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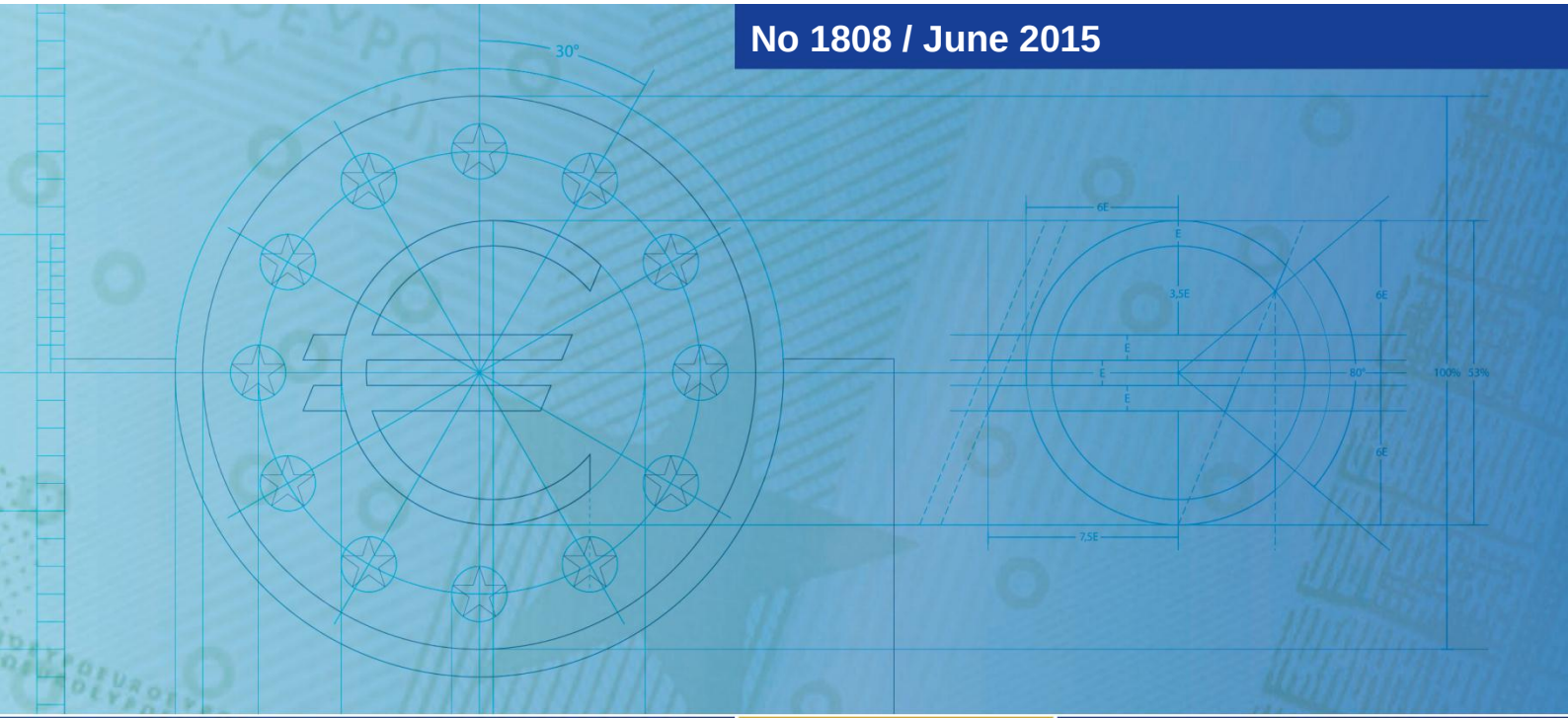
Has the publication of minutes helped markets to predict the monetary policy decisions of the Bank of England's MPC?



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Abstract

This paper examines whether the minutes of the Bank of England's Monetary Policy Committee (MPC) have provided markets with additional information about the future course of monetary policy. The paper conducts an econometric approach based on an Ordered Probit model explaining future policy rate changes (sample 1998 to 2014), and the Vuong test for model selection, which helps to identify changes in the market assessment around the release of MPC minutes. Our results suggest that the Bank of England's published minutes of the MPC's deliberations have indeed helped markets in forming their expectations on future monetary policy decisions.

JEL codes: C34, D78, E52, E58

Keywords: Communication, MPC minutes, monetary policy committee, Probit, Vuong test.

Non-technical summary

Today, there is large agreement in the economics profession that transparency on monetary policy contributes to monetary policy effectiveness. Transparency is also a vital element for independent central banks to lend legitimacy to their policy decisions in a democratic constitution. In order to provide the public with relevant information on monetary policy, central banks have adopted different communication strategies. Central banks have various tools at their disposal to explain their monetary policy decisions. On the one hand, several authors find that published minutes and voting records contribute to transparency in central banking. On the other hand, the literature has shown that different communication strategies can be equally effective. Meeting minutes of monetary policy committees are a post-meeting communication tool, which provides more detailed information on the arguments underlying the committee's assessment of financial market developments, the current and future state of the macroeconomy, the balance of risks to price stability and economic growth. If attributed voting records are published, markets also receive information about the distribution of individual votes of the members of the policy committee. Whether published central bank minutes (and voting records) help markets to better predict a monetary policy decision is an empirical issue.

This paper provides a case study by examining whether information contained in the minutes and voting records of the Bank of England's Monetary Policy Committee (MPC) has provided markets with additional information about the future course of monetary policy. Since November 1998, the publication of MPC minutes has preceded the MPC's decision to change interest rates and has contained new information that is potentially useful for a forward-looking assessment of its monetary policy stance. The approach of the paper is an empirical one explaining future interest rate changes based on an Ordered Probit model.

Overall, the paper finds that the Bank of England's published minutes of the MPC's monetary policy committee deliberations have indeed helped markets in forming their expectations on future policy decisions. The interest rate skew from the voting records of the

MPC minutes has contributed to explaining future changes of the Bank of England's bank rate. Since MPC minutes are published between two consecutive meetings, markets have the possibility to revise their expectations, as reflected in short-term money market futures, about the next movements as soon as new information becomes available. While our analysis confirms the result of the previous literature that some information provided in the minutes is not used efficiently, we find strong evidence that the publication of minutes helps markets to improve their expectations for the next interest rate move. However, markets do not use this information to revise their interest rate expectations for longer maturities of three months and beyond. The findings of the paper are robust across samples and they still hold when the episode of the Bank of England's forward guidance is taken into account.

1. INTRODUCTION

Today, there is still considerable disagreement in the economic profession about the design of appropriate institutional arrangements and operating practices governing accountability and transparency. The debate on the welfare effects of central bank communication between Morris and Shin (2002), on the one hand, and Woodford (2005) and Svensson (2006) on the other hand, illustrates this point. While over the last two decades economists and policy-makers have increasingly acknowledged the important benefits of transparency for monetary policy effectiveness, they have disagreed about whether publishing minutes of the internal deliberations of a monetary policy committee leads to more clarity about the individual views of policy-makers. For example, this point can be illustrated by the debate between two famous economists about "*Alice [Willem] in Euroland*". Buiter (1999) made a case for the publication of minutes of the meetings of the Governing Council of the ECB since this would enhance transparency, while Issing (1999) strongly opposed it, since revealing the full diversity of views among members may confuse the public and harm the independence of committee members. Nevertheless, a rethinking appears to have taken place. US Federal Reserve President Yellen (2012) made the point that the financial crisis has made it necessary for policy-makers to reconsider their views and to think about further advances in communication. Moreover, ECB President Draghi stated at the press conference on 3 July 2014 that: "*we announce our commitment to publish regular accounts of the monetary policy meetings, which is intended to start with the January 2015 meeting*" (see ECB, 2014). In fact, most major central banks publish timely minutes of their internal deliberations together with voting records (see Table 1). The debate on effective communication has recently gained further momentum due to the Warsh report (2014). One of the central recommendations in this report is to *"publish policy decision and rationale as soon as is practicable"*.

