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Assessing the Effect of Moves in the Key Policy Rate

A narrative approach for Norway

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Abstract

This thesis estimates the effect of the key policy rate on inflation and output for the Norwegian economy. It applies the narrative identification strategy, pioneered by Romer and Romer, to identify monetary policy shocks and construct a new measure of monetary policy for Norway. To our knowledge, this approach has never before been applied on Norwegian data. The new measure of monetary policy is derived through the construction of a new, real-time forecast data set, in order to purge the key policy rate of anticipatory movements. It is shown that estimating a Taylor rule captures a substantial part of Norges Bank's real-time information set.

To assess the impact of monetary policy in Norway, the new measure of monetary policy is employed in a vector autoregression. Following a one percentage point shock to the new measure of monetary policy, the thesis finds that inflation decreases by up to 1.75 percentage points after five quarters, and that output is reduced by up to 2.71 percentage points after seven quarters. These estimated effects are significantly larger than the results previously obtained on Norwegian data. Since the previous studies employ the actual key policy rate as the policy instrument, this might imply that the new measure of monetary policy, derived in this thesis, is relatively free of anticipatory movements. The new measure could therefore yield more precise estimates of the key policy rate's effect on economic variables. The inclusion of real-time forecasts, in the construction of the new measure of monetary policy, is shown to be essential for obtaining the baseline effects. This thesis demonstrates that the baseline results are relatively robust to a wide range of different specifications of the baseline vector autoregression.

Keywords: Monetary policy, monetary policy shocks, narrative identification, real-time forecasts, vector autoregression, Norway.

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1. Introduction

1.1 Motivation

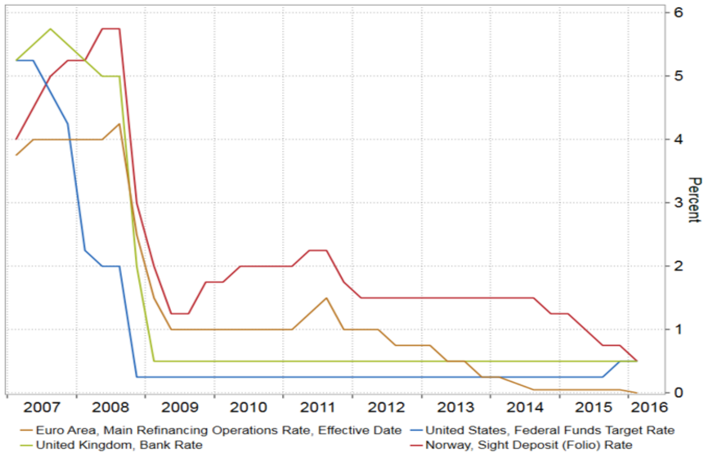
In the wake of the recent financial crisis, developed economies have experienced historically low interest rates. Since the peak of 5.25 per cent in June 2006, The Federal Reserve gradually lowered The Federal Funds Rate to 0.25 per cent in December 2008, in response to the cyclical downturn in the economy, evident from Figure 1. The economic slowdown quickly spread to other major economies, with the consequence of a drop in the central banks' policy rates. Monetary policy has in this period served as a first line of defence, in order to stimulate growth and to ensure a positive rate of inflation.

Several countries are still experiencing weak growth. With policy rates close to zero, the room for additional cuts has been limited. [1] Central banks have therefore been employing unconventional policy instruments such as quantitative easing. By purchasing securities on a large scale basis, they have decreased long-term interest rates even further. Whilst the effect of unconventional instruments has been subject to increased attention, policy rates still remain the main policy instrument.

The Norwegian economy was not hit as hard by the financial crisis as many of their main trading partners, mainly due to the high oil prices in the years following the crisis. While the oil sector contributed to several years of strong GDP growth in Norway, the revenues are now diminishing due to the sharp decline in petroleum prices (The Economist, 2015). In addition, provisions for pensions are expected to increase, placing further limitations on fiscal policy. Norway is indeed entering a restructuring phase. As recently expressed by Øystein Olsen, the governor of the Norwegian central bank, the Norwegian economy has experienced an exceptionally long summer, but winter is coming (Olsen, 2016a). With the current prospects of low future growth, having a precise estimate of the policy rate's effect on macroeconomic variables is of considerable interest to the policymakers, in order to align monetary policy optimally in the restructuring phase.

[1] However, certain central banks, like the central bank of Sweden and Switzerland, have been experimenting with negative policy rates.

Figure 1: Policy rates



Source: Macrobond

In order to obtain a precise estimate of the effect of moves in the central bank's policy rate, one needs to be aware that the policy rate is an endogenous variable, consisting of two parts (Olsen, 2011; Bjørnland & Thorsrud, 2014). The first and endogenous component is driven by the policymakers' response to data in their information set. That is, the systematic reaction to their beliefs about developments in important economic variables. The second component reflects the policymakers' unsystematic actions, not taken in response to their information set. The academic literature has typically referred to these actions as structural monetary policy shocks (Cloyne & Hürtgen, 2015, CH henceforth). This unsystematic part needs to be isolated in order to obtain a precise estimate of the policy rate's effect on economic variables. If the researcher is able to remove the systematic component of monetary policy, the residual and exogenous part of the policymakers' actions would be appropriate to use for estimation purposes.

There are several potential sources of monetary policy shocks in Norway. One source could be an evolution of The Central Bank of Norway's, Norges Bank's, operating procedures. Second, shocks could arise as a result of differences in Norges Bank's preferences and objectives. Norges Bank may for example have reached different conclusions regarding the trade-offs between output and inflation over time. Third, a potential source of monetary policy shocks is the pursuit of other not explicitly stated objectives, such as striving for a weaker exchange rate to support the internationally exposed sector. Finally, monetary policy shocks may arise from factors leading to random variation in monetary policy. Such factors are difficult to identify, and could include elements like personalities and moods of the members of Norges Bank's Executive Board.

There has been considerable research regarding the effects of monetary policy, and a range of empirical estimates has emerged in the academic literature. The validity of the estimates depends crucially on the identification strategy employed. In order to obtain precise estimates, one needs to overcome certain technical challenges. First, the policy rate and other economic variables are determined simultaneously, as central banks react to cyclical movements in addition to affect the economy. That is, it is difficult to estimate the causal effect of moves in the policy rate on economic variables. Second, policymakers are likely to be forward-looking. Thus, forecasts may be an important part of central banks' information set. Third, central banks react to what they know in real time, not ex-post revised data.

By failing to take these three technical challenges into account, one may create a relationship between monetary policy and other economic variables where there is no true causal link, or conceal a relationship that actually exists. Taking these technical challenges seriously might therefore be important to obtain precise estimates. The so-called narrative method, pioneered by Romer and Romer (2004, RR henceforth), aims to take these challenges into account when assessing the effects of monetary policy. The considerable larger effects found by RR (2004), have contributed significantly to the debate on the effects of monetary policy among academics and policymakers. By applying the narrative method, this thesis aims to construct a new, exogenous measure of Norwegian monetary policy that is suitable to employ when assessing the effects of monetary policy on macroeconomic variables. To our knowledge, there have been no applications of this methodology to identify monetary policy shocks on Norwegian data.

1.2 Research questions

This thesis aims to investigate the following:

i) Estimate time series for monetary policy shocks in Norway in the period of flexible inflation targeting (1999 – 2016), using the narrative identification strategy.

ii) By employing our new shock series in a vector autoregression, we will assess the effect of a one percentage point shock to the new measure of monetary policy on output and inflation.

We attempt to investigate these two research questions by creating a new and extensive real-time data set. The data set includes real-time backdata, in addition to real-time forecasts for current and future periods of variables central to Norges Bank's decision on the policy rate, normally referred to as the key policy rate.[2] The aim is to capture the information set of Norges Bank, prior to each key policy rate decision, to purge the key policy rate of systematic policy actions responding to anticipated movements in macroeconomic variables. By employing our new measure of monetary policy in a vector autoregression (VAR), we aim to estimate the effect of moves in the key policy rate for Norway.

1.3 Outline

The remainder of this thesis is structured as follows. Chapter 2 presents theory on Norwegian monetary policy to provide a theoretical background for the subsequent chapters. Chapter 3 gives an overview of previous research in the field of identifying and assessing the effects of monetary policy shocks. Thereafter, the narrative method will be introduced. Chapter 4 starts by presenting the construction of our real-time data set. Then, the focus is on how the new measure of monetary policy is derived, in addition to the results obtained. Chapter 5 presents the baseline VAR results and corresponding robustness checks. Chapter 6 provides final remarks.

[2] The method employed in this thesis is referred to as the narrative identification approach, since it utilizes historical documents to capture the real-time information set of Norges Bank.

2. Theory on Norwegian Monetary Policy

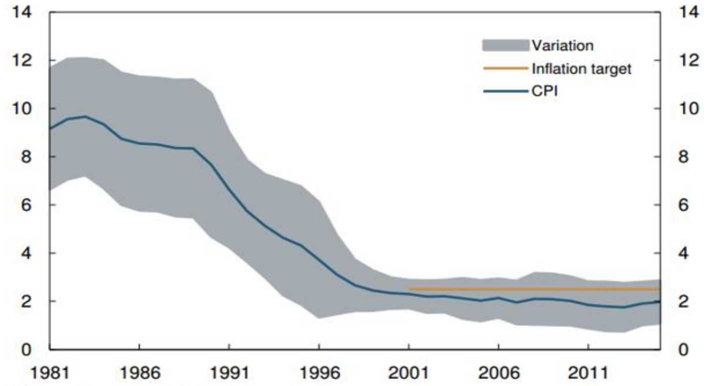
In order to assess the effect that the key policy rate has on inflation and output, it is necessary to give an overview of theory on Norwegian monetary policy. Chapter 2 therefore starts with a brief explanation on how the framework of monetary policy in Norway has developed to the current flexible inflation-targeting regime. Furthermore, it presents theory on how the key policy rate affects economic variables. Finally, the chapter ends with a short discussion on how monetary policy shocks can be interpreted in terms of deviations from Norges Bank's key policy rate path and their estimated average reaction pattern.

2.1. Norwegian monetary policy regimes

Before the introduction of an explicit inflation target of 2.5 per cent in 2001, Norwegian monetary policy shifted between different regimes. During the 1970s and early parts of the 1980s, the policymakers' decisions often contributed to large fluctuations in output and employment, in addition to high and unstable inflation, evident from Figure 2 (Gjedrem, 2005). Norges Bank's independence was limited during this period, and their role was to serve as an advisor and organizer for the authorities in the conduct of monetary policy (Store Norske Leksikon, 2016). The key policy rate was politically decided, and monetary policy was oriented towards increasing the competitiveness of the internationally exposed sector. This was achieved through a fixed exchange rate system, with sudden devaluations that surprised the market. According to Thøgersen (2011a), this type of policy was built on the belief that the policymakers systematically could achieve stronger growth and lower unemployment, by accepting higher levels of inflation. How policy decisions affected the expectations of economic agents were more or less neglected. However, throughout the 1980s, there was a growing consensus that monetary policy should contribute to low and stable inflation. This led to a change in the conduction of Norwegian monetary policy. In 1986, the low interest rate regime came to an end, as Norges Bank was given the responsibility for the key policy rate decision.

From 1994, Norges Bank aimed at keeping the Norwegian krone stable against the currencies of important European trading partners (Storvik, 1997). The objective of fiscal policy was to act as a stabilizer against cyclical imbalances. However, with revenues from the petroleum sector rising, this proved to be difficult, as the pressure of increased fiscal spending was high. From 1997 the Norwegian krone became increasingly volatile, and the aim of monetary policy shifted from stabilizing the exchange rate towards low and stable inflation (Gjedrem, 2005).

Figure 2: 10-year moving average1) and variation2) in the CPI. Annual change. Per cent.



1) The moving average is calculated 10 years back.
2) The band around the CPI is the variation in the CPI in the average period, measured by +/– one standard deviation.

Source: Norges Bank (2016a)

2.2 New guidelines for the Norwegian monetary policy

The lessons learned from the late 1990s, led to the introduction of new guidelines for fiscal and monetary policy in 2001 (The Norwegian Ministry of Finance, 2000-2001). The current mandate for Norwegian monetary policy, states that Norges Bank should stabilize the value of the Norwegian krone, and thereby contribute to stable expectations regarding the development in the exchange rate. In addition, monetary policy should underpin fiscal policy, by contributing to stable developments in output and employment (Norges Bank, 2003a). The mandate is followed through an operational target of an annual consumer price inflation of approximately 2.5 per cent over time.[3] Direct changes in consumer prices resulting from fluctuations in interest rates, taxes, excise duties and temporary disturbances are in general not taken into account.[4]

Norway's inflation target is slightly higher than the inflation target of its most important trading partners, which is set at 2.0 per cent (Central Bank News, 2016). At the same time as the inflation target was introduced in Norway, the fiscal spending rule was presented as a guideline for fiscal policy.[5] As Schjøtt-Pedersen (2001) claims, it was necessary for Norway to introduce a higher inflation target in order to ensure a stable exchange rate, while phasing the revenues from the petroleum sector. The reason is that increased spending of petroleum wealth, results in higher domestic wage growth, and the cost increase can either appear in terms of real appreciation or increased domestic prices (Norman & Orvedal, 2010).

[3] The inflation target is set above zero, as too low inflation makes it difficult to decrease real- and adjust relative wages because of price and wage stickiness (Akerlof et al., 1996).
[4] Norwegian core inflation is currently measured by the CPI-ATE, which is the consumer price index adjusted for tax changes and excluding energy products (Norges Bank, 2016b).
[5] The fiscal spending rule states that the structural, non-oil budget deficit shall correspond to the real return of The Government Pension Fund Global, estimated at four per cent (Norges Bank Investment Management, 2011).

Norges Bank is responsible for the implementation of monetary policy in Norway. They decide on their main policy tool, the key policy rate, normally six times a year with a goal of stabilizing inflation close to the inflation target in the medium term (Norges Bank, 2016a).[6] The reason is that monetary policy affects inflation with long and variable lags (Olsen et al., 2002). Norges Bank should therefore be forward-looking when making decisions regarding the key policy rate. Publishing forecasts of inflation and real activity might be useful, in order to anchor people's expectations about future developments in macroeconomic variables. Norges Bank therefore currently publishes four monetary policy reports (MPRs) a year, coinciding with four of the monetary policy meetings.[7]

2.3 Flexible inflation targeting

Most countries with an explicit inflation target are small, open economies (Røisland & Sveen, 2005). The reason is that these countries are strongly dependent on exports and imports. Thus, a stable and predictable development in the exchange rate is important. An explicit inflation target contributes to stable expectations for the exchange rate. However, Walsh (2009) argue that there is no such thing as strict inflation-targeting regimes, which are only concerned about stabilizing inflation around target. In fact, central banks with an inflation target are all aiming at stabilizing both inflation and output. This is in the literature referred to as flexible inflation-targeting. Since the early 1990s, several central banks decided to adopt a rule-based conduction of monetary policy, through the introduction of an inflation target. The current consensus is that flexible inflation-targeting regimes are best practice (Thøgersen, 2004).[8]

The guidelines for Norwegian monetary policy is given by three criteria for an appropriate key policy rate path (Norges Bank, 2016a):

1. *The inflation target is achieved*
2. *The inflation-targeting regime is flexible*
3. *Monetary policy is robust*

[6] Norges Bank has changed the time horizon for reaching the inflation target twice since the introduction of the target in 2001. Originally it was set at two years, then modified to 1-3 years in 2004, and finally changed to the medium-term in 2007 (Thøgersen, 2011b).
[7] From 1996 to 2006, the reports were called Inflation Reports (IRs). For simplicity, we will refer to Norges Bank's reports as MPRs in the remainder of the thesis.
[8] The foundation of rule-based economic policy was first introduced by Kydland and Prescott (1977).

The first criterion states that the key policy rate should be set in order to stabilize inflation at target, or bring inflation back to target after a deviation has occurred. The second criterion specifies that the key policy rate path should provide a reasonable balance between the path for expected inflation, and the path for expected overall capacity utilization in the economy. Thus, the inflation-targeting regime is made flexible. The third criterion implies that the key policy rate path should take into account particularly adverse economic outcomes.[9]

The first two criteria represent a trade-off that Norges Bank has to consider when deciding on the key policy rate. These considerations can be simplified mathematically in terms of a loss function, where the parameter λ denotes the relative weight put on output deviation (Norges Bank, 2012).

(1) $$L_t = (\pi_t - \pi^*)^2 + \lambda(y_t - y_t^*)^2$$

L_t refers to Norges Bank's loss, when deviating from the two policy targets. The first term on the right hand side represents the deviation in inflation, π_t, from the inflation target, π^*, and coincides with the first criterion presented above. The two terms on the right hand side constitute the second criterion. In addition to stabilize inflation around target, Norges Bank aims at minimizing the deviation in current output, y_t, from the potential output, y_t^*. Norges Bank's preferences are expressed through the parameter λ. A large value of λ implies a greater weight put on minimizing the output gap, at the expense of stabilizing inflation. This extends the time horizon for achieving the inflation target.

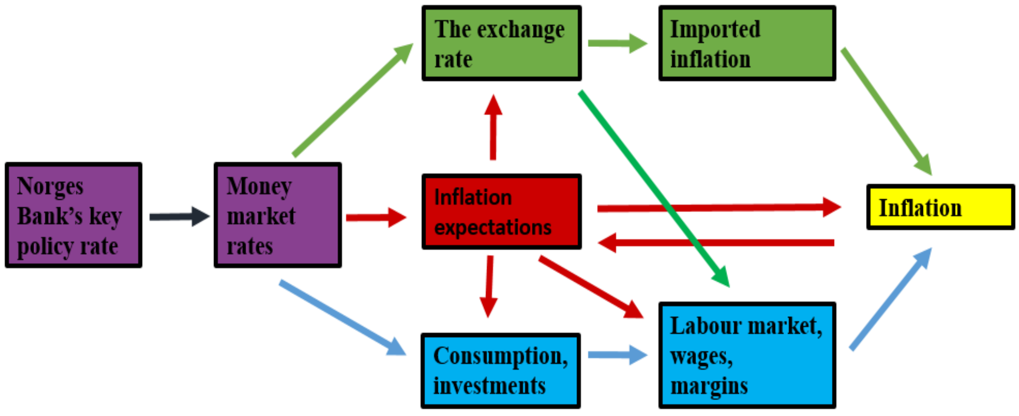
2.4 The transmission mechanism of monetary policy

A key policy rate change affects output and inflation through various channels. This is often referred to as the transmission mechanism of monetary policy, evident from Figure 3. The key policy rate is determining short-term money market interest rates.[10] Private banks' key policy rate expectations will therefore play a significant role for their lending and deposit rates. The market's forecast of future developments in the key policy rate is reflected through money market interest rates with longer maturity. This is expressed through the yield curve, which illustrates the relationship between interest rate levels and maturity (Cooper et al., 2001).

[9] The third criterion will be presented in detail in section 2.5.
[10] During the financial crisis in 2008/09, there was a significant increase in the spread between short-term money market rates and the expected key policy rate, due to increased risk premiums (Bache & Bernhardsen, 2009).

Expectations about higher levels of the key policy rate in the future lead to a rising yield curve, and vice versa.

Figure 3: The transmission mechanism of monetary policy



Source: Norges Bank (2004a).

2.4.1 The demand channel

As highlighted by Mishkin (2007), it is real interest rates, as opposed to nominal interest rates, that affect demand and investments. Due to price stickiness, short-term market rates have an impact on real interest rates. Thus, contractionary monetary policy increases the cost of capital and lowers investment spending. This will in turn decrease aggregate demand for housing and consumer durables, leading to a decline in output and a rise in unemployment. Furthermore, higher real interest rates will decrease wage growth, which in combination with lower margins in enterprises lead to decreased inflation (Norges Bank, 2004a).

