The effects of ECB's conventional and unconventional monetary policy on Norwegian asset prices*

Saskia ter Ellen, Edvard Jansen and Nina Larsson Midthjell†

April 2017

Abstract

World markets are highly interconnected, and the actions and statements of the central bank in one country may influence other countries as well. In this paper we show that monetary policy shocks of the European Central Bank have substantial effects on Norwegian asset prices and yield curve. Using high-frequency data from 2001 to 2015 we investigate intraday changes in European interest rates to identify shocks to the ECB's monetary policy. Following the methods of Gürkaynak, Sack, and Swanson (2005) we use principal component analysis to identify two factors of monetary policy shocks interpreted as a "rate setting surprise" and a "forward guidance surprise". The analysis shows that monetary policy shocks by the ECB have strong and significant immediate effects on Norwegian financial variables.

Keywords: monetary policy, forward guidance, interest rates, asset prices, small open economies

JEL classification codes: E43; E44; E52; E58; G12

*The views expressed in this paper are those of the authors and do not necessarily reflect the views of Norges Bank. This is work in progress, please do not share or cite without permission of the authors. We are very grateful to Eric Swanson for sharing his code and for comments in the early stage of the project.

†Norges Bank, Bankplassen 2, P.O. Box 1179 Sentrum, 0107 Oslo, Norway. E: Saskia.ter-Ellen@Norges-Bank.no, Edvard.Jansen@gmail.com, Nina-Larsson.Midthjell@Norges-Bank.no. Part of this project was completed when Edvard Jansen (now at Formuesforvaltning) was visiting Norges Bank.

1 Introduction

The impact of conventional and unconventional monetary policies on financial and macroeconomic variables has received a lot of attention in recent years. With few exceptions, most of the literature focuses on the effects of domestic monetary policy on domestic conditions. What is not often considered is the impact that monetary policy of major economies may have on small open economies, even though there is ample reason to believe that spillovers occur. This paper fills that gap. In particular, we investigate the effects of monetary policy and forward guidance by the ECB on Norwegian yields and asset prices.

In recent years the question has been raised whether central banks are able to influence market interest rates when policy rates are at the effective lower bound. Some central banks, like the European Central Bank (ECB) and Sveriges Riksbank, have lowered their traditional monetary policy instruments, the key policy rate, to negative levels. Reifschneider and Williams (2000) and Eggertsson and Woodford (2003) provide theoretical evidence that the Federal Open Market Committee (FOMC) is largely unhindered in its ability to conduct policy even with low or zero nominal funds rate. Because the FOMC has the ability to manipulate, or at least influence, financial market expectations, it may affect longer-term interest rates and may stimulate economic activity. Thus, even if the federal funds rate is zero, the Federal Reserve may affect the long end of the yield curve and ultimately real economic variables by implementing unconventional monetary policy measures like a clear and transparent form of forward guidance in addition to large scale asset purchases.

Gürkaynak, Sack, and Swanson (2005) and Swanson (2017) find empirical evidence of this by showing that – even in a low-inflation environment with a low or zero nominal federal funds rate – the FOMC can effectively communicate its intention to keep the federal funds rate low for an extended period of time, in order to lower longer-term interest rates and stimulate economic growth. Following up on this paper, Brand, Buncic, and Turunen (2010) find that during the press conference following a key policy rate decision by the European Central Bank (ECB), market expectations for the path of monetary policy may change considerably, illustrated by significant changes in European interest rates at medium and longer term maturities. Hence, central bank communication matters for how private agents form their expectations, and new information is quickly incorporated in market rates.[1]

Monetary policy from major central banks may, however, affect asset prices in other countries as well. The economies of the United States and Euro Area together account for around 40% of world GDP. In this respect, policy actions and statements by the Federal Open Market Committee (FOMC) and the ECB's Governing Council are likely to cause spillovers to other countries, and may even impair the ability of central banks in small open economies (SOEs) to have an autonomous monetary policy. Whereas existing literature focuses on how domestic economic and financial variables are influenced by domestic monetary policy shocks, few papers investigate how the asset prices and interest rates of small open economies are affected by foreign monetary policy. Exceptions are Falagiagrda, McQuade, and Tirpak (2015), who show that spillovers occur from ECB's unconventional monetary policy to yields in non-Euro area eastern European countries, and Rogers, Scotti, and Wright (2016), who document spillovers from US monetary policy on foreign variables in a VAR setup. Furthermore, the results of some studies indicate that forward guidance is less effective if foreign variables are not taken into account. Bjørnland, Thorsrud, and Zahiri (2016) show that foreign variables can forecast the central bank's revisions of interest rate projections, and that market participants partly anticipate this. Likewise, Syrstad and Rime (2014) and Svensson (2015) find that large gaps between the market's and the central bank's rate paths can be explained by the gap between the (domestic) central bank's path and foreign rates. There is also some evidence that money market integration may lead to the impairment of certain transmission channels. In a study using Norwegian bank-level data, Cao and Dinger (2016) find that due to access to international interbank markets, domestic banks can lend abroad, and therefore the lending channel is much less effective in times of deviations from interest parity.

In this paper, we will investigate the effect of ECB's monetary policy on Norwegian yields and asset prices. In doing so, we distinguish between conventional monetary policy, i.e. rate settings, and unconventional monetary policy, which encompasses both forward guidance and large scale asset purchases (LSAP). Looking at the effects from ECB's actions and communications in Norway is particularly interesting as many of Norway's main trading partners are member countries of the European Monetary Union (EMU) and are as such subject to the European Central Bank's (ECB) monetary policy.

[1]After all, monetary policy is to a large extent about managing expectations, as a quote from Michael Woodford summarizes: "Not only do expectations about policy matters, but [...] very little else matters."

We identify shocks to monetary policy and forward guidance using high frequency identification (HFI) techniques. Several other papers have assessed responses to monetary policy shocks in a HFI framework (e.g. Hamiltion, 2008; Hanson and Stein, 2012; and Campbell et al., 2012). We choose to adopt a methodology that is very similar to that of Gürkaynak, Sack, and Swanson (2005) and Swanson (2017), who use high-frequency data on several money market instruments to extract a monetary policy and forward guidance factor.

We take advantage of a salient feature of the ECB's monetary policy announcement, namely that the key policy rates decision is published at 13:45 CET on the central bank's webpage. This first part of monetary policy information is one-dimensional, in the sense that it is not accompanied by forward guidance.[2] Using high frequency (intraday) data we identify the rate setting surprise by measuring immediate responses in very short-term European Overnight Index Swaps. The findings suggest that a surprise to the ECB's rate decision has strong and significant effects on Norwegian asset prices and yield curve immediately after the press release. The results show strongest effects for the short- and medium-term interest rate instruments. In addition, the exchange rate and equity prices respond strongly to ECB shocks.

Based on the methods developed in Gürkaynak, Sack, and Swanson (2005), we extract two factors from a set of interest rate surprises that together explain the actions and statements of the ECB's monetary policy. At least prior to the ECB's introduction of asset purchases, these two factors can be interpreted as the rate setting surprise and forward guidance. After the ECB started with its asset purchasing program, the second factor represents a combination of forward guidance and asset purchases. Both factors have strong and significant effects on Norwegian financial variables, where the second factor has a characteristic hump-shape impact for the yield curve.[3]

The remainder of this paper is set up as follows: Section 2 provides an overview of the methods we apply. Data and descriptive statistics are presented in Section 3. The empirical results are presented in Section 4, and Section 5 concludes.

[2] Although one could argue that market participants can learn something about the reaction function of the central bank by evaluating its actions. However, as will become clear, we use instruments that have sufficiently short maturities which should thus not be affected by this.