This paper contributes to this debate on transparency in monetary policy. We examine whether information contained in the minutes and voting records of the Bank of England's Monetary Policy Committee (MPC) has provided markets with additional information about the future course of monetary policy. Several authors find that published minutes and voting records contribute to transparency in central banking (see Geraats, 2006; Cruijsen van der, Eijffinger and Hoogduin, 2010),

but only few have examined the information content of minutes and their impact on market expectations. Several studies find that the skew contained in the voting records of the minutes provides relevant information to markets, which contribute to transparency in monetary policy (see Gerlach-Kristen, 2004). Market expectations appear to react to the publication of the minutes of the meeting. However, their empirical evidence suggests that, despite its usefulness, the information provided in minutes is not utilized to its full extent. Another strand of the literature argues that different communication strategies can be equally effective (see Blinder, Ehrmann, Fratzscher and de Haan, 2008). For example, the ECB does not publish a voting record, but is nevertheless very predictable.

The present study makes a contribution by empirically testing whether the publication of the minutes causes markets to revise their predictions for future interest rate changes. For the following reasons, it seems unclear whether the publication of minutes is actually informative for markets. First, information in minutes may not be used efficiently. Second, information contained in minutes could be redundant, since markets may get sufficient information about the future monetary policy stance of a central bank from a wide range of official communications (e.g., inflation reports, press conferences, speeches, and websites) and from their own assessment of the economic outlook. Third, given that other communications, such as speeches, can blur the signal from the monetary policy meeting, it is conceivable that minutes provide additional assurance to markets. Ultimately, whether published central bank minutes (and voting records) help markets to better predict a monetary policy decision is an empirical issue, and this study provides evidence for the Bank of England´s MPC.

The paper is organised as follows. Section 2 provides a brief review of the literature. Section 3 describes the data used for this analysis. Section 4 presents the approach and empirical results for the Bank of England. Section 5 concludes.

2. BRIEF REVIEW OF THE LITERATURE

Transparency is a vital element for independent central banks to lend legitimacy to their policy decisions in a democratic constitution. Clear communication increases the effectiveness and efficiency of monetary policy in the pursuit of the statutory objectives (see Woodford, 2005). The monetary policy transparency index (see Figure 1) developed by Dincer and Eichengreen (2014) shows that over past

years, several main central banks have made significant efforts to increase transparency on monetary policy. More openness about individual views of policy-makers is widely thought to enhance monetary policy transparency. But, under certain circumstances, increasing the degree of openness may be counterproductive (see Winkler, 2000 and Issing, 2005). In this context, for example during the financial crisis, published voting records document for several monetary policy committees an increase in disagreement among members about the appropriate monetary policy response, which could destabilise market expectations (see Figure 2).

In addition, recent literature has highlighted the importance of central bank communication for understanding private expectations. This notion builds on the assumption that markets function largely in an efficient manner. They continuously process all kinds of information when forming expectations about the future monetary policy stance of a central bank. They monitor incoming data, which may give clues on the economic outlook and the implied monetary policy response. To the extent that markets believe in the predictive power of dissenting votes, it is likely that markets also form expectations regarding the content of central bank minutes and members' voting behaviour, prior to their publication. But, if markets are efficient, these expectations are fully reflected in the pricing of interest rate futures. Even though market participants seem to have relatively accurate expectations of upcoming interest rate changes, Riboni and Ruge-Murcia (2014) find that in the case of the Bank of England and the Swedish Riksbank current dissents help predict future individual policy decisions. Moreover, when deriving probabilities about future interest rate changes, markets carefully listen to central bank communications in order to obtain hints about the future course of monetary policy. They do so in particular around the time of policy meetings or other important events when media attention is high. Therefore, central bank communications should be particularly careful around these dates, since it could create excessive market volatility (see Ehrmann and Fratzscher, 2009a).

In practice, central banks have a wide range of communication tools at their disposal to provide the public with relevant information about their monetary policy decisions and assessments.[2] About 20 central banks in the world, which are mostly inflation-targeting central banks, publish minutes and a

[2] In this context, it has been argued that forward guidance by central banks gives markets an incentive to economise on their resources in assessing the economic situation. Therefore, whenever central banks adopt forward guidance on their future policy, other communication tools such as minutes are unlikely to influence market expectations about forthcoming policy changes.

voting record within six weeks after the meeting of the monetary policy committee. In several instances the tradition to publish minutes of central bank meetings goes back to their legal accountability requirements (e.g. Bank of England, Bank of Japan and US Federal Reserve). Whether a central bank publishes minutes (and voting records) is, however, not exclusively determined by the accountability regime of the policy committee. Central banks with both collective and individual accountability regimes may publish minutes, but there are no central banks with individual accountability which do not publish minutes. This issue is also unrelated to whether the central bank is embedded in a federation or a unitarian state.

Regardless of whether central banks publish minutes or not, other forward-looking information on the future policy rates may exist. Empirical studies have shown that the interest rate setting behaviour of leading central banks in the world was largely captured by forward-looking Taylor rules (or similar reaction functions) over past decades, with the possible exception of the financial crisis episode. Hence, information about inflation and output forecasts by the central bank appears to be crucial for market observers. In addition, speeches and interviews by central bankers in the intermeeting period may give important hints to financial market observers. However, the signals from these communication tools may be perceived as quite noisy, and as Hayo and Neuenkirch (2013) point out, the signal from speeches may be blurred if central bankers please regional audiences or defend their individual preferences instead of upholding the party line of the monetary policy committee. The European Central Bank (ECB) started publishing "accounts" of Governing Council meetings in January 2015. These accounts aim to offer a fair and balanced reflection of policy deliberations, but do not contain the voting record of the policy-makers. In this case, the Introductory Statement of the President at press conferences provides valuable information that allows the next policy decision to be predicted (see Sturm and de Haan, 2011).

The publication of minutes is a post-meeting communication tool which provides more detailed information on the arguments underlying the committee's assessment of financial market developments, the current and future state of the macroeconomy, the balance of risks to price stability and economic growth. If attributed voting records are published, markets also receive information about the distribution of individual votes of the members of the policy committee. In this context, central banks typically also provide a short rationale to explain if and why individual members dissented from the

majority view. Thereby, they disclose additional information on the diversity of views which existed among members at the policy meeting. Until the release, this information is largely unknown to the public in the sense that expectations about the release of minutes may exist, but clarity about the intentions is only created at the moment of their release. Most central banks usually provide this information with a lag of between one and three weeks (for an overview see Hammond, 2012).[3]

Several studies have documented that the policy decisions of the Bank of England's MPC are highly predictable, similarly to the US Federal Reserve (Fed) and the ECB (see e.g., Wilhelmsen and Zaghini, 2011). A high degree of predictability contributes to an effective transmission of monetary impulses. In order to achieve a high degree of predictability it is important for a central bank to be credible in its communications and to have members who speak with a single voice to the public. If markets have a clear understanding of policy-makers' assessments, interest rate futures will exhibit a smaller volatility than otherwise. By contrast, if policy-makers send a diffuse signal on the future monetary policy stance, a central bank's predictability may deteriorate. In this context, inflation targeting appears to have helped to increase predictability and to anchor private-sector perceptions of the future distribution of long-run inflation outcomes (Andersson, 2010). According to Gürkaynak, Levin and Swanson (2010), making the Bank of England operationally independent in 1997 had an additional positive impact on its predictability. But Wadhwani (2001) finds that, until about 2001, the Bank of England tended to surprise markets more than other central banks in Europe and the United States (US). Ehrmann and Fratzscher (2006) provide evidence for the Bank of England, the ECB and the Fed that the predictability of policy decisions decreases when the committee communicates its diverging views about policy decisions. In part, this finding may be attributable to arising herding behaviour of market participants (see e.g., Bikhchandani, Hirshleifer and Welch, 1998). In the presence of information asymmetries they follow those players who are presumably better informed. Another reason is that market participants completely ignore central bank signals once they lose confidence in their communications.