2.4.2 The exchange rate channel

If Norges Bank decides to increase the key policy rate, it becomes more attractive to invest in the Norwegian krone, relative to other currencies. The increased demand for the Norwegian krone leads to an appreciation and weakened competitiveness for firms in the internationally exposed sector (Norges Bank, 2004a). Since imported goods now become relatively cheaper, imported inflation decreases. In addition, the stronger Norwegian krone leads to lower prices on imported inputs, and lower production costs will drive inflation further down. Furthermore, a tighter monetary policy will affect the net export negatively, resulting in a decline in aggregate demand (Mishkin, 2007).

2.4.3 The expectation channel

Expectations concerning future inflation and economic stability are particularly important in the exchange rate market. The expectations about future inflation will also influence wage demands. If Norges Bank increases the key policy rate, this causes lower inflation expectations in the future (Norges Bank, 2004a). Economic agents are then likely to lower their wage demands, and the prices set by firms will fall. In addition, lower expected inflation might cause an appreciation of the Norwegian krone, contributing further to the fall in inflation.

Norges Bank puts a lot of weight on being transparent and achieving credibility, in order for the economic agents to internalize their reaction function. If Norges Bank is able to anchor the expectations of the economic agents, expected inflation will contribute to stabilize inflation around the inflation target (Norges Bank, 2004a). Thus, managing expectations is important, since it creates an additional tool for the policymakers to enforce economic stability. A commitment to future expansionary monetary policy could raise expected inflation, and thereby decrease real interest rates, even in periods where nominal interest rates are already close to its lower bound (Mishkin, 2007). Norges Bank therefore uses many resources to communicate with the economic agents. In addition to publish four MPRs a year, they attempt to be transparent through channels like extensive press releases and lectures. The goal is to explain their view regarding the macroeconomic development, and to increase the knowledge of the economic agents regarding the workings of monetary policy.

2.5 The robustness criterion

In Norges Bank's guidelines for an appropriate key policy rate path, the third criterion states that monetary policy should be robust. Among other objectives, monetary policy should seek to mitigate the risk of financial imbalances. The consideration of robustness may also imply a more active monetary policy than normal in periods when the economy is subject to major shocks (Norges Bank, 2016a). To make an illustration of the considerations that are made, Norges Bank included the robustness criterion in an extended loss function in MPR 1/12:

(2) $$L_t = (\pi_t - \pi^*)^2 + \lambda(y_t - y_t^*)^2 + \gamma(i_t - i_{t-1})^2 + \tau(i_t - i_t^*)^2$$

where the parameters λ, γ and τ denote the relative weights they put on the different terms, i_t is the current key policy rate, i_{t-1} is the key policy rate from the previous period and i_t^* is the long-term equilibrium rate (Norges Bank, 2012). The third criterion is captured by the last three terms on the right hand side of Equation (2). In addition to minimize the output gap, Norges Bank prefers a gradual change in the key policy rate. If there are large deviations from one period to the next, this might create imbalances in the economy (Nicolaisen, 2011). Norges Bank therefore seeks to avoid abrupt changes in the key policy rate. The last term on the right hand side of Equation (2), indicates that there is a loss associated with the key policy rate deviating from its normal level.[11] By taking the last term into account, Norges Bank might reduce the risk of financial imbalances. This is because low interest rates for extended periods, can increase the risk that debt and asset prices will rise and remain higher than what is sustainable over the economic cycle (Jordà et al., 2011). Norges Bank has not presented the three criteria in terms of a loss function since MPR 3/13. One possible reason could be that they do not want to appear bound by rules. In addition, the robustness criterion is complex and one can argue that it cannot be captured by simply adding two terms to the loss function, presented in Equation (1). Still, the loss function in Equation (2) provides a reasonable illustration of Norges Bank's reaction pattern.

In the wake of the financial crisis in 2008/2009, there has been a debate among researchers and macroeconomists regarding whether central banks should consider the risk of build-ups of financial imbalances. Reinhardt and Rogoff (2009) illustrate that the consequences of not taking these build-ups into account during booms could be devastating. Eichengreen et al. (2011) therefore argue that the conventional relationship between price stability and other goals of macroeconomic and financial stability clearly needs to be redefined. Monetary policy should, according to Eichengreen et al. (2011), take these risks into account. On the other hand, Svensson (2012) argue that macroprudential regulation is better suited to prevent build-ups of financial imbalances.[12] Monetary policy should therefore not take these concerns into account when deciding on the policy rate. Woodford (2012) and Smets (2014) seem to have a view in between. They argue that central banks should consider other objectives, in addition to inflation and output, at least in periods when there is a risk that financial imbalances are building up. Following Woodford (2012) and Smets (2014), Norges Bank argues that monetary policy

[11] Due to expectations about low interest rates internationally, Norges Bank changed their perception about what the normal level of the key policy rates is, down to 4 per cent (Norges Bank, 2012).

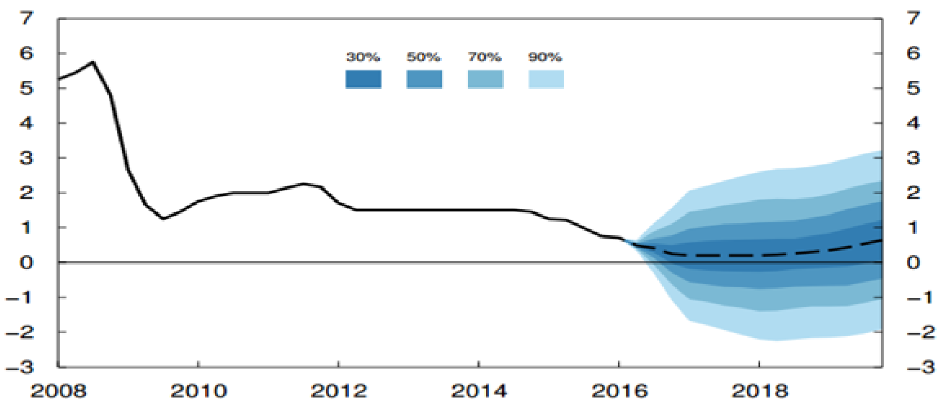
[12] Macroprudential regulation is the credit standards and capital requirements that banks are subject to. The banks should hold capital in proportion to its risk exposure, to reduce the build-up of systemic risk and ensure that the financial system is resilient to shocks (Olsen, 2013).

should “lean against the wind” by taking into account the risks of financial imbalances, as these can have substantial real economic costs (Olsen, 2014).[13]

2.6 Expectation management and monetary policy shocks

Figure 4 shows that Norges Bank is applying projections of the key policy rate path with fan charts, as a tool in their expectation management. If Norges Bank decides on a key policy rate that deviates substantially from the projected path, they will most likely take the market by surprise. Such unexpected events could be interpreted as monetary policy shocks, since the projected key policy rate path summarizes Norges Bank’s information set.[14]

Figure 4: Projected key policy rate in baseline scenario. Per cent.



1) The fan charts are based on historical experience and stochastic simulations in our main macroeconomic model, NEMO. The fan chart for the key policy rate does not take into account that a lower bound for the interest rate exists.
2) Projections for 2016 Q1 – 2019 Q4 (broken line).

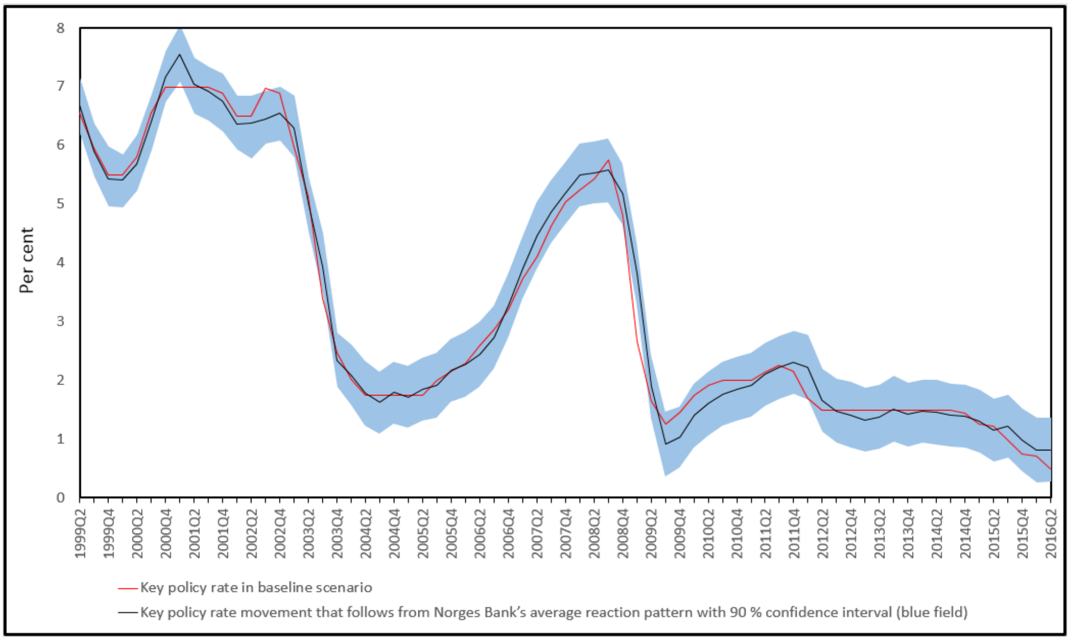
Source: Norges Bank (2016a)

Figure 5 pictures Norges Bank’s estimated average reaction pattern in monetary policy, given the development of certain macroeconomic variables in the past. However, in actual policy rate decisions, emphasis is put on many indicators. It is important to note that an estimated equation will not capture all relevant factors. In particular, it does not capture special considerations made at various monetary policy meetings (Norges Bank, 2004b). Thus, the estimated equation will be a considerable simplification and only give an indication of how the key policy rate on average has reacted to the included variables in the model. Differences between the estimated average reaction pattern, and the key policy rate in the baseline scenario, is reflecting

[13] To ”lean against the wind” implies a bias toward a tighter policy than justified by stabilizing inflation and unemployment, in order to avoid financial imbalances (Svensson, 2014).
[14] The relevant information set in our analysis, are those of the policymakers. Thus, it might be the case that actions taken by Norges Bank, in response to their information set, will be surprises relative to the information set of the private sector. Still, given the transparency of Norges Bank, it is reasonable to assume that the information set of the private sector have a reasonable degree of correlation with the information set of Norges Bank.

inconsistency that is not explained by the information set included in the model. This could be interpreted as monetary policy shocks.

Figure 5: Norges Bank's average reaction pattern of interest rate setting



Source: Norges Bank (2004b; 2016a)

Notes: Figure 5 is constructed by combining the data material from Chart 1 in IR 3/04 and Chart 2.19 in MPR 1/16. For further details on the estimated average reaction function, see Bernhardsen (2008).

It follows from Figure 5 that Norges Bank has been relatively consistent in their conduct of monetary policy. The interpretation could be that the estimated shock component is of a moderate size, making it more difficult to estimate the precise effect that the key policy rate has on macroeconomic variables.[15] However, key policy rate has deviated from the estimated average reaction pattern in certain periods. In the beginning of 2001 and during the financial crisis (2008/09), the key policy rate in the baseline scenario is considerably lower than what the estimated model predicts. This may be an indication of expansive monetary policy shocks. On the other hand, the key policy rate is substantially higher in mid-2002 than the estimated average reaction pattern. This could be a potential contractionary shock. In section 4.4, where we present our new measure of monetary policy, we show that our results are relatively consistent with the deviations from the estimated average reaction pattern of Norges Bank.

[15] This point is made by both Coibion (2012) and CH (2015).

3. Literature Review

This thesis aims to estimate the precise effect of moves in the key policy rate on output and inflation. Despite considerable research in the academic literature, there are still disagreements about the effects. The key question is the choice of an appropriate identification strategy. Throughout the history of identifying and assessing the effects of monetary policy shocks, a range of identification strategies have been applied. We will refer to these applications as the conventional literature. The estimated effect on prices and output generated by these identification strategies, following a one percentage point shock to the policy measure, tend to be between 0.5 and 1.0 per cent.[16] The most widely employed method to isolate the effects of monetary policy shocks on macroeconomic variables has been through different specifications of VAR models.

3.1 The conventional literature

3.1.1 Vector autoregression

VARs are based on the utilization of information from various highly correlated macroeconomic indicators (Bjørnland et al., 2005). VAR studies on the effects of monetary policy use economic theory to construct restrictions on the relationships between different endogenous variables, in order to identify monetary policy shocks. Following Christiano et al. (1996), the most commonly used restriction in VARs is a so-called recursiveness assumption, where the policy measure is ordered last. This allows all the included variables to contemporaneously affect the policy measure. On the other hand, the policy measure is assumed to have a lagged effect on macroeconomic variables (Bjørnland et al., 2005).

Dedola and Lippi (2005) measure the effect of unanticipated monetary policy shocks, by using a VAR approach. They argue that the VAR is well suited as a tool to analyze the effect of these shocks, since it controls for the systematic interaction between the different endogenous variables. In their study on UK data, they find that a one percentage point shock to the policy measure leads to a peak decline in output by 0.5 per cent, and an insignificant response in the price level of 0.2 per cent. Bernanke and Mihov (1998) apply the VAR approach on US data.

[16] The research presented in this chapter employ different measures for output and prices. The interpretation of the output measures is similar in the sense that all studies employ an output measure that is presented in levels. Thus, a one percentage point shock to the policy measure leads to a percentage change in the output measure. The interpretation of the price measure is similar to the output measure if it is presented in levels. However, if the price measure employed is presented as an annual change, such as an inflation rate, the interpretation is that a one percentage point shock to the policy measure leads to a percentage point change in the inflation rate. The results from the conventional literature are presented in Table 1.

They find a peak decline in output of 1.0 per cent, and a decrease in the price level of 1.6 per cent. Christiano et al. (1999) also apply the same method on US data. Their results show a peak decline in output by 0.7 per cent, and a peak decline in the price level of 0.6 per cent. The results obtained from these VAR studies are in line with the ones presented by the VAR literature in general.

3.1.2 Factor augmented vector autoregression

The results from standard recursive VAR studies have been subject to criticism regarding the sparse information sets typically used in these empirical models. To save degrees of freedom, standard recursive VARs rarely employ more than six to eight variables. Bernanke et al. (2005) argue that the small number of variables is unlikely to span the information sets used by central banks. They advocate that this leads to at least two potential problems. First, the identification of monetary policy shocks is likely to be biased if the central bank has information that is not taken into account in the VAR. One such issue could be that a standard recursive VAR does not take into account the importance of forecasts in the estimation (Barakchian & Crowe, 2013). An example is the common finding in the conventional VAR literature, referred to as the "price puzzle", where a contractionary monetary policy shock causes an initial increase in the price level. This result contradicts standard economic theory, and was first presented in Sims (1992). He argues that the price puzzle is caused by imperfectly controlling for information that the central bank may have about future inflation. The second potential problem is the parsimonious specifications that a typical VAR employs (Bernanke et al., 2005). The researchers and policymakers may, in addition to prices and output, be interested in the effect on variables such as total factor productivity, real wages, profits, investments and asset prices. Thus, the impulse responses in a VAR will only depend on a small subset of variables.[17]

To attempt to solve these potential problems, Bernanke et al. (2005) extend the standard VAR, by using factor augmented VARs (FAVARs) to exploit a wider range of data on the US market. Both Stock and Watson (2002) and Bernanke and Boivin (2003) show that the information from a large number of time series in dynamic factor models can be summarized by a relatively small number of estimated indexes. They demonstrate that forecasts based on these indexes can outperform standard VARs. FAVARs can therefore provide more precise estimates, while still conserving degrees of freedom. By using the FAVAR, Bernanke et al. (2005) find a peak

[17] An impulse response function describes how a given structural shock affects the included macroeconomic variables over time (Bjørnland & Thorsrud, 2014).

decline in output of 0.6 per cent and a peak decline in the price level of 0.7 per cent, caused by a one percentage point shock to the monetary policy measure. They also resolve the price puzzle. Ellis et al. (2014) estimate a FAVAR model for the UK. They find that a one percentage point shock to the policy measure lead to a maximum output decrease of 2.0 per cent, and a decline in the price level of 2.0 per cent. However, the FAVAR approach requires large data sets. An advantage of the narrative identification strategy, that this thesis will employ to identify monetary policy shocks, is that Norges Bank's internal forecasts can be seen as summary statistics of their information set.[18] Thus, our approach is not dependent on a wide range of data.

3.1.3 Market based identification

Another method of isolating monetary policy shocks is conducted by utilizing forward-looking financial market data. Barakchian and Crowe (2013) show, when estimating the effect of monetary policy shocks in the US, that the results obtained are sensitive to the time period of investigation. They argue that this is mostly based on the fact that central banks today have become more systematic and forward-looking when deciding on the policy rate. This reduces the size of monetary policy shocks. Their findings from the 1970s and early 1980s indicate stronger effects than the results obtained in the post 1980-period, where the identified shocks were smaller in magnitude. Hence, monetary policy appeared to have a smaller effect in this time period.

As Kuttner (2001), Gürkaynak et al. (2005) and Piazzesi and Swanson (2008), Barakchian and Crowe (2013) aim to identify the unexpected shock component of monetary policy actions, through a market based approach. This is conducted by analyzing the movements in Fed Funds Futures contract prices on the day of monetary policy announcements following The Federal Open Market Committee (FOMC) meetings.[19] By employing their shock measure in a VAR framework, they find that a one percentage point monetary contraction causes a statistically significant negative effect on output of around 0.9 per cent. In addition, they find that their shock measure can account for up to half of output volatility at a horizon of three years, around twice the proportion found in standard VARs. Regarding the effect on the price level, they find evidence of a price puzzle.

[18] This will be further clarified in section 4.1.
[19] The FOMC is the monetary policymaking body of the Federal Reserve System. It consists of seven members from the Board of Governors and five Reserve Bank presidents (Federal Reserve, 2015).

3.1.4 High frequency identification

Gertler and Karadi (2015) also focus on forward-looking financial market data when identifying monetary policy shocks. The particular approach they employ is to combine standard VAR analysis with high frequency identification (HFI). One advantage of this method is that it does not rely on the timing restriction in standard VARs. As they highlight, the timing restriction may be reasonable regarding the interaction between the policy rate and economic variables, at least for short time periods. However, once financial variables are included the timing restriction becomes problematic, as shocks to the policy rate will not only affect financial variables, they are likely to respond to them as well.[20] The HFI approach addresses the problem of simultaneity by focusing on daily data. The key identifying assumption is that news about the economy on the day of the policy rate meeting, does not affect the policy rate decision. In order to measure the persistence of monetary policy shocks, Gertler and Karadi (2015) employ a full VAR to trace out the dynamic response of real and financial variables. They find a peak decline of 2.0 per cent in output and maximum decline of 0.75 in the price level.

3.1.5 Sign restriction identification

The basic idea of the sign restriction approach is to seek identification by imposing restrictions on the shape of the impulse response functions (Bjørnland & Thorsrud, 2014). The sign restrictions are constructed on the basis of economic theory. That is, a contractionary monetary policy shock should lead to a rise in interest rates and a decline in prices and output on impact. Uhlig (2005) applies the sign restriction approach on US data. For a monetary contraction of one percentage point, he finds a peak decrease of 0.3 per cent in output and a decline in the price level of 1.0 per cent. Mountford (2005) employs this method on UK data, and finds a peak decline in output by 0.6 per cent and a maximum decline in the price level by 0.15 per cent. Bjørnland and Thorsrud (2014) point out that a possible drawback for the sign restriction approach is that it does not imply a unique identification. In particular, there tend to be many impulse responses that satisfy the imposed sign restriction. Since they are only set-identified one might end up with a multiple of responses, with the consequence of inexact identification of monetary policy shocks (Fry & Pagan, 2011).

[20] As data for financial variables are reported at a high frequency, it is more likely that simultaneity will be a problem than for variables such as output and inflation. Thus, the timing restriction will be a less suitable assumption with respect to financial variables.

