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The effectiveness of forward guidance on the Norwegian yield curve: Is this in accordance with findings in the data?

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Abstract

Inspired by previous research, we are going to perform an empirical analysis to test the effectiveness of forward guidance in Norway on market expectations using high-frequency data and an event-study approach. Further, we will investigate how forward guidance affects the term structure in Norway using the Nelson-Siegel-Svensson framework. More specifically, we will investigate Norges Bank's press conferences and the following statements to examine how market expectations are influenced by monetary policy actions and statements.

Using a two-dimensional approach, we find supporting evidence and conclude that forward guidance influences money market rates. Furthermore, by creating yield curves we examine relations between macro variables and the term structure of interest rates. We find evidence coinciding with the theory presented by Rudebusch and Wu, albeit being unable to draw any conclusion due to a limited number of observations.

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1 Introduction

Central banks have intended to affect the expected interest rates using various forms of forward guidance for many years, which started out as statements from the central bank concerning their perception of the economy outlook. Forward guidance is, in general, information communicated by the central bank regarding their own assessment of the future path of policy rates, with the main objective of influencing the public's expectations (den Haan, 2013). Our thesis presents an analysis of forward guidance effectiveness in Norway by performing a two-dimensional regression. In addition, we show the relationship between macro variables, primarily inflation and monetary policy changes, and the Norwegian yield curve.

The concept of forward guidance is not new as it was introduced in an early form by the Reserve Bank of New Zealand (RBNZ) in late 1990s. Previously, the standard practice of central banks was to provide forecasts of target values in regards of inflation rates and economic growth. The communication of the central bank went through channels such as statements, speeches, and press conferences. However, a few years after New Zealand introduced their forward guidance, Norway and Sweden adopted the method, in 2005 and 2007 respectively, by introducing an explicit form of forward guidance (Andersson & Hofmann, 2009). They took forward guidance a step further by introducing numerical forecasts of the interest rate path a few years ahead in their projections. The reasons behind Norway's move towards a more explicit form of forward guidance were twofold. First, due to a change from having an exchange rate targeting regime to a flexible inflation targeting regime. Second, globalization played a huge part in changing the world economy considerably, including Norway. Considering these severe developments, the need of new modeling tools emerged (Brubakk, Husebø, Maih, Olsen, & Østnor, 2006).

Forward guidance is classified into two categories; Delphic and Odyssean forward guidance. Usually, the monetary policy rate has a natural floor at zero and therefore cannot be used to stimulate the economy further once this point is reached. [1] Hence, the central banks need other tools. One way to stimulate the economy further is to announce to the market that the short-term interest rate will not be increased once the economy recovers, as is the case historically. Instead, central banks can wait until a target variable, be it inflation or growth, reaches a certain level before increasing the interest rate. This method of forward guidance is referred to as Odyssean, much like Odysseus tied himself to the mast to resist the sirens calls, the central banks must keep the interest rate low until the target variable is met, even when interfering may improve present and future outcomes (J. Campbell, 2013). Otherwise, their credibility in the market will deteriorate, and any future attempts to stimulate the economy at the zero lower bound will likely be fruitless as the central banks statements will not be credible in the market, leaving market expectations unchanged.

Another way central banks use forward guidance is referred to as Delphic, named after the oracle at Delphi, which provided prophecies of the future given the current situation, but did not promise. Hence, these two methods differ in that Delphic forward guidance releases forecasts without commitments, while Odyssean forward guidance releases forecasts along with a commitment to follow a certain path. Another difference is the inclusion of fan charts by Norges Bank, which serves to visualize the surrounding uncertainty of the published forecasts. The press conference following the interest rate meeting also stress that this forecast is not a promise, but rather the central banks' best guess at the time of publication of the future path of policy rates, which is conditional on the information available at that point in time.

After the global financial crisis, many central banks reduced the policy rates close to the effective lower bound with the intention of stimulating the economy. However, they were faced with the problem of not being able to incentivize further stimulus through conventional means. In result, a higher focus on alternative tools available to

[1] Some economies, like Sweden and Japan, have chosen to overcome the zero bound with negative interest rate policy.

the central banks occurred, such as forward guidance and quantitative easing. In 2012, the central bank of the United States announced that they would keep interest rates low until they met two target variables (J. R. Campbell, Evans, Fisher, & Justiniano, 2012). More specifically, the policy rate was held low until they achieved an unemployment rate below 6.5% and an inflation rate above 2.5%. Further, shortly after the US, the bank of England followed the same strategy of forward guidance, i.e. similar manner of conditioning the future interest rate path on the developments in the inflation and unemployment rates.

Woodford (2003) argue that monetary policy boils down to the "management of expectations". Woodford's beliefs are in accordance with the previous Governor of Norges Bank, Svein Gjedrem (Woodford, 2005). In 2006, Gjedrem held a speech where he explained the new monetary policy to the public. [2] According to him, communication and transparency are essential for monetary policy effectiveness.[3] Furthermore, to communicate directly to the public is perceived to be more probable of achieving an effective monetary policy by the central bank (Gjedrem, 2006). More specifically, he stated that monetary policy is only effective if the central bank can affect interest rate expectations. The latter may prove challenging as market participants rely on their own assessment of the interest path based on their estimate of current and future economic variables. Hence, the interest rate path intended by the central bank may deviate from the interest path based upon the expectations of market participants.

2 Gjedrem (2006). Speech can be retrieved here: https://www.norges-bank.no/Publisert/Foredrag-og-taler/2006/2006-03-30/

3 Bernanke (2013) among others, also emphasize the importance of transparency regarding monetary policy. Similar thoughts are shared by the current Governor of Norges Bank, Øystein Olsen. As stated in a speech held in 2014, reaching greater transparency has been an objective for the monetary policy in Norway since the 1990s, in accordance with the general trend in modern societies. Olsen emphasizes how necessary transparency in this context is for accountability. By being accountable, the central bank can build credibility through showing that long-run objectives are attained and by explaining deviations from targets.

Inspired by the paper "Forward guidance through interest rate projections: Does it work?" by Brubakk, ter Ellen, and Xu (2017) among others, this thesis contribute to the literature by testing how effective Norges Bank's forward guidance is in influencing the interest rate term structure. More specifically, we investigate the relationship between the term structure of interest rates projected by Norges Bank and the interest rate path predicted by market participants. We apply the methodology introduced by Gürkaynak, Sack, and Swanson (2005b). Lastly, this thesis investigates shared thoughts among researchers of the field within Macro-Finance, to see how macro variables, in this case inflation and monetary policy changes, relate to changes in the term structure of interest rates. Our findings may provide meaningful insight regarding macro variables and the yield curve of interest rates.

The remainder of our thesis proceeds as follows. Section 2 contains our literature review, section 3 covers the most relevant theories, section 4 explains our methodology, and section 5 displays our data. Section 6 shows our results. In section 7 we discuss any shortcomings, while section 8 concludes.

2 Literature Review

Various researchers throughout the past decades have investigated the effects of monetary policy on asset prices. Among the well-known studies of the field are Gürkaynak, Sack, and Swanson (2005b). The authors find two factors important in capturing the effects on asset prices, which have a structural interpretation as a "target" and a "market path" factor. The former factor represents a rate surprise (an action), whereas the latter summarizes all relevant forward guidance communication as perceived by market participants, which also includes the published interest rate path (a statement about the future).[4] Their findings suggest that both monetary policy actions and statements do affect asset prices significantly. More specifically, they found that policy statements proved to have greater impact on longer-term Treasury yields.

An empirical analysis done by Andersson and Hofmann (2009) indicates that the central banks of Norway, New Zealand and Sweden, have been highly predictable in their monetary policy regimes. Essentially, they test various hypotheses regarding how using an explicit forward guidance, in terms of publishing a future interest rate path, improves the central bank's ability to move market expectations. Their results are based on data up until 2007, where all three countries follow an inflation-targeting regime. However, due to data limitations, they solely investigate the effect on yields of publishing a future interest rate path for New Zealand. As opposed to finding a significant effect on five-year bond yields, they find no effect on 10-year yields. Nonetheless, they do find evidence from Norway indicating that the central bank's short-term predictability increased after they introduced forward guidance, as both target and path surprises declined significantly after November 2005.[5] Similarly, to

[4] To be discussed in detail in section 4.1.3 and 6.2
[5] When Norges Bank started releasing interest rate forecast for next following years.

our study, Andersson and Hofmann apply the methodology introduced by Gürkaynak, Sack, and Swanson (2005b).

Kool and Thornton (2012) study the effectiveness of forward guidance for the central banks of New Zealand, Sweden, the United States and Norway through testing whether forward guidance improves market participants' ability to forecast future short-term and long-term rates relative to various benchmarks. Their empirical findings do suggest improved forecast accuracy over relative short forecast horizons in New Zealand, Sweden, and Norway after these countries began publishing interest rate paths. However, their findings are weak and mostly insignificant.

The article most closely related to our work is Brubakk et al. (2017). They investigate the effectiveness of explicit forward guidance by central banks in Norway and Sweden, and how it affects the market yield curve. Specifically, the term “explicit” forward guidance refers to policymakers publishing the path of expected future policy rates. By applying the methodology introduced by Gürkaynak et al. (2005b), they capture movements in the yield curve by two latent factors, referred to as the “target factor” and “market path factor”, which capture market participants’ assessment of all relevant monetary policy communication on announcement days. Their findings suggest that information contained in the published interest rate path has a significant effect on the market path as it explains up to 47% of the market path factor. Thus, they conclude that “explicit” forward guidance succeeds in moving markets in the intended direction. Furthermore, their findings suggest that market participants largely understand the monetary policy reaction pattern. Our thesis differs from their contribution by also applying the Nelson-Siegel-Svensson model to illustrate changes on the yield curve post interest rate meetings. Doing so allow us to examine whether, and how, the adjustments of the key interest rate affect the corresponding part of the term structure.

