. The opposite is true for the Magyar Nemzeti Bank. As fan charts are usually seen to represent the common view of all members of the decision-making body, we argue that forecasting potentially asymmetric uncertainties serves to accommodate minority views on monetary policy.

Keywords: Bank of England, Magyar Nemzeti Bank
Sveriges Riksbank, Committee Dissent,
Forecast Risk, Fan Charts

JEL-Classification: E52, C12

This chapter is based on
Knüppel, M. and Schultefrankenfeld, G., 2013, What determines the Shape of Inflation Fan Charts?, mimeo.

2.1 Introduction

Many central banks publish regular assessments of the magnitude and balance of risks to their macroeconomic outlook, as surveyed in Knüppel and Schultefrankenfeld (2012). A substantial fraction of the central banks examined casts these assessments into density forecasts of their target variables. Often, the forecasting results are depicted as graphs of the central projection and potentially asymmetric uncertainty intervals surrounding this projection. Pioneered by the Bank of England (BoE), these graphs are today known as fan charts.

While asymmetric fan charts are a well established device for central banks to communicate a baseline and its uncertainties, the way of constructing them is in many cases less straightforward: central bank fan charts are typically not generated by a model. Rather, they are the result of a forecasting process where the "central tendency for inflation [...], the degree of uncertainty [...] and the balance of risks" are to be evaluated, as described by Britton, Fisher, and Whitley (1998, p.32) for the BoE. Blix and Sellin (1999, pp.2-3) describe for the Sveriges Riksbank (Riksbank) that "The traditional statistical approach to producing uncertainty intervals would involve [...] constructing a model intended for inflation forecasts. [...] The Riksbank, however, does not use the approach [...]." As further examples, the Magyar Nemzeti Bank (MNB), the Banco Central do Brazil and the Banco Central de Chile proceed similarly to the aforementioned central banks.[1]

If the 'traditional statistical approach' is not used to obtain central bank fan charts, the questions arises what determines the shape of the uncertainty intervals surrounding a central tendency. In particular, what determines the width and the skewness of central bank fan charts? Knüppel and Schultefrankenfeld (2012) have collected reasons for macroeconomic risk forecasting, which is directly related to skewed forecast distributions and asymmetric fan charts. Asymmetries in the forecast uncertainty may result from non-linearities, frozen-forecast issues, biases in recent forecast errors, expert expectations about future asymmetries of shocks or simply from central bank communication strategies. A further reason that virtually summarizes the aforementioned ones is provided by disagreement in decision making. Both forecasting and monetary policy decisions are usually the concern of several decision-makers in a decision-making body of a central bank. If the views on future values of the instrument and the target variable(s) of the decision-making body as a whole are represented by fan charts, then minority views leading to disagreement about such variables may have their effects on the shape of these fan charts.

Disagreement on forecasts can either term deviations between competing forecasts for one variable of forecasters *from different institutions* or *within one institution*. Differences

[1] See the MNB's Inflation Report of May 2004, p.108, the Banco Central do Brazil's Inflation Report of September 1999, p.79, and the Banco Central de Chile's December 2011 Monetary Policy Report, p.33, exemplarily for further details.

across institutions can for instance occur in statistical surveys like the Survey of Professional Forecasters or the Livingston Survey, as analyzed for instance by Banternghansa and McCracken (2009) or D'Amico and Orphanides (2008). The cross-sectional dispersion of mean forecasts from surveys is known to be a proxy for forecast uncertainty, as shown in Bomberger (1996) or Giordani and Söderlind (2003). Relationships between macroeconomic uncertainty approximated by survey dispersion and stock market volatility have been found by Arnold and Glasbeek (2011).

Disagreement plays a prominent role in decision-making within institutions, in particular in the form of disagreement about and dissenting views on the level of the monetary policy instrument within monetary policy committees. Modern, inflation-targeting central banks usually employ such a decision-making body to decide on the level of interest rates based on forecasts for inflation. Monetary policy committees typically consist of several members and are chaired by the bank's governor or president. Examples for such central bank committees include the Monetary Policy Committee (MPC) of the BoE, the Policy Board of the Bank of Japan, the Federal Open Market Committee at the Federal Reserve System and the Governing Council of the European Central Bank. The standard task for the committees is to obtain decisions on future monetary policy, i.e. deciding if to raise, maintain or lower the key interest rate. These decisions are usually achieved by letting the members vote on an interest rate proposal made by the chairman. At the end of the voting process, which may have several stages, the proposal that has attained the majority of the member votes will be the aggregate interest rate decision. If there is no unanimity about the instrument level, it is implied that a minority of decision makers has been outvoted.

Numerous reasons lead members to vote for or against an interest rate proposal such that there is dissent in voting. Particulary important is that committee members may have different inflation expectations due to different priors, models and other differences in their information set about the future, such that their individually preferred level of interest rates required for achieving target inflation may also be different from the aggregate interest rate decision. Other reasons that may cause members to deviate from the majority include professional skill, geographical and professional background, uncertainty about policy effectiveness, social reasons, etc., as discussed for example by Belden (1989), Gerlach-Kristen (2002), Meade and Sheets (2005), Chappell Jr. et al. (2000, 2004, 2007), Gerlach-Kristen and Meade (2010), and in the literature surveyed by Gerlach-Kristen (2006).

If the majority voters achieved an aggregate interest rates decision, the task for the whole committee (or the staff on behalf of the committee, depending on the central bank) is to form an aggregate inflation forecast that is consistent with the new level of the instrument. This typically results in a central tendency for inflation. Yet, the minority voters that opted for another level of the monetary policy instrument have their individual inflation forecasts that are likely to be different from the central tendency. Hence, these minority views may be factored in by widening the confidence intervals to attach a certain probability of occurrence to these alternative views on future inflation. Moreover, minority views can be accommodated by introducing skewness to the forecast density.

Although no individual inflation forecasts are available, the BoE, the MNB and the Riksbank are the only central banks that make attributed interest rate voting records as well as the entire forecast densities published in their inflation reports available. Hence, the individual paths of interest rates for the committee members can be determined. This gives us the unique opportunity to investigate if there is a systematic connection between the degree of disagreement about monetary policy committee decisions on the level of the policy instrument and risks and uncertainties to forecasts of the target variable inflation, as published in the subsequent monetary policy reports. In case of the MNB, we find that the more minority views deviate from the aggregate interest rate decision, the wider are the MNB inflation fan charts. For the BoE and the Riksbank, however, we cannot link dissenting views to the width of fan charts. Yet, there is statistical evidence that the more minority voters dissent from the majority's vote on the level of the monetary policy instrument, the more skewed are the forecast inflation fan charts published in the monetary policy reports. Therefore, we argue that dissent in voting is a reason for forecasting risk to accommodate and communicate minority views about monetary policy.

The remainder of the paper is structured as follows. Section 2 provides an overview on the data we use. Section 3 sets up our hypotheses, the corresponding regression models, and presents test results. Section 4 studies possible effects of hawkish and dovish interest rate voting on the shape of inflation fan charts. Section 5 concludes.

2.2 Data

2.2.1 Fan Chart Width and Skewness

To *measure the width of the fan charts* for inflation, we use the forecast standard deviation as the most common measure for forecast uncertainty. The BoE's, the MNB's and the Riksbank's inflation forecasts have a two-piece normal (*tpn*) distribution.[2] The *tpn* distribution is described for instance by Wallis (2012). Given values for the mode, the mean and a dispersion parameter, one can easily calculate the standard deviation of a *tpn*-distributed variable following the manual in Wallis (2004).

The BoE provides on its website all parameters needed for calculating the standard deviation. These are the BoE's central projection which is a mode forecast, an average of likely alternatives which is the mean forecast, and a measure of uncertainty which is the

[2] For further details on the fan charts of BoE, MNB, and Riksbank, see Britton et al. (1998), the MNB's Quarterly Report on Inflation of May 2004, and Blix and Sellin (1999), respectively. Further work using the *tpn* distribution in the context of central bank forecasting is provided by Novo and Pinheiro (2005).

dispersion parameter.[3] All three central banks under study publish a mode forecast as the central projection for inflation. Yet, from the required parameters listed above, the MNB and the Riksbank do not publish mean forecasts and dispersion parameters. In addition to their mode forecasts, the MNB publishes quantiles belonging to 30%, 60%, and 90% confidence bands, while the Riksbank publishes quantiles belonging to 50%, 75% and 90% confidence bands. To the modes and quantiles available we fit a *tpn* distribution as proposed by García and Manzanares (2007) to back out the relevant parameters for calculation of the standard deviation. Further details on the procedure are described by Knüppel and Schultefrankenfeld (2012) on the basis of the Riksbank data set. The resulting standard deviation series for inflation for the BoE, the MNB and the Riksbank are denoted by $\sigma_{\pi,t+h|t}$. The forecast horizon is indexed by $h = 0, \ldots, H$. Once the standard deviations for all periods across forecast horizons are retrieved from the fan charts, we can easily calculate a measure of forecast risk known as Pearson mode skewness:

$$\kappa_{t+h|t} \equiv \frac{\pi^e_{t+h|t} - \pi_{t+h|t}}{\sigma_{\pi,t+h|t}}. \tag{2.1}$$

The mean forecast for inflation, made in period t for period $t + h$, is denoted by $\pi^e_{t+h|t}$, the corresponding mode forecast is denoted by $\pi_{t+h|t}$. The Pearson mode skewness is a scale-free measure of forecast risk, whose desirable test properties for evaluating macroeconomic risk forecasts have been investigated in Knüppel and Schultefrankenfeld (2011). The Pearson mode skewness is closely related to the original BoE (and, hence, MNB and Riksbank) definition of forecast inflation risk, given by the difference between the mean forecast, $\pi^e_{t+h|t}$, and the mode forecast, $\pi_{t+h|t}$. This difference is simply scaled by the forecast standard deviation. The Pearson mode skewness will be the *measure of the asymmetry of the fan charts* in the following analysis.

The BoE data set of forecasts, made conditional on interest rates as expected by market participants, ranges from 1998Q1 to 2011Q2 and thus over 54 quarters. The BoE publishes a nowcast and forecasts for up to two years out such that the maximum forecast horizon is $H = 8$.[4] For the MNB, we can back out the nowcasts and forecasts for up to seven quarters out from 2002Q4 to 2011Q2, where 2008Q4 is missing.[5,6] Since the attributed voting record

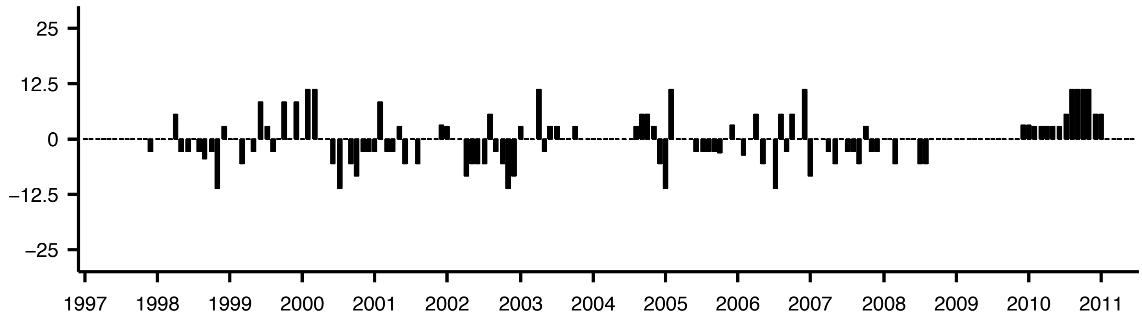
[3]See `http://www.bankofengland.co.uk/publications/inflationreport/irprobab.htm`.

[4]In addition to market-rate forecasts, BoE risk and uncertainty forecasts made under the assumption that interest rates remain constant over the forecast horizon are available from 1997Q4 on. Since 2004Q3, the BoE publishes market-rate forecasts for up to three years ahead.

[5]The MNB inflation forecasts used in this study were made assuming a constant repo rate over the forecasting period. With the Quarterly Report on Inflation of March 2011, the MNB forecasts are based on endogenous monetary policy.

[6]The forecast data for 2008Q4 is missing because, as stated in the MNB November 2008 Quarterly Report on Inflation, p.7, "The November projection was produced in a much more uncertain financial and macroeconomic environment compared with previous years. Therefore, we departed from the past practice of building the forecast around a central estimate."

Figure 2.1: Disagreement in the Bank of England's monthly interest rate decisions



Note: The bars show the degree of disagreement, calculated as the difference between the average of the members' preferred interest rate and the level of the official bank rate agreed upon in the MPC meeting, measured in basis points.

of the MNB begins in 2005Q4, we have to skip the first 12 quarters of the inflation forecast dataset for the regression analysis. Overall, we have 22 observations for each of the seven forecast horizons, and $H = 6$. For the Riksbank, we use monthly forecasts starting with the first publication date of December 1999. Potentially asymmetric fan charts were discontinued in October 2006, such that this date marks the end of the Riksbank sample used in this study.[7] From the 24 forecast horizons available, we choose the month of an Inflation Report publication to be the nowcast date. Then, we select every third forecast to achieve a quarterly timing, with the maximum number of forecast horizons being $H = 7$. The sample starts in 1999Q4, ends in 2006Q4 and comprises 27 observations for each of the eight forecast horizons, since the data of the first Inflation Report of 2000 are not available and for 2006, only three Inflation Reports were published.

2.2.2 Individual and Aggregate Interest Rate Decisions

BoE, MNB and Riksbank publish the individual interest rate votes of the committee members and the underlying motivation in form of minutes of the monetary policy meetings. For further user convenience, all three central banks issue regularly updated voting spreadsheets which contain the entire histories of interest rate voting.

For the BoE, we consider 162 monthly MPC decisions on the official bank rate from 1998Q1 to 2011Q2 to match the time span of the available inflation forecast data.[8] To create individual interest rate series for all past and present members for a current month, we take the level of the official bank rate from a previous month and add the individually desired

[7]The Riksbank inflation forecasts are made conditional on a constant interest rate assumption up to the third Inflation Report of 2005.

[8]The historical interest voting spreadsheet starts with the interest rate decision of June 1997 and is available under `www.bankofengland.co.uk/monetarypolicy/decisions.htm`.

interest rate change from the current monthly meeting. The resulting 'member interest rates' are denoted i_t^m, where m indexes the number of members such that $m = 1, \ldots, M$.

To investigate fan chart width using the forecast standard deviation as uncertainty measure requires a corresponding measure that gauges the degree of disagreement on the monetary policy decisions. To this extent, we calculate the root mean squared deviations of the member interest rates from the aggregate interest rate decision, i_t:

$$d_{\sigma,t} \equiv \sqrt{\frac{1}{M}\sum_{m=1}^{M}(i_t^m - i_t)^2}. \tag{2.2}$$

We name this variable $d_{\sigma,t}$ 'interest rate deviation', where the letter d synonymously implies disagreement, dissent, deviation or dissension. The subscript σ indicates that we use this measure in the context of fan chart width only. Using squared deviations prevents that negative and positive dissent cancel each other out, although such occasions are extremely rare, as already noted by Gerlach-Kristen (2004).

To generate a measure for the degree of disagreement that corresponds to the Pearson mode skewness, we first average the individual interest rate series over all M members of the MPC to obtain $\bar{i}_t$, the 'member's average rate'.[9] Then, we calculate the difference between this member's average rate and the MPC's aggregate interest rate decision:

$$d_{\kappa,t} \equiv \bar{i}_t - i_t, \quad \bar{i}_t = \frac{1}{M}\sum_{m=1}^{M} i_t^m. \tag{2.3}$$

The advantages of this measure of the degree of disagreement is that it preserves the direction of dissent and thus potentially allows to discuss qualitative aspects of dissenting views. Moreover, it has the characteristic of a mean-mode difference, since the majority decision on the instrument can be interpreted as a modal value. Appropriately, Gerlach-Kristen (2004) terms this measure for committee disagreement 'skew'. As we will elaborate on issues of forecast inflation skewness throughout this paper, we name this variable $d_{\kappa,t}$ the 'interest rate skew' to avoid any ambiguities. Moreover, we use $d_{\kappa,t}$ to measure the degree of disagreement on monetary policy when analyzing fan chart skewness only. As an example for dissent in central bank voting, figure 2.1 shows the monthly interest rate skew series for the BoE, as calculated using definition (2.3).

The two monthly series $d_{\sigma,t}$ and $d_{\kappa,t}$ are converted to quarterly periodicity by simply selecting the values of every first month of the quarter, i.e. from January, April, July and October. We do so in order to avoid endogeneity, since the BoE inflation reports are published

[9] The BoE MPC is regularly made up of nine members, with Governor Mervin King having the casting vote when no majority is achieved. The number of attendants of the MPC policy meetings, however, has varied occasionally.

in the mid-quarter months February, May, August and November. Thus, the index $t = 1, \ldots, T$ refers to the date of the quarterly inflation report publication of the BoE in the following. Moreover, the new quarterly measures of the degree of disagreement are denoted by $d_{\sigma,t-\tau}$ for the interest rate deviation and by $d_{\kappa,t-\tau}$ for the interest rate skew, respectively. Yet, the subscript $t - \tau = 1, \ldots, T$ indicates that data stems from the month before the publication of the Inflation Report.

For the MNB, the publication practice follows the same timing as those of the BoE, so that we can proceed in the same fashion, using the monthly interest rate decisions of the Monetary Council (MC) on the level of the base rate. Before September 2005, the voting record of the MNB has been unattributed, that is, no individual interest rate changes are available. Yet, for the period 2005Q4 to 2011Q2 we can calculate monthly dissent series. We have to number inflation forecasts by $n = 1, \ldots, N$, however, since the 2008Q4 inflation forecast is missing. After time-matching the two disagreement series to the forecast data, we are left with a sample of both 22 quarterly observations in the interest rate deviation series $d_{\sigma,n-\tau}$ and the interest rate skew series $d_{\kappa,n-\tau}$.[10]

Individual interest rate decisions of the Riksbank's Executive Board (EB) members are available from January 1999 onwards. In case of the Riksbank, τ can sometimes imply a delay of almost two months for the inflation forecasts to follow the interest rate decisions. That is, the Inflation Report may follow up to eight weeks after the policy meeting where interest rates are set. Table 2.5 shows the detailed announcement dates $t - \tau$ [MNB, Riksbank: $n - \tau$] of the interest rate decisions and the publication dates t [MNB, Riksbank: n] for the respective inflation reports of the three central banks under study.[11] Because earlier Riksbank interest rate decision and forecast publication dates are unequally spaced, we take the dates of the numbered inflation forecasts and select the interest rate votes from the meeting preceding the Inflation Report. Therefore, for the Riksbank data, $n - \tau$ in the following simply means 'one time before n' and refers to the previous meeting before the current inflation report forecasts, where n denotes the publication date of the report. Again, we calculate the interest rate deviation $d_{\sigma,n-\tau}$ and the interest rate skew $d_{\kappa,n-\tau}$ according to the definitions (2.2) and (2.3) and obtain series with both 27 observations matching the Riksbank inflation forecast series.[12]

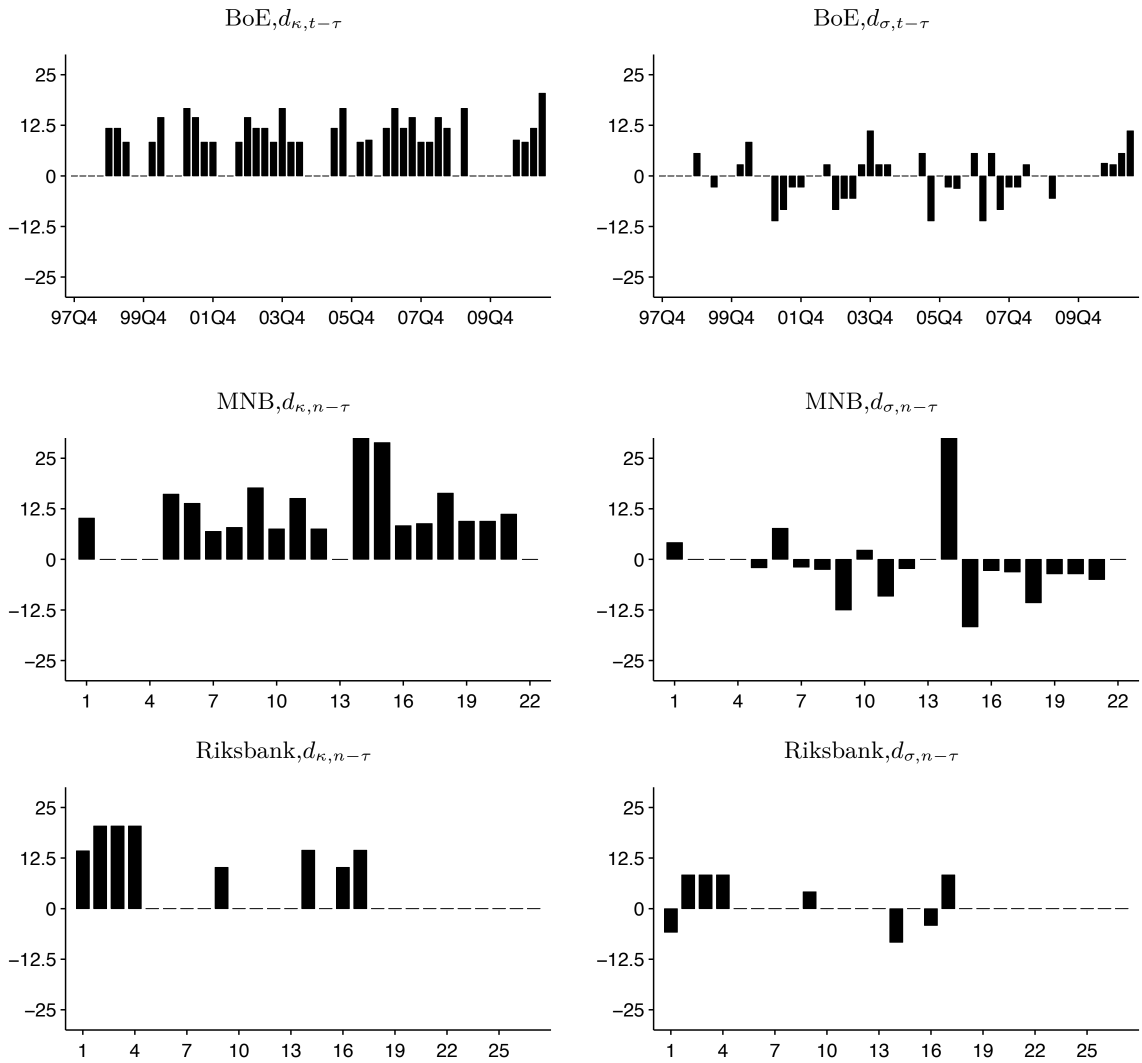
Figure 2.2 shows the quarterly measures of the degree of disagreement for the BoE (top row), the MNB (middle row) and the Riskbank (bottom row). The left panels show bar plots of interest rate deviation, based on definition (2.2). The right panels show plots of interest

[10] The "voting records of the Monetary Council members" are available online under `english.mnb.hu/Monetaris_politika/decision-making/voting-records-of-the-mc-members`.

[11] Usually, the monetary policy meetings last over two days, and the second day sees the announcement of the interest rate decisions. Hence, meeting dates and announcement dates coincide. Yet, the publication date of the minutes of the policy meeting is not an issue in the ex-post perspective we concentrate on.

[12] For the sake of convenience, in the following hypothetical explanations and setting-up of models will only be made using the $t - \tau$ subscripting.

Figure 2.2: Disagreement in central bank's interest rate decisions



Note: Bar plots show the quarterly interest rate deviation (left panels) and interest rate skew (right panels) for the Bank of England, the Magyar Nemzeti Bank and the Sveriges Riksbank, where the bars' height shows the degree of disagreement measured in basis points.

rate skew, based on definition (2.3). In these quarterly series, there is dissent in 33 out of 56 BoE MPC meetings held in the first month of a quarter. In absolute terms, the average degree of disagreement in first-month-of-quarter meetings measures about 5.5 basis points (5.49 basis points). For the MNB, we have in our sample 22 meetings held in a first month of quarter. Only 5 meetings show unanimous interest rate decisions of the Monetary Council, and the average absolute deviation from the aggregate decision is 7.25 basis points. For the Riksbank, the bar plots show much less unanimity, and only 8 out of 27 meetings are marked by dissent. In these meetings, the average absolute deviation measures roughly 7 basis points (6.98 basis points).

2.3 Investigating Fan Chart Width and Skewness

2.3.1 Two Options to Accomodate Minority Views

> "Although not every member will agree with every assumption on which our projections are based, the fan charts represent the MPC's best collective judgement about the most likely paths for inflation [...], and the uncertainties surrounding those central projections."
> — Introductory note in the Bank of England Inflation Report.

The introductory note printed in the BoE Inflation Reports already hints at a relationship between minority views on conditioning assumptions and the fan charts. Moreover, in their description of the BoE's iterative forecasting process, Britton et al. (1998) state that MPC and bank staff at their initial meeting, shortly after the MPC decision of the mid-quarter months, discuss "the key assumptions, the main issues and the starting-point for the risk assessment" and that after that meeting, "the forecast team map the decisions of the MPC onto a central projection and risk distribution."

To investigate how width and skewness of inflation-targeting central banks' fan charts are determined, we consider the following stylized but, for BoE, MNB and Riksbank alike, realistic scenario, bearing the description of Britton et al. (1998) in mind. In every monetary policy meeting, individual members of the decision-making body come up with their individual assessment of the future economic environment, i.e., members have their own forecasts of the target variable inflation.[13] Given his individual inflation forecast, each committee member has a preference for the level of the instrument which is his best approximation of the unobservable optimal rate, subject to the constraint that the interest rate choice usually obeys a 25-basis-point steps structure, see Gerlach-Kristen (2004). The member's individually desired level of the instrument may coincide with the level resulting from the interest rate step proposed by the chairman, but it may also be different from that proposal.

The level of the policy instrument to be set determines the future path of the target variable, and ideally, inflation two years ahead is kept on or brought back to target. Voters who see the interest rate proposal of the chairman to be consistent with their own desired interest rate path, based on their individual inflation forecast, will support the proposal, while the others will vote against the proposal. The majority of voters that have supported the aggregate interest rate decision will agree upon a joint central projection consistent with the

[13]We solely concentrate on inflation forecasts in this paper and neglect GDP issues.

interest rate choice. A different instrument level, however, is consistent with a future inflation path different from the central projection. A dissenting member that has voted for a different level of the instrument will argue that the aggregate interest rate decision is inappropriate such that inflation can be expected to differ from the central projection. If a hawkish minority votes for monetary policy tightening such that $\bar{i_t} > i_t$, minority voters may see inflationary pressure, for instance arising from relaxed credit conditions, and expect future inflation to lie above the level that the majority finds to correspond to the aggregate interest rate decision. Vice versa, if a minority votes for a looser monetary policy and considers the interest rate set too high, it will expect inflation to undershoot the majority's view.

If there are dissenting views about the future path of inflation, and central bank communication is supposed to subtly transport these views without blurring the central tendency agreed upon, we see basically two ways to incorporate minority views into the fan charts. First, the uncertainty bands surrounding the central projection can simply be widened. The central projection is then surrounded by confidence bands such that majority and minority positions alike are accommodated. This task can easily be accomplished, though, but may not be an option in practice. Uncertainty itself is a forecast object and the expected range of possible outcomes is an important source of information that draws public attention and potentially influences private sector expectations.

As the BoE, the MNB and the Riksbank all use a *tpn* distribution for their forecasts, there might be a second option to incorporate minority views. The central tendency, or, the central projection, or, simply, the point forecast for inflation of all three central banks is a mode forecast. The mode forecast is the single most likely outcome. The *tpn* distribution can be asymmetric, so that the mean can differ from the mode. The mean forecast can be used to summarize dissenting views on future inflation and may serve as an average of likely alternative outcomes. Hence, it could be that dissent on interest rates, which are the conditioning assumption for the subsequent inflation forecast, translate into forecast skewness of the aggregate inflation forecast density to accommodate minority views.

2.3.2 Regression Models

Widening and skewing the fan charts are not necessarily mutually exclusive options. However, both can be addressed by simple regression-based tests. To check whether the fan charts of the inflation forecasts will widen with more disagreement about monetary policy, we regress the inflation forecast standard deviation on a constant and the interest rate deviation:

$$\sigma_{t+h|t} = \alpha_\sigma + \beta_\sigma d_{\sigma,t-\tau} + \varepsilon_t, \quad E(\varepsilon_t) = 0. \tag{2.4}$$

Particularly important is the impact of the degree of disagreement, whose strength is measured by β_σ. If disagreement about monetary policy translates into fan chart width, we would expect an estimate for β_σ to be significantly positive. Hence, we should be able to reject the single hypothesis $\beta_\sigma = 0$, but not $\beta_\sigma > 0$.

As regards dissent in voting as determinant of fan charts skewness, we analyze whether the Pearson mode skewness is responsive to a change in interest rate skew:

$$\kappa_{t+h|t} = \alpha_\kappa + \beta_\kappa d_{\kappa,t-\tau} + \eta_t, \quad E(\eta_t) = 0. \tag{2.5}$$

Here, we are interested in the impact of dissent in voting on fan chart skewness, whose strength is measured by β_κ. We would want to reject $\beta_\kappa = 0$, but not $\beta_\kappa > 0$, which implies that more disagreement on the level of interest rates results in larger forecast inflation risk. In that case, minority views favoring higher [lower] interest rates are captured by forecast upwards [downward] risks to inflation.

2.3.3 Results

Results for estimating equation (2.4) by OLS are shown in Table 2.1. For all three central banks, estimates of the coefficient α_σ grow across forecast horizons, which implies increasing forecast uncertainty the farther out the central bank forecasts. Hence, it represents the fanning-out of the confidence intervals around a baseline forecast. For the BoE and the Riksbank, we find no support for the hypothesis that disagreement about the level of the monetary policy instrument leads to wider fan charts. For the BoE, estimates for β_σ are negative for all forecast horizons, but estimation uncertainty is extremely large so that nothing is significant. The Riksbank's coefficient estimates for β_σ are near zero in magnitude and insignificant. OLS estimates of the MNB intercept term are all significant at the 1% level. With exception of the nowcast, estimates of the intercept are larger than those of the BoE and Riksbank for $h > 0$. In contrast to BoE and Riksbank, disagreement on MNB monetary policy seems to widen the inflation fan charts, as implied by positive estimates for β_σ being significant at the 5% level for forecast horizons 1 to 4. For $h = 5$, the coefficient estimate is siginificant at the 10% level, for $h = 6$ at the 1% level. As the coefficient estimates grow with the horizon, it seems that dissenting views on interest rates become a more important determinant of fan chart width for forecasts farther out. This is particularly interesting since the forecasts are made conditional on a constant interest rates assumption, such that no interest rate variation to be expected in the future drives the degree of uncertainty.[14]

OLS estimation results for equation (2.5) are shown in Table 2.2. The intercept terms for all central banks and for all horizons except the MNB nowcast horizon are estimated close to but slightly above zero. The BoE and Riksbank results shown for β_κ are in support of our hypothesis that dissent is informative about the asymmetry of the inflation fan charts.

[14]Yet, forecasts for 2011Q1 and 2011Q2 are made 'conditional' on central bank expectations.