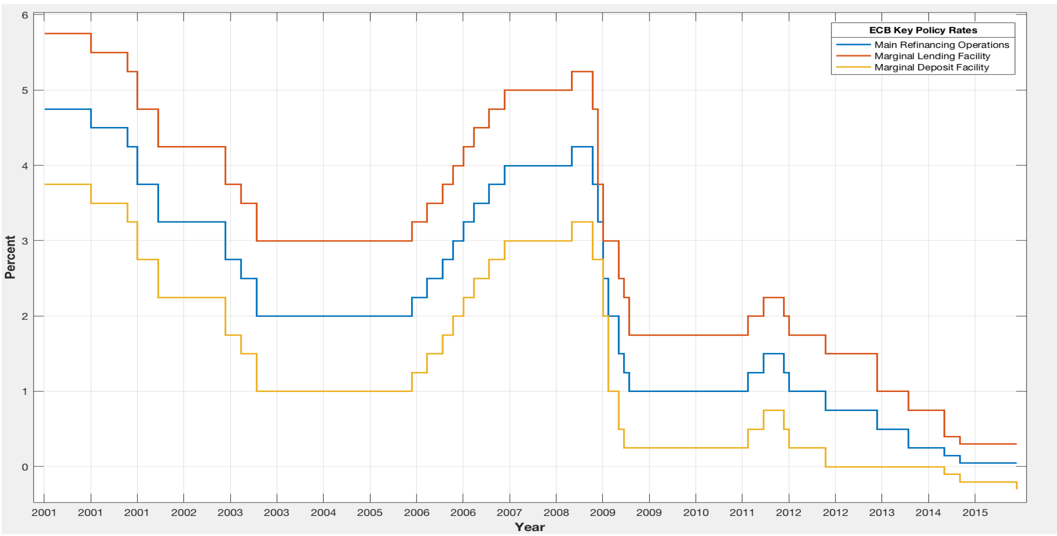
[3] This hump-shape impact is identified in Gürkaynak, Sack, and Swanson (2005) and interpreted as forward guidance.

2 Methodology

2.1 Affecting long and short term interest rates

The ECB has three key interest rates: marginal lending facility, main refinancing operations (fixed rate), and marginal deposit facility. The ECB's monetary policy regime has been consistent since the founding in 1999, namely to ensure price stability in the Euro zone, defined as inflation close to but below two percent. To steer the short-term money market rates, the ECB manages the liquidity in the money market. The ECB also aims to ensure a well-functioning market where banks meet their (short and longer term) liquidity needs. Figure 1 shows the key policy rates for 2001-2015. As rates came down to levels close to the lower bound after of the financial crisis, the ECB increasingly supplemented the already expansionary monetary policy with unconventional measures.

Figure 1: ECB Key Policy Rates: 2001Q1 to 2015Q4



Source: ECB, https://www.ecb.europa.eu

In contrast to real economic variables, which may take several quarters or years to affect, financial variables often react instantly to new information provided by the central bank. Hence, they could be considered as a starting point of the transmission mechanism before employment, output and consumer prices are affected. In that regard, the responses of financial variables may be considered as indicators of how real economic variables eventually will react.

In the short run, a change in money market interest rates sets in motion a number of mechanisms by economic agents, which ultimately influence developments in real economic variables such as output and inflation (ECB, pp.55). This transmission mechanism – initiated by a monetary policy decision – is complex and not unique, leading to difficulties in understanding the many processes as exogenous factors also may influence. Asset prices and the economy in general are affected by the entire path of expected future short-term interest rates, not only the current level of the overnight key policy rate. Changes in expectations of future key policy rates affect longer-term market interest rates as they are strongly related to the future development of short-term rates. This interest rate channel works through households' decisions by changing the relative attractiveness of saving or investing.

In recent years, monetary policy has not been able to effectively stimulate inflation and aggregate demand solely by conventional means. To affect medium and longer-term market rates in deflationary economies, many central banks have extended their policy to include more open and transparent communication of future policy, in addition to liquidity improving actions in the form of quantitative easing.

In addition to the large scale asset purchase program, clear and transparent communication of future monetary policy implementation became an increasingly important aspect of the ECB's monetary policy conduct. The responses of forward guidance are highly dependent on the credibility of the ECB. Stated differently, as economic agents and financial markets are forward looking, if credible, the ECB can influence future expectations with consequences for the economy today. The crucial part of this expectation transmission is that agents believe in the ECB's communication today. This fact has lead many central banks to focus on their transparency and market communication regarding policy decisions in later years.

Financial markets are sensitive to what central banks communicate - especially ahead of and in the immediate presence of policy meetings. In order to influence expectations about the long-term evolution of short-term interest rates, Praet (2013) argues that forward guidance may be effective. Praet (2013) describes the expectation channels by which economic actors anticipate the path of future monetary policy in two parts. First, agents themselves interpret the strategy of central bank actions in response to economic actions, and second, economic agents form expectations based on the ECB's appraisal about economic outlook and inflation.

2.2 Methods using high-frequency data

2.2.1 One-dimensional measures of monetary policy shocks

In line with Gürkaynak, Sack, and Swanson (2005), we estimate effects of the ECB's unexpected monetary policy actions by using an interest rate instrument that covers expectations about the short-term monetary policy stance.

Let the (money market) interest rate on the ECB monetary policy date at day d and time t be given by $i_{d,t}$, while $i_{d,t-j}$ be the corresponding OIS interest rate for the j-th lag of t. For small j, $\Delta i_{d,t}$ denotes the movement in the interest rate at day d and time t.

$$i_{d,t} - i_{d,t-j} = \Delta i_t \tag{1}$$

If d is at a ECB monetary policy announcement date, t is some time after the ECB publicly announces the rates at that same date and $t - j$ right before, we can interpret Δi_t as the unexpected part of the ECB's rate setting. To ensure that these surprises adequately reflect the rate setting surprises, we measure changes in interest rates for a 45-minute window around the announcement (i.e. from 15 minutes before the time of the announcement until 30 minutes after).[4] Kuttner (2001) measures the surprise in the target rate using changes in the fed funds futures rate by this methodology.

2.2.2 Timing of the ECB's actions and statements

When using intraday data to estimate the responses of surprises to the ECB's monetary policy decisions, a particularly important aspect is to correctly measure the actual time the markets got access to new information – namely the new key policy rates decisions and forward guidance. After investigating the ECB's monetary press releases from 2001 to 2015, we have identified that, with two exceptions, key policy rate announcements have been made public on the ECB's official webpage at 13:45 Central European Time (CET).[5] The press conferences following the press release have, for all the scheduled monetary policy meetings, begun at 14:30 CET. The conference includes Introductory

[4] As most money market instruments contain a risk-premium term, the crucial assumption for this identification to hold is that the risk-premium is constant over the time windows we employ.

[5] All press releases are public on the ECB's webpage. The two exceptions were the decision on September 17th 2001 (17:30 CET), and the decision on October 8th 2008 (13:00 CET). The 2001 decision was a response to economic uncertainty caused by the 9/11 attacks, whereas the 2008 decision was a response to financial distress after the Lehman Brothers collapse.

Statements with a subsequent session of Q&A. The number of monetary policy meetings were 24 in 2001. Before 2002, a press conference followed only after the first meeting of the month.

2.3 Factor analysis using principal components

The surprise to the key policy rate setting is an important component of the responses to the ECB's total set of monetary policy tools. However, other components may also have an influence on markets. To identify different components of the ECB's monetary policy, both conventional and unconventional, we employ principal component analysis following Gürkaynak, Sack, and Swanson (2005). Using U.S. financial variables, they identify two factors of the FOMC's monetary policy, interpreted as shocks to the current federal funds rate target and the future path of policy, and estimate the impacts of these shocks on U.S. equity prices and interest rates. We apply the same methodology to identify "rate setting surprises", denoted as the target factor, and a "forward guidance/large scale asset purchase" component, referred to as the path factor. The way we differ from their approach is that we identify and extract the two factors from a set of *European* financial variables, before estimating effects on *Norwegian* financial variables using the factors as independent variables.

2.3.1 Extraction of factors for the ECB's policy announcements

Rates over several horizons are affected by two types of monetary policy shocks: (unexpected) changes to the short term interest rate, i.e. the key policy rate, and (unexpected) changes to long term interest rates, i.e. changing expectations of future short term interest rates or directly affecting the longer end of the yield curve with asset purchasing programs. The methodology developed by Gürkaynak, Sack, and Swanson (2005) offers a way to separate the effect of these two shocks from data on yield movements around monetary policy announcements.