3.2 Studies on Norwegian data

Bjørnland (2008) estimates a non-recursive VAR that imposes a long-run neutrality assumption to the exchange rate.[21] In particular, monetary policy shocks are restricted from having long-run effects on the real exchange rate. Bjørnland (2008) finds that a one percentage point shock to the policy measure decreases output by 0.25 per cent at the peak, and causes a peak decline in inflation of 0.1 percentage points. Bjørnland and Jacobsen (2009) estimate a similar VAR, where the policy measure in addition is restricted from influencing output in the long run. They find a peak decline in output of 1.0 per cent, while the response of inflation shows evidence of a price puzzle. The effect on inflation does, however, eventually turn negative and reaches a peak decline of 0.25 percentage points. In addition, Bjørnland and Jacobsen (2009) estimate a standard recursive VAR with the policy rate ordered last. When this identification strategy is employed, they find a peak decline in inflation of 0.2 percentage points, with a slightly larger price puzzle compared to their preferred approach.

Robstad (2014) estimates a VAR with the standard recursive ordering, and finds that inflation increases on impact before the effect eventually dies out. The effect on output on the other hand, is negative and reaches a peak decline of approximately 1.7 per cent. However, by estimating a VAR using a sign restriction approach, Robstad (2014) is able to remove the price puzzle. The peak decline in inflation is then estimated to approximately 0.4 percentage points and about 1.5 per cent for output. To allow for multidirectional effects between interest rates and asset prices, Robstad (2014) follows Bjørnland and Jacobsen (2009), and estimates a non-recursive VAR. By employing this identification strategy, most of the price puzzle is eliminated. The peak decline in inflation and output is approximately 0.3 percentage points and 1.0 per cent respectively. Llaudes (2007) investigates the effect of monetary policy shocks on different economies in Europe. Employing the recursive identification strategy for Norway, Llaudes (2007) finds evidence of a large and significant price puzzle with respect to the price level. For output, the effect is divided into a tradable and a non-tradable sector. The peak decline in the non-tradable sector is estimated at 0.45 per cent, and 0.9 per cent for the tradable sector.

[21] Non-recursive identification states that the matrix, which contemporaneously links structural shocks and reduced form residuals in the VAR, is no longer lower triangular. Instead, one assumes a general form indicated by theory, such that the rows of the matrix have a structural interpretation (Rusnák et al., 2013).

3.3 The conventional literature summarized

The conventional literature has produced a range of empirical estimates regarding the effect on inflation and output, following a one percentage point shock to the policy measure. The estimates tend to be between 0.5 and 1 per cent, summarized in Table 1.

Table 1: The effects of monetary policy in the conventional literature

Method	**Authors**	**Country**	**Peak Effects**	
			Output	**Price measure**
VAR (recursive)	Dedola and Lippi (2005)	UK	-0.5 (IP)	0.2 (CPI)
	Christiano et al. (1999)	US	-0.7 (GDP)	-0.6 (GDP defl.)
	Robstad (2014)	NOR	-1.7 (GDP)	0.0 (CPI-ATE)
	Bjørnland and Jacobsen (2009)	NOR	n/a.	-0.2 (CPI-ATE)
	Bernanke and Mihov (1998)	US	-0.6 to -1.0 (IP)	-0.7 to -1.6 (GDP defl.)
	Llaudes (2007)[22]	NOR	-0.45/-0.9 (GDP)	0.2 (CPI)
FAVAR	Bernanke et al. (2005)	US	-0.6 (IP)	-0.7 (CPI)
	Ellis et al. (2014)	UK	-1.0/-2.0 (IP, 75-91/92-05) -0.5/-0.5 (GDP,75-91/92-05)	-0.3/-2.0 (CPI, 75-91/92-05)
Market based	Barakchian and Crowe (2013)	US	-0.9 (IP)	-0.1 (CPI)
VAR-HFI	Gertler and Karadi (2015) [23]	US	-1.0 to -2.0 (IP)	-0.75 to 0.3 (CPI)
Sign restriction	Uhlig (2005)	US	-0.3 (GDP)	-1.0 (GDP defl.)
	Mountford (2005)	UK	-0.6 (GDP)	-0.15 (GDP defl.)
	Robstad (2014)	NOR	-1.5 (GDP)	-0.4 (CPI-ATE)
VAR (non-recursive)	Bjørnland (2008)	NOR	-0.25 (GDP)	-0.1 (CPI-ATE)
	Robstad (2014)	NOR	-1.0 (GDP)	-0.3 (CPI-ATE)
	Bjørnland and Jacobsen (2009)	NOR	-1.0 (GDP)	-0.25 (CPI-ATE)

Notes: The numbers in the table are results from impulse responses presented in the conventional literature. The specific output and price measures are shown in brackets, where IP represents industrial production and GDP defl. is the GDP deflator. The peak effects are presented in per cent or percentage points, depending on the measure that is employed. See Footnote 16 for more information regarding the interpretation of the peak effects.

[22] The first output result reported is for the non-tradable sector, while the second is for the tradable sector.
[23] The results reported are for the full sample (1979-2012) and the sample excluding the financial crisis (1979-2008).

Most of the recent literature on the effects of monetary policy has employed standard recursive VARs, relying on the identifying assumption that monetary policy shocks have no contemporaneous effect on macroeconomic variables (Coibion, 2012). The other identification strategies discussed above, have tried to overcome some of the limitations in the standard VAR. Despite the effort, the results obtained have not been considerably different than the effects from standard recursive VARs. The predominant finding of the effects that the policy measure has on macroeconomic variables still remains relatively small. Following RR (2004), CH (2015) present three technical challenges that could explain the rather weak response to monetary policy shocks found in the conventional literature. These issues will be presented in section 3.4.

3.4 Three technical challenges

3.4.1 Simultaneity bias

One central issue in monetary policy analysis is the presence of endogeneity as interest rates and macroeconomic variables are determined simultaneously. The standard VAR literature has partially tackled the simultaneity problem by imposing the recursiveness assumption. However, to be able to identify exogenous monetary policy shocks, one also has to separate cyclical movements in the short-term market interest rates, from the central bank's intended change in the policy target rate. Endogenous movements in short-term rates that are not controlled for could lead to a bias in the estimates of the policy rate's effect on macroeconomic variables (RR, 2004). This issue is particularly relevant for the US, where the FOMC sets a target for the federal funds rate and attempts to hit the target by buying or selling government securities (Federal Reserve Bank of St. Louis, 2016). The implication is that the fed funds rate moves a great deal from day to day for reasons unrelated to monetary policy. When estimating the effect of the policy rate on macroeconomic variables one should rather focus on the central bank's intended policy rate.

3.4.2 Omitted variable bias

Another technical problem when identifying the effects of moves in the policy rate is that they most likely contain anticipatory movements (RR, 2004). Central banks in an inflation-targeting regime invest many resources in producing forecasts when deciding on the policy rate (Olsen et al., 2002). They are therefore likely to react to both expected future economic conditions, as well as current and past information. Furthermore, forecasts are often designed to offset future business cycle movements, and are therefore likely an important part of the systematic component of the policy rate decision. The failure to incorporate forecasts, when identifying and assessing the effect of moves in the policy rate, could therefore lead to an incorrect identification of the unsystematic component of monetary policy. For example, if the central bank predicts that the economy is entering an expansionary phase, it will typically raise the policy rate. In theory, this will counteract the cyclical movement. A regression that does not incorporate forecasts in the estimation, may therefore underestimate the negative relationship between the policy rate and output growth (RR, 2004). The reason is that the identified monetary policy shocks still contain anticipatory movements.

CH (2015) argue that excluding forecasts in a regression designed to identify monetary policy shocks would cause an omitted variable bias.[24] Following Wooldridge (2013), the bias from omitting a variable that belongs in the true model can be summarized by Equation (3), if the true population model has two explanatory variables and an error term:

$$(3) \qquad Bias\,(\tilde{\beta}_1) = E(\tilde{\beta}_1) - \beta_1 = \beta_2 \tilde{\delta_1}$$

where $E(\tilde{\beta}_1)$ is the expected value of the coefficient $\tilde{\beta}_1$ from the underspecified model, β_1 is the true coefficient of x_1, β_2 is the true coefficient of the omitted variable, x_2, and $\tilde{\delta_1}$ is the sample covariance between the two variables. The direction of the bias in $\tilde{\beta}_1$ therefore depends on the signs of both β_2 and $\tilde{\delta_1}$.

An example of a simplified underspecified model, is presented in Equation (4):

$$(4) \qquad Policy\,rate = \beta_0 + \beta_1 \mathcal{F}[GDP_t] + v, \qquad \text{where } v = \beta_2 \mathcal{F}\left[GDP_{t+1,t+2,\dots,t+n}\right] + u$$

where $\mathcal{F}$ denotes the forecasts of GDP growth, t represents the time period and v is the identified monetary policy shock from the underspecified model. A consequence of leaving out future forecasts of GDP growth $\left(GDP_{t+1,t+2,\dots,t+n}\right)$ from the model, could be an omitted variable bias. Standard economic theory predicts that the coefficients on both current and future forecasts on GDP growth, in addition to the correlation between the two variables, are positive. According to Wooldridge (2013), the result might be a positive bias in the estimated β_1

[24] This will violate the so-called zero conditional mean assumption. That is, the explanatory variables will be correlated with the error term in the regression (Wooldridge, 2013).

coefficient. The reason is that some of the estimated variation in the forecasted current GDP growth is caused by the effect of future forecasts on GDP growth that are left in the error term, v. The error term will then still contain anticipatory movements, and not reflect exogenous monetary policy shocks. By employing v as the unsystematic component and measure of monetary policy, one will most likely end up with imprecise estimates on the effect of moves in the policy rate.

3.4.3 Real-time data

A third problem often neglected in the conventional literature on the effects of monetary policy, is the failure to take into account that central banks base their decisions on the information available in real time. Many empirical articles, instead base their analysis on ex-post data that are often not available for policymakers when they decide on the policy rate. In particular, historical GDP data are often subject to considerable revisions, compared to the first estimates given (Olsen et al., 2002). For example, in 2013, the historical estimates on GDP data for Mainland Norway were revised up in the range of 1.5 to 2.1 per cent in the period between 1995 and 2013 (SSB, 2014).

Several studies show that estimated monetary policy reaction functions are substantially different when using real-time instead of ex-post data. Orphanides (2001) finds, by estimating a Taylor rule, that US monetary policy is less accommodative to inflation using real-time rather than revised data.[25] Olsen et al. (2002) found that the Taylor rate for Norway was on average 1.5 percentage points higher with revised compared to real-time data, in the period from 1998 to 2001. Regressions that intend to recover monetary policy shocks should therefore be based on the real-time information set of the central banks. Residuals obtained from reaction functions fitted with ex-post revised data will be difficult to interpret as monetary policy shocks, since they contain the effect of data revisions. Monetary authorities respond to data available at the time of the decision, and revised data is therefore a poor guide to capture their information set.

3.5 The narrative identification strategy

By employing the narrative method, RR (2004) find that the effects of monetary policy shocks are relatively larger than the effects obtained in the conventional literature. RR (2004) utilize historical documents to construct a series for the intended policy target rate and to capture the

[25] For more information on the Taylor rule, we refer to the original paper by Taylor (1993).

real-time information set of the policymakers. They highlight that the included forecasts need to be orthogonal to the policy rate decision.[26] The relatively large effects of monetary policy, found by RR (2004), suggest that the narrative method is successful in taking the three technical challenges presented above into account.

RR (2004) construct a series of the implied policy target rate through detailed readings of the Federal Reserve's narrative accounts of each FOMC meeting, in order to extract information about moves in the intended policy rate. They thereby removed any endogenous movements in the fed funds rate. As for CH (2015), we do not need to construct this series, since Norges Bank's key policy rate is the intended policy target rate. While central banks in other countries set the policy rate through open market operations, Norges Bank's key policy rate is in fact the rate on their standing facilities. That is, banks' interest rate on sight deposits in Norges Bank (Olivei, 2002). This implies that the simultaneity problem faced by RR (2004) is not relevant when identifying monetary policy shocks in Norway.

RR (2004) are handling the problem of omitted variable bias by removing systematic policy actions that the policymakers are taking in response to forecasted macroeconomic fluctuations. By controlling for the central bank's own forecasts, RR (2004) are able to purge the policy rate of systematic responses to future developments in macroeconomic variables. In addition, when applying the narrative method, both RR (2004) and CH (2015) are controlling for the relevant real-time information available to the policymakers at the time of their decision. Thus, they are taking the problem regarding real-time versus ex-post data seriously.

3.5.1 Results from the narrative identification strategy

Different studies using the narrative method have in common that they find considerably larger effects of monetary policy shocks on macroeconomic variables, compared to the conventional literature. Both RR (2004) and Coibion (2012) apply the identification strategy on US data, while CH (2015) applies it on UK data.

All three empirical articles first use a single equation approach to estimate the effect of monetary policy shocks. RR (2004) find a peak decline in output of 4.3 per cent and a 5.9 per

[26] To ensure that the forecasts are orthogonal, the information set of the central banks has to be uncorrelated with the unsystematic shock component, in order for the zero conditional mean assumption not to be violated (Bjørnland & Thorsrud, 2014).

cent drop in the price level, evident from Table 2. The results are in line with the ones obtained by Coibion (2012), which finds a peak decline in output of 4.3 per cent, and a maximum decline in the price level of 4.2 per cent. CH (2015) find a maximum decline in output of 2.3 per cent, and a peak decline in inflation of 1.5 percentage points.

In order to make their studies comparable to the wider literature on the effects of monetary policy, all three articles follow Christiano et al. (1996), and employ a recursive VAR with their new measure of monetary policy ordered last. According to CH (2015), the advantage of applying the hybrid VAR approach is that it makes the magnitude of the shocks more comparable as the single equation and VAR method consider different shock paths. While shocks in a single equation framework are implicitly assumed to be permanent, the VAR approach assumes that monetary policy shocks are temporary.[27]

In their hybrid VAR estimation, RR (2004) find a peak decline of 2.9 per cent in output and a 5.0 per cent maximum decline in the price level. Coibion (2012) find a somewhat smaller effect, with a peak decline in output of 1.6 per cent and a 1.8 per cent decline in the price level. CH (2015) find a peak effect on output of 0.6 per cent, and a decline in inflation of 1.0 percentage point when estimating a hybrid VAR. The conclusion to be drawn so far is that the effect of monetary policy shocks, when employing the hybrid VAR, is in between the results from the conventional methods and the baseline single equation results from RR (2004).

Table 2: The effects of monetary policy in narrative studies

Method	**Authors**	**Country**	**Peak Effects (in %)**	
			Output	**Price measure**
Narrative (Single equation/ Hybrid VAR)	Romer and Romer (2004)	US	-4.3 (IP)/-1.9 to -2.9 (IP)	-3.6 to -5.9 (CPI/PPI)/-3.8 to -5.0 (PPI)
	Coibion (2012)	US	-4.3 (IP)/-1.6 (IP)	-4.2 (CPI)/ -1.8 (CPI)
	Cloyne and Hürtgen (2015)	UK	-2.3 (IP)/-0.6 (IP)	-1.5 (RPIX inflation)/-1.0 (RPIX inflation)

Notes: The numbers in the table are results from impulse responses presented in narrative studies of monetary policy shocks. The specific output and price measures are shown in brackets. IP represents industrial production, PPI is the producer price index and RPIX is the twelve-month percentage change in the retail price index, excluding mortgage payments.

[27] Due to the scope of this thesis, in addition to ensure comparability to the wider literature, the focus will be on VARs.

4. The New Measure of Monetary Policy

Chapter 4 presents the methodology and results regarding the construction of our new measure of monetary policy. First, the data construction process will be presented. Second, the chapter provides a formal presentation of the first stage regression, and how the new measure of monetary policy is identified. Finally, the chapter ends with a discussion of the results from the first stage regression.

4.1 Data construction

Norges Bank's key policy rate series serves as our intended policy target rate. To construct our new, exogenous measure of monetary policy, we have to gather real-time data to capture the information set of Norges Bank prior to each key policy rate decision. It is important to note that the proxy we use should reflect the information Norges Bank has as precisely as possible. Since Norges Bank has published relatively detailed forecasts in the period of investigation, we have a reliable real-time proxy regarding their beliefs about the future economic development.[28] Norges Bank invests many resources in producing these forecasts, and as a result the forecasts are likely to be of high quality. The possession of such valuable forecasts means that successful anticipatory movements may be present in Norges Bank's conduct of monetary policy. Thus, controlling for the forecasts might be important.

The real-time forecasts are based on a cut-off date, usually six days ahead of the key policy rate meeting. It is therefore unlikely that useful information becomes available between the cut-off date and the subsequent meeting. The real-time data are available from the MPRs at Norges Bank's website, and are based on information in a baseline scenario that were known prior to the key policy rate announcement. We can therefore consider Norges Bank's forecasts as appropriate to capture their information set prior to the key policy rate decisions.

We collect real-time data for variables central to the key policy rate decision. However, Norges Bank has not been completely consistent with respect to the publication of certain forecasted variables in the period of investigation. One example is the different inflation measures emphasized in the MPRs. The inflation measures varied between CPI-ATE, CPIXE and CPI

[28] The publication interval of forecasts has changed between three and four MPRs in the period of investigation. In 1999 and 2000, Norges Bank published four MPRs a year, from 2001 to 2012 three MPRs a year were published, while in the subsequent period (2013-2016) four MPRs per year have been published.

during the sample period.[29] We choose to make use of the inflation measure emphasized by Norges Bank at each key policy rate meeting. Furthermore, data on a quarterly frequency for GDP growth are limited in our sample. From IR 1/99 to MPR 1/08, Norges Bank only presents annual forecasts on a yearly frequency. In addition, forecasts on a quarterly frequency are often limited to one quarter ahead in the recent MPRs. We therefore have to use real-time data on GDP in levels, from Statistics Norway, together with the annual forecasts presented in the MPRs to interpolate to quarterly figures.

Despite the prominence in most of the MPRs, Norges Bank did not publish forecasts on the output gap in some of the reports. In particular, they did not publish output gap forecasts for the meetings in 2001, 2002 and the meeting in December 2008, which constitutes six meetings in total. For these meetings we use real-time data from OECD as a proxy.[30] As we have the publication date of these forecasts, we ensure that they do not contain the effect of the relevant key policy rate decision. A possible concern is whether the OECD forecasts are suitable as a proxy for Norges Bank's real-time information on the output gap, for the few meetings where we do not have access to official forecasts. We therefore collect OECD forecasts for the full sample period, even when real-time forecasts from Norges Bank are available. This is advantageous as we can verify that they are highly correlated with the forecasts of Norges Bank. In fact, the correlation between Norges Bank and OECD's forecasts on the output gap is at around 0.7 for up to two quarter ahead forecasts in the overlapping sample period. In addition, we only use the OECD forecasts for six out of the in total 58 included meetings. It is therefore unlikely that the inclusion of these forecasts will significantly alter our baseline results, compared to the ideal situation of including official forecasts from Norges Bank for the full sample period.