Table 2.1: Effects of monetary policy committee dissent on fan charts width

h	0	1	2	3	4	5	6	7	8
	Bank of England								
α_σ	0.30	0.44**	0.56***	0.65***	0.68**	0.73**	0.80	0.88	0.93
	(0.73)	(0.21)	(0.18)	(0.22)	(0.29)	(0.34)	(0.55)	(1.95)	(3.23)
β_σ	-0.01	-0.08	-0.12	-0.14	-0.10	-0.21	-0.31	-0.43	-0.49
	(7.96)	(3.39)	(3.50)	(4.85)	(6.53)	(5.58)	(5.93)	(11.27)	(18.60)
	Magyar Nemzeti Bank								
α_σ	0.23***	0.55***	0.72***	1.06***	1.34***	1.46***	1.62***		
	(0.01)	(0.02)	(0.10)	(0.11)	(0.13)	(0.18)	(0.19)		
β_σ	-0.02**	0.05**	0.30**	0.35**	0.40**	0.68*	0.80***		
	(0.01)	(0.02)	(0.12)	(0.15)	(0.17)	(0.24)	(0.24)		
	Sveriges Riksbank								
α_σ	0.30***	0.39***	0.49***	0.59***	0.73***	0.84***	0.96***	1.09***	
	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	
β_σ	0.07	0.01	-0.03	-0.02	-0.02	-0.02	-0.01	-0.02	
	(0.09)	(0.03)	(0.09)	(0.08)	(0.07)	(0.08)	(0.09)	(0.10)	

Notes: Figures in parentheses are Newey-West (1987) standard errors. Sample ranges: Bank of England - 1998Q1 to 2011Q2 (56 observations), Magyar Nemzeti Bank - 2005Q4 to 2011Q2 (22 observations), Sveriges Riksbank - 1999Q4 to 2006Q3 (27 observations).

For the BoE, dissent in voting on the official bank rate translates into fan chart skewness for forecast horizons of up to six quarters ahead. Estimates of β_κ are significant at the 5% level for the nowcast and up to five quarters ahead and significant at the 10% level for one and a half year out. Although we find insignificant estimates for $h = 7, 8$, the coefficients' magnitude ranges between 0.50 and 0.57 over all forecast horizons.

The results are even stronger for the Riksbank. Except for the insignificant impact of dissent on nowcast skewness, the coefficient steadily grows over the forecast horizons, ranging between 0.45 for one quarter ahead and 1.21 for seven quarters out. The impact of dissent on fan chart skewness is significant at the 5% level for $h = 1, 2, 6, 7$ and at the 10% level for $h = 3, 4, 5$. For the MNB, however, we do not find any relationship between interest rate skew and fan chart skewness, reflected by insignificant coefficient estimates which are basically zero in magnitude.

To sum up, dissent in voting on MNB monetary policy results in wider fan charts, but does not affect forecast skewness in any way. In particular, the interest rate deviation is positively correlated with the forecast inflation standard deviation, while the interest rate skew shows no significant correlation with the forecast Pearson mode skewness for inflation. For the BoE and the Riksbank, in turn, fan chart width is unaffected by dissent in voting. The BoE's forecast fan charts for up to five quarters ahead and all Riksbank's fan charts except the nowcast fan chart, we find a significant relationship between the degree of disagreement on the level of the instrument, as measured by the interest rate skew, and the forecast Pearson mode skewness for inflation. That is, at the BoE and the Riksbank, minority views are accommodated by skewing the inflation forecast density.

Table 2.2: Effects of monetary policy committee dissent on fan chart skewness

h	0	1	2	3	4	5	6	7	8
	Bank of England								
α_κ	0.04**	0.05**	0.05**	0.05**	0.05**	0.05**	0.05*	0.05	0.05
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.04)
β_κ	0.52**	0.53**	0.51**	0.51**	0.50**	0.54*	0.56	0.56	0.57
	(0.25)	(0.25)	(0.24)	(0.24)	(0.24)	(0.29)	(0.40)	(0.50)	(0.56)
	Magyar Nemzeti Bank								
α_κ	-0.01	0.00**	0.01**	0.01**	0.01**	0.01**	0.02***		
	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)		
β_κ	0.05	-0.02	-0.03	-0.00	0.01	0.00	-0.02		
	(0.05)	(0.01)	(0.06)	(0.05)	(0.07)	(0.09)	(0.10)		
	Sveriges Riksbank								
α_κ	0.00	0.03*	0.02**	0.03	0.02	0.02	0.02	0.02*	
	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	
β_κ	0.07	0.45**	0.68**	0.76*	0.98*	1.04*	1.13**	1.21**	
	(0.07)	(0.21)	(0.33)	(0.44)	(0.54)	(0.53)	(0.52)	(0.52)	

Notes: Figures in parentheses are Newey-West (1987) standard errors. Sample ranges: Bank of England - 1998Q1 to 2011Q2 (54 observations), Magyar Nemzeti Bank - 2005Q4 to 2011Q2 (22 observations), Sveriges Riksbank - 1999Q4 to 2006Q3 (27 observations).

2.4 Accounting for Hawkish and Dovish Voting

2.4.1 Individual Monetary Policy Stances

Monetary policy makers are often classified into hawks, favoring tighter monetary policy, and doves, opting for relaxed monetary policy. Table 2.6 shows such a classification based on average dissent, i.e. classified by checking whether the deviation of the individual member's interest rate from the aggregate interest rate decision was on average positive or negative during the term in the committee. Besides hawks and doves, a third group can be made up by of those that (on average) vote with the majority. For the BoE, we find both eleven hawkish and dovish members, while nine members show no dissent in voting on average. Sir Edward George as the BoE Governor until June 2006, however, has to be taken out since his interest rate proposals always achieved the necessary majority, thus he never 'dissented'. For the MNB, we identify eight hawkish and seven dovish members while five members show no dissent in voting. Of the Riksbank's ten Executive Board members of the sample period there is one hawkish versus three dovish members, while the other members show no dissent on average.

2.4.2 Regression Models

Since members of monetary policy committee change from time to time, and the individual monetary policy stance of a new member may not necessarily coincide with the one of its predecessor, we cannot build long time series measuring the individual degree of disagreement for estimating a panel model. Rather, we classify the voting sessions themselves into hawkish and dovish rounds. A hawkish voting round is marked by a negative interest rate skew, such that the members' average interest rate falls short of the aggregate interest rate decision. This implies that that at least one dovish member and hence a dovish minority was outvoted. To the contrary, a dovish voting round is marked by positive interest rate skew, with the members' average rate exceeding the aggregate interest rate decision. This indicates that at least one hawk has been outvoted.

To this extent, we build two indicator variables for hawkish and dovish voting rounds:

$$I_t^H = \begin{cases} 1, & \text{if } d_{\kappa,t-\tau} < 0 \\ 0 & \text{else} \end{cases}, \qquad I_t^D = \begin{cases} 1, & \text{if } d_{\kappa,t-\tau} > 0 \\ 0 & \text{else} \end{cases}. \tag{2.6}$$

These indicator variables are used in rewritten versions of the models (2.4) and (2.5) to control for potentially asymmetric effects of voting, in particular to gauge the impact of hawkish and dovish voting on fan chart width and skewness. The resulting regression model to analyze fan chart width is given by

$$\sigma_{t+h|t} = \alpha_\sigma + \beta_\sigma^H I_t^H d_{\sigma,t-\tau} + \beta_\sigma^D I_t^D d_{\sigma,t-\tau} + \varepsilon_t, \quad E(\varepsilon_t) = 0. \tag{2.7}$$

If hawkish [dovish] dissent widens the fan charts, an estimate of β_σ^H [β_σ^D] should be significantly positive. The magnitude of the estimates should be equal if on average hawks and doves are equally often outvoted. For analyzing effects on the fan charts' skewness, we estimate the model

$$\kappa_{t+h|t} = \alpha_\kappa + \beta_\kappa^H I_t^H d_{\kappa,t-\tau} + \beta_\kappa^D I_t^D d_{\kappa,t-\tau} + \eta_t, \quad E(\eta_t) = 0, \tag{2.8}$$

such that the estimates for parameters β_κ^H and β_κ^D capture the impact of hawkish and dovish voting on forecast inflation skewness.

2.4.3 Results

Results for estimating equation (2.7) by OLS are shown in Table 2.3. For the BoE and the Riksbank, we do not find any statistical evidence that minority views translate into fan chart width. Accounting for hawkish and dovish voting round yields no additional insights compared to the results from Table 2.1.

For the MNB, however, the widening impact of hawkish voting is significant at least at the 10% level. While the coefficient estimates for β_σ^H are close to zero for the nowcast and one quarter ahead, estimates are significantly positive for $h = 2, \ldots, 6$ and ascend from 0.51 and 1.38. This implies a strong influence of hawkish voting on the width of the fan charts, in particular for $h = 5$ and $h = 6$, where the coefficient estimates are significant at the 5% level

Table 2.3: Effects of hawkish and dovish monetary policy meetings on fan chart width

h	0	1	2	3	4	5	6	7	8
	Bank of England								
α_σ	0.30***	0.44***	0.56***	0.65***	0.68***	0.74***	0.81***	0.88***	0.93***
	(0.08)	(0.10)	(0.12)	(0.13)	(0.14)	(0.15)	(0.15)	(0.15)	(0.15)
β_σ^H	-0.30	-0.54	-0.69	-0.78	-0.79	-0.89	-0.97	-1.05	-1.13
	(0.44)	(0.56)	(0.70)	(0.79)	(0.82)	(0.84)	(0.88)	(0.90)	(0.90)
β_σ^D	0.34	0.40	0.46	0.50	0.55	0.41	0.25	0.07	0.01
	(0.77)	(1.12)	(1.35)	(1.44)	(1.46)	(1.48)	(1.72)	(1.96)	(2.08)
	Magyar Nemzeti Bank								
α_σ	0.23***	0.54***	0.71***	1.05***	1.33***	1.43***	1.58***		
	(0.00)	(0.01)	(0.08)	(0.09)	(0.11)	(0.14)	(0.14)		
β_σ^H	-0.03*	0.09*	0.51*	0.59*	0.68*	1.16**	1.38**		
	(0.01)	(0.05)	(0.26)	(0.30)	(0.35)	(0.55)	(0.60)		
β_σ^D	-0.01**	0.04**	0.24**	0.29**	0.33**	0.56***	0.66***		
	(0.01)	(0.02)	(0.10)	(0.12)	(0.14)	(0.20)	(0.21)		
	Sveriges Riksbank								
α_σ	0.30***	0.39***	0.49***	0.60***	0.74***	0.84***	0.96***	1.09***	
	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	
β_σ^H	0.08	-0.06	-0.14	-0.10	-0.10	-0.11	-0.11	-0.13	
	(0.12)	(0.06)	(0.12)	(0.09)	(0.09)	(0.11)	(0.12)	(0.13)	
β_σ^D	0.06	0.03	-0.00	-0.00	-0.00	0.00	0.01	0.01	
	(0.08)	(0.05)	(0.08)	(0.07)	(0.07)	(0.08)	(0.09)	(0.10)	

Notes: Figures in parentheses are Newey-West (1987) standard errors. Sample ranges: Bank of England - 1998Q1 to 2011Q2 (54 observations), Magyar Nemzeti Bank - 2005Q4 to 2011Q2 (22 observations), Sveriges Riksbank - 1999Q4 to 2006Q3 (27 observations).

and exceed unity. A weaker but nonetheless clearly detectable influence on forecast inflation uncertainty comes from the doves, where the coefficient estimates ascend from 0.24 for $h = 2$ to 0.66 for $h = 6$. Estimates for β_σ^D are significant at the 5% [1%] level for forecast horizons $h = 0, \ldots, 4$ [$h = 5, 6$]. One possible explanation for this finding could be that Hungarian inflation has been in excess of the target of 3% annual CPI inflation, with a median excess of 2.01. Loose monetary policy as implied by dovish voting, however, is probably the wrong signal to the public if the central projection has to convey that the central bank will credibly aim at hitting the inflation target at the policy horizon. Thus, from the bank's perspective, the MNB accommodates dovish voters, but to the public, votes on loose monetary policy are veiled by wider confidence bands.

OLS estimation results for equation (2.8) are shown in Table 2.4. The BoE's dovish voters have no impact on the fan chart skewness, as the insignificant estimates of β_κ^D close to zero reveal. The impact of hawkish voting on the nowcast and on forecasts for five quarters out, however, is significant at the 5% level, with a coefficient estimate ranging closely around unity. This could be interpreted as such that the fan charts are skewed to accommodate dovish voting, while a hawkish regime in general prevails. Such an interpretation is supported by results from Hix, Høyland, and Vivyan (2010), who estimate MPC member monetary policy preferences and find a clear tendency toward hawkishness.

Table 2.4: Effects of hawkish and dovish monetary policy meetings on fan chart skewness

h	0	1	2	3	4	5	6	7	8
	Bank of England								
α_κ	0.06**	0.06**	0.07**	0.06**	0.06**	0.07**	0.07*	0.07	0.07
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.05)	(0.05)
β_κ^H	1.06**	1.03**	1.03**	0.98**	0.97**	1.04**	0.99	0.93	0.93
	(0.49)	(0.47)	(0.46)	(0.47)	(0.46)	(0.51)	(0.75)	(0.99)	(1.13)
β_κ^D	-0.17	-0.12	-0.14	-0.08	-0.10	-0.10	0.01	0.09	0.11
	(0.50)	(0.50)	(0.50)	(0.52)	(0.50)	(0.50)	(0.64)	(0.79)	(0.90)
	Magyar Nemzeti Bank								
α_κ	-0.01	0.00	0.01	0.01	0.01	0.01	0.01		
	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)		
β_κ^H	0.07	-0.04	-0.10	-0.06	-0.09	-0.14	-0.24		
	(0.09)	(0.03)	(0.12)	(0.12)	(0.15)	(0.20)	(0.22)		
β_κ^D	0.04	-0.01**	0.01	0.03	0.05	0.07	0.08		
	(0.03)	(0.00)	(0.02)	(0.01)	(0.02)	(0.02)	(0.02)		
	Sveriges Riksbank								
α_κ	0.00	0.03	0.02	0.02	0.01	0.01	0.01	0.00	
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	
β_κ^H	0.07	0.38	0.27	0.25	0.11	0.14	0.10	0.07	
	(0.24)	(0.29)	(0.43)	(0.62)	(0.79)	(0.72)	(0.64)	(0.57)	
β_κ^D	0.08	0.48*	0.89*	1.01*	1.41**	1.49**	1.64**	1.78***	
	(0.19)	(0.26)	(0.44)	(0.57)	(0.68)	(0.68)	(0.66)	(0.64)	

Notes: Figures in parentheses are Newey-West (1987) standard errors. Sample ranges: Bank of England - 1998Q1 to 2011Q2 (54 observations), Magyar Nemzeti Bank - 2005Q4 to 2011Q2 (22 observations), Sveriges Riksbank - 1999Q4 to 2006Q3 (27 observations).

For the Riksbank, in turn, we can find no relationship between hawkish voting and forecast risk. It is rather the case that the doves determine the fan chart skewness for all forecast horizons except the nowcast. For $h = 1, \ldots, 7$, the estimates increase steadily from 0.48 to 1.78, being significant at the 10% level for up to one year out and at the 5% level for horizons farther out. For seven quarters out, the impact of dovish voting is significant even at the 1% level. Based on the classification of Table 2.6, it seems plausible that a dovish majority accommodates hawkish voters with skewing the fan charts, although the cross-sectional dimension is very small to allow final conclusions on this. Yet, for the MNB, we cannot make any conclusions, since all coefficients estimated are very close to zero, although β_κ^D for $h = 2$ is significant.

Summing up, we find that at the MNB, in case of dissent in voting, both hawkish and dovish minority views lead to wider fan charts, where the impact of hawkish voting on the forecast inflation standard deviation is stronger than that of dovish voting. Yet, forecast inflation skewness remains unaffected by disagreement on monetary policy at the MNB. To the contrary, for the BoE and the Riksbank there is no relationship between minority views on interest rates and forecast uncertainty detectable. Minority views on BoE and Riksbank monetary policy, though, translate into the skewness of the forecast inflation fan charts. The BoE's on-average hawkish MPC accommodates dovish voting, while the on-average more dovish EB of the Riksbank incorporates hawkish minorities into skewness of the fan charts.

2.5 Conclusion

In this study we investigated if dissent in voting on monetary policy affects the shape of the forecast inflation fan charts of the Bank of England, the Sveriges Riksbank and the Magyar Nemzeti Bank. These three inflation targeting banks were subject of the analysis because they are the only central banks to use identical approaches for generating density forecasts and in addition to publish detailed interest rate voting information for the sample periods considered.

Using simple OLS regressions, we obtained statistical evidence that there is a relationship between the degree of disagreement on the level of the policy instrument and the shape of inflation fan charts. In particular, we find that the Magyar Nemzeti Bank fan charts get wider when the degree of disagreement is higher. We do not find such a relationship for the Bank of England and the Sveriges Riksbank. Rather, we find that minority views are accommodated by skewing the fan charts, such that disagreement on monetary policy, measured by the difference between the members' average interest rate and the aggregate interest rate decision, translates into forecast inflation risks. For the Magyar Nemzeti Bank, in turn, forecast risks seem to be unrelated to dissent in voting.

When controlling for hawkish and dovish voting behavior, we find that Magyar Nemzeti Bank hawks and doves alike determine the fan chart width, although the impact of the hawkish voters is significantly stronger. This can be interpreted such that the width of inflation fan charts is adjusted to rather accommodate dovish voting. For the Bank of England and the Sveriges Riksbank, fan chart width remains unrelated to voting. There is statistical evidence, however, that a hawkish minority is accommodated by a more in inflation fan chart skewness at the Sveriges Riksbank, where the Executive Board is on average rather dovish. To the contrary, the rather hawkish Monetary Policy Committee of the Bank of England incorporates dovish voting on the official bank rate into more skewed forecast inflation fan charts.

Overall, we conclude that dissenting views in monetary policy committees voting on central banks' level of the policy instrument are a significant determinant of the shape of forecast inflation fan charts.

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Table 2.5: Timing of central banks' interest rate announcements and inflation report publications

	Bank of England		Magyar Nezemti Bank		Sveriges Riksbank	
	announcement *official bank rate*	publication *Inflation Report*	announcement *base rate*	publication *Report on Inflation*	annoucement *repo rate*	publication *Inflation Report*
	$t-\tau$	t	$n-\tau$	n	$n-\tau$	n
1998Q1	08.01.1998	11.02.1998				
1998Q2	09.04.1998	13.05.1998				
1998Q3	09.07.1998	12.08.1998				
1998Q4	08.10.1998	11.11.1998				
1999Q1	07.01.1999	10.02.1999				
1999Q2	08.04.1999	12.05.1999				
1999Q3	08.07.1999	11.08.1999				
1999Q4	07.10.1999	10.11.1999			11.11.1999	09.12.1999
2000Q1	13.01.2000	17.02.2000			*(03.02.2000)*	*(23.03.2000)*
2000Q2	06.04.2000	10.05.2000			04.05.2000	08.06.2000
2000Q3	06.07.2000	09.08.2000			16.08.2000	10.10.2000
2000Q4	05.10.2000	16.11.2000			09.10.2000	07.12.2000
2001Q1	11.01.2001	14.02.2001			01.02.2001	27.03.2001
2001Q2	05.04.2001	23.05.2001			26.04.2001	31.05.2001
2001Q3	05.07.2001	08.08.2001			17.09.2001	16.10.2001
2001Q4	04.10.2001	14.11.2001			15.10.2001	05.12.2001
2002Q1	10.01.2002	13.02.2002			07.02.2002	19.03.2002
2002Q2	04.04.2002	15.05.2002			25.04.2002	06.06.2002
2002Q3	04.07.2002	07.08.2002			15.08.2002	17.10.2002
2002Q4	10.10.2002	13.11.2002			14.11.2002	05.12.2002
2003Q1	09.01.2003	12.02.2003			06.02.2003	18.03.2003
2003Q2	10.04.2003	15.05.2003			24.04.2003	05.06.2003
2003Q3	10.07.2003	13.08.2003			14.08.2003	16.10.2003
2003Q4	09.10.2003	12.11.2003			15.10.2003	05.12.2003
2004Q1	08.01.2004	11.02.2004			31.03.2004	30.04.2004
2004Q2	08.04.2004	12.05.2004			28.04.2004	28.05.2004
2004Q3	08.07.2004	11.08.2004			19.08.2004	14.10.2004
2004Q4	07.10.2004	10.11.2004			13.10.2004	09.12.2004
2005Q1	13.01.2005	16.02.2005			27.01.2005	15.03.2005
2005Q2	07.04.2005	11.05.2005			28.04.2005	21.06.2005
2005Q3	07.07.2005	10.08.2005			23.08.2005	20.10.2005
2005Q4	06.10.2005	16.11.2005	24.10.2005	28.11.2005	19.10.2005	02.12.2005
2006Q1	12.01.2006	15.02.2006	23.01.2006	27.02.2006	19.01.2006	23.02.2006
2006Q2	06.04.2006	10.05.2006	24.04.2006	22.05.2006	27.04.2006	20.06.2006
2006Q3	06.07.2006	09.08.2006	24.07.2006	28.08.2006	29.08.2006	26.10.2006
2006Q4	05.10.2006	15.11.2006	24.10.2006	20.11.2006		
2007Q1	11.01.2007	14.02.2007	22.01.2007	26.02.2007		
2007Q2	05.04.2007	16.05.2007	23.04.2007	21.05.2007		
2007Q3	05.07.2007	08.08.2007	23.07.2007	27.08.2007		
2007Q4	04.10.2007	14.11.2007	29.10.2007	26.11.2007		
2008Q1	10.01.2008	13.02.2008	21.01.2008	25.02.2008		
2008Q2	10.04.2008	14.05.2008	28.04.2008	26.05.2008		
2008Q3	10.07.2008	13.08.2008	21.07.2008	25.08.2008		
2008Q4	08.10.2008	12.11.2008	*(20.10.2008)*	*(24.11.2008)*		
2009Q1	08.01.2009	11.02.2009	19.01.2009	23.02.2009/25.02.2009‡		
2009Q2	09.04.2009	13.05.2009	20.04.2009	25.05.2009/27.05.2009‡		
2009Q3	09.07.2009	12.08.2009	27.07.2009	24.08.2009/26.08.2009‡		
2009Q4	08.10.2009	11.11.2009	19.10.2009	23.11.2009/25.11.2009‡		
2010Q1	07.01.2010	10.02.2010	25.01.2010	22.02.2010/24.02.2010‡		
2010Q2	08.04.2010	12.05.2010	26.04.2010	31.05.2010/02.06.2010‡		
2010Q3	08.07.2010	11.08.2010	19.07.2010	25.08.2010		
2010Q4	07.10.2010	10.11.2010	25.10.2010	29.11.2010/01.12.2010‡		
2011Q1	10.02.2011	16.02.2011	28.03.2011	28.03.2011/30.03.2011‡		
2011Q2	05.05.2011	11.05.2011	20.06.2011	20.06.2011/22.06.2011‡		

Notes: Magyar Nezmeti Bank - Dates in parentheses denote missing data. The forecasts from the Report on Inflation of 20.10.2008 are not available. The symbol ‡ marks dates where the projections for inflation and output were already released two working days before the official publication date of the Report on Inflation. Sveriges Riksbank - Dates in parentheses denote missing data. The forecasts from the 2000Q1 Inflation Report from 23.03.2000 are not available.

Table 2.6: Typecasting of monetary policy committee members by measuring average dissent

Bank of England			Magyar Nemzeti Bank			Sveriges Riksbank		
Monetary Policy Committee member	Average dissent from official bank rate	Type	Monetary Council member	Average dissent from repo rate	Type	Executive Board member	Average dissent from repo rate	Type
Sir Edward George	0.00	·	Péter Adamecz	0.06	H	Villy Bergström	-0.00	D
Sir Mervyn King	0.02	H	Henrik Auth	0.06	H	Urban Bäckström	0.00	·
Rachel Lomax	-0.00	D	Tamás Bánfi	-0.18	D	Lars Heikensten	0.00	·
Sir Andrew Large	0.06	H	Andrea Bártfai Máger	0.00	·	Kerstin Hessius	0.00	·
Paul Tucker	0.01	H	Péter Bihari	-0.01	D	Stefan Ingves	0.00	·
Charles Bean	-0.01	D	Vilmos Bihari	-0.07	D	Lars Nyberg	-0.01	D
Kate Barker	-0.01	D	János Cinkotai	0.00	·	Kristina Persson	-0.02	D
Stephen Nickell	-0.03	D	Csaba Csáki	-0.05	D	Irma Rosenberg	0.00	·
Christopher Allsopp	-0.07	D	Ferenc Gerhardt	0.00	·	Eva Srejber	0.07	H
Marian Bell	0.03	D	Ilona Hardy	0.00	D	Svante Öberg	0.00	·
Richard Lambert	0.00	·	Zsigmond Járai	0.06	H			
Sir Alan Budd	0.00	·	Béla Kádár	0.00	·			
Willem Buiter	0.02	D	Ferenc Karvalits	0.03	H			
Charles Goodhart	0.00	·	Júlia Király	0.03	H			
John Vickers	0.04	H	György Kopits	0.04	H			
DeAnne Julius	0.05	D	Judit Neményi	0.07	D			
Sushil Wadhwani	0.08	D	Gábor Oblath	0.01	D			
Ian Plenderleith	0.00	H	György Kocziszky	0.00	·			
Howard Davies	NaN	·	András Simor	0.04	H			
David Clementi	0.01	H	György Szapáry	0.02	H			
David Walton	0.02	H						
Sir John Gieve	0.01	D						
David Blanchflower	0.15	D						
Tim Besley	0.05	H						
Andrew Sentance	0.09	H						
Spencer Dale	0.03	H						
Paul Fisher	0.00	·						
David Miles	0.00	·						
Adam Posen	0.00	·						
Martin Weale	0.14	H						
Ben Broadbent	0.00	·						

Chapter 3

The Empirical (Ir)Relevance of the Interest Rate Assumption for Central Bank Forecasts

Abstract: The interest rate assumptions for macroeconomic forecasts differ considerably among central banks. Common approaches are given by the assumption of constant interest rates, interest rates expected by market participants, or the central bank's own interest rate expectations. From a theoretical point of view, the latter should yield the highest forecast accuracy. The lowest accuracy can be expected from forecasts conditioned on constant interest rates. However, when investigating the predictive accuracy of the forecasts for interest rates, inflation and output growth made by the Bank of England and the Banco Central do Brasil, we hardly find any significant differences between the forecasts based on different interest assumptions. We conclude that the choice of the interest rate assumption, while being a major concern from a theoretical point of view, appears to be at best of minor relevance empirically.

Keywords: Forecast Accuracy, Density Forecasts, Projections

JEL-Codes: E52, C12

This chapter is based on
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3.1 Introduction

It is well known that, due to lags in the monetary transmission mechanism, central banks have to rely on forecasts for the variables they intend to control, often given by inflation and output. In these forecasts, the policy variable, i.e. the short-term interest rate set by the central bank, plays a special role. According to Galí (2011), in practice one can basically distinguish three approaches. Firstly, forecasts can be conditioned on a constant interest-rate (henceforth CIR) assumption where the interest rate is assumed to remain at the level it had attained at the time the forecast was made. The CIR approach was pursued, for example, by the ECB until 2006 and the Sveriges Riksbank until the end of 2005. Secondly, the expectations of market participants can serve as a conditioning assumption about the interest rate path, which is current practice at, for example, the Bank of Japan and the ECB. Market expectations (ME) are usually derived from the term structure of interest rates. Finally, a central bank can issue unconditional forecasts for its target variables by using its own expectations about the interest rate path. The central bank expectation (CBE) approach has been adopted, for instance, by the Norges Bank, the Riksbank and the Federal Reserve System. The Fed's December 2011 FOMC statement, announcing that "participants agreed that adding their projections of the target federal funds rate to the economic projections already provided in the SEP [Summary of Economic Projections] would help the public better understand the Committee's monetary policy decisions", contributed to drawing the attention of economists to the topic of interest rate assumptions.

Among academics, there seems to be a clear favorite among the three approaches, CIR, ME and CBE, in terms of its suitability for central bank forecasts. Galí (2011), Svensson (2006) and Woodford (2005) advocate the CBE approach, i.e. unconditional forecasts. Galí (2011) shows that it is possible to construct different forecasts conditional on one given nominal interest rate path based on different policy rules, thus calling into question any conditioning assumptions about interest rates. A similar point is raised by Woodford (2005). However, if central bank forecasts are based on models, in practice the modest-interventions approach in the spirit of Leeper and Zha (2003) appears to be the most popular approach when conditioning assumptions are used.[1] In this case, a sequence of unanticipated monetary policy shocks generating the desired conditional interest rate path is assumed, yielding unique conditional forecasts.[2]

Independently of the method employed to construct the conditional forecasts, it is evident that the CBE approach is supposed to yield the highest forecast accuracy.[3] Actually, this

[1] This approach is employed in the models used by Christoffel, Coenen, and Warne (2007) and Adolfson, Laséen, Lindé, and Villani (2005). Faust and Wright (2008) state that the conditional forecasts of the Bank of England are also produced in a way that is in line with the modest-interventions approach. Yet, the work of Laséen and Svensson (2011) suggests that a different approach is currently considered at the Sveriges Riksbank.

[2] Yet, the assumption that the associated policy interventions are modest is not necessarily justified, as found by Adolfson et al. (2005).

[3] The forecast-accuracy measure should, of course, take the forecaster's loss function into account. We will

property serves as one of the main reasons for preferring the CBE approach over conditional forecasts. Gali (2011, p.539) states that "it is not clear why the central bank would want to base its projections on a rule other than the actual rule it follows for, among other things, in that case the projections would also correspond to the best unconditional forecasts". Svensson (2006) also resorts to the potential gains in forecast accuracy when advocating the CBE approach.[4] The literature does not provide comparably clear ideas concerning the relative forecast accuracy of the ME approach with respect to the CIR approach. However, it seems plausible that the ME approach should perform better unless the policy rate is best described by a random walk.[5]

Practitioners do not necessarily share the views prevalent among academics, as reflected by the fact that a large share of central banks does not base its forecasts on its own interest rate expectations. This could be due to several reasons, among other things communication issues. For example, Goodhart (2009) finds that using the central bank's expectations of the interest rate could be misunderstood as a commitment. Therefore, an interest rate path derived from market expectations could be regarded as "a brilliant compromise" (Goodhart 2009, p.94) between the potential lack of credibility of a constant rate assumption and the problems associated with publishing a path of future interest rates expected by the central bank. However, there are also central banks that use the constant interest rate assumption, for instance the Swiss National Bank. Arguments in favor of this approach can be found in Goodhart (2001). An interesting argument against the CBE approach follows from Morris and Shin (2002), who find that more precise public information can, in principle, decrease welfare by crowding out private information.

Several empirical aspects related to interest rate assumptions are investigated in Andersson and Hofmann (2009). When comparing central banks which either use the ME approach or the CBE approach, Andersson and Hofmann (2009) conclude that if a central bank is transparent and committed to maintaining price stability, the behavior of key variables like inflation expectations and long-term bond yields does not seem to be affected by the type of interest-rate assumption. In contrast to that, Winkelmann (2010) finds that using the CBE approach instead of the ME approach leads to better private-sector forecasts of longer-term interest rates.

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elaborate on this issue below.

[4]Svensson (2006, p.2), referring to the CBE approach as the optimal projection, claims that "Since monetary policy has an impact on the economy via the private-sector expectations of inflation, output, and interest rates that it gives rise to, announcing the optimal projection (including the instrument-rate projection) and the analysis behind it would have the largest impact on private sector expectations and be the most effective way to implement monetary policy. Since the optimal projection is the best forecast in the sense of minimizing expected squared forecast errors, it also provides the private sector with the best aggregate information for making individual decisions."

[5]Svensson (2006, p.5) notes that "ME are usually more realistic than the CIR, depending on the market's understanding and prediction of future instrument-rate decisions. This makes projections based on ME better forecasts of future instrument-rate decisions than CIR projections."

In this paper, we propose to assess the effects of the interest rate assumptions by testing for differences in forecast accuracy. We do so because forecast accuracy is one the main reasons given in the academic literature for preferring the CBE approach. Forecast accuracy is, of course, also directly related to all other issues mentioned above. For example, it appears unlikely that the central bank will be able to better steer market expectations for interest rates, inflation, and growth, and, thus, financial variables like bond yields, with the CBE approach, if the central bank's forecasts with the CBE approach do not turn out to be more accurate than with the CIR approach or the ME approach, at least in the medium term.[6] The validity of the reasons brought forward against the CBE approach depends on forecast accuracy as well. For example, misunderstanding the CBE approach as the central bank's commitment to an interest rate path will be unlikely, if the CBE approach does not turn out to yield better interest rate forecasts than the ME approach or the CIR approach. The potential crowding out of private information as stated by Morris and Shin (2002) also requires the forecasts with the CBE approach to be sufficiently precise.