Other articles that are relevant to our thesis are the articles written by Rudebusch and Wu (2008), and Barr and Campbell (1997). The former mentioned investigate the relationship between the term structure of interest rates and macro variables. They develop and estimate a macro-finance model that combines a canonical affine no-arbitrage finance specification of the yield curve with standard macroeconomic aggregate relationships for output and inflation. In short, their findings suggest that the latent term structure factors from no-arbitrage finance models have important macroeconomic and monetary policy underpinnings. In addition, they find no evidence of a slow partial adjustment of the monetary policy rate by the central bank, and that both forward-looking and backward-looking elements play roles in macroeconomic dynamics.

Rudebusch and Wu (2008) argue that a model that take on a joint macro-finance perspective can illuminate different macroeconomic issues, since the addition of term structure information to a macroeconomic model may help sharpen inference. Conversely, such a model-perspective can also help provide crucial insight into the behavior of the yield curve beyond what a pure finance model can suggest. Furthermore, as term structure factors summarize expectations regarding future short rates, they also reflect expectations about the future dynamics of the economy. Then, in an economy consisting of forward-looking economic agents, these expectations should be critical determinants of current and future macroeconomic variables. They also argue that having an explicit macro structure can provide insight into the behavior of the yield curve even more so than what a pure finance model can offer.

Barr and Campbell (1997) investigate the term structure of interest rates and find a close relationship between the level factor and inflation expectations. In fact, the authors conclude that in the UK "almost 80 percent of the movement in long-term nominal rates appears to be due to changes in expected long-term inflation."[6]

[6] Similarly, Gürkaynak, Sack, and Swanson (2005a) claims that movements in long rates reflect fluctuations in inflation perception and not real rates.

3 The yield curve of interest rates

We are going to measure how forward guidance, through changing the key policy rate and publishing the projected interest path, affects Norwegian money market rates. Furthermore, we measure how policy decisions followed by press conferences may influence three different components of the yield curve - level, slope and curvature, as introduced by Nelson-Siegel and further developed by Svensson among others. [7] Therefore, we present relevant theories related to the yield curve of interest rates in the subsequent paragraphs. In addition, we present a theory in subsection 3.2 applied to construct our measure of a key policy rate surprise.

3.1 The Expectations Hypothesis (EH)

One of the most applied theories used to describe the term structure of interest rates, or the shape of the yield curve, is the expectations hypothesis (Fisher, 2001). According to the expectation hypothesis, from now on referred to as EH, the prices of long-term bonds depends on expectations of future short-term interest rates, which are extracted from forecasts of the outlook of the economy. Whereas the long-term interest rates are determined without any direct control by the central bank, they depend on the current short-term interest rate, which is determined by the central bank. Thus, the lower the short-term interest rate is, the lower the long-term interest rate must be. These assumptions are fundamental in the EH, other fundamental elements are that a no- arbitrage condition must hold and that investors are risk neutral (Bodie, Marcus, & Kane, 2014).

Summarized, the EH specify that interest rates with different maturities vary due to changes in the future short-term interest rates, which are determined by the market based on macroeconomic expectations. In accordance with the prediction of the

[7] Diebold and Li (2006) use variations of the Nelson-Siegel exponential components framework to model the whole yield curve. They show that three time-varying parameters may be interpreted as factors corresponding to level, slope and curvature.

theory, one can know what investors are expecting the future interest rate to be, by solely looking at the present period's yield curve. Hence, the EH can be used to explain why bonds with different time to maturity may have various yields, as the current yields reflects investors beliefs in regards of future interest rates. In general, the hypothesis can be expressed as follows:

$$(1 + r_{n-1})^{n-1} \; x \; (1 + E({}_{n-1}r_n)) = (1 + r_n)^n$$

$$\rightarrow \; (1 + E({}_{n-1}r_n)) = \frac{(1+r_n)^n}{(1+r_{n-1})^{n-1}} \tag{1}$$

Thus, one can see that the present interest rate, denoted as r_n , depends on the previous period's interest rate, r_{n-1}, multiplied with the previous period's *expected* interest rate for the present period, denoted as $E({}_{n-1}r_n)$. Further, one can apply the following, commonly used relationship in finance where one derives the forward rate from today's spot rates from the yield curve:

$${}_{n-1}f_n = E({}_{n-1}r_n) \tag{2}$$

According to the above relationship, the higher the expected future spot rate is, the higher the forward rate will be. In addition, one notices the close relation between the predictions of the expectations theory and the forward interest rate, since the forward rate is derived from the present spot rate.

Unfortunately, a majority of the literature regarding the EH have struggled in finding evidence supporting the validity of the hypothesis, as it has been rejected several times in empirical studies. Studies performed by, among others, Roll (1970), Fama and Bliss (1987), Campbell and Shiller (1991), Bekaert, Hodrick and Marshall (1997) and Sarno, Thorton and Valente (2007) have all found evidence in disfavor of the theory. However, Longstaff (2000) and the extended work done by Della Corte et al. (2008), have found favorable evidence of support by using a different approach in their studies and testing at the extreme short end of the yield curve.

3.2 Covered Interest Rate Parity (CIP)

When finding a proxy for a one-month Norwegian interest rate we apply the covered interest rate parity to construct a one-month synthetic interest rate. Covered interest parity is a theoretical condition where the relationship between interest rates and the spot and forward currency values of different countries are in equilibrium. The formula is:

$$1 + r_t^d = \left(\frac{1+r_t^f}{F_t}\right) S_t \qquad (3)$$

where r_t^d denotes the domestic interest rate and r_t^f denotes the foreign interest rate. S_t denotes the spot foreign exchange rate and F_t denotes the forward foreign exchange rate.

Following is the intuition behind the covered interest rate parity. An investor with one NOK today would own (1+r_t^d) NOK *t* years from now by investing in the domestic market. Alternatively, the investor may exchange one NOK for S_t units of foreign currency and invest abroad, giving the investor a return of (1+r_t^f) S_t units of foreign currency *t* years from now. In order to recieve the return in NOK, the investor would enter a forward contract that would be signed today. The cost and profit of both strategies are known and as such should be equal to prevent any arbitrage, hence the covered parity condition is a simple no-arbitrage condition.

Worth mentioning, the covered interest rate parity has recieved critizism as there are literature pointing to the covered interest parity's failure to hold, and thus there exist arbitrage opportunites. Many of these opportunities can be explained by credit risk or transaction costs, which is common in the market and results in Equation 3 being violated.

3.3 The Nelson-Siegel Model

Milton Friedman acknowledged the need for a parsimonious model of the yield curve when he stated: "*Students of statistical demand functions might find it more productive to examine how the whole term structure of yields can be described more compactly by a few parameters*." (Friedman, 1977)

Over the last decades, researches of the yield curve have proposed various attributions in explaining its relation to yield/maturity data, as well as fitting parametric models to yield curves. Nelson and Siegel introduced a well-known contribution to the field in 1987, often referred to as the Nelson-Sigel model (1987). By using a less parameterized model in explaining the most common shapes of yield curves, namely the monotonic, S shaped, and humped, the authors find the model to explain 96% of the variation in bill yields across various maturities during the period 1981 – 1983. Thus, the parsimonious model proves to capture meaningful attributes to the relation between yield and maturity, and the model will be presented in the following.

The authors ended up with the following simple model in describing the different, albeit common, shapes of the yield curve:

$$r(m) = \beta_0 + \beta_1 e^{(-\frac{m}{t})} + \beta_2 \left[\left(-\frac{m}{t} \right) e^{-(\frac{m}{t})} \right] \tag{4}$$

Here, $r(m)$ denotes the instantenous forward rate at maturity m. The three betas are determined by intial conditions, while t is a time constant associated with the equation. Equation 4, from now on referred to as the N-S model, may also be viewed as a constant plus a Laguerre function, where the latter term consists of a polynomial multiplied with an exponential decay term. One can interpret the coefficients of the model as measuring the strengths of the short-, medium-, and long-term components of the forward rate curve, and thus also the yield curve, to demonstrate the shape flexibility of the second-order model. Furthermore, by modelling the components of the forward rate curve in a figure, the N-S model show that these assignments are suitable.

Figure 1: The Nelson-Siegel model

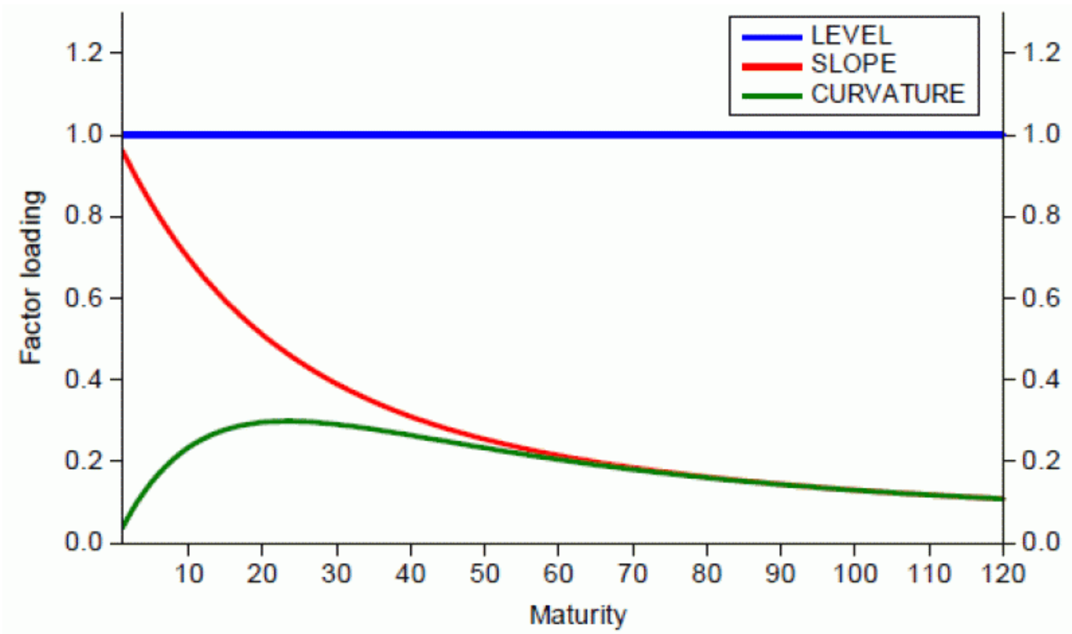

Figure 1: This figure shows the different components of the yield curve. Specifically, the level factor is indicated by β_0, while β_1 corresponds to the slope factor and β_2 illustrates the curvature of the yield curve.[8]

The long-term component's contribution is indicated by β_0 is a constant that, in limit, does not decay to zero. The contribution of the medium-term component is β_2 and is the sole function to start out at zero (and is thus not short-term) and decays to zero (and is thus not long-term). Nonetheless, the fastest decay of all functions within the

[8] The figure is extracted from the following page: https://goo.gl/images/LkpWC9.

model that decay monotonically to zero, is the short-term curve, which component is β_1.