The authors use principal component analysis to summarize the movements in the yields following monetary policy announcements. Intuitively, these movements should be almost fully explained by two unobservable (latent) variables: conventional monetary policy and forward guidance (/unconventional monetary policy). Indeed, the authors find that two factors suffice to explain most variation in those yield changes. We employ the same methodology to identify monetary policy shocks from the ECB.

Specifically, using principal component analysis on the data matrix X (containing a number of European interest rates changes of various maturities), we estimate the unobserved factors F. In this way, we can represent the joint variability of the correlated observed n European interest rates in the matrix X, in terms of a smaller set of independent unobserved factors. The set of orthogonal factors F_i with $i = 1, ..., k$ are decomposed from X in such a way that F_1 accounts for as much of the variability as possible of X. F_2 is the factor that has maximum explanatory power for the residuals of X after estimating F_1, and so on. The number of factors will be limited to two based on the results from the Cragg-Donald rank test.[6] They are the two factors that together explain most of the variation in X. The set of observed variables in X that are used to estimate the factors are described in the data section 3.2.

The extracted factors are only a statistical decomposition from X, without having a structural interpretation. In order to provide a more structural interpretation of the factors, we rotate the extracted factors F_i into a new set of factors, and denote these rotated factors Z_i for $i = 1, ..., k$, in line with the approach in Gürkaynak, Sack, and Swanson (2005). The computational details of this factor rotation, can be found in the appendix of Gürkaynak, Sack, and Swanson (2005). The most important identifying restriction is that a monetary policy surprise should only be related to the surprise in setting the key policy rate, whereas a surprise in forward guidance should move interest rates with maturities beyond the current policy meeting, but should not at all be related to the surprise in current policy. In other words, the forward guidance factor, Z_2, should not load onto the surprise of the ECB's key policy rate setting (which is the first column of X).

Finally, to facilitate the interpretation of the first rotated factor Z_1 as the surprise component of the ECB's rate setting, the rotated factors are rescaled such that Z_1 moves one-for-one with the surprise component of key rate setting. In addition, the second rotated factor is calibrated such that both factors have the same effect on the 3rd column of X. This normalization is to facilitate interpretation of the factor.

[6] More on this test in Section 3.3. Results are available upon request.

3 Data and descriptive statistics

We analyze intraday data on a variety of Norwegian and European financial variables over the sample period 2001Q1 to 2015Q4. All the data are 15-minutes frequency observations obtained from Thomson Reuters and Bloomberg.[7] Over the sample period, the ECB had 187 scheduled meetings with a key policy rate decision. Two decision meetings were unscheduled.[8] We start the sample in 2001, as this is the year in which Norges Bank implemented inflation targeting, and so we don't have to take into account different regimes in the sample. Moreover, high-frequency data on many variables of interests before 2001 are not available to us.

3.1 European data

3.1.1 Event windows

We conduct an event study for which the events of interest are the ECB's monetary policy announcement, hereby defined as ECB dates. We define the *announcement* as the time window from 13:30 to 15:45 CET, containing both the *press release* (at 13:45 CET) and the *press conference* (starting at 14:30 CET). Thus, data sets containing only observations from these dates are constructed for the full sample period. Based on the time window employed, we extract observations to calculate changes in interest rates and returns asset prices.

We employ two different event windows in order to identify shocks to components of monetary policy. When we look at a one-dimensional monetary policy surprise, i.e. just the rate setting shock, we employ an event window from the time of the press release (13:45 CET) until 45 minutes after the release (14:30 CET).The full announcement, containing both the press release and the press conference, will include not only information about the key policy rate decision, but also the ECB's communication. This window, labeled the 'whole announcement window' runs from 15 minutes before the press release (i.e. 13:30 CET) until shortly after the press conference (15:45 CET). We will apply the factor

[7] The raw data are tick-by-tick data, so that the observation at 13:45 CET is the latest tick just before 13:45 CET (e.g. a tick quote from a dealer at 13:44:58 CET).

[8] The two are described in the section 3.1. These two rate decisions are considered as outliers and eliminated from all data sets for the empirical analysis. As these two unscheduled policy rate decisions were joint central bank actions to cut rates, it would be hard to solely identify the effects to the ECB's action. All dates for the ECB's monetary policy decisions are collected from the ECB's webpage.

analysis introduced in the previous section in order to extract the separate components of the ECB's monetary policy during this 'whole announcement window'.

3.1.2 Defining the rate setting surprise

Following the HFI literature, the set of potential instruments to use for identification of immediate monetary policy shocks consists of surprises to Overnight Index-Swaps, key policy rate futures, and Euribor futures, all with maturities shorter than the frequency of the ECB's monetary policy announcements. As there is no futures market for the key policy rate set by the ECB, we identify rate setting surprises by immediate changes in European OIS-rates.[9] Changes in the fixed rate of the OIS contracts should identify updates in expectations of ECB's key policy rate setting.

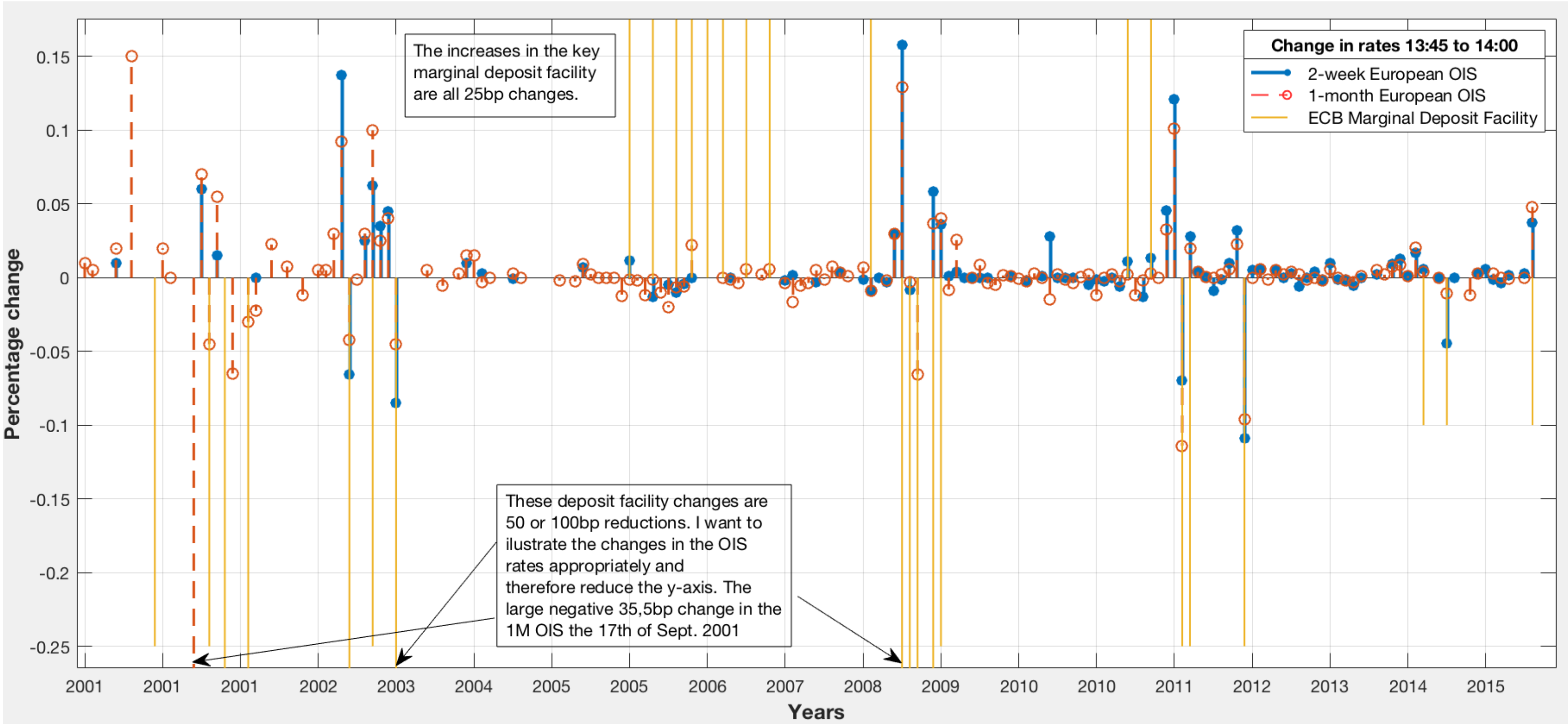
In the beginning of the sample period, the two-week OIS data contain quite many missing values (especially for the observation at 13:45 CET), while the one-month OIS data are more complete. However, as there has been less than one month between the ECB's monetary policy decisions, the one-month OIS contains expectations about more than one key policy rate decision. Based on these contracts, estimated effects of a rate setting surprise may be imprecise.[10] We therefore utilize the two-week OIS data for our first part of the analysis in which we estimate the effect of pure monetary policy shocks, where it is important to have a clear identification of this shock. Considering that in the second part we need as much data as we can to extract the factors, we use the one-month OIS data there. This should not affect the total explanatory power of the two factors much – in the worst case, we slightly underestimate the effect of unconventional monetary policy, as a small part of that will be captured by the monetary policy shock.