In general, monetary policy communication is found to exert a significant effect along the yield

[3] The Bank of England "shall publish minutes of the [MPC] meeting before the end of the period of 6 weeks beginning with the day of the meeting" (Bank of England Act of 1998). Initially, the minutes were published about five weeks after the meeting. Since October 1998 the MPC has published the minutes of its monthly meetings on the Wednesday of the second week after the meetings take place, i.e., they are published at 9.30 a.m. on the Wednesday 13 days after the monthly policy decision.

curve, in particular on short- and medium-term horizons (Ehrmann and Fratzscher, 2006). Several studies for the US (see Kohn and Sack, 2003; Bernanke, Reinhart and Sack, 2004) show that the publication of minutes affects interest rate expectations along the entire yield curve. A study for the United Kingdom by Reeves and Sawicki (2007) finds that the Bank of England's minutes only affect short-term interest rate expectations. Moreover, in her analysis of the Bank of England's voting records, Gerlach-Kristen (2004) finds that the skew derived from the MPC's voting records contains valuable information about future changes in the policy rate, which could be exploited by market participants. Similar conclusions have been reached for Japan (Fujiki, 2005) and for Sweden (Apel and Blix-Grimaldi, 2014). A recent study by Horváth, Smidková and Zápal (2012) suggests that this is a more general phenomenon. They find evidence that the skew contains valuable information about future interest rate moves for several central banks.

Providing markets with more information in the form of minutes can have undesirable side-effects as well. First, it may reduce the incentives for the public to gather information on its own and thereby complicate a forward-looking assessment of a central bank, because measures of private expectations no longer contain extra information (see Morris and Shin, 2002). In this context, when assessing the impact, it is also relevant to distinguish between two conceptually different sources of diversity: those related to the economic outlook and those related to members' interest rate reaction function. Second, as shown in a theoretical model by Weber (2010), it is in general beneficial for a central bank to be transparent about the diversity of views on the economic outlook. Hence, communicating the diversity of views about the interest rate response (e.g., via the publication of voting records) would be beneficial in the longer term, but may have costs associated with it in the shorter term (i.e., an increase in short-run variability of inflation and the output gap). Third, the practice of publishing voting records soon after the policy meeting may give incentives to policy-makers not to disclose their dissent, because they do not want to be on record with it and publicly defend it (see Meade and Stasavage, 2008). In the case of the Federal Reserve, it was observed that for this reason the dissent contained in the voting records became less pronounced than the genuine dissent at the meeting as soon as it was decided to publish a transcript of the Federal Open Market Committee (FOMC) meeting five years later.

3. DATA

The empirical analysis focuses on the Bank of England for the following reasons. First, since 1998 the Bank of England minutes are published with a short time lag after the meeting so that sufficient long time series are available for this study. Second, the publication of the minutes and voting records is separated from the announcement of the decision. This allows the news from the press release after the meeting to be disentangled from that generated by the publication of minutes. Third, for some central banks the publication of minutes overlaps with concrete forward guidance for the next meeting (Federal Reserve) or is supplemented by the publication of the policy committee's interest rate path projection (Swedish Riksbank). Under these conditions, it is not possible to extract the specific impact of the publication of minutes on the market expectations for the next policy meeting. Nevertheless, we also provide results for that more recent episode in order to check how this tool influences the information content of the skew. Fourth, for other central banks like those of the Central and Eastern European (CEE) inflation-targeting countries, a significant convergence process has been observed in the transition process (see Jung and Kiss, 2012), and the practice to publish minutes shortly after the meeting dates back to more recent years. Therefore, estimations for these countries would be likely subject to a small sample bias.

For the present analysis the paper uses the sample from the MPC meeting of October 1998 to end-2014. Like other inflation-targeting central banks, the Bank of England publishes minutes in the intermeeting period (see Hammond, 2012). The MPC announces its decision on interest rates at 12 noon following the Thursday policy meeting. Its meeting minutes, including a record of the vote, are then published at 9.30 a.m. on the Wednesday of the second week after the meeting (i.e., 13 days after the policy decision). We include the official bank rate for each meeting from the Bank of England's website. Moreover, the Bank of England issues a calendar on its website which provides the exact dates and times when it will release the MPC minutes. It allows us to determine the period during which the publication of minutes potentially impacts market expectations and to distinguish them from other systematic releases (such as the Inflation Report).

Figure 3 illustrates the timing of the MPC's communications of its monetary policy assessment relative to the announcement of the policy decision. When communicating about interest rates, the MPC uses standard communication tools such as press releases for each meeting. It announces the decision

and sometimes provides a short rationale, but does not provide information that would allow markets to compute the MPC's interest rate skew. Like other inflation-targeting central banks, the Bank of England publishes a quarterly Inflation Report (for the meetings in February, May, August and November), which is presented at a (quarterly) press conference about one week after the decision. On that occasion, the MPC prominently explains its risk assessment, inter alia using fan charts that assign probabilities to different future outcomes of inflation and output. This tool, however, does not provide information about individual views of MPC members. Later, when the MPC publishes its minutes together with a voting record, it does not separately publish the interest rate skew, but this information can be computed from the published voting record using information on dissent and agreement with the interest rate decision. Moreover, outside blackout periods, MPC members explain their views on the monetary policy stance in speeches for which no recurring pattern exists.

The Bank's MPC is made up of nine members: five internal and four external members. The diversity of views of these members is reflected in the voting record. Data on the interest rate skew of the MPC were computed from information contained in the Bank of England's voting record, which is available for each meeting (i.e. at a monthly frequency). We define a measure of disagreement in the MPC in line with Gerlach-Kristen (2004). The variable skew measures for each period the size of dissent in the MPC. The interest rate skew is given by:

$$skew_t = \frac{\sum_{j=1}^{n} i_{j,t}}{n} - i_t \qquad (1)$$

where i_t denotes the bank rate and $i_{j,t}$ is the interest rate voted for by MPC member j at the MPC meeting at time t, and n is the number of members attending the meeting. Like previous studies, we ignore the possibility that new appointments to the MPC would structurally change the interest rate skew in that this would systematically change the distribution of preferences in the committee.

An analysis of the predictive content of voting in monetary policy committees should take into account a host of factors explaining heterogeneity in voting behaviour. The MPC of the Bank of England consists of internal and external members and, owing to the possibility of reappointments and staggered contracts, members differ in terms of their seniority. Therefore, some further refinements can be made by distinguishing between the membership status ("insiders" versus "outsiders") and the

seniority of committee members when calculating the skew. Recent studies have investigated this point for the Bank of England. In her empirical analysis, Gerlach-Kristen (2009) finds that a skew based only on the dissenting votes of "outsiders" is more informative in predicting future policy changes than those based on "insiders". Moreover, Riboni and Ruge-Murcia (2014) show that a skew based on the votes of more experienced committee members does not predict future interest rates better than a skew based on the less experienced members.

Figure 4 shows that the (lagged) skew from the voting record may contain information about forthcoming changes in the MPC's bank rate at the next meeting. More precisely, in slightly more than 50% of the meetings the skew correctly signalled the direction of the change (or that the bank rate remained unchanged). In this context, the skew could be zero even in the presence of dissenting members, for example if two (or several) members switch their preferences simultaneously in an opposite direction. However, this was rarely the case in our sample. It occurred at two consecutive meetings in July and August 2008, when one member wanted to hike interest rates by 25 basis points and one other member wanted to lower them by the same amount, whereas all other MPC members favoured unchanged interest rates. Another question is whether the skew may have become less important over time. This could happen, if for example the Bank of England changes the timing of the release of the minutes and the voting record, MPC members' voting pattern change systematically, as well as monetary policy could become constrained by the zero lower bound. There are some indications that the skew deteriorated during the financial crisis. The chart illustrates that the skew did not provide useful information during some periods of the financial crisis episode, while interest rates were maintained at low levels close to zero. In particular, between July 2010 and July 2012 and at the end of 2014, the MPC minutes (and the voting record) signalled disagreement in the MPC about when to exit from the extraordinary accommodative stance. Nevertheless, the Bank of England maintained its bank rate unchanged at the level of 0.5%.

MPC minutes are published twelve times a year, and the Bank of England releases its Inflation Report four times a year, together with holding a press conference (the Governor, Chief Economist, and Executive Director for Markets at the Bank of England hold a press conference at 10.30 a.m.). This paper measures the market reaction using daily financial market data. While our baseline specification uses information on (trading) days before and after the release of the minutes, we also test several other

specifications using alternative time windows. We consider using intradaily data in addition to daily data, as is done in Reeves and Sawicki (2007). This would allow us to measure more closely the response of interest rate futures during the day when new information is released. However, obtaining longer runs of intradaily data is very expensive. Hence, we do not measure the impact of MPC minutes during the day of their release. In this context, the use of daily data still allows the effects of the release of the MPC minutes after each meeting to be distinguished from those of other communication tools, namely those related to Inflation Reports and the press conferences. This is because since November 1998, MPC minutes have been released a few days after the Inflation Report and several days before the next MPC meeting in those months for which releases were coinciding.

