

Publishing interest rate forecasts – how does the market react?

An analysis of market reactions since Norges Bank introduced forecasts
for the key policy rate

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Abstract

The aim of this study is to evaluate some aspects of how Norges Bank's forecasts for the key policy interest rate have affected market behaviour, and more precisely the volatility of short money market interest rates. The main theoretical arguments in favour of central bank forecasts for the key policy rate are related to improved management of expectations, and the results from this study indicate that private sector expectations have become better aligned with central bank reactions after the forecasts were introduced. This can be interpreted as a greater market understanding of Norges Bank's reaction pattern, in line with the intended effect and with positive implications for an efficient monetary policy.

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Examiner: David Domeij
Discussant: Jan Hannes Lang
Presented: 7 December 2007

¹ I would like to thank my tutor, Martin Flodén, as well as Rickard Sandberg, Per-Olov Edlund, Øistein Røisland, Tom Bernhardsen, Øystein Thøgersen, Christian Kascha, Francesco Ravazzolo, Dag Henning Jacobsen, Hilde Bjørnland and Norges Bank Monetary Policy Department for sharing their knowledge and generously devoting their time to comments and discussions. I would also like to thank Agnar Sandmo and David Domeij for initial inspiration and interesting discussions on thesis topics. Knut Eeg, Jannecke Ebbesen, Geir Engesland Alstad, Terje Åmås and Jostein Eide have provided thorough support on figures and methods. Editorial suggestions from Kjersti Haugland, Ingrid Solberg, Mathias Kube and Dag Henning Jacobsen are gratefully acknowledged. The analyses were carried out using PcGive 10.1 (Hendry and Doornik 2001) and Eviews 5 (Quantitative Micro software 2004).
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1. Introduction

Central bank transparency² has improved substantially in recent years. Three central banks have introduced their own forecasts for the key policy rate, pioneered by the Royal Bank of New Zealand in 1997. Thereby, one of the strongest central banking taboos has been broken: the prohibition to talk about future interest rates.³ The approach to monetary policy has changed from the traditional conventional wisdom “silence is golden”⁴ to the contemporary view of monetary policy as “management of expectations”⁵. In the last two decades, some 20 countries have adopted inflation targeting, making the aims of the monetary policy clear and increasing the commitment of policymakers. Transparency is emphasised as the “core of inflation targeting”⁴ as signals of future policy plans have become more important than current interest rate decisions. Norges Bank, the Norwegian central bank, introduced its own forecasts for the key policy rate in November 2005, taking on the challenge from recent literature on monetary policy.

This thesis reviews the theoretical background for this increased transparency, and evaluates in light of the literature some aspects of how the forecasts for the key policy rate have affected market participants. The empirical analysis looks into effects of the introduction of a central bank interest rate forecast in Norway and briefly compares these with studies of other countries and transparency strategies. Transparency is expected to increase the predictability of central bank actions, resulting in lower interest rate volatility in the market when policy announcements are made. Furthermore, when the market knows more about the central bank reaction function, market reactions should be more in line with central bank behaviour. Based on these expectations, the thesis investigates the volatility of short term money market interest rates as a reaction to monetary policy announcements⁶ and macro news and asks whether the volatility around policy announcements has diminished and if the reactions to macro news have changed.

The analyses indicate positive answers to both questions for the longest interest rates in the sample. The general macroeconomic environment has been more stable after the endogenous interest rate path was introduced in November 2005 than in the previous years, and this is likely to influence the results, especially when it comes to the interest rate surprises. Based on the literature, however, it is reasonable to believe that the results are also related to the increased transparency with interest rate forecasts and that these have had an effect on market reactions. This effect, that is, the improved predictability of monetary policy announcements and changed market reactions, is then as expected.

The thesis contributes to the new and growing area of studies investigating concrete effects of the interest rate forecasts on the Norwegian markets. Due to the short time period at hand, only a few analyses on the topic have been published so far. This is likely to change in the near future. There have, however, been conducted numerous studies on the effects of other or more general forms of transparency, and the experiences from some of these are the basis of the analyses in this thesis. In addition to enlarging the limited number of analyses in this specific area, the main contribution of this study is the combination of analyses of market

² Central bank transparency is in this paper defined as the amount of information about the goals and conduct of monetary policy regularly released to the public, in line with Swanson (2006).

³ Rudebush and Williams (2006), page 4: “Indeed, one of the strongest central banking taboos is to the prohibition against talking publicly about future interest rates”.

⁴ Faust and Leeper (2005).

⁵ Woodford (2005).

⁶ Monetary policy announcements are in the thesis defined as announcements of interest rate decisions and publications of monetary policy reports.

reactions to policy announcements and macro news as an approach to investigating the effects of the interest rate forecasts.

Part 2 of the thesis reviews the broad academic discussion on central bank transparency and interest rate projections, while part 3 gives a brief introduction to the monetary policy regime in Norway and recent developments in the key policy rate. Part 4 is an introduction to the empirical analysis in the two following sections. Part 5 and 6 investigate the development of short Norwegian money market interest rates since the key rate forecasts were introduced with respect to surprises in policy announcements and key figures. Overall conclusions are found in part 7. Readers of the thesis are expected to be familiar with basic monetary policy theory.

2. Literature review

2.1 “Management of expectations” and central bank transparency

The improved transparency in central banking has been in line with the theoretical achievements in the area of monetary policy. Private expectations about future policy have been increasingly recognised as the main channel of influence for monetary policy. According to Woodford (2005) and Svensson (2007), the current level of the overnight interest rates is of negligible importance for economic decision-making. What matters are the private sector expectations of future policy, and monetary policy primarily affects the economy through its influence on these. In line with this development, strategies of communication and transparency have become increasingly important parts of the conduction of monetary policy. Svensson (2003a) emphasises that transparency may have a large impact on private sector learning in helping agents to form correct expectations about the economy and inflation. Hence, “educating the market and the general public about monetary policy is a natural part of successful inflation targeting”⁷. This development has led the way from the view that the only way for a central bank to affect markets is by surprises, to the comprehensive communication strategies of today. Blinder (1998) argues that increased transparency makes independent central banking more consistent with democracy and improves the stabilisation properties of monetary policy.⁸

Bernhardson and Kloster (2002) define effective monetary policy as stable inflation expectations close to the inflation target and market expectations of future policy changes based on a correct understanding of the central bank’s response pattern. This is what is expected to improve following increased transparency. According to Geraat’s (2006) review, main theoretical results are that monetary policy transparency increases the predictability of monetary policy actions and outcomes, induce reputation building, enhance credibility and makes long-run private sector inflation expectations more stable. Results that support transparency are reported by most empirical analyses investigating the effects of this development so far, as shown by Van der Cruysen and Eijffinger (2007).

Today, the ultimate transparency among inflation targeting central banks is to communicate projections of the key policy rate. Although most theoretical and empirical research on the topic support transparency in general, the discussion of whether to communicate projections of the key policy rate has been less conclusive, and the theory is continuously developing. Three central banks have taken transparency as far as introducing their own interest rate forecasts. The Reserve Bank of New Zealand (RBNZ) published interest rate forecasts as early as 1997, while Norges Bank and Sveriges Riksbank followed in 2005 and 2007.

⁷ Svensson (2006a), page 11.

⁸ According to Goodfriend et al (2007), transparency can be counterproductive if it exposes the fact that a central bank has inconsistent objectives, hidden or otherwise, or incoherence in its internal analysis of monetary policy. Such counterproductive effects will, despite being a potential problem, not be the focus of this thesis, which rather emphasizes market effects of transparency assuming consistent objectives and analysis within the central banks.

2.2 Publish or not?

The academic discussion on central bank's interest rate projections

2.2.1 Arguments in favour of central bank forecasts for the key policy rate

The main arguments in favour of central bank transparency and interest rate forecasts are improved management of expectations, based on better possibilities to commit and resulting in more stable macroeconomic outcomes and a policy in line with democratic principles.

Democratic transparency is emphasised by some of the advocates of key policy rate projections, e.g. Mishkin (2004) and Issing (2005), arguing that increased transparency in general is a positive development in a democracy. Faust and Leeper (2005) also emphasize democracy when they argue that such forecasts enable the public to test the consistency of central bank policy and make the policymakers more accountable for their actions. Ferrero et al (2007) refer to a wide consensus that some level of transparency is necessary to counterbalance the increased independence of central banks in democratic societies. However, according to Geraats (2006), transparency practices do not seem to be driven primarily by required accountability. Instead, central banks appear to have embraced transparency for its perceived economic benefits.

The main arguments in favour of central bank forecasts for the key policy rate are related to such benefits, achieved through the management of expectations that in different respects are affected by increased transparency and policy rate projections. Most advocates argue that key rate projections will increase the central bank's influence on private sector expectations. Some also emphasize that the projections enable a stronger commitment for the policymakers, while others consider positive macroeconomic effects of better expectations management. Svensson (2007) argues how forecasts for other economic variables are likely to be improved with more realistic and possibly optimal interest rate projections. The following section will briefly review some of the most outspoken arguments for how interest rate projections can improve the management of expectations.

Svensson (2007) argues that a forecast of the key policy rate is the most efficient way to manage private sector expectations, and hence, to implement monetary policy. In Svensson's view, the effects of announcing a future path of the key policy rate will be a more efficient implementation of monetary policy and better managed and founded private sector expectations. This is in line with Rosenberg (2007) who emphasises increased central bank influence on market expectations as the main reason to publish interest rate forecasts in Sweden. Kahn (2007) agrees that credible paths are likely to influence market rates in the direction of the central bank policy, enhancing the policy, and Faust and Henderson (2004) include such openness as one of the core requirements for best-practice monetary policy. Many central banks recognise the importance of future interest rates and expectations over the current level of interest rates and try to communicate some aspects of their future outlook and policy plans. However, Svensson (2006a) is critical to this implicit signalling procedure, along with Woodford (2005), Rudebush and Williams (2006), Faust and Leeper (2005) and many others, and argues that "the central banks should be more specific, systematic and transparent about key policy rate paths and plans"⁹ – hence, make interest rate projections rather than giving hints.

Woodford (2005) advocates interest rate projections as a mean of commitment assumed to improve the expectations management. He connects such projections to the more general discussion on time inconsistency, rules and discretion based on Kydland and Prescott

⁹ Svensson (2006a), page 8.

(1977)¹⁰ by giving examples of how projections can be a source of commitment. Projections can be a substitute to communicating a general strategy for central banks reluctant to commit to or communicate a long-term strategy, but occasionally willing to depart from total discretion. Woodford refers to The Federal Reserve and Bank of Japan as examples of such central banks that do not announce a complete path for the key policy rate, but still communicate expectations or plans for the near future. Key policy rate projections can also be relevant for central banks that follow rules and want to show implications of the strategy and increase the understanding of the bank's reaction function without revealing a specific rule.¹¹ Furthermore, Woodford (2005) argues that key policy rate projections can be helpful to conduct an optimal policy based on a history-dependent policy rule¹², where the central bank clarifies a desirable policy path given the absence of economic disturbances.

Many scholars argue that improved management of expectations can give better macroeconomic outcomes defined as increased stability in output and inflation. Rudebush and Williams (2006) emphasise this as the main argument in favour of key policy rate forecasts from central banks. Their findings show that fluctuations in inflation and output are reduced as the path of the key policy rate facilitates the economy's convergence back to the inflation objective after a shock. The results are based on recent research on how implicit signalling from central banks affects financial markets, and their model shows that endogenous interest rate paths better align the expectations of the public and the central bank. The alignment of expectations reduces the magnitude of fluctuations in output and inflation.¹³ Hence, the macroeconomic performance is improved, in line with central bank goals for an optimal policy.¹⁴ Kahn (2007) also argues that an economy with well founded private sector inflation expectations and a credible monetary policy may also be characterised by more stable macroeconomic conditions, as temporary inflationary shocks are less likely to be built into prices and wages. Kahn (2007) also expects more efficient asset pricing in financial markets to be a positive effect of interest rate forecasts, as he believes that reduced uncertainty will reduce volatility in asset prices. Rudebush and Williams (2006) conclude that "Publishing interest rates (projections) facilitates the management of expectations and the yield curve"¹⁵, and they go further than most other advocates of key policy paths when supporting full central bank transparency.¹⁶

¹⁰ Kydland and Prescott (1977) showed that if the authorities in each period attempt to optimise on a discretionary basis, a suboptimal equilibrium may arise due to economic agents' expectations formation. Kydland and Prescott argued in favour of a rule-based policy, where policymakers commit to a certain pattern of behaviour. For this to be successful, the commitment must be credible so that economic agents can assume that decision-makers will not "reoptimise" later on but actually follow their announced response pattern.

¹¹ Woodford (2005) emphasize that it is impossible to commit to a specific rule, but the bank may still want to reveal some of its reaction function..

¹² An optimal policy depends on the bank to commit to some history-dependent policy rule, i.e. the policy depends on the way previous actions and happenings were perceived at the time.

¹³ The findings are in line with Orphanides and Williams (2005), who show that the central bank loss is lower when the public knows the monetary policy rule than if they are to estimate it using limited data.

¹⁴ An optimal policy is in this respect an interest rate path minimizing the intertemporal loss function of the central bank). Such a loss function is a common way to specify the trade-offs between stabilising inflation and the real economy faced by policymakers. The central bank attempts to minimise the loss function. (Bergo, 2007). Svensson (2003b) shows how the cumulative loss can be expressed by the following equation:

$$L = E_t \sum_{k=0}^{\infty} \beta^k [\pi_{t+k} - \pi^*]^2 + \lambda(y)^2]$$
 where π is inflation, π^* is the inflation target, y is the output gap and β is a

discount factor. λ is a parameter that expresses how much weight is given to stable output versus low and stable inflation. If λ is greater than 0, this is often referred to as flexible inflation targeting.

¹⁵ Rudebush and Williams (2006), page 4.

¹⁶ Faust and Leeper (2005) are even less orthodox when suggesting unconditional central bank forecasts for all economic variables, including the instrument rate.