Comparisons of forecast accuracy under different approaches can also be important in other respects. When investigating the reasons for the Great Moderation as described by McConnell and Perez-Quiros (2000), an important role is often attributed to the improvements in monetary policy, especially for inflation, as, for example, done in Boivin and Giannoni (2006) and Nakov and Pescatori (2010). If this is true, we would expect forecasts conditional on 'bad' monetary policy to yield inferior forecast accuracy than forecasts based on 'good' monetary policy, i.e. with the CBE approach. In general, forecasts based on the CIR approach can be regarded as forecasts conditional on 'bad' monetary policy, because 'good' monetary policy usually implies a mean-reverting behavior of the policy rate.

Finally, another very basic interest in the comparison between the forecast accuracies with the different interest rate assumptions results from the way central banks construct prediction intervals around their forecasts. Many central banks assess their future forecast uncertainty based on past forecast errors.[7] If there was a switch in the interest assumption, the question arises whether using forecast errors from the time before the switch may distort the prediction intervals too much.[8] Similarly, the evaluation of central bank forecasts commonly ignores their conditionality with respect to the assumed interest rates, as stated in Faust and Wright (2008). Therefore, Faust and Wright (2008) derive an evaluation framework which

[6]In the short term, market participants might simply believe that the central bank's forecasts become more accurate with the CBE approach. In the medium term, this belief can be assessed using the forecasting record obtained with the CBE approach.

[7]For a short survey, see Deutsche Bundesbank (2010, p.13).

[8]For example, Reifschneider and Tulip (2007) ask if the interest rate assumption affects the usefulness of past forecast errors of the Greenbook forecasts (produced with the CIR approach) for assessing the uncertainty surrounding current FOMC forecasts (employing the CBE approach). Reifschneider and Tulip (2007, p.13) conjecture that "the Greenbook's historical forecast errors may tend to overstate the uncertainty of the outlook to some degree."

takes the conditionality into account. It is, thus, interesting to assess how large the errors might be if conditionality is ignored and simple standard evaluation procedures are used.

In principle, comparisons of forecast accuracy could be made for two central banks which operate under distinct interest rate assumptions, or for two samples from a single central bank which switched from one approach to another approach. Both types of comparisons can be found in Andersson and Hofmann (2009), and only the latter is used in Winkelmann (2010). However, when comparing the forecasts of two central banks, the differences in forecast accuracy could, of course, be due to country-specific issues. A comparison of two samples from a single central bank is likely to suffer from the instability of the predictive content of forecasting models over time often encountered in the case of macroeconomic forecasts.[9]

In this work, we therefore exploit the forecasts of the Bank of England (BoE) in order to assess the impact of the interest rate assumption on forecast accuracy. The feature which makes these forecasts excellent candidates for our investigation is given by the fact that, since 1998, the BoE has published forecasts for inflation and GDP growth conditional on two different interest rate assumptions: CIR and ME. Thus, conclusions reached with these data should be rather robust with respect to instabilities over time. A drawback of these data is the absence of forecasts with the CBE approach. However, reasonable proxies for CBE forecasts can be constructed using additional data on forward rates.

In addition to the BoE data, we also consider forecasts issued by the Banco Central do Brasil (BCB). Similar to the BoE, the BCB has published forecasts for inflation conditional on two different interest rate assumptions: CIR and ME. Yet, due to data limitations, we cannot construct proxies for forecasts with the CBE approach in this case.

The remainder of this paper is organized as follows. Section 2 describes the data set of this study, and in Section 3 proxies for additional BoE forecasts are constructed. Section 4 presents some properties of the forecasts, and in Section 5, test results for equal predictive accuracy of point and density forecasts are presented. Section 6 concludes.

3.2 Data

There have been many changes in the interest rate assumptions used for central bank forecasts. In Table 3.1 we show the history for selected central banks that have varied their assumptions in recent years.[10] In general, central banks have tended to move away from the CIR approach towards the ME or the CBE approach. In some cases, the ME approach has turned out to be an intermediate step only on the way towards the CBE approach.

With respect to data availability, the BoE and the BCB are special cases among the central banks considered. Since 1998, the BoE's quarterly Inflation Reports comprise two

[9] See, for instance, Rossi (forthcoming).

[10] Appendix A.2 lists references and statements of central bank publications on which Table 3.1 is based.

Table 3.1: Interest rate assumptions in central banks

Central Bank	Constant Rates (**CIR**)	Market Expectations (**ME**)	Central Bank Expectations (**CBE**)
Banco Central do Brasil	CIR since report of September 1999	ME since report of September 1999	-
Banco Central de Chile	CIR for reports of May 2000 to May 2004	ME since report of September 2004	-
Bank of England	CIR since report of February 1993 for inflation and since August 1997 for real output growth	ME added with report of February 1998	-
Bank of Japan	CIR for reports of October 2000 to October 2005	ME since report of April 2006	-
Board of Governors of the Federal Reserve System	CIR assumption for earlier Greenbook forecasts*	-	CBE assumption for FOMC forecasts since 2007**
European Central Bank	CIR for Eurosystem Staff Macroeconomic Projections from June 2001 to March 2006	ME for Eurosystem Staff Macroeconomic Projections since June 2006	-
Magyar Nemzeti Bank	CIR for reports of June 2000 to November 2010	-	CBE since report of March 2011
Norges Bank	CIR for reports of June 2001 to June 2003	ME for reports of March 2000 to March 2001 and March 2003 to November 2004	CBE since report of March 2005
Reserve Bank of Australia	CIR up to report of May 2009	ME since report of August 2009	-
Reserve Bank of New Zealand	CIR before 1997	-	CBE since 1997
Sveriges Riksbank	CIR for reports from March 1997 to June 2005***	ME for reports from October 2005 to October 2006	CBE since report of February 2007
Swiss National Bank	CIR since 1999	-	-

Note: The above categorization is based on references and quotations shown in Appendix A.2.
* Based on Reifschneider and Tulip (2007) and Goodhart (2009).
** Based on the Fed's Semiannual Monetary Policy Report to the Congress of February 2007.
*** Including scenario analyses using market rates.

different forecasts for inflation and output growth, respectively, made by the Monetary Policy Committee (MPC) for up to eight quarters ahead. The difference between the forecasts is given by the underlying interest rate assumption. For one of the forecasts, nominal interest rates are assumed to be constant over the forecast horizon (CIR approach), whereas the other forecast is conditioned on an interest rate path that is based on market expectations about the future level of the official bank rate (ME approach). The forecast data are publicly available on the BoE website.[11] The BoE has no clearly laid-out preference for one over the other interest rate assumption. With the Inflation Report of August 2004, however, the emphasis was slightly shifted towards the ME approach.

In a similar fashion, the BCB Inflation Reports since 1999Q4 contain quarterly inflation nowcasts and forecasts for at least up to five quarters out, based on the CIR approach as well as the ME approach.[12] In contrast to the BoE, the BCB forecasts are also made conditional on exchange rate paths using the two competing conditioning assumptions, i.e. constant exchange rates and market expectations. These exchange rate paths, however, are rather similar, because the market expectations are mostly very close to a random walk. Therefore, we neglect the exchange rates issue in the following analysis.[13] Regarding the preference of the conditioning assumption, the BCB's September 1999 Report, p.79, puts more weight on the CIR approach when stating that "Normally, the Inflation Reports will issue two fan charts. The first and most important is constructed on the assumption of a constant nominal interest rate over the course of the projection period, while the second is accessory by nature and is based on the assumption that the nominal interest rate will be that built-into market expectations."

A special feature of the BoE Inflation Report forecasts, or, rather, the forecasts by the Monetary Policy Committee (MPC) is that they are actually issued as density forecasts, using the two-piece normal distribution. The BoE reports the three location parameters mean, mode, and median along with measures of skew and uncertainty, from which the parameters of the forecast densities can be inferred using the formulas in Wallis (2004). The inflation forecasts will be evaluated based on the price indices targeted and forecast by the BoE.[14] Real output growth realizations are those calculated for the seasonally adjusted GDP

[11] The forecast data are available at `www.bankofengland.co.uk/publications/inflationreport/irprobab.htm`.

[12] Up to December 2000, the number of forecast horizons of the BCB inflation forecasts varied between six and at most ten. With the December 2000 report, the BCB started to publish forecasts for up to the end of the next year, with the December forecasts made for up to eight quarters out and the number of forecast horizons diminishing one by one over the three consecutive Inflation Reports. Since December 2007, every Inflation Report contains quarterly forecasts made for up to eight quarters out.

[13] Exchange rate expectations are available from the BCB online under `https://www3.bcb.gov.br/expectativas/publico/en/serieestatisticas`.

[14] Before 2004, the relevant price index was the 'retail price index excluding mortgage interest payments', called RPIX in short. Since 2004, the forecast objective is the inflation rate of the 'all items consumer price index', abbreviated CPI. The UK's Office for National Statistics (ONS) provides inflation figures for RPIX

chained volume measure ABMI, taken from the BoE realtime database.[15] We use the second vintage thereof, yielding observations up to 2010Q4 for the construction of forecast errors and determining the end of the BoE data set.[16] The forecast horizons under study range from 0 (the nowcast) to 8 quarters ahead, such that $h = 0, \ldots, 8$.[17]

The forecasts made by the BCB's monetary policy committee, the COPOM (Comitê de Política Monetária), are also published as density forecasts. Yet, different from the BoE's publication practice, the COPOM forecasts are presented as quantiles belonging to the 10%, 30% and 50% prediction intervals of the central projection for inflation. Moreover, this central projection is a median forecast. The forecast data are publicly available in the Inflation Reports from 1999Q4 to 2011Q4.[18] To utilize information from the entire period, we restrict the sample to contain the nowcast and forecasts for up to five quarters out, i.e. $h = 0, \ldots, 5$. Yet, there are no market rate forecasts available for 2002Q4 and 2003Q1, such that these quarters are missing in our data set. As we are interested in the mean and standard deviation of the distributions underlying the fan charts, we back out these parameters by fitting a normal distribution to the medians and quantiles provided in the BCB Inflation Reports, using a least squares criterion. Since the confidence intervals are symmetric around the median, and there is no significant forecast skewness in the BCB figures, the normal distribution appears to be a proper choice and the central projection being a median no crucial point.[19] The BCB generally forecasts inflation in the *Broad National Consumer Price Index*, or IPCA (Índice Nacional de Preços ao Consumidor Amplo), as reported by the Brazilian Institute of Geography and Statistics (IBGE). "The IPCA is the most important price index from the standpoint of macroeconomic policy because it is the consumer price index that is used in the country's inflation targeting regime adopted in June 1999" , as stated in the BCB's 'Price Indices' explanations on p.7.[20]

In addition to the BoE inflation and output growth forecasts and BCB inflation forecasts, we also evaluate the BoE's and BCB's interest rate paths. The constant interest rate path used by the BoE corresponds to the level of the official bank rate (formerly the repo rate) in the mid-quarter months February, May, August and November, constantly written

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and CPI with one decimal place. To be closer to the two-decimal-place precision of the BoE inflation forecasts, we recalculate the quarterly year-on-year growth rates of these indices.

[15]The realtime database is available under `http://www.bankofengland.co.uk/statistics/gdpdatabase/`.

[16]In anticipation of the statistical inference conducted later in this study, we can state at this point that all test results are robust with respect to varying the real GDP vintage. For the price indices, there are no real-time data available. However, the RPIX figures are never revised, see for instance the discussion in Groen, Kapetanios, and Price (2009). The CPI comprises only minimal revisions, as described by the ONS (2003).

[17]The BoE has been publishing CPI inflation forecasts and real output growth forecasts made conditional on market rates for up to 12 quarters ahead since August 2004.

[18]See `http://www.bcb.gov.br/?id=INFLAREPORT&ano=1999` for further details.

[19]Specifically, the Inflation Report of September 2005, p.96, says that "With the exception of June 1999 and December 2002, past issues of the *Inflation Report* presented symmetric fan charts."

[20]IPCA figures are obtained from the International Monetary Fund's International Finance Statistics database.

forth over the two-year horizon. The available market rates data begin in 2000Q1 and thus determine the start date of the BoE data set. This date corresponds to the introduction of a new calculation method for market expectations of the BoE's official bank rate, as stated in the August 2000 Inflation Report.[21] Forecast errors of the interest rate paths are calculated by subtracting a quarterly average of the monthly interest rates from the respective interest rate forecast. It should be noted at this stage that the constant interest rate path uses the interest rate which is set in the MPC meetings in February, May, August and November. The market rate path is constructed based on data available until the day *before* these meetings. Thus, the constant rate path contains information which is not present in the market rate path. This issue will be addressed in the following analysis.

The constant interest rate path that is underlying the BCB's benchmark scenario for inflation is the level of the SELIC rate set by the COPOM in the meeting of the publication month of the Inflation Report.[22,23,24] Since the Inflation Reports are published quarterly in the end-of-quarter months March, June, September and December, we naturally obtain a quarterly series of interest rate decisions, which is written forth constantly over the forecast horizon.[25] The market expectations about the SELIC rate are also publicly available on the BCB's website.[26] The daily data is carefully matched to the constant-rate path using the fixing dates provided in the BCB Minutes and Inflation Reports. The starting date of the interest rate sample is determined by the availability of the market expectations, which are reported from November 2001 onwards. Both the constant-rate path and the market-rate path aim at forecasting SELIC interest rates at the end the quarter. Hence, the series of SELIC observations is identical to the nowcast of the constant-rate path.

[21] The passage cites as follows: "Since the November 1999 Report, market expectations have been derived from interest rates on gilt-edged securities used as collateral in short-term sale and repurchase agreements and from the gilt-edged yield curve. These rates provide a more direct guide to market expectations of the future path of official interest rates." The data are available at `www.bankofengland.co.uk/publications/inflationreport/market_profiles.xls`. Moreover, the calculation of the market rates path is changing from time to time to adjust to market conditions, as stated under `http://www.bankofengland.co.uk/publications/inflationreport/conditioning_path.htm`.

[22] The 2006Q2 fan charts' rates were set in May 2006, see the BCB Inflation Report June 2006, p.89, while the 2006Q3 fan charts' constant rates were set in August 2006, see the BCB Inflation Report September 2006, p.108.

[23] The SELIC rate is a short-term interest rate and the main monetary instrument of the BCB, where SELIC is an acronym terming the *Sistema Especial de Liquidação e Custodia*, translated as *Special Clearance and Escrow System*.

[24] Until March 1999, the TBC rate (basic interest rate) and the TBAN (Financial Assistance Rate) served as main monetary instruments.

[25] Although the BCB publishes forecasts four times a year, there are eight MPC meetings a year since 2006. Initially, there were monthly COPOM meetings, beginning with the first meeting of June 1996, with occasional extra meetings, see `http://www.bcb.gov.br/?COMMITTEE`.

[26] Again, see `http://www.bcb.gov.br/?id=INFLAREPORT&ano=1999` for further details.

3.3 Proxies for BoE Forecasts under Additional Interest Rate Assumptions

3.3.1 The Interest Rate Forecast of the BoE

As mentioned above, due to timing issues, the CIR forecasts contain information which is not present in the ME forecasts. This might make the forecasts with the CIR approach more accurate than those with the ME approach, above all at short horizons. Moreover, no CBE forecasts are available. In the following subsections, these problems will be addressed for the case of the BoE.

In a first step, we will try to construct proxies for the own interest rate forecast of the BoE. In order to do so, it is convenient to employ daily yield curve data on forward rates for UK government bonds and forward interbank rates published by the BoE. The policy rate forecast of the ME approach is actually based on these data. In order to derive the forward rates of the policy rate, the level of the yield curve data has to be adjusted due to certain types of premia and other issues, as explained in Brooke, Cooper, and Scholtes (2000).[27] Denoting the instantaneous forward rate m months ahead that was expected on the day d of the policy rate decision by $g_m(d)$, we measure the monetary policy surprise with respect to the m-months-ahead policy rate forecast based on the published yield curve data as

$$\tilde{s}_m(d) = g_m(d+1) - g_m(d)\,. \tag{3.1}$$

Note that, by taking differences, the difference in levels between the published forward rates and the forward rates of the policy rate does not affect our measure of the monetary policy surprise as long as that difference in levels is approximately constant over time. According to the information in Brooke et al. (2000), this appears to be a reasonable assumption, but this issue will be briefly discussed below. While the surprises have a monthly frequency and are defined for monthly policy rates, the forecasts to be investigated are available on a quarterly basis only. Since the surprises are a relatively smooth and persistent function of the horizon in months, i.e. because of $\tilde{s}_m(d) \approx \tilde{s}_{m+1}(d)$, we simply use $\hat{s}_q(d) := \tilde{s}_{3h+1}(d)$ as the measure of the surprise for the quarterly rates with respect to a horizon of h quarters. Note that $\hat{s}_q(d)$ itself has a monthly frequency, because the surprises for the quarterly rates are calculated

[27] The data are available at `http://www.bankofengland.co.uk/statistics/Pages/yieldcurve/default.aspx`. As done by the BoE when deriving the market expectations of the policy rate, for our analysis, we employ the government liability curve until October 2004 and the commercial bank liability forward curve thereafter. Due to problems related to the financial crises, the BoE has further modified its derivation of market expectations since November 2007, but the corresponding yield curves are not available on its website. However, the modifications were necessary mainly in order to estimate the correct levels of forward rates. We will be using differenced data only, which should be robust with respect to level effects caused by higher liquidity or risk premia. See `http://www.bankofengland.co.uk/publications/Pages/inflationreport/conditioning_path.aspx` for further details.

for each MPC meeting, and these meetings take place every month. Henceforth, a hat will be used to indicate quantities that are subject to measurement uncertainty or estimation uncertainty.[28]

The measures $\tilde{s}_m(d)$ and, thus, $\hat{s}_q(d)$ might be distorted mainly due to three reasons. Firstly, news other than the monetary policy surprise also affect the forward rates. However, since the window for these shocks to occur lasts 24 hours only, their effect should be relatively small. Secondly, in contrast to what was observed in the more distant past considered by Brooke et al. (2000), it might be that the risk premia in the forward curves changed due to the monetary policy decision during the financial crisis, but it is difficult to quantify the importance of this issue. Yet, for example, on 06 November 2008, the BoE decreased the policy rate by as much as 150 basis points in order to demonstrate its resoluteness to dampen the effects of the financial crisis, which might have led to a pronounced decrease in risk premia. While the financial markets had apparently expected the policy rate to decrease strongly in the coming months, they were surprised by the unprecedented size of the decrease on a single day.[29] Consequently, the 1-month forward rate dropped by 119 basis points, but the change in the 60-month forward rate amounted to 8 basis points only. This might suggest that the risk-premia effects of the monetary policy decisions do not lead to large distortions in the measurement of the monetary policy shock at least at longer horizons.[30] Finally, as pointed out by Anderson and Sleath (1999), there can be considerable uncertainty about the rates at the short end of the forward curve.

Denoting the market expectations of the policy rate in quarter t for quarter $t+h$ by $ME_{t+h|t}$ with $h = 0, 1, \ldots, 8$, we calculate a proxy for the BoE's own interest rate forecast $\widehat{CBE}_{t+h|t}$ as

$$\widehat{CBE}_{t+h|t} = ME_{t+h|t} + \sum_{i=0}^{h} \hat{s}^{(t)}_{t+h|t+i} \tag{3.2}$$

where $\hat{s}^{(t)}_{t+h|t+i}$ is the monetary policy surprise that occurred in quarter $t+i$ for the forecast made in quarter t for $t+h$. In general, this quarterly surprise is the sum of the three monthly monetary policy surprises that occurred within quarter $t+i$. To be more precise, $\hat{s}^{(t)}_{t+h|t+i}$ is

[28] Measurement uncertainty is only indicated for variables constructed in this work. Of course, $\tilde{s}_m(d)$ is also subject to measurement uncertainty, but it will not be used in what follows.

[29] According to the Consensus Forecasts from 13 October 2008, the most likely policy rate change mentioned by survey participants was a decrease by 50 basis points. Put differently, financial markets had expected the interest to decrease by 150 basis points and more, but they had not expected this decrease to happen immediately.

[30] This conclusion rests on the assumption that on 06 November 2008, the BoE did not make statements which led the markets to revise their expectations concerning the interest rate in 60 months upwards. However, we have not found any indications for such statements.

determined by

$$\hat{s}^{(t)}_{t+h|t+i} = \hat{s}_h(d_{1,t+i}) + \hat{s}_h(d_{2,t+i}) + \hat{s}_h(d_{3,t+i}) \quad \text{for } i = 1, 2, \ldots, h;\ h > 0 \tag{3.3}$$

$$\hat{s}^{(t)}_{t+h|t+i} = \hat{s}_h(d_{2,t+i}) + \hat{s}_h(d_{3,t+i}) \quad \text{for } i = 0; h \geq 0 \tag{3.4}$$

where $d_{j,t+i}$ is the day of the monetary policy decision in the jth month of quarter $t+i$. Since the Inflation Reports are published in the second month of a quarter, and, thus, the market expectations of the policy rate are also determined at that date, $\hat{s}^{(t)}_{t+h|t+i}$ only contains the surprises of the second and third month if $i = 0$.

At first sight, it might appear that we assume that the BoE knows how it will surprise the markets h quarters ahead, which might seem implausible. However, the approach proposed should rather be thought of as capturing surprises which result from the updating of market expectations.[31] Whether the proxy of the BoE's own interest forecast defined by equation (3.2) is useful in spite of the simplifications used and the distortions potentially having occurred is also an empirical question. Below, we will present empirical evidence suggesting that the proxy appears to be useful.

3.3.2 Synchronizing Market Expectations and Constant Rate Forecasts

In order to make the interest rate forecasts based on market expectations and the constant interest rate forecasts comparable, they should be adjusted such that both forecasts are conditioned on information at the same point in time. In order to clarify the differences between the forecasts, a more precise notation than used before is now needed.

The market expectations of the policy rate are based on data immediately before the MPC decision. Instead of denoting these forecasts by $ME_{t+h|t}$, they will henceforth be referred to as $ME^{pre}_{t+h|t}$. Consequently, the h-quarter-ahead constant-rate policy rate forecasts based on the rate immediately after the MPC decision in quarter t will be denoted by $CIR^{post}_{t+h|t}$. These are the two interest rate paths that the BoE (and the BCB) actually condition their forecasts on. In what follows, the constant-rate policy rate forecasts based on the rate before the MPC decision will be denoted by $CIR^{pre}_{t+h|t}$, and the market expectations of the policy rate based on data immediately after the MPC decision by $ME^{post}_{t+h|t}$.

[31] To give an example, neglecting the nowcasting issue, assume that in quarter $t-2$, markets expect an interest rate of 3% in quarter t, while the central bank expects 4%. In quarter $t-1$, the central bank still has the same expectation, and in its Inflation Report, it thus communicates that its own expectations are above those of the markets (without stating the number itself). The markets then revise their expectations upwards from 3% to x%. Finally, in quarter t, the central bank sets the interest rate to 4%. The central bank's expectation of 4% in quarter $t-2$ thus equals the markets' expectation of 3% in quarter $t-2$ plus the two surprises $x\% - 3\%$ (the surprise in quarter $t-1$) and $4\% - x\%$ (the surprise in quarter q). This example can easily be extended to more general cases with more periods and time-varying expectations due to shocks.

The latter forecast is calculated as

$$\widehat{ME}^{post}_{t+h|t} = ME^{pre}_{t+h|t} + \hat{s}_h\left(d_{2,t}\right). \tag{3.5}$$

Thus, the construction of $\widehat{ME}^{post}_{t+h|t}$ uses the monetary policy surprises as defined above, but only those which occurred on the day of the MPC decisions prior to which $ME^{pre}_{t+h|t}$ was calculated.

3.3.3 Effects of an Interest Rate Change on Inflation and Growth

The previous calculations yield additional interest rate paths that can be investigated. In what follows, corresponding proxies for inflation and output growth will be constructed.

The basis for this construction is given by the forecasts based on $ME^{pre}_{t+h|t}$ and $CIR^{post}_{t+h|t}$. The BoE does not mention any differences between these forecasts except for the interest rate path. Thus, the differences between the inflation and growth forecasts should be uniquely determined by the differences in interest rates. We assume that the modest-interventions approach is used for the forecasts. As mentioned above, this assumption is based on Faust and Wright (2008) and the corresponding references therein. Moreover, like Faust and Wright (2008), we assume that the responses of inflation and growth to an interest rate shock are linear.

Under the assumptions mentioned, forecasts for a variable x made in t are related by

$$\left(x^{ME^{pre}}_{t+h|t} - x^{CIR^{post}}_{t+h|t}\right) = \sum_{j=0}^{h} \alpha_{t,j}\left(ME^{pre}_{t+h-j|t} - CIR^{post}_{t+h-j|t}\right), \tag{3.6}$$

with $h = 0, 1, 2, \ldots, H$, where $x^{p}_{t+h|t}$ denotes the h-period-ahead mean forecast conditional on the interest rate path $p = \left\{p_{t|t}, p_{t+1|t}, \ldots, p_{t+h|t}\right\}$. That is, the H coefficients $\alpha_{t,j}$ for the forecast from period t can simply be calculated using the corresponding H observations concerning the differences with respect to the interest rate and the variable x. Note that time variation is accounted for by letting the response coefficient $\alpha_{t,j}$ depend on t. Given the coefficients $\alpha_{t,j}$, forecasts $x^{q}_{t+h|t}$ being conditional on the interest rate path q can either be constructed as

$$x^{q}_{t+h|t} = x^{CIR^{post}}_{t+h|t} + \sum_{j=0}^{h} \alpha_{t,j}\left(q_{t+h-j|t} - x^{CIR^{post}}_{t+h|t}\right) \tag{3.7}$$

or

$$x^{q}_{t+h|t} = ME^{pre}_{t+h-j|t} + \sum_{j=0}^{h} \alpha_{t,j}\left(q_{t+h-j|t} - ME^{pre}_{t+h-j|t}\right). \tag{3.8}$$

Under the assumptions mentioned, expression (3.6) holds with equality. However, even in this case, the coefficients $\alpha_{t,j}$ could not be pinned down exactly based on the available data, because all variables used are only published as rounded numbers.[32] If equation (3.6) is nevertheless used to calculate the coefficients $\alpha_{t,j}$, they can imply very implausible effects of interest rate changes, such as sign switches and explosive dynamics. This issue is also described in Faust and Leeper (2005). Moreover, if $ME^{pre}_{t+h|t} - CIR^{post}_{t+h|t}$ equals zero for at least one h, it is impossible to calculate the coefficients $\alpha_{t,j}$.

Therefore, we use more data and restrictions on the coefficients to estimate them. In order to rely on more data, if the time variation is not too extreme, one can estimate the coefficients employing the system of equations

$$\left(x^{ME^{pre}}_{t+i+h|t+i} - x^{CIR^{post}}_{t+i+h|t+i}\right) = \sum_{j=0}^{h} \alpha_{t,j} \left(ME^{pre}_{t+i+h-j|t+i} - CIR^{post}_{t+i+h-j|t+i}\right) + \varepsilon_{t+i,h} \qquad (3.9)$$

with $h = 0, 1, 2, \ldots, H$ and $i = -n, -n+1, \ldots, n$ with $n \geq 1$. This system collapses to the case described above if $n = 0$. Implicitly, here it is assumed that the coefficients $\alpha_{t,j}$ for the forecast made in t are well approximated by the average of these coefficients for the forecasts made in $t-n, t-n+1, \ldots, t+n$. Thus, mH observations are used to estimate H coefficients, with $m = 2n + 1$.

Instead of estimating H coefficients $\alpha_{t,j}$ for the forecast made in t, one can also try to model the coefficients as a function of a smaller number of parameters. This can be achieved using the functional form proposed by Almon (1965), yielding

$$\alpha^{A}_{t,h} = \sum_{k=0}^{K} \gamma_{t,k} h^k, \qquad (3.10)$$

with $K < H$. Given that inflation and output growth are unlikely to increase in response to higher interest rates, it is also interesting to consider the exponential Almon lag model proposed by Lütkepohl (1981), with the coefficients determined by

$$\alpha^{eA}_{t,h} = -\exp\left(\sum_{k=0}^{K} \gamma_{t,k} h^k\right). \qquad (3.11)$$

In what follows, we set $K = 2$.[33] It should be noted that the estimation uncertainty for $\alpha_{t,h}$, $\alpha^{A}_{t,h}$ and $\alpha^{eA}_{t,h}$ increases with h, because the number of equations which include these coefficients decreases with h.

The estimated coefficients imply a response path with respect to a change in the interest rate. This response path is only indirectly related to the impulse-responses with respect to a

[32] Rounding is important here, because, for example, the differences in inflation rates due to interest rate differences are very close to zero for short horizons. The rounded effects are thus likely to equal zero, but setting $a_{t,0}, a_{t,1}, \ldots$ to zero distorts the values of $a_{t,h}$ for larger horizons.

[33] Similar results are obtained with $K = 3$, but the estimation uncertainty increases with K.

monetary policy shock. While monetary policy shocks tend to lead to long-lasting increases in interest rates, as, for example, found in Stock and Watson (2001), the response paths described by the coefficients $\alpha_{t,h}$ with $h = 0, 1, 2, \dots, H$ are caused by a one-unit increase in the interest rate in t, a one-unit decrease in $t+1$ and no changes after that period. That is, for example $\alpha_{t,4}$ indicates how much lower inflation would be in $t+4$ due to a one-unit increase in the interest rate in t which is offset in $t+1$.

The estimated coefficients for inflation $\hat{\alpha}_{t,h}$, $\hat{\alpha}^{A}_{t,h}$, and $\hat{\alpha}^{eA}_{t,h}$, i.e. the response paths for inflation are displayed in Figure 3.1. Due to the time variation, each panel contains $44-m+1$ response paths. The upper left panel shows the results if equation (3.6) is employed to calculate $\hat{\alpha}_{t,h}$. Obviously, increasing m, i.e. using more data, yields more plausible results. However, the inflation response can become positive for longer horizons. Using the Almon lag model displayed in the panels in the middle leads to smoother responses, but the values for longer horizons are still positive. By construction, this problem is avoided with the exponential Almon lag model for which results are shown in the right panel. In general, increasing m from 9 to 13 only leads to minor changes, whereas an increase from 5 to 9 has noticeable effects.

Corresponding results for output growth can be found in Figure 3.2. The response paths with unrestricted coefficients and with the Almon lag model do not appear to be very plausible even for large values of m. Often, the responses are negative for short horizons, positive for medium horizons, and again pronouncedly negative for long horizons. Even using the exponential Almon lag model would result in some very peculiar paths.[34] Therefore, the additional restriction $\gamma_{t,2} < 0$ is imposed in the estimations. This approach leads to several paths with a negative response on impact and almost no response thereafter. However, there is also a large number of responses that approach zero for long horizons only. Again, increasing m from 9 to 13 only leads to minor changes.

Apart from plausibility considerations, statistical criteria are helpful for selecting a set of coefficients. In Table 3.2, the average R^2 of the regressions for each panel is shown. For inflation, the restrictions imposed with the exponential Almon lag model lead to an almost identical R^2 as the standard Almon lag model and the approach with unrestricted coefficients, and the R^2 always exceeds 0.9. Thus, the restrictions imposed on the coefficients $\hat{\alpha}^{eA}_{t,h}$ appear to be very mild. Since they also give economically plausible response paths, in what follows they will be used, with m set to 9. For output growth, the results are not as clear. In order to facilitate comparisons with inflation, and because of the still relatively high fit obtained, we will focus on the coefficients $\hat{\alpha}^{eA}_{t,h}$ and $m = 9$ also for output growth.