In the database we include alternative measures of asset prices which may track changes in the market assessment of upcoming policy changes. It comprises several measures of interest rate expectations, the FTSE 100 equity index, and the bilateral sterling exchange rate vis-à-vis the euro and the pound (daily data). When assessing the market response to the MPC's communications, for the purpose of empirical research, among these variables short-term interest rate futures (and OIS rates) are by far the best proxies of the market reaction (see also Reeves and Sawicki, 2007). In order to capture changes in interest rate expectations, the empirical analysis examines whether systematic changes occur, as observable in the behaviour of alternative proxies for the market response around the publication date of the minutes. This paper uses three proxies: (a) the (one-month) market spread between the current policy rate and the interest rate implied by short-term (one-month) money market futures; (b) the corresponding (one-month) future spread of these money market futures between the publication of the minutes and one day after the announcement of the policy decision, and (c) the (three-month) market spread between the current policy rate and the interest rate implied by the futures (three-month) (sources: all Bank of England). In addition, we augment the Probit regressions with other potentially relevant variables, such as the market skew derived from short-term sterling options (source: Bank of England) and its standard deviation.

4. AN ECONOMETRIC ANALYSIS

In this section, we present the method and results of our econometric analysis. In this context, the sample October 1998 to end-2014 includes the recent episode during which the Bank of England has

given forward guidance to markets (i.e., effective August 2013), whereas the two subsamples deliberately exclude it. In the descriptive analysis of the previous section, the two states "normal times" and "crisis times" were used to distinguish episodes during which the transmission mechanism may have changed. In an international comparison, it needs be taken into account that central banks reached the zero lower bound at different points in time. The descriptive analysis shows that, given the enormous uncertainties and the increased volatility during crisis times, disagreement among policy-makers increased strongly. But, still central banks were changing their policy rates implying that the skew could have continued to be informative about future monetary policy intentions. However, during times when central banks maintained their policy rates at a low and constant level, the skew may have lost its information value to the extent that policy-makers disagreed on the policy rate. In the case of the Bank of England, the constraint of the zero lower bound became effective in March 2009. We distinguish between the full sample (October 1998 to end-2014) and two subsamples (October 1998 to September 2012; October 1998 to March 2009), both excluding the episode of the very low interest rates. During the financial crisis the MPC maintained the bank rate at 0.5% (i.e., a level that is very close to the zero lower bound). By comparing both samples, we can assess whether the results are robust to the inclusion of the extraordinarily long period of very low interest rates, which implied no change in the bank rate since March 2009. Moreover, during this period, MPC communications were also aimed at clarifying that interest rates would remain at these low levels as long as the Bank engaged in quantitative easing policies. On the one hand, this could imply that over shorter horizons market participants can more easily predict interest rate decisions by the MPC, since they expect unchanged policy rates. This would be reflected in a zero skew, implying that the estimated Probit model would still be valid. On the other hand, this may make it even more difficult for them, since markets could be concerned that the central bank surprises them with an exit from the low interest rates in response to suddenly changing fundamentals. If such concerns exist in the MPC, this would imply a non-zero skew, which could over time render the Probit model invalid.

When measuring the impact of the release of minutes on expectations, an important issue is identification. Other communication tools (such as the quarterly Inflation Report or the press conference) may already provide markets with ample information about the next policy decision. Whenever other communication tools provide the markets with information on the Bank of England's

likely monetary policy response, the signal coming from the publication of minutes is expected to be weaker, since information provided by it would be already priced in.

The publication of new information in MPC minutes has typically preceded the MPC's decision to change interest rates and has contained information that is useful for a forward-looking assessment of its monetary policy stance. Moreover, the Bank of England has changed interest rates only when sufficient evidence had been accumulated that it was necessary (i.e. this was typically the case in those months when an Inflation Report was published together with a new inflation forecast). This behaviour is also evident from the fact that about 60% of the interest rate changes (sample October 1998 to end-2014) coincided with the publication of the Inflation Report. By contrast, only about 20% of the interest rate changes were made when the Inflation Report preceded the change in the policy rate, and thus could have contained relevant information about a forthcoming interest rate change. Hence, the MPC's Inflation Report appears to be mainly a tool for post-meeting communications explaining in more detail the reasoning behind the last decision(s).

In this context, the study by Ehrmann and Fratzscher (2006) finds that the collegial approach to communication followed by the Bank of England has implied that markets were less prepared for upcoming decisions than was the case for other central banks which care about this issue. Hence, it would be expected that financial markets react rather moderately to the MPC communications. However, available evidence from Reeves and Sawicki (2007) suggests that the publication of the MPC minutes significantly influenced near-term interest rate expectations. But, concerning the Inflation Report and the press conferences, they find that these events only led to transitory market reactions and created additional volatility, although these reactions tend to disappear when using daily data.

In the following, Section 4.1 explains the econometric approach and Section 4.2 presents the empirical results.

4.1. The econometric approach

The objective of our empirical analysis, which uses Ordered Probit models to forecast interest rates on the day before and on the day after the publication of MPC minutes, is threefold. First, we examine whether MPC minutes contain information about the correct direction of the MPC's next

interest rate decision, which would allow market participants to (systematically) improve their predictions of the next policy move. This hypothesis would require that information obtained from the minutes is significant in predicting future policy changes in a model which includes market expectations that are measured before the minutes are published. Second, we assess whether market participants efficiently use the information provided in the MPC minutes when forming their expectations about the next policy move once the minutes are published. This hypothesis would require that information obtained from the minutes no longer helps to increase the predictive power for (policy) interest rate changes in a model that also includes a valid indicator of market expectations. Third, we check whether market participants obtain relevant information from the minutes at all or whether information contained in the minutes is redundant (i.e., just noise). This hypothesis would require that a model predicting monetary policy using market expectations that reflect market perceptions (immediately) after the publication of the MPC minutes significantly outperforms a model predicting monetary policy using expectations formed before the publication of the minutes.

An ordered Probit Model

At a meeting the MPC faces three mutually exclusive choices: it can tighten the monetary policy stance, loosen it or keep it unchanged. Because the MPC changes the bank rate in multiples of 25 basis points, and changes of more (less) than 25 basis points are rare, it is preferable to transform these choices into a discrete variable. Unlike the observed interest rate (i), which is continuous in time, the dependent variable (Δr) in our model is discrete and has been coded applying the following three categories: -1: interest rate decrease ($\leq$ -25 basis points), 0: no policy change, 1: interest rate hike ($\geq$ 25 basis points). We therefore use an Ordered Probit model to predict the MPC's policy actions.[5]

In this respect, we follow the recent literature on voting in monetary policy committees (see

[5] Instead of specifying a conventional Ordered Probit model, as is done in this paper, interest rate changes could be modelled by means of a Zero-Inflated Ordered Probit model (see Brooks, Harris and Spencer, 2012). For example, the use of such a model would be indicated if the large majority of decisions taken by the MPC fell into one particular choice category of the decision tree (e.g., a majority of decisions would imply interest rate hikes of a specific amount). However, this methodological advancement is not necessary here for the following reasons. First, the observed distribution of interest rate changes appears to be fairly symmetric around the choice of no change in interest rates (see Figure 5). In addition, the MPC's bank rate changes were mostly made in steps of 25 basis points in either direction. Although many meetings ended with the MPC decision to leave bank rates unchanged, the sample includes a sufficient number of changes in the dependent variable. Second, while we are analysing whether market expectations correctly anticipate the direction of a future interest rate change, we are not assessing whether these expectations fully anticipate the size of the change.

Harris, Levine and Spencer, 2011; Gerlach-Kristen and Meade, 2011, Horváth, Smidková and Zápal, 2012; Riboni and Ruge-Murcia, 2014). These studies have used the skew as an explanatory variable for future interest rate changes.