For data on a quarterly frequency we collect forecasts for up to four quarters ahead, in addition to forecasts for the current quarter. We also include real-time backdata of the previous quarter, which may differ from the finally revised series. For data on a yearly frequency, we include forecasts of the current and next year. Our new data set consists of 47 potential variables that

[29] CPIXE is the CPI adjusted for tax changes and excluding temporary changes in energy prices. Norges Bank began to calculate CPIXE to take into account the high trend rise in energy prices, which is excluded in CPI-ATE (Norges Bank, 2013).
[30] The OECD real-time forecasts are presented in the publication of their Economic Outlooks.

could explain Norges Bank's key policy rate decisions from 1999Q1 to 2016Q1.[31] Table 3 pictures the construction of our new, real-time data set. The unit of observation in our new shock series is the date of Norges Bank's key policy rate meetings, with a corresponding MPR. That is, we decide to exclude meetings without a new release of forecasts.[32] Our data set therefore consists of forecasts from 58 different key policy rate meetings.[33]

Table 3: Assignment of forecasts to the included key policy rate meetings

Date of key policy rate meeting	Cut-off date	Current quarter	$\theta^F_{m,t-1}$	$\theta^F_{m,t}$	$\theta^F_{m,t+1}$	$\theta^F_{m,t+2}$	$\theta^F_{m,t} - \theta^F_{m-1,t}$
• • •							
24.09.15	18.09.15	Q3	$\mathcal{F}^{MPR[Q2,15]}_{18.09.15}$	$\mathcal{F}^{MPR[Q3,15]}_{18.09.15}$	$\mathcal{F}^{MPR[Q4,15]}_{18.09.15}$	$\mathcal{F}^{MPR[Q1,16]}_{18.09.15}$	$\mathcal{F}^{MPR[Q3,15]}_{18.09.15} - \mathcal{F}^{MPR[Q3,15]}_{12.06.15}$
17.12.15	11.12.15	Q4	$\mathcal{F}^{MPR[Q3,15]}_{11.12.15}$	$\mathcal{F}^{MPR[Q4,15]}_{11.12.15}$	$\mathcal{F}^{MPR[Q1,16]}_{11.12.15}$	$\mathcal{F}^{MPR[Q2,16]}_{11.12.16}$	$\mathcal{F}^{MPR[Q4,15]}_{11.12.15} - \mathcal{F}^{MPR[Q4,15]}_{18.09.15}$
17.03.16	11.03.16	Q1	$\mathcal{F}^{MPR[Q4,15]}_{11.03.16}$	$\mathcal{F}^{MPR[Q1,16]}_{11.03.16}$	$\mathcal{F}^{MPR[Q2,16]}_{11.03.16}$	$\mathcal{F}^{MPR[Q3,16]}_{11.03.16}$	$\mathcal{F}^{MPR[Q1,16]}_{11.03.16} - \mathcal{F}^{MPR[Q1,16]}_{11.12.15}$

Notes: θ symbolizes the quarterly variables included in the information set of Norges Bank. The forecasts in the table are denoted by $\mathcal{F}^{Source[Current\ quarter,current\ year]}_{Cut-off\ date}$. All the variables in our data set are carefully matched following the same procedure as in Table 3.

Our approach differs from the one used by CH (2015). They decide to keep all policy rate meetings, by assigning the latest available forecast to each meeting, while still controlling for developments in unemployment since the last available forecast. By including all available policy rate decisions, they argue that this approach makes it possible to obtain a high-frequency monetary policy shock series that identifies a possible shock for all meetings. We acknowledge the importance of keeping all key policy rate decisions, but decide to choose a different approach for two reasons. First, official MPR forecasts are not released at each key policy rate

[31] Information regarding the variables of the real-time data set used in different permutations of the first stage regression is presented in Table 7 in the Appendix.

[32] The meeting in December 2008 is an exception. We decide to include this meeting because Norges Bank published more forecasts than they usually do for meetings without a corresponding MPR. In addition, it captures relevant data regarding the outbreak of the financial crisis. We will assess the sensitivity of the baseline VAR results regarding the exclusion of this meeting in section 5.3.3.

[33] Relevant information regarding the included key policy rate meetings is pictured in Table 8 in the Appendix.

meeting during the period of investigation. In order to include all policy rate meetings, we would therefore have to assign the latest available forecast to each subsequent policy rate decision. However, decisions made at key policy rate meetings are based on updated information. The forecasts from the previous meeting are therefore likely to be a poor proxy for the real-time information set of Norges Bank. This approach is in line with RR (2004) that exclude all policy rate meetings without a new release of forecasts. They argue that the exclusion of all such policy rate decisions will not bias the estimates in the regression, only make them less precise. Second, CH (2015) investigate whether their results are sensitive to the exclusion of meetings without a new release of forecasts. They find that the results obtained are very similar to their baseline approach. Based on these arguments, we therefore choose to keep only the key policy rate meetings with a new release of forecasts.

4.2 Methodology: first stage regression

The narrative method aims to isolate the unsystematic component of monetary policy, m_t, from the systematic movements in the key policy rate, S_t:

(5) $$S_t = f(\theta_t) + m_t$$

where the systematic component of S_t consists of Norges Bank's response to their information set, θ_t, and $f(\cdot)$ is a function of their systematic reaction. The unsystematic component, m_t, reflects unexpected shifts in monetary policy, and represents considerations made by Norges Bank beyond what is included in their information set. Any estimated regression with the purpose of identifying m_t, should take into account that real-time data and forecasts are important determinants for monetary policy. Otherwise, the unsystematic component might still contain anticipatory movements and could eventually lead to a downward bias in the estimated effect of the key policy rate (RR, 2004).

The first step of the narrative identification approach is to estimate a regression with the change in the key policy rate as the dependent variable, and real-time forecasts of important macroeconomic variables as independent variables. In particular, the first stage equation we estimate is[34]:

[34] However, to ensure comparability, section 4.3 presents the results from the replication of RR (2004). This approach includes forecasts on GDP growth and unemployment, instead of forecasts on the output gap. The arguments for choosing a different approach than RR (2004), are presented in section 4.3.2.

(6) $$\Delta i_m = \alpha + \beta i_{m-d1} + \sum_{t=-1}^{2} \varphi \pi_{cd,t}^{F} + \sum_{t=-1}^{2} \mu(\pi_{cd,t}^{F} - \pi_{cd-1,t}^{F}) + \sum_{t=-1}^{2} \omega \hat{x}_{cd,t}^{F} + \sum_{t=-1}^{2} \delta(\hat{x}_{cd,t}^{F} - \hat{x}_{cd-1,t}^{F}) + \epsilon_m$$

where Δi_m is the change in the key policy rate at meeting date m. On the right hand side of Equation (6), the key policy rate on the day prior to the meeting, i_{m-d1}, is included. The current key policy rate level is included because it could explain a tendency towards the long-term equilibrium rate. The subscript t denotes the quarter relative to the cut-off date, cd. $\pi_{cd,t}^{F}$ denotes the forecasts of inflation, and $\hat{x}_{cd,t}^{F}$ denotes the forecasts of the output gap. As one would expect that the change in forecasts, as well as the level, will affect the key policy rate decision, we include revisions in forecasts relative to the previous round of forecasts for both the output gap, $\hat{x}_{cd,t}^{F} - \hat{x}_{cd-1,t}^{F}$, and inflation, $\pi_{cd,t}^{F} - \pi_{cd-1,t}^{F}$.

This thesis follows RR (2004) and CH (2015), and includes the one and two quarter-ahead forecasts, forecasts for the current quarter and real-time backdata for the previous quarter. A critical assumption regarding the inclusion of forecasts is that they should not contain the effect of the subsequent policy rate decision. If the effect of the policy rate decision were included in the forecasts, the zero conditional mean assumption would be violated. The reason is that the forecasts would be correlated with the error term in our first stage regression. This would bias the regression results. To ensure that the forecasts are orthogonal to the residual, ϵ_m, we choose not to include forecasts for additional periods, since forecasts further ahead are likely to contain information about the future key policy rate path. The usual assumption of some lag in the implementation of monetary policy also makes it unlikely that forecasts only two quarters ahead are affected by the projected key policy rate path (RR, 2004).

After regressing the change in the key policy rate on the regressors in Equation (6), the second step is to predict the residual, ϵ_m. In section 4.4, we transform the residual into a quarterly shock series that we denote m_t. If we are successful in capturing the relevant information set of Norges Bank, the residual should be relatively free of anticipatory movements. Since we control for Norges Bank's information set, there is no reason to expect that our shock series should be predictable from developments in ex-post revised data.[35]

[35] In section 4.4.1, we will assess whether our results are unpredictable from developments in ex-post revised data, by conducting several Granger causality tests.

4.3 Empirical findings: first stage regression

The empirical findings from the first stage regression are reported in Table 4. To ensure comparability to RR (2004), we start by replicating their preferred first stage regression on Norwegian data.[36] Thereafter, we present the results from our preferred approach, and argue why this specification has a better fit on Norwegian data. Then, we assess whether our shock series has any remaining endogeneity and discuss potential sources of the estimated shocks. Finally, we consider alternative permutations to our baseline approach.

4.3.1 Empirical findings: replication of Romer and Romer (2004)

The specific equation we estimate to replicate RR (2004) on Norwegian data is:

$$(7) \quad \Delta i_m = \alpha + \beta i_{m-d1} + \sum_{t=-1}^{2} \varphi \pi_{cd,t}^F + \sum_{t=-1}^{2} \mu(\pi_{cd,t}^F - \pi_{cd-1,t}^F) + \sum_{t=-1}^{2} \psi \hat{y}_{cd,t}^F + \sum_{t=-1}^{2} \eta(\hat{y}_{cd,t}^F - \hat{y}_{cd-1,t}^F) + \rho \hat{u}_{j-1} + \epsilon_m$$

where $\hat{y}_{cd,t}^F$ is the forecast of real GDP growth, and $\hat{u}_{j-1}$ refers to the unemployment rate of the previous month. The results from estimating Equation (7) are shown in the left column of Table 4. The sum of the estimated coefficients on the real GDP growth forecasts is 0.20 for the level and 0.04 for the change in forecasted real GDP growth. Thus, a one percentage point increase, from one meeting with a forecast release to the next, in the real GDP growth forecasts, at all the included horizons, leads to a rise in the key policy rate of 24 basis points. The estimated total response is lower than the findings of both RR (2004) (29 basis points) and CH (2015) (39 basis points). Further, a one percentage point increase in the inflation forecasts leads to a rise in the key policy rate of 12 basis points, which is in between the results of RR (2004) (7 basis points) and CH (2015) (30 basis points).

However, the estimated coefficients on the level of inflation sum up to the wrong sign (-0.02). This is also the case for the estimated coefficients on both the level of the initial key policy rate (0.008), and the unemployment rate (0.146). According to standard economic theory, one would instead expect Norges Bank to lower the key policy rate if the initial key policy rate was higher, and if the unemployment rate increased.

[36] As we do not have access to unemployment forecasts for the contemporaneous quarter, we instead choose to include data on unemployment for the previous month, as this is as close we can get to the procedure followed in RR (2004).

Table 4: Determinants of the change in the key policy rate

Replication Romer and Romer (2004)			Our preferred baseline approach		
Variable	Coefficient	Standard error	Variable	Coefficient	Standard error
Constant (α)	-0.877**	0.370	Constant (α)	-0.069	0.227
Initial key policy rate (i_{m-d1})	0.008	0.020	Initial key policy rate (i_{m-d1})	-0.014	0.017
Forecasted output growth ($\hat{y}^F_{cd,t}$)			Forecasted output gap ($\hat{x}^F_{cd,t}$)		
Quarters ahead:			Quarters ahead:		
-1	-0.035	0.079	-1	-0.965**	0.463
0	0.114	0.116	0	1.459*	0.851
1	-0.011	0.177	1	-1.224	1.250
2	0.132	0.146	2	0.754	0.797
Forecasted inflation ($\pi^F_{cd,t}$)			Forecasted inflation ($\pi^F_{cd,t}$)		
Quarters ahead:			Quarters ahead:		
-1	-0.189	0.234	-1	-0.253	0.181
0	0.376	0.377	0	0.215	0.297
1	0.474	0.435	1	0.410	0.387
2	-0.679*	0.347	2	-0.305	0.305
Change in forecasted output growth ($\hat{y}^F_{cd,t} - \hat{y}^F_{cd-1,t}$)			Change in forecasted output gap ($\hat{x}^F_{cd,t} - \hat{x}^F_{cd-1,t}$)		
Quarters ahead:			Quarters ahead:		
-1	0.015	0.078	-1	0.515	0.353
0	0.009	0.109	0	-0.973*	0.482
1	0.057	0.117	1	1.727**	0.775
2	-0.038	0.108	2	-1.105*	0.595
Change in forecasted inflation ($\pi^F_{cd,t} - \pi^F_{cd-1,t}$)			Change in forecasted inflation ($\pi^F_{cd,t} - \pi^F_{cd-1,t}$)		
Quarters ahead:			Quarters ahead:		
-1	-0.156	0.257	-1	0.092	0.248
0	-0.527	0.626	0	-0.259	0.371
1	0.589	0.712	1	0.298	0.417
2	0.233	0.397	2	0.125	0.290
Unemployment rate (u^F_{j-1})					
Previous month:					
-1	0.146	0.124			

Notes RR (2004) replication: R^2 = 0.59. Adj. R^2 = 0.40. D.W. = 1.84. F-statistic = 3.11. N = 58.

Notes baseline approach: R^2 = 0.75. Adj. R^2 = 0.65. D.W. = 1.50. F-statistic = 7.11. N = 58.

Notes: The sample consists of key policy rate meetings with a new release of a MPR, in addition to the meeting in December 2008, over the period 1999Q1 – 2016Q1. */**/*** indicate significance at the 10/5/1 per cent level. The reported standard errors are White heteroskedasticity robust standard errors.

The adjusted R^2 of the regression is 0.40, which indicates that the RR (2004) replication model captures a fairly large amount of the information set of Norges Bank.[37] Still, we focus on a period with a flexible inflation-targeting regime and increased focus on the importance of being forward-looking and transparent. Thus, one could expect that a larger fraction of Norges Bank's actions had been taken in response to their forecasts of future output and inflation.

4.3.2 Empirical findings: the baseline approach

We choose to estimate a different specification than RR (2004) in our baseline first stage regression. In particular, we estimate a Taylor rule. Thus, we keep forecasts on inflation but substitute data on real GDP growth and unemployment, with forecasts on the output gap. It is important to note that we are not trying to capture the precise reaction function of Norges Bank, merely purge the series of any movements taken in response to useful information about future economic developments. The variation that remains will then be used to estimate the effects of monetary policy in a VAR model in the second stage regression. The use of a Taylor rule is advantageous as it summarizes the information set of Norges Bank, while conserving degrees of freedom.

Norges Bank puts a lot of emphasis on forecasts on the output gap in the MPRs, suggesting a more central role in their key policy rate decisions. This becomes visible when we analyze the forecasts presented in the MPRs, as forecasts on the output gap have a greater prominence than forecasts on real GDP growth and the unemployment rate. Forecasts on a quarterly frequency for GDP growth are for example not presented in over half of the MPRs in our sample, and we often lack forecasts for two quarters ahead. Regarding forecasts for the unemployment rate, we only have access to historical data for the full sample period.

RR (2004) have to include forecasts on the unemployment rate for the contemporaneous quarter to be able to control for the current state of the economy, since forecasts on real GDP growth only controls for the growth level. In our case, this is not necessary as forecasts on the output gap give a description of the overall capacity utilization in the economy (Sturød & Hagelund, 2012). The mandate for Norwegian monetary policy states that Norges Bank, in addition to reach the inflation target of 2.5 per cent over time, should contribute to stable developments in

[37] In order to compare the replication of RR (2004) with our preferred baseline approach, we report the adjusted R^2 of both series, since it takes into account the number of explanatory variables included in the regression.

output and employment. A reasonable interpretation is that Norges Bank should aim at stabilizing output and employment around the maximum sustainable level of output over time, often referred to as the potential output. Since the output gap is measured as the percentage deviation between GDP and potential GDP for Mainland Norway, it captures important information that Norges Bank needs to take into account in the implementation of monetary policy. Short-term forecasts on real GDP growth on the other hand, are often volatile and do not provide a reasonable explanation regarding the state of the economy (Bjørnland et al., 2005). In addition, to cross-check their estimates of the output gap, Norges Bank adjusts the forecasts against key information from indicators that can measure the capacity utilization in the economy. In particular, they emphasize developments in the labour market, as unemployment indicators have a stable pattern over the cycles and summarize the level of economic activity. The relationship between unemployment and the output gap is also fairly close.[38] Thus, by including the output gap in our first stage regression we do not need to control for unemployment.

The results from estimating our baseline approach in Equation (6) are shown in the right column of Table 4. The sum of the estimated coefficients on the forecasted output gap is 0.02 for the level and 0.17 for the change. Thus, a one percentage point increase, at all included horizons in the forecasted output gap, leads to an increase in the key policy rate of 19 basis points. The sum of the estimated coefficients on the inflation forecasts is 0.07 for the level and 0.26 for the change in the inflation forecasts. Thus, a one percentage point increase in inflation at all horizons, from one forecast release to the next, leads to a rise in the key policy rate of 33 basis points.[39] In our baseline approach, all the signs are in line with standard economic theory and our results suggest that Norges Bank's behaviour has been countercyclical during the period of investigation. Our preferred approach has a much better fit than the replication of RR (2004) on Norwegian data, which is proven by the adjusted R^2 of 0.65. This suggests that a substantial fraction of the actions taken by Norges Bank has been in response to their expectations about future developments in the output gap and inflation.

[38] This relationship is in the literature referred to as Okun's Law, and has proved to be a relatively good fit on Norwegian data (Olsen, 2011). For the interested reader we refer to the original paper by Okun (1962).
[39] This result contradicts the so-called Taylor principle, which states that the nominal interest rate should be raised more than proportional to the expected increase in inflation, in order to stabilize inflation around target (Taylor, 1993).

4.4 The new measure of monetary policy

After predicting the residuals from Equation (6), ϵ_m, they must be converted to a quarterly series before our new measure of monetary policy can be used in further analysis. This is because the variables we include in the second stage regression are reported on a quarterly frequency, while the shock series from the first stage regression corresponds to the date of each of the included key policy rate meetings. We denote the quarterly shock series m_t, and transform the residuals from our shock series as follows. In a quarter with an included key policy rate decision we assign the shock to the respective quarter in which the meeting occurred. If there are several meetings in a quarter, we sum the shocks. In a quarter without any included key policy rate meetings, we set the observation to zero.[40] Table 5 reports our results.

Table 5: New measure of monetary policy shocks

	Q1	Q2	Q3	Q4
1999	0.0	-0.592	0.090	0.111
2000	0.460	0.337	-0.038	-0.224
2001	0.0	0.087	0.0	0.124
2002	0.030	0.0	0.164	-0.001
2003	-0.331	-0.322	0.0	0.068
2004	0.343	0.0	-0.017	-0.192
2005	-0.133	-0.041	0.0	0.009
2006	0.130	-0.110	0.0	0.060
2007	0.071	0.126	0.0	0.021
2008	-0.141	0.229	0.0	-0.336
2009	0.227	0.212	0.0	0.033
2010	-0.166	0.035	0.0	-0.026
2011	0.072	-0.055	0.0	0.040
2012	-0.074	-0.087	0.0	0.102
2013	0.175	-0.027	-0.213	0.092
2014	-0.031	0.139	0.072	-0.020
2015	0.086	-0.181	-0.273	-0.031
2016	-0.082	n/a	n/a	n/a

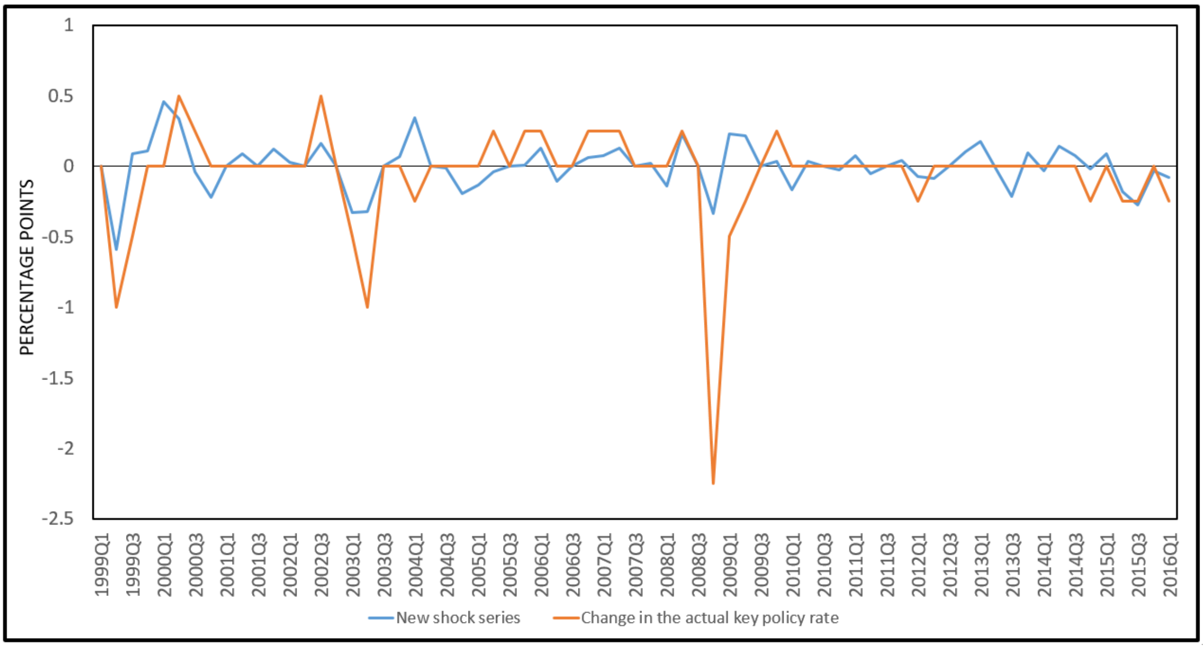
Notes: The reported results are in percentage points.