It should be noted that the importance of the estimated coefficients for the subsequent analyses decreases with h. This is due to the the fact that, for example, $\hat{\alpha}^{eA}_{t,H}$ only affects the forecast $x_{t+H|t}$, and that this effect is only caused by the differences in the interest rate

[34] These paths show a strong negative response on impact, then virtually no response for all horizons but the longest, and then again a strongly negative response for the latter.

assumptions in t, where these differences are typically small. In contrast to that, $\hat{\alpha}^{eA}_{t,0}$ affects all forecasts $x_{t+h|t}$ with $h = 0, 1, 2, \ldots, H$ given the differences in the interest rate assumptions in $t, t+1, \ldots t+H$. Therefore, the differences in the coefficients observed across methods for large h hardly affect the following results.[35]

For the construction of the proxies based on $\widehat{CBE}_{t+h|t}$ and $\widehat{ME}^{post}_{t+h|t}$, we use equation 3.8, i.e. these proxies are calculated using the BoE's forecasts with the ME approach as the baseline. For the determination of the proxies based on $CIR^{post}_{t+h|t}$, equation 3.7 is employed, so that these proxies are calculated using the BoE's forecasts with the CIR approach as the baseline.[36]

3.4 Properties of the Forecasts

It might be interesting to shed some light on the results of the constructions in the previous section. A good impression can be obtained simply by looking at two examples. In Figure 3.3, the different forecasts of the BoE dating from 2004Q2 and 2008Q4, respectively, are displayed together with the corresponding realizations. At both forecast dates, the policy rate was changed. In 2004Q2, the proxy $\widehat{CBE}_{t+h|t}$ suggests that the BoE was aiming for lower future policy rates than expected by the markets, whereas in 2008Q4, there were no such discrepancies for the longer horizons.[37]

The most striking feature of the inflation and growth forecasts based on different interest rate assumptions is their strong similarity. At short horizons, the forecasts are virtually indistinguishable. While small differences can be observed for longer horizons, the forecast errors appear to be of similar magnitudes. At best, the inflation forecasts based on $CIR^{pre}_{t+h|t}$ might be expected to perform somewhat differently.

The observations based on two examples only are confirmed by the correlations of the forecasts. For the interest rate forecasts considered, these are shown in Table 3.3. Obviously, the correlations between all interest rate forecasts are very pronounced for short horizons. For medium and long horizons, the correlations between constant rates and market rates are mostly below 0.9, with 0.35 being the lowest value observed.

The correlations of the inflation forecasts can be found in Table 3.4. In the case of the BoE, except for long horizons, they are close to 1. Only for $h = 7$ and $h = 8$, the correlations between forecasts based on constant rates and the other forecasts can fall short of 0.9, with the

[35] We also conducted large parts of the following analyses using the coefficients $\hat{\alpha}_{t,h}$ and $\hat{\alpha}^{A}_{t,h}$. Basically, this led to the same conclusions as those reached with the coefficients $\hat{\alpha}^{eA}_{t,h}$. The results are available upon request.

[36] We also conducted the following analyses employing all other possible combinations of baselines. Again, this led to the same conclusions as with the choices described above. The results are available upon request.

[37] In the short run, however, before the interest rate decision the markets had expected the interest rate to decrease to 3% over the next quarters, but did not expect this to happen immediately. The surprise observed is thus similiar to what is called a timing surprise by Gürkaynak (2005) and Gürkaynak, Sack, and Swanson (2007).

lowest value being equal to 0.78. In contrast to that, for the BCB, the correlations are around 0.7 for the medium horizons $h = 4$ and $h = 5$. Of course, the strong correlations at short horizons are, in both cases, due to the fact that interest rate surprises affect inflation with a certain delay only. In the case of the BoE, even stronger correlations than for inflation can be observed for the GDP growth forecasts, which are given in Table 3.5. Here, the smallest correlation equals 0.84.

It remains to be investigated whether the proxies for the policy rate forecasts constructed above have plausible empirical properties. To this end, we compute the root mean squared errors (RMSEs) of the forecasts which are displayed in Table 3.6. Obviously, the RMSEs are as expected. For horizons $h \geq 1$, the ME approach gives more accurate forecasts than the corresponding CIR approach, and the best forecasts are obtained with the CBE approach. Moreover, forecasts based on information including the policy rate decision are more accurate than their respective counterparts that do not contain the information about the policy rate decision. The ME approach gives better forecasts than the CIR approach for $h \geq 2$ even if the former is based on pre-decision information while the latter is not. For the BCB forecasts and $h = 5$, the forecast accuracy of the CIR approach is larger, but this might at least partly be due to the small sample size for this horizon.

The fact that the ranking of the ME approach, the CIR approach and the CBE approach with respect to forecast accuracy is different for $h = 0$ could be caused by the difficulties in estimating the rates at the short end of the forward curve mentioned by Anderson and Sleath (1999). Of course, the information about the policy rate decision is especially important for the nowcasts, so that it is not too surprising that, for example, $CIR^{post}_{t+h|t}$ gives better forecasts than $ME^{pre}_{t+h|t}$ for $h = 0$.

For inflation and GDP growth, in addition to the mean forecasts, we can also evaluate the density forecasts. BoE density forecasts under the ME approach and the CIR approach only differ with respect to the location parameter, whereas the variance and the skewness parameters are always identical. Therefore, we use these two parameters for the construction of the density forecasts as well. We employ a standard scoring function for density forecasts, the logarithmic score.[38] Since density forecasts are available, we could also evaluate other types of point forecasts like quantiles which imply loss functions other than the quadratic loss associated with the mean forecast.[39] However, using, for example, the absolute errors of the median forecasts of the BoE does not yield additional insights, so that we do not report them in what follows.[40]

[38]The logarithmic score is the only proper local scoring rule as shown by Bernardo (1979) and explained in Gneiting and Raftery (2007).

[39]See Gneiting (2011) for a comprehensive treatment of loss functions and the corresponding point forecasts. The central forecast discussed by the BoE is the mode forecast, but as pointed out by Wallis (1999), the corresponding all-or-nothing loss function is unrealistic.

[40]The results for the median forecasts conditional on $CIR^{post}_{t+h|t}$ and $ME^{pre}_{t+h|t}$ are available from the authors

The results for inflation can be found in Table 3.7. As expected, the differences between the RMSEs and the mean logarithmic scores (henceforth referred to as MLSs) are very small for short horizons at least in the case of the BoE. For medium and long horizons, the differences become larger, but remain at a low level. For example, one of the largest differences observed for the BoE occurs for $h = 8$, where the RMSE of $\hat{\pi}_{t+h|t}^{CIR^{pre}}$ is about 10% larger than the RMSE of $\hat{\pi}_{t+h|t}^{ME^{post}}$.

The accuracy ranking found for interest rates does not hold for the inflation forecasts. While $\hat{\pi}_{t+h|t}^{CIR^{pre}}$ tends to be the least accurate forecast, $\hat{\pi}_{t+h|t}^{CBE}$ is never the single most accurate forecast. Especially with respect to the MLS, the performance of $\hat{\pi}_{t+h|t}^{CBE}$ is often worse than that of all other forecasts except for $\hat{\pi}_{t+h|t}^{CIR^{pre}}$. The highest MLS for $h \geq 5$ is mostly obtained by $\pi_{t+h|t}^{CIR^{post}}$.

In the case of GDP growth, the results differ pronouncedly from what one would expect, as shown in Table 3.8. While also in this case, the differences between the RMSEs and the MLSs are very small, the most accurate forecasts are almost always given by $\hat{y}_{t+h|t}^{CIR^{pre}}$ and $y_{t+h|t}^{CIR^{post}}$. $\hat{y}_{t+h|t}^{CBE}$ tends to deliver the least accurate forecasts, and its performance is very similar to that of $\hat{y}_{t+h|t}^{ME^{post}}$.

In summary, while the results for the interest rate forecasts are in line with our expectations, the inflation forecasts and the GDP growth forecasts do not display the expected patterns of forecast accuracy.

3.5 Testing for Equal Predictive Accuracy

In this section, we try to compare the predictive accuracy of the forecasts based on different interest rate assumptions. Given the sample sizes and the strong correlations observed, the tests can, of course, not be expected to have large power.

The forecasts for inflation and output growth can probably be thought of as coming from nested models. However, the forecast models are not available to us, so that its population-level predictive accuracy cannot be evaluated.[41] Yet, the test for finite-sample predictive accuracy by Giacomini and White (2006) can be employed, assuming that the forecasting models are subject to non-vanishing parameter estimation uncertainty. Put differently, this test is valid if the central banks do not expand the size of the estimation window over time.[42]

upon request.

[41] See Clark and McCracken (2010) for a survey on forecast evaluation methods.

[42] Probably, none of the estimation schemes typically considered in the literature (recursive, rolling, fixed) exactly corresponds to the approach of practitioners. Rather, practitioners might switch between the schemes, with their choice depending on structural breaks and data availability. For example, the estimation window might expand for some time and then be reduced again, because data prior to a structural break is discarded. Therefore, asymptotically, the assumption of non-vanishing estimation uncertainty is probably justified here, even if neither the rolling nor the fixed scheme are used.

Concerning the point forecasts, in the following analysis we concentrate on the means of the forecast series. Moreover, as also noted by Mitchell and Wallis (2011), the framework of Giacomini and White (2006) is general enough to encompass density forecasts. Therefore, we also evaluate the competing density forecasts for inflation and for real output growth based on their logarithmic scores. Let

$$d_{SE}(x^p_{t+h|t}, x^q_{t+h|t}) \equiv (x^p_{t+h|t} - x_{t+h})^2 - (x^q_{t+h|t} - x_{t+h})^2 \tag{3.12}$$

denote the difference in the squared forecast errors of two competing mean forecasts for the variable x based on the interest rate paths p and q, respectively.[43] Furthermore, let

$$d_{LS}(x^p_{t+h|t}, x^q_{t+h|t}) \equiv -\Big(\log(f^p_{t+h|t}(x_{t+h})) - \log(f^q_{t+h|t}(x_{t+h}))\Big) \tag{3.13}$$

be the difference in the logarithmic scores of the two competing density forecasts. The score is the value of the forecast density made in t for $t+h$ at the value of the realization x_{t+h}. Note that both differences are defined such that positive values occur if the forecasts using interest rate path q imply a higher forecast accuracy than the forecasts based on the interest rate path p. Given the ordering of interest rate paths that we are going to use (CIR^{pre}, CIR^{post}, ME^{pre}, ME^{pre}, CBE), we would expect the means of the loss differentials d_{SE} and d_{LS} to be positive.

We calculate the loss differentials for the interest rate, inflation, and output growth forecasts. To conduct a Giacomini and White (2006) test (henceforth GW test), we simply regress the respective differences on a constant. An estimate of the constant being significantly different from zero implies the rejection of the null of equal predictive accuracy of the two competing forecasts. We use a significance level of 5%. Note that, given that there are going to be many pairwise tests, one can expect some rejections even if all forecasts are equally accurate.[44]

The results for the interest rate mean forecasts, based on quadratic loss, are shown in Table 3.9. In line with the RMSEs displayed in Table 3.6, the means of d_{SE} are positive except for some cases at short horizons for the BoE and for $h = 4$ for the BCB. However, it turns out that d_{SE} is never significantly different from zero. Thus, even for the conditioning assumptions themselves, we cannot detect significant differences in their forecast accuracies. Of course, this result suggests that significant results for inflation and output growth are unlikely, at least with respect to the mean forecasts, because of the uncertainty about the

[43] If x refers to the interest rate forecast, we have $x^p_{t+h|t} = p_{t+h|t}$ and $x^q_{t+h|t} = q_{t+h|t}$.

[44] Moreover, according to the results in Harvey, Leybourne, and Newbold (1997), the GW test can be expected to overreject pronouncedly in small persistent samples. In order to avoid this problem, we estimate the variance of the loss differentials under the null hypothesis of equal predictive accuracy, i.e. with the mean of d_{SE} and d_{LS} set to zero. This Lagrange Multiplier version of the test is more conservative in small samples.

effects of an interest rate change on these variables. If, for instance, the true inflation response to an interest rate change does not coincide with the response assumed by the forecaster, it could easily happen that an inflation forecast based on the CBE approach is not more accurate than an inflation forecast based on the CIR approach, even if the interest rate forecast of the central bank is very precise.

For the inflation mean forecasts, indeed, there are no significant differences, as shown in Table 3.10. For GDP growth, the results reported in Table 3.11 contain three significant differences. Two of them, however, are negative. Thus, in the samples under study, there is no convincing evidence for differences in mean forecast accuracy for inflation and GDP growth caused by the rate interest assumption.

For the tests of the density forecasts of inflation and GDP growth based on the logarithmic scores, displayed in Tables 3.12 and 3.13, in total, four significant differences appear. Yet, two of them are negative. Thus, again, there is no evidence that ‘better’ interest rate assumptions lead to more accurate forecasts of inflation and GDP growth.

It might be argued that the sample sizes under study are simply to small in order to detect significant differences in forecast accuracy. The results observed for the interest rate forecasts of the BoE, indeed, suggest that with moderately larger samples it might become possible to empirically confirm the results expected based on economic theory, because the differences, albeit insignificant, have the expected signs. For inflation and output growth, however, many differences are negative. Thus, much larger samples would be needed in order to unveil the supposed superiority of, for example, the CBE approach, if this superiority exists at all. In our opinion, this need for much larger samples casts considerable doubts on the empirical relevance of the interest rate assumption.

3.6 Conclusion

The choice of the interest rate path underlying the forecasts of central banks has been intensively discussed in the economic literature. Empirical studies concerning the choice of the interest rate assumption have hardly been conducted. In this work, we attempt to rank the different approaches with respect to their effects on forecast accuracy. From a theoretical point of view, the CBE approach is the preferred option and should lead to the highest accuracy. While there is no clear theoretical ranking for ME approach and the CIR approach with respect to forecast accuracy, it seems plausible to expect the ME approach to yield more accurate forecasts than the CIR approach.

The macroeconomic forecasts by the BoE and the BCB turn out to be ideal candidates for a comparison, because both central banks publish forecasts using the ME approach as well as the CIR approach. The data situation for the BoE also allows the construction of proxies for the CBE forecasts.

In stark contrast to our expectations, we hardly find any significant differences between the performance of forecasts based on different interest rate assumptions. In general, for the interest rate mean forecasts themselves, the proxy for the central bank's own expectations are more accurate than the market expectations. The latter yield better forecasts than the assumption of a constant interest rate. However, the differences are all insignificant. For the inflation and output growth mean and density forecasts, there is no clear relation between forecast accuracy and the interest rate assumption. Very few significant differences are found, and about half of them do not have the expected sign.

One might argue that the sample under study is simply too small in order to find significant differences between the forecasts conditioned on constant or on market rates. Yet, if about ten years of data are not enough to detect such differences, it seems that the relevance of the conditioning assumption is rather limited, at least empirically.

The empirical irrelevance of the interest rate assumption for forecast accuracy has important implications for the issues raised at the beginning. Firstly, at least in the medium term, it is going to be difficult for central banks to steer market expectations by using the CBE approach, especially for variables other than the policy rate itself. Of course, this also implies that it does not appear very likely that markets misunderstand the central bank's own interest rate expectation as a commitment. Secondly, at least for the samples under study, monetary policy is unlikely to be a major cause for the level of macroeconomic volatility observed, because the inflation and growth forecasts conditional on 'bad' monetary policy (on the CIR approach) have virtually the same accuracy as forecasts conditional on 'good' monetary policy (on the CBE approach). This might cast doubts on the prominent role that is sometimes attributed to monetary policy concerning the Great Moderation.[45] Thirdly, the construction of prediction intervals for central bank forecasts and the evaluation of central bank forecasts can probably be agnostic toward the underlying interest rate assumptions. Put differently, past forecast errors are a good indicator for future forecast uncertainty if the only structural change is due to a change in the interest rate assumption used. And the errors made when using standard evaluation procedures instead of those proposed by Faust and Wright (2008) are probably going to be small. Finally, the risk that private information is crowded out if central banks switch to the CBE approach is unlikely as well.

[45] However, it might also be that, currently, 'good' monetary policy is responsible for a regime with relatively high macroeconomic stability where the differences in forecast accuracy between the CIR approach and the CBE approach are relatively small, and that 'bad' monetary policy would lead to a different regime with strong differences between the forecast accuracy of both approaches.

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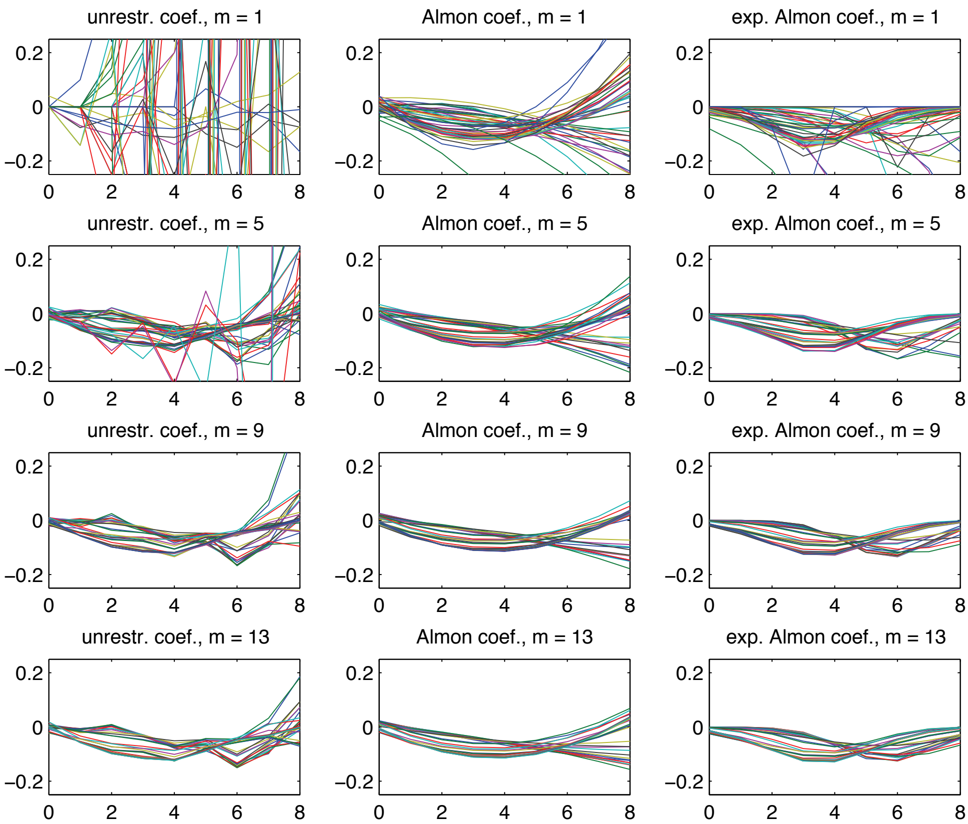
Appendix

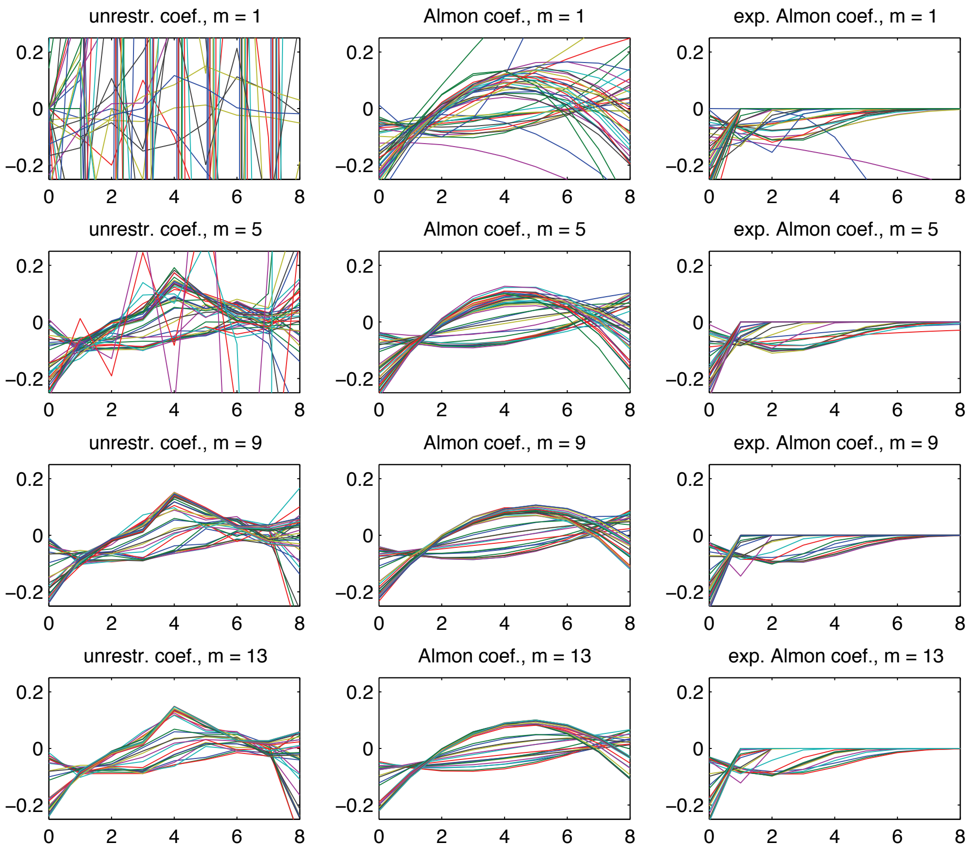
A.1 Plots and Results Tables

Figure 3.1: Response paths for inflation



Note: Response paths for inflation, given by the coefficients $\hat{\alpha}_{t,h}$ (unrestricted coefficients, shown in first column), $\hat{\alpha}^{A}_{t,h}$ (coefficients restricted by Almon lag model, shown in second column), and $\hat{\alpha}^{eA}_{t,h}$ (coefficients restricted by exponential Almon lag model, shown in third column). These are responses to a one-unit increase in the interest rate in $h = 0$, a one-unit decrease in $h = 1$ and no changes thereafter. m denotes the number of adjacent forecasts used to estimate the coefficients.

Figure 3.2: Response paths for real GDP growth



Note: Response paths for GDP growth, given by the coefficients $\hat{\alpha}_{t,h}$ (unrestricted coefficients, shown in first column), $\hat{\alpha}^{A}_{t,h}$ (coefficients restricted by Almon lag model, shown in second column), and $\hat{\alpha}^{eA}_{t,h}$ (coefficients restricted by exponential Almon lag model, where the additional restriction $\gamma_{t,2} < 0$ is imposed, shown in third column). These are responses to a one-unit increase in the interest rate in $h = 0$, a one-unit decrease in $h = 1$ and no changes thereafter. m denotes the number of adjacent forecasts used to estimate the coefficients.

Table 3.2: Average R^2 for different estimation approaches

m	inflation	output growth
	unrestricted coefficients	
1	–	–
5	0.96	0.96
9	0.94	0.94
13	0.93	0.93
	Almon lag	
1	0.96	0.98
5	0.95	0.95
9	0.94	0.94
13	0.93	0.92
	exponential Almon lag	
1	0.97	0.86
5	0.96	0.85
9	0.94	0.85
13	0.93	0.85

Note: No entries for $m = 1$ and unrestricted coefficients, because coefficients cannot be calculated for forecasts where values of conditioning interest rate paths are identical for at least one horizon.

Figure 3.3: Forecasts by the BoE and corresponding realizations for the policy rate, inflation, and GDP growth from 2004Q2 and 2008Q4, respectively

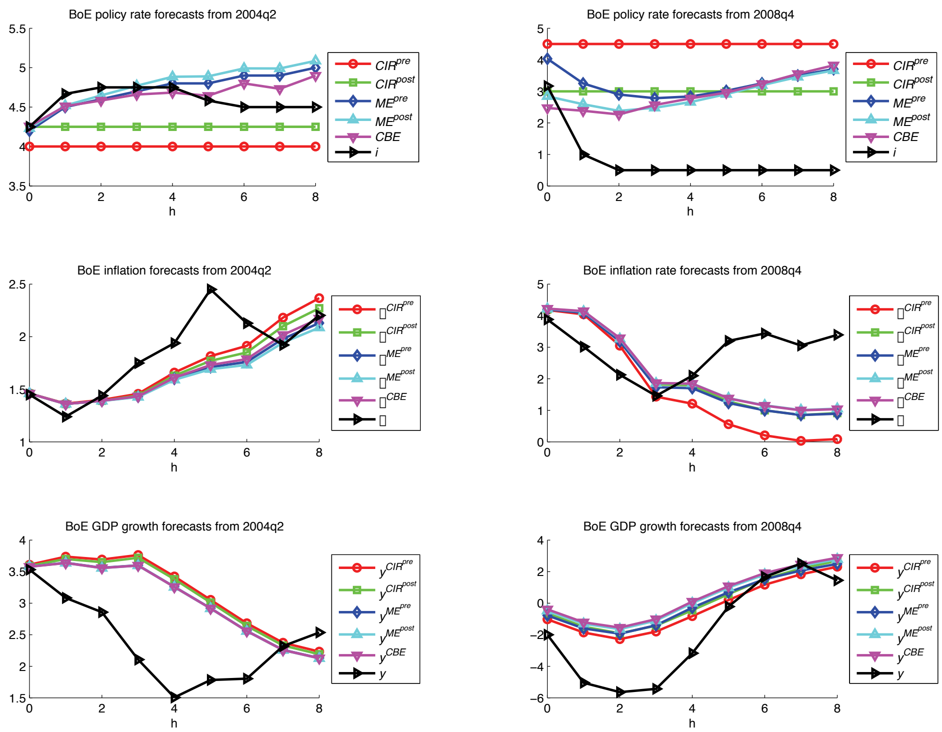


Table 3.3: Correlations of interest rate forecasts

h	0	1	2	3	4	5	6	7	8
	Bank of England								
N	36	36	36	36	36	35	34	33	32
	correlation of $CIR^{pre}_{t+h\|t}$ with...								
$CIR^{post}_{t+h\|t}$	0.98	0.98	0.98	0.98	0.98	0.97	0.96	0.94	0.89
$ME^{pre}_{t+h\|t}$	1.00	0.96	0.94	0.91	0.89	0.84	0.79	0.68	0.39
$\widehat{ME}^{post}_{t+h\|t}$	0.98	0.95	0.92	0.90	0.88	0.83	0.77	0.65	0.35
$\widehat{CBE}_{t+h\|t}$	0.97	0.93	0.90	0.85	0.83	0.79	0.78	0.70	0.55
	correlation of $CIR^{post}_{t+h\|t}$ with...								
$ME^{pre}_{t+h\|t}$	0.99	0.99	0.98	0.96	0.94	0.91	0.88	0.81	0.59
$\widehat{ME}^{post}_{t+h\|t}$	1.00	0.99	0.97	0.95	0.94	0.90	0.86	0.79	0.56
$\widehat{CBE}_{t+h\|t}$	1.00	0.97	0.95	0.91	0.88	0.86	0.83	0.78	0.63
	correlation of $ME^{pre}_{t+h\|t}$ with...								
$\widehat{ME}^{post}_{t+h\|t}$	0.99	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99
$\widehat{CBE}_{t+h\|t}$	0.98	0.98	0.98	0.98	0.97	0.94	0.91	0.85	0.73
	correlation of $\widehat{ME}^{post}_{t+h\|t}$ with...								
$\widehat{CBE}_{t+h\|t}$	1.00	0.98	0.98	0.98	0.97	0.95	0.92	0.86	0.74
	Banco Central do Brasil								
N	39	38	37	30	19				
	correlation of $CIR^{post}_{t+h\|t}$ with...								
$ME^{pre}_{t+h\|t}$	1.00	0.98	0.95	0.93	0.93				

Note: N denotes the sample size, h is the forecast horizon in quarters.

Table 3.4: Correlations of inflation forecasts

h	0	1	2	3	4	5	6	7	8
	Bank of England								
N	36	36	36	36	36	35	34	33	32
	correlation of $\hat{\pi}_{t+h\|t}^{CIR^{pre}}$ with...								
$\pi_{t+h\|t}^{CIR^{post}}$	1.00	1.00	1.00	0.99	0.97	0.97	0.97	0.97	0.97
$\pi_{t+h\|t}^{ME^{pre}}$	1.00	1.00	1.00	0.99	0.97	0.94	0.92	0.88	0.85
$\hat{\pi}_{t+h\|t}^{ME^{post}}$	1.00	1.00	1.00	0.99	0.95	0.93	0.90	0.86	0.83
$\hat{\pi}_{t+h\|t}^{CBE}$	1.00	1.00	1.00	0.99	0.94	0.90	0.88	0.87	0.78
	correlation of $\pi_{t+h\|t}^{CIR^{post}}$ with...								
$\pi_{t+h\|t}^{ME^{pre}}$	1.00	1.00	1.00	1.00	0.99	0.98	0.97	0.93	0.89
$\hat{\pi}_{t+h\|t}^{ME^{post}}$	1.00	1.00	1.00	1.00	0.99	0.98	0.96	0.93	0.88
$\hat{\pi}_{t+h\|t}^{CBE}$	1.00	1.00	1.00	1.00	0.98	0.96	0.93	0.91	0.83
	correlation of $\pi_{t+h\|t}^{ME^{pre}}$ with...								
$\hat{\pi}_{t+h\|t}^{ME^{post}}$	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
$\hat{\pi}_{t+h\|t}^{CBE}$	1.00	1.00	1.00	1.00	0.99	0.99	0.98	0.98	0.96
	correlation of $\hat{\pi}_{t+h\|t}^{ME^{post}}$ with...								
$\hat{\pi}_{t+h\|t}^{CBE}$	1.00	1.00	1.00	1.00	0.99	0.99	0.98	0.98	0.97
	Banco Central do Brasil								
N	47	46	45	44	43	42			
	correlation of $\pi_{t+h\|t}^{CIR^{post}}$ with...								
$\pi_{t+h\|t}^{ME^{pre}}$	1.00	1.00	0.98	0.90	0.72	0.67			

Note: N denotes the sample size, h is the forecast horizon in quarters.

Table 3.5: Correlations of GDP growth forecasts

h	0	1	2	3	4	5	6	7	8
	Bank of England								
N	36	36	36	36	36	35	34	33	32
	correlation of $\hat{y}_{t+h\|t}^{CIR^{pre}}$ with...								
$y_{t+h\|t}^{CIR^{post}}$	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.98
$y_{t+h\|t}^{ME^{pre}}$	1.00	1.00	1.00	1.00	0.99	0.97	0.93	0.89	0.87
$\hat{y}_{t+h\|t}^{ME^{post}}$	1.00	1.00	1.00	1.00	0.98	0.96	0.92	0.87	0.84
$\hat{y}_{t+h\|t}^{CBE}$	1.00	1.00	1.00	0.99	0.98	0.96	0.93	0.88	0.87
	correlation of $y_{t+h\|t}^{CIR^{post}}$ with...								
$y_{t+h\|t}^{ME^{pre}}$	1.00	1.00	1.00	1.00	0.99	0.98	0.94	0.90	0.87
$\hat{y}_{t+h\|t}^{ME^{post}}$	1.00	1.00	1.00	1.00	0.99	0.97	0.93	0.90	0.87
$\hat{y}_{t+h\|t}^{CBE}$	1.00	1.00	1.00	1.00	0.99	0.97	0.95	0.92	0.91
	correlation of $y_{t+h\|t}^{ME^{pre}}$ with...								
$\hat{y}_{t+h\|t}^{ME^{post}}$	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99
$\hat{y}_{t+h\|t}^{CBE}$	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.98	0.98
	correlation of $\hat{y}_{t+h\|t}^{ME^{post}}$ with...								
$\hat{y}_{t+h\|t}^{CBE}$	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Note: N denotes the sample size, h is the forecast horizon in quarters.