2.2.2. Arguments against central bank forecasts for the key policy rate.

The main arguments against central bank forecasts for the key policy rate are the risk of market misunderstandings of the forecasts as unconditional commitments, that the MPC may find it difficult to agree on a specific future interest rate path, that the central bank may be reluctant to deviate from an announced path that is no longer optimal and that there may be negative consequences reduced information diversity in the market.

A projection of the key policy rate may be misleading if perceived as an unconditional commitment from the central bank. Goodhart (2005) and Mishkin (2004) argue that interest rate forecasts can lead private expectations in wrong directions when some private actors do not understand that the interest rate paths are conditional upon the information available at the time of announcement, and Trichet (2006) has announced that the ECB for this reason will not introduce forecasts for the key policy rate. Furthermore, policymakers making interest rate paths can be less willing to change the paths in light of new information as the central bank may lose credibility by deviating from an announced plan, according to Mishkin (2004), Archer (2005) and Kahn (2007). If the public perceives the interest rate path as an unconditional forecast, the central bank can lose credibility when deviating from the original path, even when new information suggests a change. The results from such reluctance to change an interest rate path can be non-optimal paths and policy. The risk of misunderstandings is also recognised by Svensson (2001, 2007) and Woodford (2005). However, instead of seeing this as an obstacle, they emphasize the importance of educating the markets as a potential way of getting around this problem, e.g. by stressing that the path is an illustration of current expectations of the future rather than a policy plan and by showing paths of alternative scenarios, like Norges Bank and Sveriges Riksbank. The risk that policymakers will be reluctant to deviate from an announced path is, however, only partly avoided by these means. Archer (2004, 2005) and Svensson (2001) show how evidence from New Zealand indicates that the private sector understands the conditional nature of the projections and that they will change with new information. Policymakers in Sweden and Norway, Rosenberg (2007) and Berge (2006), support this view, and Svensson (2006a) expects future experience from Norway to indicate the same market understanding as in New Zealand¹⁷.

Monetary Policy Committees may find it difficult to agree on a future path of interest rates. Goodhart (2001, 2005), Blinder (2004) and Mishkin (2004) argue that communicating projected key policy rates is an impractical approach, as it is more difficult for a monetary policy committee (MPC) to decide on a complete path of key policy rates than a single move, and this could impair the decisionmaking process of the MPC.¹⁸ However, Svensson (2007) argues that the monetary policy committee needs to have some view of the future development in any case, and as every “decision about the key policy rate is in effect a decision about the path of the key policy rate, it is better that this is explicitly acknowledged”¹⁹. Hence, agreeing on future key policy rate paths should not necessarily be more difficult than coming to an understanding of a suitable path for inflation projections.²⁰

¹⁷ Svensson (2006a), page 10 – 11. The statement was made before Sveriges Riksbank introduced an endogenous instrument rate path.

¹⁸ Kahn (2007) argues further that some situations can be too complex not just for the MPC to agree on a policy path, but to actually form such a path. The uncertainty of e.g. special geopolitical events, rapid technological change or the outlook of near-term financial market crises can make it impossible to form a complete interest rate path, and such basic uncertainty can make the central banks reluctant to communicate future policy plans.

¹⁹ Svensson (2006a), page 8.

²⁰ Svensson (2007) suggests that the instrument path can be decided by majority voting over different instrument rate paths corresponding to different scenarios and values of λ in the intertemporal loss function of the central bank.

Kahn (2007) argues that keeping “the diversity of views may be a strength of MPCs that offsets some or all of the benefits associated with forging a consensus on an explicit policy path”²¹. Keeping a diversity of information is also emphasized by other scholars and practitioners focusing on the diversity of information in the market, arguing that central bank projections of the key policy rate can reduce the economic information content of market interest rates. Hetzel (2006) refers to the early views of Volcker, previously Chairman of the Federal Reserve, who was sceptical to central bank interest rate projections for such reasons. Rudebush and Williams (2006) agree that the presence of forward-looking policy signals may change the behaviour of financial markets so that they provide a less useful summary of private sector information, which may be a disadvantage for the central bank.

The research on welfare effects resulting from increased transparency and reduced diversity of market information shows that model specifications are crucial for the outcomes,²² and welfare effects of transparency can consequently be used to argue either way. Several scholars have investigated this topic. Morris and Shin (2002) make detailed analyses on the availability of private and public information and how transparency affects welfare. They argue that an increase in public information may result in reduced welfare when the private information is very precise and the public signal is wrong²³. Woodford (2005) shows that these results depend on the way social welfare is defined and computed and argues that such an outcome is unlikely, as the central bank can be expected to have better information about its future policy than has the private sector, in line with findings of Romer and Romer (2000). Svensson (2006b) interprets Morris and Shin (2002) to be pro-transparency and shows that with equal precision of public and private information, social welfare increases with the provision of public information²⁴. Lindner (2006) finds that public information increases the precision of private information, while Walsh (2006) and Gosselin et al (2006) find that the effects of transparency depend on the accuracy of the central bank’s forecasts for shocks to the economy. Roca (2005) and Hellwig (2005) show in more general models that transparency can increase welfare, and Svensson (2006b) concludes that increased transparency in most cases gives positive contributions to social welfare. Hence, the results in this field vary and are likely to depend on model specifications.

2.2.3 Conclusions from the discussion so far

Geraats (2006) emphasises how monetary policy transparency displays substantial heterogeneity both across and within different monetary policy frameworks, while Coppel and Connolly (2003) find similar predictability of monetary policy across central banks with different communication strategies. This suggests that, despite differences in the communication framework, these central banks convey information to financial markets to a similar degree. Mahadeva (2007) argue that improved transparency in objectives typically lowers the volatility of market interest rates and implies less market surprises, but that this happens at a decreasing rate, as improvements in transparency from already high levels have less effect on reducing the likelihood of market surprises than improved transparency from very low levels. Hence, whether an increase in transparency such as an interest rate forecast is

²¹ Kahn (2007), page 45.

²² Rudebush and Williams (2006)

²³ Morris and Shin (2002) argue that when private information is very precise and the public information is wrong, increased availability of public information is likely to lower welfare. In this case, the coordination motive causes agents to put more weight on the public signal than is justified by its level of precision. The variation in market views may decrease with more public information, and if the public signal is wrong, this may result in reduced social welfare compared to a situation with less public information

²⁴ The exception is some very special instances where the precision of the private information is eight times higher than that of the public.

a positive development, that is, whether the positive aspects outweigh the negative, this will depend on the central bank.

Furthermore, different central banks will need different approaches to communication, transparency and interest rate paths. Kahn (2007) takes these differences into account and argues that the advantages of endogenous interest rate paths so far are not clear. Different central banks have chosen different approaches to this issue of transparency, and inflation targeting regimes may be more appropriate than other monetary policy regimes for communicating such paths. Whether the market will understand a conditional interest rate path is likely to depend on the previous communication and credibility of the central bank. Hence, such interest rate forecasts may be more appropriate for central banks that have already achieved a good market understanding through their actions and communication. Furthermore, small MPCs may be more capable of agreeing on an interest rate path than are large committees.

These criteria are in line with the characteristics of the three central banks that have adopted endogenous interest rate paths so far. Their MPCs are relatively small, for RBNZ actually consisting of only one person, and their communication has become gradually more transparent in recent years. In the 2006 independent review of monetary policy in Norway, Dørum et al (2006) find the negative aspects of the endogenous interest rate path being of minor importance in the Norwegian case. Hence, this new step seems suitable for monetary policy in Norway.

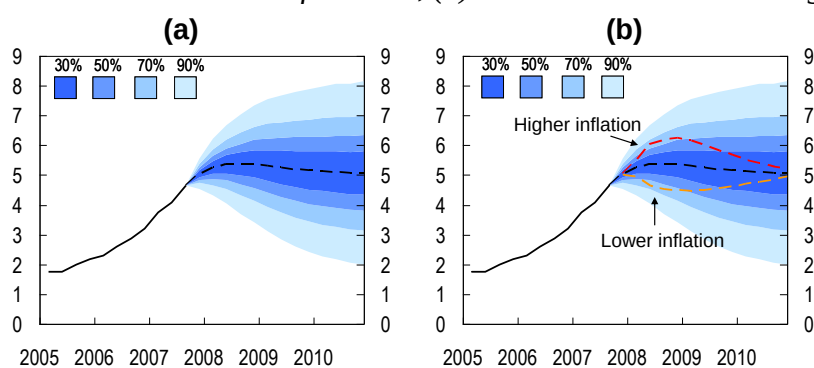
3. Monetary Policy in Norway

Since 29 March 2001, monetary policy in Norway has been conducted according to an inflation target defined by the Government. Norges Bank's conduct of monetary policy shall be oriented towards low and stable inflation. The operational target is consumer price inflation of close to 2.5 per cent over time. Monetary policy shall also contribute to stabilising output and employment. Hence, the conduct of monetary policy in Norway can be described in the traditional loss function framework.¹⁴ Norges Bank operates a flexible inflation targeting regime, emphasizing that weight is given to both variability in inflation and variability in output and employment.²⁵ The interest rate on banks' deposits with Norges Bank (the sight deposit rate or key policy rate) is the most important monetary policy instrument, while the main channel for monetary policy to affect the economy is through private sector expectations, according to Bergo (2006).

Norges Bank's Executive Board (the MPC), made up by the Governor, the Deputy Governor and five external members, sets the key rate. Monetary Policy Meetings where the key rate is decided normally take place every sixth week, and minutes from the meetings are not published. The interest rate decisions are based on the analyses and the monetary policy strategy presented in Norges Bank's *Monetary Policy Report* (Inflation report until 2007) that is published three times a year. Norges Bank has gradually increased transparency. A strategy interval for the key rate was published ex post since October 2002 and ex ante since July 2004. The strategy applies for the period up to the next Monetary Policy Report. Endogenous interest rate forecasts were introduced in the Monetary Policy Report in November 2007, replacing market forward rates as exogenous assumptions.

Norges Bank is careful to emphasize that the forecasts are conditional upon the bank's assessment of the current economic situation and its understanding of the transmission mechanism. According to Rudebush and Williams (2006), Norges Bank took the projections one step further than RBNZ when introducing probability distributions around the baseline interest rate projection and concrete state-contingent alternative scenarios, see chart 1.

Chart 1: Projected key policy rate from Norges Bank, Monetary Policy Report 3/07. (a) In the baseline scenario with fan chart, (b) In the alternatives with higher and lower inflation



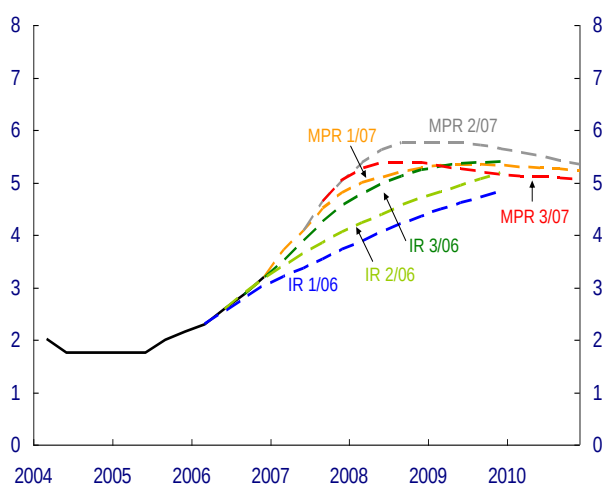
Per cent. Quarterly figures. 05 Q1 - 10 Q4. Source: Norges Bank

²⁵ A flexible inflation targeting regime means a positive λ in the loss function described above.

Norges Bank (2007) has translated the theoretical framework of interest rate paths into five concrete criteria for evaluating an interest rate path in practice, illuminating the main preferences of Norges Bank in the judgmental process of selecting an appropriate interest rate path. The criteria are derived from the loss function¹⁴ balancing central bank objectives and are normative guidelines for an interest rate path that provides a reasonable balance between the objectives of monetary policy, that is, an appropriate interest rate path. The criteria are listed in appendix A.

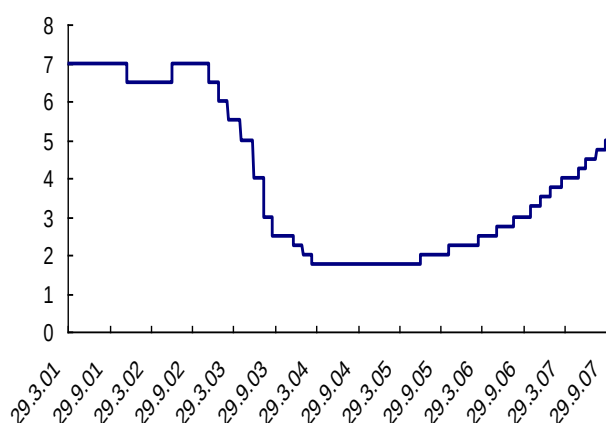
Seven Monetary Policy Reports with endogenous interest rate forecasts have been published so far. Chart 2 gives an overview of the seven interest rate forecasts published so far, showing how the path until June 2007 has been adjusted upwards as the economic growth proved stronger than expected. Based on these, Norges Bank does not seem to be reluctant to change the forecasts in line with new information. Movements in the implied market rates have been similar to the changes in the forecasts from the central bank, indicating that the forecasts have affected market participants. Chart 3 shows the development in the key policy rate since the inflation target was introduced, while table 1 gives an overview of the number of Monetary Policy Reports and interest rate decisions since March 2001 and November 2005.

Chart 2: Interest rate paths Nov 05 – Oct 07



Per cent. Quarterly figures. 04 Q1 - 10 Q4. Source: Norges Bank

Chart 3: The key policy rate



Per cent. 29 Mar 2001 – 1 Nov 2007. Source: Norges Bank

Table 1: Interest rate decisions and reports since 29 March 2001, distinguishing period 1 (March 01 – November 05) and period 2 (November 05 – November 07).

	Total	Period 1: Exogenous interest rate forecasts	Period 2: Endogenous interest rate forecasts
Interest rate decisions	59	40	19
Monetary Policy Reports	20	13	7

4. Introduction to the empirical analyses

4.1 Research questions

The aim of this empirical analysis is to look into the actual effects of the endogenous key policy rate and compare these with academic expectations. The thesis will evaluate some aspects of how the forecasts for the key policy rate have affected the market, and more specifically the volatility of short term interest rates and the market reactions to policy announcements and macro news.