Furthermore, in their parsimonious model, Nelson and Siegel define the average yield to maturity on a bill, denoted *R(m)*, as the average of the forward rates

$$R(m) = \frac{1}{m}\int_0^m r(x)d(x) \tag{5}$$

where the yield curve implied by the model present the same range of shapes as Equation 4. Apparently, the initial equation suggested by Nelson and Siegel proved to be over-parameterized by having unequal values of the time constants. Lastly, to obtain yield as a function of maturity for the equal roots one can write the N-S model as

$$R(m) = \beta_0 + \ (\beta_1 + \ \beta_2) \cdot \frac{\left[1-e^{-\left(\frac{m}{t}\right)}\right]}{\frac{m}{t}} - \ \beta_2 \cdot \ e^{-\left(\frac{m}{t}\right)} \tag{6}$$

where the resulting function is linear in coefficients given τ.

3.4 The Nelson-Siegel-Svensson Model (NSS)

In 1994, Lars Svensson proposed an extended version of the N-S model. The so-called Nelson-Siegel-Svensson model, from now on referred to as NSS, is widely used among central banks and professionals. The main difference between the original model and NSS is an additional term added in the latter, which is included to increase flexibility in the model, by enabling the model to have two extrema.

More specifically, Svensson extends N-S's function to increase flexibility and improve the fit by adding a fourth term, $\beta_3 \frac{m}{\tau_2} e^{-(\frac{m}{\tau_2})}$, which is a second hump-shape (U-shape if β_3 is negative). By adding two more parameters to the model, β_3 and τ_2, the function is written

$$f(m;b) = \beta_0 + \beta_1 e^{-(\frac{m}{\tau_1})} + \beta_2 \frac{m}{\tau_1} e^{-(\frac{m}{\tau_1})} + \beta_3 \frac{m}{\tau_2} e^{-(\frac{m}{\tau_2})} \tag{7}$$

where b = ($\beta_0, \beta_1, \beta_2, \beta_3, \tau_1, \tau_2$) is a vector of parameters. Also, β_0, τ_1 and τ_2 must be positive. In contrast to the original N-S model, the extended function allows up to two hump- or U-shapes. Thus, the model may have two extrema. As argued by Svensson, the N-S model usually fit well. However, when it does not, NSS improves the fit considerably.

Worth mentioning is that Svensson believe that forward rates contain the same information as the standard yield curve. Moreover, he states that forward rates present the information in a fashion that is easier to interpret for monetary policy purposes. He further states that forward rates are superior to the spot rate curve when it comes to separation of expectations for the short-, medium- and long-term. We are going to study this more closely.[9]

3.5 Macro-Finance Theory – The Relationship with Latent Factors

Ang and Piazzessi (2003), among other scholars such as Diebold and Li (2006) and Rudenbusch and Wu (2008), have examined the latent factors in the yield curve, which is also represented in the Nelson-Siegel-Svensson yield curve. The consensus is that the slope factor predicts the real economic activity and inflation, while the

[9] See section 4.4 for approach and section 6 for results.

level factor represents the long-run inflation expectations, which is the perceived inflation target of the central bank. However, there seems to be no clear interpretation of the curvature factor.

Diebold and Li (2006) finds that an increase in the slope factor is immediately followed by an almost one-to-one increase in the funds rate, meaning that there is a close connection between the instrument of monetary policy and the slope factor. They contribute two possible explanations to this, the first being that the Fed may be reacting to yields in the setting of the funds rate, which are measured in the beginning of the month. The second explanation is that given the institutional frictions of monetary policy decision making, in other words the 6-week spacing between policy meetings and the requirement of committee approval, it is more likely that the yields are reacting to the macroeconomic information in anticipation of the Fed actions. Hence, if the Fed has a transparent monetary policy regarding macroeconomic information then the movements in the bond market may often appear to predate the actions of the central bank. Further, Rudebusch and Wu (2008) among others find the level factor to be closely connected to the inflation expectations and accordingly, a shock in the level factor can be interpreted as an underlying shock to inflation.

4 Methodology

In the following, two different factors will be described in detail; both of which capture the effects of monetary policy shocks on interest rate instruments. Moreover, our methods to identify these shocks to monetary policy follow the methodology first presented by Gürkaynak et al. (2005b), from now on referred to as GSS. In addition, we apply the Nelson-Siegel-Svensson theory to investigate the relationship between the central bank communicating *explicitly* changes in inflation and monetary policy rate and the following effects on the structure of the yield curve, i.e. the slope, curvature and level.

4.1 High-Frequency Data: Daily versus Intraday

All methods used in our research rely on using high-frequency data around announcements, which led us to a discussion early in our thesis work regarding the use of daily data and the possible issues it might lead to.[10] GSS argue the use of intraday data to be superior as it removes potential simultaneity problems or troubles with omitted variables. Moreover, they argue one usually cannot use monthly or quarterly data, as this would lead to simultaneous equations and omitted variables bias. If either of the former mentioned cases where to happen, the classical regression assumption that ε_t is orthogonal to Δx_t is violated. Thus, one should preferably use higher-frequency data like intraday or daily data.

Rudebusch (1998), and Bernanke and Kuttner (2004), discuss that simultaneity is still a potential issue when using daily data concerning Federal Open Market Committee’s (FOMC) announcements. Moreover, they argue intraday data to be superior in terms of measuring the effectiveness of monetary policy actions and statements on asset prices. The reasoning behind their claim is, since one can be more certain about capturing solely the response without noise from other economic events that may

[10] See section 7 for further details.

have interfered and thus affected the interest rate (there is less likely that other influencing economic news was released exactly during that interval compared to a whole day). Unfortunately, we were unable to acquire the relevant intra-day data and therefore had to rely on daily, last price data. As such, our estimations and results will be affected by effects other then what we wanted to capture, such as other macroeconomic news influencing the interest rates in the market. It is also highly likely that any shocks will be softened as the market has a whole day to readjust from the initial shock. Thus, we will be unable to capture the markets immediate response. On the other hand, having daily data protects our results from the possible overreaction in the market that otherwise would have been captured by a small estimation window.

As opposed to GSS, Brubakk et al. (2017) used a 15-minute interval for measuring the monetary policy surprise using a one-dimensional regression, as well as using both the short interval and daily data for the remainder of their analysis. The latter method was supported by performing robustness checks. Further, they state these findings to be qualitatively similar. When analyzing the effects of the central bank's press conference, Brubakk et al. (2017) increase the event window from 15 minutes to a day. Reasoning behind their choice is due to the fact that most of the forward guidance will follow from the press conference, and not solely from providing the projected interest rate path. As the press conferences last more than 15 minutes, a larger estimation window was necessary to capture the markets responses sufficiently.

4.1.1 A Classical Linear Regression

The first equation we are going to use when measuring unexpected changes in the monetary policy rate, the *action* made by the central bank and its effects on asset prices, is an equation frequently used within the field of study. Brubakk et al. (2017) refer to it as a "monetary policy shock" defined as follows

$$\Delta y_t = \alpha + \beta \Delta MPS_t + \varepsilon_t \tag{8}$$

where Δy_t denotes the change in both forward rates and swap rates over an interval that brackets the monetary policy announcement. The independent variable denoted ΔMPS_t , reflects the surprise component of the change in the key interest rate target announced by the Norges Bank.[11] Lastly, ε_t denotes a stochastic error term that captures the effects of other factors that may influence the rate instrument in question.

We run ordinary least squares regressions for all the interest rate instruments over our event-window to estimate corresponding coefficients, β's. [12] We can interpret the coefficients as percentage points changes in money market rates from a one percentage point change in MPS.

4.1.2 Measure of Forward Guidance Predictability

In their working paper, Brubakk et al. (2017) propose a measure of policy predictability defined as the correlation between the two following measures $R^{MKT}_{m,\ t+n} - R^{MKT}_{m^-,\ t+n}$ and $R^{CB}_{m,\,t+n} - R^{CB}_{m^-,\,t+n}$.