Table 3.6: Root mean squared errors of interest rate mean forecasts

h	0	1	2	3	4	5	6	7	8
	Bank of England								
N	36	36	36	36	36	35	34	33	32
$CIR^{pre}_{t+h\|t}$	0.27	0.76	1.13	1.44	1.69	1.93	2.15	2.34	2.51
$CIR^{post}_{t+h\|t}$	0.06	0.51	0.94	1.27	1.54	1.80	2.04	2.24	2.43
$ME^{pre}_{t+h\|t}$	0.16	0.54	0.90	1.18	1.46	1.75	2.00	2.22	2.40
$\widehat{ME}^{post}_{t+h\|t}$	0.08	0.46	0.85	1.15	1.43	1.73	1.99	2.20	2.38
$\widehat{CBE}_{t+h\|t}$	0.14	0.33	0.72	1.06	1.37	1.64	1.91	2.14	2.34
	Banco Central do Brasil								
N	39	38	37	30	19				
$CIR^{post}_{t+h\|t}$	0	1.85	2.96	3.70	4.69				
$ME^{pre}_{t+h\|t}$	0.15	1.62	2.66	3.69	4.83				

Note: N denotes the sample size, h is the forecast horizon in quarters.

Table 3.7: Root mean squared errors and mean logarithmic scores of inflation mean and density forecasts

h	0	1	2	3	4	5	6	7	8
	Bank of England								
N	36	36	36	36	36	35	34	33	32
	RMSE of mean forecasts								
$\hat{\pi}_{t+h\|t}^{CIR^{pre}}$	0.18	0.45	0.71	0.92	1.03	1.12	1.10	1.08	1.03
$\pi_{t+h\|t}^{CIR^{post}}$	0.18	0.45	0.71	0.92	1.01	1.06	1.02	1.00	0.96
$\pi_{t+h\|t}^{ME^{pre}}$	0.18	0.45	0.70	0.91	1.02	1.09	1.05	1.01	0.94
$\hat{\pi}_{t+h\|t}^{ME^{post}}$	0.18	0.45	0.70	0.90	1.01	1.07	1.04	1.01	0.93
$\hat{\pi}_{t+h\|t}^{CBE}$	0.18	0.46	0.72	0.92	1.02	1.08	1.04	1.01	0.94
	MLS of density forecasts								
$\hat{\pi}_{t+h\|t}^{CIR^{pre}}$	0.13	−0.51	−1.00	−1.34	−1.50	−1.59	−1.48	−1.44	−1.44
$\pi_{t+h\|t}^{CIR^{post}}$	0.13	−0.52	−1.00	−1.33	−1.48	−1.53	−1.41	−1.38	−1.41
$\pi_{t+h\|t}^{ME^{pre}}$	0.13	−0.51	−0.99	−1.31	−1.48	−1.57	−1.46	−1.40	−1.39
$\hat{\pi}_{t+h\|t}^{ME^{post}}$	0.13	−0.52	−0.99	−1.31	−1.47	−1.55	−1.45	−1.40	−1.39
$\hat{\pi}_{t+h\|t}^{CBE}$	0.13	−0.52	−1.01	−1.34	−1.49	−1.58	−1.47	−1.43	−1.43
	Banco Central Do Brasil								
N	47	46	45	44	43	42			
	RMSE of mean forecasts								
$\pi_{t+h\|t}^{CIR^{post}}$	0.19	0.78	3.53	8.07	13.52	17.64			
$\pi_{t+h\|t}^{ME^{pre}}$	0.19	0.89	3.76	8.22	12.80	15.77			
	MLS of density forecasts								
$\pi_{t+h\|t}^{CIR^{post}}$	−0.41	−1.14	−1.85	−2.42	−2.83	−2.99			
$\pi_{t+h\|t}^{ME^{pre}}$	−0.43	−1.14	−1.87	−2.45	−2.77	−2.88			

Note: N denotes the sample size, h is the forecast horizon in quarters.

Table 3.8: Root mean squared errors and mean logarithmic scores of GDP growth mean and density forecasts

h	0	1	2	3	4	5	6	7	8
	Bank of England								
N	36	36	36	36	36	35	34	33	32
	RMSE of mean forecasts								
$\hat{y}_{t+h\|t}^{CIR^{pre}}$	0.53	0.88	1.32	1.77	2.19	2.48	2.67	2.82	2.92
$y_{t+h\|t}^{CIR^{post}}$	0.56	0.92	1.36	1.79	2.21	2.48	2.67	2.82	2.92
$y_{t+h\|t}^{ME^{pre}}$	0.55	0.91	1.37	1.82	2.24	2.51	2.69	2.84	2.95
$\hat{y}_{t+h\|t}^{ME^{post}}$	0.57	0.95	1.39	1.84	2.26	2.51	2.69	2.84	2.95
$\hat{y}_{t+h\|t}^{CBE}$	0.58	0.96	1.40	1.85	2.26	2.51	2.69	2.84	2.95
	MLS of density forecasts								
$\hat{y}_{t+h\|t}^{CIR^{pre}}$	−1.08	−1.30	−2.07	−2.82	−3.46	−3.75	−3.89	−4.09	−4.56
$y_{t+h\|t}^{CIR^{post}}$	−1.10	−1.34	−2.12	−2.86	−3.48	−3.75	−3.88	−4.08	−4.54
$y_{t+h\|t}^{ME^{pre}}$	−1.09	−1.34	−2.14	−2.90	−3.54	−3.78	−3.90	−4.11	−4.60
$\hat{y}_{t+h\|t}^{ME^{post}}$	−1.10	−1.37	−2.17	−2.93	−3.56	−3.78	−3.90	−4.11	−4.60
$\hat{y}_{t+h\|t}^{CBE}$	−1.11	−1.39	−2.18	−2.95	−3.57	−3.79	−3.90	−4.11	−4.60

Note: N denotes the sample size, h is the forecast horizon in quarters.

Table 3.9: Test results for equal predictive accuracy of interest rate mean forecasts based on squared errors

h	0	1	2	3	4	5	6	7	8
	Bank of England								
N	36	36	36	36	36	35	34	33	32
	mean of $d_{SE}\left(CIR^{pre}_{t+h\|t}, x^q_{t+h\|t}\right)$ with $x^q_{t+h\|t} = \ldots$								
$CIR^{post}_{t+h\|t}$	0.07	0.32	0.40	0.45	0.48	0.48	0.45	0.43	0.38
	(0.17)	(0.16)	(0.13)	(0.09)	(0.08)	(0.10)	(0.15)	(0.19)	(0.26)
$ME^{pre}_{t+h\|t}$	0.05	0.29	0.48	0.67	0.72	0.68	0.59	0.54	0.54
	(0.11)	(0.15)	(0.11)	(0.09)	(0.17)	(0.26)	(0.30)	(0.30)	(0.28)
$\widehat{ME}^{post}_{t+h\|t}$	0.06	0.37	0.56	0.73	0.79	0.75	0.64	0.61	0.63
	(0.16)	(0.17)	(0.12)	(0.09)	(0.16)	(0.25)	(0.31)	(0.30)	(0.27)
$\widehat{CBE}_{t+h\|t}$	0.05	0.48	0.76	0.93	0.98	1.03	0.97	0.89	0.81
	(0.14)	(0.16)	(0.12)	(0.12)	(0.19)	(0.24)	(0.27)	(0.25)	(0.20)
	mean of $d_{SE}\left(CIR^{post}_{t+h\|t}, x^q_{t+h\|t}\right)$ with $x^q_{t+h\|t} = \ldots$								
$ME^{pre}_{t+h\|t}$	−0.02	−0.03	0.07	0.22	0.25	0.20	0.14	0.11	0.16
	(0.28)	(0.33)	(0.19)	(0.24)	(0.48)	(0.65)	(0.74)	(0.75)	(0.61)
$\widehat{ME}^{post}_{t+h\|t}$	0.00	0.05	0.15	0.28	0.31	0.27	0.19	0.18	0.25
	(0.27)	(0.27)	(0.14)	(0.20)	(0.41)	(0.58)	(0.69)	(0.67)	(0.52)
$\widehat{CBE}_{t+h\|t}$	−0.01	0.15	0.35	0.48	0.51	0.55	0.52	0.46	0.42
	(0.25)	(0.22)	(0.18)	(0.22)	(0.39)	(0.45)	(0.49)	(0.50)	(0.47)
	mean of $d_{SE}\left(ME^{pre}_{t+h\|t}, x^q_{t+h\|t}\right)$ with $x^q_{t+h\|t} = \ldots$								
$\widehat{ME}^{post}_{t+h\|t}$	0.02	0.08	0.08	0.06	0.07	0.07	0.05	0.07	0.09
	(0.29)	(0.25)	(0.20)	(0.14)	(0.10)	(0.18)	(0.41)	(0.37)	(0.33)
$\widehat{CBE}_{t+h\|t}$	0.01	0.19	0.28	0.26	0.26	0.35	0.38	0.35	0.26
	(0.33)	(0.23)	(0.20)	(0.23)	(0.30)	(0.30)	(0.33)	(0.38)	(0.50)
	mean of $d_{SE}\left(\widehat{ME}^{post}_{t+h\|t}, x^q_{t+h\|t}\right)$ with $x^q_{t+h\|t} = \ldots$								
$\widehat{CBE}_{t+h\|t}$	−0.01	0.11	0.20	0.20	0.19	0.28	0.33	0.28	0.17
	(0.27)	(0.30)	(0.25)	(0.28)	(0.38)	(0.33)	(0.33)	(0.41)	(0.62)
	Banco Central do Brasil								
N		38	37	30	19				
	mean of $d_{SE}\left(CIR^{post}_{t+h\|t}, x^q_{t+h\|t}\right)$ with $x^q_{t+h\|t} = \ldots$								
$ME^{pre}_{t+h\|t}$		0.82	1.70	0.07	−1.36				
		(0.26)	(0.36)	(0.98)	(0.83)				

Note: N denotes the sample size, h is the forecast horizon in quarters. Positive values of d_{SE} indicate that the forecast $x^q_{t+h|t}$ is more accurate. p-values are in parentheses. For the tests, Newey-West (1987) standard errors are employed. The truncation lag is set to h.

Table 3.10: Test results for equal predictive accuracy of inflation mean forecasts based on squared errors

h	0	1	2	3	4	5	6	7	8
	Bank of England								
N	36	36	36	36	36	35	34	33	32
	mean of $d_{SE}\left(\hat{\pi}^{CIR^{pre}}_{t+h\|t}, x^q_{t+h\|t}\right)$ with $x^q_{t+h\|t} = \dots$								
$\pi^{CIR^{post}}_{t+h\|t}$	0.00	0.00	−0.01	0.01	0.04	0.12	0.16	0.17	0.14
	(0.45)	(0.44)	(0.59)	(0.16)	(0.27)	(0.33)	(0.31)	(0.34)	(0.37)
$\pi^{ME^{pre}}_{t+h\|t}$	0.00	0.00	0.01	0.03	0.03	0.07	0.10	0.15	0.19
	(0.56)	(0.80)	(0.57)	(0.09)	(0.41)	(0.57)	(0.55)	(0.43)	(0.33)
$\hat{\pi}^{ME^{post}}_{t+h\|t}$	0.00	0.00	0.00	0.03	0.05	0.10	0.12	0.16	0.20
	(0.44)	(0.53)	(0.90)	(0.07)	(0.27)	(0.46)	(0.50)	(0.43)	(0.37)
$\hat{\pi}^{CBE}_{t+h\|t}$	0.00	−0.01	−0.02	0.00	0.03	0.08	0.11	0.15	0.19
	(0.44)	(0.31)	(0.43)	(0.91)	(0.41)	(0.49)	(0.52)	(0.50)	(0.46)
	mean of $d_{SE}\left(\pi^{CIR^{post}}_{t+h\|t}, x^q_{t+h\|t}\right)$ with $x^q_{t+h\|t} = \dots$								
$\pi^{ME^{pre}}_{t+h\|t}$	0.00	0.00	0.01	0.02	−0.01	−0.05	−0.06	−0.02	0.05
	(0.31)	(0.16)	(0.08)	(0.11)	(0.55)	(0.09)	(0.09)	(0.53)	(0.31)
$\hat{\pi}^{ME^{post}}_{t+h\|t}$	0.00	0.00	0.01	0.02	0.01	−0.02	−0.04	−0.01	0.06
	(0.46)	(0.95)	(0.13)	(0.09)	(0.55)	(0.34)	(0.19)	(0.86)	(0.42)
$\hat{\pi}^{CBE}_{t+h\|t}$	0.00	0.00	−0.01	−0.01	−0.01	−0.03	−0.05	−0.02	0.05
	(0.46)	(0.25)	(0.39)	(0.65)	(0.46)	(0.12)	(0.13)	(0.76)	(0.67)
	mean of $d_{SE}\left(\pi^{ME^{pre}}_{t+h\|t}, x^q_{t+h\|t}\right)$ with $x^q_{t+h\|t} = \dots$								
$\hat{\pi}^{ME^{post}}_{t+h\|t}$	0.00	0.00	0.00	0.00	0.01	0.03	0.02	0.01	0.01
	(0.32)	(0.31)	(0.46)	(0.39)	(0.05)	(0.10)	(0.22)	(0.49)	(0.74)
$\hat{\pi}^{CBE}_{t+h\|t}$	0.00	−0.01	−0.02	−0.03	−0.01	0.01	0.02	0.00	−0.01
	(0.35)	(0.20)	(0.20)	(0.32)	(0.75)	(0.54)	(0.52)	(0.99)	(0.92)
	mean of $d_{SE}\left(\hat{\pi}^{ME^{post}}_{t+h\|t}, x^q_{t+h\|t}\right)$ with $x^q_{t+h\|t} = \dots$								
$\hat{\pi}^{CBE}_{t+h\|t}$	0.00	0.00	−0.02	−0.03	−0.02	−0.01	0.00	−0.01	−0.02
	(0.45)	(0.21)	(0.17)	(0.20)	(0.33)	(0.47)	(0.87)	(0.66)	(0.60)
	Banco Central Do Brasil								
N	47	46	45	44	43	42			
	mean of $d_{SE}\left(\pi^{CIR^{post}}_{t+h\|t}, x^q_{t+h\|t}\right)$ with $x^q_{t+h\|t} = \dots$								
$\pi^{ME^{pre}}_{t+h\|t}$	0.00	−0.11	−0.22	−0.15	0.72	1.87			
	(0.31)	(0.45)	(0.57)	(0.78)	(0.34)	(0.15)			

Note: N denotes the sample size, h is the forecast horizon in quarters. Positive values of d_{SE} indicate that the forecast $x^q_{t+h|t}$ is more accurate. p-values are in parentheses. For the tests, Newey-West (1987) standard errors are employed. The truncation lag is set to h.

Table 3.11: Test results for equal predictive accuracy of GDP growth mean forecasts based on squared errors

h	0	1	2	3	4	5	6	7	8
	Bank of England								
N	36	36	36	36	36	35	34	33	32
	mean of $d_{SE}\left(\hat{y}^{CIR^{pre}}_{t+h\|t}, x^q_{t+h\|t}\right)$ with $x^q_{t+h\|t} = \ldots$								
$y^{CIR^{post}}_{t+h\|t}$	−0.03	−0.08	−0.09	−0.09	−0.06	−0.01	0.01	0.02	0.02
	(0.17)	(0.26)	(0.25)	(0.25)	(0.28)	(0.65)	(0.61)	(0.35)	(0.66)
$y^{ME^{pre}}_{t+h\|t}$	−0.02	−0.07	−0.12	−0.19	−0.22	−0.14	−0.09	−0.08	−0.13
	(0.16)	(0.19)	(0.16)	(0.20)	(0.29)	(0.40)	(0.45)	(0.31)	(0.09)
$\hat{y}^{ME^{post}}_{t+h\|t}$	−0.05	−0.13	−0.19	−0.26	−0.27	−0.16	−0.09	−0.07	−0.15
	(0.22)	(0.24)	(0.19)	(0.20)	(0.27)	(0.39)	(0.47)	(0.38)	(0.09)
$\hat{y}^{CBE}_{t+h\|t}$	−0.05	−0.15	−0.21	−0.30	−0.30	−0.17	−0.09	−0.08	−0.16
	(0.23)	(0.25)	(0.19)	(0.18)	(0.24)	(0.36)	(0.47)	(0.35)	(0.08)
	mean of $d_{SE}\left(y^{CIR^{post}}_{t+h\|t}, x^q_{t+h\|t}\right)$ with $x^q_{t+h\|t} = \ldots$								
$y^{ME^{pre}}_{t+h\|t}$	0.01	0.01	−0.04	−0.10	−0.16	−0.13	−0.10	−0.11	−0.15
	(0.26)	(0.61)	(0.27)	(0.26)	(0.31)	(0.37)	(0.35)	(0.22)	(0.05)
$\hat{y}^{ME^{post}}_{t+h\|t}$	−0.01	−0.05	−0.10	−0.17	−0.21	−0.14	−0.10	−0.10	**−0.16**
	(0.39)	(0.21)	(0.16)	(0.20)	(0.28)	(0.36)	(0.37)	(0.27)	(0.04)
$\hat{y}^{CBE}_{t+h\|t}$	−0.02	−0.07	−0.12	−0.20	−0.24	−0.16	−0.10	−0.10	**−0.18**
	(0.34)	(0.23)	(0.16)	(0.17)	(0.24)	(0.32)	(0.37)	(0.25)	(0.03)
	mean of $d_{SE}\left(y^{ME^{pre}}_{t+h\|t}, x^q_{t+h\|t}\right)$ with $x^q_{t+h\|t} = \ldots$								
$\hat{y}^{ME^{post}}_{t+h\|t}$	−0.02	−0.06	−0.06	−0.07	−0.05	−0.01	0.00	**0.01**	−0.01
	(0.32)	(0.30)	(0.29)	(0.28)	(0.30)	(0.44)	(0.06)	(0.04)	(0.54)
$\hat{y}^{CBE}_{t+h\|t}$	−0.03	−0.08	−0.09	−0.10	−0.08	−0.03	0.00	0.01	−0.03
	(0.31)	(0.30)	(0.27)	(0.22)	(0.21)	(0.24)	(0.73)	(0.48)	(0.30)
	mean of $d_{SE}\left(\hat{y}^{ME^{post}}_{t+h\|t}, x^q_{t+h\|t}\right)$ with $x^q_{t+h\|t} = \ldots$								
$\hat{y}^{CBE}_{t+h\|t}$	−0.01	−0.02	−0.02	−0.03	−0.03	−0.01	0.00	−0.01	−0.02
	(0.28)	(0.31)	(0.22)	(0.12)	(0.09)	(0.15)	(0.71)	(0.29)	(0.06)

Note: N denotes the sample size, h is the forecast horizon in quarters. Positive values of d_{SE} indicate that the forecast $x^q_{t+h|t}$ is more accurate. Bold numbers are significantly different from 0 at the 5% significance level. p-values are in parentheses. For the tests, Newey-West (1987) standard errors are employed. The truncation lag is set to h.

Table 3.12: Test results for equal predictive accuracy of inflation density forecasts based on logarithmic scores

h	0	1	2	3	4	5	6	7	8
	Bank of England								
N	36	36	36	36	36	35	34	33	32
	mean of $d_{LS}\left(\hat{\pi}^{CIR^{pre}}_{t+h\|t}, x^q_{t+h\|t}\right)$ with $x^q_{t+h\|t} = \dots$								
$\pi^{CIR^{post}}_{t+h\|t}$	0.00	0.00	0.00	0.01	0.03	0.06	0.07	0.05	0.04
	(0.70)	(0.50)	(0.79)	(0.10)	(0.26)	(0.40)	(0.37)	(0.49)	(0.61)
$\pi^{ME^{pre}}_{t+h\|t}$	0.00	0.00	0.01	0.03	0.02	0.02	0.02	0.04	0.06
	(0.95)	(0.98)	(0.45)	(0.07)	(0.48)	(0.84)	(0.86)	(0.72)	(0.59)
$\hat{\pi}^{ME^{post}}_{t+h\|t}$	0.00	0.00	0.01	0.04	0.04	0.03	0.03	0.04	0.05
	(0.69)	(0.63)	(0.64)	(0.07)	(0.25)	(0.67)	(0.78)	(0.73)	(0.70)
$\hat{\pi}^{CBE}_{t+h\|t}$	0.00	−0.01	−0.02	0.00	0.01	0.01	0.01	0.01	0.01
	(0.68)	(0.29)	(0.48)	(0.87)	(0.69)	(0.87)	(0.93)	(0.96)	(0.92)
	mean of $d_{LS}\left(\pi^{CIR^{post}}_{t+h\|t}, x^q_{t+h\|t}\right)$ with $x^q_{t+h\|t} = \dots$								
$\pi^{ME^{pre}}_{t+h\|t}$	0.00	0.00	0.01	0.02	0.00	−0.04	−0.05	−0.02	0.02
	(0.31)	(0.17)	(0.08)	(0.09)	(0.86)	(0.27)	(0.23)	(0.52)	(0.60)
$\hat{\pi}^{ME^{post}}_{t+h\|t}$	0.00	0.00	0.01	0.03	0.01	−0.02	−0.04	−0.02	0.01
	(0.74)	(0.82)	(0.18)	(0.10)	(0.48)	(0.52)	(0.27)	(0.59)	(0.81)
$\hat{\pi}^{CBE}_{t+h\|t}$	0.00	−0.01	−0.01	−0.01	−0.02	−0.04	**−0.06**	−0.05	−0.02
	(0.70)	(0.22)	(0.37)	(0.69)	(0.45)	(0.11)	(0.05)	(0.28)	(0.80)
	mean of $d_{LS}\left(\pi^{ME^{pre}}_{t+h\|t}, x^q_{t+h\|t}\right)$ with $x^q_{t+h\|t} = \dots$								
$\hat{\pi}^{ME^{post}}_{t+h\|t}$	0.00	0.00	0.00	0.00	**0.01**	**0.02**	0.01	0.00	−0.01
	(0.36)	(0.29)	(0.45)	(0.35)	(0.03)	(0.04)	(0.33)	(0.92)	(0.68)
$\hat{\pi}^{CBE}_{t+h\|t}$	0.00	−0.01	−0.03	−0.03	−0.01	0.00	−0.01	−0.03	−0.04
	(0.40)	(0.18)	(0.14)	(0.21)	(0.56)	(0.86)	(0.68)	(0.25)	(0.31)
	mean of $d_{LS}\left(\hat{\pi}^{ME^{post}}_{t+h\|t}, x^q_{t+h\|t}\right)$ with $x^q_{t+h\|t} = \dots$								
$\hat{\pi}^{CBE}_{t+h\|t}$	0.00	−0.01	−0.02	−0.03	−0.03	−0.02	−0.02	−0.03	−0.03
	(0.58)	(0.20)	(0.13)	(0.13)	(0.23)	(0.29)	(0.23)	(0.09)	(0.17)
	Banco Central Do Brasil								
N	47	46	45	44	43	42			
	mean of $d_{LS}\left(\pi^{CIR^{post}}_{t+h\|t}, x^q_{t+h\|t}\right)$ with $x^q_{t+h\|t} = \dots$								
$\pi^{ME^{pre}}_{t+h\|t}$	−0.02	0.00	−0.02	−0.03	0.06	0.11			
	(0.43)	(0.96)	(0.70)	(0.63)	(0.35)	(0.18)			

Note: N denotes the sample size, h is the forecast horizon in quarters. Positive values of d_{LS} indicate that the forecast $x^q_{t+h|t}$ is more accurate. Bold numbers are significantly different from 0 at the 5% significance level. p-values are in parentheses. For the tests, Newey-West (1987) standard errors are employed. The truncation lag is set to h.

Table 3.13: Test results for equal predictive accuracy of GDP growth density forecasts based on logarithmic scores

h	0	1	2	3	4	5	6	7	8
	Bank of England								
N	36	36	36	36	36	35	34	33	32
	mean of $d_{LS}\left(\hat{y}^{CIR^{pre}}_{t+h\|t}, x^q_{t+h\|t}\right)$ with $x^q_{t+h\|t} = \ldots$								
$y^{CIR^{post}}_{t+h\|t}$	−0.02	−0.05	−0.04	−0.04	−0.02	0.00	0.01	0.01	0.01
	(0.44)	(0.28)	(0.29)	(0.30)	(0.38)	(0.87)	(0.56)	(0.28)	(0.37)
$y^{ME^{pre}}_{t+h\|t}$	−0.01	−0.04	−0.06	−0.08	−0.08	−0.03	−0.01	−0.02	−0.04
	(0.75)	(0.22)	(0.20)	(0.32)	(0.41)	(0.62)	(0.79)	(0.44)	(0.14)
$\hat{y}^{ME^{post}}_{t+h\|t}$	−0.02	−0.08	−0.10	−0.11	−0.10	−0.04	−0.01	−0.02	−0.04
	(0.52)	(0.24)	(0.21)	(0.28)	(0.37)	(0.59)	(0.80)	(0.50)	(0.15)
$\hat{y}^{CBE}_{t+h\|t}$	−0.03	−0.09	−0.11	−0.13	−0.11	−0.04	−0.01	−0.02	−0.05
	(0.48)	(0.25)	(0.20)	(0.25)	(0.33)	(0.55)	(0.78)	(0.46)	(0.12)
	mean of $d_{LS}\left(y^{CIR^{post}}_{t+h\|t}, x^q_{t+h\|t}\right)$ with $x^q_{t+h\|t} = \ldots$								
$y^{ME^{pre}}_{t+h\|t}$	0.01	0.01	−0.02	−0.05	−0.06	−0.03	−0.02	−0.03	−0.05
	(0.20)	(0.70)	(0.39)	(0.43)	(0.45)	(0.58)	(0.66)	(0.28)	(0.07)
$\hat{y}^{ME^{post}}_{t+h\|t}$	0.00	−0.03	−0.06	−0.08	−0.08	−0.04	−0.02	−0.03	−0.06
	(0.77)	(0.20)	(0.19)	(0.30)	(0.38)	(0.55)	(0.68)	(0.33)	(0.07)
$\hat{y}^{CBE}_{t+h\|t}$	−0.01	−0.04	−0.07	−0.09	−0.09	−0.04	−0.02	−0.03	−0.06
	(0.59)	(0.23)	(0.17)	(0.24)	(0.33)	(0.50)	(0.66)	(0.30)	(0.05)
	mean of $d_{LS}\left(y^{ME^{pre}}_{t+h\|t}, x^q_{t+h\|t}\right)$ with $x^q_{t+h\|t} = \ldots$								
$\hat{y}^{ME^{post}}_{t+h\|t}$	−0.01	−0.04	−0.03	−0.03	−0.02	0.00	0.00	0.00	0.00
	(0.39)	(0.29)	(0.29)	(0.28)	(0.29)	(0.44)	(0.27)	(0.07)	(0.70)
$\hat{y}^{CBE}_{t+h\|t}$	−0.02	−0.05	−0.05	−0.05	−0.03	−0.01	0.00	0.00	−0.01
	(0.37)	(0.30)	(0.26)	(0.21)	(0.18)	(0.19)	(0.87)	(0.95)	(0.26)
	mean of $d_{LS}\left(\hat{y}^{ME^{post}}_{t+h\|t}, x^q_{t+h\|t}\right)$ with $x^q_{t+h\|t} = \ldots$								
$\hat{y}^{CBE}_{t+h\|t}$	−0.01	−0.01	−0.01	−0.02	−0.01	−0.01	0.00	0.00	**−0.01**
	(0.34)	(0.33)	(0.19)	(0.10)	(0.08)	(0.15)	(0.54)	(0.20)	(0.03)

Note: N denotes the sample size, h is the forecast horizon in quarters. Positive values of d_{LS} indicate that the forecast $x^q_{t+h|t}$ is more accurate. Bold numbers are significantly different from 0 at the 5% significance level. p-values are in parentheses. For the tests, Newey-West (1987) standard errors are employed. The truncation lag is set to h.

A.2 Central Bank Statements on Forecast Conditioning Assumptions

Banco Central Do Brasil

First report available is from September 1999 ("Inflation Report") and states on p.79 that "Normally, the Inflation Reports will issue two fan charts. The first and most important is constructed on the assumption of a constant nominal interest rate over the course of the projection period, while the second is accessory by nature and is based on the assumption that the nominal interest rate will be that built-into market expectations."

Banco Central de Chile

Reports available since May 2000 ("Monetary Policy Report").

CIR for reports of May 2000 to May 2004. For instance, the report of September 2000, p.8, states that
"Confidence intervals [...] summarize the Central Bank's risk assessment for future economic growth, on the assumption that the monetary policy rate will remain at UF + 5.0% over the next two years."

ME assumption since report of September 2004, p.63:
"This section presents the Board's recent evaluation of Chile's economic prospects for the next two years, including the analysis and the decisions made during the last monetary policy meeting of 7 September 2004. It provides projections for the most likely course of inflation and economic growth, and examines the main risks. These projections are based on the methodological assumption that the monetary policy rate will reflect a gradual decline in the monetary impulse in coming years, consistent with achieving the inflation target focused on 3% and which is comparable to trends deduced from financial asset prices. Projections are also conditional on a series of developments that make up the baseline, or most likely, scenario. New information will modify this scenario and associated projections. Forecasts are presented in the form of confidence intervals, to reflect the future risks to monetary policy."

Also variations are reported, e.g. in the report of May 2009, p.23:
"The projections used in this Report are based on the working assumption that, in the short term, the MPR path will be similar to what can be inferred from financial asset prices on 8 May 2009. However, toward the end of the projection horizon, the MPR path will be lower than the trend being signaled by these prices."

Bank of England

Reports are available since 1997 ("Inflation Report").

CIR inflation forecasts since 1993 are available in a spreadsheet format under `www.bankofengland.co.uk/publications/inflationreport/irprobab.htm`

The report of February 1998 states on p.42 that
"The projection for inflation is based on the assumption that official interest rates will remain unchanged at 7.25% during the next two years. The projection was agreed by the Monetary Policy Committee (MPC) on 5 February. In addition, for the first time, a new projection is presented under the assumption that official interest rates follow market expectations over the next two years."

Bank of Japan

Reports available since October 2000 ("Outlook and Risk Assessment of the Economy and Prices", since April 2004 "Outlook for Economic Activity and Prices").

CIR assumption in early days, for instance in October 2000 (only available online under `http://www.boj.or.jp/en/mopo/outlook/gor0010.htm/`):
"The forecasts of Policy Board members are based on the assumption that there will be no change in monetary policy. Forecasts of the majority of Policy Board members are shown as a range with the highest and lowest figures excluded. If there are multiple highest and/or lowest figures, only one from either end is excluded."

Switch from CIR to ME assumption made with report of April 2006, p.8:
"Individual Policy Board members make the above forecasts with reference to market participants' view regarding the future course of the policy interest rate that is incorporated in market interest rates. Their forecasts made in October 2005 were based on the assumption that there would be no change in monetary policy."

Example of ME assumption in report of October 2011, p.17:
"Individual Policy Board members make their forecasts with reference to the view of market participants regarding the future course of the policy interest rate - a view that is incorporated in market interest rates."

Board of Governors of the Federal Reserve System

The conditioning assumptions of the Fed are not entirely clear.

Reifschneider and Tulip (2007), pp.12-13, state that Greenbook based on interest rate assumptions, while FOMC projections are made rather on a CBE assumption:
"A final issue of comparability concerns the conditionality of forecasts. Currently, each FOMC participant conditions his or her individual projection on "appropriate monetary policy", defined as the future policy most likely to foster trajectories for output and inflation consistent with the participant's interpretation of the dual mandate. Although the definition of "appropriate monetary policy" was less explicit in the past, Committee participants presumably

had a similar idea in mind when making their forecasts historically. Whether or not the other forecasters in our sample generated their projections on a similar basis is unknown, but we think it reasonable to assume that most sought to maximize the accuracy of their predictions and so conditioned their forecasts on their assessment of the most likely outcome for monetary policy. However, this assumption is not valid for the Greenbook projections. Through most of the 1990s, the Federal Reserve staff conditioned its forecasts on a roughly flat path for the federal funds rate. This practice meant that real activity and inflation might evolve over the projection period in a way that was potentially inconsistent with the FOMC's policy objectives and, therefore, unlikely to occur. That is, the staff took the approach over much of our sample period of designing its forecasts not to maximize forecasting accuracy but instead to inform the FOMC about the potential consequences of unchanged policy. Thus, the Greenbook's historical forecast errors may tend to overstate the uncertainty of the outlook to some degree."