According to the academic discussion on whether interest rate projections are suitable, these outcomes are likely to depend on the country and the central bank. In the case of Norway, Dørum et al (2006) find that the main negative aspects are of minor importance and emphasise that the market appears to have a good understanding of the communication. The MPC, that is small, has managed to agree on the paths. Furthermore, chart 2 does not give an impression of a central bank reluctant to change the path in light of new information. Hence, some of the most important negative aspects that can be commented so far point to conclusions in line with Dørum et al (2006). The focus of the empirical part of this study will rather be on the positive effects of such interest rate paths and whether these have been as expected.²⁶

The main positive aspects are related to improved management of expectations. According to part 2, this is expected to result in a more effective monetary policy and better macroeconomic performance, measured by the stability of inflation and output. Hence, a suitable test of the effects of the interest rate forecasts should measure changes in the management of expectations and macroeconomic performance.

Because monetary policy affects the economy with some lags, it is too early to conclude on the effects of endogenous interest rates on macroeconomic performance in Norway. However, as improved management of expectations should eventually lead to a more effective monetary policy and hence, improved macroeconomic stability, testing some effects on expectations so far gives an indication of whether the forecasts have had the intended influence.

Kohn and Sack (2003) find that central bank communication significantly affects American interest rate expectations and that this communication is more important than the actual interest rate decisions for the formation of expectations. Effects on expectations from communicating the future policy plans can be investigated by looking at the predictability of monetary policy announcements. One intended consequence of interest rate forecasts from the central bank is that the market participants get a better idea of the central bank reaction function. According to Holmsen et al (2007) and Bernhardsen and Kloster (2002) they will then adjust market rates more gradually to the interest rate paths, avoiding large movements at the time of policy announcements. Ferrero and Secchi (2007) refer to widespread evidence that transparency improves the predictability of monetary policy decisions, while Geraats' (2006) empirical evidence show that monetary policy transparency could lead to greater predictability of policy actions, reduced average inflation and a lower sacrifice ratio, that is, lower loss for the central bank.¹⁴ For inflation targeting central banks, Fracasso et al (2003) have demonstrated how superior informational transparency in inflation reports is associated with smaller interest rate surprises. To sum up, according to Swanson (2006), the increased

²⁶ Possible negative consequences of reduced information diversity in the market are left for future research.

transparency “should lead, *ceteris paribus*, to an increase in the private sector’s ability to forecast the central bank’s policy instrument”.²⁷

Studies of the overall impact of transparency are based on the hypothesis that if transparency increases the ability of market operators to correctly anticipate current and future policy actions, then a smaller reaction of short and long term interest rates should be observed on days when policy decisions are taken. The development of interest rate volatility can indicate whether the management of expectations has improved since the increase in transparency. This gives the first question of the thesis:

Has the volatility in market interest rates at the time of policy announcements diminished?

Reduced market rate volatility at the time of policy announcements implies that policy outcomes to a larger extent are already incorporated in the market rates. According to the literature, e.g. Holmsen et al. (2007) and Haldane and Read (1999), this is possible because the increased transparency enables the market to react more in line with the central bank to economic news between the monetary policy reports. Hence, another way to investigate the impact of the interest rate forecasts is to test whether the market reactions to macro news have changed. A change of market reactions to key figures may indicate that the market behaviour has changed to incorporate new market figures more in line with a new knowledge about the central bank behaviour, as expected in the literature. This leads to the second question:

Have market reactions to macro news changed?

The questions are related to the effects of changed expectations. The time period since the interest rate forecasts were introduced in November 2005 is too small to draw conclusions on many of the effects of endogenous interest rates expected in the literature, such as how the new regime might have affected the macroeconomic performance or whether economic forecasts have been improved. Hence, when it is possible to investigate some of the aspects related to the management of expectations, this is a reasonable approach.

There have been two main and related challenges to the thesis. The first is the limited number of observations at hand since the introduction of interest rate forecasts, both for the total inflation targeting period and especially since the interest rate forecasts were introduced. The seven endogenous paths so far and 505 daily observations of interest rates since November 2005 give little data to work with in the empirical analyses. The second challenge is also related to the short time period since the interest rate forecasts were introduced, which does not include a complete business cycle and makes it difficult to see whether the changes since then are due to fundamentals or transparency. Hence, the results can not be claimed too boldly.

Despite the shortcomings due to small samples, the questions should be able to point out some effects of the interest rate forecasts so far. The first question looks at how the market has responded to the first seven endogenous interest rate paths. As regular interest rate decisions are more frequent than the monetary policy reports and are announced every six weeks, considering the effects of policy announcements as well as reports gives an opportunity to analyse the effects with more observations, see table 1. The second question looks into another possible aspect of increased transparency that is related to question 1 and allows even more observations, as key figures are released monthly.

The two questions are linked to the anchoring of private sector expectations, central bank commitment and the outlook for the central bank’s ability to contribute to a stable

²⁷ Swanson (2006), page 3 (793).

economic environment – some of the definitions of effective monetary policy, see part 2 above²⁸. Hence, as well as giving insight to how the forecasts for the key policy rate have affected the management of expectations, investigating whether monetary policy predictability has improved and market expectations have become better aligned with the central bank reaction function can indirectly tell something about the implications for policy effectiveness.

4.2 Methods and data on interest rates

If the interest rate paths achieve the aim of improving the predictability of monetary policy, the introduction of these paths should reduce the surprises associated with monetary policy announcements and change the market responses to key figures as the market reactions become more aligned with the central bank reaction function.

The analyses related to the first question will be based on a model measuring monetary policy surprises. This aims both to answer the question of diminished volatility in market interest rates around policy announcements and to further specify the question to focus on whether the surprises in monetary policy announcements have been reduced since the endogenous interest rate forecast was introduced. The second question will investigate the effects of surprising key figures and test if the market responds differently to such surprises in the period with interest rate forecasts. The methods for both parts are more precisely described in section 5 and 6.

Both analyses will concentrate on daily changes in short-term money market interest rates in Norway. The reason to use short-term rates is partly Haldane and Read (1999), who show how different news and changes in transparency affect interest rates of different maturities. While changes in central bank credibility and the market's understanding of the central bank's goals affect medium and long-term rates, changes in transparency and macro news affect short-term rates. Hence, with a need to narrow down the scope of the thesis, it was relevant to focus on the short end of the yield curve. To be able to compare the differences between the series, all short rates from one week up to twelve months have been included, eight in total. The reason for this broad approach is to investigate the differences between the series. The interest rate series are listed in table 2. See appendix B for charts.

Table 2: Interest rate series in the analyses

Series	12 months, 9 months, 6 months, 3 months, 2 months, 1 month, 2 weeks, 1 week
Description	Money market eurorates NOK, NIBOR, right side 12.00. Source: Reuters NIBQ.
Frequency	Business days
Time period	29 March 2001 - 1 November 2007

The time period investigated is the period of inflation targeting in Norway and runs from 29 March 2001, when the inflation target was introduced, to 1 November 2007. The sample has been divided into two periods: period 1 from 29 March 2001 up to and including 1 November

²⁸ Measures of monetary policy effectiveness are usually related to the intertemporal loss function of the central bank [which states the central bank objectives as stability of output and inflation]. Hence, increased stability is one indication of a more efficient monetary policy, as suggested by Cecchetti et al (2004) and Bernhardsen and Kloster (2002).

2005, and period 2 from 2 November 2005 to 1 November 2007. With business day frequency, this gives 1151 interest rate observations before the regime change on 2 November 2005, 505 observations after this date and a total of 1656 observations. The interest rate series are transformed into daily changes to make them stationary and to measure changes in reactions related to interest rate expectations.²⁹

The interest rate changes have been computed over 24 hours. A better measure of the interest rate changes would be a narrow window of changes around the time of policy announcements or key figure releases, in line with research by e.g. Ederington and Lee (1995) and Fleming and Remolona (1999) showing that most of the price response to scheduled economic announcements is completed within few minutes and that the optimal time frame in which to assess reactions is considerably less than a day. Obtaining shorter intervals is, however, outside the scope of this thesis. Hence, the changes in interest rate figures capture everything affecting the interest rates during this 24 hours time span and are not likely to be perfect measures of the reactions following policy announcements or key figure surprises, but they are the closest timeframe available around these happenings.

²⁹ Most studies in this area assume changes in interest rates to reflect changes in interest rate expectations and do not take changes in the risk premium into account. According to Beechey (2007), changes in short interest rates are mainly explained by changed interest rate expectations, and hence, for these analyses on the short term interest rates, the assumption is relevant.

5. A less surprising central bank?

This part investigates the volatility in short money market rates after announcements of interest rate decisions or publications of monetary policy reports and aims to answer the first research question: *Has the volatility in market interest rates at the time of policy announcements diminished?* This is further specified to a question of whether the central bank has become less surprising in its decisions. According to the literature, the interest rate volatility is expected to decrease following the introduction of interest rate forecast and the expected answer to the question is yes. The number of observations for this section is listed in table 1.

5.1 Analyses of central bank surprises

5.1.1 Framework for the analyses

Estimating effects of monetary policy surprises on interest rates has been the subject of numerous studies on the predictability of monetary policy, such as Haldane and Read (2000), Kuttner (2001), Lange et al (2003), Bernhardsen and Kloster (2002) and Ross (2002). As the interest rate expectations are not directly observable, these studies often define monetary policy surprises as the changes in the 30-day interest rate on the days of announcements, which is found to be closely related to the changes in the expected policy rate over the following month. The analysis in this section is based on a more general framework by Fracasso et al (2003), allowing analyses of all the interest rate series in the sample, including the 30 days rate.

Movements in market interest rates can be interpreted as responses to different kinds of market news. Based on Fracasso et al. (2003), such responses are

1. Responses to changes in the macro picture, e.g. macro news and key figures
2. Responses to central bank communication

The first part is about responses to regular market news and surprises, while the second part can be explained by new knowledge or interpretations of the central bank's reaction function. According to the theoretical discussion above, both responses are expected to change with the introduction of interest rate forecasts.

The changes in money market interest rates from just before to just after a policy announcement are likely to be composed of the two responses above. Fracasso et al (2003) outline a simple framework for analyses of central bank surprises. In this model, the money market rate of maturity h at time t is given by i_t^h . On the times of monetary policy announcements, $t = D$. The efficient market hypothesis suggests that all relevant information available about future interest rates is incorporated in the current market rates. Assuming that this holds, expected outcomes are likely to be incorporated in the money market rates before the central bank announces its decision, in line with Eeg (2007). Then the responses of interest rates to news at times D , i.e. $\Delta_D^h \equiv i_{D+1}^h - i_{D-1}^h$, are likely to be due to surprise elements in the policy announcement and other news arriving at the same time. The absolute value of the interest rate changes have been applied for this analysis. A measure of surprises in monetary policy announcements can be calculated from

$$(5.1) \quad \Delta i_D^h \equiv i_{D+1}^h - i_{D-1}^h = SURPRISE_D + NEWS_{D-1, D+1}$$

where $SURPRISE_D$ is the measure of monetary policy surprise and $NEWS_{D-1, D+1}$ is a proxy for the interest rate effects of other news. Based on Connolly et al (2004), the largest sources of variation in domestic interest rates, that is, the $NEWS$ effects, are likely to be foreign market information and domestic key figures or economic news. With the Norwegian data, D is the time of announcement, i.e. 14.00 on the days of interest rate meetings.

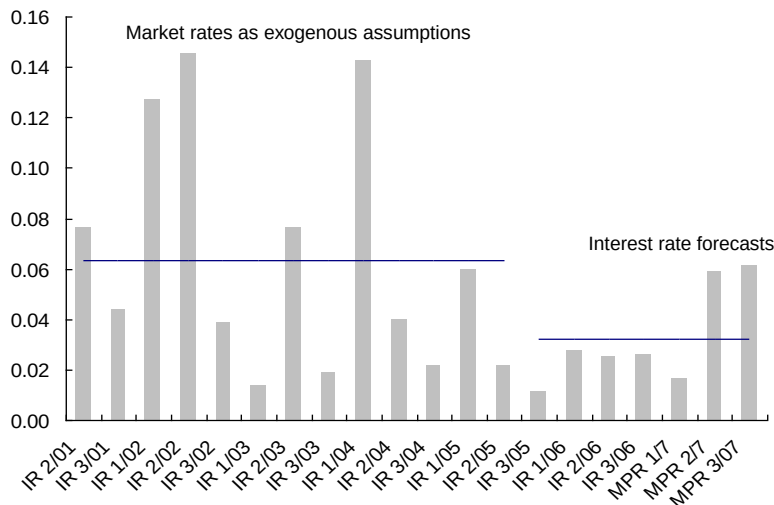
$D-1$ and $D+1$ are the interest rate notations giving the smallest possible window around the announcement. This time span will be from the announcement day at 12.00 ($D-1$) to 12.00 the following day ($D+1$). The interest rates that are examined are the short money market rates listed table 2, for which absolute values of the interest rate changes have been computed.

In addition to the news and surprise effects, the responses of the shortest interest rates are also likely to include movements due to actual changes in the key policy rate. The shortest rates are likely to respond in line with the monetary policy decisions even when these are expected. This has to be kept in mind when interpreting the results.