Figure 2 visualises the reactions for two-weeks and one-month European OIS rates around the ECB's press release over an event window from 13:45-14:30 CET. It clearly shows that a monetary policy shock does not always coincide with a change in the key policy rate: if market participants had expected a monetary policy action from the ECB

[9] We use the two-week and one-month European OIS. OIS contracts are fixed-for-floating interest rate swaps, where, for European OIS contracts, EONIA (Euro Overnight Index Average) is the floating leg interbank rate. EONIA is the weighted average of the interest rates on overnight unsecured transactions for the panel banks. These banks can be found here: http://www.emmi-benchmarks.eu/euribor-eonia-org/about-eonia.html.

[10] Clearly, there is a trade-off in the precision of the estimates to changed expectations to one key policy rate decision, and the number of observations. While the two-weeks OIS will isolate expectations about one policy decision, the data for one-month OIS are of better quality.

Figure 2: Change in two-week and one-month OIS around ECB announcements (13:45-14:30 CET) (2001 to 2015)



Source: ECB's webpage and Thomson Reuters while the ECB did nothing, this is also measured as a shock. This also implied that rate surprises were not necessarily in the same direction as changes in the ECB's key policy rates. If changes in European OIS rates are zero (no blue or red stems – only blue dots and/or red hollow circles), markets perfectly anticipated the ECB's policy rate decision. Although perfectly anticipating the rate decision for a number of occasions, the majority of rate decisions to some extent surprised the markets.

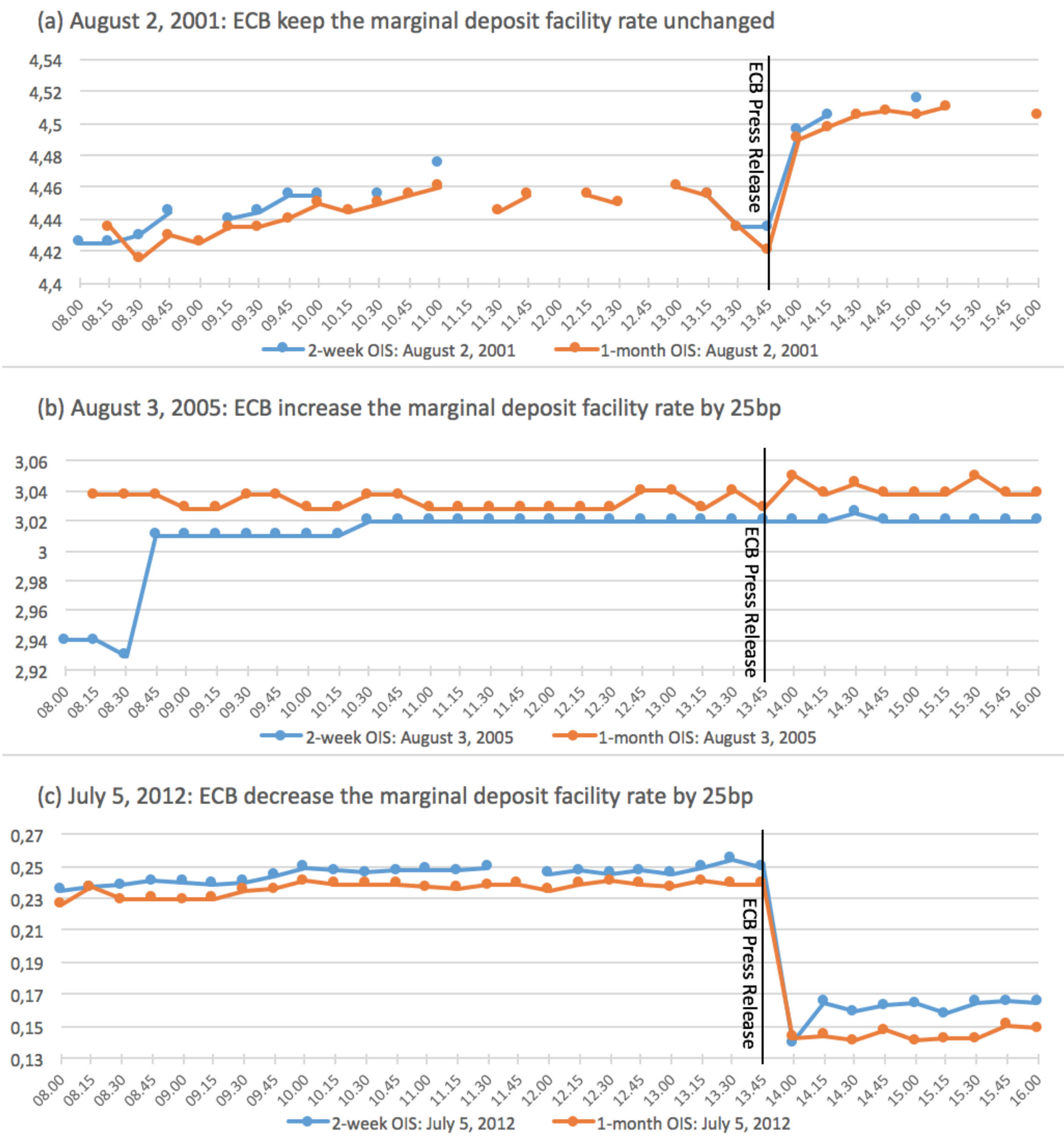
To provide additional sense of the data quality and to show that OIS-rates are able to identify rate setting surprises, we plot intraday trading for three days when the ECB announced key policy rates (see figure 3). Panel (a) shows trading on August 2, 2001 when the ECB announced that key policy rates remained unchanged. At the time of publishing the rate decision (13:45 CET), the two-week and one-month OIS rates rose by 6 and 7 basis-points respectively. Thus, markets had priced in a rate cut with some probability. For the meeting on August 3, 2005 (panel (b)), key policy rates were hiked by 25 bp. The market responses in OIS-rates were relatively small, implying that financial markets had more or less anticipated ECB's rate hike. Panel (c) shows the responses to a 25bps. key policy rate cut on July 5, 2012. Judging from the reactions in OIS-rates, markets did not expect a rate cut, illustrated by a fall of 11 bp. and 10 bp. in the two-weeks and one-month OIS contracts, respectively. These examples support the use of the high frequency method of identifying surprises to the ECB's rate setting, and show that European OIS contracts capture these surprises. In addition, financial markets seem to incorporate the new (unexpected) information and instantly re-price.