The interpretation of the identified monetary policy shocks is that Norges Bank has decided on a different key policy rate than what our estimated model predicts. Our quarterly shock series therefore captures an unpredictable movement, not taken in response to information about the future developments in the output gap and inflation. However, there might be good reasons for deviating from what the model predicts. Thus, it is useful to compare our quarterly shock series with the actual change in the key policy rate.[41] The changes in the actual key policy rate and

[40] This does not imply a missing observation, simply a monetary policy shock of zero.
[41] We transform the change in the actual key policy rate into a quarterly series following the same procedure as for our monetary policy shock series.

our quarterly shock series are pictured in Figure 6. The correlation between our baseline shock series and the change in the actual key policy rate is 0.51. This is in line with the correlation of 0.43 that RR (2004) find in their narrative study. The finding of a positive correlation is reasonable, as a negative correlation would imply that the shocks and the change in the actual key policy rate had different signs most of the time. This means in general that an increased key policy rate would provide an expansive shock, and vice versa. Compared to RR (2004) and CH (2015), we focus on a period with a stable monetary policy regime. Hence, our estimated shock series contains less volatility.[42] However, the estimated shock series contains more volatility in the early part of the sample before the introduction of the explicit inflation target in 2001.

Figure 6: Measure of monetary policy



4.4.1 Granger causality tests

Our new quarterly monetary policy shock series should, in principle, be exogenous given that we have been successful in capturing the relevant information set of Norges Bank. To assess whether our shock series is predictable from movements in ex-post data, we perform a series of Granger causality tests. This is a concept that is often employed when conducting structural analysis. The idea behind this notion of causality is that a cause cannot come after the effect. That is, if one assumes that an independent variable affects a dependent variable, then the former variable should help improving the predictions of the latter, and not vice versa

[42] This point is verified when we plot the three narrative quarterly shock series together in Figure 14.

(Bjørnland & Thorsrud, 2014). The concept of Granger causality can be implemented by performing a series of joint hypothesis tests. As shown in Equation (8), regressing the shock series, m_t, on a constant, c, and lags of ex-post revised macroeconomic variables, x_{t-i}, can verify if there is any remaining endogeneity in our shock series:

(8) $$m_t = c + \sum_{i=1}^{I} \beta_i \, x_{t-i} + u_t$$

where I denotes the amount of lags included. The null hypothesis states that the included variables have no statistically significant effect on the shock series. In order not to reject the null hypothesis of joint significance, the reported *F*-statistics must provide sufficiently high *p*-values. Table 6 presents the results from the Granger causality tests. Following CH (2015), we perform the tests with lags of both $I = 1$ and $I = 2$.[43]

Table 6: Granger causality tests

	I = 1 lag		I = 2 lags	
Variable	F-statistics	P-values	F-statistics	P-values
Real GDP growth	0.00	0.98	0.80	0.45
Inflation	0.10	0.75	0.90	0.41
Unemployment rate	1.00	0.32	0.55	0.58
Output gap	2.00	0.16	0.99	0.38

Notes: The standard errors are corrected for the possible presence of heteroskedasticity and autocorrelation using Newey-West heteroskedasticity and autocorrelation robust standard errors. Inflation is measured by the four-quarter change in the GDP deflator for Mainland Norway.

The relatively high *p*-values obtained from the Granger causality tests are promising, and imply that our new monetary policy shock series cannot be rejected as being exogenous. Thus, the series provides a good starting point for further analysis. The following section will therefore analyze possible sources of some selected estimated monetary policy shocks.

[43] CH (2015) convert their shock series into a monthly series and perform the tests with 3 and 6 lags respectively. We therefore use 1 and 2 lags for quarterly data. Information regarding the data included in these tests are shown in Table 9 in the Appendix.

4.4.2 Possible sources of the expansive shocks

During the first half of 2003, Norges Bank decided to cut the key policy rate by 1.5 percentage points in total. These cuts appear in our shock series as two of the largest expansionary shocks. During this period, Norges Bank observed low inflation and growth below the potential. This forced Norges Bank to cut the key policy rate. However, these factors cannot solely explain the total change in the key policy rate. In fact, Norges Bank explicitly stated their concern in both MPRs regarding the competitiveness of the internationally exposed sector, due to the strong Norwegian krone exchange rate (Norges Bank, 2003b; Norges Bank, 2003c). This behavior could be a potential source of these monetary policy shocks.

The two included key policy rate meetings in 2008Q4 stands out in our sample. During these two meetings in the breakout of the financial crisis, Norges Bank decided to decrease the key policy rate by 2.25 percentage points. This resulted in a large estimated expansive shock. The most important determinants for the dramatic change in the key policy rate were the uncertainty regarding both domestic and international future economic growth (Norges Bank, 2008a; Norges Bank, 2008b). The economic downturn was mostly demand driven, where Norges Bank observed that the household's expectations about their own economic situation, as well as the Norwegian economy, had deteriorated. In addition, oil prices had dropped substantially, which resulted in additional uncertainty regarding future growth in the oil-dependent Norwegian economy. Given the information available in real time, Norges Bank changed the key policy rate by about 34 basis points too much at these two meetings, compared to what our estimated model predicts.[44] The decreased key policy rate level, in addition to the drop in oil prices, resulted in a depreciation of the Norwegian krone exchange rate. This had a positive impact on the short-term CPIXE projections. However, our model does not take into account that the positive effect the weak exchange rate had on CPIXE, was only temporary, and that inflation was expected to decline further in subsequent periods. This may indicate that our model slightly exaggerates the size of the estimated monetary policy shock at these particular key policy rate meetings.

Given the information Norges Bank had about future developments in inflation and the output gap ahead of the key policy rate meeting in June 2015, our model predicts that the key policy

[44] This finding is broadly consistent with the estimated average reaction pattern of Norges Bank, evident from Figure 5.

rate should have been kept unchanged. Still, they decided to cut the key policy rate by 25 basis points. A possible source of this shock may be the reduced investments in the oil-sector following the persistently low oil price. This caused a decline in forecasted capacity utilization, and increased long-term projected unemployment (Norges Bank, 2015). In order to maintain a robust monetary policy, and thereby secure a stable development in long-term projected inflation and employment, Norges Bank found it necessary to follow a more expansionary key policy path than what their short-term projections indicated.

4.4.3 Possible sources of the contractive shocks

In IR 2/02, Norges Bank emphasized how the pressure in the labour market led to higher wage growth, tighter monetary policy, and deteriorating profitability in the internationally exposed sector (Norges Bank, 2002). The Norwegian krone appreciated remarkably during the first half of 2002, mainly due to expectations of increased interest rates as a result of the development in the wage settlements. As a response to the wage settlements, Norges Bank decided to increase the key policy rate by 50 basis points. The increase has in the aftermath been widely discussed, as it further weakened the competitiveness of the internationally exposed sector. High interest rates and low imported inflation resulted in a subsequent inflation below the target. The decision to increase the key policy rate may indicate that the social partners had not fully internalized the reaction function of Norges Bank, with respect to the linkages between wage growth and interest rates. In order to prevent an excessive contraction of the internationally exposed sector, they needed to reduce wage growth to a long-term acceptable level. The Norwegian krone had already appreciated in response to the expectations of higher interest rates, and Norges Bank may therefore have considered the short-term loss of a hike in the key policy rate to be small. This might have caused Norges Bank to set the key policy rate differently than they otherwise would have done, given their forecasts of the output gap and inflation. Still, the consensus view is that the key policy rate was set too tight in this period (Dørum et al., 2005).

At the key policy rate meeting in March 2004, Norges Bank decided to cut the key policy rate by 25 basis points (Norges Bank, 2004c). This meeting is particularly interesting, as the actual change in the key policy rate and the shock series have opposite signs. In fact, what shows up as an expansion in the actual key policy rate is a period of contraction in our new monetary policy shock series. Given Norges Bank's information about future inflation and the output gap, our model predicts that they should have cut the key policy rate by 34 additional basis points. Norges Bank expected the capacity utilization to pick up during the projection period, and the focus was primarily on the current and expected low inflation rate (Bjørnland et al., 2004). A persistently low inflation rate could reduce the inflation expectations, and thereby make the key policy rate less effective. Prospects of a weaker Norwegian krone exchange rate, however, gave expectations of increased inflation in the end of the projection period. This might be the explanation regarding why Norges Bank decided to keep a tighter key policy rate than suggested by our estimated model.

At the key policy rate meeting in June 2008, where Norges Bank decided to increase the key policy rate by 25 basis points, our estimated shock is at the same size as the change in the key policy rate itself. In MPR 2/08, they expressed a concern regarding the slowdown in economic growth, both domestically and globally (Norges Bank, 2008c). However, their main concern was directed at the increasing trend in food and energy prices. Norges Bank highlighted that the trend rise could be troubling if it led to expectations of higher wage growth and a rise in core inflation. The experience from the 1970s and 1980s showed that it could be costly if monetary policy did not react to an unanticipated increase in inflation. Since Norges Bank employed CPI-ATE as their measure of core inflation, a trend rise in energy prices was not taken into account. However, in MPR 2/08 Norges Bank introduced CPIXE as a new measure of core inflation, to take into account that energy prices had risen faster than other prices in recent years. CPIXE is calculated as CPI-ATE plus an estimated trend in energy prices in the CPI. The introduction of CPIXE therefore led to estimates of inflation that were somewhat higher than CPI-ATE. Ahead of the meeting in June 2008, researchers and chief economists warned Norges Bank on putting too much emphasis on the increased food and energy prices, as it could be harder for the economic agents to internalize their reaction function (Staude, 2008). Still, Norges Bank decided to increase the key policy rate to slow inflation measured by CPIXE. This may indicate that their preferences, regarding the trade-off between inflation and capacity utilization at this particular meeting, changed towards stabilizing inflation. It can therefore be a possible source of the estimated contractive shock.

4.5 Alternative permutations of the first stage regression

To assess the robustness of our baseline approach we first compare our new quarterly shock series with alternative permutations of the first stage regression, by calculating the correlation coefficient between the series. Since the shock series we consider do not have a noticeable trend, a possible high correlation will indeed indicate similar movements. In addition, we assess whether the various permutations have any effect on the sum of the estimated coefficients on inflation and the output gap. We follow the same procedure as for our new shock measure, and transform the residuals from the alternative permutations into a quarterly series.

The first alternative permutation we consider is the replication of RR (2004). The correlation with our baseline approach is 0.77. As the adjusted R^2 is substantially lower (0.40) compared to our preferred series (0.65), the estimated shocks are larger. Hence, the RR (2004) replication shock series contains relatively more volatility. The additional variation is likely to contain anticipated movements, and suggests that the specification used by RR (2004) does not reflect the true monetary policy shocks on Norwegian data. Since some of the individual coefficient estimates showed up with the wrong sign, as presented in section 4.3.1, the RR (2004) shock series seems to give misleading results on Norwegian data. We will therefore not employ this shock series in the further analysis.

Our second alternative permutation is to include forecasts for the current and next year on wage growth, in addition to the output gap and inflation. As wage growth may have been a source of the estimated monetary policy shocks, and is emphasized in most of the MPRs, it is interesting to assess whether forecasts on wage growth are an important part of the information set of Norges Bank. The correlation between the two series is 0.95, which makes the permutation very similar to our baseline approach. In addition, the sum of the estimated coefficients is qualitatively similar to our baseline approach.

Third, we consider the inclusion of the one and two quarter lagged variables of the four-quarter change in house prices. Ideally we would, in addition to real-time backdata, include contemporaneous and future forecasts for the growth in house prices. However, these real-time forecasts are not available for almost the entire sample period. Given the introduction of the robustness criterion, presented in section 2.5, Norges Bank has been devoting their attention to the recent years' rapid growth in house prices. Thus, including data on house prices might yield more precise estimates. The correlation between this permutation and our baseline approach is 0.87. The sum of the estimated coefficients is also very similar to our baseline specification.

Given the high correlation, and the qualitatively similar sum of the estimated coefficients, our baseline shock series seems to be robust to the different permutations we consider. The forecasts on wage growth, and the lagged data on house prices, do therefore not seem to explain any additional variation in the key policy rate. We therefore choose not to include them in our baseline first stage regression. However, in order to assess whether the alternative permutations will affect our results from the second stage regression, we include them in the VAR estimation in section 5.3.5.

4.6 First stage regression summarized

In this chapter, we have constructed a new quarterly measure of monetary policy on Norwegian data, for the period 1999Q1 to 2016Q1. Our new measure of monetary policy should be relatively free of anticipatory movements. Thus, the conclusion to be drawn from the first stage regression is that our new measure of monetary policy is well suited to assess the effect of monetary policy on output and inflation for Norway.

5. The Effects of Monetary Policy

In the following, the VAR model employed in the second stage regression will be formally introduced. We will also present important econometric issues that need to be taken seriously in order to provide reliable results. Thereafter, the baseline VAR estimation results and corresponding robustness checks are presented.

5.1 Methodology: second stage regression

5.1.1 VAR models

The conventional literature on the effects of monetary policy usually achieve identification through the use of different specifications of a VAR model. The VAR is also employed by RR (2004), Coibion (2012) and CH (2015), in the second stage regression of their narrative studies. VARs consider monetary policy shocks to be temporary, which is in contrast to single equation models where shocks are assumed to be permanent (CH, 2015). Hence, single equation models tend to produce results that are larger than the ones obtained through VARs. The implication is that the results from single equation models are not directly comparable to the wider literature. We therefore want to estimate a VAR, where we employ our new measure of monetary policy, instead of the actual key policy rate, as the policy measure. In addition, the use of a VAR model allows us to control for the combined dynamics of all the variables in the system, and may yield more precise estimates in shorter samples (Coibion et al., 2012). Furthermore, if there is any residual endogeneity in our new measure of monetary policy, the VAR model will remove this as well (CH, 2015).

Our focus is essentially related to the effects on inflation and output of a one percentage point contraction to the key policy rate. This imposes a challenging identification problem, since we need to disentangle cause and effect. To adequately capture the precise impact, we have to isolate how the key policy rate affects the macroeconomic variables of interest, and not vice versa. We will in the following focus on how the VAR model use restrictions, motivated by economic theory, to identify the structural monetary policy shocks.

The VAR was introduced by Sims (1980) as an alternative to the large-scale macroeconomic models used at the time. In particular, the new methodology was a result of a dissatisfaction with the large-scale models, in which identification was achieved by excluding variables (often lagged endogenous variables), without any theoretical or statistical justification (Bjørnland &

Thorsrud, 2014). The traditional identification procedure of the large-scale models, contradicted the notion that macroeconomic variables in a complex system, are determined endogenously and simultaneously. The VAR on the other hand, is an n-equation, n-variable, linear model in which each variable is in turn explained by its own lagged values, plus the current and past values of the remaining $n-1$ variables (Stock & Watson, 2001). Hence, all the included variables of interest in a VAR are determined endogenously. This provides a more credible framework for macroeconomic studies, compared to what Sims (1980) referred to as non-justified exclusion restrictions in the large-scale models.

To identify the structural parameters from a reduced form VAR model, Sims (1980) assumed a recursive structure regarding how the structural shocks affected the included variables in the system. Following Sims (1980), Bjørnland and Thorsrud (2014) present how identification is achieved through a simple bivariate reduced form VAR (1) model, which can be expressed as:

$$(9) \qquad \begin{bmatrix} y_{1,t} \\ y_{2,t} \end{bmatrix} = \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix} \begin{bmatrix} y_{1,t-1} \\ y_{2,t-1} \end{bmatrix} + \begin{bmatrix} e_{1,t} \\ e_{2,t} \end{bmatrix}$$

where $\begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix}$ is the so-called companion form matrix.

Equation (9) can be written more compactly as:

$$(10) \qquad A(L)y_t = e_t$$

where $A(L)$ is the lag polynomial, y_t is a vector of variables and e_t is Gaussian white noise errors, i.e. $e_t \sim$ independently and identically distributed, $N(0, \Sigma_e)$. The errors represent the surprise movement in the variables. However, the different variables are likely to be correlated with each other. Hence, the errors in the reduced form model are likely to be correlated across the equations (Stock & Watson, 2001). This implies that a shock in one of the included variables is likely to be followed by a shock in one of the others. Thus, shocks from a reduced form VAR are uninterpretable (Bjørnland, 2000). To adequately assess the ceteris paribus effect on $y_{1,t}$ of an increase in $y_{2,t}$, i.e. to perform structural analysis, the shocks need to be uncorrelated.[45] This

[45] The notion of ceteris paribus implies that all other (relevant) factors are kept constant, and plays an important role on the ability to perform causal analysis (Wooldridge, 2013).

can be conducted through the construction of a recursive VAR, which constructs the error term in each regression to be uncorrelated with the error term in the preceding equation (Stock & Watson, 2001). The most employed method to achieve this type of identification is through the so-called Cholesky decomposition.[46] The Cholesky decomposition restricts the shock of the second endogenous variable in Equation (9), $y_{2,t}$, to affect the first endogenous variable, $y_{1,t}$, contemporaneously (at time t), while both shocks can affect the second variable contemporaneously. After one period, no further restrictions are present.[47]

While the Cholesky decomposition restricts the shocks from being correlated, another question is if the ordering of the variables makes sense in terms of economic theory, since the impulse responses will be affected by the ordering of the variables. The solution might be to employ identifying assumptions in line with economic theory to sort out the contemporaneous links among the included variables, and thereby allow correlations to be interpreted causally (Stock & Watson, 2001). In particular, a conventional recursiveness assumption is that there is a lag (depending on the sample frequency) in the implementation of monetary policy. With only one such restriction, we can recover the structural model based on the reduced form representation.

In monetary policy analysis we are interested in the effects of a shock to the monetary policy measure on economic variables. If we assume that monetary policy affects the other included variables in the VAR system with a lag, the structural model can be expressed as the following in a three variable VAR, comprising the output gap ($\hat{x}_t$), inflation (π_t) and a monetary policy measure (MP_t):

$$(11) \quad \begin{bmatrix} \hat{x}_t \\ \pi_t \\ MP_t \end{bmatrix} = \begin{bmatrix} \theta_{11,0} & 0 & 0 \\ \theta_{21,0} & \theta_{22,0} & 0 \\ \theta_{31,0} & \theta_{32,0} & \theta_{33,0} \end{bmatrix} \begin{bmatrix} \varepsilon_{\hat{x},t} \\ \varepsilon_{\pi,t} \\ \varepsilon_{MP,t} \end{bmatrix} + \psi_1 \varepsilon_{t-1} + \cdots$$

where the matrix in front of the shocks is a lower triangular matrix with positive diagonal elements (and zero above the diagonal), $\varepsilon_{\hat{x},t}$ is a shock to output, $\varepsilon_{\pi,t}$ is an inflation shock and $\varepsilon_{MP,t}$ is a shock to the policy measure (Bjørnland & Thorsrud, 2014).

[46] Since we want to ensure comparability to the wider literature, we employ the Cholesky decomposition. However, several other identification strategies have been employed in the literature, as presented in Chapter 3. These alternative identification strategies will not be formally introduced.
[47] For the full mathematical proof and structure behind the Cholesky decomposition, we refer to Bjørnland and Thorsrud (2014).