5.1.2 Measuring interest rate volatility on policy announcements

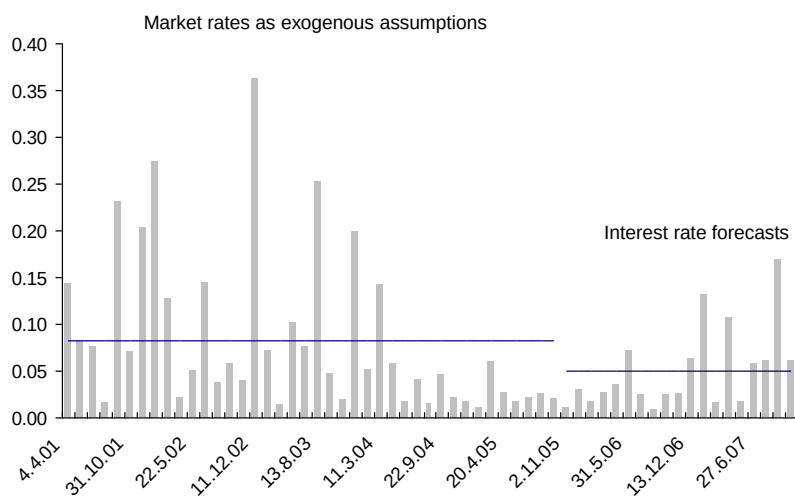
The average volatility in short interest rates around the release of the Monetary Policy Reports, $\Delta i_{D-report}^{avg}$, is measured as the average of the absolute changes in each interest rate series from $D-1$ to $D+1$, in line with Holmsen et al. (2007). Chart 4 shows smaller changes in short market rates for the seven reports with interest rate forecasts than for the previous 13 reports. While the average absolute change from the day a report was published to the following day was 0.63 basis points for the first 13 reports in the sample, it was reduced to 0.32 basis points for the 7 reports with endogenous interest rate paths. This is in line with analyses by Holmsen et al (2007), finding that for forward rates 0 – 3 years ahead the adjustments have been smaller after the interest rate projections were introduced. The results are listed in table 3.

Chart 4: Average absolute change in short term interest rates (1 week – 12 months) on publication of Monetary Policy Reports.



Change from the day the reports were presented to the day after. Percentage points.

Chart 5: Average absolute change in short term interest rates (1 week – 12 months) after announcements of interest rate decisions.



Change from the day the reports were presented to the day after. Percentage points.

The market reactions following policy announcements are illustrated by Δi_D^{avg} ; the average absolute value of the changes in the interest rate series at times D . These figures also point to lower volatility around policy announcements since Norges Bank started to publish interest rate forecasts. The average absolute change in short term interest rates following the 40 interest rate decisions in the first part of the sample was 0.83 basis points, reduced to 0.51 basis points for the 19 announcements since the introduction of the endogenous interest rate path. See chart 5. Similar results are found by Aksnes and Bakken (2007).

Table 3: Results for each interest rate series, 1 week - 12 months. Percentage points.

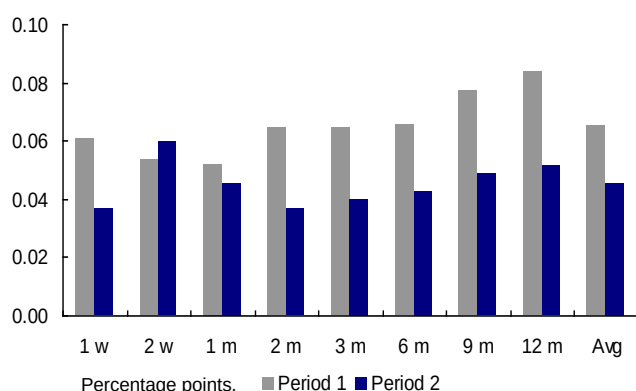
Interest rate series	1 week	2 weeks	1 month	2 m	3 m	6 m	9 m	12 m	Average
<i>NEWS + SURPRISE</i>									
Total	0.069	0.066	0.062	0.062	0.064	0.073	0.083	0.089	0.071
Period 1	0.080	0.073	0.072	0.074	0.075	0.086	0.097	0.103	0.083
Period 2	0.041	0.046	0.038	0.031	0.036	0.043	0.048	0.052	0.042
<i>MedianNEWS</i>									
Total	0.020	0.020	0.010	0.010	0.010	0.010	0.020	0.020	0.015
Period 1	0.020	0.020	0.020	0.010	0.010	0.020	0.020	0.020	0.018
Period 2	0.020	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.011
<i>SURPRISE</i>									
Total	0.049	0.046	0.052	0.052	0.054	0.063	0.063	0.069	0.056
Period 1	0.060	0.054	0.052	0.064	0.065	0.066	0.077	0.083	0.065
Period 2	0.021	0.036	0.028	0.021	0.026	0.033	0.038	0.042	0.031

Holmsen et al (2007) point out that the measures of volatility may be misleading if the central bank is giving information about future policy decisions between the interest rate meetings. Perez -Quiros and Sicilia (2002) argue that shocks may also appear on days when there are no MPC meetings, and they find that only some 22-23% of the monetary policy surprises in the US and the Euro area appeared on the days of MPC meetings.³⁰ The leadership of Norges Bank has, however, not given hints at future policy decisions since the endogenous path was introduced³¹, so this can not explain the lower volatility in the second period.

5.1.3 News and surprises

To isolate the $SURPRISE_D$ effects from the total changes in market rates Δ_D^h , some proxy for the *NEWS* is needed. In line with Fracasso et al. (2003), the median daily changes in interest rates are used as a proxy for these effects.³² This proxy does, however, not only contain the general news effects from macro figures, but is the general market reaction to both macro news and central bank communication. As the aim here is to isolate $SURPRISE_D$, the surprise effects of the specific interest rate announcements, and not the general market reactions to central bank actions and communication, *NEWS* is still a relevant proxy measuring the changes in market rates on a normal day.

Chart 6: Average $SURPRISE_D$ effects on interest rate announcements in period 1 and 2.



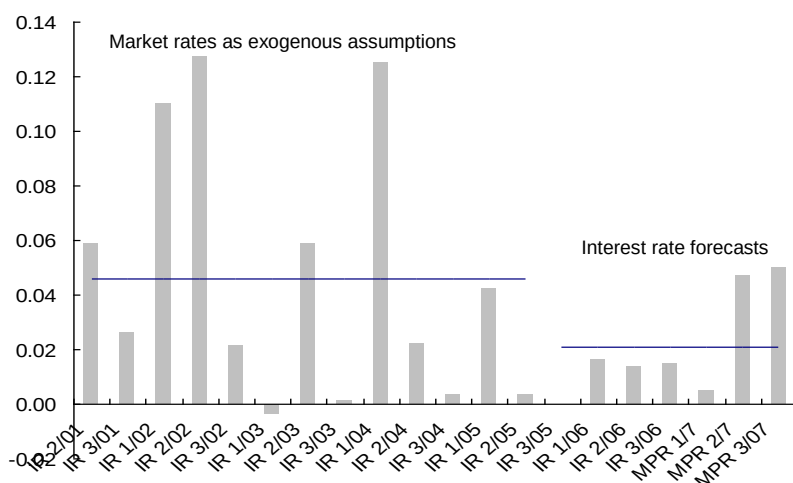
The average median change is higher in period 1 than in period 2, indicating that the volatility is generally lower in this period, see table 3. By subtracting the proxy for each period from the absolute market rate changes, a measure of the surprise effects is obtained. The average $SURPRISE_D$ effect for interest rate announcements is lower in period 2 than in period 1 for all short interest rate series investigated, except the volatile 2 weeks rate, see chart 6. Chart 7 and 8 show the average responses to each report and interest rate announcement. The reduced $SURPRISE_D$ effects may be related to increased central bank transparency in the period with interest rate forecasts.

³⁰ This analysis covers the period from 1999 – 2002.

³¹ The last such hints were given by the Governor in a speech in June 2003. Despite this information, the market reactions following the subsequent policy announcement were substantial.

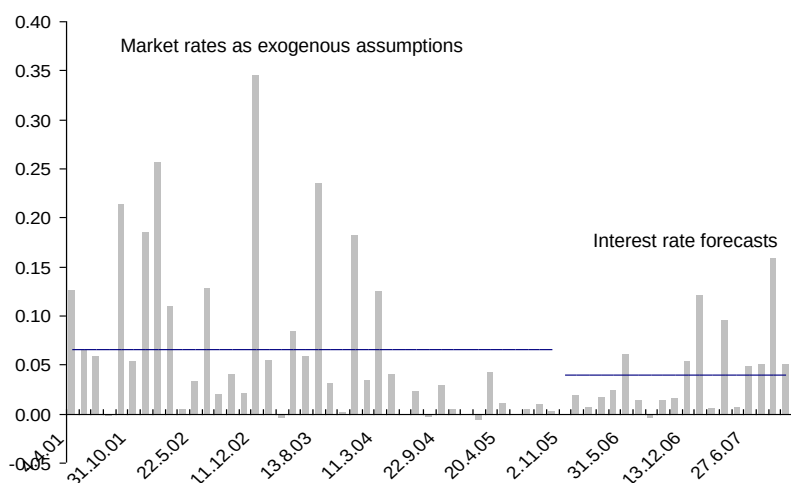
³² The median change is less sensitive than the mean to outliers due to special events.

Chart 7: Average $SURPRISE_D$ effect on publication of monetary policy reports



Average absolute changes in short term money market interest rates on publication of monetary policy reports minus median absolute change over each period. Change from the publication day to the following day. Percentage points.

Chart 8: Average $SURPRISE_D$ effect on announcements of interest rate decisions



Average absolute changes in short term money market interest rates on key policy rate announcements minus median absolute change over each period. Change from the day of a policy announcement to the following day. Percentage points.

The $SURPRISE_D$ effects will be affected by news that deviate from the proxy measure. These effects are not expected to be systematically different in the two periods investigated and should not disturb the comparison between the periods. However, as some of the surprise effects are large, each announcement date has been investigated to reveal special effects that may have moved the markets that day, focusing on foreign markets and domestic key figure announcements, in line with Connolly et al (2004). The only special event found to coincide with a policy announcement was the general unrest of financial markets in September 2001, influencing the market expectations before the interest rate decision on 19 September 2001. This will be kept in mind when interpreting the results. It is likely that the other surprises are closely related to the monetary policy announcements.

5.1.4 Testing different surprises

The significance of the differences found in the previous analyses can be tested by a two-sample, one-sided t-test³³, in line with Gujarati (2003), Eviews (2005) and Holmsen et al (2007), testing the null hypothesis $H_0: SURPRISE_1 \leq SURPRISE_2$, against the alternative $H_1: SURPRISE_1 > SURPRISE_2$. The test was conducted for all interest rate series in the sample, and the results are described in appendix C. The test variable is the mean of the *SURPRISE* effects for each series. The 13 reports in period 1 and 7 in period 2 are too few too for such a test to give reasonable results, so the t-tests are conducted for the observations of all policy announcements, 40 in period 1 and 19 in period 2. The results, see table 4, show that H_0 can be rejected at the 10 per cent level for the average of all the interest rate series. Furthermore, several series have significantly smaller effects in period 2 also when applying a 5 per cent significance level. This is, however, not the case for the 1 month interest rate that is often used as the main proxy of surprise effects. The most significant differences are found for the longest money market rates in the sample. The responses of the longest interest rates are likely to be more affected by changes in expectations and central bank communication than are the shorter rates, which to a larger extent follow the current key rate than expected future paths. Hence, it is reasonable that the most significant results are obtained for the longest interest rates.

Table 4: Results (p-values) from t-tests of the surprise effects

	Avg	12m	9m	6m	3m	2m	1m	2w	1w
P(T<=t) one side	0,063	0,012	0,021	0,050	0,056	0,034	0,260	0,478	0,100

Bold figures are significant at the 5 per cent level.

5.2 Discussion on general interest rate volatility

5.2.1 Measures of interest rate volatility

In the first period of the sample, the uncertainty concerning both the economic development and the direction of interest rate changes was larger than in the most recent period. During the total sample period, there has been an increase both in central bank transparency, leading up to endogenous interest rate paths, and an increase in the general economic stability. Neither of these developments is exclusive for Norway. Aksnes and Bakken (2007) find similar results for Sweden, the UK, the US, New Zealand and the EMU. These countries also have, with some exceptions, larger surprise effects and reactions to regular news in period 1, reflecting both a more stable international economy and more transparent central banks in recent years. BIS (2006)³⁴ emphasises the general reduction of financial market volatility in the last few years, reflecting the phase of expansion, as financial volatility is typically countercyclical. Hence, the recent improvement in predictability is unlikely to be related to increased transparency alone. One other important factor is the reduced volatility in the key rate. According to Swanson (2006), the variability in the key rate was the most important cause of the increased interest rate volatility observed in the US in 2001, and changes in the key policy

³³ The t-test requires is based on the assumption of a normal distribution. By the central limit theorem, this is assumed for the two sub-samples. The central limit theorem demands 20 observations to assume normality, and the lack of one observation in period 2 (with 19 observations) must be remembered when interpreting the results.

³⁴ The report analyses the US, Germany, Japan, France, Switzerland, the UK and Italy.

rate should reflect variability of economic fundamentals. BIS (2006) emphasises the relation between the level and volatility of interest rates and argue that the currently low volatility may increase when interest rates are raised and the direction of changes may be less clear to the markets than it has been in recent years.

This indicates that a stable key policy rate which direction of changes has been clear and a stable economic environment in general may also explain the results above. The level and especially the volatility of the Norwegian key policy rate have been lower in period 2 than in period 1, despite the long period of constant interest rates in 2004 and the first half of 2005, included in period 1. See table 5 and chart 3 above. The average change in the key policy rate in period 1 was negative, while the average change in period 2 was positive. This characteristic also applies to the money market rates in the sample.

Table 5: Details on the key policy rate in Norway

	Dates	Average key policy rate	Variance in the key policy rate	Avg. change in the key policy rate
Total	29 Mar 01 - 02 Aug 07	3,97	4,150	-0,001
Period 1	29 Mar 01 - 01 Nov 05	4,25	5,368	-0,004
Period 2	02 Nov 05 - 01 Nov 07	3,36	0,787	0,006

The lower volatility of the key policy rate in period 2 is likely to have affected the general volatility of the interest rate series in this period and is in line with the lower effects of news and surprises in period 2 found in the previous section. Simple tests comparing the variance of short Norwegian interest rates in the two periods confirm the lower volatility in period 2. The differences between the two periods are significant at the 1 per cent level for the key rate and the other series in the sample. The tests are described in appendix D.