Here, $R^{CB}_{m,\,t+n}$ refers to the projected average three-month money market rate in quarter $t+n$ provided by the central bank at interest meeting m (where m is a date in quarter t), while $R^{MKT}_{m,\ t+n}$ refer to the market's projected average three-month money market rate in the same period.[13] Moreover, the subscript m^- represents a point in time shortly after the previous interest rate announcement. Then, $R^{MKT}_{m,\ t+n} - R^{MKT}_{m^-,\ t+n}$ mirrors the market's revision of future expected money market rates shortly prior to the announcement, whereas $R^{CB}_{m,\,t+n} - R^{CB}_{m^-,\,t+n}$ represents the revision of the expected path, in between two following meeting, provided by the central bank. To

[11] The independent variable denoted MPS is a one-month synthetic interest rate. See section 5.1.3.
[12] Our event-window is one day; see further discussion in section 5.
[13] Here, represented by four FRA-contracts. See subsection 5.1.2.

clarify, we can define $R^{MKT}_{m,\ t+n} - R^{MKT}_{m^-,\ t+n}$ as the market revision from shortly *after* the last published interest rate path to shortly *prior* to the most currently published interest rate path. [14]

4.1.3 Factor Analysis – Target and Path

According to GSS, among others, there exists more than one shock component of monetary policy influencing asset prices and interest rate instruments. Therefore, we test for additional dimensions of monetary policy. We apply the factor-based methodology introduced in GSS. In general, we perform a factor analysis using principal components and the following equation:

$$X = F \wedge + \varepsilon \tag{9}$$

Here, we let X denote a T x n matrix, where the columns of X corresponds to changes in money market instruments, whereas the rows correspond to announcements regarding monetary policy. The matrix contains desired variables for our research, consisting of various responses in money market instruments caused by monetary policy announcements. Furthermore, matrix F is a T x k matrix with T rows and $k < n$ columns, consisting of unobserved factors, while $\wedge$ is a k x n matrix of factor loadings and ε is a T x n white noise disturbances matrix.

Based on the relations above, we want to investigate how many factors (columns of F) we need in order to describe X satisfactorily. To test for additional dimensions of Norges Bank's monetary policy that adequately account for the variation in X we use Kaisers Criterion. According to Kaiser's criterion, one should retain components having an eigenvalue equal to or above one.[15] By relying on our findings, and the

[14] These results are presented in section 6.2.
[15] An eigenvalue is the variance of the factor. In Factor analysis the first factor will account for most of the variance, the second will account for the next highest amount and so on.

results of previous studies as mentioned above, we conclude two factors being necessary in capturing the effects of monetary policy.[16]

We use principal component analysis to estimate the unobserved factors F *after* normalizing each column of X to have zero mean and unit variance. Then, using the factor based method, we are able to represent the joint variability of the correlated observed n money market instruments in matrix X, by the means of a smaller set of unobserved variables, i.e. the latent factors, which make the most important contribution to the variation in matrix X. Moving our study forward, we need to rearrange the latent factors, or principal components, F_i, such that one column of F can be associated with changes in the key interest rate, while the second can be associated with changes in forward guidance. Thus, the first column can be referred to as the "Target" factor, while the second column can be referred to as a "Path" factor, capturing all the relevant information for the future interest rate path. We rotate the factor matrix by multiplying with a rotation matrix U as follows

$$Z = FU \tag{10}$$

where U is any orthogonal $2\ x\ 2$ matrix, such that the matrix $F^* = FU$ and loadings $\wedge^* = U' \wedge$ refers to an alternative factor model that fits the data of matrix X precisely as F and U. Moreover, the latter matrix produces residuals equivalent to ε in Equation 9. [17]

It appears that the two principal components of X does not correspond to the changes in key interest rate and forward guidance as desired and mentioned above. However, by construction (after rotating), all of the variation in MPS (up to the white noise residuals ε) responds solely to changes in the first factor, and thus represent the

[16] Results are presented in section 6.3.
[17] The orthogonal transformation method is explained in detail in the appendix of GSS.

surprise component of changes in the rate decisions. Further, we interpret the second factor as changes in the projected interest rate. In other words, as Swanson (2015) states, the Path factor refers to all the *other* information in the central bank's announcements, except to solely changing the policy rate, and thereby corresponding to the *future path* of the key interest rate. Hence, one can also refer to the second factor as a "forward guidance" factor.

Before running regressions, we re-scale both factors to ease interpretation of our results. Similarly, as in GSS and Brubakk et al. (2017), we re-scale the Target factor such that it corresponds one-to-one with a percentage change in the synthetic one-month interest rate (MPS). Thus, we can interpret the estimated coefficients of the Target factor as the basis points interest rate change per one basis point change in MPS. In addition, the Path factor is calibrated such that both factors influence the fourth FRA contract in an equal magnitude. In fact, the Target and the Path factor have equal effect on the three-month money market rate effective in approximately one year. As a result, comparing the relative size of coefficients of the two factors for interest rate instruments with shorter or longer horizons than a year, are easier.

4.1.4 A Two-Dimensional Regression

In order to measure the effects of monetary policy and forward guidance, we run the following regression as presented in GSS

$$\Delta y_t = \alpha + \beta_1 Z_{1,t} + \beta_2 Z_{2,t} + \varepsilon_t \tag{11}$$

where Δy_t and ε_t represents the same as previously presented, and $Z_{1,t}$ and $Z_{2,t}$ refer to the Target and the Path factor, respectively.[18] During this stage of the research, our main objective is to investiagte how much of the variation can be explained by the

[18] See Equation 8 under section 4.1.1.

factors and how large the impact of the Path factor is compared to the Target factor for different yield maturities.[19]

4.2 A Macro-Finance Perspective

By using the NSS model presented previously, we are going to investigate the effects of changing the policy rate on the yield curves of chosen dates.[20] First, we are interested in finding out *why* the central bank chose to change the policy rate. Second, by constructing yield curves, we can investigate whether the central banks reasoning coincides with the effects observed on the yield curves. We will analyze the effects of the central bank explicitly communicating to the public their reasoning behind the change of policy rate, whether it being stabilizing the inflation level or boosting the economy in general, on the change in relevant factors from one meeting to the next. The research method applied to construct the yield curves, and by such extracting the relevant factors, is presented in Figure 2 and explained in the following.

Figure 2: NSS modeling

[19] See section 6.4 for empricial results and interpretations.
[20] The chosen dates are presented in subsection 5.2.2.

M	Yield	NSS	Residual
1	4,74 %	0,047243	2,4666E-08
2	4,75 %	0,047021	2,2946E-07
3	4,77 %	0,04789	3,6028E-08
6	4,97 %	0,051248	2,3973E-06
12	5,69 %	0,054876	4,0949E-06
18		0,056341	
24	5,76 %	0,05709	2,3569E-07
30		0,05754	
36		0,05784	
60	5,81 %	0,058441	1,3390E-07
120	5,80 %	0,058891	8,3989E-07
		Sum	7,9919E-06

β1	0,059342
β2	-0,00894
β3	-0,00336
β4	-0,01853
τ1	2,375171
τ2	1,341626

Figure 2: This figure shows how we used the NSS model to construct yield curves for each chosen interest rate meeting.

When creating yield curves for each of our chosen dates, we use Nibor, FRA, - and swap rates. More specifically, with maturities one, two, three and six-months for the Nibor rate, in combination with the fourth FRA rate, and two, five and ten-year swap rates. As Figure 2 shows, we plot a timetable ranging from one to 120 months in the first column to the left. The corresponding yields, which we have data on, are listed in the second column. Originally, we plot “0.01” for each beta in the box to the right, whereas we plot “1” for each lambda (these figures can be chosen arbitrarily and will be changed by using the Excel solver). We use the NSS formula (Equation 7) to calculate another yield curve, as shown in the third column, for each of the chosen interest variables. The formula includes our yields with corresponding maturities, as well as the betas and lambdas. Further, we calculate each residual by taking the difference between the actual yield and the created yield to the power of two. Having created the residual for all the variables, we move on to estimating the coefficients by using the solver function in Excel, with the objective of minimizing the sum of residuals on behalf of the coefficients. Finally, we have constructed the estimated coefficients for the NSS yield curve and for our whole sample, which is used for further investigation. Three of our resulting yield curves are shown in Figure 5-7 in section 6.5

5 Data

Our analysis consists of daily, last price data provided from the databases of Norges Bank, Bloomberg and Oslo Stock Exchange.

Our sample period is divided into two periods; our first sample stretches from March 2001 to June 2005 and our second sample stretches from November 2005 until the end of 2017. We use high-frequency data to study the effect of the monetary policy by Norges Bank on the yield curve. To do this we use the same approach as Brubakk et al. (2017) and GSS in order to measure the Target and Path factor, as well as their influence on several financial instruments before and after 2005.

The reasons behind the chosen start and end dates of our samples, before and after forward guidance was introduced, are the following. First, Norges Bank began inflation targeting in March 2001, whereas they previously had an exchange rate regime. Second, Norges Bank started publishing the interest path as of November 2005. However, due to the limited size and liquidity in the Norwegian government bond market we use swap rates instead of government bond yields in the analysis of long-term rates.[21] We also create a synthetic one-month interest rate instrument using the covered interest rate parity.

5.1 Norwegian Interest Rates

5.1.1 Nibor

The Norwegian Interbank Offered Rate (NIBOR) is an indicative reference rate for Norwegian money market and is an important benchmark for valuations and pricing of financial rates and derivatives in Norway.[22] Since the Nibor rate is specified as the

[21] Other data used is announced interest rate paths by Norges Bank, which appear in the monetary policy reports. Furthermore, data provided by Bloomberg are used regarding FRAs and swap rates, whereas Oslo stock exchange provided the data for Nibor after 2013.
[22] For more information visit: https://www.norges-bank.no/Publisert/Brev-og-uttalelser/2010/brev-06-10-2010-2/ .

reference rate for forward rate agreements and interest rate swaps, we can construct various yield curves based on these three instruments.[23] For the second part of the analysis, we therefore employ the Nibor rate with one, two, three and six months to maturity.