In order to deal with missing values, we modify the European OIS data sets. By assuming that NaN-observations mean that there is no change from the previous non-NaN observation, we reduce the number of missing values by looking for the closest tick as much as four quarters prior. To illustrate with an example: If there is no tick for a 14:30 CET observation in the original data, the modified data set is looking for the closest non-NaN tick from 14:15, 14:00, 13:45 and 13:30 on the same day.[11] If none of those four previous quarters is a non-NaN value, the observation is left blank.

The descriptive statistics for the OIS data are summarized in table 1. The mean change for the two-week and one-month OIS contracts is quite small, with considerably higher standard deviations.

[11] In order to avoid overlap with the ECB's press conference to affect, we do not modify beyond 14:30 CET.

Figure 3: Intraday Trading in European two-week and one-month OIS Contracts



Source: Thomson Reuters

Table 1: Descriptive statistics: two-week & one-month OIS rates (2001-2015)

	OIS changes				
	Mean	Std.Dev	Obs	Min	Max
$\Delta OIS2W$	0.0077	0.0349	139	-0.1270	0.1800
$\Delta OIS1M$	0.0032	0.0444	180	-0.3650	0.1420

3.1.3 Data for the factor analysis: European variables

In order to extract the factors to measure conventional and unconventional monetary policy surprises, we use data on interest rates of maturities up to 10 years. In addition to the one-month European OIS data set, we use data for the three-month European OIS, the seventh (21-month) Euribor futures contract, and the two-, five-, and ten-years German Treasury Bonds. The one and three-month OIS contracts provide good estimates of the market expectations for the key policy rates after the upcoming and closest future rate decisions. The seventh Euribor future contract represents information about market expectations for the path of the ECB's key policy rate over the medium term.[12] Yields on German treasuries are used as benchmarks to provide information about the expectations for the long horizon. While all the other data except German Treasuries are in CET-format, they are in GMT-format. The data for treasuries therefore require a seasonally-varying time adjustment to CET. For the data set of the Euribor futures contract, we calculate mid-quotes as the average of bid and ask quotations. While the data for German treasuries are complete, the data for OIS-contracts and Euribor futures contain some missing values for the time-window of interest.

To identify more than one dimension of monetary policy shocks, we employ the whole announcement window for the factor extraction and the estimation of effects on Norwegian financial variables. Therefore, we need to modify the above mentioned data for European interest rate contracts slightly differently from the modification procedure explained before. Because the ECB's announcement is defined to range over the time window 13:30 CET - 15:45 CET, and the press conference begins at 14:30 CET, the modification is conducted as follows.

For an observation at 14:30, 14:00, and 13:30 CET, we look for the closest non-NaN four quarters earlier. This yields a non-NaN observation for a very large part of the NaN observations. If a non-NaN observation is still not found, we look for the closest non-NaN observation four quarters later, but no later than 14:30 CET. If the observation is still missing, we look for the closest earlier non-NaN observation, but not earlier than 10:00 CET. If this still does not yield an observation, the observation is left blank.

Missing observation at 15:45 CET are filled up in a similar fashion, but rather than looking back more than an hour (as we don't want to get in the period before the start of the press conference), we look for observations later than 15:45 CET, but no later than 18:00 CET. Again, if the observation is still NaN, the observation is left blank.

The method may potentially induce (small) measurement errors for the true changes

[12]European FRAs and futures contracts have EURIBOR as the underlying (floating) interest rate. Euribor futures are standardized contracts traded on an exchange.

in variables as it allows for wider windows. That being said, to support the modification, the results provided in Gürkaynak, Sack, and Swanson (2005) and Brubakk, Ter Ellen, and Xu (2017) indicate estimates using data for daily changes would not differ greatly from narrow windows.

3.2 Norwegian data

The Norwegian interest rates in our sample represent a wide variety of financial derivatives contracts that reflect both short, medium and long term interest rates. These are money market rates up to two years (Forward rate agreements: FRAs), and interest rate swaps with maturities of 2, 5 and 10 years.[13] The FRA contracts reflect the short to medium end of the yield curve, while the swap contracts reflect the expected average short-term interest rates over the 2, 5, and 10 year horizons.[14] We include the first to eighth quarter FRA contracts. These contracts capture the maturities of three, six, nine, 12, 15, 18, 21, and 24 months ahead, where the first FRA denotes the three-month, and the eighth FRA refers to the 24-month maturity. For the first four FRAs, the data set is from 2001 to 2015 and is complete. For the fifth and sixth FRA contracts, the data begin on the 6th of September 2007. The first observation for the seventh and eighth FRA is on the 4th of June 2009. Thus, the estimated effects on those interest rates will only account for their respective sample periods.

We include data for the spot EURNOK. For Norwegian equity prices, we use data for the OSEBX equity index (Oslo Børs). The data set of OSEBX begins on May 23, 2001.

[13]Like Brubakk, Ter Ellen, and Xu (2017) we use Norwegian swap rates rather than Norwegian government bond yields due to the low volume and poor liquidity of that bond market. The FRA market is regarded as the most liquid part of the Norwegian money market.

[14]FRAs are over the counter (OTC) cash settled agreements of the difference between the fixed interest rate and reference rate (NIBOR) on a notional amount of NOK 1 million. An interest rate swap is an agreement between two parties to swap interest rate payments where the buyer pays a fixed rate (swap rate) and the seller pays the floating for a pre-determined period.

3.3 Factor estimation

We use a number of European interest rate instruments to extract factors as described in the methodology section.[15] This can be represented by:

$$X = F\Lambda + \eta \tag{2}$$

where X is a $T\times n$ matrix of $T = 187$ scheduled ECB key policy rate announcements and $n = 6$ European financial variables. Each element of X is the change in the n variables for the whole ECB announcement window. F denotes a $T\times k$ matrix of the unobserved factors with $k < n$, and Λ a $k\times n$ matrix of factor loadings. η represents white noise error terms. The n variables in matrix X are:

$$X = [1MOIS, 3MOIS, \textit{7th E.FUT}, 2YGT, 5YGT, 10YGT] \tag{3}$$

where 1M OIS is the one-month European Overnight Index Swap, seventh E.FUT is the 21-month Euribor future, and 2Y GT is the two-year German Treasury Bond. The hypothesis is that the ECB's announcements may not only contain a rate setting surprise component, but that other dimension(s) of monetary policy may also influence European financial variables (with potential spill-over effects on Norwegian interest rates and asset prices). OIS contracts provide a good estimate of the market expectation of the ECB's key policy rates for the closest upcoming Governing Council meetings. The seventh E.FUT and 2Y GT give information about the market expectations about the key policy rate over the medium to long term. Five-year and ten-year GTs account for the European interest rate expectations for very long maturities.

Using this model, we want to know how many factors (dimensions of monetary policy) are needed to satisfactorily describe the ECB's policy announcements (i.e. the movements in X). In accordance with Gürkaynak, Sack, and Swanson (2005), we use the reduced rank test developed by Cragg and Donald (1997).[16] The null hypothesis of the test is that X is described by k_0 factors against the alternative hypothesis of $k > k_0$ factors.[17]

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[15] Given the fact that the ECB only held press conferences for every second rate decision in 2001, we re-define the full sample period for the factor analysis to be 2002-2015.

[16] As Brand, Buncic, and Turunen (2010) argue, since the column dimension of X is quite small, this Cragg-Donald test is to be preferred over other tests relying on the columns and rows of the X matrix to go to infinity (see e.g. Bai and Ng (2002)).