The GARCH framework, or Generalized Autoregressive Conditional Heteroscedasticity Model, as developed by Bollerslev (1986) and Taylor (1986), offers a more sophisticated method for modelling interest rate volatility.³⁵ Empirical modelling of changes in interest rates often finds that the volatility varies over time. This is referred to as volatility clustering and can be modelled as GARCH processes of the conditional variance. In this case, GARCH(1,1) models can take into account the different volatility in the two periods, given the development of the key policy rate, and the differences can be compared. The following GARCH(1,1) models the conditional volatility of the daily changes in the interest rate series: $r_t = R_t - R_{t-1}$, based on the following set-up:

$$(5.2) \quad r_t = \gamma k_t + \varepsilon_t \sigma_t^2$$

$$(5.3) \quad \sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2$$

$$\text{where } \varepsilon_t \sim N(0,1) \text{ implies that } r_t | I_{t-1} \sim N(\gamma \mu_k, \sigma_t^2)$$

$k_t = K_t - K_{t-1}$ is the change in the key policy rate, and this variable is only relevant on days when the MCP decides to change the interest rate. The purpose of including this term is to try to control for the differences in volatility that are related to the key rate changes when comparing the two periods. In this set-up, the higher the sum of coefficients in σ_t^2 , that is $\alpha_1 + \beta_1$, the higher is the volatility in the series. A sum close to one indicates high persistence in the shocks, while a sum larger than 1 indicates that the series are non-stationary with explosive responses to shocks. The presence of $\alpha_1 + \beta_1$ equal to one is referred to as

³⁵ For an overview of GARCH modeling of interest rate series, see Bollerslev et al (1992).

IGARCH behaviour. Models with $\alpha_1 + \beta_1 \geq 1$ are invalid for research, as the processes are unstable. According to Bollerslev et al (1992), this is a common feature of the parameters obtained from such interest rate models, and this was also the outcome here. The estimated GARCH(1,1) models were IGARCH-processes for 7 of the 8 interest rate series.³⁶ The 12-month rate is the only interest rate series for which the sum of $\alpha_1 + \beta_1$ is below one in both periods, and for this series, the sum of $\alpha_1 + \beta_1$ is smaller in period 2, indicating a lower volatility after the key rate forecasts were introduced.

The estimated conditional volatility for the interest rate series in the two periods can be compared to decide if the volatility is lower in period 2 than in period 1. A two-sample, one-sided t-test, testing $H_0: \sigma_{period1}^2 \leq \sigma_{period2}^2$ against $H_1: \sigma_{period1}^2 > \sigma_{period2}^2$ shows that the estimated conditional volatility in the two periods is significantly lower in period 2 than in period 1 for all the interest rates in the sample at the one per cent level. Hence, it is reasonable to conclude that the volatility of the interest rate series is lower in period 2, even when controlling for the changes in the key deposit rate. See appendix E for details on the GARCH(1,1) models and the tests.

5.2.2. Implications for the results

The volatility of the money market interest rates in the sample has decreased even when controlling for different development and volatility in the key rate in the two periods. This general reduction in volatility could point to an effect of increased transparency on the general volatility of interest rates. It could, however, also indicate that the lower surprise effects in period 2 are not due to increased transparency, but to the same factors explaining the reduced volatility in general. Considering the short time period since the interest rate forecasts were introduced and knowing that the Norwegian economy has been rather stable in this period, the development in interest rates is unlikely to be caused by transparency alone. However, changes in the general economic stability are already accounted for when distinguishing the effects from news and surprises, and the improved stability is reflected by the reduced effects of news in period 2. The surprise effects are reactions to the monetary policy, and a decrease in the surprises in period 2 is likely to be explained by both the increased transparency and the more stable key policy rate. Several studies relate such increased predictability to improved central bank transparency. Poole (2005) and Swanson (2006) suggest that policy transparency and consistency has improved the predictability of the central bank's policy decisions and contributed to the economy's improved stability in recent years, especially in the US and the Euro area. Swanson argues that the increased predictability of short term interest rates is likely to be associated with changes in transparency, as the ability of the public to forecast other macroeconomic variables has remained unchanged in the same period. Ferrero et al (2007), who also include data for Norway, find a widespread increase in predictability that coincided with the diffusion of communication strategies based on revelation of information about future policy. Hence, it is reasonable to expect that the significant decrease in surprise effects is related to the increased transparency.

³⁶ This was the case even when taking away outliers larger than 1.5*se of the series, as the GARCH(1,1) process is usually sensitive to outliers. In this case, however, the results were hardly affected by the outliers.

5.4 Conclusions on news and surprises

The volatility in the market rates following policy announcements has diminished since the interest rate forecasts were introduced. This applies to both types of interest rate responses, as both the surprise effects and the news effects are lower in the second period. The differences are significant at the five per cent level for several of the series, including the longest interest rates. All the series have significant differences at the ten per cent level, except the volatile two weeks rate, that actually has higher surprise effects in period 2. It is reasonable that the shortest interest rates are less significant, as the longest rates are most likely to be affected by changes in expectations.

The changes in surprises include effects of lower volatility in the key policy rate in period 2. This makes it difficult to conclude if the results are mainly due to increased transparency or a more stable key policy rate. Based on the literature, however, it is reasonable to believe that the interest rate forecasts have had an effect. This effect is then as expected for all interest rates longer than two weeks and indicates a positive answer to research question 1.

The results can be interpreted as a greater market understanding of Norges Bank's reaction pattern after the introduction of the endogenous interest path. This is supported by Holmsen et al (2007), who assume that Norges Bank's forecasts have had

*“a reasonable impact on the market rates in the short run. More importantly, the bank's reaction pattern has affected the market rates continuously, so that the market has reacted adequately on economic news between the reports. In most cases, the market rates have adjusted before the presentation of the Bank's forecast so that, in practice, the discrepancy between the two, at least up to the 12-month horizon, has been rather narrow at the time of publishing”.*³⁷

³⁷ Holmsen et al (2007) page 22 – 23.

6. Market reactions to macro news

6.1. Introduction

This section aims to answer the second research question: *Have market reactions to macro news changed since the interest rate forecasts were introduced?* The reduced market rate volatility at the time of policy announcements found above implies that policy outcomes may to a larger extent be incorporated in the market rates before the announcements. According to Svensson (2007), key rate projections increase market knowledge about the central bank reaction function and enables market participants to react more in line with the central bank to economic news between the monetary policy reports.

Haldane and Read (1999) find that if the aims of monetary policy are clear and it is possible to predict interest rate decisions accurately using publicly available macroeconomic data, then the interest rate decisions themselves will usually be less noteworthy and so will, on the whole, provoke little reaction in financial prices. News will, however, be conveyed in macroeconomic data releases. Over a period when the monetary policy process becomes more transparent, the reaction to these macroeconomic announcements could therefore increase while the reaction to interest rate decisions declines. Several other studies, e.g. Clare and Courtenay (2000), Lasasosa (2005) and Joyce and Read (1999) find the opposite: the evidence from these papers suggest that market participants react less to macroeconomic announcements following increased transparency, while the reactions to policy rate changes are about the same. Swanson (2006) concludes that the ability of the public to forecast macroeconomic news has remained unchanged.

The diverse results of these studies are reasonable, as the intuition behind the changes in market behaviour does not necessarily mean that the market rates have to move more if the interest rate reactions to policy announcements become smaller. With increased transparency, the market is expected to have better knowledge about the central bank reaction function and follow the bank's behaviour more closely. This does, however, not indicate any direction of the changes, that will depend on the perceived reaction function of the central bank both before and after the increase in transparency. Hence, the expected direction of a possible change in reactions to key figures – that is, whether the market should react more or less to macro news in a more transparent monetary regime – is not obvious. The following tests will ask whether there is a difference in behaviour, rather than looking for a specific direction of it.

This section evaluates market reactions following macro news, that is, announcements of key figures, and whether these reactions have changed since November 2005. Part 6.2 goes through the data and is followed by a preliminary analysis of the contributions of surprises in different key figures to daily changes in interest rates. The key figures with significant results in this preliminary analysis are taken further to investigate whether the effect of significant news has changed since the interest rate forecasts were introduced.

6.2 Data on key figures

Macro news are assumed to have an effect on interest rates only if they are surprising, as key figures in line with market expectations should already be incorporated in the money market interest rates. A reasonable proxy for surprise effects in the key figures can be based on the average market expectations of macro news from Bloomberg News surveys of market

economists, in line with Eeg (2007).³⁸ The surprise effects are found by comparing these market expectations to the actual outcomes for the key figures.

As a starting point, all main macro figures that market participants watch closely are relevant for this analysis, and given the inflation targeting regime, inflation figures are expected to be the most important. The main figures included in the analysis are core inflation³⁹, two different unemployment series, retail trade and the credit growth of households and firms, see table 6. These figures have been compared to Bloombergs' survey of market expectations for all observations from the inflation target was introduced in March 2001 up to July 2007, collected from Norges Bank's reports and databases.⁴⁰ For the core inflation figures, more observations were included towards the end of the analyses, giving a time span from April 2001 to October 2007 and a total of 79 observations of inflation announcements, 24 of these from period 2. For the other variables there are some missing figures in the sample, and the total number of observations is between 65 and 71.

Table 6: Key figures

Series	Description	Frequency	Source	Time period
Core inflation (CPI-ATE)	Consumer prices adjusted for taxes and energy. Measure of core inflation.	12-month change	Statistics Norway	10 April 2001 - 10 October 2007
LFS unemployment	Unemployment rate based on the Labour Force Survey	Monthly rate	Statistics Norway	31 August 2001 - 26 June 2007
Registered unemployed	Unemployment registered by the employment offices	Monthly rate	Norwegian Labour and welfare Organisation	1 October 2001 - 28 June 2007
Retail trade	Index of turnover volume in retail trade	12-month change	Statistics Norway	8 August 2001 - 29 June 2007
Credit growth	Credit to households and enterprises	12-month change	Statistics Norway	31 July 2001 - 2 July 2007

The surprises in key figures have been computed as the differences between actual and expected figures and standardised by their sample standard deviation to make the regression coefficients of the models comparable across indicators, in line with Reeves and Sawichi (2005):

$$\text{Key figure surprise}_i = (A_i - E_i) / \sigma_{\text{totalsample}},$$

where A_i = actual outcome

E_i = expected outcome

$\sigma_{\text{totalsample}}$ = sample standard deviation of the surprises in the key figure

³⁸ In the days before a main key figure is announced, Bloomberg News conducts a survey among market participants that make forecasts for these figures, typically chief economists of the large commercial banks, and calculate the consensus (mean market expectation). This proxy for the overall expectation is used as the market expectation here. Figures from Reuters are used in cases when a consensus from Bloomberg News is lacking.

³⁹ Core inflation in Norway is measured by consumer prices adjusted for taxes and energy prices.

⁴⁰ The Reuters' figures of expected outcomes are collected from market reports about each the key figure release and outcomes written by the Department of Market Operations and Analyses in Norges Bank.

The interest rate reactions following the macro news were computed as changes from the day before the announcements to the day of the announcements. The interest rates are noted at 12.00, while the key figures are released at 10, and the daily changes will capture market effects of surprising key figures.⁴¹

6.3 Preliminary analysis

Before testing whether market reactions have changed since the interest rate paths from Norges Bank were introduced, the first step is to test whether these key figure surprises affect the changes in interest rates. The following model was estimated for all eight series of short-term interest rates and for all key figures listed in table 6:

$$(6.1) \quad i_t - i_{t-1} = \beta_0 + \beta_1 \frac{(X_t - X_t^e)}{\sigma_x} + u_t$$

Explanations:

i_t	Interest rate day t
i_{t-1}	Interest rate in day $t-1$
$i_t - i_{t-1}$	Change in interest rates from $t-1$ to t
X_t^e	Expected key figure to be announced on day t
X_t	Actual key figure announced on day t
$(X_t - X_t^e) / \sigma_x$	Standardised surprise in key figure announced on day t
β_0, β_1	Coefficients

Three of the key figures; core inflation, credit growth and retail trade, had a significant impact on interest rate series. The effects of these were as expected, with positive signs of the β_1 coefficients indicating that higher than expected figures imply higher interest rates. The standardised surprises in core inflation figures were significant at the 5 per cent level for all interest rate series from 1 to 12 months and at the ten per cent level for the 2 weeks rate. Credit growth surprises were significant explanation factors at the 5 per cent level for the two shortest interest rates in the sample, that is, the 1 and 2 weeks rates, while the surprises in retail trade figures had significant effects on the 6 months interest rate at the 10 per cent level. The results of the preliminary analysis are listed in table 7 below.

The core inflation figures have larger coefficients than the other significant variables and substantially higher R^2 for all interest rates longer than 1 month. The core inflation models of the longest interest rates both have the highest R^2 and the highest significance. Hence, this preliminary analysis indicates that the core inflation figures are the most relevant key figures in explaining changes in interest rates, and that their explanatory power is especially high for the longest interest rates in the sample.

⁴¹ Except reg. unempl., announced at 12.00, which makes the 2-days change in int. rates is the relevant measure.