5.1.2 Norwegian Money Market Rates

We use data on forward rate agreements and swap rates. Forward rate agreements let us analyze money market rates with maturities up to one year, while we can analyze two, five, and ten year rates with the swap rates. We differentiate between four different FRA's, FRA 1 and up to FRA 4. The first reflects the expected money market rate on the first upcoming IMM-date, FRA 2 for the second IMM-date and so on. Hence, by using forward rate agreements we can decipher the expectations of market participants of the three-month money market rate on a specific date in the future. The swap rates indicate the expected average over the contract period.

5.1.3 The Monetary Policy Surprise (MPS) Instrument

Andersson and Hofmann (2009) present two different approaches to capture target surprises; either by using a survey approach, or measures based on the financial market. There are benefits and disadvantages for each method.[24] We use the latter method in combination with the covered interest rate parity (CIP) to create a one-month synthetic interest rate.

Due to the lack of an OIS or interest futures market in Norway, we cannot use a one-month OIS or futures contract to extract the unexpected changes in the policy rate. Therefore, to identify a proxy that captures the unexpected changes in the key policy rate, we will follow the working paper by Brubakk et al. (2017). We use the one-month forward USDNOK exchange rate, spot USDNOK exchange rate, and the

[23] Similar analysis method has been applied by Reppa (2008). For further details visit: https://www.mnb.hu/letoltes/op-73.pdf

[24] See Andersson & Hoffman (2009) for more details.

nominal one-month US interest rate. Thus, the CIP condition enables us to extract the one-month Norwegian interest rate that reflects expectations about the prevailing key policy rate setting. Changes in this proxy refers to the monetary policy surprise (MPS).

In the following, we present a figure illustrating the interest rate variables used (except for the policy rate that are included for comparison) and a correlation matrix of changes in the variables.

Figure 3: Interest Rate Movements

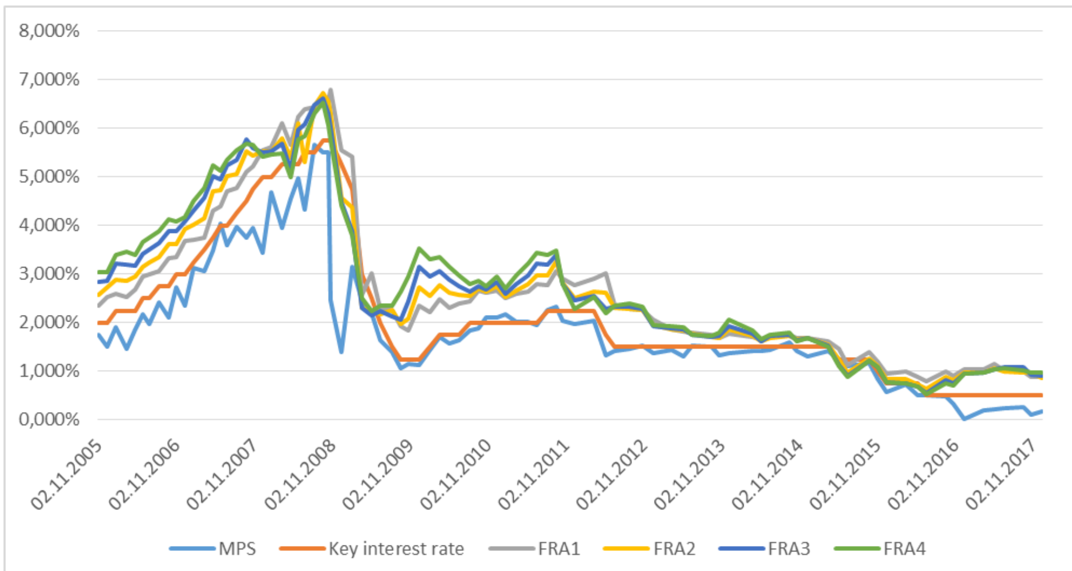

Figure 3: This figure illustrates the movements in interest rates over our sample period, which are interest rate meetings stretching from 2005-2017, resulting in 92 observations as listed in the horizontal axis.

According to Figure 3, our synthetic one-month interest rate, MPS, move more or less in line the policy rate and the FRA rates over our sample period. However, we also notice two exceptions where MPS move somewhat out of line. Especially, during the financial crisis (dates 23.04.2008-13.08.2008) we see that MPS has a descending slope, more so than the other interest rates. One reason for this deviation may be due to the US economy being affected by the financial crisis earlier than the Norwegian economy, making our synthetic interest rate more volatile during that period.

Table 1: Correlation Matrix

	MPS	FRA1	FRA2	FRA3	FRA4	yr2	yr5	yr10
MPS	1.0000							
FRA1	0.4367	1.0000						
FRA2	0.2931	0.5750	1.0000					
FRA3	0.3158	0.6421	0.5902	1.0000				
FRA4	0.2229	0.7196	0.6480	0.8746	1.0000			
yr2	0.2196	0.6900	0.5909	0.8651	0.8868	1.0000		
yr5	0.1575	0.5073	0.5080	0.7811	0.8062	0.9091	1.0000	
yr10	0.1315	0.3378	0.4097	0.6819	0.6761	0.7881	0.9344	1.0000

Table 1: This table presents correlation coefficients for changes in the MPS-rate, FRA's and the three swap rates around the monetary policy announcements.

Table 1 shows the correlation coefficients for changes in the MPS-rate, FRA- and swap rates. We see that the correlation between the changes in MPS and the various money market rates are higher between shorter maturity rates compared to further out on the yield curve, which appear as expected. In addition, we notice that correlations between the money market rates in general are fairly high. Especially, interest rate instruments with closer maturities, e.g. 2-year and 5-year swap rates have higher correlations. The correlations coefficients indicate that surprise changes in money markets rates move in the same direction.

5.2 Descriptive Statistics

5.2.1 Forward Guidance Sample

Table 2: Descriptive Statistics

	Before 2005			After 2005		
	Mean	St.dev.	Obs.	Mean	St.dev.	Obs.
MPS				0,116 %	0,121 %	92
FRA1	0,094 %	0,099 %	36	0,050 %	0,061 %	92
FRA2	0,119 %	0,115 %	36	0,067 %	0,111 %	92
FRA3	0,132 %	0,129 %	36	0,065 %	0,088 %	92
FRA4	0,128 %	0,117 %	36	0,063 %	0,060 %	92
2 yr Swap	0,097 %	0,096 %	36	0,050 %	0,050 %	92
5 yr Swap	0,065 %	0,065 %	36	0,048 %	0,042 %	92
10 yr Swap	0,058 %	0,071 %	36	0,043 %	0,038 %	92

Table 2: This table presents descriptive statistics for our samples - the period before and after 2005.

Table 2 presents the descriptive statistics for our chosen variables. Firstly, we notice that the average mean (of absolute value) and standard deviation of the changes decrease quite drastically for all maturities from the sample period of 2001-2005 to 2005-2017. We can interpret this as forward guidance has increased the transparency in the market after the publication of the interest rate path in 2005, leading to less sizable shocks and therefore a more predictable monetary policy by market participants. However, we move our thesis further by performing a closer investigation before drawing any conclusions.

5.2.2 Sample for NSS

Our sample for constructing the various term structures is extracted from the period after the central bank began to *explicitly* communicate their monetary policy.
To investigate how the yield curve is affected by the Norges Banks policy rate decision we need to know their reason behind the decision. Hence, we chose the interest rate meetings where Norges Bank also published an interest rate path and, as a result, we ended up with a small sample – ten interest rate meetings – as listed in Table 3.

Table 3: Sample for the NSS Method

Dato	Key interest rate (in %)	Change in %
02.11.2005	2.25	Up 0.25%
16.03.2006	2.50	Up 0.25%
01.11.2006	3.25	Up 0.25%
15.03.2007	4.00	Up 0.25%
27.06.2007	4.50	Up 0.25%
17.06.2009	1.25	Down 0.25%
28.10.2009	1.50	Up 0.25%
24.03.2010	1.75	No change
16.03.2011	2.00	No change
14.03.2012	1.50	Down 0.25%

Table 3: Sample selection for our NSS model. The mid column represents the key interest rate at the current date (to the left), while "Change in %" refer to changes in the key interest rate from the last meeting to the one listed.

Clearly, our sample mainly consist of meetings where the central bank changed the policy rate, except from two meetings where it remained at its respective level.

6 Analysis and Results

In this section, we present our results along with our interpretations, both of which rely on the theory presented in section 3, the methodology explained in section 4, and the data presented in section 5.

6.1 A Classical Linear Regression

We began our analysis by running the classical ordinary least squares regression as presented in Equation 8. Using a one-dimensional test with daily data quickly became a problem as the estimation window proved to be too long. As mentioned earlier, we will be unable to gauge the markets initial response to any changes in the interest rate, which were apparent in our regression results. We found that the change in the monetary policy rate had little explanatory power for the change in our chosen instruments, especially on the long end of the yield curve. As this is in direct conflict with multiple other studies, who relied on tighter estimation windows, we account this discrepancy to the fact that we did not have access to intraday-data and had to rely on daily, last price data. Consequently, our daily data included excessive noise.[25] The regressions results are presented in Table 4.

[25] In this case, noise refers to other macroeconomic news that could have arrived during our event window which would have a direct effect on the variables we chose to examine. As the event window is broader than other similar studies noise would also include the softening of the markets reaction as they have an entire day to reevaluate the shock. Hence, the direct effect of a change in monetary policy will not be captured.