The "Semiannual Monetary Policy Report to the Congress" of February 2007 names for the first time the term "appropriate monetary policy" which is likely to correspond to a CBE assumption (available online under `http://www.federalreserve.gov/newsevents/testimony/bernanke20070214a.htm`):
"The central tendency of those forecasts - which are based on the information available at that time and on the assumption of appropriate monetary policy–is for real GDP to increase about 2-1/2 to 3 percent in 2007 and about 2-3/4 to 3 percent in 2008."

Goodhart (2009), p.87, finds that
"For simplicity, most MPCs initially chose constant future policy interest rates, from the latest available level, as their main framing assumption. Occasionally, such an assumption would have been grossly at odds with perceived reality, as in the case of the United States from 2004 until early 2006, when the explicit position of the Federal Open Market Committee (FOMC) was for there to be a "measured increase" in policy rates over time. In that case, the Greenbook conditioning assumption, which has also been usually for constant rates,3 is widely believed to have been changed, but the degree of secrecy, and length of lag before publication (five years), means that we will not have confirmation of this for some time."

European Central Bank

The ECB in "A Guide to Eurosystem Staff Macroeconomic Projection Exercises" of June 2001 states on p.7 the CIR assumption:
"The projections are based on the technical assumption that three-month interest rates in the euro area remain constant over the horizon of the projection."

Publication of June 2006 staff projections, p.1, available online under `http://www.ecb.int/pub/pub/mopo/html/index.en.html?skey=staff+macroeconomic+projections`, has

the ME assumption underlying:
"For the first time, the Eurosystem projections are based on the technical assumption that short-term market interest rates move in line with market expectations rather than, as previously assumed, remain constant over the projection horizon. This change is of a purely technical nature. It was introduced in order to further improve the quality and the internal consistency of the macroeconomic projections and does not imply any change in the ECB's monetary policy strategy or in the role of projections within that strategy."

Magyar Nemzeti Bank

Reports available since June 2000 ("Report on Inflation").

MNB has moved from CIR assumption to CBE assumption, as stated in the report of March 2011 on p.15:
"Starting in march 2011, the staff of the national Bank of Hungary moved on to the preparation of a forecast with endogenous policy rate path from former forecasts with unchanged policy rate. The change is in line with the practice of inflation targeting central banks, the majority of which also having shifted to forecasts with endogenous policy rate path."

Reserve Bank of Australia

First report available is from February 1997 (changing names since then; "Quarterly Report on the Economy and Financial Markets", "Semi-Annual Statement on Monetary Policy", "The Economy and Financial Markets"; since November 2000 "Statement on Monetary Policy").

Switch from CIR to ME assumption with "Statement on Monetary Policy" of August 2009:
"The forecasts presented below are based on the assumption that the exchange rate remains around its current level and that oil prices move broadly in line with near-term futures pricing. In previous Statements the forecasts were prepared using the additional technical assumption that the cash rate remained constant throughout the forecast period. In the current environment, however, it is not particularly realistic to assume that the cash rate remains at the historically low level of 3 per cent out to the end of 2011. Given this, the current forecasts have been prepared on the technical assumption of a return towards a more normal setting of monetary policy over the forecast horizon. This use of a more realistic technical assumption by the Bank staff in no way constitutes a commitment by the Board to a particular future path of the cash rate."

Reserve Bank of New Zealand

In the Reserve Bank of New Zealand Bulletin 65 No. 2 of June 2002, the article by Hampton (2002) states on p.6:

"In order to understand our preference for using an endogenous interest rate path, it is intuitive to refer to the period prior to our use of the endogenous policy reaction function. Up until 1997, the projections used in policy evaluation and in the Bank's publications were conventional constant interest rate projections. Interest rates and the exchange rate were generally held constant throughout the projection horizon at the values prevailing at the time the forecasts were prepared."

Sveriges Riksbank

The report of March 1997, p.21, ("Inflation Report" until 2007, since 2007 "Monetary Policy Report") introduces CIR assumption; before 1997 not really forecasting but rather deriving inflation expectations:
"The assessment of inflation in the coming years is presented in this chapter, together with some conceivable alternative paths. [...] A technical assumption for the assessment is that economic policy remains unchanged."

Example from report of December 2002, p.46 hints at scenario analysis with ME assumption:
"In the Riksbank's main scenario [...], inflation is forecast as usual on the technical assumption that the repo rate will be unchanged at the present level of 4.0 per cent; this serves to bring out the consequences for the formation of monetary policy. An illustrative calculation is therefore presented here that incorporates a path for the repo rate that is in line with market expectations as reported in the survey that Prospera undertook on behalf of the Riksbank in November 2002."

Switch to ME assumption with report 2005:3, p.5, of October 2005:
"The analyses in the Report's main scenario to date have been based on the assumption that the repo rate is held unchanged for the coming two years. In this Report the forecasts in the main scenario are based instead on the assumption that the repo rate evolves in line with financial market expectations, as reflected in implied forward interest rates. These forecasts extend three years ahead. One advantage of such an assumption is that it normally provides a more realistic picture of future monetary policy. Another benefit is that it makes it easier to compare the Riksbank's forecasts with those of other forecasters. Moreover, it facilitates evaluations of the forecasts. One advantage of extending the forecast horizon is that it gives a clearer idea of how inflation is being influenced by various temporary shocks."

Explanations on the entire strategy are provided in the Monetary Policy Report 2007/1 of February 2007 in a box starting on p.19:
"Up to the autumn of 2005, the Riksbank based its forecasts in the main scenario on the assumption that the repo rate remained constant during the forecast period. This made it easy for the Riksbank to communicate, which was particularly important when establishing

the new monetary policy regime and building up credibility for the inflation target. At the same time, it was mostly an unrealistic assumption that made it difficult to make good forecasts. Moreover, it gave no clear guidance as to how the Riksbank viewed future interest rate developments. This was a disadvantage since the general public's and the markets' expectations of the future interest rate path are just as important for the way monetary policy influences the economy as the expectations regarding the decision on the current level of the interest rate. These problems diminished when the Riksbank began making forecasts based on market expectations, as reflected in implied forward rates (Footnote: Between 1999 and 2003, the Riksbank published alternative inflation forecasts based on repo rate expectations in market surveys. The Riksbank's decision to publish its own forecasts for the repo rate is a further step towards greater clarity. Market expectations do not necessarily reflect the considerations that form the basis for monetary policy decisions. By making its own forecasts for the repo rate, the Riksbank can explain more clearly to the general public and the financial markets how it envisages future interest rate developments and how it reasons when making monetary policy decisions. It is also natural in forecasting work to treat the repo rate as one forecast variable among others."

Swiss National Bank

SNB has introduced the CIR assumption in 1999 and has since not changed it.

In the Monetary Policy Report of 2000, p.1, available online under `http://www.snb.ch/en/iabout/monpol/earlier/id/monpol_earlier_1999/pdf/monpol_earlier_1999.pdf`, is says that

"At the end of 1999, the National Bank for the first time published a medium-term inflation forecast and a target range for the three-month Libor rate."

The Monetary Policy Report of 2001, p.1, available online under `http://www.snb.ch/en/iabout/monpol/earlier/id/monpol_earlier_2000/pdf/monpol_earlier_2000.pdf`, completes:

"The inflation forecast published by the National Bank in December 2000 predicted that, at an unchanged interest rate of 3.5%, inflation would increase somewhat in the course of 2001 and slightly exceed 2% for a limited period of time."

The Quarterly Bulletin of December 2011 reports on p.7 that

"These forecasts are based on the assumption of a constant three-month Libor of 0% over the entire twelve-month forecast horizon and implies a depreciating Swiss franc."

Chapter 4

Forecast Uncertainty and the Bank of England's Interest Rate Decisions

Abstract: To assess the Bank of England's Monetary Policy Committee decisions on the official bank rate under forecast uncertainty, I estimate simple forecast-based interest rate rules augmented by the exact forecast standard deviations recovered directly from the Inflation Report fan charts. I find that forecast inflation uncertainty strongly intensifies the reaction of the interest rate decisions to a forecast deviation of inflation from target. Conversely, forecast output growth uncertainty attenuates the reaction of the interest rate decisions to a forecast deviation of output growth from its long-run mean. Asymmetries in forecast uncertainty are highly relevant for inflation. Forecast upward risks to inflation contribute strongly to the intensifying effect of forecast inflation uncertainty, while forecast downward risks have hardly any significant impact. Moreover, I find that forecast risks to inflation have a direct effect on the interest rate decisions, in particular when inflation is forecast close to target. Uncertainty forecasts obtained from the Survey of External Forecasters, though, contain no explanatory power.

Keywords: Forecast Uncertainty, Forecast Risk, Bank of England
Monetary Policy Committee, Forecast-based Interest Rate Rules
JEL-Codes: E37, C12, C53

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4.1 Introduction

Adequate monetary policy is widely recognized to be forward-looking. It is a common view that interest rate decisions hinge crucially on a proper assessment of future developments in prices and output so as to account for the lags in monetary policy transmission. As the future is unknown, practical central banking is concerned with forecasting inflation and output growth. Forecasts, however, are inherently subject to uncertainty. Nowadays, monetary policy makers are aware of this significant issue and central banks, such as the Bank of England, Sveriges Riksbank, Banco de Portugal, or Magyar Nemzeti Bank, to name but a few, publish not only point forecasts for inflation and output growth but entire probability distributions of the forecast variables. By doing so, these institutions explicitly quantify forecast uncertainty.

Forecasting entire densities is not an end in itself. If monetary policy decisions are made subject to economic prospects, it seems reasonable that uncertainty about these prospects may have an influence on the decisions. The Bank of England (BoE) refined its inflation targeting and introduced its Monetary Policy Committee (MPC) in June 1997. Since then, it has been a leading institution in making monetary policy decisions and forecasts publicly available. In 1997Q4, the BoE started to jointly publish quarterly forecasts for inflation and real output growth, together with their corresponding forecast uncertainty measures, for up to two years out in its Inflation Report. I use the considerable record of interest rate decisions and quarterly forecasts to contribute to the still narrow field of literature dealing with forecast-based interest rate rules augmented by measures of forecast uncertainty and forecast risk.

Forecast-based rules encompass the lags of monetary policy transmission, and the forecast data are already conditioned on the relevant information set on future economic developments, see Batini and Haldane (1999). Thus, forecast-based rules can be a fairly precise and yet compact tool for characterizing historical monetary policy decisions, as shown by Kuttner (2004) who evaluates forecast-based rules for New Zealand, Sweden, the United Kingdom, and the United States. Similarly, Goodhart (2005) presents estimates of a forecast-based BoE MPC reaction function and emphasizes the MPC's high degree of forward-looking with respect to inflation. Besley, Meads, and Surico (2008) analyze the role of heterogeneity among the board members of the BoE MPC in a forecast-based rule setting. Gorter et al. (2008, 2009) provide evidence for the performance of interest rate rules for the European Central Bank, based on expectations data constructed from Consensus Economics forecasts. Orphanides and Wieland (2008) explain the Federal Open Market Committee decisions by its own projections for inflation and unemployment.

Regarding the impact of forecast uncertainty on interest rate decisions, Bhattacharjee and Holly (2010) use a mix of observed and forecast data, including the BoE fan chart one-year-ahead input standard deviations for inflation and output growth when analyzing the BoE

MPC members' decisions in a panel estimation of interest rate reaction functions. Despite the fact that most of their coefficient estimates on uncertainty measures are insignificant, inflation uncertainty is positively correlated with the change in interest rates while output uncertainty is negatively correlated. Kim and Nelson (2006) use standardized prediction errors for inflation and output as a bias correction in their forecast-based interest rules for the Federal Reserve. Their findings differ over subsamples, but basically show that the probability of an interest rate reaction to a change in inflation, sufficiently strong to stabilize the economy, deteriorates when accounting for inflation uncertainty. Accounting for output uncertainty tends to improve the probability of a sufficiently strong reaction. The studies by Martin and Milas (2005a, 2005b, 2006, 2009), who investigate UK and US monetary policy in forward-looking policy rules are noteworthy. They use observed inflation and output data and control for the impact of inflation and output volatility derived from GARCH processes. Their basic result is that inflation uncertainty dampens the policy response to inflation, favoring the attenuation principle of Brainard (1967).

The uncertainty measures mentioned above are already good approximations. Yet, they do not reflect the measure of uncertainty that the institution under study was facing when making the monetary policy decision. For the BoE, I therefore recover the exact forecast standard deviation for inflation and for output growth directly from the forecast densities published by the BoE, as proposed by Wallis (2004). These forecast standard deviations originally associated with the forecast location parameters reflect the genuine and thus relevant measure of uncertainty about future economic developments which the MPC has available at the time the interest rate decision is made. I include the forecast standard deviations directly in reaction functions in order to estimate the strength and the direction of the impact of forecast uncertainty on the MPC interest rate responses to forecast deviations of inflation from target and output growth from long-run mean. Since the BoE emphasizes its use of the two-piece normal distribution, potential asymmetries in forecast uncertainty have to be taken into consideration. Forecast uncertainty is asymmetric when an average of likely alternative outcomes for one variable is seen to exceed or to fall short of the central projection for that variable. The MPC defines such a difference between mean and mode forecast as forecast risk to the central projection. I control for these risks by incorporating their normalized values, the exact forecast Pearson mode skewness for inflation and for output growth, into the regression models.

I find that the MPC interest rate decisions react to deviations of forecast inflation from target in the medium term, that is, for one and a half year or more out. When accounting for the forecast inflation uncertainty, I find a strongly intensifying effect on interest rate reactions. The partial effect of the forecast standard deviation implies a very aggressive MPC behavior in order to pursue the inflation target. Forecasts for current and near-term inflation and their associated forecast uncertainty measures have no significant impact. On the other hand, information from forecast demeaned output growth for the near term is used, and its associated forecast uncertainty has an attenuating effect on the interest rate decision response. Unlike inflation, output growth medium-term forecasts have no explanatory power for the interest rate decisions.

When accounting for asymmetries in forecast uncertainty I find that forecast upward risks to inflation contribute to the intensifying effect of forecast inflation uncertainty, while the corresponding downward risks to inflation hardly have an effect. This casts doubt on the BoE statement that the inflation target is symmetric. Forecast risks of either direction to forecast output growth have no significant effect for the relevant forecast horizons. Moreover, I find that the forecast risk for inflation has a direct effect on interest rate decisions, in particular when the central projection for inflation is close to target.

Using direct uncertainty and risk measures constructed from the density forecasts of the Survey of External Forecasters (SEF), which is prominently featured in each Inflation Report, adds no information to the Monetary Policy Committee's own uncertainty forecasts. While forecast standard deviations for inflation and output growth are insignificant, risk measures constructed from the survey data are indicating the same directions of risks as their bank counterparts. Although there is mild evidence that the committee reacts to risk measures derived from the survey, these results have to be interpreted with caution due to the, in comparison with the BoE mode forecast, rougher construction of the modal value from SEF histogram data.

The paper is organized as follows: Section two explains the data set used. Section three shows the regression model and estimation results for a forecast-based interest rate reaction function augmented by forecast uncertainty. Section four assesses asymmetries in the forecast uncertainty. Section five provides results from re-estimating the models on SEF data. Section six concludes.

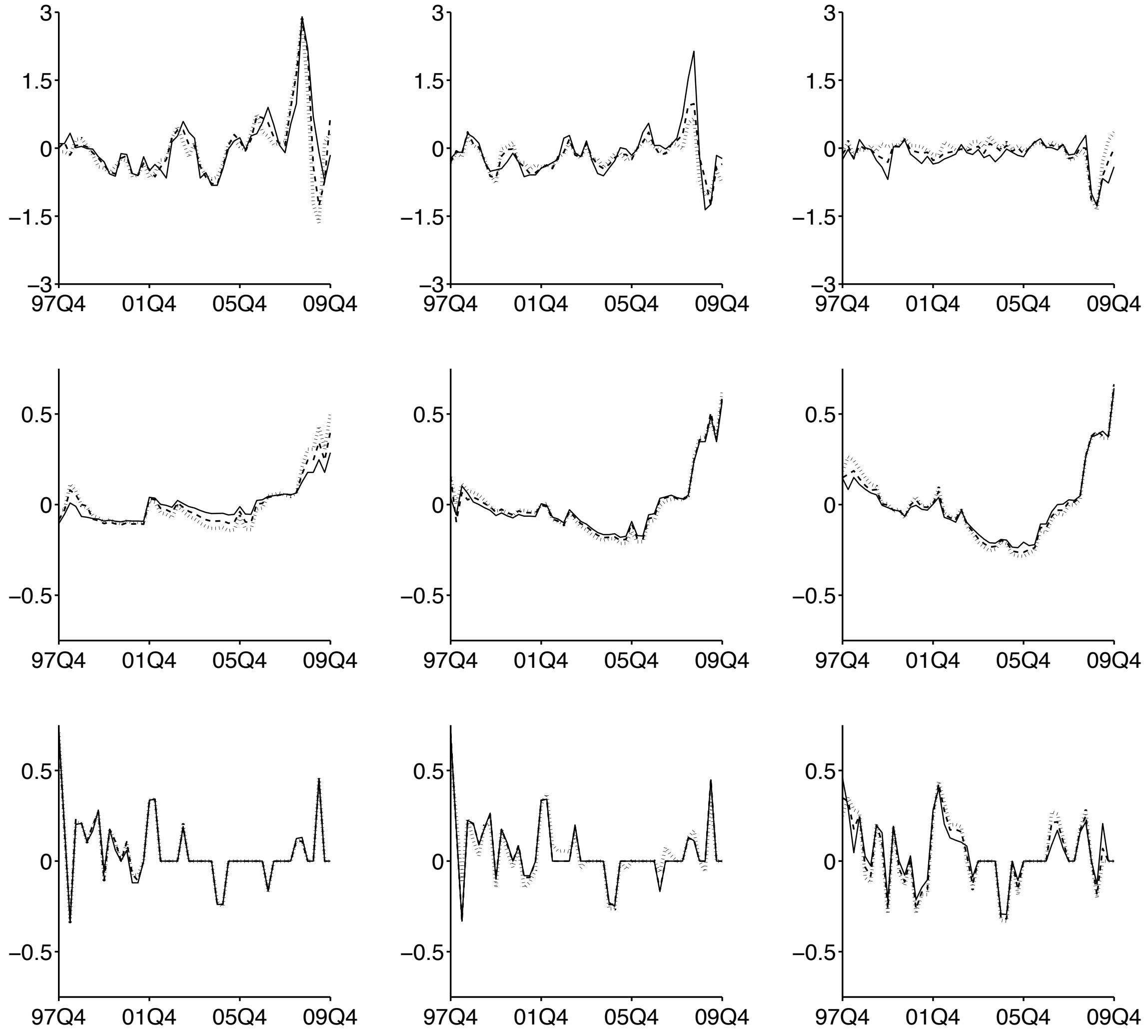
4.2 Data

4.2.1 Interest Rate Decisions

The interest rate data for this study have been collected from the interest rate voting spreadsheet published on the BoE website. They refer to the decision of the MPC on the level of the key interest rate, the official bank rate, from 1997Q3 to 2009Q4.[1] Interest rate decisions are made monthly by the MPC. I select, however, only the values of the end-of-quarter months, that is, of March, June, September and December, for mainly two reasons. First, I thereby choose only those decisions which are made in light of the most recent forecast results pre-

[1] The BoE key interest rate was (named) the 'repo rate' from 1997 to 2006.

Figure 4.1: Plots of Bank of England forecast data for inflation



Note: Bank of England data spans from 1997Q4 to 2009Q4 (49 observations). Top panels: deviation of mode forecast from target. Middle panels: demeaned forecast standard deviation. Bottom panels: forecast Pearson mode skewness. Panels in left column show forecast horizons $h = 0$ (solid), $h = 1$ (dashed) and $h = 2$ (dotted), panels in middle column $h = 3$ (solid), $h = 4$ (dashed) and $h = 5$ (dotted) and panels in right column $h = 6$ (solid), $h = 7$ (dashed) and $h = 8$ (dotted).

sented in the BoE Inflation Report.[2] These reports, and thus the forecasts, are published only quarterly, in the middle of the mid-quarter months February, May, August and November. The assessment of the economy underlying the decisions of the first and second months of the quarters are not available, such that it is a natural switch to quarterly frequency for the following analysis. Second, with the timing of the dependent variable, I aim to circumvent the undesired introduction of endogeneity between interest rate decisions and forecasts for

[2]The observation resulting from the extra meeting after September 11 is dropped. It was unanimously decided to lower interest rates by 25 basis points.

inflation and output growth. The standard notation for the quarterly series of the bank rate and the lagged series with 49 observations in each is i_t and i_{t-1}, respectively.[3]

4.2.2 Forecast Inflation and Forecast Real Output Growth

The BoE has popularized presenting its forecasts for inflation and real output growth as fan charts, a bird's-eye view of the probability distributions of the forecasts made for the two-year forecast horizon. These "fan charts [...] encompass the views of all members" with respect to the medium-term outlook for the UK economy, as stated on the top page of the Inflation Report of February 1998.[4] Underlying the fan charts is an entire forecast density based on the two-piece normal distribution. Hence, the BoE publishes three forecast location parameters, mean, mode and median, together with a measure of uncertainty and a measure of the skew of the distribution.[5]

From the location parameters, I choose the mode forecast as the relevant point forecast, since it is highlighted as the central projection by the BoE. Moreover, I focus on the available constant-rate nowcasts and forecasts, made for up to eight quarters ahead. In the BoE terminology, 'constant-rate forecasts' means that forecasts are made conditional on the assumption that monetary policy remains unchanged over the forecast horizon.[6] The inflation forecasts are indexed by $h = 0, \dots, 8$, and the output growth forecasts are indexed by $k = 0, \dots, 8$.[7] Using constant-rate forecasts only should drain another source of endogeneity that may arise from forecasts conditioned on interest rates which, in turn, depend on market expectations about the future course of monetary policy. The Bank used to forecast RPIX inflation until the end of 2003, targeted at 2.5%. Since the Inflation Report of February 2004, the target has remained at an annual CPI inflation of 2%.[8] As an inflation measure for the interest rate

[3]The official bank rate has been lowered massively since the financial turmoil following the Lehman collapse, from a 2008Q3 value of 5% to a 2009Q1 value of 0.5%. Since then it has remained at that level. As a consequence, a decreasing time trend might indeed be eye-balled out in the MPC interest rate decisions. I skip plots and detailed unit root test results here, but the four alternative test results obtained from conducting the Ng and Perron (2001) test utilizing a spectral GLS-detrended autoregression based on modified AIC with automatic lag length selection indicate three times a rejection and one time no rejection of the null of a unit root. To this end, interest rates are treated as being stationary throughout this study.

[4]The Inflation Report's introductory statement on the fan charts has been refined over time. In the Inflation Report of August 1998, it already says that the "fan charts represent the MPC's best collective judgement about the most likely paths for inflation and output, and the uncertainties surrounding those central projections."

[5]The entire forecast history is provided as 'Numerical Parameters for [...] Probability Distributions' on the BoE website.

[6]Since 1998Q1, in addition to its density forecasts made conditional on constant interest rates, the BoE publishes 'market-rate' density forecasts, where it is assumed that interest rates follow a path as expected by market participants, given certain adjustments.

[7]The BoE presents fixed-horizon forecasts for up to two years ahead, although market-rate forecasts for up to three years ahead are available from 2004Q3 onwards. I repeated the estimation exercises with market-rate forecast data and also instrumented the forecast data by lagged forecast data. The efforts, however, did not result in further insights beyond the results shown here.

[8]Actually, the Chancellor of the Exchequer, the British cabinet minister responsible for economic and financial matters, announces the inflation target every 12 months.

rules, I calculate the deviation of forecast inflation from target for time $t + h$, made at time t, denoted by $\tilde{\pi}_{t+h|t} \equiv \pi_{t+h|t} - \pi^*$. Since the BoE's potential output or trend output measure data are not published, I use the deviation of forecast output growth from its long-run mean as an output measure instead.[9] This is denoted by $\tilde{y}_{t+k|t} \equiv y_{t+k|t} - \bar{y}_k$, where the latter term, $\bar{y}_k$, implies that the mean is taken horizon-wise over the time domain.[10] Using data as deviations from target and mean, respectively, imposes an expected value of zero for the exogenous regressors. The top panels of figures 4.1 and 4.2 show plots of these variables.

4.2.3 Forecast Inflation Uncertainty and Forecast Real Output Growth Uncertainty

The BoE forecasts have a two-piece normal distribution potentially skewed, as described in Britton, Fisher, and Whitley (1998). The aforementioned measure of uncertainty, also called 'input standard deviation' in the BoE material, corresponds to the forecast standard deviation of this two-piece normal distribution only if its forecast density is symmetric, see Wallis (2004). Whenever forecast mode and forecast mean do not coincide, the forecast variance and, hence, the forecast standard deviation have to be calculated using the reported parameters. For a two-piece normal distributed variable X, the variance is given by

$$\sigma_X^2 = \left(1 - \frac{2}{\pi}\right)(\sigma_2 - \sigma_1)^2 + \sigma_1\sigma_2. \tag{4.1}$$

A two-piece normal distribution has parameters μ, σ_1 and σ_2, where μ is the mode of the distribution, and σ_1 and σ_2 are the dispersion parameters, see, for instance, Novo and Pinheiro (2005). The larger the difference between σ_1 and σ_2 is, the more skewed is the density. While the mode forecast published by the BoE corresponds to μ, the dispersion parameters have to be calculated as described by Wallis (2004). They are given by $\sigma_1 = \omega/(1 + \gamma)$ and $\sigma_2 = \omega/(1 - \gamma)$, where γ can be recovered from

$$\gamma = sign(s)\sqrt{1 - 4\left(\frac{\sqrt{1 + \pi s^2} - 1}{\pi s^2}\right)}, \tag{4.2}$$

which depends on a standardized measure of skewness,

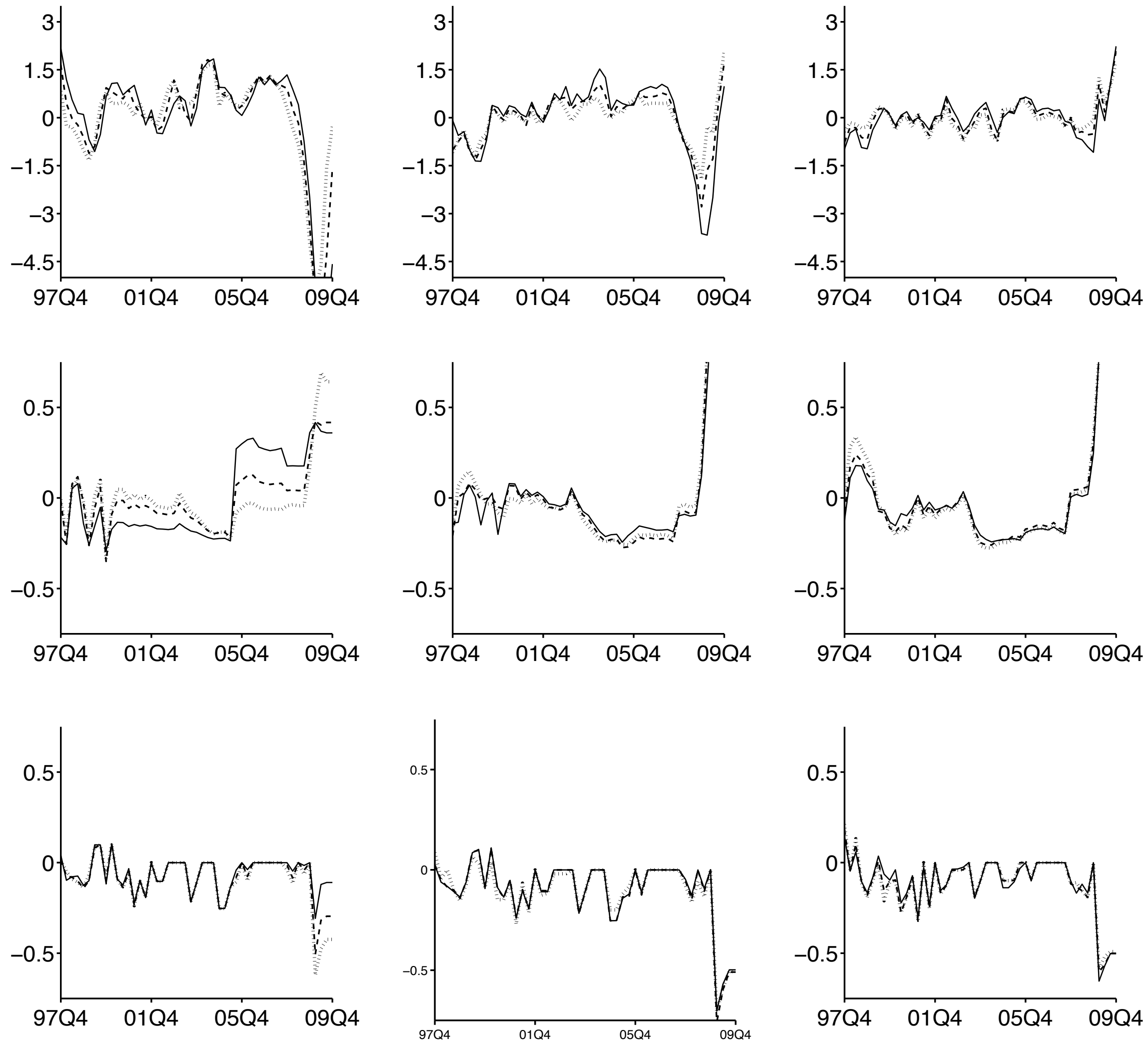
$$s = \frac{E(X) - \mu}{\omega}. \tag{4.3}$$

Inserting the BoE mean forecasts for $E(X)$, the mode forecasts for μ, and the input standard deviations for ω, we can calculate the latter quantity as the starting value to recover the fore-

[9] Using HP-filtered output data alternatively has not led to results different from those presented below.

[10] For all demeaned figures presented in this study, the mean is taken, for each forecast horizon separately, over the time domain.

Figure 4.2: Plots of Bank of England forecast data for real output growth



Note: Bank of England data spans from 1997Q4 to 2009Q4 (49 observations). Top panels: demeaned mode forecast. Middle panels: demeaned forecast standard deviation. Bottom panels: forecast Pearson mode skewness. Panels in left column show forecast horizons $h = 0$ (solid), $h = 1$ (dashed) and $h = 2$ (dotted), panels in middle column $h = 3$ (solid), $h = 4$ (dashed) and $h = 5$ (dotted) and panels in right column $h = 6$ (solid), $h = 7$ (dashed) and $h = 8$ (dotted).

cast standard deviation for each inflation report density. I repeat this exercise for all nine forecast horizons. The resulting series are demeaned and in the following denoted by $\tilde{\sigma}_{\pi,t+h|t} \equiv \sigma_{\pi,t+h|t} - \bar{\sigma}_{\pi,h}$ for forecast inflation uncertainty and by $\tilde{\sigma}_{y,t+h|t} \equiv \sigma_{y,t+h|t} - \bar{\sigma}_{y,h}$ for forecast real output growth uncertainty. The middle panels of figures 4.1 and 4.2 provide plots of the time series.

4.2.4 Forecast Inflation Risk and Forecast Real Output Growth Risk

The BoE uses the functional form of the two-piece normal distribution also to communicate forecast risks to its central projection, which is the mode forecast. If an average of considered alternatives is likely to exceed [fall short of] the central projection, then the forecast mean is larger [smaller] than the mode forecast. In that case, the BoE speaks of an upward [downward] risk.