[17] By measuring the minimum distance between Cov(X) and the covariance matrices of all possible

To capture all components over the ECB's announcement, the whole window is employed. We test the number of factors for the full sample and post-LSAP sample in order to test for a potential large scale asset purchase factor in the ECB's announcement. Testing the full sample over the whole window rejects the hypothesis of more than two factors at the 5% level. In other words, the test implies that markets have reacted to the ECB's announcement as one additional factor beyond the rate setting surprise is enough to explain inter-announcement variation in European interest rates. The test for the post-LSAP sample also strongly rejects more than two factors. [18]

Based on these results we extract two factors from X. These two factors do not have a structural interpretation. We therefore employ a factor rotation following Gürkaynak, Sack, and Swanson (2005) in such a way that only the first factor loads onto the one-month European OIS, as explained in the methodology section. Hence, the second factor does not have any relation with the one-month European OIS. Consequently, the first factor, Z_1, is interpreted as the rate setting surprise of the ECB's announcement – denoted as the *Target factor*. At this stage, the second factor, Z_2, can be interpreted as *all other information* in the ECB's announcements that changes financial market expectations about the future path of key policy rates (Swanson (2017)). In that regard, the second factor has close correspondence to forward guidance. However, for the post-LSAP sample, the second factor is likely a representation from both forward guidance and the effects of LSAP. We will further discuss this in the results section.

3.3.1 Rotated loading matrices from the factor analysis

Table 2 reports the rotated loadings, Λ, from the factor model in equation (9) for the full, pre-LSAP and post-LSAP sample.[19] The table shows that the overall effects of the first factor, interpreted as the rate surprise, is strongest for the shortest maturities and decreases for longer maturities.[20] The downward-sloping shape implies that a rate setting surprise by the ECB dies out for longer maturities, consistent with theory – key policy

factor models (9) with k_0 factors. After normalizing, this distance has a limiting χ^2 distribution with $(n-k_0)(n-k_0-1)/(2-n)$ degrees of freedom. For further details, see the appendix of GSS2005.

[18] Surprisingly, there is weak evidence of a third factor in the *pre-LSAP* sample rather than the *LSAP* sample. However, with principal component methods, the first factors do not change when one allows or does not allow for an additional factor. We are therefore confident that we extract the information we're after (monetary policy surprises and forward guidance) with the first two factors.

[19] We separately extract and rotate two factors for the different sample periods.

[20] Note that comparing relative sizes of impacts on the European interest rates can only be done for the same factor.

rates affect the short end of the yield curve. The second (path) factor has a characteristic hump-shape with strongest effects on European interest rates with maturities of about two years.[21] These rotated loadings of the extracted factors are interpreted as: *A one standard deviation increase in factor i is estimated to cause the j-th interest rate to rise by b basis points.* As an example, a one standard deviation change in the path factor is estimated to cause a 4.3 basis points increase in the two-year German Treasury (full sample). The factor loading of the 10-year German Treasury yield is clearly higher for the LSAP sample than for the sample covering the time before LSAPs were introduced. This indicates that the second factor picks up a combination of forward guidance and LSAP.

Table 2: Rotated loadings of X: Estimated effects of conventional and unconventional monetary policy announcements by the ECB

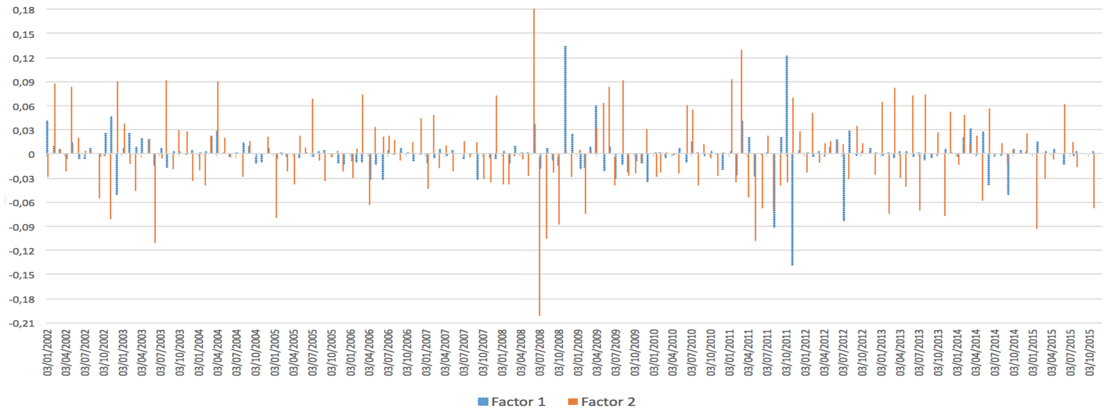
		1M OIS	***3M OIS***	***7th EF***	***2y G. Tr.***	***5y G. Tr.***	***10y G. Tr.***
2002-2015	ΔFactor 1	3,2373	3,0126	1.8242	2.6549	1.5619	0.1427
	ΔFactor 2	0.0000	0.9728	2.1930	4,2999	4,1995	2.8905
Pre-LSAP	ΔFactor 1	3,2937	2.8844	1.9688	2.6113	1.5437	0.2235
	ΔFactor 2	0.0000	0.9376	2.2358	4,7043	4,2731	2.6445
Post-LSAP	ΔFactor 1	3,1242	3,2730	1.5640	2.6953	1.5820	0.0308
	ΔFactor 2	0.0000	1.0595	2.1163	3,5623	4,1070	3,3679

Following Gürkaynak, Sack, and Swanson (2005), we facilitate interpretation by re-scaling Z_1 so that a rate setting surprise by the ECB (measured as the change in one-month OIS) is calibrated to correspond one-to-one with the Target factor, Z_1. In addition, we re-scale the second (path) factor so that both factors have the same effect on the seven-quarter-ahead Euribor future. By such a normalization, comparing the relative size of coefficients on the target and path factor for interest rates with shorter of longer maturity than the seventh Euribor future are easier. Thus, only the effects of the target factor has a clear numerical interpretation, while the estimated effects on Norwegian financial variables of the path factor can only be compared relatively between estimates.

Figure 4 plots the target and path factor. An interesting aspect is that factor realizations do not necessarily have the same direction. This implies that different surprise

[21]By construction, the second factor has no effect on the one-month OIS, implied by the coefficient of zero for the second factor.

Figure 4: Target and Path factors: Two dimensions of ECB shocks (2002 - 2015)



Source: ECB and Thomson Reuters

components of the ECB's announcement may influence interest rates in opposite directions.

4 Empirical results and interpretations

4.1 The effects of shocks to the ECB's rate decision

We start by estimating the effect of monetary policy shocks, i.e. unexpected changes in the ECB's key policy rate, on Norwegian yields and asset prices:

$$\Delta R_t = \alpha + \beta \Delta X_t + \epsilon_t \tag{4}$$

Table 3 provides the results of running separate regressions for all the dependent Norwegian financial variables. ΔX_t is the change in 2-weeks European OIS rates, and ΔR_t denotes the change in European yields and asset prices. The first column in the table indicates the dependent variable. For the Norwegian interest rates, the estimated coefficients can be interpreted as *the percentage point change in the specific interest rate instrument from a one-percentage point rate setting surprise*. For the Norwegian asset price (OSEBX and EURNOK) the interpretation of the estimated coefficients is: *a one-percentage point rate setting surprise is associated with a 100*β percent change in the asset price.*

A surprise change in the ECB's rate decision has both statistically and economically significant effects on short and medium term Norwegian interest rates. A shock in the

ECB's rate setting, measured as the change in two-weeks European OIS rate, has strong immediate impacts in the same direction on Norwegian money market rates with short maturity. These results clearly imply that shocks in the ECB's rate setting are influential for Norwegian money markets. The effect of a European monetary policy shock decreases over the maturity of FRAs, as seen by the size of the effect (coefficient) and the explanatory power (R^2) of the shock.

For Norwegian interest rate swaps, the estimated effects are not as strong, but statistically significant for the two-year maturity. The estimated effects for the longest end of the Norwegian yield curve (five- and 10-year swaps) are small and only significant at the 10% level. These results are consistent with both theory that conventional monetary policy affects the short and medium end of the yield curve, and earlier findings in e.g. Gürkaynak, Sack, and Swanson (2005).

Norwegian equity prices (OSEBX) are strongly and statistically significantly affected by a rate setting surprise. Explicitly, following an unexpected rate increase of one percentage point, the index is estimated to fall 3.37%. This result can be explained with a prevailing discount effect, meaning that the effects of higher discount factor of future dividends have a strong influence. Interestingly, these results are much stronger than what Brubakk, Ter Ellen, and Xu (2017) find in an earlier version of their paper. This indicates that for large Norwegian companies it is foreign, rather than domestic, interest rates and funding that matters.