Table 4: A Classical Linear Regression - Results

	Const	MPS	adj. R2
FRA 1	0.0051343	0.2062044**	0.19
	[0.0068076]	[0.0813285]	
FRA 2	0.0192055	0.2271407**	0.09
	[0.0135132]	[0.1110022]	
FRA 3	0.0162676	0.2066897*	0.10
	[0.0114066]	[0.1063863]	
FRA 4	0.0158122	0.1151223	0.05
	[0.0087339]	[0.0828644]	
2yr Swap	0.0119169	0.0922665	0.05
	[0.0070208]	[0.0682305]	
5yr Swap	0.0112279	0.0593781	0.03
	[0.0065632]	[0.0537057]	
10yr Swap	0.0099513	0.0444683	0.02
	[0.0060809]	[0.0447819]	

*Table 4: This table presents the regression results from Equation 8 presented in section 4.1.1. *, **, *** denote significance at 10%. 5% and 1%, respectively. Heteroscedastic standard errors are given in brackets.*

One can interpret the coefficients in Table 4 as percentage points changes in market rates from a one-percentage point surprise change in the policy rate. As evident from our results, MPS only have significant, and thus economically meaningful, effects on the three first FRA rates. Hence, it appears that a surprise change in the policy rate have impact on market rates with maturity approximately nine months out on the yield curve. However, considering the arguments mentioned above and our regressions results, we choose to focus on tests where daily data is more applicable and move on with our investigation.

6.2 Forward Guidance Predictability

Before presenting our results from our two-dimensional regressions, we show our results from the discussion of forward guidance predictability presented in subsection 4.1.2. One indication of transparency in monetary policy is the correlation between path revisions of the central bank and revisions of market expectations, as presented in Table 5.

Table 5: Correlation Between Rate Revisions

Q1	Q2	Q3	Q4
0,73	0,66	0,48	0,46

Table 5: This table presents the correspondence between the central bank interest rate path revisions and market revisions up until the day before the new path is published.

The correlations between the market and Norges Bank's revision of the implied short-term rate is 0.73 one quarter out and 0.46 four quarters out, which is high. In short, this indicate that market participants understand the reaction pattern of the central bank reasonably well.

6.3 Estimation of two Latent Factors – Target and Path

Using the factor based methodology presented in GSS, we constructed a matrix X that has dimensions 92 x 8, where the rows correspond to the 92 interest rate meetings and columns refer to eight asset prices of interest. More specifically, we have

$$X = [MPS, FRA1, FRA2, FRA3, FRA4, 2yr\ swap, 5yr\ swap, 10yr\ swap]$$

Our variables illustrate the whole yield curve. Specifically, MPS and the FRAs provide estimates for the short-term market expectation, while the 2-year swap rate provide information regarding the medium to long-term. Lastly, market expectations about the key policy rate for a longer horizon are represented by the 5-, and 10-year swap rates.

In Equation 9, matrix F contains the unobserved factors with dimensions $92\ x\ 2$, whereas $\wedge$ include its correspondent loadings on asset price responses, with dimensions of $2\ x\ 8$. Moreover, the white noise residuals, matrix ε, has dimensions $92\ x\ 8$.

Using the methodology explained in subsection 4.2, we run a factor analysis using principal components in Stata. In line with GSS, we test the null hypothesis of one dimension against the alternative of additional dimension(s) needed to adequately explain monetary policy surprises, or changes in X. More precisely, we test

$$H_0\colon X\ is\ described\ by\ k_0\ common\ factors$$

versus

$$H_1\colon X\ is\ described\ by\ k > k_0\ common\ factors$$

The results are reported in Table 6.

Table 6: Factor Analysis Using Principal-Components Factors

	Eigenvalue	Difference	Porportion	Cumulative
Factor 1	5.28036	4.11475	0.6600	0.6600
Factor 2	1.16561	0.51716	0.1457	0.8057
Factor 3	0.64845	0.19831	0.0811	0.8868
Factor 4	0.45014	0.20419	0.0563	0.9431
Factor 5	0.24594	0.14655	0.0307	0.9738
Factor 6	0.09939	0.01884	0.0124	0.9862
Factor 7	0.08056	0.05100	0.0101	0.9963
Factor 8	0.02956		0.0037	1.0000

Table 6: This table presents all eight factors corresponding eigenvalues, and the difference between them. In addition, the variance is presented in the fourth column, whereas the fifth lists the cumulative variance.

Evidently, Table 6 shows that there are two factors with an eigenvalue above one. Further, we run a "screeplot" command in Stata to visualize our findings, see Figure 4. Doing so allows us to gauge and determine the appropriate number of unobserved factors that are required to sufficiently explain the variation in X. Hence, following the Kaiser criterion we find the appropriate number to be two, as these two unobserved factors explain up to 81% of all the variation in X and still maintain an eigenvalue above one.

Figure 4: Scree Plot of Eigenvalues

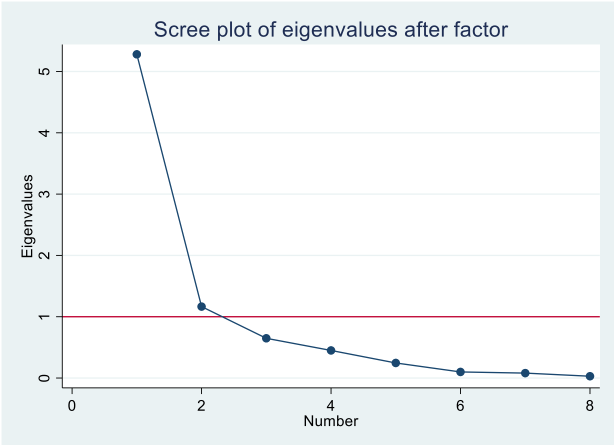

Figure 4: This figure illustrates the eigenvalues of the factors.

Table 7: (Unrotated) Factor Loadings and Unique Variances

Variable	Factor1	Factor2	Uniqueness
z1MPS		**0.7735**	**0.2804**
z2FRA1	**0.7501**		**0.2452**
z3FRA2	**0.7088**		**0.4260**
z4FRA3	**0.9140**		**0.1647**
z5FRA4	**0.9345**		**0.1260**
z6yr2	**0.9559**		**0.0684**
z7yr5	**0.9074**		**0.0685**
z8yr10	**0.8051**		**0.1748**

Table 7: This table shows the unrotated factor loadings. Clearly, factor 2 represent the Target factor as it loads heavily on MPS, while factor 1 refers to the Path factor as it loads on the other variables.

Moving forward with our analysis, we extract f_1 and f_2 and their loadings. By rotating orthogonally as explained in section 4.1.3, we use these factors to run a two-dimensional regression. [26] More specifically, we run Equation 11 with all the interest rate instruments and present our results in the subsequent section.

[26] Comprehensive, technical, details regarding the factor rotation is presented in the appendix of GSS. Also, Swanson (2015) provides a thoroughly explanation of the procedure.

6.4 Two-Dimensional Regression Results

In the following, we will present our two-dimensional regression results from the regression (Equation 11) presented in subsection 4.1.4.

Table 8: Two-Dimensional Regression Results

	Const	TarFact	adj. R2
FRA 1	0.0014891	0.3982062***	0.51
	[0.0057712]	[0.0645322]	
FRA 2	0.0151902	0.496114***	0.30
	[0.0113783]	[0.1595845]	
FRA 3	0.0126141	0.3012248***	0.15
	[0.0105364]	[0.0683833]	
FRA 4	0.0137772	0.2264931***	0.14
	[0.0083827]	[0.0576483]	
2yr Swap	0.0102859	0.1411386***	0.08
	[0.0070425]	[0.0499824]	
5yr Swap	0.0101783	0.0388971	0.008
	[0.0065669]	[0.0421328]	
10yr Swap	0.0091652	(0.0156594)	0.002
	[0.0059091]	[0.0351518]	

*Table 8: This table presents diagnostics for the Target factor. *, **, *** denote significance at 10%. 5% and 1%, respectively. Heteroscedastic standard errors are given in brackets. Negative coefficients are given in parentheses.*

Table 9: Two-Dimensional Regression Results

	Const	TarFact	PathFact	adj. R2
FRA 1	0.0014891	0.3982062***	0.1190863***	0.76
	[0.0041123]	[0.0490083]	[0.0290731]	
FRA 2	0.0151902*	0.496114***	0.2093298***	0.57
	[0.008894]	[0.1475084]	[0.0222016]	
FRA 3	0.0126141***	0.3012248***	0.2765647***	0.84
	[0.0046703]	[0.0358697]	[0.0462378]	
FRA 4	0.0137772***	0.2264931***	0.2264931***	0.87
	[0.003224]	[0.0279334]	[0.0120364]	
2yr Swap	0.0102859***	0.1411386***	0.1981323***	0.93
	[0.0019317]	[0.0211655]	[0.0064949]	
5yr Swap	0.0101783***	0.0388971***	0.1852849***	0.93
	[0.0017353]	[0.0142321]	[0.0088377]	
10yr Swap	0.0091652***	(0.0156594)	0.1569463***	0.83
	[0.0024862]	[0.0191592]	[0.0123762]	

*Table 9: This table presents diagnostics for the Target and Path factor. *, **, *** denote significance at 10%. 5% and 1%, respectively. Heteroscedastic standard errors are given in brackets. Negative coefficients are given in parentheses.*

Table 8 shows our regression results when including only the Target factor, whereas we have included both factors in the results summarized in Table 9. At first glance, we see that the Target factor significantly affects almost all of the interest rate instruments, with exceptions at the very long end of the yield curve. In addition, there seems to be an indication that the effect of the Target factor is diminishing over the sample period. Changes in the short-term interest rate will have a greater effect on short-term maturities, while less on longer-term maturities that are more influenced by market expectations. Further, we see that the results show that the two chosen factors can account for almost all the variation in these variables, especially regarding the FRA rates. We notice that both the Target and the Path factor have a significant effect on all the variables, excluding the 10-year swap, indicating that these two factors are sufficient to explain most of the variation in the data. In other words, this confirms the results from the Keiser's criterion test.