The reported measure of skew, i.e. the difference between the mean and mode forecast, is the quantification of that risk. I normalize the risk figures with the respective forecast standard deviation and obtain a simple and scale-free measure of skewness, known as Pearson mode skewness:

$$\kappa_{x,t+h|t} \equiv \frac{x^e_{t+h|t} - x_{t+h|t}}{\sigma_{x,t+h|t}}, x \in \{\pi, y\}. \tag{4.4}$$

Besides its desirable testing properties that have been analyzed in Knüppel and Schultefrankenfeld (2011), the Pearson mode skewness is a measure of risk that is most closely related to the original BoE measure of risk and the quantities used to construct the Inflation Report's density forecasts. The relationship becomes obvious when comparing the definition in equation (4.4) with equation (4.3).

The Pearson mode skewness is used to account for the asymmetries of forecast uncertainty in the following regression analysis. In addition, I separate the interest rate reactions under forecast uncertainty into the cases where alternative outcomes of inflation and output growth are likely to either exceed or to drop below the respective central projection. Yet, I reduce the information of the Pearson mode skewness to the direction of risk. A variable $I^+_{x,t+h}, x \in \{\pi, y\}$ takes value one when the central projection is subject to an upward risk and the forecast period considered is marked by an upward risk and, accordingly, by a positive Pearson mode skewness. In the case of downward risks and balanced risks it takes value zero:

$$I^+_{x,t+h} = \begin{cases} 1, & \text{if} \quad \kappa_{x,t+h|t} > 0 \\ 0, & \text{if} \quad \kappa_{x,t+h|t} \leq 0 \end{cases}. \tag{4.5}$$

Conversely, if the central projection is subject to downward risks, a variable $I^-_{x,t+h}, x \in \{\pi, y\}$ takes value -1 and is zero otherwise:

$$I^-_{x,t+h} = \begin{cases} -1, & \text{if} \quad \kappa_{x,t+h|t} < 0 \\ 0, & \text{if} \quad \kappa_{x,t+h|t} \geq 0 \end{cases}. \tag{4.6}$$

Table 4.1 shows the number of forecast risks by forecast horizons h and k. The first row of the top panel shows the number of occasions when the inflation mean was forecast to exceed the inflation mode forecast, implying an upward risk forecast. This is the prevalent

Table 4.1: Overview on the Bank of England's number of forecast upward, balanced and downward risks

h	0	1	2	3	4	5	6	7	8
$\pi^e_{t+h\|t} - \pi_{t+h\|t} > 0$	16	16	16	16	16	22	22	21	18
$\pi^e_{t+h\|t} - \pi_{t+h\|t} = 0$	26	26	26	26	26	15	16	15	18
$\pi^e_{t+h\|t} - \pi_{t+h\|t} < 0$	7	7	7	7	7	12	11	13	13
k	0	1	2	3	4	5	6	7	8
$y^e_{t+h\|t} - y_{t+h\|t} > 0$	4	4	4	4	4	4	3	3	2
$y^e_{t+h\|t} - y_{t+h\|t} = 0$	18	17	17	17	17	14	13	15	15
$y^e_{t+h\|t} - y_{t+h\|t} < 0$	27	28	28	28	28	31	33	31	32

Note: Bank of England data spans from 1997Q4 to 2009Q4 (49 observations).

case for forecasts made for more than four quarters out, i.e. $h = 5 \dots, 7$. At the policy horizon ($h = 8$), upward and balanced risks have been forecast equally often. For the nowcast and forecasts up to one year out, however, balanced risks to inflation are the major case, with 26 out of 49 risk forecasts being balanced.

Downward risks to inflation, where the mean is forecast to fall short of the mode, were present in 7 out of 49 forecasting rounds for the forecast horizons up to one year. Forecast output growth has tended to be subject to balanced risks and even more so to downward risks over the sample period of this study. This is also reflected in the data plots in the bottom panels of figure 4.1 and figure 4.2, where the Pearson mode skewness series for all forecast horizons over the entire sample are drawn, thus adding the time dimension to Table 4.1. Only the early forecast history shows upward risks to forecast output growth, and there has been no forecast upward risk after 2001Q1.[11] Moreover, the plots reveal that risk forecasts are relatively close together over horizons, where inflation risk shows more cross-sectional variation when approaching the policy horizon.

4.3 Forecast-based Interest Rate Rules augmented by Forecast Uncertainty

4.3.1 The Regression Model

The starting point for the regression analysis are forecast-based interest rate rules as proposed by Batini and Haldane (1998, 1999) and analyzed by, e.g., Levin, Wieland, and Williams (2003) or Kuttner (2004). The functional forward-looking specification is also known from Clarida et al. (1998, 2000). Since forecasts are inherently subject to uncertainty, the question arises of whether (and, if so, in which direction and to what extent) the responses to forecast

[11] See Knüppel and Schultefrankenfeld (2012) for a comprehensive study of the BoE inflation risk forecasts.

inflation and forecast output growth are affected when forecast uncertainty is included in a forecast-based rule. The BoE has emphasized the role of forecast uncertainty by reporting entire probability distributions for inflation and output growth in its Inflation Reports. The importance of forecast uncertainty is underlined by the careful construction of the Inflation Report fan charts which visualize ranges of possible future developments in prices and output. When the MPC decides on the level of interest rates in response to economic prospects, then the Bank's own measures of uncertainty about these prospects should play a significant role in the decision-making process.

To this extent, I augment a forecast-based rule by an interaction term of the forecast inflation gap with the demeaned forecast standard deviation for inflation and an interaction term of demeaned forecast real GDP growth with the corresponding demeaned forecast standard deviation. Since demeaned uncertainty measures enter the specification it is assumed that the MPC in general recognizes forecasts to be subject to uncertainty. Only deviations from the 'usual level' of uncertainty play a role. The resulting model is written as

$$i_t = c + \rho i_{t-1} + \alpha_\pi \tilde{\pi}_{t+h|t} + \alpha_y \tilde{y}_{t+h|t} + \alpha_{\pi\pi} \tilde{\pi}_{t+h|t} \tilde{\sigma}_{\pi,t+h|t} + \alpha_{yy} \tilde{y}_{t+h|t} \tilde{\sigma}_{y,t+h|t} + \varepsilon_t, \qquad (4.7)$$

where ε_t is a zero-mean error term.[12] The parameters α_π and α_y represent the reaction to a change in the forecast inflation gap and forecast demeaned output growth when forecast uncertainty is on track, i.e. equals the long-run mean. Whenever the forecast standard deviations depart from their mean, $\alpha_{\pi\pi}$ and α_{yy} capture the response of the MPC decisions to forecast uncertainty. The partial effects of forecast inflation gap and demeaned forecast output growth are thus linear transformations of the respective forecast standard deviations. That is, the policy reactions depend on forecast uncertainty:

$$\frac{\partial i_t}{\partial \tilde{\pi}_{t+h|t}} = \alpha_\pi + \alpha_{\pi\pi} \tilde{\sigma}_{t+h|t}, \qquad \frac{\partial i_t}{\partial \tilde{y}_{t+h|t}} = \alpha_y + \alpha_{yy} \tilde{\sigma}_{t+h|t}. \qquad (4.8)$$

The reaction function given by equation (4.7) is estimated for all 81 possible combinations of the forecast horizons h for inflation and k for output growth. This is to check, without preconceived notions, which combination of forecast data has the greatest explanatory power for interest rate decisions. Moreover, this is intended to detect the degree of forward-looking of the MPC, since the forecasts might not be equally informative to the decision makers. To account for the sluggish adjustment of output, it is likely that the MPC considers current or very near-term output developments for today's interest rate decisions. These developments can be evaluated and the interest rate can be set such that a desired growth path in the future is more likely to be achieved. Yet, output data as provided by the Office for National Statistics (ONS) are published, at best, with a lag of one quarter. Furthermore, GDP figures are usually

[12]Below, ε_t always denotes a zero-mean error term.

subject to extensive revision after their initial release. If the MPC wants to respond to current and very-near term output developments, it is ultimately forced to forecast.

As regards the inflation forecasts, inflation today cannot be affected by monetary policy action, so the inflation nowcast might not be important for the interest rate decision. The BoE medium-term objective, though, is to have two-year-ahead inflation back on target. Although not explicitly stated, this two-year policy horizon is highlighted in every Inflation Report inflation prospects section and, for instance, was referred to in a recent speech by former MPC member Kate Barker (2010), p.9, where "the MPC has tended to put weight on the projection for CPI inflation around two years ahead". Thus, the inflation forecasts for one and a half years up to two years ahead, i.e. for $h = 6, 7, 8$, can be expected to be highly informative. If the Bank forecasts a deviation from target for the medium-term perspective, it seems reasonable that today's interest rate decisions respond to them. Yet, the BoE is leaving herself a way out in the Inflation Report of November 2000, when stating on p. 67 that "The inflation projection is a key input to policy decisions. However, there is no mechanical link between the projected level of inflation in two years' time based on constant interest rates and the appropriate current setting of monetary policy."

4.3.2 Estimation Results

Figure 4.3 visualizes the p-values for the usual two-sided t-tests when estimating equation (4.7). One array consists of $(\max(h) + 1) \times (max(k) + 1) = 81$ tiles. The conventional row- and column order of a matrix is changed here. Along the x-axis, the horizon of the inflation forecasts, h, ascends from 0 quarters (the nowcast) to 8 (the policy horizon), and along the y-axis, real output growth forecast horizon k ascends from 0 to 8 quarters out. White [light gray, dark gray] tiles imply significance of the estimate at the 1% [5%, 10%] level, and black tiles imply an insignificant estimate. That is, the tile in a bottom left corner corresponds to the marginal significance level of a coefficient estimate when the regression model is estimated on a combination of nowcast data. The tile in a right upper corner consequently implies a combination of forecasts for the policy horizon, and so on. For instance, in the lower right panel for $\alpha_{\pi\pi}$, the white tile at $(h = 0, k = 0)$ implies that an estimate of the coefficient $\alpha_{\pi\pi}$ is significantly different from zero at the 1% level, when the rule is estimated on inflation data for $h = 0$ and real output growth data for $k = 0$. It is significantly different from zero at the 10% level, when the rule is estimated on inflation data for $h = 0$ and real output growth data for $k = 8$, as indicated by the dark gray tile. Finally, the p-value exceeds 0.10 for the combination $h = 8$ and $k = 0$, rendering this estimate insignificant. As indicated by the shading, the MPC interest rate decisions respond to forecasts for output growth for up to one and a half years ahead. Longer-term forecasts, i.e. horizons $k = 6, 7, 8$, are not taken into account. Conversely, the responses to the inflation gap vanish for $h = 0, \ldots, 6$, whereas for

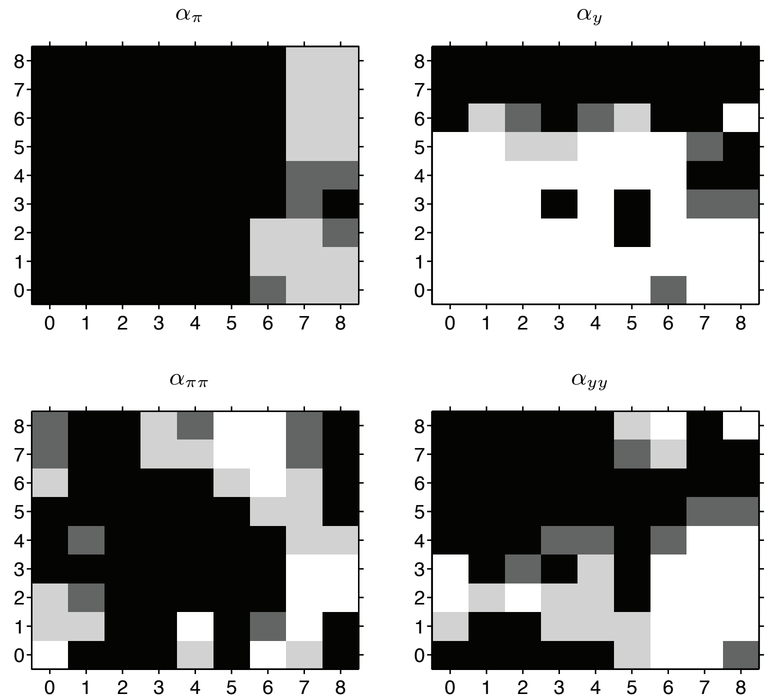
$h = 7, 8$ they seem to provide the relevant information content required to set interest rates in response to forecasts. The arrays for the estimates of $\alpha_{\pi\pi}$ and α_{yy}, though, are more mixed. The significance pattern, however, remains intact, with short-term output growth uncertainty forecasts and inflation uncertainty forecasts at the policy horizon mattering, as indicated by white tiles.

Combining inflation forecasts for $h = 7, 8$ and real output growth forecasts for $k = 1, 2, 3$ yields the most promising specifications in terms of the log-likelihood, as Table 4.2, comprising the best results from estimating equation (4.7), selected by their log-likelihood, shows. The findings on the horizon choice of the MPC reverify the results of Goodhart (2005), who similarly detects diminishing estimates for inflation at shorter horizons and for output growth at farther horizons. The results based on inflation forecasts for $h = 7$ have an even higher log-likelihood than for the policy horizon $h = 8$. This can be interpreted as support to the argument of Bhattacharjee and Holly (2010), who state that two-years ahead forecasts are less informative since they are adjusted to meet the inflation target in a policy-consistent manner, while the forecast deviations from target for one period earlier are less subject to judgement but yield more information content on which to base interest rate decisions.

The immediate implication of the results in Table 4.2 is that the MPC is very forward-looking with respect to inflation, but considers the very near term with respect to output growth. In terms of the log-likelihood, the horizon combination ($h = 7, k = 2$) yields the best description of monetary policy for the period 1997Q4 to 2009Q4. The autoregressive parameter, however, reflects quite inertial interest rates, with $\hat{\rho} = 0.99$.[13] The MPC seems to have a strong desire to smooth interest rates, with only little additional information from the forecasts utilized, given the degree of forward-looking implied by this horizon combination. Hence, the reaction to a change in forecast inflation seven quarters ahead is relatively weak, implied by $\hat{\alpha}_\pi = 0.68$, significant at the 5% level. Hence, this estimate does not satisfy the principle proposed by Taylor (1993), according to which the coefficient should exceed unity, implying an overproportional reaction of interest rates to a change in inflation to stabilize the economy. What is highly significant is the fairly weak reaction to a change in output growth, as reflected by $\hat{\alpha}_y = 0.20$. The findings of the optimal degree of forward-looking implied by ($h = 7, k = 2$) partly contradict the results of the theoretical literature on optimal monetary policy rules, for instance, by Svensson (2001) and by Giannoni and Woodford (2003), where optimal policy should, rather, depend on forecasts for the current period or the very near term. Levin et al. (2003) come to similar conclusions. Their benchmark rule for US data, however, depends on the current output gap forecast and the one-year-ahead inflation gap forecast, with interest rates being very persistent. Longer horizons are advocated by Batini and Nelson (2001), who provide UK data VAR evidence that the optimal feedback horizon of monetary policy is between two and four years.

[13]Throughout this study, I stick to the notational convention using hat characters to denote estimates of coefficients.

Figure 4.3: Visualized marginal significance levels for coefficient estimates when varying the forecast horizons in equation (4.7)



Note: X-axes show forecast horizons h and Y-axes forecast horizons k. White [light gray, dark gray] tiles imply significance of the estimate at the 1% [5%, 10%] level, and black tiles imply an insignificant estimate.

The significant estimates of coefficients $\alpha_{\pi\pi}$ and α_{yy}, which capture the interest rate reactions in response to a change in forecast uncertainty, are remarkable. In particular for the tuple $(h = 7, k = 2)$, the high value of $\hat{\alpha}_{\pi\pi} = 3.51$ is significant at the 1% level and implies a very aggressive reaction by the MPC when forecast inflation in almost two years ahead becomes very uncertain. The positive sign of the estimate is particularly sensible bearing in mind that the BoE seeks to have two-year-ahead inflation back on target. Any uncertainty about achieving this target results in increased efforts to finally succeed.

A hint that these clear-cut results are not obvious comes again from the Inflation Report of November 2000, p.67. If forecast uncertainty proxies the uncertainty "about the current conjuncture or the impact of any policy change, both of which tend to encourage more cautious decisions", then a reading of this report's box would lead one to expect a negative value of $\alpha_{\pi\pi}$.

However, the significantly positive value found is not overly surprising and corresponds to the idea of "preventing particularly costly outcomes", as Ben Bernanke (2007) puts it.[14]

[14]The speech "Monetary Policy under Uncertainty" is available on the Board of Governors of the Federal Reserve System webpage.

Table 4.2: Selected OLS estimation results for equation (4.7) - Accounting for forecast uncertainty

(h,k)	c	ρ	α_π	α_y	$\alpha_{\pi\pi}$	α_{yy}	ℓ
$(7,1)$	-0.03	0.98***	0.82**	0.20***	3.70***	−0.95***	-7.71
	(0.24)	(0.05)	(0.33)	(0.05)	(0.90)	(0.14)	
$(7,2)$	-0.08	0.99***	0.68**	0.20***	3.51***	−0.75***	-5.97
	(0.18)	(0.04)	(0.34)	(0.07)	(0.80)	(0.07)	
$(7,3)$	0.19	0.95***	0.70*	0.16*	3.18***	−0.51***	-10.49
	(0.26)	(0.05)	(0.41)	(0.09)	(1.07)	(0.08)	
$(8,1)$	-0.20	1.00***	1.04***	0.24***	0.98	−0.70***	-13.64
	(0.23)	(0.05)	(0.26)	(0.04)	(0.94)	(0.17)	
$(8,2)$	−0.46***	1.05***	0.71**	0.27***	1.64***	−0.68***	-10.61
	(0.17)	(0.04)	(0.28)	(0.06)	(0.54)	(0.07)	
$(8,3)$	−0.35***	1.04***	0.72*	0.23**	1.95***	−0.55***	-12.48
	(0.13)	(0.03)	(0.39)	(0.10)	(0.70)	(0.06)	

Note: Bank of England data spans from 1997Q4 to 2009Q4 (49 observations). Figures in parentheses are Newey-West (1987) standard errors where the bandwidth parameter is chosen based on the procedure proposed by Andrews (1991). Asterisks [*, **, ***] correspond to the marginal significance level of the coefficient estimates of [10%, 5%, 1%].

When the MPC forecasts that two-year-ahead inflation will be off target, it will change interest rates today. If forecast uncertainty becomes larger and confidence bands widen so to give a certain probability to values that are even more off target, the MPC will increase efforts to ultimately meet its two-year-ahead objective. Such aggressive behavior is in line with the robust control theory of Hansen and Sargent (2008). In the context of a New-Keynesian model, Soederstroem (2002) finds on p.126 that "when the central bank attaches some weight to stabilizing output in addition to inflation", uncertainty about inflation (persistence) increases the policy response, while "uncertainty about other parameters, in contrast, always dampens the policy response".

That finding is supported by the highly significant coefficient estimate $\hat{\alpha}_{yy} = -0.75$ for $(h = 7, k = 2)$. Forecast uncertainty of output growth can be considered as a proxy for uncertainty about the current state of the economy. If forecast uncertainty is high such that positive point estimates are surrounded by confidence bands that reach well into negative territory, the MPC might be better off with a cautious interest rate change, as suggested by the Inflation Report of November 2000. The motivation could be to avoid the danger of having changed interest rates too much when output growth indeed materializes below zero. The cautious MPC dampens its response to a change in forecast output growth when the forecast standard deviation of output growth increases, in favor of the attenuation principle of Brainard (1967). Another explanation for the dampened response could be based on a certain trade-off between forecast uncertainty and data uncertainty the MPC might have. Estimates of current real GDP are subject to forecast uncertainty, as early releases of GDP are subject to revisions. Any change in forecast uncertainty also affects the forecast uncertainty/data uncertainty trade-off. As the reliability of forecast output growth deteriorates with increasing forecast uncertainty, and the relative reliability of reported data thus improves, the response of interest rates to a change in forecast output growth becomes muted.

4.4 Accounting for Asymmetric Uncertainty Forecasts

4.4.1 The Regression Model

In every forecasting period there is a certain probability that forecast inflation exceeds the inflation target. In particular for $h = 7$, the best horizon in terms of the log-likelihood, and for $h = 8$, the policy horizon, inflation is usually forecast close to target, as seen in the top panels of figure 4.1. Given that forecast uncertainty is higher at longer-term forecast horizons, outcomes well above the target are to be taken into account. The BoE explains in its current monetary policy framework statements that "Inflation below the target of 2% is judged to be just as bad as inflation above the target. The inflation target is therefore symmetrical".[15] This implies a symmetric loss function and concern about either forecast upward and forecast downward risks.

However, a development of prices towards high inflation is in general considered a more important issue than a development towards low inflation. A forecast upward risk implies that inflation is expected to materialize above the central projection. If the central projection is forecast close to target, forecast upward risk indicates that inflation is more likely to be materialize even closer to target. Since upward risks also mean that forecast uncertainty is greater on the upside, inflation can be expected to realize above target with a certain probability. To the contrary, downward risks imply that inflation is expected to fall below the central projection and to drop below the inflation target more likely.

One way to account for forecast risks and to assess whether the MPC loss function is probably asymmetric is to include the Pearson mode skewness into the regression model introduced by equation (4.7). The resulting reaction function is written as

$$\begin{aligned} i_t = & c + \rho i_{t-1} + \alpha_\pi \tilde{\pi}_{t+h|t} + \alpha_y \tilde{y}_{t+h|t} + \alpha_{\pi\pi} \tilde{\pi}_{t+h|t} \tilde{\sigma}_{\pi,t+h|t} + \alpha_{yy} \tilde{y}_{t+h|t} \tilde{\sigma}_{y,t+h|t} \cdots \\ & + \gamma_\pi \kappa_{\pi,t+h|t} + \gamma_y \kappa_{y,t+h|t} + \varepsilon_t. \end{aligned} \tag{4.9}$$

Estimates for γ_π and γ_y measure the response of the interest rate decisions to forecast risk and are expected to be positive. That is, if inflation (the same holds true for output

[15] See the BoE's 'Monetary Policy Framework' webpages for further documentation.

growth) is expected to materialize above the central projection, the interest rates change should be stronger than in the absence of risks. Conversely, a forecast downward risk should imply a less strong interest rate change than in the absence of risks. Another way to assess whether the interest rate reaction with respect to inflation (again, the same argument goes for output growth) in the presence of upward risks is different from those in the presence of downward risks, is to estimate a model that incorporates interactions of the indicator variables for the direction of forecast risk with the respective demeaned forecast standard deviation:

$$\begin{aligned} i_t =& c + \rho i_{t-1} + \alpha_\pi \tilde{\pi}_{t+h|t} + \alpha_y \tilde{y}_{t+h|t} + \alpha_{\pi\pi} \tilde{\pi}_{t+h|t} \tilde{\sigma}_{\pi,t+h|t} + \alpha_{yy} \tilde{y}_{t+h|t} \tilde{\sigma}_{y,t+h|t} \cdots \\ &+ \gamma^+_{\pi\pi} I^+_{\pi,t+h} \tilde{\sigma}_{\pi,t+h|t} + \gamma^+_{yy} I^+_{y,t+h} \tilde{\sigma}_{y,t+h|t} \cdots \\ &+ \gamma^-_{\pi\pi} I^-_{\pi,t+h} \tilde{\sigma}_{\pi,t+h|t} + \gamma^-_{yy} I^-_{y,t+h} \tilde{\sigma}_{y,t+h|t} + \varepsilon_t. \end{aligned} \tag{4.10}$$

The parameters $\gamma^+_{\pi\pi}$ and γ^+_{yy} capture the response to a forecast upward risk to forecast inflation and to forecast output growth. Conversely, $\gamma^-_{\pi\pi}$ and γ^-_{yy} are the responses to the respective forecast downward risks. The partial effects of forecast uncertainty are given by

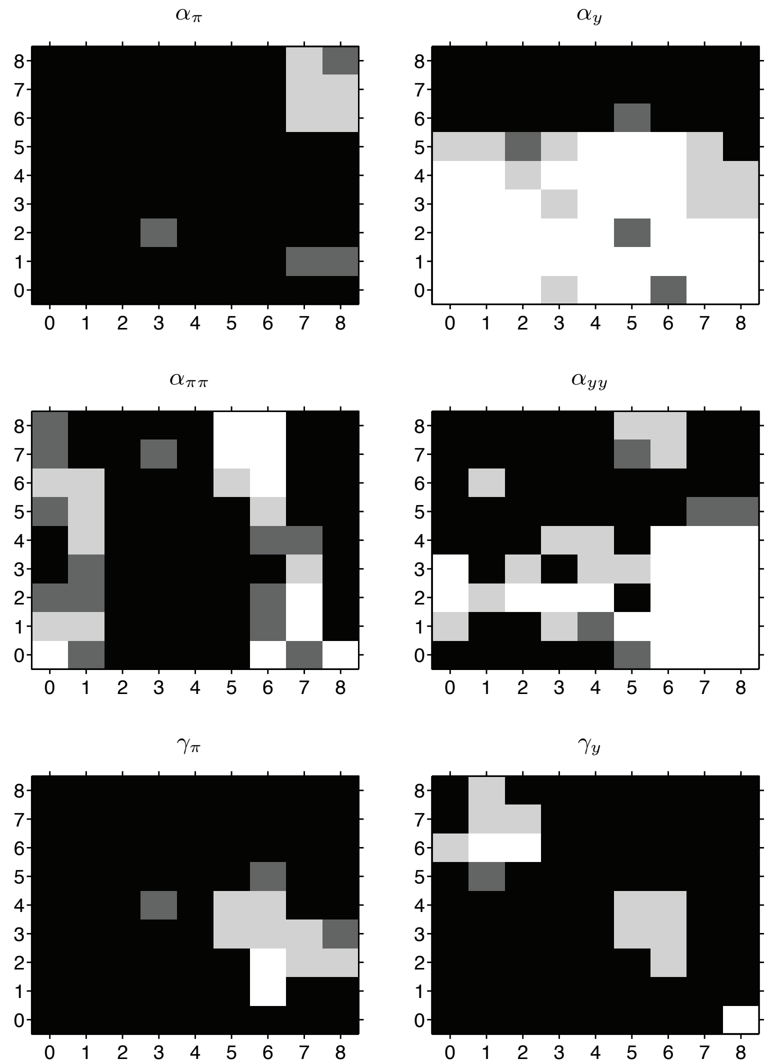
$$\begin{aligned} \frac{\partial i_t}{\partial \tilde{\sigma}_{\pi,t+h|t}} &= \alpha_{\pi\pi} \tilde{\pi}_{t+h|t} + \gamma^+_{\pi\pi} I^+_{\pi,t+h} + \gamma^-_{\pi\pi} I^-_{\pi,t+h}, \\ \frac{\partial i_t}{\partial \tilde{\sigma}_{y,t+h|t}} &= \alpha_{yy} \tilde{y}_{t+h|t} + \gamma^+_{yy} I^+_{y,t+h} + \gamma^-_{yy} I^-_{y,t+h}. \end{aligned} \tag{4.11}$$

If the BoE's loss function is symmetric, the reactions to a change in forecast uncertainty in the presence of forecast upward and forecast downward risks should be equally strong, i.e. $\gamma^+_{\pi\pi} = -\gamma^-_{\pi\pi}$ and $\gamma^+_{yy} = -\gamma^-_{yy}$ should hold.

4.4.2 Estimation Results

Except for slight variations, estimating equation (4.9) for all combinations of forecast horizons h and k yields about the same results as estimating equation (4.7), i.e. when not accounting for forecast risk. The overall significance pattern is again visualized by p-value arrays, shown in figure 4.4. The best six specifications selected by the log-likelihood are presented in Table 4.3, and the horizon combination ($h = 7, k = 2$) is again providing the best description of MPC interest rate decisions. Yet, the coefficient estimate on the inflation gap is insignificant. Coefficient estimates for $\alpha_{\pi\pi}$ and α_{yy}, however, are significant at the 1% level and quite strong, with values of 3.07 and -0.73, respectively. As before, the impact of forecast inflation uncertainty strengthens the response to a change in forecast inflation while the response to output growth is attenuated by forecast output growth uncertainty.

Figure 4.4: Visualized marginal significance levels for coefficient estimates when varying the forecast horizons in equation (4.9)



Note: X-axes show forecast horizons h and Y-axes forecast horizons k. White [light gray, dark gray] tiles imply significance of the estimate at the 1% [5%, 10%] level, and black tiles imply an insignificant estimate.

As the results show, asymmetries in the uncertainty forecast have a direct impact on interest rate decisions. An upward risk to the central projection for inflation causes an interest rate increase as reflected by $\hat{\gamma}_\pi = 0.69$, significant at the 1% level. If inflation is forecast to exceed the central projection at the policy horizon, the MPC responds with a stronger interest rate step than in a situation of balanced risks.

Table 4.3: Selected OLS estimation results for equation (4.9) - Accounting for forecast risk

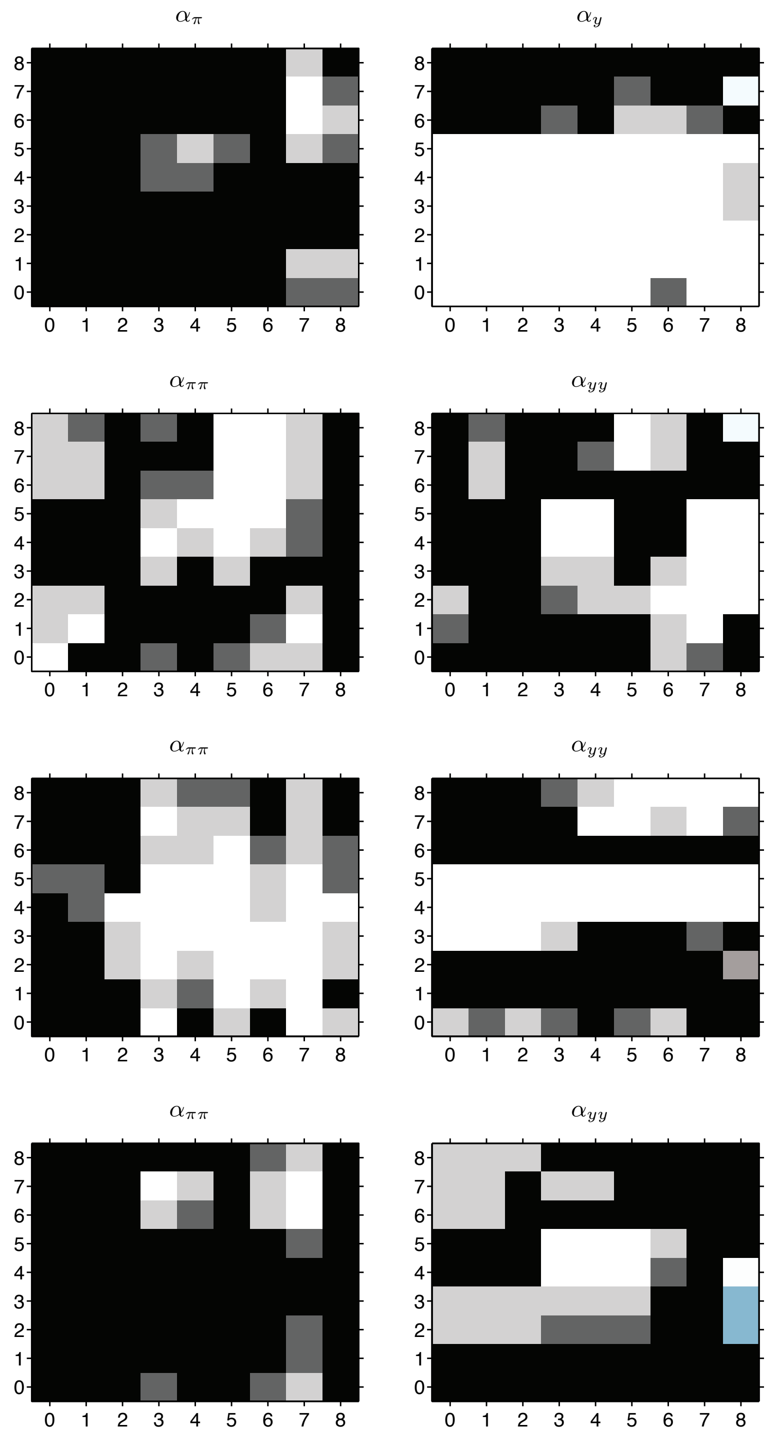
(h,k)	c	ρ	α_π	α_y	$\alpha_{\pi\pi}$	α_{yy}	γ_π	γ_y	ℓ
$(7,1)$	-0.05	0.98***	0.84*	0.22***	3.46***	-0.99***	0.60	-0.08	-4.73
	(0.19)	(0.05)	(0.47)	(0.04)	(1.18)	(0.17)	(0.40)	(0.97)	
$(7,2)$	-0.21	1.00***	0.65	0.25***	3.07***	-0.73***	0.69***	-0.49	-2.72
	(0.18)	(0.03)	(0.45)	(0.06)	(1.11)	(0.09)	(0.26)	(0.53)	
$(7,3)$	-0.12	0.99***	0.64	0.23***	2.80**	-0.48***	0.71**	-0.70	-7.28
	(0.25)	(0.04)	(0.55)	(0.09)	(1.38)	(0.05)	(0.35)	(0.46)	
$(8,1)$	-0.27	0.99***	1.19***	0.27***	0.40	-0.71***	0.82*	-0.61	-9.64
	(0.18)	(0.03)	(0.32)	(0.04)	(1.20)	(0.13)	(0.43)	(1.35)	
$(8,2)$	-0.57***	1.06***	0.85***	0.31***	0.92	-0.65***	0.78**	-0.59	-6.49
	(0.13)	(0.02)	(0.27)	(0.04)	(0.67)	(0.08)	(0.33)	(0.78)	
$(8,3)$	-0.51***	1.06***	0.88**	0.27***	1.18	-0.51***	0.69**	-0.48	-9.40
	(0.16)	(0.03)	(0.39)	(0.08)	(0.86)	(0.06)	(0.33)	(0.46)	

Note: Bank of England data spans from 1997Q4 to 2009Q4 (49 observations). Figures in parentheses are Newey-West (1987) standard errors where the bandwidth parameter is chosen based on the procedure proposed by Andrews (1991). The log-likelihood values are denoted by ℓ. Asterisks [*, **, ***] correspond to the marginal significance level of the coefficient estimates of [10%, 5%, 1%].