Following Gerlach-Kristen (2004) and Horváth et al. (2012), we specify the following baseline Ordered Probit model:

$$\Delta r^*_{t+1} = \beta_1 \, \Delta i_{t-1} + \beta_2 skew_t + \beta_3 \, market_{X(t)\pm\tau} + \omega_t \qquad (2)$$

$$\text{with} \quad \Delta r_{t+1} = \begin{cases} -1 \; if \; \Delta r^*_{t+1} < \mu^- \\ 0 \; if \; \mu^- < \Delta r^*_{t+1} < \mu^+ \\ 1 \; if \; \Delta r^*_{t+1} > \mu^+ \end{cases},$$

where Δr is the ordinal variable capturing the change of the policy rate, Δr^* is the corresponding latent variable, Δi refers to the (lagged) change of the interest rate in basis points as reported by the Bank of England, *skew* is the skewness indicator, *market* is the financial market indicator used in the respective regressions, t is a time index which corresponds to each monthly meeting of the MPC (in this specification, we follow Gerlach-Kristen (2004, p. 303) and specify the date of the interest rate decision as t-1 and the date of publication of the minutes with the vote as t, whereas t+1 is the time of the next policy decision), X(t) denotes the publication date of the minutes for the meeting in t, i.e., t <X(t)< t+1, τ is one (trading) day, i.e., ±τ indicates that our financial market data is obtained one day before the meeting or one day after it respectively.[6] The β_i are regression coefficients, ω is a Gaussian error term, and μ^- and μ^+ denote the thresholds for a change of the ordinal dependent variable. These regressions are estimated separately with $market_{X(t)-\tau}$ and with $market_{X(t)+\tau}$.

In order to check for robustness, we also perform tests with two variants of equation (2). In the first variant, we replace the skew variable by its corresponding changes. This equation performs well in terms of the significance of the explanatory variables, although it has a slightly lower R^2 throughout all variants. Moreover, the results with the Vuong tests are the same for both specifications and across samples. However, from a conceptual perspective, it is the skew in levels (and not in changes) which should be a leading indicator for future interest rate changes, since it contains information about the direction of the disagreement within the monetary policy committee. In the second variant, we drop the

[6] In some rare instances where it was not possible given data availability constraints, we took data corresponding most closely to these dates.

skew from the model. By contrast to the other specification with the skew, which examines whether the market is efficient in incorporating incoming information, this specification is a check whether markets have learnt anything from the release of the minutes. Consistent with the notion that the skew is an important explanatory factor, the R^2 is reduced in this alternative model. Though, in terms of the overall assessment applying the Vuong tests the results remain robust. Therefore, for brevity of the exposition, in the following we only report the results with (2).[7]

An augmented ordered Probit Model

In addition, we augment our original specification (2) with further information on the distribution of interest rate expectations. It is unclear whether the skew (which has been derived from the votes of the MPC members; see equation (1)) already reflects the full distribution of market interest rate expectations of the next move or only mirrors the mean of their expectations. By contrast, the market skew, as reported on the Bank of England's website, is a risk-neutral measure, which incorporates risk premia and contains information on both the skewness and the variance of the preference distribution of market participants. For the robustness check, three additional variables are included in the above model: the skewness of market participants, their standard deviation and a corresponding interaction term. We estimate the following variant of the above Ordered Probit model for the day before and after the publication of minutes:

$$\Delta r^{*}_{t+1} = \beta_1 \Delta i_{t-1} + \beta_2\, skew_t + \beta_3\, market_{X(t)\pm\tau} + \beta_4\, mskew_t + \beta_5\, \sigma_t(mskew) + \beta_6\, \mathrm{int}_t + \upsilon_t \quad (3)$$

with the notations as above, *mskew* denotes the skew derived from market expectations, *σ(mskew)* its standard deviation and *int* denotes an interaction term (the product of the market skew and its standard deviation).

Furthermore, in order to check for the robustness of the results, we estimate the above specifications with alternative proxies of financial market indicators capturing different horizons of market expectations.

[7] The results are available from the authors.

The Vuong test

By means of the Vuong test we check whether alternative specifications of an Ordered Probit model before and after the release of the minutes are similar. The Vuong test compares predicted probabilities of two non-nested models (see Vuong, 1989).[8] In this context, the Vuong test does not allow any inference about which of the two models is the "true" model, but this is not needed for the present exercise. For the benchmark specification, the Vuong test compares model 1 (the Ordered Probit model which uses the market variable on the day before the publication of the minutes) with model 2 (the Ordered Probit model which uses the market variable on the day after the publication). Other than using market variables from different days, model 1 and model 2 are identical. Therefore, the Vuong test would only reject the null hypothesis that both models explain the data equally well in favour of model 2, if the post-meeting market variable contains additional information that contributes to improved predictions of the MPC's future interest rate changes. In order to detect a significant improvement in the formation of market expectations to the publication of minutes, the test therefore has to indicate that the model 2 incorporating information from the release of the minutes is significantly superior to the pre-release model 1.

While this test can show whether markets gain relevant information during the time window between the market variables used in model 1 and model 2, the newly gained information may not necessarily come from the release of MPC minutes. The uncertainty regarding future policy changes should generally decline when moving closer to the MPC meeting, whether or not minutes are published. To assess this point, we repeat the test for additional control windows, which are either 7±1 days before the release of the minutes or 7±1 days after the release of the minutes. Here, we check whether the Vuong-test gives similar indications for additional information as for the window around the minutes release. If "*moving closer to the MPC meeting*" is not the driving factor of the results, this robustness check should show that there are no such differences for the other periods.

4.2. Empirical results

Overall, our results suggest that the MPC minutes have helped private market participants to

[8] In this paper, we report the results with the one-step Vuong test. Given that the distribution could be skewed, we also performed the two-step Vuong test, and found that these tests fully confirmed the results reported.

forecast the next interest rate move of the Bank of England. Markets take that information into account when forming interest rate expectations, but do not fully exploit information on the skew when forming their expectations for the next meeting. Tables 2 and 3 show that all Probit regressions of equation (2) and (3) respectively display satisfactory statistical properties. With the exception of the market skew and the interaction term, coefficient estimates are generally significant and have the expected sign. Moreover, as indicated by the pseudo R^2 statistics, which have a magnitude of between 0.25 and 0.50, the regressions display a fit that is reasonable for this type of analysis. When comparing the fit of the regressions using market expectations before and after the MPC minutes release, it turns out that the fit typically increases somewhat for regressions that included information after the release. This result is a first indication that the MPC meeting minutes provide new information to the market assessment of future policy changes of the Bank of England.

In line with a recent study by Horváth et al. (2012) and Gerlach-Kristen (2004), both types of regressions show that the skew adds significantly to explaining forthcoming changes of the bank rate. This result is robust to the inclusion of financial market indicators for market expectations of interest rate changes around the date of the publication of MPC minutes. Moreover, the lagged interest rate change is significant, thus indicating a high degree of persistence in the policy rate. While persistence could also indicate that markets underestimate the momentum of the policy rate, relative to other factors its quantitative contribution is rather small. In this context, the estimates for equation (3) show that the lagged interest rate is not generally significant, while the skew still is.

An important issue is whether the stability of the relationship may have been affected by the Bank of England's adoption of quantitative easing in an environment of very low interest rates. Under these circumstances, MPC minutes may contain little information to provide markets with additional insights on the monetary policy stance, and in particular on the next interest rate move. Though, the voting record of the MPC makes a distinction between disagreement on non-standard measures and conventional interest rate changes. This implies that when calculating the skew only disagreement on the lift-of from the low interest rates is included, whereas disagreement on non-standard measures is excluded. A comparison of the results for the two longer samples (upper half of Tables 2 and 3) and the shorter sample ending in 2009 (lower half of Tables 2 and 3) shows that this relationship is robust, since

the skew is significant in all regressions and coefficients are fairly similar for these samples.[9] Moreover, additional tests with longer maturities of 6 and 12 months show that minutes do not become more informative for these longer horizons.