Table 7: Results from the preliminary regressions.

a) Core inflation (CPI-ATE, consumer prices adjusted for taxes and energy)

Series	Results Core Inflation (CPI-ATE), n=79			
12m	-0,0003 + 0,0470 (0.0048) (0.0047)**	CPI-ATE	R ²	0,565
9m	-0,0024 + 0,0429 (0.0042) (0.0042)**	CPI-ATE	R ²	0,578
6m	0,0012 + 0,0380 (0.0044) (0.0044)**	CPI-ATE	R ²	0,497
3m	0,0022 + 0,0247 (0.0041) (0.0041)**	CPI-ATE	R ²	0,324
2m	-0,0009 + 0,0213 (0.0047) (0.0046)**	CPI-ATE	R ²	0,217
1m	-0,0025 + 0,0131 (0.0044) (0.0043)**	CPI-ATE	R ²	0,106
2weeks	-0,0033 + 0,0056 (0.0034) (0.0033)*	CPI-ATE	R ²	0,036
1week	-0,0023 + 0,0053 (0.0053) (0.0046)	CPI-ATE	R ²	0,017

b) Credit growth (C2) and Retail trade

Series	Results Credit Growth (C2), n=71				Results Retail Trade, n=67			
12m	-0,0011 + 0,0013 (0.0039) (0.0036)	C2	R ²	0,002	0,0000 + 0,0078 (0.0052) (0.0052)	RetTr	R ²	0,034
9m	-0,0011 + 0,0013 (0.0039) (0.0036)	C2	R ²	0,002	0,0013 + 0,0060 (0.0043) (0.0043)	RetTr	R ²	0,029
6m	-0,0037 + 0,0011 (0.0040) (0.0037)	C2	R ²	0,001	-0,0019 + 0,0061 (0.0036) (0.0036)*	RetTr	R ²	0,043
3m	0,0010 + 0,0010 (0.0035) (0.0032)	C2	R ²	0,001	0,0003 + 0,0007 (0.0028) (0.0028)	RetTr	R ²	0,001
2m	-0,0028 + 0,0025 (0.0033) (0.0031)	C2	R ²	0,009	0,0009 + 0,0009 (0.0026) (0.0026)	RetTr	R ²	0,002
1m	-0,0074 + 0,0060 (0.0040) (0.0037)	C2	R ²	0,037	-0,0040 + -0,0046 (0.0037) (0.0037)	RetTr	R ²	0,023
2weeks	-0,0077 + 0,0126 (0.0053) (0.0039)**	C2	R ²	0,088	-0,0046 + -0,0049 (0.0032) (0.0032)	RetTr	R ²	0,035
1week	-0,0121 + 0,0126 (0.0055) (0.0051)**	C2	R ²	0,082	0,0041 + 0,0048 (0.0075) (0.0075)	RetTr	R ²	0,006

c) LFS unemployment and Registered unemployment.

Series	Results LFS, n=67				Results Reg. unemployment, n=65			
12m	0,0030 - 0,0031 (0.0049) (0.0049)	LFS	R ²	0,006	-0,0034 - 0,0019 (0.0061) (0.0060)	RegUn	R ²	0,002
9m	0,0027 - 0,0029 (0.0044) (0.0045)	LFS	R ²	0,007	-0,0030 - 0,0028 (0.0058) (0.0056)	RegUn	R ²	0,004
6m	0,0008 + 0,0010 (0.0043) (0.0043)	LFS	R ²	0,001	-0,0044 - 0,0033 (0.0056) (0.0054)	RegUn	R ²	0,006
3m	0,0002 + 0,0009 (0.0034) (0.0034)	LFS	R ²	0,001	-0,0032 + 0,0026 (0.0049) (0.0048)	RegUn	R ²	0,005
2m	-0,0014 + 0,0008 (0.0027) (0.0027)	LFS	R ²	0,001	-0,0065 + 0,0028 (0.0045) (0.0044)	RegUn	R ²	0,006
1m	0,0006 + 0,0023 (0.0030) (0.0030)	LFS	R ²	0,009	-0,0044 + 0,0095 (0.0055) (0.0054)	RegUn	R ²	0,047
2weeks	-0,0056 - 0,0015 (0.0038) (0.0038)	LFS	R ²	0,002	-0,0157 + 0,0012 (0.0061) (0.0060)	RegUn	R ²	0,001
1week	0,0010 + 0,0027 (0.0043) (0.0043)	LFS	R ²	0,006	-0,0053 + 0,0060 (0.0074) (0.0072)	RegUn	R ²	0,011

Figures in brackets denote standard errors of the coefficients. ** is significant at the 5 per cent level, * at the 10 per cent level. Significant key figure coefficients are marked grey.

For the models including credit growth and retail trade, R^2 is so low that these key figures, although significant, hardly have an effect on the interest rate series. The results for the unemployment figures are insignificant and appear less reliable. The signs of the coefficients are mixed, although they should all be negative, as higher unemployment indicates lower interest rates. R^2 is very low for all models including unemployment.

The special influence of inflation figures for interest rates in an inflation targeting regime is not a surprise. These figures are more directly linked to the development of the key policy rate and expectations of future monetary policy than are the other key figures that give information on the level of economic activity rather than the inflation outlook. This is in line with Eeg (2007). However, Eeg (2007) also discusses how the high importance of the core inflation figures in explaining Norwegian interest rates contrasts similar studies of other countries, where real economic factors and foreign news have a larger influence on the interest rates. This may be related to the deviations of core inflation from the inflation target during much of the sample period.

For the rest of part 6, the analyses will proceed with the significant figures only, and the main focus will be on the core inflation figures.⁴²

6.4 Key figure surprises and interest rate reactions

6.4.1 Model and expected outcomes

A model using dummy variables to test for a break at a known date was estimated to investigate whether there has been a change in market reactions to surprising key figures after the forecasts for the key policy rate were introduced. The model is based on Gujarati (2003) and Stock and Watson (2007). The description of the setup is based on the core inflation figures:

$$(6.2) \quad i_t - i_{t-1} = \beta_0 + \beta_1 \frac{(\pi_t - \pi_t^e)}{\sigma_\pi} + \beta_2 D_t + \beta_3 D_t \frac{(\pi_t - \pi_t^e)}{\sigma_\pi} + u_t$$

Explanations:

i_t	Interest rate day t
i_{t-1}	Interest rate day $t-1$
$i_t - i_{t-1}$	Change in interest rates from one day to the next
π_t^e	Expected core inflation to be announced on day t
π_t	Actual core inflation announced on day t

⁴² The time of appearance of the figures relative to the time the monetary policy reports are published must be taken into consideration when evaluating interest rate response and the information value. Hess (2000) finds more impact from macro news coming out during the first month of a reporting period than the news coming out during the second month. However, when it comes to inflation figures, Hess finds that “the only category for which we do not find any significant differences [of impact from figures released at different points in time in the reports period]...are the figures providing measurement of past price changes. The exceptional role of inflation does not come as a surprise considering the key role of inflation expectations for the interest rate”, (Hess (2000), p. 25.) Hence, the inflation figures from different points in time during a reporting period can be treated as equal considering information value and expected responses.

$\frac{(\pi_t - \pi_t^e)}{\sigma_\pi}$	Standardised surprise in core inflation figure announced on day t
D_t	Binary dummy variable, equals 0 before 2 November 2005 (the break date) and 1 after 2 November 2005
u_t	Error term / residual
$\beta_0, \beta_1, \beta_2, \beta_3$	Coefficients

This model is a binary interaction regression testing for a break on 2 November 2005 when the endogenous interest rate path was introduced.⁴³ The aim is to test whether the interest rate series have a different reaction pattern following surprises in core inflation figures in period 2. This corresponds to a significant β_3 in the model. A significant β_3 indicates that the interest rate response has changed significantly after 2 November 2005, giving a different slope of the regression in period 2. A significant β_2 indicates that the average changes in interest rates on the days of key figure announcements are different in the two periods.⁴⁴ When the average changes in the sample interest rates are negative in period 1 and positive in period 2, β_2 should be positive to ensure a higher average change after the break. These characteristics of the interest rate changes in the two periods, listed in table 5, also apply to the days of key figure surprises, so β_2 is expected to be positive. The coefficient β_1 should also have a positive sign, as interest rates should increase when inflation figures are higher than expected. This also applies to the series of credit growth and retail trade. The sign to expect for β_3 is, as discussed in the introduction to this part, less obvious. The model has been estimated for all series of key figures and interest rates obtaining significant results at the 5 or 10 per cent level in the preliminary analyses. These are listed in table 8.

Table 8: Data for estimation of the model

	Interest rate series
Core inflation	12m, 9m, 6m, 3m, 2m, 1m, 2 weeks
Credit growth	2 weeks, 1 week
Retail trade	6m

6.4.2 Assumptions

If the surprise figures are correlated to other factors explaining the interest rate changes on the same days, an omitted variable bias will be a problem in (6.2). In line with Connolly et al (2004), changes in foreign interest rates and surprises in domestic key figures are likely to be the most important explanatory factors for domestic interest rate volatility. It is reasonable to believe that this is the case also for Norway, in line with Eeg (2007). Hence, for model (6.2) to be valid, the surprise series can not be correlated to each other or foreign interest rate

⁴³ It is reasonable to believe that the market participants use some time to get to know a new communication system like this, so a clear break at the date of introduction seems unlikely. Furthermore, Norges Bank started to announce strategy intervals for the key rate ex post in October 2002 and ex ante in July 2004. Hence, the key rate projection is the last of many steps towards increased transparency, and the other dates could also be tested for. However, as the forecasts for the key policy rate represented a major change, it is reasonable to look for a break around 2 November 2005.

⁴⁴ Hence, the model intercepts differ in the two periods.

changes. It is reasonable to believe that such correlations are not present, as the differences between actual and expected key figures are likely to be independent of other information in the market. Very low correlations between these series, see table 9, confirm that an omitted variable bias is not likely to occur in (6.2).

Table 9: Correlation matrix for the key figure series and foreign interest rates⁴⁵

	Core inflation	Retail Trade	Credit growth	3 months eurorate
Core inflation	1	0	0	-0,0043231
Retail Trade	0	0	0	0
Credit growth	0	0	0	0
3 months eurorate	-0,0043231	0	0	1

6.5 Results and discussion

The results from the estimations show expected, positive signs for the coefficient β_1 for all the regressions, and the significance corresponds to the results in the preliminary regressions. Table 10 gives the estimation results for all series. Core inflation is significant at the 5 per cent level for all the interest series except 2 weeks. Credit growth is significant at the 5 per cent level for the changes in the 1 and 2 weeks interest rate series, while the retail trade is no longer significant. The positive sign of β_2 is as expected and in line with the generally more positive changes in interest rates in the second period of the sample. Hence, the constant for the period 2 regression, that is, the sum of β_0 and β_2 , is higher than the constant in period 1, β_0 . The interaction term β_3 is significant only for the core inflation figures explaining the 12-months and 9-months interest rate series and the credit growth explaining the 2 weeks series, all at the 5 per cent level. Interestingly, all the significant β_3 coefficients are negative, indicating smaller reactions to key figure surprises in the new regime. Hence, if the market has learned more about the central bank reaction function in period two and adjusted its behaviour accordingly, the reactions to surprising inflation figures were perhaps too high in period 1. Another interpretation may be that the changes are not related to increased transparency, but to a change in the central bank reaction function from period 1 to period 2. Investigating this is, however, outside the scope of this thesis.

The regressions of the 12-months rate and the 9-months rate on core inflation obtain the highest values of R^2 and β_1 coefficients, an indication that these models contain more information value than the others and that the two significant models on inflation figures are clearly better than the credit growth model. Despite the lack of significance, the core inflation models of the other longer interest rates, especially the 6 months rate, are quite similar to these two models when it comes to R^2 , coefficients and standard errors. The differences in p-values may be related to the small number of observations, making it hard to obtain significant results. Hence, it may be more relevant to compare standard errors than p-values in this case, and with this approach, the 6 months rate is also showing a different behaviour in period 2.

⁴⁵ The 3-months eurorate has been included as a representative of foreign interest rates.

Table 10: Overview of estimation results

Figures in brackets denote standard errors of the coefficients. ** is significant at the 5 per cent level, * at the 10 per cent level. Significant interaction terms are marked grey.

The inflation figures have been more stable in period 2, see chart 9. More stable inflation could improve the market predictions of these figures, which again may be a reason for lower reactions in period 2. The average standardised surprise in new figure announcements is, however, somewhat larger in period 2, see table 11. For both periods in the sample, the average surprise in core inflation has been negative. For the whole period in question, inflation has been low and stable compared to its long term development, and since August 2002, the core inflation rate has been below the inflation target. During this period, the inflation has often been expected to pick up, and both the market participants and Norges Bank have often been surprised by lower figures than expected. This indicates that a more stable economic environment does not necessarily make it easier to predict the exact monthly

figures of core inflation, and neither changes in inflation surprises or the reduced general volatility should alter the conclusions from this part.

Chart 9: Core inflation development

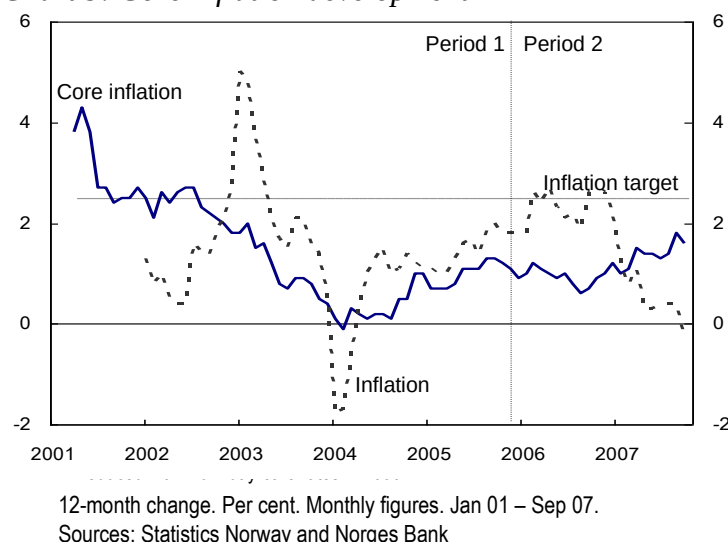


Table 11: Average standardised surprise in core inflation figures

	Average surprise
Period 1	-0.210
Period 2	-0.225
Total	-0.218

6.6 Conclusions on key figure responses

The answer to the second research question; whether market reactions to macro news have changed since the interest rate forecasts were introduced, is similar to the answer to the first one: a conditional yes, as it depends on which series of key figures and market rates are considered. The results indicate that market participants have gained knowledge of the central bank reaction function in recent years, and that the behaviour of the longest interest rates in the sample, the ones being most influenced by inflation expectations, has changed accordingly. The 2 weeks interest rate series also shows a significant change in the reaction to surprises in credit growth figures period 2, but as the model is generally weak, the results for the core inflation figures appear more relevant.

The interest rate reactions to these key figures are smaller in the second period, indicating a result in line with Clare and Courtenay (2000), Lasaosa (2005) and Joyce and Read (1999) who suggests that market participants appear to react less to macroeconomic announcements as transparency increases. This may indicate too large reactions to such surprises in the first period of the sample, compared to the central bank reaction function. Another possibility could be that the central bank reaction function has changed in recent years. Investigating this is, however, outside the scope of this thesis. Although the answer to the second question does not conclude on causality, it is reasonable to believe that the changes in market reactions found above are related to the new monetary policy regime of interest rate forecasts.