Furthermore, since the factors are uncorrelated by construction, adding or subtracting one factor does not change the coefficients of the other factor. However, we notice that it increases the explanatory power quite substantially, which is logical as two factors explain more of the variation in the dependent variable than only one. One interesting discovery is that the explanatory power of the two factors are quite substantial, especially at longer maturities. We also notice that this is mainly due to the inclusion of the Path factor, which may provide evidence in favor of forward guidance having an economically meaningful effect on interest rates. Conclusively, the results indicate that the central bank's communication, through press conferences and the following statements have a major influence on interest rate expectations for very long maturities.

6.5 Effects of Monetary Policy on the Term Structure – NSS

Table 10 presents a sub-sample from our full sample of constructed yield curves.[27] Here, we have included three different scenarios of monetary policy decisions, i.e. an increase, a decrease and an unchanged rate. Our sub-sample provides results as expected. For instance, an expansionary monetary policy leads to an increase in the level factor, β_0. Similarly, a tightening monetary policy lead to a decreased level factor. Overall, these findings coincide with the theory presented by Rudebusch and Wu (2008).

Table 10: NSS Estimation Results - Subsample

Date	B1	B2	B3	B4	Lambda 1	Lambda 2
27.06.2007	0,05917	-0,07221	-0,02494	-0,03291	0,05360	1,73442
15.08.2007	0,05676	-0,00671	-0,00139	-0,00698	1,42310	1,22450
Δ	*0,00241*	*-0,06550*	*-0,02355*	*-0,02594*	*-1,36950*	*0,50991*
28.10.2009	0,05091	-0,03513	0,00574	-0,02645	7,10033	13,90161
16.12.2009	0,05030	-0,03404	0,00792	-0,03145	6,62388	12,00382
Δ	*0,00061*	*-0,00110*	*-0,00217*	*0,00500*	*0,47645*	*1,89778*
14.03.2012	0,03274	-0,01126	-0,00143	-0,00820	1,56552	0,89365
10.05.2012	0,03195	-0,01301	-0,00149	-0,00961	1,84939	0,92658
Δ	*0,00079*	*0,00174*	*0,00006*	*0,00141*	*-0,28388*	*-0,03293*
15.03.2007	0,05676	-0,00671	-0,00139	-0,00698	1,42310	1,22450
25.04.2007	0,05401	-0,00959	-0,00081	-0,01211	1,59927	1,92720
Δ	*0,00274*	*0,00288*	*-0,00058*	*0,00513*	*-0,17617*	*-0,70269*
02.11.2005	0,04408	-0,07573	-0,03824	-0,05656	0,12179	3,51768
14.12.2005	0,04314	-0,07470	-0,03700	-0,05074	0,10918	3,05755
Δ	*0,00094*	*-0,00103*	*-0,00124*	*-0,00582*	*0,01260*	*0,46012*

Table 10: This table shows the estimated coefficients of the NSS variables on chosen dates. The difference between the variables from the date of the interest rate meeting where Norges Bank published an interest rate path and the consecutive interest rate meeting is given in cursive.

[27] Table A.1 in the appendix summarizes the central bank's main reasoning behind each rate decision of our sample.

However, when we created the yield curves for the interest rate meeting where there was no change in the rate decision, we still notice that the variables have changed. This indicates that there may be several other factors influencing the yield curve. Most likely, time is a governing reason as there is almost one and a half month between these two interest rate meetings the outlook of the economy is bound to change, if only by a fraction. In addition, we acknowledge that it may be difficult to give any clear interpretations of a change in the level factor as it is long-term. The change in the slope, β_1, is interesting as the monetary policy was unchanged. As one can see, the expectations regarding the short-term interest rate also remained unaffected.

In Figure 5-7, we present six different constructed yield curves from our NSS sample. In each figure, we compare yield curves from a date where the central bank has published an interest rate path with the following interest rate meeting. When comparing the constructed yield curves, we observe that there are only minor differences, except for the two dates 01.11.2006 and 13.12.2006. We find this surprising as Norges Bank continuously express their intention of enforcing smooth transitions when publishing their interest rate forecasts.

Figure 5: Yield Curve for 17.06.2009 – 12.08.2009

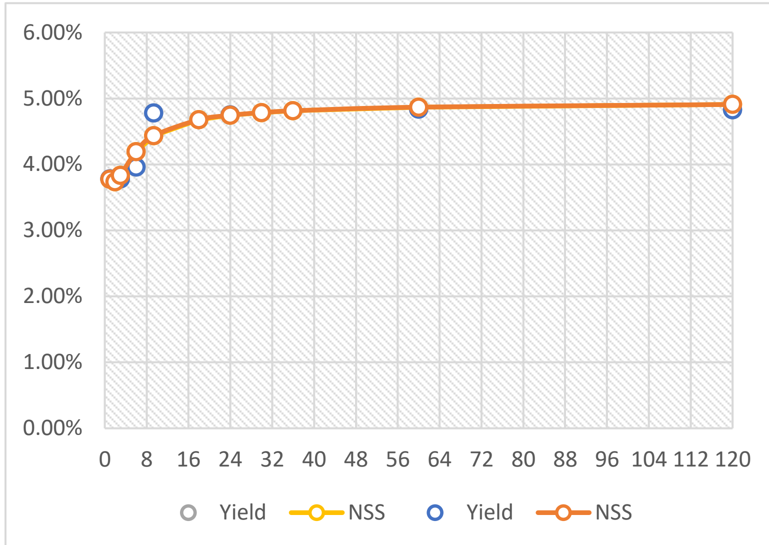

Figure 5 shows constructed yield curves between interest rate meetings. The horizontal axis present maturities in months, while the vertical axis show the interest rates.

Figure 6: Yield Curve for 01.11.2006 – 13.12.2006

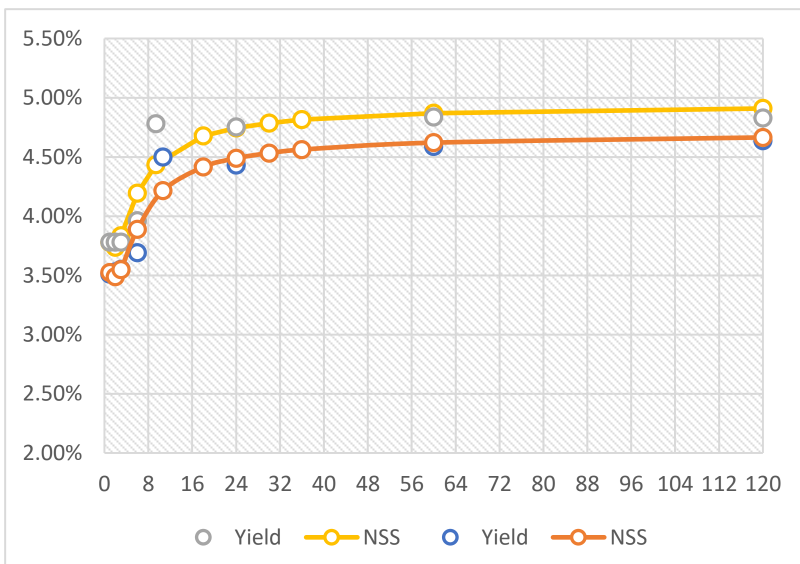

Figure 6 shows constructed yield curves between interest rate meetings. The horizontal axis present maturities in months, while the vertical axis show the interest rates.

Figure 7: Yield Curve for 24.03.2010 – 05.05.2010

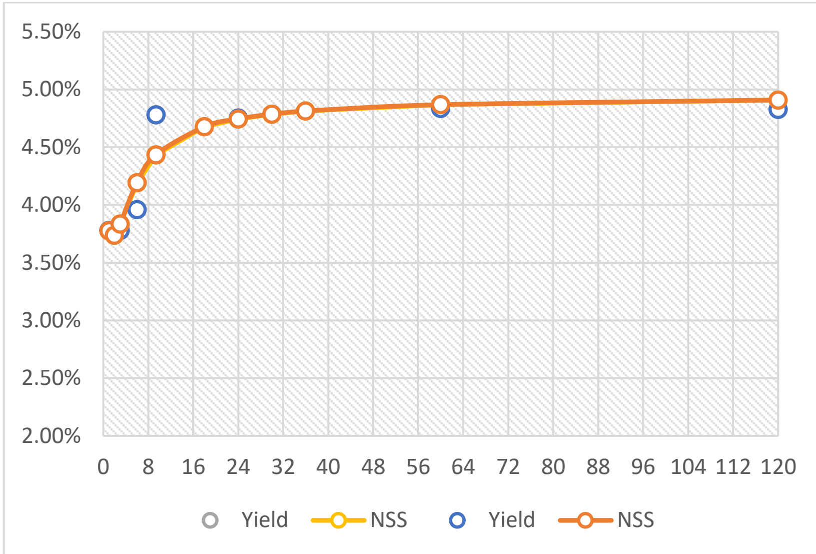

Figure 7 shows constructed yield curves between interest rate meetings. The horizontal axis present maturities in months, while the vertical axis show the interest rates.

Table 11 presents our estimated coefficients from the full sample.