Table 2 reports the results from the comparison of the Probit models one day before the release of the MPC minutes and with those from the day after it. When using the difference between the current policy rate and the interest rate implied by short-term (one-month) money market futures as a market variable, the Vuong test clearly indicates superiority of the Probit model after the release of minutes. This would indicate that markets could improve their prediction model of the future bank rate by exploiting information on the day of the publication of minutes. This result holds for both the full sample and the two subsamples. Nevertheless, when other proxies for the market response are used (either the change of the interest rate implied by the futures (three-month) between the day after the MPC meeting and the day before the publication of the minutes (or the market skew derived from short-term sterling options), the Vuong test cannot reject that the Probit models before and after the release of minutes are similar; that is, these checks for robustness suggest that if the (short-term) market response is measured with other proxies, the result of the superiority of the model one day after the publication of the MPC minutes no longer holds. Furthermore, when repeating the tests for arbitrarily chosen control days during periods when no minutes were released, we find that the Vuong tests, as they should, do not reject that the Probit models before and after the day are similar for all market spreads considered in the present analysis.[10] This suggests that the test approach is sufficiently sensitive so as to distinguish between a "placebo effect" and a genuine effect of central bank communications.

Table 3 shows that the augmented set of Probit regressions (equation 3) has a somewhat better fit than the above regressions (equation 2), as indicated by the higher pseudo R^2 statistics. Among several additional controls (market skew, standard deviation of the market skew, interaction term), only the standard deviation of market expectations is significant and has a negative sign. This might lend support to the view that the Bank of England actively attempts to calm markets in times of high uncertainty by aiming at a level of the bank rate which corresponds to the lower end of the distribution of what markets expect. Otherwise, the robustness checks fully confirm the results obtained for equation (2).

[9] The difference among the regressions is so small that a break-point test would reject instability.
[10] For brevity of the analysis, we do not report the results here, but they are available from the authors.

Only when the difference between the current policy rate and the interest rate implied by short-term (one-month) money market futures is used as market proxy do the results suggest that markets have improved their forecasting model between the day before and after the release of the MPC minutes.

5. CONCLUSIONS

When designing an effective communication policy, central bankers need to choose appropriate channel(s) by which they regularly communicate information about monetary policy to markets. Does the publication of central bank meeting minutes help markets to better predict monetary policy decisions? This paper examines that question for the case of the Bank of England, whose MPC has been publishing timely minutes (with voting records) since 1998. The approach is an empirical one explaining future interest rate changes based on an Ordered Probit model and applying the Vuong test to identify changes in the market assessment coinciding with the release of the MPC minutes. The empirical evidence presented in this paper suggests that published minutes of the MPC's deliberations have helped markets in forming their expectations on future policy decisions.

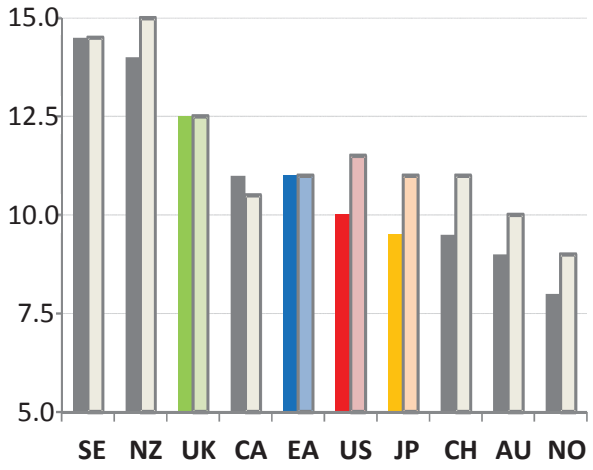
In line with Gerlach-Kristen (2004) and Horváth et al. (2012), we find that the interest rate skew from the voting records of the MPC minutes contributes to explaining future changes of the Bank of England's bank rate. Our results show that, in the very short term, markets already make use of new information from the MPC minutes and thereby improve their expectations of the next interest rate move, as reflected in short-term money market futures (one-month). However, markets do not use this information to revise their interest rate expectations for longer maturities of three months and beyond. Furthermore, controls for (three-day) periods when no minutes are released are indicative of no significant changes in the market assessment for all market spreads considered, thereby confirming the robustness of the present approach.

In terms of extending this analysis, the present approach could be also used to test for the impact of other communication tools on private interest rate expectations, such as press conferences (see Ehrmann and Fratzscher, 2009b). In this context, results from Reeves and Sawicki (2007) suggest that other communication tools of the Bank of England, such as press conferences and central bankers' speeches, are less effective compared to the meeting minutes, since the former mainly lead to increased volatility of

asset prices.

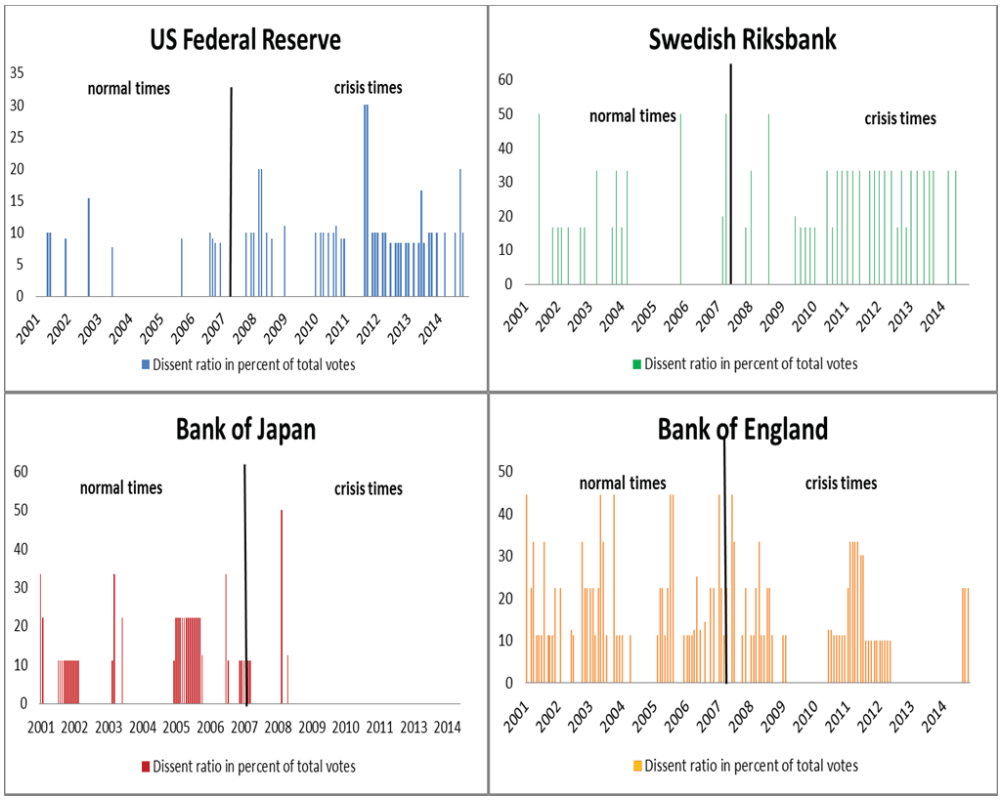
Finally, in terms of policy implications, the present analysis identifies the practice of publishing minutes of monetary policy meetings (with voting records) as a useful tool for central banks. Published minutes allow central banks to improve short-term predictability of future interest rates, but an increase in asset price volatility in the very short term can occur. This result still holds when the episode of the Bank of England's forward guidance is taken into account. Nevertheless, forward guidance, if credible, may have advantages compared with the MPC minutes when policy-makers aim to influence interest rate expectations along a longer horizon. But the MPC minutes may contain important information, if policy-makers want to explain conditionality of their assessments and intentions to markets.

FIGURE 1: A comparison of monetary policy transparency indices



Source: Dincer and Eichengreen (2014) and Horváth and Vaško (2012). Note: Pre-crisis 2006 level (left bars) and observed level in 2011 (right bars). SE: Swedish Riksbank, NZ: Reserve Bank of New Zealand, UK: Bank of England, CA: Bank of Canada, EA: ECB, US: Federal Reserve, JP: Bank of Japan, CH: Swiss National Bank, AU: Reserve Bank of Australia, NO: Norges Bank.

FIGURE 2: Votes and dissenting votes in selected monetary policy committees



Source: Websites of the central banks.