7. Overall conclusions

The thesis aims to answer the following questions:

Has the volatility in market interest rates at the time of policy announcements diminished?

Have market reactions to macro news changed?

The analyses indicate positive answers to both questions when considering the longer interest rates in the sample. The volatility around monetary policy announcements has diminished and the response of the longest interest rate series to surprises in core inflation figures has changed since Norges Bank introduced forecasts for the key policy rate in 2005. The findings are related. The interest rate forecast is likely to increase market knowledge of the central bank reaction function. This implies both improved market predictability of policy announcements, investigated by the first research question, and more adequate market reactions to macro news between the monetary policy reports, in line with the second question.

The positive answer to the first question applies to all except the two shortest interest rate series in the sample, while the findings related to the second question are valid for the 12 month and 9 month interest rates, with the 6 month rate being close to obtaining the same result. It is reasonable that the results for the longest rates are the most significant, as these are the most likely to be affected by changes in expectations regarding future interest rates and inflation.

The general macroeconomic environment in Norway has been more stable after the endogenous interest rate path was introduced in November 2005 than in the previous years, and the volatility of the key policy rate has dropped significantly. The increased stability is likely to influence the results and especially the interest rate surprises. The analysis can not conclude on whether the increased predictability is due to the key rate development or increased transparency. Furthermore, the changes in market rate reactions to key figures may not necessarily be a result of increased knowledge about the central bank reaction function, but could be a response to a perceived change in this reaction function in recent years. However, based on the literature, it is reasonable to believe that the results are not explained by the improved stability or a possible change in reaction function alone. It is likely that the observed effects are related to the increased transparency from interest rate forecasts and that these have affected market reactions. These effects, the improved predictability of monetary policy announcements and changes in market reactions, are then as expected.

The main theoretical arguments in favour of central bank forecast of the key rate are related to improved management of expectations. The results of this study indicate that private sector expectations, and especially regarding the longest market interest rates in the sample, have become better aligned with central bank reactions after Norges Bank introduced forecasts of the key policy rate, with the implications this has for an efficient monetary policy and the commitment possibilities of the central bank. The results can be interpreted as a greater market understanding of Norges Bank's reaction pattern after the introduction of the endogenous interest path, in line with the intended effect.

The longer-term effects of the interest rate forecasts will be a topic for future research to investigate and draw bolder conclusions based on more observations. Future studies may be able to decide whether the results of this thesis are also valid when considering a longer time horizon and to evaluate a larger spectre of possible effects of interest rate forecasts as a way of improving central bank transparency.

8. References

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9. Appendix A– E

Appendix A: Criteria for an appropriate interest rate path

Norges Bank Monetary Policy Report 3/07, page 9. See also Qvigstad (2005).

“The operational target of monetary policy is low and stable inflation, with annual consumer price inflation of approximately 2.5 per cent over time. In interest rate setting, the forecast for future interest rate developments should satisfy the following main criteria:

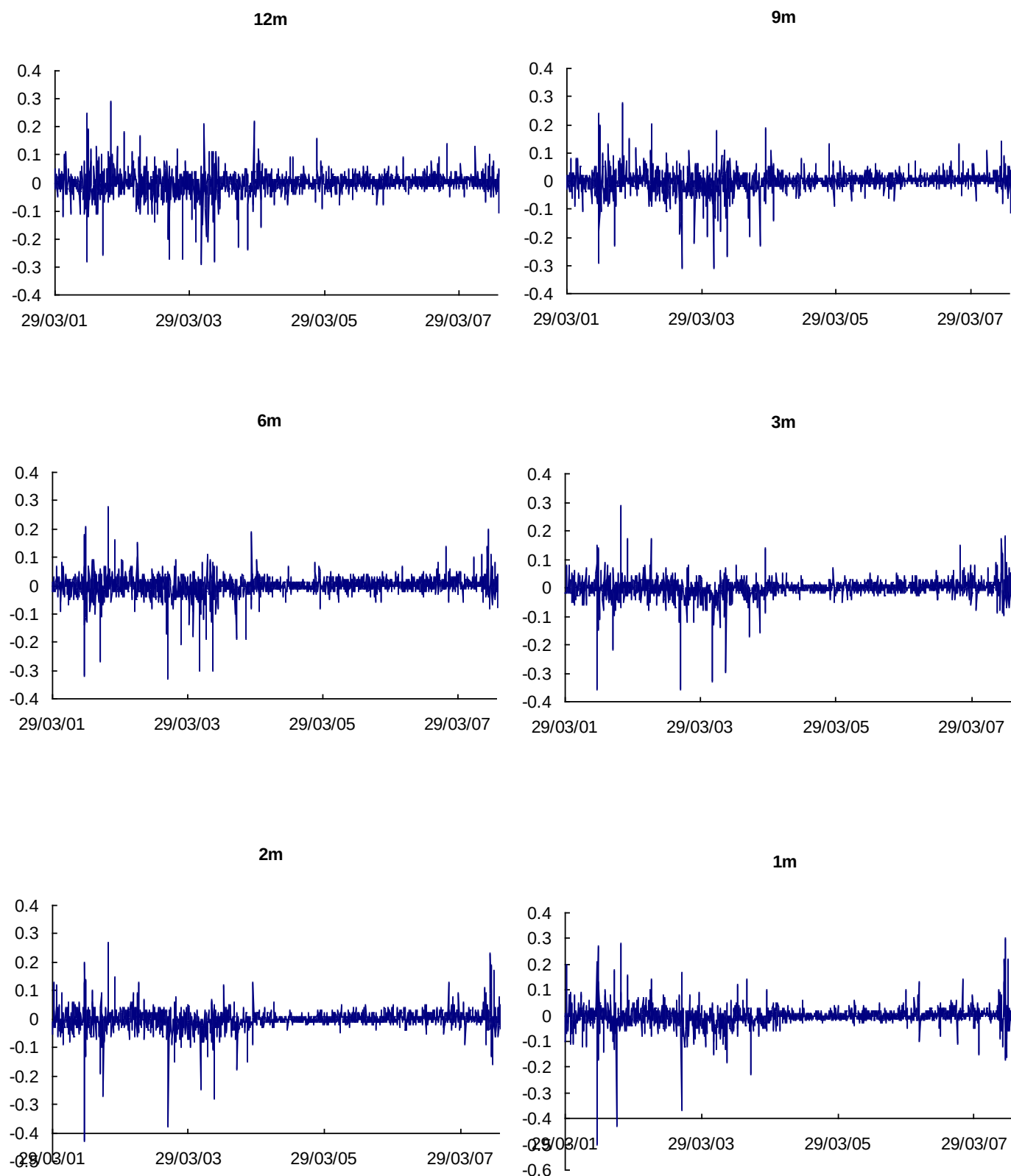
1. The interest rate should be set with a view to stabilising inflation close to the target in the medium term. The horizon will depend on disturbances to which the economy is exposed and the effects on the prospects for the path for inflation and the real economy.
2. The interest rate path should provide a reasonable balance between the path for inflation and the path for capacity utilisation.

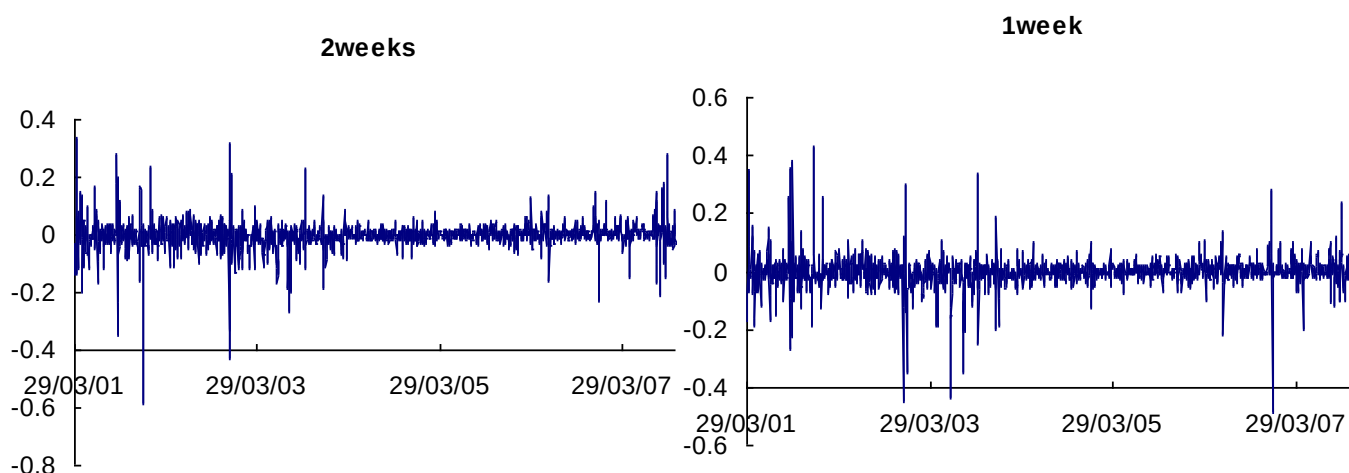
In the assessment, potential effects of asset prices, such as property prices, equity prices and the krone exchange rate on the prospects for output, employment and inflation are also taken into account. Assuming the criteria above have been satisfied, the following additional criteria are useful:

3. Interest rate developments should result in acceptable developments in inflation and output also under alternative, albeit not unrealistic assumptions concerning the economic situation and the functioning of the economy.
4. Interest rate adjustments should normally be gradual and consistent with the Bank’s previous response pattern.
5. As a cross-check for interest rate setting, it should be possible to explain any substantial and systematic deviations from simple monetary policy rules.”

Appendix B: Interest rate series

*Daily changes in interest rate series in the sample from 29 Mar 2001 – 31 Oct 2007.
Percentage points.*





Appendix C: Tests of differences in $SURPRISE_D$ effects in period 1 and 2

The test of different means in the surprise series (period 1 and 2) for each interest rate was conducted in two steps:

1. F-tests of two samples of variances (to decide which type of t-test to conduct in the next step)

Table C.1: Results from F-tests

Money mkt rates	Avg		12m		9m		6m		3m		2m		1m		2w		1w	
Mean	0,065	0,039	0,083	0,047	0,077	0,046	0,066	0,037	0,065	0,036	0,064	0,032	0,052	0,039	0,054	0,052	0,060	0,031
Variance	0,007	0,002	0,008	0,002	0,007	0,001	0,008	0,002	0,008	0,002	0,008	0,002	0,008	0,004	0,009	0,005	0,012	0,004
Obs.	40	19	40	18	40	18	40	19	40	19	40	19	40	19	40	19	40	19
fg	39	18	39	17	39	17	39	18	39	18	39	18	39	18	39	18	39	18
F	3,721		4,699		5,214		5,183		3,398		3,745		2,129		1,764		2,792	
P(F<=f) one side	0,002		0,001		0,000		0,000		0,004		0,002		0,044		0,098		0,011	
F critical, one side	2,066		2,107		2,107		2,066		2,066		2,066		2,066		2,066		2,066	

P-values for significantly different variances (5%) are marked grey.

According to this test, all series except the 2 weeks rate have different variances in the two sub-samples. Hence, t-tests assuming different variances will be conducted for all series except the 2 weeks rate, for which the relevant test is a t-test assuming the same variance in the two samples.

2. T-tests of two samples with variances assumed to be different, except for the 2 weeks rate, for which equality of variances is assumed

Table C.2: Results from T-tests

Money mkt rates	Avg		12m		9m		6m		3m		2m		1m		2w		1w	
Mean	0,065	0,039	0,083	0,044	0,077	0,044	0,066	0,037	0,065	0,036	0,064	0,032	0,052	0,039	0,054	0,052	0,06	0,031
Variance	0,007	0,002	0,008	0,002	0,007	0,001	0,008	0,002	0,008	0,002	0,008	0,002	0,008	0,004	0,009	0,005	0,012	0,004
Obs.	40	19	40	19	40	19	40	19	40	19	40	19	40	19	40	19	40	19
fg	56		57		57		57		56		56		49		57		54	
t-stat	1,552		2,315		2,072		1,675		1,611		1,86		0,647		0,056		1,297	
P(T<=t) one side	0,06		0,012		0,021		0,05		0,06		0,034		0,26		0,478		0,1	
T critical, one side	1,673		1,672		1,672		1,672		1,673		1,673		1,677		1,672		1,674	
P(T<=t) two sides	0,126		0,024		0,043		0,1		0,113		0,07		0,521		0,955		0,2	
T critical, two sides	2,003		2,002		2,002		2,002		2,003		2,003		2,01		2,002		2,005	
Group variance 2w															0,008			

Significant results on the 5 per cent level are marked grey, while significant results at the ten per cent level are bold and framed.

Table C.3 sums up all the results, including those from the two sided tests.

Table C.3: *P-values from t-tests*

	Avg	12m	9m	6m	3m	2m	1m	2w	1w
P(T<=t) one side	0,06	0,012	0,021	0,05	0,06	0,034	0,26	0,478	0,1
P(T<=t) two sides	0,126	0,024	0,043	0,1	0,113	0,07	0,521	0,955	0,2

The $SURPRISE_D$ effects are significantly *smaller* in period 2 for the average of the series (10%). The 12m, 9m, 6m and 2m rate have significantly smaller surprises at the 5 per cent level, while the 3m rate has significant effects at the 10 per cent level. The average surprises are significantly *different* in period 2 for the 12m and 9m rates (5%) as well as the 6m and 2m rates (10%).

Appendix D: Tests of volatility in the interest rate series

D.1 The key policy rate

Descriptive statistics for the key policy rate. Eviews output.

	TOTAL	PERIOD_1	PERIOD_2
Mean	3.974638	4.256082	3.333168
Median	3.25	4	3
Maximum	7	7	5
Minimum	1.75	1.75	2
Std. Dev.	2.037182	2.316849	0.886972
Variance	4.150110501	5.367789289	0.786719329
Skewness	0.392188	0.070966	0.37027
Kurtosis	1.524729	1.149233	1.847538
Jarque-Bera	192.6252	165.2397	39.48614
Probability	0	0	0
Sum	6582	4898.75	1683.25
Sum Sq. Dev.	6868.435	6172.957	396.5069
Observations	1656	1151	505

Test of equality of variance between the two periods of the key policy rate

$$H_0: \sigma_1^2 \leq \sigma_2^2$$

$$H_1: \sigma_1^2 > \sigma_2^2$$

The F-test in the table below (and the other tests performed by Eviews) shows that H_0 can be rejected at the 1 per cent significance level.