By writing out the VAR matrix in Equation (11), we obtain:

(12) $\hat{x}_t = \theta_{11,0}\varepsilon_{\hat{x},t} + \cdots$ lags of all shocks

(13) $\pi_t = \theta_{21,0}\varepsilon_{\hat{x},t} + \theta_{22,0}\varepsilon_{\pi,t} + \cdots$ lags of all shocks

(14) $MP_t = \theta_{31,0}\varepsilon_{\hat{x},t} + \theta_{32,0}\varepsilon_{\pi,t} + \theta_{33,0}\varepsilon_{MP,t} + \cdots$ lags of all shocks

Equation (12) and (13) illustrate that it takes one period before unsystematic moves in the policy measure affect output and inflation. On the other hand, Equation (14) shows that the policy measure is affected by all shocks immediately. When the policy measure is ordered last in the Cholesky ordering, the responses to the monetary policy shock will be invariant to the ordering of the variables above the policy measure (Bjørnland & Thorsrud, 2014).

However, in order to obtain consistent and reliable results when assessing the effects of monetary policy on output and inflation, certain econometric issues must be taken into account. Three fundamental concepts are stationarity, autocorrelation and the choice of lags. These concepts will be presented in the following sections.

5.1.2 Stationarity

The concept of stationarity is important in time series analysis, since the results obtained when using non-stationary time series in a regression might create a relationship between variables that does not exist. Hence, the regression results may be spurious. Following Wooldridge (2013), a time series, y_t, is covariance-stationary if it has a constant mean, $E(y_t) = \mu$, a constant variance, $Var(y_t) = \sigma^2$, and a covariance that depends only on the intervals separating the dates, s, and not on the date itself, t, i.e. $cov(y_t, y_{t-s}) = \gamma_s$.

To ensure stability of the VAR, i.e. a covariance-stationary process, the effect of the shocks must eventually die out. This will be the case if all of the eigenvalues of the companion form matrix in Equation (9), are less than one in absolute value (Bjørnland & Thorsrud, 2014). To assess the stability of a VAR model, one can test if the eigenvalues lie within the unit circle. If they do, the VAR system cannot be rejected as being covariance-stationary.

5.1.3 Autocorrelation

Another potential problem in time series econometrics is the presence of autocorrelation in the error term (Wooldridge, 2013). That is, time series data typically depend on their past values. Hence, variables are not independent across observations (Bjørnland & Thorsrud, 2014). The consequences of conducting regression analysis with autocorrelation in the error term are that confidence intervals and hypothesis tests based on the *t*- and *F*-distributions are unreliable. Therefore, one cannot make inference even though the OLS estimators are still unbiased and linear. In order to assess whether autocorrelation is a problem, one can analyze the sample autocorrelation function (ACF) for each of the included variables. The ACF shows the correlation between a time series and its past values, and whether the correlation is statistically significant. The null hypothesis is that there is no autocorrelation, and it cannot be rejected at the chosen significance level as long as the confidence interval contains the value zero.

5.1.4 Lag selection

Before estimating a VAR, it is useful to examine the sample ACFs of the included variables, since they can give an indication on how many lags one should include in the estimation. If we include too few lags, we might omit important information from the model, and the residuals can easily become autocorrelated. On the other hand, by including too many lags in a VAR model, one estimates more coefficients than needed. This introduces additional estimation error, and might lead to imprecisely estimated parameters (Bjørnland & Thorsrud, 2014).

The appropriate lag length can be determined by different statistical procedures, which focus on minimizing an information criterion function. Two such information criterion functions are the Bayes (BIC), and the Akaike (AIC) information criterion. They are both evaluating the trade-off between increased model fit, by the inclusion of more lags, and increased parameter uncertainty as the model becomes larger (Bjørnland & Thorsrud, 2014). The difference between the BIC and AIC, is that the BIC is more restrictive and will penalize the size of the model more than the AIC. For this reason, the AIC will tend to suggest models with more lags than the BIC.

5.2 Empirical findings: second stage regression

Having constructed a new measure of monetary policy, we will estimate the effect of the key policy rate on output and inflation for Norway from 1999Q1 to 2015Q4.[48] Section 5.2.1 presents our baseline results. Thereafter, section 5.2.2 compares our baseline VAR with a conventional VAR using the actual key policy rate as the policy measure. Finally, section 5.3 provides a range of sensitivity tests to assess the robustness of our baseline VAR results.[49]

To estimate the effect of the key policy rate on Norwegian data, we normalize the increase in the policy measure to one percentage point. Then, we assess the effect of this shock on the included variables in the VAR through an impulse response function. However, the interpretation of an impulse response function is complicated (Cochrane, 1998). Traditionally, Lucas (1972) argues that only unexpected shifts to monetary policy may have real economic effects. The implication is that anticipated monetary policy movements are excluded from the analysis. According to Cochrane (1998), this assumption is not very plausible, since the effects of monetary policy shocks seem to build up slowly over time. Impulse response functions from structural VARs take into account that the initial surprise movement, and the later anticipated movements in the policy measure, might have real economic effects (Cochrane, 1998). Thus, the impulse response functions show the combined dynamics of the shock to the policy measure, and how it moves back towards its steady state. [50]

5.2.1 Baseline VAR results

Following Christiano et al. (1996), we employ the recursive identification strategy, with the measure of monetary policy ordered last. However, in contrast to conventional VAR studies we employ our new measure of monetary policy, instead of the actual policy rate, as the policy measure. This is in line with the baseline VAR approach in RR (2004) and CH (2015).[51] The VAR specification we consider has three endogenous variables. We include the output gap, $\hat{x}_t$, the four-quarter change in the GDP deflator for Mainland Norway, π_t, and our new quarterly

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[48] Data for 2016Q1 is not available for all the included variables. We therefore exclude this quarter from the period of investigation in the second stage regression.
[49] Table 10 in the Appendix gives an overview of the VAR models presented in the thesis.
[50] Assuming that the estimated shock in the error term of our shock series returns to zero in subsequent periods and that all other errors are equal to zero (Stock & Watson, 2001).
[51] As we are using quarterly data, the recursiveness assumption implies that monetary policy cannot affect output and inflation during the first quarter. This assumption is more restrictive than by using monthly data as RR (2004) and CH (2015). In section 5.3.1 we relax this assumption, as our new shock series, in principle, should be exogenous.

shock series cumulated, cs_t, as the policy measure.[52] Since conventional VARs enter the policy rate in levels, we cumulate our new shock series ($cs_t = \sum_{i=0}^{t} m_i$) to make our VAR specification comparable to the wider literature. We could potentially have included the quarterly growth rate of an inflation measure in the VAR, e.g. by taking the log difference. On the other hand, annual inflation is a more informative measure for Norges Bank with respect to reaching the inflation target (Bjørnland & Jacobsen, 2009). Even though Norges Bank targets CPI-ATE as the core inflation measure, we decide to include the GDP deflator following Bernanke and Mihov (1998), and Uhlig (2005). However, section 5.3.6 shows that our baseline results are robust to the use of CPI-ATE and the Harmonised Index of Consumer Prices (HICP), as alternative inflation measures. An advantage of employing the GDP deflator, as opposed to a CPI measure, is that it presumably is a better indicator to capture broad macroeconomic conditions. In addition to consumption, the GDP deflator takes into account the price development in investment, government spending and net exports. It is therefore preferable to employ the GDP deflator, since it is broader in the sense that it captures the dynamics in the price developments across all components of GDP.

A possible drawback is that the GDP deflator for Mainland Norway only considers inflation in domestically produced goods and services. Our estimated response will therefore not include the potential effects on inflation from the exchange rate channel, presented in section 2.4.2. However, Norges Bank's influence on imported inflation may be limited during the sample period. The low imported consumer price inflation since the early part of the 2000's is, to a large degree, determined by increased import from low-cost countries rather than moves in the key policy rate (Jonassen & Nordbø, 2006). Furthermore, in Norges Bank's model for forecasting and monetary policy analysis, the Norwegian Economy Model (NEMO), imported inflation is determined by foreign firms' expected earnings, measured in foreign currency (Brubakk & Sveen, 2009). This implies that Norwegian monetary policy is assumed to have a low impact on the development in imported inflation. The use of a GDP deflator for Mainland Norway in the estimation might therefore be a more appropriate measure, in order to estimate the effect that our new measure of monetary policy has on inflation.

[52] Data on the three variables included in the baseline VAR, are plotted in Figure 15, 16 and 17.

Given the discussion above, the specific baseline VAR we employ to estimate the effects of monetary policy is the following:

(15) $$X_t = A_0 + B(L)X_{t-1} + \epsilon_t$$

where A_0 denotes a vector of intercept terms and $B(L)$ is a lag polynomial with P lags. The vector with the included variables is $X_t = [\hat{x}_{t,} \pi_t, cs_t]$. We choose not to include a trend in the VAR, since it is insignificant in all the estimated OLS regressions at the five per cent significance level.[53] RR (2004) choose to include three years of lags in their baseline VAR specification. The ACFs from the included variables in the baseline VAR shows evidence of autocorrelation, as the first lags are statistically significant.[54] We employ the AIC in order to determine the appropriate lag length. On the other hand, the BIC is likely to suggest a too short lag length in small samples, thereby not sufficiently allowing for monetary policy to have a lagged effect on the included variables (Coibion, 2012). It is also important to note that we estimate a smaller sample than RR (2004). Thus, including too many lags, relative to the number of observations, are likely to lead to poor and inefficient estimates of the parameters.

We decide to include four lags as suggested by the AIC. However, Figure 20 in the Appendix shows that our baseline results are robust to different lag lengths. Still, the confidence intervals (not reported) for the VARs with five and six lags confirm that uncertainty increases relative to our baseline results. Hence, the inclusion of four lags seems appropriate given the relatively small sample compared to RR (2004). In addition, to include one year of lags is the most common in VARs estimating the effects of monetary policy (Coibion, 2012). To ensure comparability across the VAR specifications, we employ four lags in the alternative models for the remainder of this thesis. The ACFs from the baseline VAR shows that the estimated residuals do not seem to inhabit any significant autocorrelation.[55] Furthermore, all the eigenvalues lie within the unit circle. Hence, the VAR system cannot be rejected as being covariance-stationary.[56]

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[53] In Figure 18 in the Appendix, we show that the results from the baseline VAR are robust to including a trend.
[54] The ACFs of the included variables in the VAR are pictured in Figure 19 in the Appendix.
[55] The estimated residuals from the baseline VAR are shown in the ACFs in Figure 21 in the Appendix.
[56] Figure 22 in the Appendix pictures the unit circle from the baseline VAR.

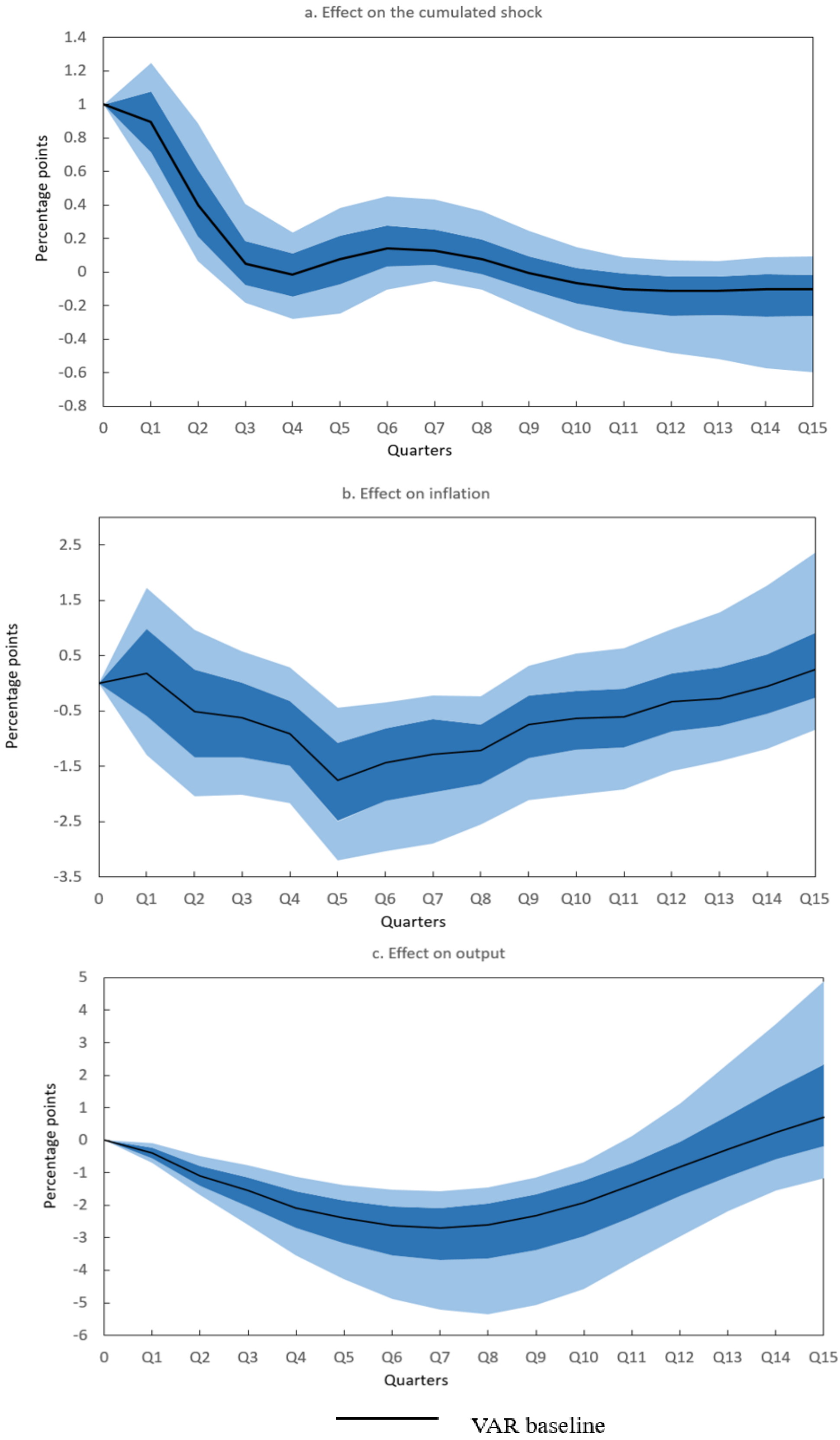
Figure 7 shows the results from the use of our preferred shock series in a VAR together with the 68 and 95 per cent bootstrapped confidence bands using 2000 repetitions.[57] The effect on the cumulated shock shows that it declines to zero in quarter four, before it stabilizes around its steady state. The estimated peak decline in the inflation rate is 1.75 percentage points in quarter five. Inflation does not react strongly on impact, but turns negative during the second quarter after the shock. The effect is significant at the five per cent level from quarter five to eight. The output gap is negative on impact, with a maximum decline of 2.71 percentage points in quarter seven. The effect on output is highly significant.

In addition, we assess the impact of monetary policy shocks to business cycle fluctuations, as describing the effects of monetary policy shocks alone make less sense if the shocks only explain a negligible share of the variance in output and inflation. In order to determine the contribution of structural monetary policy shocks to business cycle fluctuations, it is useful to employ a forecast error variance decomposition (FEVD). A FEVD shows how much of the forecast error variance, for the particular variable of interest, that is due to variations in the structural monetary policy shocks, ε_{MP}, at different horizons, $t + s$, given the information available at time t (Bjørnland & Thorsrud, 2014). Together with the impulse response functions, a FEVD provides us with useful information about the importance of the shocks.

By applying a FEVD, we find that the policy measure can account for around 15 per cent of the fluctuations in inflation, and 37 per cent of the fluctuations in output at a four-year horizon.[58] The finding that our new measure of monetary policy can account for a substantial part of output volatility is in line with the results obtained by Barakchian and Crowe (2013). However, the estimated effects are relatively uncertain. Still, the policy measure seems to be an important determinant for economic fluctuations.

[57] The bootstrapped confidence intervals are robust to 10 000 repetitions. A wild bootstrap is employed in all the estimated VAR models in this thesis, to account for the possible presence of heteroscedasticity in the error terms.
[58] Figure 23 in the Appendix reports the FEVDs for inflation and output.

Figure 7: Baseline VAR results



It is interesting to compare the estimated peak effects from our baseline VAR, with the narrative VAR results obtained by RR (2004), Coibion (2012) and CH (2015).[59] Our baseline results are in line with the results from these narrative studies.[60] The estimated baseline VAR effects obtained by RR (2004), are somewhat larger than our estimates. One reason might be that we investigate a time period with less volatility. In order to control for the possibility that increased volatility might produce larger estimates, CH (2015) extend the original shock series of RR (2004). They show that when estimating a VAR for the same sample period (1975-2007) on US data, the results obtained are largely within the 95 per cent confidence intervals of their own UK estimates. Following Coibion (2012), this indicates that the estimated effects of monetary policy shocks vary over time. Thus, our results on inflation and output are comparable to the ones presented by the literature on the narrative method.

The estimated peak effects on output and inflation from our baseline VAR are considerably larger than the results obtained from previous VAR studies on Norwegian data.[61] In addition, Llaudes (2007), Bjørnland and Jacobsen (2009) and Robstad (2014) all find evidence of a price puzzle. The conventional VAR literature is all using the actual policy rate directly in the VAR to identify the effects of monetary policy. The relatively small effects reported from this literature, compared to our baseline results, suggest that the shocks identified in VARs using the actual key policy rate still contain anticipatory movements. On the other hand, our baseline VAR, using the new measure of monetary policy, provides evidence that the key policy rate has stronger effects on inflation and output than previously thought.

5.2.2 Comparison with the key policy rate as the policy measure

As the narrative method aims at constructing a monetary policy shock series that controls for anticipated movements, it is important to compare our baseline VAR results with a conventional recursive VAR using the actual key policy rate as the policy measure. Moves in the key policy rate should, in principle, contain anticipatory movements. Thus, one can expect a conventional

[59] However, since both RR (2004) and CH (2015) use the log of industrial production as the output measure, the results on output are not directly comparable as the output gap is presented in percentages rather than in levels. The interpretation of the impulse responses for the output gap is therefore denoted in percentage points rather than per cent. The same interpretation applies to the price measure, where RR (2004) report the estimated percentage effect on the price level, rather than the percentage point effect on inflation as we report. Still, the alternative measures we employ are broadly similar to the ones used by RR (2004) and CH (2015).

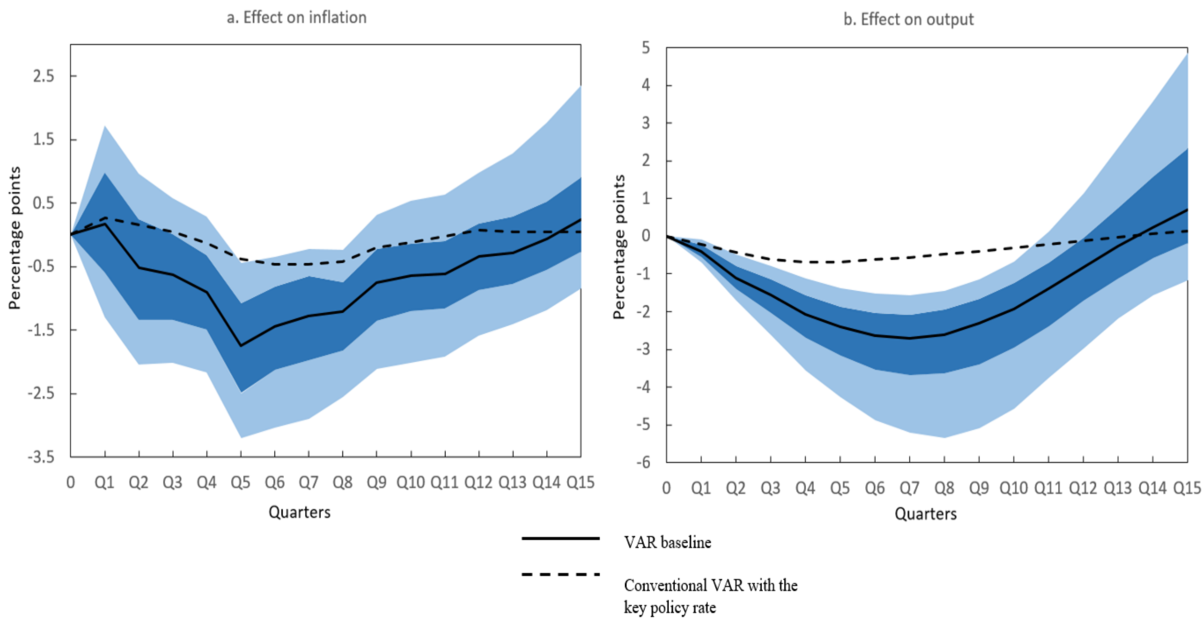
[60] Results from the narrative VAR studies are reported in Table 2 in Chapter 3. The results reported in this table are obtained using monthly data. However, CH (2015) show that their baseline results are very similar as when estimating a quarterly VAR.