As the inflation forecasts for $h = 7$ are close to the inflation target, upward risks to the central projection imply that inflation is seen more likely to materialize above target than below. This seems to require a rise in interest rates today, such that inflation in the future is prevented from materializing above target. Asymmetries in the forecast uncertainty of output growth, however, seem to carry no information content, as the insignificant estimates for γ_y, in particular for $(h = 7, k = 2)$, show and the p-value tiles in figure 4.4 indicate.

The significant risk term and, thus, the relevance of asymmetries for the monetary policy decisions could cast doubt on the statement of a symmetric loss function. To elaborate further on this issue, estimation of equation (4.10) serves to assess whether and how the direction of risk contributes to the effect of forecast uncertainty. Figure 4.5 visualizes the significance patterns of the relevant coefficient estimates. Table 4.4 picks out the best six models from the results when controlling separately for the impact of upward risks and downward risks. The horizon combination $(h = 7, k = 2)$ yields the largest log-likelihood value of all models estimated, as shown in Table 4.4. The effect of asymmetric forecast uncertainty is captured by $\hat{\gamma}^+_{\pi\pi} = 2.32$, which is significant at the 1% level. This underlines the previous findings that forecast risk matters in explaining the MPC interest rate decisions. Moreover, upward risks to inflation contribute to the intensifying effect of forecast uncertainty on the responses to a change in forecast inflation. Given the width of the fan charts, with every quarterly forecast for inflation, there is a certain probability of inflation exceeding the target. However, the forecasts for seven quarters ahead are generally close to the inflation target. If the MPC is serious about its medium-term objective to have two-year-ahead inflation back on target, then alternative outcomes that are, first, seen to exceed the central projection for inflation

Figure 4.5: Visualized marginal significance levels for coefficient estimates when varying the forecast horizons in equation (4.10)



Note: X-axes show forecast horizons h and Y-axes forecast horizons k. White [light gray, dark gray] tiles imply significance of the estimate at the 1% [5%, 10%] level, and black tiles imply an insignificant estimate.

and, second, seen likely to exceed the inflation target, must be undesirable. Hence, if the MPC forecasts upward risk for seven quarters ahead, it is plausible that this intensifies the interest rate response.

Forecast downward risks to inflation appear to have a much smaller influence on the interest rate decisions. The coefficient estimate $\hat{\gamma}^{-}_{\pi\pi} = 1.02$ is significant at the 10% level only. The stark difference in the coefficient estimates $\gamma^{+}_{\pi\pi}$ and $\gamma^{-}_{\pi\pi}$ seems to be in line with the presumption that the loss function of the MPC is not symmetric. However, the significance of the coefficient estimate on downward risks to inflation and the rather large standard errors may not rule out the possibility that the coefficient estimates on forecast upward and forecast downward risks are equal at some reasonable significance level. With this in mind, I conduct F-tests for the following null hypotheses: a.) $H_0^a : \gamma^{+}_{\pi\pi} + \gamma^{-}_{\pi\pi} = 0$ and $\gamma^{+}_{yy} + \gamma^{-}_{yy} = 0$, b.) $H_0^b : \gamma^{+}_{\pi\pi} + \gamma^{-}_{\pi\pi} = 0$, and c.) $H_0^c : \gamma^{+}_{yy} + \gamma^{-}_{yy} = 0$. The F-test for two restrictions yields a p-value of 0.40. Hence, I cannot reject H_0^a and therefore cannot rule out symmetric reactions to forecast upward and forecast downward risks. The difference in the coefficient estimates on output growth upward and downward risk are smaller than the differences in the corresponding inflation estimates. Separating into two tests for a single restriction, however, does not allow other conclusions. H_0^b cannot be rejected with a p-value for the F-test statistic of 0.21, and the corresponding p-value of the test statistic for H_0^c is 0.87.

Thus, although coefficient estimates are apparently different in magnitude and have opposite signs in case of inflation, F-tests fail to reject the null that the estimates sum up to zero. For inflation, these findings are in line with the statement that the BoE MPC considers the inflation target to be symmetrical. I cannot reject a symmetric loss function, although the evaluation of single estimates indicates major concern about upward risks to inflation rather than about downward risks. A BoE MPC loss function seems to be symmetric in output growth, too. Yet, there is no publicly available statement about a growth target to be evaluated analogously to the symmetric inflation target statement.

4.4.3 Remarks on Robustness Checks

From the interest rate voting spreadsheet provided by the BoE I calculated a member-specific interest rate i_t^m, which is the previous-month level of the official bank rate plus the basis point change the individual MPC member voted for in the current month.[16] For every month, the resulting rates are averaged across the total M members. This yields $\bar{i}_t = M^{-1} \sum_{m=1}^{M} i_t^m$, the average member interest rate, which is used similarly by Gerlach-Kristen (2004). As an example, I consider February 2006, with January 2006 interest rates of 5%. Incidentally, only one member (Stephen Nickell) voted for a 25 basis point decrease. The MPC decision in

[16]Before November 1998, for some members only the direction of the preferred interest rate change is available but not the number of basis points. I assume the change then to be 25 basis points in line with Besley et al. (2008).

Table 4.4: Selected OLS estimation results for equation (4.10) - Separating the direction of forecast risk

(h,k)	c	ρ	α_π	α_y	$\alpha_{\pi\pi}$	α_{yy}	$\gamma^+_{\pi\pi}$	γ^+_{yy}	$\gamma^-_{\pi\pi}$	γ^-_{yy}	ℓ
$(7,1)$	0.32	0.91***	0.69**	0.26***	3.11***	−0.68***	1.95***	-0.46	−0.77*	-0.18	-2.06
	(0.25)	(0.06)	(0.34)	(0.06)	(1.00)	(0.17)	(0.56)	(2.46)	(0.46)	(0.31)	
$(7,2)$	0.15	0.94***	0.57	0.32***	2.24**	−0.47***	2.32***	0.55	−1.02*	-0.06	0.88
	(0.17)	(0.04)	(0.40)	(0.08)	(1.06)	(0.09)	(0.78)	(2.75)	(0.61)	(0.21)	
$(7,3)$	0.15	0.95***	0.56	0.32***	2.08	−0.29***	2.43***	−2.20*	-1.08	0.02	-1.39
	(0.25)	(0.04)	(0.42)	(0.11)	(1.30)	(0.08)	(0.88)	(1.28)	(0.70)	(0.17)	
$(8,1)$	0.15	0.92***	1.27***	0.28***	0.06	-0.54	2.03	-1.28	-0.53	-0.37	-8.07
	(0.34)	(0.07)	(0.37)	(0.08)	(2.59)	(0.44)	(1.46)	(4.61)	(1.40)	(0.96)	
$(8,2)$	-0.10	0.97***	0.74**	0.35***	1.28	−0.70***	2.56*	-0.38	-0.72	0.28	-1.71
	(0.23)	(0.05)	(0.32)	(0.06)	(0.81)	(0.09)	(1.14)	(4.97)	(0.72)	(0.30)	
$(8,3)$	0.05	0.95***	0.81*	0.29***	1.84*	−0.61***	2.49***	-2.14	-0.87	0.40	-2.80
	(0.23)	(0.04)	(0.45)	(0.11)	(1.02)	(0.05)	(0.82)	(1.40)	(0.85)	(0.33)	

Note: Bank of England data spans from 1997Q4 to 2009Q4 (49 observations). Figures in parentheses are Newey-West (1987) standard errors where the bandwidth parameter is chosen based on the procedure proposed by Andrews (1991). The log-likelihood values are denoted by ℓ. Asterisks [*, **, ***] correspond to the marginal significance level of the coefficient estimates of [10%, 5%, 1%].

February was to maintain interest rates at 5%, but for nine board members, the resulting member average is roughly 4.97%. The average member interest rate can be motivated to be closer to the optimal rate, since in the event of positive [negative] dissent it incorporates a minority belief that optimal interest rates should be higher [lower] than the aggregate MPC sets them.[17] However, using the members' interest rate average as dependent variable when estimating equations (4.7), (4.9) and (4.10) basically yielded about the same coefficient estimates as presented up to now. Although there where minor variations in the responsiveness, there were no significant differences in the partial effects of forecast uncertainty and forecast risk.

As regards the estimation technique, recent work, for example by Chevapatrakul, Kim, and Mizen (2009) for the Fed and the Bank of Japan and Wolters (2012) for the Fed has featured LAD quantile regressions. In these papers, it is shown that across the conditional distribution of interest rates, central banks deviate significantly from their reactions evaluated at the conditional mean, and the interest rate reactions are significantly different at the various quantiles. After having run quantile regressions on the BoE data, however, I can state that the MPC does not deviate from its conditional mean reaction function at a reasonable significance level. Despite variations in the responses across the conditional distribution of both the MPC interest rate decisions and the member interest rate average, these interest rate reactions are not significantly different from the OLS estimates in terms of a 10% confidence band.

[17]For the average member interest rate, the same results for tests of stationarity apply as to the decisions on the official bank rate.

4.5 Forecast Uncertainty derived from the Survey of External Forecasters

4.5.1 Data Description

Since 1998, the section on 'Prospects for inflation' in the BoE Inflation Reports also contains 'Other Forecasts' for the future developments in inflation and in real output growth. These forecasting results are obtained from the Survey of External Forecasters (SEF), where "Every three months, the Bank asks a sample of external forecasters for their latest economic projections.", see for instance the August 2009 Inflation Report on p.50.[18] The survey, usually carried out in the first month of the quarter, comprises point and density forecasts in the form of histograms, made by a varying number of professional economists that are "regularly providing forecasts and analysis to economic and financial institutions [...]", as pointed out by Boero et al. (2008, p.1108).

The SEF data of the Inflation Reports are presented as histograms, aggregated from the individual respondents' histograms. The aggregate histograms are characterized by probabilities that inflation and output growth, respectively, fall into a certain interval. The number of intervals and their width varies over time, and left and right intervals are open in general. For the SEF inflation forecasts starting in 1998, there were initially four intervals, or, bins, where the interior bins had a width of 100 basis points. After five survey rounds, the number rose to six bins and the grid was refined to a bin width of 50 basis points. Since 2009Q1, there are seven bins for the inflation forecast histograms. For output growth, there were initially six bins, four bins from 2002Q1 to 2008Q3, five for the report of 2008Q4, and six bins afterwards. The bin width has always been 100 basis points.

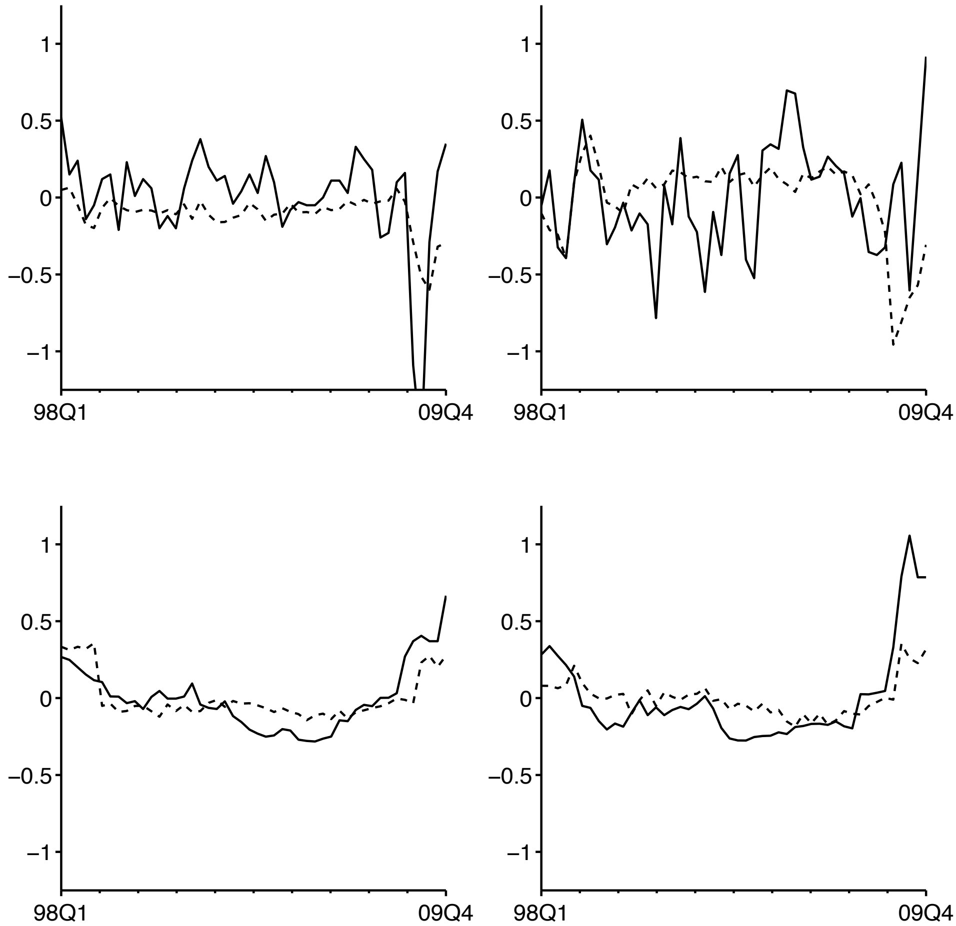
Forecast mean, mode and standard deviation of each (aggregate) histogram can be calculated. Although each SEF survey contains three different histograms for three distinct forecast horizons, I concentrate on the forecasts for two years out, since they are the only 'fixed-horizon' forecasts available for all 48 survey rounds from 1998Q1 to 2009Q4.[19] I assume that the reported probabilities are concentrated at the mid-points of the respective intervals and that open intervals at the left and right end of each histogram are closed and to have double width (Boero et al. 2008, pp. 1112-1113).[20] As the mode, denoted by $x_{t+h|t}, x \in \{\pi, y\}$ as before for notational consistency, I choose the mid-point of the interval the highest

[18]The survey started in 1996 for inflation only. With the Inflation Report of February 1998 (see p.49), output growth was added.

[19]The SEF data comprises forecasts for the end of the current year, forecasts for the end of next year and forecasts for two years out. The methodology was changed for inflation in 2006Q2 and for real output growth in 2007Q4, such that variables are now forecast for one, two and three years ahead, respectively. Between 2006Q3 and 2007Q3, only two- and three-year-ahead forecasts are available in the reports. These issues are discussed in detail by Boero, Smith, and Wallis (2008).

[20]With the latter point, Boero et al. (2008) are following Batchelor and Dua (1996).

Figure 4.6: Comparing Bank of England's and the Survey of External Forecasters' point and uncertainty forecasts at the policy horizon



Note: Bank of England (solid lines) and Survey of External Forecaster (dashed lines) data spans from 1998Q4 to 2009Q4 (48 observations). All forecasts shown are made for $h = k = 8$. Top left to right: deviation of forecast inflation from target and demeaned forecast real output growth. Bottom left to right: demeaned forecast standard deviation for inflation and demeaned forecast standard deviation of real output growth.

probability is assigned to.[21] The mean $x^e_{t+h|t}$ for each survey round t is calculated using a standard textbook formula:

$$x^e_{t+h|t} = \sum_{j=1}^{B} p_{x,t+h|t,j} a_{x,t+h|t,j}. \tag{4.12}$$

[21] Choosing the mid-point as the modal value is of course a simplifying assumption. See Engelberg, Manski, and Williams (2009) for potential issues when inferring the mode from survey data histograms.

Similarly, one can compute the standard deviation $\sigma_{x,t+h|t}$:

$$\sigma_{x,t+h|t} = \sqrt{\sum_{j=1}^{B} p_{x,t+h|t,j} \left(a_{x,t+h|t,j} - x^e_{t+h|t}\right)^2}. \tag{4.13}$$

The value $a_{x,t+h|t,j}$ denotes the mid-point of interval j, and $p_{x,t+h|t,j}$ the forecast probability that a realization of x falls into interval j. The plots in figure 4.6 show that point and uncertainty forecasts for inflation and real output growth constructed from SEF data are much smoother, while the overall direction is equal to the corresponding BoE series.

4.5.2 Estimation Results

Estimation results using the SEF data are shown in Table 4.5. In the top panel, coefficients of equations (4.7) and (4.10) are estimated on the survey's point and uncertainty forecasts. The point forecasts in this case are the mean forecasts, rather than the mode forecasts.[22] When using SEF inflation and real output growth data for the policy horizon, i.e. $h = k = 8$, I find that the reaction to a change in the SEF forecast inflation gap is extremely strong, with $\hat{\alpha}_\pi = 3.14$ being significantly different from zero at the 5% level. The fairly strong reaction to a change in the SEF real output growth gap of $\hat{\alpha}_y = 1.28$ is significant at the 1% level.

SEF uncertainty measures, however, are insignificant. Although their signs hint at attenuation in decision-making under uncertainty, estimation uncertainty is too large to allow any conclusions about the impact of SEF forecast uncertainty on the BoE monetary policy conduct. Standard errors for the uncertainty measures are about the same when controlling for forecast upward and downward risks in inflation and output growth. An attenuated reaction to a change in the real output growth gap, however, is now significant at the 5% level. Given the crude measure for the forecast mode, there are no balanced risks for the SEF. The signs of the Pearson mode skewness derived from SEF data, indicating the direction of risk, however, are in line with the directions of risk implied by the figures in Table 4.1.

The lower panel of Table 4.5 shows estimation results when only the BoE forecast standard deviations of inflation and real output growth are substituted by SEF measures in equation (4.7), while the point forecasts are the BoE MPC forecasts. Then, only the smoothing parameter and the reaction to a change in the forecast inflation gap remain significantly different from zero. The forecast deviation of output growth from its long-run mean as well as both uncertainty measures are statistically insignificant.

[22] To be precise, the gap variables are redefined for estimating equations (4.7) and (4.10) on the SEF data. The forecast inflation gap is given by $\tilde{\pi}_{t+h|t} \equiv \pi^e_{t+h|t} - \pi^*$, and the forecast real output growth gap by $\tilde{y}_{t+k|t} \equiv y^e_{t+k|t} - \bar{y}_k$, where $x^e_{t+h|t}$ is the forecast mean as given by equation (4.12).

Table 4.5: OLS estimation results for data from Survey of External Forecasters

(h,k)	c	ρ	α_π	α_y	$\alpha_{\pi\pi}$	α_{yy}	$\gamma^+_{\pi\pi}$	γ^+_{yy}	$\gamma^-_{\pi\pi}$	γ^-_{yy}	ℓ
	SEF point and uncertainty forecasts										
	Estimation results for equation (4.7)										
$(8,8)$	0.71	0.87***	3.14**	1.28***	-4.12	-3.55					-22.54
	(0.44)	(0.07)	(1.49)	(0.41)	(7.89)	(2.87)					
	Estimation results for equation (4.10)										
$(8,8)$	0.38	0.91***	1.91	1.77***	6.53	−6.05**	0.25	5.13***	−1.63*	0.84	-15.06
	(0.40)	(0.09)	(1.16)	(0.45)	(7.93)	(2.40)	(0.78)	(0.85)	(0.88)	(1.00)	
	BoE MPC point forecasts, SEF uncertainty forecasts										
	Estimation results for equation (4.7)										
$(8,8)$	0.21	0.93***	2.06**	-0.09	-5.17	-0.49					-40.37
	(0.32)	(0.06)	(1.03)	(0.23)	(5.10)	(1.87)					
	Estimation results for equation (4.10)										
$(8,8)$	-0.10	0.99***	1.99**	-0.12	-5.12	0.72	-0.39	1.77**	-0.15	1.28**	-37.93
	(0.31)	(0.07)	(1.00)	(0.22)	(5.28)	(1.14)	(0.54)	(0.84)	(0.67)	(0.59)	

Note: Bank of England and Survey of External Forecaster data spans from 1998Q4 to 2009Q4 (48 observations). Figures in parentheses are Newey-West (1987) standard errors where the bandwidth parameter is chosen based on the procedure proposed by Andrews (1991). The log-likelihood values are denoted by ℓ. Asterisks [$^{*}, ^{**}, ^{***}$] correspond to the marginal significance level of the coefficient estimates of [10%, 5%, 1%].

When adding the indicator variables for forecast risk in the SEF, results are roughly equal. Finally, it seems that forecast upward and downward risks for real output growth in the SEF, however, are considered by the BoE MPC, as implied by $\hat{\gamma}^+_{yy} = 1.77^{**}$ and $\hat{\gamma}^-_{yy} = 1.28^{**}$. Yet, given the the crude measure for the forecast mode, these results are to be interpreted with caution.

4.6 Conclusion

The historical Bank of England Monetary Policy Committee decisions about the official bank rate can be described fairly well by a simple forecast-based interest rate rule. In terms of log-likelihood, the combination of forecast inflation gap for seven quarters ahead and demeaned output growth for the very near term of two quarters ahead has the greatest explanatory power.

The Monetary Policy Committee is very forward-looking with respect to inflation, but less forward-looking with respect to output. An estimated interest rate rule for this best horizon combination displays a fairly high degree of interest rate smoothing. Nonetheless, the Monetary Policy Committee utilizes the information content of the forecast inflation gap and of forecast demeaned output growth. Estimates show greater weights on inflation forecasts than on output growth, although the coefficient on the forecast deviation of inflation from target is estimated below unity, implying an insufficiently strong interest rate reaction, inconsistent with the Taylor principle.

Forecast uncertainty measures are found to be highly significant. In particular, the positive and strong coefficient estimates on forecast inflation uncertainty at the policy horizon imply very aggressive interest rate reactions when inflation two years out is forecast to deviate from target. Conversely, forecast output growth uncertainty leads to attenuation in decision making when near-term forecasts see output growth deviating from its long-run mean.

The aggressive reaction under inflation uncertainty and the attenuated reaction under output growth uncertainty is confirmed when assessing the asymmetries of forecast uncertainty. It is shown that forecast upward risks to inflation have a direct and positive impact on Monetary Policy Committee interest rate decisions. Moreover, there is econometric evidence that the asymmetry of forecast uncertainty contributes to the intensifying effect of forecast uncertainty on the reaction of interest rates to a change in forecast inflation. When the central projection for inflation is close to target, but an average of alternative outcomes is forecast to exceed this central projection, the partial effect of the forecast standard deviation of inflation is stronger than without controlling for upward risk. The Monetary Policy Committee is found to be very concerned about upward risks to inflation, while downward risks have hardly any significant effect. Although coefficient estimates for upward and downward risks differ apparently in size and sign, F-tests cannot reject the null hypothesis about the Bank of England's statement that the inflation target is symmetrical.

Using direct uncertainty and risk measures constructed from the density forecasts of the Survey of External Forecasters, which is prominently featured in each Inflation Report, adds no information to the Monetary Policy Committee's own uncertainty forecasts. While forecast standard deviations for inflation and output growth are insignificant, and risk measures constructed from the survey data are in line with their bank counterparts. Although there is mild evidence that the committee reacts to risk measures derived from the survey, these results have to be interpreted with caution due to the different nature of the Bank of England's mode forecast and the modal value of the histograms from the Survey of External Forecasters.

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Conclusion

This thesis provided potential answers to four specific questions related to the informational and political dimensions of central bank density forecasts and fan charts by questioning, first, the information content of macroeconomic risk forecasts, second, the construction principles of fan charts, third, the implication of conditioning assumptions for forecast accuracy of point and density forecasts and, fourth, the overall usability of uncertainty and risks forecasts for monetary policy decisions.

The information content of macroeconomic risk forecasts was investigated by first surveying how central banks address macroeconomic risks. It was shown that many central banks augment their point forecasts with assessments of the balance of risks. Moreover, almost all central banks surveyed state relatively clearly that the presence of unbalanced forecast risks corresponds to an asymmetry of forecast densities. Surprisingly, the point forecasts published almost always correspond to the modes of the forecast densities. Central banks risk forecasts were found to be either quantitative, as in the case of the BoE and the Riksbank, or qualitative, thus only indicating the direction of the balance of risks, as, for example, in the case of the Federal Reserve and the ECB. Risk forecasts were also found to be be discussed without referring to the balance of risks, as for instance is practice for the Reserve Banks of Australia and New Zealand. Furthermore, balance-of-risks forecasts were found to be frequently represented in potentially asymmetric fan charts.

Since the balance of risks is supposed to contain information about the asymmetries of the densities of the forecast variables, a systematic connection between risk forecasts and realized risks was investigated. Results for quantitative forecasts and direction-of-risk forecasts based on the risk forecast data for inflation produced by the BoE and the Riksbank yielded no evidence for the existence of such a connection. Therefore, it seems questionable whether macroeconomic risk forecasts are meaningful and this exercise illustrated the difficult challenges in making accurate real-time assessments of temporal changes in the distribution of forecast errors.

In the light of the apparent lack of information content in macroeconomic risk forecasts, the construction principles underlying potentially asymmetric fan charts were further analyzed. Specifically, it was investigated if dissent in voting on monetary policy affects the shape of the forecast inflation fan charts of the Bank of England, the Sveriges Riksbank and the Magyar Nemzeti Bank. These three inflation targeting banks were subject of the analysis because they are the only central banks to use identical approaches for generating density forecasts and in addition to publish detailed interest rate voting information for the sample periods considered.

Results from simple OLS regressions provided statistical evidence that there is a relationship between the degree of disagreement on the level of the policy instrument and the shape of inflation fan charts. In particular, it was shown that the Magyar Nemzeti Bank fan charts get wider when the degree of disagreement is higher while fan charts at the Bank of England and the Sveriges Riksbank become more skewed to accommodate minority views on monetary policy. Hawkish and dovish voting behavior was found to have significant impact on the shape of inflation fan charts. At the Magyar Nemzeti Bank, hawks and doves alike were found to determine the fan chart width, although the hawks' impact was found to be stronger. The analysis of the Bank of England fan charts yielded evidence that the hawkish Monetary Policy Committee incorporates dovish voting into more skewed forecast inflation fan charts, while test results for the Sveriges Riksbank fan charts showed that a hawkish minority is accommodated by a more in inflation fan chart skewness. Overall, it was found that dissenting views in monetary policy committees voting on central banks' level of the policy instrument are a significant determinant of the shape of forecast inflation fan charts.

Furthermore, this dissertation attempted to rank different approaches regarding the choice of the interest rate assumption underlying central bank forecasts with respect to their effects on forecast accuracy, where the approach of using unconditional forecasts, from a theoretical point of view, should be ranked higher than using the approaches of using forecasts made conditional on market interest rates or constant interest rates, respectively.

Results obtained from analyzing interest rate, inflation and real output growth forecasts from the Bank of England and the Banco Central Do Brazil, did not reveal any significant differences between the performance of forecasts based on different interest rate assumptions. Although proxies for the central bank's own expectations were found to be more accurate than market expectations, where the latter yielded better forecasts than the assumption of a constant interest rate, all differences in forecast accuracy were found insignificant. For the inflation and output growth mean and density forecasts, there was no clear relationship between forecast accuracy and the interest rate assumption.

The empirical irrelevance of the interest rate assumption for forecast accuracy has important implications. Firstly, at least in the medium term, it is going to be difficult for central banks to steer market expectations by using the approach of central bank expectations, especially for variables other than the policy rate itself. This also implies that it does not appear very likely that markets misunderstand the central bank's own interest rate expectation as a commitment. Secondly, at least for the samples under study, monetary policy is unlikely to be a major cause for the level of macroeconomic volatility observed, because the inflation and growth forecasts conditional on 'bad' monetary policy (on the approach of constant interest rates) have virtually the same accuracy as forecasts conditional on 'good' monetary policy (on the approach of central bank expectations). This might cast doubts on the prominent role that is sometimes attributed to monetary policy concerning the Great Moderation. Thirdly, the construction of prediction intervals for central bank forecasts and the evaluation of central bank forecasts can probably be agnostic toward the underlying interest rate assumptions. Put differently, past forecast errors are a good indicator for future forecast uncertainty if the only structural change is due to a change in the interest rate assumption used. Finally, the risk that private information is crowded out if central banks switch to the CBE approach is unlikely as well.

Finally, it was analyzed how information on potentially asymmetric uncertainties of future values are utilized when it is to decide on monetary policy. The analysis conducted revealed that the historical Bank of England Monetary Policy Committee decisions about the official bank rate can be described fairly well by a simple forecast-based interest rate rule. The bank's Monetary Policy Committee was found to be very forward-looking with respect to inflation, but less forward-looking with respect to output and to show a fairly high degree of interest rate smoothing. Forecast uncertainty measures were found to be highly significant when deciding on interest rates, where strongly positive coefficient estimates on forecast inflation uncertainty at the policy horizon implied very aggressive interest rate reactions when inflation two years out is forecast to deviate from target. Conversely, forecast output growth uncertainty was found to lead to attenuation in decision making when near-term forecasts see output growth deviating from its long-run mean.

It was shown that forecast upward risks to inflation have a direct and positive impact on Monetary Policy Committee interest rate decisions and that the asymmetry of forecast inflation uncertainty contributes to the intensifying effect of forecast uncertainty on the reaction of interest rates. Using direct uncertainty and risk measures constructed from the density forecasts of the Survey of External Forecasters, which is prominently featured in each Inflation Report, added no information to the Monetary Policy Committee's own uncertainty forecasts. Overall, these results showed that the bank's own assessments of future uncertainties are informative for the Monetary Policy Committee decisions on interest rates.

Ehrenwörtliche Erklärung

Ich habe die vorgelegte Dissertation selbst verfasst und dabei nur die von mir angegebenen Quellen und Hilfsmittel benutzt. Alle Textstellen, die wörtlich oder sinngemäß aus veröffentlichten oder nicht veröffentlichten Schriften entnommen sind, sowie alle Angaben, die auf mündlichen Auskünften beruhen, sind als solche kenntlich gemacht.

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