FIGURE 3: Timing of the Bank of England's communications

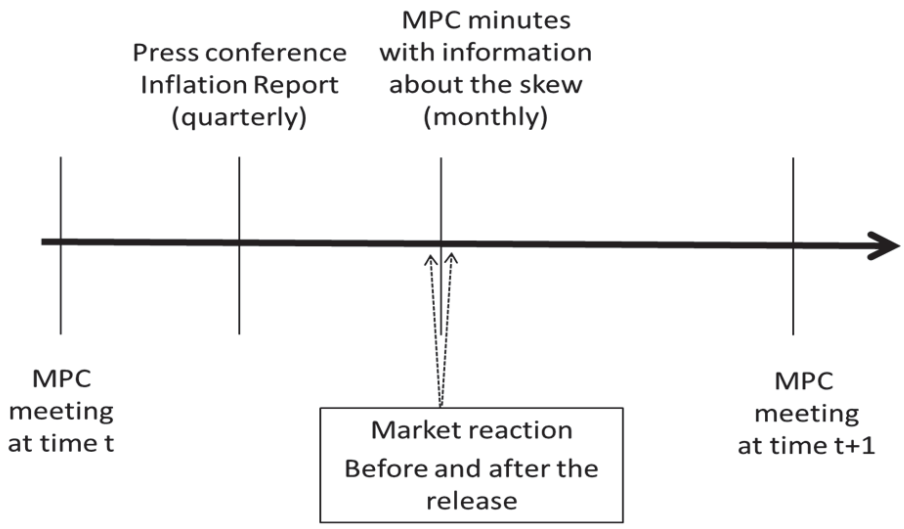
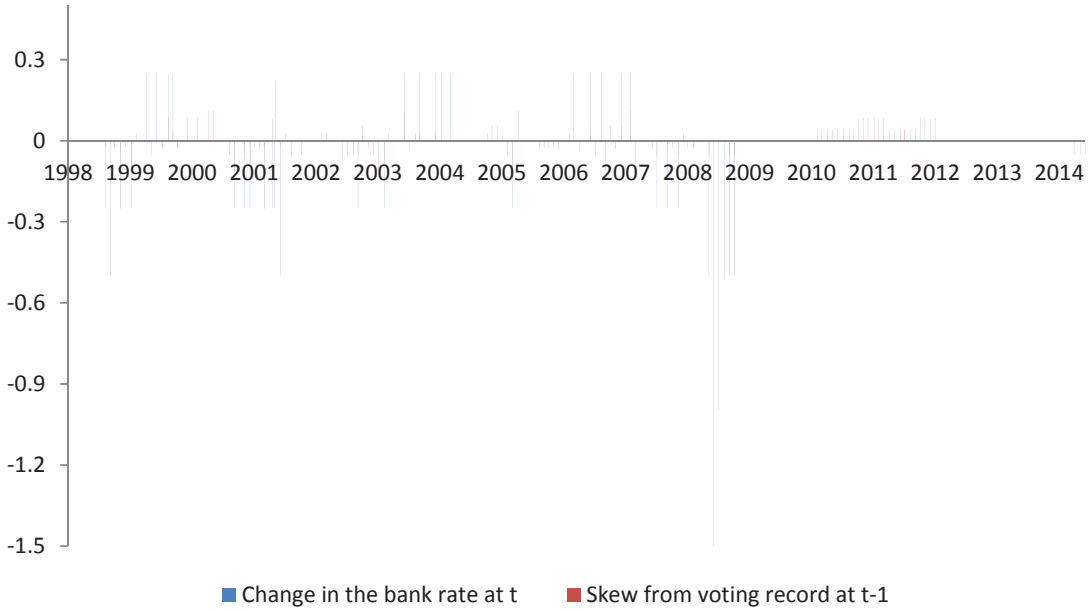


FIGURE 4: MPC bank rate changes and the skew

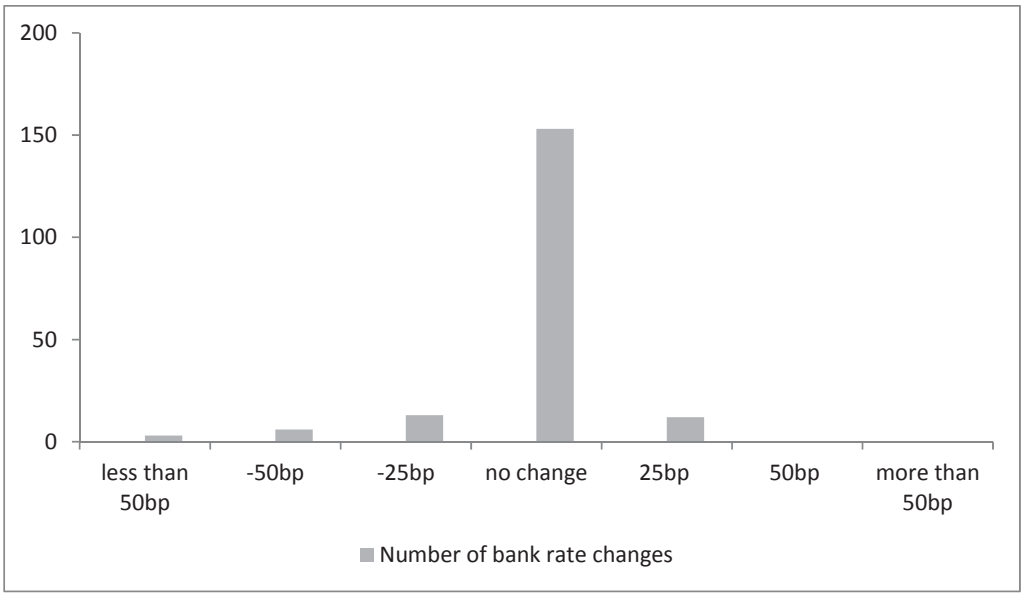
(in per cent)



Source: Bank of England.

FIGURE 5: Distribution of the MPC's bank rate changes (1998 to 2014)

(number of observations)



Source: Bank of England.

Table 1: Publication of minutes by main central banks

Central bank	Meetings (per year)	Published Minutes	Publication lag (in weeks)	Published voting record
Bank of Canada	8	no	no	no
Bank of England	12	yes	2	yes
Bank of Japan	14-19	yes	3 to 4	yes
European Central Bank	8 (1)	yes(2)	4	no
US Federal Reserve	8	yes	3	yes
Norges Bank	6	no	after 12 years	yes
Reserve Bank of Australia	12	yes	2	no
Swedish Riksbank	6	yes	2	yes
Swiss National Bank	4	no	no	no

Source: Websites of the central banks.

Notes: (1) Until December 2014 the Governing Council of the ECB held monthly meetings on monetary policy matters, but as of January 2015 it changed to a six-week cycle. (2) The ECB publishes so called "accounts" of monetary policy discussions from January 2015. Since these accounts aim to offer a fair and balanced reflection of policy deliberations, and are therefore close to what other central banks call "minutes".