[61] Table 1 in Chapter 3 presents the results from the conventional VAR studies.

VAR to underestimate the real effects of monetary policy (RR, 2004). On the other hand, if the estimated effects are similar to our baseline VAR, this could indicate that the actual key policy rate could be used with more confidence in academic research.

Figure 8 shows the inflation and output response to a one percentage point shock to the key policy rate, compared to the baseline VAR results using our new measure of monetary policy. Inflation is largely unaffected for the first four quarters, and reaches its peak decline of 0.47 percentage points in quarter six. This is considerably weaker than our baseline results. The same is true for the estimated peak decline of 0.69 percentage points on output, which is about one-fourth of our baseline results. The contrast between the different estimates, suggests that the actual key policy rate is contaminated by anticipatory movements. Thus, our new measure of monetary policy should provide more precise estimates of the effect of monetary policy, than by using the actual key policy rate as the policy measure.

Figure 8: Comparison between the baseline VAR and a conventional VAR



5.3 Robustness and extensions

5.3.1 Alternative timing assumptions

The conventional literature has usually estimated a recursive VAR with the policy measure ordered last. This implies that systematic monetary policy is affected by the shocks from the other included variables contemporaneously, while it takes one period before unsystematic monetary policy affects the included variables. So far, we have followed this assumption for the purpose of comparison to the conventional VAR literature on the effects of monetary policy.

Alternatively, one can assume the opposite recursive order, i.e. with the policy measure ordered first. Then, all the included variables in the VAR are allowed to respond to a monetary policy shock on impact. This is not a plausible assumption for conventional VAR studies, since it implies that systematic monetary policy cannot respond to current macroeconomic fluctuations (Bjørnland & Thorsrud, 2014). On the other hand, we should be able to relax this assumption and estimate a VAR with our new measure of monetary policy ordered first for the following reason. In the first stage regression, we constructed a real-time forecast data set on important variables to Norges Bank's key policy rate decisions. In addition, we ensured that the forecasts were orthogonal. This should have purged the key policy rate of monetary policy actions taken by Norges Bank, in response to information about future economic developments. That is, it should be contemporaneously exogenous as supported by the Granger causality tests performed in section 4.4.1. By estimating a VAR, with our new measure of monetary policy ordered first, contemporaneous macroeconomic fluctuations do not affect the key policy rate decision other than via the forecasts in the first stage regression (CH, 2015).

Figure 9: Alternative timing assumptions

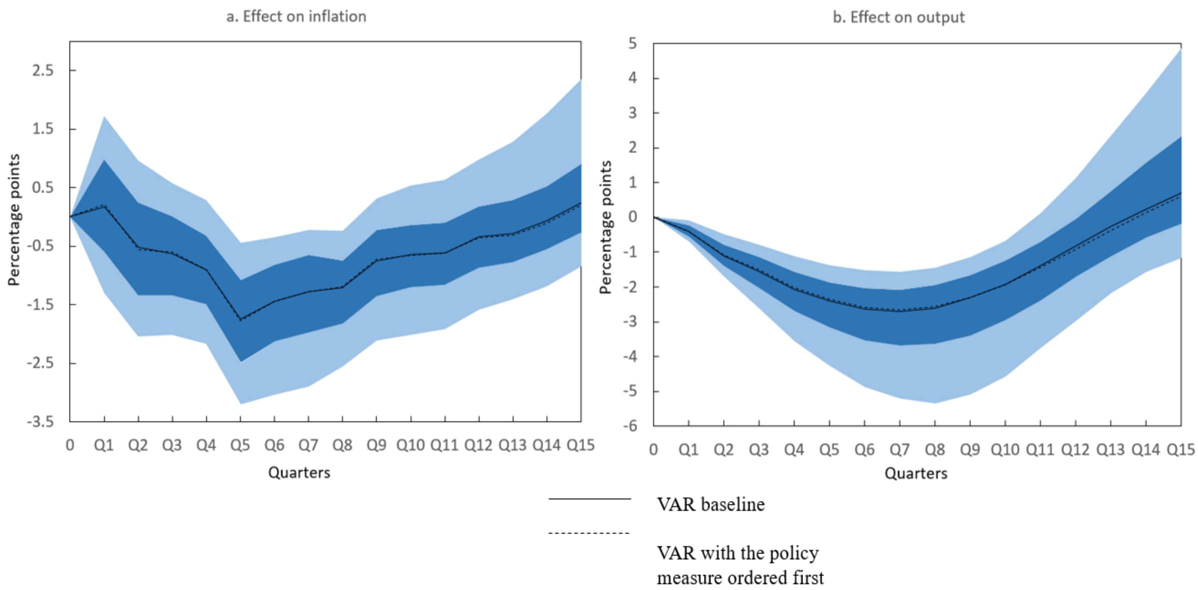
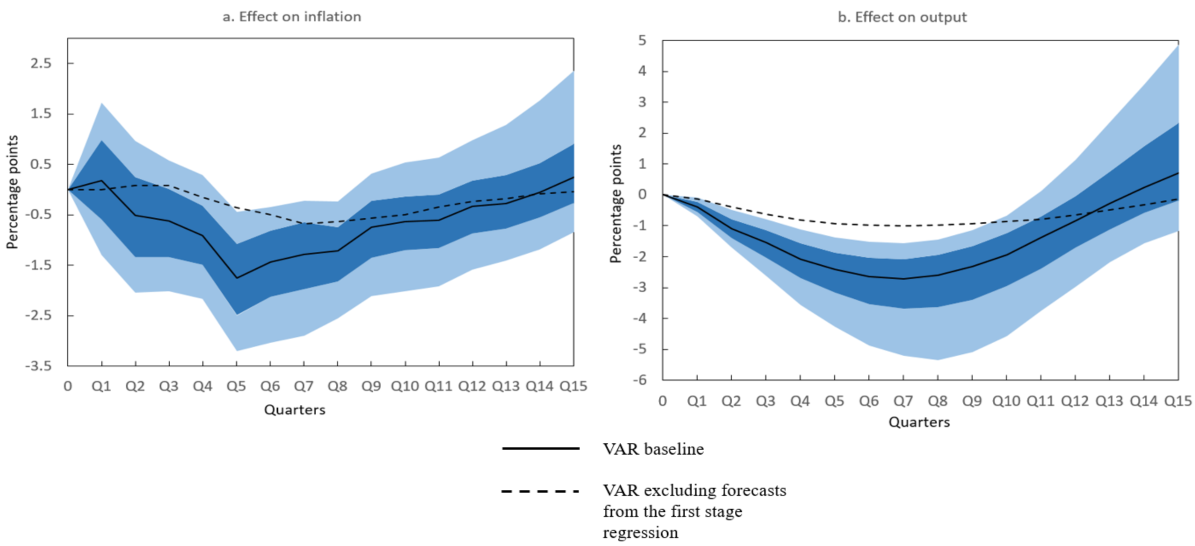


Figure 9 pictures the effects of monetary policy on inflation and output when allowing the policy measure to have a contemporaneous effect, compared to our baseline results. The impulse responses are almost identical. This suggests that the effect on inflation and output seems to build up slowly over time. The ordering of the variables in the estimated VAR does therefore not seem to have any effect on the results using our new measure of monetary policy.

5.3.2 The importance of the forecasts

To assess the importance of the forecasts, it is useful to investigate whether our baseline results are sensitive to excluding them from the first stage regression. The forecasts should, in principle, be a good indicator of the information set of Norges Bank, and allow us to control for key policy rate moves that are designed to offset future movements in the business cycle. On the other hand, if Norges Bank did not react to changes in the forecasts, excluding them from the first stage regression should not alter our baseline results. To investigate the importance of including the forecasts, we re-estimate the first stage regression by only including lagged real-time variables of the output gap and inflation, in addition to the current level of the key policy rate.[62] When excluding the forecasts, the adjusted R^2 is 0.17. This is substantially lower than the adjusted R^2 of our baseline approach (0.65), and suggests that the forecasts constitute a large fraction of Norges Bank's information set. The impulse responses from the VARs are shown in Figure 10.

Figure 10: Comparison between VAR baseline and VAR excluding forecasts



With the forecasts excluded, the estimated results weaken significantly. The estimated peak effect on inflation and output is about 38 per cent of our baseline results. The differences suggest that Norges Bank has been forward-looking, and responding to anticipated movements in the business cycle, during the period of investigation. Hence, forecasts seem to be an important part of their information set. That is, excluding the forecasts from the first stage regression could cause an omitted variable bias.

[62] The specific equation we estimate is Equation (6) for $t = -1$ instead of $t = -1, 0, 1, 2$.

5.3.3 Sensitivity regarding the policy rate meeting in December 2008

Another potential concern is whether our baseline results are sensitive to the inclusion of the key policy rate meeting in December 2008, during the outbreak of the financial crisis. To assess the impact of this meeting, we treat the policy measure as missing in December 2008 before cumulating the baseline shock series. The impulse responses are reported in Figure 24 in the Appendix. The effect on inflation lies within the 68 per cent confidence intervals of our baseline VAR, while the effect on output seems to be somewhat delayed compared to our baseline results. Still, the peak effects are qualitatively similar. This suggests that our results are relatively robust to omitting the meeting in December 2008.

5.3.4 Extensions of the baseline VAR

A natural robustness check of our baseline VAR is to control for other variables that may affect output and inflation. However, since we control for Norges Bank's information about future output and inflation in our first stage regression, we could expect that the new measure of monetary policy is uncorrelated with other variables that influence output and inflation. Still, it might be possible that some anticipatory movements are present in our new policy measure. Such anticipatory movements could be the result of Norges Bank responding to other variables not included in the first stage regression. For this reason, we choose to expand the baseline VAR with additional control variables.

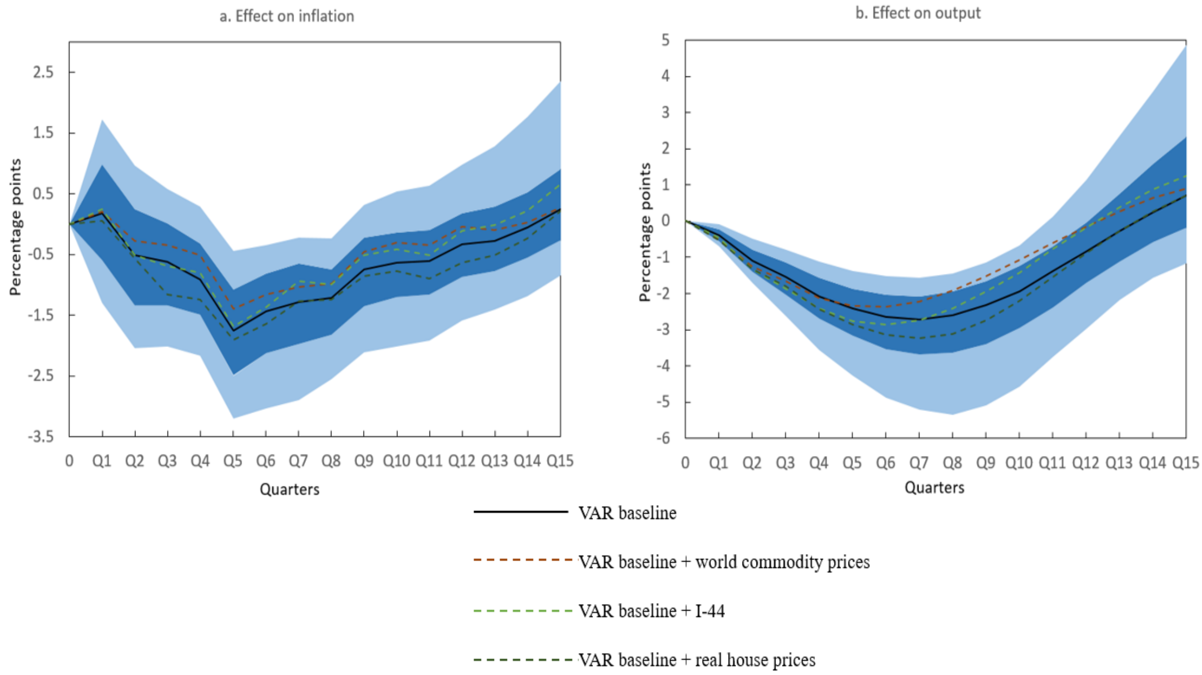
Following RR (2004), we expand our baseline VAR specification with data on world commodity prices to capture possible additional information Norges Bank has about supply shocks.[63] If some of the changes in the policy measure, which we identified as monetary policy shocks, are in fact responses to a negative supply shock that is assumed to lower output in the future, this will likely lead to overestimates of the negative effect that the policy measure has on output. Likewise, a negative supply shock will lead to higher inflation in the future. Such uncaptured responses in the estimation, would likely lead to underestimates of the negative effect on inflation of a contractionary shock to the policy measure. Furthermore, as Norway is a small, open economy, we might omit important dynamics by excluding the exchange rate from the estimation. We therefore follow Bjørnland (2008), and control for the import-weighted

[63] Data on world commodity prices is added as an exogenous variable in the VAR, as Norway is a small, open economy. The assumption that domestic monetary policy has a negligible effect on foreign prices is a common small, open economy assumption (Dornbusch, 1976).

exchange rate (I-44).[64] Finally, we add real house prices to the baseline VAR as Norges Bank aims at conducting a robust monetary policy. Including developments in the housing market may therefore be important to capture relevant dynamics.

The impulse responses on inflation and output of the different extensions are pictured in Figure 11.[65] All the impulse responses are largely within the 68 per cent confidence intervals of the baseline VAR. Hence, the results are relatively similar to our baseline VAR results.[66] Controlling for these additional variables does therefore not seem to have any important effect on the baseline estimates. The results suggest that our new measure of monetary policy does not contain responses to supply shocks, movements in the exchange rate or house prices. Thus, our new measure seems to largely reflect independent changes in monetary policy.

Figure 11: Extensions of the baseline VAR

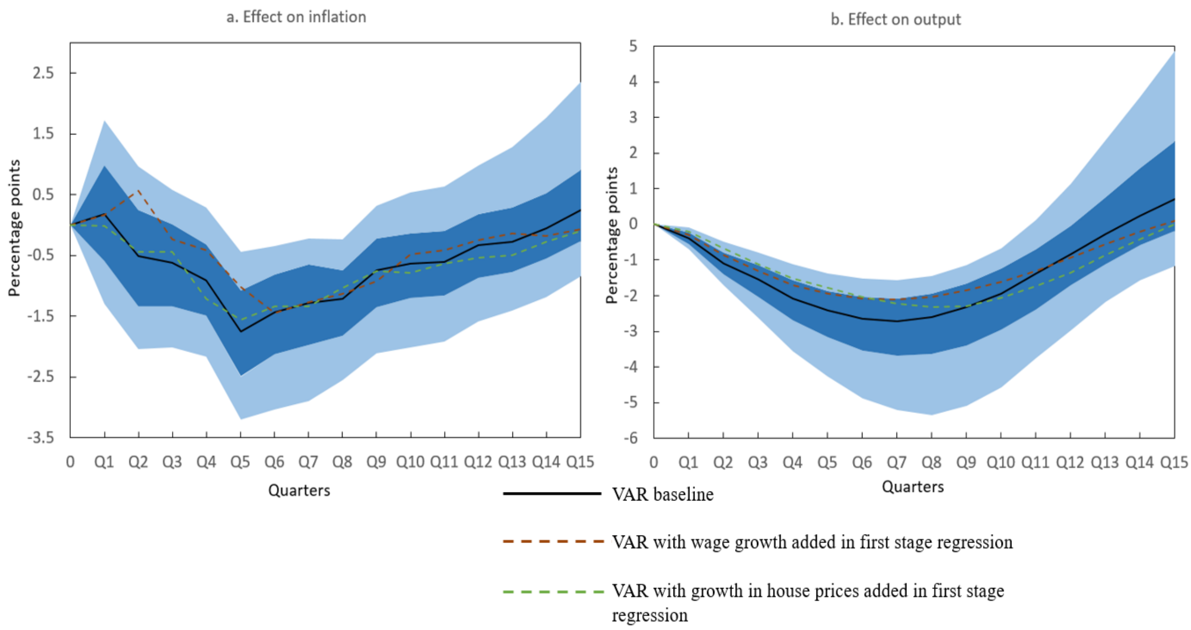


[64] The I-44 is estimated on the basis of Norwegian imports from 44 different countries, which comprise 97 per cent of total Norwegian imports (Norges Bank, 2016a).
[65] All the additional variables in the VAR extensions are log-transformed. Furthermore, we include a trend. The impulse responses on the exchange rate (I-44) and on house prices are pictured in Figure 25 and 26 in the Appendix.
[66] To assess possible important dynamics between the additional control variables, we also combine them in separate VARs (not reported). This does not alter the baseline VAR results.

5.3.5 Permutations of the first stage regression

We also assess the robustness of our findings to the alternative specifications presented in section 4.5. Cumulating these alternative shock series and applying them in a VAR with the same specifications as in our baseline approach produce impulse responses that are largely within the 68 per cent confidence intervals of our baseline results. With wage growth added in the first stage regression, the peak decline in inflation and output is 1.45 and 2.11 percentage points respectively. When adding the one and two quarter lagged four-quarter changes in house prices, the peak decline in inflation is 1.55 percentage points and the peak decline in output 2.32 percentage points. This indicates that our results seem to be robust against these alternative permutations of the baseline shock series.

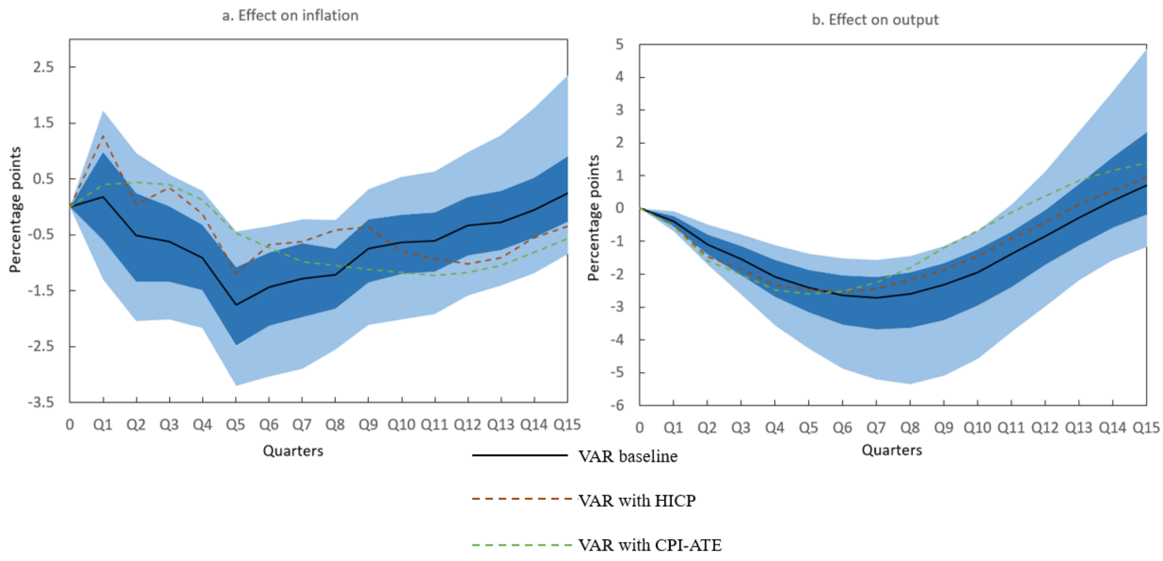
Figure 12: Permutations first stage regression



5.3.6 Alternative inflation measures

In order to assess the robustness of using the GDP deflator for Mainland Norway as the inflation measure, we re-estimate the baseline VAR using both CPI-ATE and the HICP. It is natural to compare our baseline VAR results with the use of CPI-ATE as the inflation measure, since it is the core inflation measure of Norges Bank. An advantage of using the HICP, is that its main purpose is to compare the inflation developments between countries (SSB, 2016). The impulse responses on both alternative inflation measures are shown in Figure 13, and lie within the 95 per cent confidence intervals for both inflation and output. Thus, it seems like the use of the GDP deflator for Mainland Norway in our baseline VAR is robust to these alternative inflation measures. However, the estimated effect on the inflation rate shows evidence of an insignificant price puzzle using both alternative inflation measures.[67] Rusnák et al. (2013) discuss several potential explanations for obtaining a price puzzle when estimating a VAR.