EvIEWS output from the test:

Test for Equality of Variances Between Series

Date: 11/01/07 Time: 23:01

Sample: 1 1656

Included observations: 1656

Method	df	Value	Probability
F-test	(504, 1150)	6.822997	0
Siegel-Tukey		28.13963	0
Bartlett	1	469.3264	0
Levene	(1, 1654)	2526.754	0
Brown-Forsythe	(1, 1654)	1848.472	0

Category Statistics

Variable	Count	Std. Dev.	Mean Abs. Mean Diff.	Mean Abs. Median Diff.	Mean Tukey- Siegel Rank
PERIODE_1	1151	2.316849	2.239553	2.231321	611.1793
PERIODE_2	505	0.886972	0.778363	0.767822	1323.819
All	1656	2.037182	1.79396	1.785024	828.5

Bartlett weighted standard deviation: 1.992954

D.2 Money market interest rates

F-test of general volatility

A regular F-test of the null hypothesis of the same variance in the two periods against the alternative hypothesis of higher variance in period 1 can be conducted in line with Gujarati (2003). $H_0: \sigma_1^2 \leq \sigma_2^2$, $H_1: \sigma_1^2 > \sigma_2^2$. The test statistic for the F-test is given by

$$F = \frac{S_1^2}{S_2^2} \sim F_{n_1-1, n_2-1} \text{ and } H_0 \text{ is rejected if } \frac{S_1^2}{S_2^2} > F_{n_1-1, n_2-1}^{46}$$

The critical F-value is 1.1345 at the 5 per cent level and 1.1958 at the 1 per cent level. The table below shows the test results for the short interest rate series, that the variance in period 1 is significantly higher than in period 2 for all the interest rate series at the 5 per cent significant level. For the longest interest rates in the sample, 6 months, 9 months and 12 months, the difference in variance is also significant at the 1 per cent level.

Table D.1: Results from F-tests of variances in period 1 and period 2

F-test of variances								
	12m	9m	6m	3m	2m	1m	2 weeks	1 week
Variance 1	0.00252	0.00213	0.00185	0.00147	0.00147	0.00182	0.00226	0.00298
Variance 2	0.00055	0.00052	0.00066	0.00079	0.00076	0.00111	0.00153	0.00193
F-value	4.5942	4.1325	2.7849	1.8509	1.9293	1.6338	1.4818	1.5439
Significance								
5 per cent	yes	yes	yes	yes	yes	yes	yes	yes
1 per cent	yes	yes	yes	no	no	no	no	no

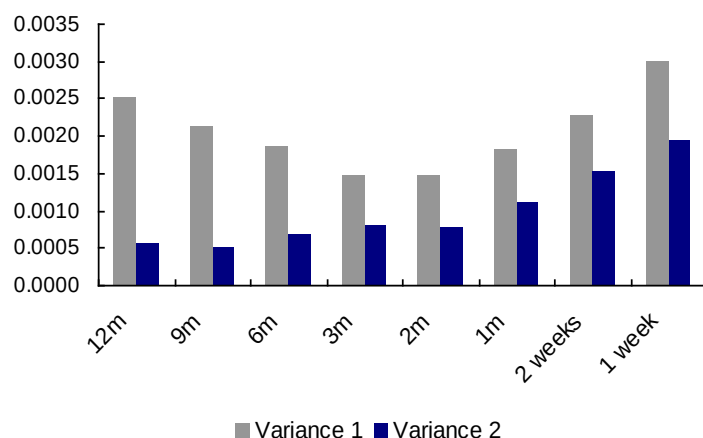
⁴⁶ σ_1^2 and σ_2^2 are the two population variances, while S_1^2 and S_2^2 are the sample variances. The test is in line with section 8.5 in Gujarati and has been confirmed by the SSE Department of Economic Statistics.

Table D.2: Descriptive statistics on the daily changes in the short interest rate series
Source: Eviews.

_1 and _2 indicate period 1 and 2.

	12M_2	12M_1	9M_2	9M_1	6M_2	6M_1	3M_2	3M_1	2M_2	2M_1	1M_2	1M_1	2W_2	2W_1	1W_2	1W_1
Mean	0.006	-0.004	0.006	-0.004	0.006	-0.004	0.006	-0.004	0.006	-0.004	0.005	-0.005	0.006	-0.005	0.005	-0.006
Median	0	0	0.01	0	0.01	0	0.01	0	0	0	0	0	0	0	0	0
Maximum	0.14	0.29	0.14	0.28	0.2	0.28	0.18	0.29	0.19	0.27	0.22	0.28	0.28	0.34	0.24	0.36
Minimum	-0.110	-0.290	-0.120	-0.310	-0.080	-0.330	-0.100	-0.360	-0.160	-0.430	-0.170	-0.500	-0.230	-0.430	-0.490	-0.590
Std. Dev.	0.023	0.050	0.023	0.046	0.026	0.043	0.028	0.038	0.028	0.038	0.033	0.043	0.039	0.048	0.044	0.055
Variance	0.00055	0.00252	0.00052	0.00213	0.00066	0.00185	0.00079	0.00147	0.00076	0.00147	0.00111	0.00182	0.00153	0.00226	0.00193	0.00298
Skewness	0.724	-0.855	0.511	-1.013	1.502	-1.676	0.969	-2.087	0.711	-2.249	-0.128	-1.724	0.102	-1.472	-2.683	-2.228
Kurtosis	9.160	11.389	10.301	13.791	13.247	18.622	10.607	28.072	14.365	31.739	11.978	29.484	15.521	20.922	38.552	28.467
Jarque-Bera	840.847	3514.91	1141.47	5781.693	2394.5	12242.3	1294.25	30983.6	2754.727	40581.48	1693.98	34208.52	3293.24	15820.2	27147.6	32055.6
Probability	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	2.86	-4.44	2.95	-4.63	3.09	-4.77	3.17	-4.89	2.99	-4.94	2.46	-5.21	2.92	-5.86	2.705	-6.45
Sum Sq. Dev.	0.276	2.897	0.259	2.449	0.334	2.126	0.399	1.690	0.383	1.689	0.561	2.095	0.769	2.604	0.971	3.429
Observations	504	1151	504	1151	504	1151	504	1151	504	1151	504	1151	504	1151	504	1151

Chart D.1: Variance in the daily changes in short interest rate series in period 1 (var. 1) and period 2 (var. 2)



Appendix E: GARCH (1,1) models

The results from the GARCH(1,1) models indicate that volatility in interest rates has diminished since Norges Bank introduced interest rate forecasts, supporting the findings in 5.2.

GARCH is a common way to measure volatility in financial time series, in line with Stock and Watson (2007), Gujarati (2003), Brooks (2002) and Longstaff and Schwartz (1992). For an overview of GARCH models for modelling of interest series, see Bollerslev et al (1992). The Normal distribution is assumed for the series modelled by GARCH, and the models were estimated by PCGive 10.

The volatility of the interest rate series in the two periods has been compared using the GARCH(1,1) model. Table A.5.1 shows the comparison of (alfa + beta) for the 12 months

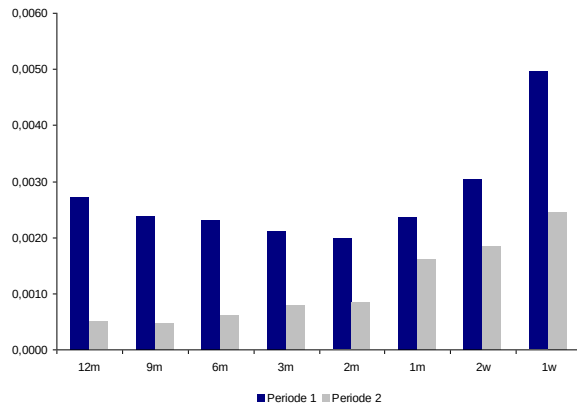
rate in the two periods. As the models for the other interest rate series had sums of (alfa + beta) larger than one, the only valid result is for the 12 month rate.

Table E.1: Sums of coefficients from the GARCH process for the 12 months rate

	12m
Period 1	0,997
Period 2	0,993
Diff	0,004

Another way of comparing the volatility is by comparing the mean conditional variance estimated for each of the two periods. The estimated conditional variance is higher in period one than in period 2 for all interest rate series in the sample, see chart A.5.1.

Chart E.1: Average estimated conditional variance from GARCH(1,1) for the money market interest rates in the sample



The difference is tested by a two-sample, one-sided t-test⁴⁷ of

$$H_0: \sigma_1^2 \leq \sigma_2^2 \text{ against } H_1: \sigma_1^2 > \sigma_2^2$$

where σ_1^2 and σ_2^2 are the conditional variances in period one and period 2. H0 is rejected at the one per cent level for all series, and it is reasonable to believe that the conditional variance of the series is lower in period 2. See table A.5.2.

Table E.2: Results from tests of differences in mean conditional variance in period 1 and 2
T-tests of two samples with variances assumed to be different

	12m	9m	6m	3m	2m	1m	2w	1w
t-stat	32,43	27,16	19,43	12,83	10,79	3,66	7,07	5,19
P(T<=t) one side	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
T critical, one side	1,646	1,646	1,646	1,646	1,646	1,647	1,646	1,646

⁴⁷ The t-test is based on the assumption of a normal distribution. This may not be fulfilled in the case of the conditional variance, and this must be kept in mind when stating the test results. Furthermore, the t-statistic for comparison of the mean conditional variances in period one and two is based on an assumption of different variances in the two periods. The difference of variances was confirmed by a preliminary F-test of the variances of the conditional variance series.

Table E.3: Results from the GARCH(1,1) models

		Period 1 1151 obs.				Period 2 506 obs			
Series		Coefficient	Std,Error	robust-SE	t-prob	Coefficient	Std,Error	robust-SE	t-prob
12m									
Constant	X	0,000	0,001	0,001	0,946	0,005	0,001	0,001	0,000
dKEYRATE	X	0,127	0,028	0,072	0,077	0,186	0,024	0,064	0,004
alpha_0	H	0,000	0,000	0,000	0,338	0,000	0,000	0,000	0,773
alpha_1	H	0,073	0,014	0,040	0,072	0,016	0,009	0,015	0,305
beta_1	H	0,924	0,013	0,042	0,000	0,977	0,024	0,035	0,000
9m									
Constant	X	0,000	0,001	0,001	0,762	0,005	0,001	0,001	0,000
dKEYRATE	X	0,117	0,027	0,067	0,083	0,157	0,022	0,056	0,005
alpha_0	H	0,000	0,000	0,000	0,250	0,000	0,000	0,000	0,604
alpha_1	H	0,082	0,014	0,038	0,032	0,030	0,011	0,018	0,092
beta_1	H	0,921	0,011	0,032	0,000	0,964	0,019	0,028	0,000
6m									
Constant	X	0,000	0,001	0,001	0,586	0,005	0,001	0,001	0,000
dKEYRATE	X	0,114	0,026	0,069	0,101	0,144	0,023	0,056	0,010
alpha_0	H	0,000	0,000	0,000	0,474	0,000	0,000	0,000	0,318
alpha_1	H	0,101	0,014	0,047	0,034	0,060	0,021	0,045	0,179
beta_1	H	0,918	0,009	0,030	0,000	0,916	0,032	0,054	0,000
3m									
Constant	X	0,001	0,001	0,001	0,388	0,005	0,001	0,001	0,000
dKEYRATE	X	0,101	0,022	0,058	0,080	0,088	0,023	0,046	0,056
alpha_0	H	0,000	0,000	0,000	0,731	0,000	0,000	0,000	0,262
alpha_1	H	0,160	0,023	0,103	0,119	0,098	0,026	0,032	0,002
beta_1	H	0,887	0,014	0,058	0,000	0,892	0,029	0,037	0,000
2m									
Constant	X	0,001	0,000	7,482e-0251	0,000	0,005	0,001	0,001	0,000
dKEYRATE	X	0,150	0,000	3,313e-0261	0,000	0,076	0,022	0,048	0,113
alpha_0	H	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,054
alpha_1	H	0,116	0,000	7,177e-0251	0,000	0,116	0,029	0,063	0,068
beta_1	H	0,914	0,000	1,364e-0246	0,000	0,866	0,029	0,049	0,000
1m									
Constant	X	0,000	0,001	0,001	0,847	0,005	0,001	0,001	0,000
dKEYRATE	X	0,140	0,023	0,070	0,047	0,067	0,025	0,045	0,134
alpha_0	H	0,000	0,000	0,000	0,543	0,000	0,000	0,000	0,003
alpha_1	H	0,121	0,023	0,090	0,177	0,434	0,079	0,103	0,000
beta_1	H	0,903	0,015	0,060	0,000	0,591	0,050	0,068	0,000
2w									
Constant	X	0,000	0,001	0,001	0,816	0,002	0,001	0,001	0,061
dKEYRATE	X	0,088	0,028	0,044	0,045	0,081	0,033	0,059	0,170
alpha_0	H	0,000	0,000	0,000	0,528	0,000	0,000	0,000	0,181
alpha_1	H	0,088	0,015	0,052	0,092	0,241	0,042	0,069	0,001
beta_1	H	0,921	0,012	0,047	0,000	0,783	0,028	0,064	0,000
1w									
Constant	X	0,000	0,001	0,001	0,926	0,002	0,001	0,002	0,319
dKEYRATE	X	0,304	0,033	0,143	0,034	0,146	0,043	0,077	0,057
alpha_0	H	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,014
alpha_1	H	0,663	0,079	0,191	0,001	0,291	0,054	0,078	0,000
beta_1	H	0,430	0,035	0,067	0,000	0,702	0,037	0,077	0,000

dKEYRATE is the daily change in the key policy rate. This is 0 most of the days in the sample.