Table 11: NSS Estimation Results – Full Sample

Date	Beta 1	Beta 2	Beta 3	Beta 4	Lambda 1	Lambda 2	Change in %
02.11.2005	0.04247	-0.09870	-0.02776	-0.04921	0.08005	2.21937	Up 0.25%
14.12.2005	0.04184	-0.08958	-0.02704	-0.04638	0.07056	1.83292	
Δ	*0.00063*	*-0.00912*	*-0.00072*	*-0.00284*	*0.00949*	*0.38645*	
16.03.2006	0.04256	-0.08726	-0.02674	-0.04431	0.06831	2.12401	Up 0.25%
26.04.2006	0.04553	-0.09409	-0.02737	-0.05069	0.07530	2.10492	
Δ	-0.00296	0.00683	0.00063	0.00638	-0.00699	0.01909	
01.11.2006	0.04709	-0.07370	-0.02843	-0.03483	0.03942	1.40095	Up 0.25%
13.12.2006	0.04950	-0.00729	-0.00183	-0.02278	2.33349	1.21815	
Δ	-0.00241	-0.06641	-0.02660	-0.01205	-2.29407	0.18280	
15.03.2007	0.05147	-0.00853	-0.00279	-0.00773	1.58474	1.02278	Up 0.25%
25.04.2007	0.05401	-0.00959	-0.00081	-0.01211	1.59927	1.92720	
Δ	*-0.00254*	*0.00106*	*-0.00198*	*0.00438*	*-0.01453*	*-0.90442*	
27.06.2007	0.05934	-0.00894	-0.00336	-0.01853	2.37517	1.34163	Up 0.25%
15.08.2007	0.05703	-0.00812	-0.00125	-0.00395	1.56304	1.08812	
Δ	*0.00231*	*-0.00082*	*-0.00211*	*-0.01458*	*0.81213*	*0.25351*	
17.06.2009	0.05508	-0.03599	-0.03228	-0.07229	1.65962	11.84531	Down 0.25%
12.08.2009	0.05487	-0.03666	-0.04588	-0.04715	2.11653	13.87039	
Δ	*0.00021*	*0.00067*	*0.01359*	*-0.02513*	*-0.45691*	*-2.02508*	

28.10.2009	0.05315	-0.03896	-0.00008	-0.03234	5.17561	19.40035	Up 0.25%
16.12.2009	0.05340	-0.03939	-0.00008	-0.03782	4.52956	18.97361	
Δ	*-0.00025*	*0.00044*	*0.00000*	*0.00548*	*0.64605*	*0.42674*	
24.03.2010	0.05037	-0.03044	-0.02595	-0.04696	1.90895	13.40379	No change
05.05.2010	0.04858	-0.03044	-0.00008	-0.04310	3.93573	14.67953	
Δ	0.00179	0.00000	-0.02587	-0.00387	-2.02678	-1.27574	
16.03.2011	0.05051	-0.02944	-0.00008	-0.02963	4.83090	17.13195	No change
12.05.2011	0.04861	-0.02576	-0.00008	-0.02349	5.46628	17.94381	
Δ	0.00190	-0.00368	0.00000	-0.00614	-0.63538	-0.81185	
14.03.2012	0.03708	-0.06025	-0.02509	-0.03589	0.16544	7.05549	Down 0.25%
10.05.2012	0.03774	-0.02269	-0.01033	-0.03307	1.13432	10.87942	
Δ	*-0.00066*	*-0.03756*	*-0.01476*	*-0.00282*	*-0.96888*	*-3.82393*	

Table 11: This table presents our estimated coefficient of the full sample of our NSS Model.

Our full sample provide results coinciding with theory, albeit finding two conflicting results. Obviously, due to only having ten observations we cannot conclude anything based on our estimates. However, it may provide insight in how monetary policy relate to the term structure of interest rates. In the following section we explain possible reasons to these deviations.

7 Shortcomings

7.1 Daily Data Limitations

During our research, the importance of using intraday data when studying the effect of forward guidance became eminently clear. Obviously, if we were to take a more in-depth study within forward guidance and its effects, it would not be satisfactory to use solely daily data. Originally, we wanted to base our study on intraday data and have a sample period that separated the press conference from the following publication of the monetary policy report, in order to limit noise to the minimum. Lastly, we acknowledged the fact that if we were to search for more specific answers regarding forward guidance and its effects, intraday data would be crucial to reach any solid conclusions.

Nevertheless, our data sample proved to be sufficient for our research objective as we were able to interpret that there was in fact a significant effect, and we were able to move our study further.

7.2 NSS Limitations

Forward guidance is relatively new in modern economies, which is evident in the few interest rate meetings where publications of the future path of policy rate have been revealed in Norway. Consequently, this leaves us with a short sample and as such cast doubt over our results. Ideally, we would work with thousands of observations to increase our estimation precision, and thereby make conclusions supported by empirical evidence.

8 Concluding Remarks

In this paper, we investigate the effectiveness of forward guidance by using the methodology first presented by Gürkaynak, Sack, and Swanson (2005b). We use Norwegian money market rates as well as Nibor to extract market expectations. By examining the correlations between changes in the interest rate instruments, we find evidence that the market seems to anticipate the rate decision reasonably well. Furthermore, we reject the null hypothesis that one common factor is sufficient to explain changes in monetary policy surprises and find that two factors are necessary. Despite being limited by daily data, we find significant results that Norges Bank influences market expectations. However, we notice the importance of using intra-day data when studying this in greater depth.

By using the NSS approach, we highlight the relationship between macro variables and the term structure of interest rates. A popular belief among scholars is that inflation is closely related to long-term interest rates, while monetary policy influences the short-term interest rates. By constructing yield curves, we study these relations closely. Our findings seem to coincide with common beliefs and these factors influence the yield curve as anticipated. However, there were some deviations, which we believe to have been caused by the limited sample we used. Consequently, this makes us unable to draw any conclusions supported by sufficient evidence.

Appendix

Table A.1:

Date	Central Bank's Reason
02.11.2005	Keeping the inflation from increasing
14.12.2005	
16.03.2006	Adjust the inflation towards the desired target
26.04.2006	
01.11.2006	Expecting increased inflation
13.12.2006	
15.03.2007	Aiming at the inflation target
25.04.2007	
27.06.2007	Keep inflation at a minimun
15.08.2007	
17.06.2009	Trying to boost national economy
12.08.2009	
28.10.2009	Preventing the inflation from increasing further
16.12.2009	
24.03.2010	Estimate that this is the desired rate at this time
05.05.2010	

16.03.2011	Estimate that this is the desired rate at this time
12.05.2011	
14.03.2012	Keeping the inflation at a desirable level
10.05.2012	

Table A.1: The main reason behind interest rate decisions.

Table A.2

Dato	Key interest rate (in %)
28-01-99	7.50
03-03-99	7.00
26-04-99	6.50
17-06-99	6.00
23-09-99	5.50
13-04-00	5.75
15-06-00	6.25
10-08-00	6.75
21-09-00	7.00
10-01-01	7.00
21-02-01	7.00
04-04-01	7.00
16-05-01	7.00
20-06-01	7.00
08-08-01	7.00
19-09-01	7.00
31-10-01	7.00

12-12-01	6.50
23-01-02	6.50
27-02-02	6.50
10-04-02	6.50
22-05-02	6.50
03-07-02	7.00
07-08-02	7.00
18-09-02	7.00
30-10-02	7.00
11-12-02	6.50
22-01-03	6.00
05-03-03	5.50
30-04-03	5.00
25-06-03	4.00
13-08-03	3.00
17-09-03	2.50
29-10-03	2.50
17-12-03	2.25
28-01-04	2.00
11-03-04	1.75
21-04-04	1.75
26-05-04	1.75
01-07-04	1.75
11-08-04	1.75
22-09-04	1.75
03-11-04	1.75
15-12-04	1.75
02-02-05	1.75
16-03-05	1.75

20-04-05	1.75
25-05-05	1.75
30-06-05	2.00

Table A.2: List of interest meetings before forward guidance was introduced.

Table A.3:

Dato	Key interest rate (in %)
02-11-05	2.25
14-12-05	2.25
25-01-06	2.25
16-03-06	2.50
26-04-06	2.50
31-05-06	2.75
29-06-06	2.75
16-08-06	3.00
27-09-06	3.00
01-11-06	3.25
13-12-06	3.50
24-01-07	3.75
15-03-07	4.00
25-04-07	4.00
30-05-07	4.25
27-06-07	4.50
15-08-07	4.75
26-09-07	5.00
31-10-07	5.00
12-12-07	5.25

23-01-08	5.25
13-03-08	5.25
23-04-08	5.50
28-05-08	5.50
25-06-08	5.75
13-08-08	5.75
24-09-08	5.75
15-10-08	5.25
29-10-08	4.75
17-12-08	3.00
04-02-09	2.50
25-03-09	2.00
06-05-09	1.50
17-06-09	1.25
12-08-09	1.25
23-09-09	1.25
28-10-09	1.50
16-12-09	1.75
03-02-10	1.75
24-03-10	1.75
05-05-10	2.00
23-06-10	2.00
11-08-10	2.00
22-09-10	2.00
27-10-10	2.00
15-12-10	2.00
26-01-11	2.00
16-03-11	2.00
12-05-11	2.25

22-06-11	2.25
10-08-11	2.25
21-09-11	2.25
19-10-11	2.25
14-12-11	1.75
14-03-12	1.50
10-05-12	1.50
20-06-12	1.50
29-08-12	1.50
31-10-12	1.50
19-12-12	1.50
14-03-13	1.50
08-05-13	1.50
20-06-13	1.50
19-09-13	1.50
24-10-13	1.50
05-12-13	1.50
27-03-14	1.50
08-05-14	1.50
19-06-14	1.50
18-09-14	1.50
23-10-14	1.50
11-12-14	1.25
19-03-15	1.25
07-05-15	1.25
18-06-15	1.00
24-09-15	0.75
05-11-15	0.75
17-12-15	0.75

17-03-16	0.50
12-05-16	0.50
23-06-16	0.50
22-09-16	0.50
27-10-16	0.50
15-12-16	0.50
16-03-17	0.50
04-05-17	0.50
22-06-17	0.50
21-09-17	0.50
26-10-17	0.50
14-12-17	0.50

Table A.3: List of interest rate meetings after forward guidance was introduced.

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