The foreign exchange (FX) market is extremely liquid and tends to respond fast to new information. If the ECB surprises the FX market by a one percentage point rate hike, the Euro is estimated to appreciate by around 1% to the Norwegian krone. A higher expected risk-free rate of return for savings denominated in Euro will increase demand for Euros, leading to appreciation.

In short, the results show strong evidence that Norwegian financial markets are affected by shocks in the ECB's rate setting, and the re-pricing seems to happen quite immediately after the new information, which is in line with the findings in Gürkaynak, Sack, and Swanson (2005), Brubakk, Ter Ellen, and Xu (2017), and Brand, Buncic, and Turunen (2010).[22] The short and medium end of the Norwegian yield curve responds most to rate setting surprises. In line with theory, longer-term interest rate instruments

[22]Notably, these papers differ in the way that they are not estimating cross border effects.

Table 3: Effects of a ECB Rate Setting Surprise: two-week European OIS (2001-2015)

	MP Surprise (std.err)	R^2	*Obs*
FRA1	0.2068** (0.0895)	0.22	139
FRA2	0.3017*** (0.0991)	0.34	139
FRA3	0.2706*** (0.0957)	0.20	139
FRA4	0.2673** (0.1110)	0.17	139
FRA5	0.5072*** (0.1185)	0.34	91
FRA6	0.3872*** (0.0581)	0.27	91
FRA7	0.3616*** (0.0815)	0.19	74
FRA8	0.3260*** (0.0653)	0.15	74
2Y SWAP	0.1884** (0.0818)	0.13	139
5Y SWAP	0.0857 (0.0648)	0.04	139
10Y SWAP	0.0536 (0.0412)	0.02	139
OSEBX	-0.0337** (0.0159)	0.08	134
EURNOK	0.0117** (0.0045)	0.08	139

***=1% **=5% *=10% significance level.

HAC standard errors in parentheses.

Constant terms are excluded for presentation convenience.

are not strongly affected by the interest rate surprise.

4.1.1 Two dimensions of ECB shocks: Effects on Norwegian markets

The preceding sections show that variation in European interest rates over the ECB's monetary policy announcements is not only described by a rate setting surprise. In the following, we explain how two dimensions of surprises to the ECB's monetary policy announcement affect Norwegian financial variables.

Table 4 presents the results of ordinary least squares estimations for Norwegian financial variables of the following equation:

$$\Delta R_t = \alpha + \beta_1 Z_{1,t} + \beta_2 Z_{2,t} + \epsilon_t \tag{5}$$

where ΔR_t is the observed change in the Norwegian interest rate or asset price of interest for the whole announcement window. $Z_{1,t}$ is the re-scaled rotated factor 1, and $Z_{2,t}$ the factor 2. β_1 is therefore the effect of the target factor on Norwegian financial variables, while β_2 is the effect of the path factor. ϵ_t is an stochastic error term. The sample period is 2002-2015. An important feature to keep in mind, as the whole announcement window (i.e. two hours after the press release) is employed to capture the entire monetary policy announcement by the ECB, is that the estimates are subject to a higher probability of being influenced by other variables.

The results indicate that the target factor has strong positive effects on short and medium-term Norwegian interest rates, while the impacts on longer maturities are lower. Because different time windows are applied, the estimated coefficients of the target factor cannot be directly compared with the results of the one-dimensional analysis.[23]

The new feature is the effects of the path factor. The estimated coefficients are highest for the medium and longer-term interest rates, while the shortest end of the Norwegian yield curve is not affected to the same extent. Estimates indicate the characteristic hump-shape with a peak around 18-24 months. Comparing the effects of the path factor to the target factor, effects on very long-term interest rates (5 and 10 year swap) are much stronger for the path factor, while the opposite is true for the short end of the yield curve. These findings are consistent with the shape of forward guidance's impact in Gürkaynak, Sack, and Swanson (2005), Swanson (2017) and Brubakk, Ter Ellen, and Xu (2017). Adding the second dimension of monetary policy increases the explanatory power, which now ranges between 40 and 76 percent for the Norwegian interest rates. A striking result is the response in the 10-year swaps: 62% of variation in the two hours following the ECB's announcement can be explained by surprises in the ECB's conventional and unconventional monetary policy.

The path and target factors have opposite signs for the estimated coefficients on

[23]Moreover, the monetary policy surprise results are obtained using two-week OIS contracts, whereas the target factor is based on the one-month OIS and hence measures the current rate surprise and updates in expectations of potential other meetings in yhe coming month.

equity prices. As higher interest rates affect the discount factor of future dividends, the coefficient on the rate surprise is negative. Specifically, for a one percentage point rate surprise, OSEBX falls by almost 3 percent. Hence, the discount effect is prevailing for the target factor. In contrast, the estimated coefficient of the path factor is positive. A way of interpreting that is – given that factor 2 is solely a forward guidance component – when the ECB (surprisingly) signals higher future interest rates, they implicitly signal a boom ahead. Consistent with Gürkaynak, Sack, and Swanson (2005), as financial markets revise upward their forecasts of output in response to positive path factor surprises, the negative dividend impact of the rate setting surprise is dampened. The estimated effects for the exchange rate are not statistically significant for the target factor over the course of the whole window. This is in contrast to the strongly significant estimates found for the narrower window in the one-dimensional analysis. Hence, there are indications that effects from a rate setting surprise are quickly dampened for the exchange rate. This may potentially be caused by an offsetting effect of Norwegian rates reacting to the ECB's moentary policy shocks: an unexpected increase in European interest rates will appreciate the Euro, but it also increases the Norwegian rates which, in turn, appreciate the Norwegian krone.

4.2 A pre and post LSAP evaluation

4.2.1 Effects of one-dimensional surprises on Norwegian variables

By applying sub-samples of pre and post the ECB introduced asset purchases, we run regressions of Equation 4.[24] Results are provided in Table 5. Estimated effects of a rate setting surprise are stronger for the post LSAP period, and all coefficients are statistically significant.[25] It is not obvious whether we should interpret this as a time-effect or as something specific to monetary policy in a time when unconventional monetary policy is also conducted and interest rates are near their effective lower bound. The parameter instability between the sub-samples may simply come from stronger rate setting surprises and reactions in Norwegian interest rates for the post LSAP sample, caused by other factors than LSAP. Results indicate that the right candidate should probably be found

[24] For the 5th-8th Norwegian FRA, the sample size is too small and regressions are eliminated.

[25] Keep in mind that the data sets for European OIS contracts are fairly complete for the post LSAP sample period, while missing a substantial amount of observations pre-LSAP. That may influence the results in such a way that post-LSAP estimates are more precise.