Table 2: Results of Ordered Probit models (equation 2)

	Variable			one month market spread		one month future spread		three month market spread		μ-	μ+	Pseudo	Vuong
Sample		Δi(t-1)	skew(t)	day -1	day +1	day -1	day +1	day -1	day +1			R squared	test
		2.47**	7.42**	5.40**						-2.20**	1.68**	0.37	
		(2.83)	(2.43)	(5.22)						(8.88)	(9.58)		-2.57
		1.94*	8.24**		5.71**					-2.25**	1.68**	0.40	[0.011]
		(2.04)	(3.32)		(5.67)					(9.12)	(9.46)		
		3.99**	9.33**			4.84**				-1.60**	1.79**	0.26	
1998-2014		(5.26)	(4.13)			(3.11)				(9.57)	(10.45)		-1.15
		2.83**	7.82**				9.65**			-1.62**	1.86**	0.34	[0.251]
		(3.06)	(3.34)				(4.67)			(9.64)	(10.27)		
		2.94**	9.25**					2.48**		-1.25**	2.62**	0.38	
		(3.68)	(3.86)					(5.27)		(6.74)	(8.91)		0.81
		2.96**	9.13**						2.03**	-1.23**	2.42**	0.36	[0.418]
		(3.55)	(3.85)						(5.07)	(6.79)	(9.24)		
		2.35**	7.08**	5.04**						-2.07**	1.61**	0.35	
		(2.75)	(2.93)	(4.93)						(8.18)	(8.95)		-2.56
		1.84*	7.81**		5.38**					-2.12**	1.61**	0.39	[0.012]
		(1.98)	(3.17)		(5.40)					(8.41)	(8.86)		
		3.73**	8.93**			4.58**				-1.49**	1.71**	0.25	
1998-2012		(4.97)	(3.99)			(2.97)				(8.74)	(9.75)		-1.15
		2.59**	7.56**				9.31**			-1.51**	1.79**	0.33	[0.252]
		(2.85)	(3.27)				(4.54)			(8.79)	(9.63)		
		2.69**	8.82**					2.44**		-1.12**	2.58**	0.38	
		(3.40)	(3.69)					(5.23)		(5.83)	(8.77)		0.76
		2.69**	8.72**						2.01**	-1.11**	2.38**	0.36	[0.450]
		(3.28)	(3.68)						(5.02)	(5.89)	(9.01)		
		2.09*	8.61**	5.22**						-2.08**	1.23**	0.36	
		(2.44)	(2.57)	(4.82)						(7.54)	(6.40)		-1.96
		1.5	9.45**		5.69**					-2.16**	1.22**	0.41	[0.053]
		(1.58)	(3.56)		(5.31)					(7.83)	(6.29)		
		3.40**	9.40**			4.09**				-1.36**	1.48**	0.25	
1998-2009		(4.65)	(3.92)			(2.62)				(7.48)	(7.98)		-1.13
		2.43**	7.61**				8.52**			-1.33**	1.58**	0.31	[0.260]
		(2.60)	(2.98)				(3.95)			(7.30)	(7.99)		
		2.36**	9.64**					2.37**		-1.04**	2.28**	0.37	
		(2.97)	(3.82)					(4.93)		(5.10)	(7.65)		1.05
		2.45**	9.34**						1.89**	-1.03**	2.09**	0.35	[0.297]
		(2.95)	(2.49)						(4.63)	(5.20)	(7.81)		

Notes: Z-statistics are reported in parentheses; ** refers to the 1% significance level, * refers to the 5% significance level; m^n_t is the interest rate implied by *n* month ahead money market futures at time *t*. Hence, one-month market spread refers to: $m^1_{S(t)} - i_t$; one-month future spread refers to: $m^1_{S(t)} - m^1_t$; three-month market spread refers to: $m^3_{S(t)} - i_t$. The row "*Vuong test*" reports likelihood ratio statistics of the Vuong test and the *p* values are reported in square brackets. The null hypothesis is that both models under consideration are equally close to the true model.

Table 3: Results of Ordered Probit models (equation 3)

	Variable			one month market spread		one month future spread		three month market spread							Pseudo	Vuong
Sample		Δi(t-1)	skew(t)	day -1	day +1	day -1	day +1	day -1	day +1	mskew(t)	σ(t)[mskew]	int(t)	μ-	μ+	R squared	test
		1.90*	8.09**	5.57**						-0.66	-3.04*	1.56	-3.21**	0.72*	0.40	
		(1.97)	(3.15)	(5.07)						(1.55)	(2.39)	(1.03)	(6.45)	(2.00)		-2.88
		1.45	9.26**		6.03**					-0.57	-2.88*	1.10	-3.24**	0.72**	0.44	[0.004]
		(1.42)	(3.47)		(5.49)					(1.33)	(2.34)	(0.72)	(6.43)	(2.01)		
		3.15**	8.80**			4.54**				-0.45	-2.81*	1.59	-2.40**	0.99**	0.28	
1998-2014		(3.75)	(3.71)			(2.79)				(1.18)	(2.33)	(1.19)	(5.79)	(2.79)		-1.74
		1.96*	6.82**				10.20**			-0.39	-2.90*	1.80	-2.36**	1.08**	0.36	[0.085]
		(2.00)	(2.70)				(4.53)			(0.99)	(2.40)	(1.26)	(5.63)	(2.98)		
		0.95	8.85**					3.91**		-0.42	-7.50**	1.20**	-3.51**	1.20**	0.50	
		(0.92)	(3.17)					(5.66)		(0.84)	(4.31)	(2.89)	(5.71)	(2.89)		-0.55
		0.37	7.62**						3.99**	-0.18	-8.28**	1.05**	-3.75**	1.05**	0.51	[0.582]
		(0.34)	(2.66)						(5.65)	(0.38)	(4.69)	(2.69)	(5.80)	(2.69)		
		1.90*	8.13**	5.42**						-0.80	-3.00*	1.99	-3.14**	0.69	0.4	
		(1.98)	(3.13)	(4.95)						(1.62)	(2.31)	(1.18)	(6.19)	(1.86)		-2.86
		1.43	9.18**		5.87**					-0.64	-2.84*	1.33	-3.17**	0.69	0.43	[0.005]
		(1.41)	(3.41)		(5.37)					(1.35)	(2.29)	(0.81)	(6.22)	(1.91)		
		3.10**	8.81**			4.39**				-0.55	-2.73*	1.89	-2.30**	0.96**	0.28	
1998-2012		(3.67)	(3.67)			(2.71)				(1.25)	(2.21)	(1.26)	(5.49)	(2.63)		-1.74
		1.90	6.85**				9.97**			-0.45	-2.82*	1.96	-2.30**	1.05**	0.36	[0.084]
		(1.96)	(2.68)				(4.44)			(1.02)	(2.31)	(1.26)	(5.38)	(2.85)		
		0.99	8.87**					3.80**		-0.54	-7.27**	1.10	-3.41**	1.19**	0.49	
		(0.96)	(3.15)					(5.46)		(0.97)	(4.13)	-0.60	(5.47)	(2.83)		-0.52
		0.36	7.50**						3.90**	-0.20	-8.13**	-0.05	-3.68**	1.02**	0.50	[0.604]
		(0.33)	(2.69)						(5.45)	(0.39)	(4.56)	(0.03)	(5.62)	(2.61)		
		1.08	7.57**	5.39**						1.11	-3.68*	-1.10	-3.28**	0.31	0.40	
		(1.08)	(2.82)	(4.71)						(0.93)	(2.61)	(0.34)	(5.75)	(0.77)		-2.46
		0.96	9.16**		5.52**					1.16	-3.04*	-2.85	-3.14**	0.48	0.44	[0.015]
		(0.94)	(3.29)		(4.97)					(1.04)	(2.41)	(0.89)	(5.96)	(1.31)		
		2.59**	8.35**			4.09**				0.92	-3.25*	-1.10	-2.32**	0.67	0.27	
1998-2009		(2.90)	(3.35)			(2.50)				(0.82)	(2.44)	(0.33)	(5.10)	(1.74)		-1.75
		1.36**	6.42*				9.18**			1.40	-3.59**	-0.52	-2.50**	0.68	0.37	[0.083]
		(3.31)	(2.39)				(3.94)			(1.33)	(2.74)	(0.19)	(5.25)	(1.77)		
		-0.08	8.79**					3.95**		0.94	-7.52**	-3.76	-3.32**	0.96*	0.49	
		(0.07)	(3.05)					(5.18)		(0.69)	(3.99)	-1.02	(4.93)	(2.21)		-0.53
		-0.67	7.10*						4.09**	2.37	-8.57**	-5.80	-3.81**	0.86*	0.51	[0.600]
		(0.57)	(2.38)						(5.12)	(1.75)	(4.50)	(1.83)	(5.17)	(2.09)		

Notes: Z-statistics are reported in parentheses; ** refers to the 1% significance level, * refers to the 5% significance level; int is an interaction term; m^n_t is the interest rate implied by *n* month ahead money market futures at time *t*. Hence, one-month market spread refers to: $m^1_{S(t)} - i_t$; one-month future spread refers to: $m^1_{S(t)} - m^1_t$; three-month market spread refers to: $m^3_{S(t)} - i_t$. The row "*Vuong test*" reports likelihood ratio statistics of the Vuong test and the *p* values are reported in square brackets. The null hypothesis is that both models under consideration are equally close to the true model.

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