Table 4: Effects on Norwegian financial variables: Two Factors (2002-2015)

Two Factors (2002-2015)					
	Constant (std.err)	*Target Factor (std.err)*	*Path Factor (std.err)*	*Adjusted* R^2	*Obs*
FRA1	0.0015 (0.0013)	0.4496*** (0.1028)	0.2046*** (0.0398)	0.40	162
FRA2	-0.0020 (0.0019)	0.5449*** (0.0818)	0.2531*** (0.0565)	0.47	162
FRA3	-0.0023 (0.0020)	0.5589*** (0.0801)	0.4055*** (0.0502)	0.51	162
FRA4	-0.0038* (0.0021)	0.5609*** (0.0807)	0.4971*** (0.0527)	0.57	163
FRA5	-0.0007 (0.0020)	0.5606*** (0.0606)	0.5629*** (0.0397)	0.76	95
FRA6	0.0008 (0.0029)	0.7358*** (0.1910)	0.5744*** (0.0384)	0.72	95
FRA7	-0.0021 (0.0022)	0.4835*** (0.0458)	0.5984*** (0.0566)	0.73	73
FRA8	-0.0035 (0.0024)	0.4582*** (0.0636)	0.6323*** (0.0656)	0.71	73
2Y SWAP	-0.0013 (0.0015)	0.3886*** (0.0532)	0.4012*** (0.0317)	0.57	162
5Y SWAP	-0.0018 (0.0017)	0.2872*** (0.0810)	0.4371*** (0.0354)	0.53	162
10Y SWAP	-0.0006 (0.0013)	0.1662*** (0.0490)	0.4267*** (0.0296)	0.62	162
OSEBX	-0.0934** (0.0449)	-2.961** (1.3006)	2.414** (0.9700)	0.06	161
EURNOK	-0.0367** (0.0171)	0.6555 (1.1259)	1.2778*** (0.4698)	0.06	162
1M EURNOK	-0.0450*** (0.0169)	0.4971 (1.1783)	1.309** (0.5073)	0.06	148

***=1% **=5% *=10% significance level. HAC standard errors in parentheses. Whole window employed. Data starting in 2007Q2 for FRA 5-6, 2009Q3 for FRA 7-8, and 2001Q3 for OSEBX.

in the risk premia spheres, given that even very long yields (five- and 10-year swaps) are affected in the second sample. However, stock markets haven't reacted stronger to the ECB's monetary policy shocks in the second sample. There is also some evidence that the exchange rate channel has become stronger, judging from the size and significance of the EURNOK response to a monetary policy shock. In the later sample, monetary policy shocks explain around 27% of variation in the exchange rate in the 45 minute window following the ECB's press release.

Table 5: Effects of a ECB Rate Setting Surprises: two-week European OIS (Pre/Post LSAP)

	Pre-LSAP			**Post-LSAP**		
	MP Surp. *(Std.err.)*	R^2	*Obs*	*MP Surp.* *(Std.err.)*	R^2	*Obs*
FRA1	0.1139 (0.0824)	0.08	76	0.4678*** (0.0805)	0.72	63
FRA2	0.2019** (0.0965)	0.22	76	0.5646*** (0.1089)	0.71	63
FRA3	0.1781* (0.0938)	0.11	76	0.4991*** (0.1163)	0.57	63
FRA4	0.1658 (0.1227)	0.08	76	0.5282*** (0.0661)	0.56	63
FRA5				0.3777*** (0.0716)	0.48	63
FRA6				0.3879*** (0.0780)	0.45	63
FRA7				0.3646*** (0.0816)	0.38	63
FRA8				0.3285*** (0.0649)	0.36	63
2Y SWAP	0.0775 (0.0694)	0.03	76	0.4845*** (0.0728)	0.57	63
5Y SWAP	-0.0100 (0.0502)	0.01	76	0.3628*** (0.0307)	0.55	63
10Y SWAP	-0.0107 (0.0354)	0.00	76	0.2340*** (0.0656)	0.22	63
OSEBX	-0.0377* (0.0224)	0.08	71	-0.0208** (0.0098)	0.08	63
EURNOK	0.0060 (0.0048)	0.04	76	0.0282*** (0.0067)	0.27	63

***=1% **=5% *=10% significance level.

Constant terms are excluded for presentation convenience. HAC standard errors in parentheses.

4.2.2 Effects of two-dimensional surprises on Norwegian variables

We report the regression results of Equation 5 for pre and post LSAP sample in Table 6. The estimated coefficients of the target factor are virtually the same for the two sub-samples. The effects of a rate surprise has strongest effects for the short-term maturities and are dying out for longer maturities. The path factor of the post LSAP sample show fairly similar estimates as pre-LSAP for the short end of the Norwegian yield curve, although explanatory power is substantially higher during the second sub-sample. Estimated effects on the longest maturities are much larger for the post-LSAP period. This indicates that a potential interpretation of the post-LSAP path factor may be a *combined unconventional policy component* on Norwegian interest rates.

However, the underlying assumption that the relative impacts of the ECB's forward guidance are similar between the two sub-samples is rather strict. The ECB has in recent years changed its monetary policy communication strategy to include both more forward guidance, but also more transparent guidance. Therefore, the fact that the hump-shapes of the path factor for the two sub-samples are different could be as a result of changed communication strategy having relatively stronger effects for the longest Norwegian maturities.

5 Concluding remarks

This paper employs the HFI approach to measure the immediate effects of the ECB's monetary policy surprises on Norwegian asset prices and interest rates. We found that surprise decisions in the ECB's key policy rates are important to explain the effects on the short end of the Norwegian yield curve. The results are statistically and economically significant: a 10 basis points rise in the European OIS rate increases Norwegian short term rates by about 5 basis points. In addition, rate setting surprises have strong significant effects on the exchange rate and on equity prices.

However, a rate setting surprise does not tell the whole story. The results provide evidence that (at least a) second factor, above and beyond the rate setting surprise, is needed to adequately describe movements in European interest rates around the ECB's monetary policy announcements. Using the methodology in Gürkaynak, Sack, and Swanson (2005) we extracted two factors of the ECB's policy announcements. The second factor contains

Table 6: Effects on Norwegian financial variables: Two factors (Pre/Post LSAP)

	Two Factors: 2002 - LSAP				**Two Factors: Post-LSAP**			
	Target Factor (std.err)	*Path Factor (std.err)*	*Adjusted* R^2	*Obs*	*Target Factor (std.err)*	*Path Factor (std.err)*	*Adjusted* R^2	*Obs*
FRA1	0.4491** (0.2041)	0.1714*** (0.0390)	0.34	100	0.4279*** (0.1108)	0.1627*** (0.0415)	0.55	62
FRA2	0.4905*** (0.0691)	0.2088*** (0.0530)	0.41	100	0.5667*** (0.1379)	0.2116*** (0.0526)	0.58	62
FRA3	0.5581*** (0.1293)	0.3262*** (0.0405)	0.47	100	0.5319*** (0.1059)	0.3565*** (0.0525)	0.69	62
FRA4	0.5334*** (0.0882)	0.3592*** (0.0604)	0.50	100	0.5716*** (0.0715)	0.5454*** (0.0529)	0.73	62
FRA5					0.5482*** (0.0737)	0.6147*** (0.0581)	0.77	62
FRA6					0.4970*** (0.0545)	0.6974*** (0.0544)	0.83	62
FRA7					0.4743*** 0.0470)	0.7151*** (0.0670)	0.77	62
FRA8					0.4589*** (0.0504)	0.7860*** (0.0709)	0.78	62
2Y SWAP	0.3503*** (0.0932)	0.2887*** (0.0318)	0.51	100	0.4168*** (0.0557)	0.4460*** (0.0448)	0.71	62
5Y SWAP	0.3103* (0.1699)	0.2880*** (0.0308)	0.45	100	0.2459*** (0.0622)	0.5635*** (0.0652)	0.69	62
10Y SWAP	0.2436*** (0.0882)	0.2777*** (0.0236)	0.56	100	0.1125* (0.0572)	0.5441*** (0.0535)	0.73	62
OSEBX	-3.5726 (2.3137)	2.4530** (1.0446)	0.09	100	-2.7933** (1.1381)	0.6810 (1.0973)	0.03	61
EURNOK	-1.9785** (0.8589)	0.3432 (0.2410)	0.04	100	2.4604 (1.6787)	3.3431*** (1.0199)	0.29	62

***=1% **=5% *=10% significance level.

Constant terms are excluded for presentation convenience. HAC standard errors in parentheses.

Pre-LSAP sample: 2002 to May 10. 2010 / Post-LSAP sample: May 10. 2010 to 2015.

We extract the two principal components separately for these two sub-samples.

information provided by the ECB other than the rate decision itself. Specifically, it can be interpreted as forward guidance, indicating how markets react to the ECB's communication of the future monetary policy path. The path factor has larger effects on the medium and longer-term Norwegian interest rates compared to the rate setting surprise.

Furthermore, sub-sample analysis showed that Norwegian financial variables were much more affected by announcements from the ECB after the ECB introduced their asset purchasing program. Whether this is a direct effect of the LSAPs or affected by other factors remains an open question.

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