Figure 13: Alternative inflation measures



First, the price puzzle could emerge if the VAR does not contain enough information about future inflation. However, this explanation does not seem very plausible, as the inclusion of additional control variables in our baseline approach did not affect our results. These results support that our policy measure is relatively exogenous. Since we employ the same policy measure in the alternative inflation measure models presented above, there is no reason to expect that the impulse responses will change if additional control variables were added.

Second, the price puzzle could arise from implausible identification of monetary policy shocks. That is, the standard Cholesky assumptions may distort the impulse response functions, as proposed by Carlstrom et al. (2009). However, our baseline results do not show evidence of a price puzzle using the Cholesky identification strategy. This might indicate that the initial increase in inflation in the alternative VARs is not caused by the identification strategy employed.

[67] The estimated short-term increase in the inflation rate is not statistically significant, since the lower end of the 95 per cent confidence band is below zero at all horizons (the confidence intervals are not reported).

Third, it could be that the price puzzle is caused by the so-called cost channel of monetary policy. Firms may be dependent on credit to finance their production. Hence, a monetary tightening could increase their production costs and cause them to increase their prices initially (Barth & Ramey, 2002). If the effects of the supply-side dominate the demand-side in the short term, the price puzzle obtained using the alternative inflation measures might be caused by the cost channel of monetary policy. Thus, the initial increase in inflation would represent a genuine response to the contractionary shock in the policy measure. Chowdhury et al. (2006) investigate the relevance of the cost channel for inflation dynamics in G7 countries. They find evidence from VARs, studying the impact of monetary policy shocks, which indicates that the effect of the cost channel on macroeconomic variables can be substantial. This is consistent with the findings of Llaudes (2007), Bjørnland and Jacobsen (2009), and Robstad (2014), which all find evidence of a price puzzle when using different identification strategies. They are all employing other inflation measures than the GDP deflator, which may indicate that the potential short-term domination of a cost channel is not adequately captured in our baseline VAR. To our knowledge, there have been no studies investigating the effect of the cost channel on Norwegian data. However, evidence of the cost channel's impact in other countries is mixed. Results from Rabanal (2007) on US data, and Henzel et al. (2009) on data for the Euro area, indicate that the demand-side effects of monetary policy dominate the supply-side effects, even in the short term. Thus, their findings suggest that the cost channel of monetary policy may be relatively unimportant.

The discussion above does not seem to provide a plausible explanation for obtaining a price puzzle, when employing the CPI-ATE and the HICP as inflation measures. The use of the GDP deflator in our baseline VAR on the other hand, appears to capture the short-term dynamics between the key policy rate and inflation as predicted by standard economic theory. This might imply that it is a better indicator of broad macroeconomic conditions (Bernanke & Mihov, 1998). Our baseline results therefore suggest that employing the GDP deflator is more appropriate when assessing the effects of monetary policy for Norway.

6. Final remarks

This thesis makes use of the narrative identification strategy, pioneered by RR (2004), in order to estimate a new measure of monetary policy for Norway. The new measure is then employed in a vector autoregression (VAR) to assess the effect of the key policy rate on output and inflation. However, identifying the effects of moves in the key policy rate is challenging. Norges Bank is forward-looking, and changes in the key policy rate are therefore likely to include anticipated movements. The reason is that Norges Bank is reacting to both expected future economic conditions, in addition to current and past information. Thus, the use of the actual key policy rate in empirical studies will likely lead to biased estimates of the effects of monetary policy. Furthermore, Norges Bank bases their decisions on information available in real time, not ex-post revised data.

The advantage of using the narrative identification strategy is that we can tackle the three technical challenges directly. By constructing a new and extensive data set, consisting of real-time data, this thesis aims at capturing the complete information set of Norges Bank prior to each of the included key policy rate decisions. By estimating a first stage regression, the key policy rate is purged of systematic and anticipatory movements to construct a new measure of monetary policy for Norway. The thesis finds that estimating a Taylor rule gives a considerable better fit on Norwegian data, compared to the replication of RR (2004).

To ensure comparability to the wider literature on the effects of monetary policy, we employ our new measure, instead of the actual key policy rate, as the policy measure in a VAR. In the baseline VAR, the estimated peak decline is 1.75 percentage points in inflation and 2.71 percentage points in output, following a one percentage point shock to the new policy measure. The peak declines are reached after five and seven quarters respectively. The baseline results are shown to be relatively robust to a wide range of different specifications. The estimated peak effects are significantly larger than the results previously obtained when using the actual key policy rate as the policy measure on Norwegian data. This might indicate that our new measure of monetary policy is relatively free of anticipatory movements. Thus, it should provide more precise estimates and be a suitable measure to assess the effect of monetary policy, during the period of flexible inflation-targeting investigated in this thesis (1999Q1 – 2016Q1).

In the wake of the financial crisis, many developed economies have been experiencing historically low policy rates. Even though Norway was not hit as hard by the crisis, the current key policy rate level is all-time low due to the decreased activity in the oil sector. However, despite the low key policy rate, it still remains the main tool in Norges Bank's conduct of monetary policy, and serves as the first line of defence in stabilizing the economy. With the current prospects of low future growth, the key policy rate continues to approach its lower bound. As Øystein Olsen recently expressed, this increases the uncertainty regarding its effect (Olsen, 2016b). Knowing the precise effect of the key policy rate is therefore of considerable interest for Norges Bank, in order to align monetary policy optimally in the restructuring phase. The baseline results in this thesis, suggest that moves in the key policy rate have considerable impact on the development in macroeconomic variables. This may have important implications regarding the future conduct of monetary policy for Norges Bank. The first two criteria for an appropriate key policy rate path, state that Norges Bank should reach the inflation target of 2.5 per cent in the medium term, and contribute to stable developments in output and employment (Norges Bank, 2016a). The strong estimated effects of the key policy rate found in this thesis are encouraging, and suggest that Norges Bank has an effective instrument to achieve these two criteria.

The baseline results of this thesis contribute to the ongoing debate in the literature regarding the effects of monetary policy. By constructing a new, real-time forecast data set, and a new measure of monetary policy, we provide tools that we hope can be used in future research. One application could be to assess the effect that the new measure of monetary policy has on variables such as credit growth and asset prices. Such research could provide useful insights regarding Norges Bank's ability to ensure a robust monetary policy.

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8. Appendix

Table 7: Variables of real-time forecasts data set

Variable	Source	Description	Available period	Comments
Key policy rate	Norges Bank	The interest rate on banks' deposits up to a quota in Norges Bank.	1999-2016	Used as the intended target rate of Norges Bank.
CPI-ATE	Norges Bank	CPI adjusted for tax changes and excluding energy products. Four-quarter change, per cent.	IR 3/01 – MPR 1/08, MPR 2/13 – 1/16	
CPIXE	Norges Bank	CPI adjusted for tax changes and excluding temporary changes in energy prices. Four-quarter change, per cent.	IR 2/01, MPR 2/08 - 1/13	IR 2/01: CPIXE measured as the CPI excluding direct effects of changes in excise duties and energy prices.
CPI	Norges Bank	Consumer price inflation.	IR 4/98 – 3/00	
CPI	Norges Bank	Underlying consumer price inflation, excluding indirect taxes and electricity prices.	IR 4/00 - 1/01	The description is obtained from IR 1/01.
Output gap	Norges Bank	The percentage deviation between mainland GDP and projected potential mainland GDP.	IR 1/99 – 1/01, IR 1/03 – MPR 3/08, MPR 1/09 – 1/16	Interpolated from annual to quarterly figures for 1999, 2000, 2003 and 2004.
Output gap	OECD Economic outlook (64 – 98)	The percentage deviation between mainland GDP and projected potential mainland GDP.	1999 – 2016	Interpolated from annual to quarterly figures. Employed as a proxy for Norges Bank's forecasts for IR, 2/01 – 3/02 and Dec.08. (6 meetings).
GDP growth	Norges Bank, Statistics Norway	GDP growth for mainland Norway. Four-quarter change, volume, per cent (S.A.).	MPR 2/08 – 1/16	For the two quarter ahead forecasts we interpolated from real GDP in levels to four-quarter change.
GDP growth	Statistics Norway	GDP growth for mainland Norway. Four-quarter change, volume, per cent (S.A.).	MPR 1/99 – 1/08	Interpolated from real GDP in levels to four-quarter change for all quarters.
Wage growth	Norges Bank	Annual change in nominal wages. Per cent.	1999-2016	Forecasts for the current and next year.
Unemployment	Norges Bank	Unemployment as a share of the labour force. Norwegian Labour and Welfare Administration (NAV), (S.A.).	1999-2016	Monthly historical data available for the full sample period.
House prices	Norges Bank	House prices. Four-quarter change. Per cent.	1999 – 2015	Quarterly historical data available for the full sample period.

Notes: Variables from the real-time data set included in different permutations of the first stage regression. The specific data material from IR 1/99 to IR 3/03 is not available online, and was obtained from Norges Bank directly. The complete data set consists of in total 2726 manually typed in values, distributed into 47 different variables. The variables could explain Norges Bank's key policy rate decisions in the 58 included policy rate meetings from 1999Q1 to 2016Q1. The data set is available from the authors on request.

Table 8: Included policy rate meetings in the first stage regression

Meeting date	Initial key policy rate (per cent)	Change in key policy rate (percentage point)	Meeting date	Initial key policy rate (per cent)	Change in key policy rate (percentage point)
24.04.1999	7.00	-0.50	13.03.2008	5.25	0.00
16.06.1999	6.50	-0.50	25.06.2008	5.50	0.25
22.09.1999	6.00	-0.50	29.10.2008	5.25	-0.50
22.12.1999	5.50	0.00	17.12.2008	4.75	-1.75
16.03.2000	5.50	0.00	25.03.2009	2.50	-0.50
14.06.2000	5.75	0.50	17.06.2009	1.50	-0.25
20.09.2000	6.75	0.25	28.10.2009	1.25	0.25
13.12.2000	7.00	0.00	24.03.2010	1.75	0.00
04.04.2001	7.00	0.00	23.06.2010	2.00	0.00
20.06.2001	7.00	0.00	27.10.2010	2.00	0.00
31.10.2001	7.00	0.00	16.03.2011	2.00	0.00
27.02.2002	6.50	0.00	22.06.2011	2.25	0.00
03.07.2002	6.50	0.50	19.10.2011	2.25	0.00
30.10.2002	7.00	0.00	14.03.2012	1.75	-0.25
05.03.2003	6.00	-0.50	20.06.2012	1.50	0.00
25.06.2003	5.00	-1.00	31.10.2012	1.50	0.00
29.10.2003	2.50	0.00	14.03.2013	1.50	0.00
11.03.2004	2.00	-0.25	20.06.2013	1.50	0.00
01.07.2004	1.75	0.00	19.09.2013	1.50	0.00
03.11.2004	1.75	0.00	05.12.2013	1.50	0.00
16.03.2005	1.75	0.00	27.03.2014	1.50	0.00
30.06.2005	1.75	0.25	19.06.2014	1.50	0.00
02.11.2005	2.00	0.25	18.09.2014	1.50	0.00
16.03.2006	2.25	0.25	11.12.2014	1.50	-0.25
29.06.2006	2.75	0.00	19.03.2015	1.25	0.00
01.11.2006	3.00	0.25	18.06.2015	1.25	-0.25
15.03.2007	3.75	0.25	24.09.2015	1.00	-0.25
27.06.2007	4.25	0.25	17.12.2015	0.75	0.00
31.10.2007	5.00	0.00	17.03.2016	0.75	-0.25

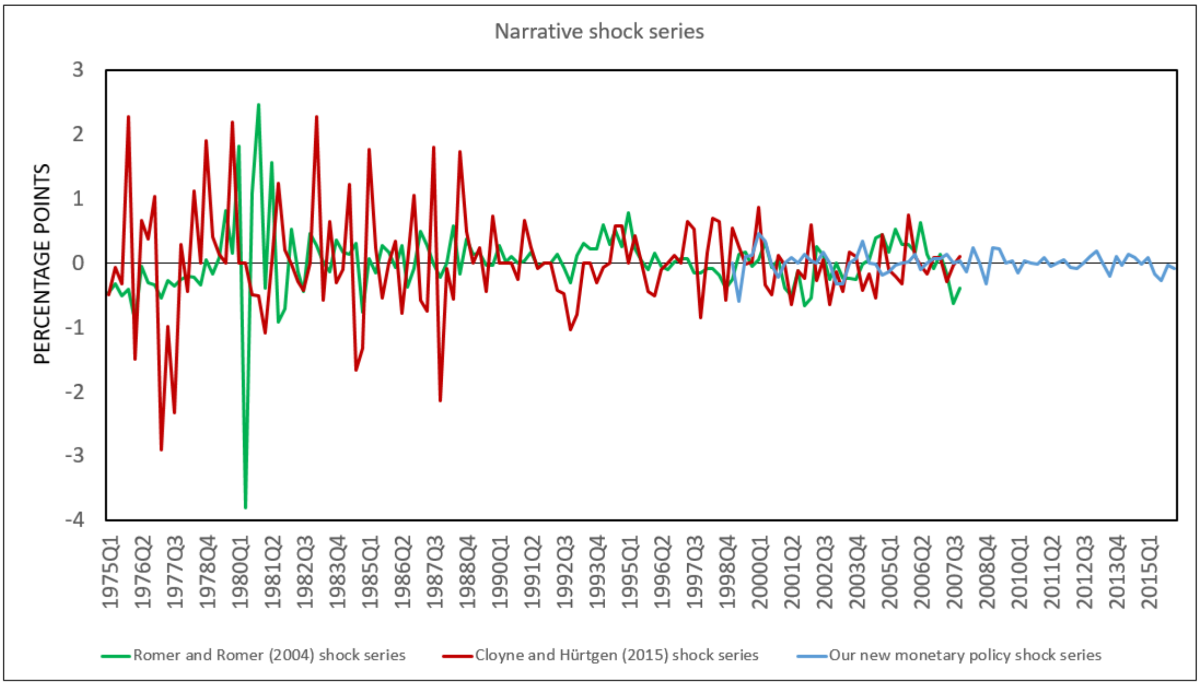
Notes: Information regarding the 58 key policy rate meetings included in the estimation of the first stage regression. Source: Norges Bank.

Table 9: Data sources

Variable	Source	Description	Series
Real GDP growth	Statistics Norway	Real GDP for Mainland Norway (S.A.). Four-quarter change.	QSA_YMN
Inflation (GDP deflator)	Norges Bank	GDP deflator for Mainland Norway (S.A.). Four-quarter change.	QSA_PYMN
Inflation (CPI-ATE)	Norges Bank	CPI adjusted for tax changes and excluding energy products. Four-quarter change (S.A.).	QSA_PCPIJAE
Inflation (HICP)	Statistics Norway	Covers consumer goods and services purchased by means of monetary transactions (household final monetary consumption expenditure). Four-quarter change.	Table 03700
Unemployment rate	NAV	Unemployment as a share of the labour force (S.A.).	QSA_URR
Output gap	Norges Bank	The percentage deviation between Mainland GDP and projected potential Mainland GDP (S.A.).	NB.QSA_GAPNB_Y
Key policy rate	Norges Bank	The interest rate on banks' deposits up to a quota in Norges Bank.	NB.QA_RNFOLIO
World Commodity Prices	IMF	All Commodity Price Index, 2005 = 100, includes both Fuel and non-fuel Price indices.	PALLFNF_Index
Import weighted krone exchange rate (I-44)	Norges Bank	Estimated on the basis of Norwegian imports from 44 different countries, which comprise 97 per cent of total Norwegian imports.	NB.QA_SI44
House prices	Norges Bank	Real house price index (S.A.).	QSA_PHN
Romer and Romer (2004) shock series	Cloyne and Hürtgen (2015)	Quarterly shock series of Romer and Romer (1975 – 2007).	Cloyne and Hürtgen (2015) online data set
Cloyne and Hürtgen (2015) shock series	Cloyne and Hürtgen (2015)	Cloyne and Hürtgen (2015) shock series (1975 – 2007).	Cloyne and Hürtgen (2015) online data set

Notes: Ex-post data employed in the conduction of the Granger causality tests (section 4.4.1) and in all the VAR models estimated in Chapter 5. The HICP series and the Romer and Romer (2004) shock series is reported on a monthly frequency (and converted to quarterly figures), while the other series are reported on a quarterly frequency.

Figure 14: Narrative shock series



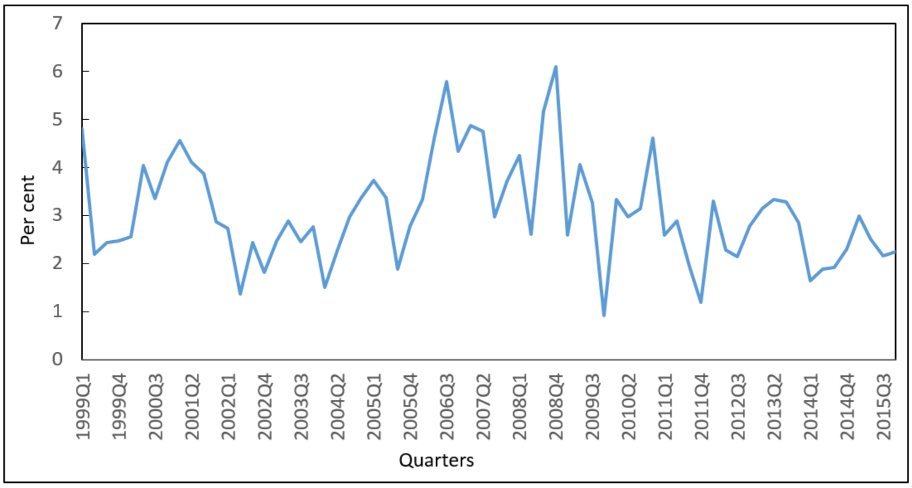
Notes: Figure 14 pictures the different shock series from the narrative studies of Romer and Romer (2004), Cloyne and Hürtgen (2015) and our new quarterly shock series for Norway. The Romer and Romer (2004) series was originally estimated from 1969 to 1996. However, the Romer and Romer (2004) shock series presented here (green coloured line) is estimated by Cloyne and Hürtgen (2015) on the sample 1975 to 2007, to ensure comparability with their own results. The Romer and Romer (2004) shock series is converted from a monthly to a quarterly frequency. The shock series from Cloyne and Hürtgen (2015) (red coloured line) is their original quarterly shock series.

Table 10: VAR models

Variables	Trend	Lags	Description	Section
The output gap, four-quarter change in the GDP deflator for Mainland Norway and the cumulated shock series	No	4	Baseline VAR results	5.2.1
The output gap, four-quarter change in the GDP deflator for Mainland Norway and the cumulated shock series	Yes	4	Baseline VAR including a trend	5.2.1
The output gap, four-quarter change in the GDP deflator for Mainland Norway and the cumulated shock series	No	2/3/5/6	Alternative lag specifications of the baseline VAR	5.2.1
The output gap, four-quarter change in the GDP deflator for Mainland Norway and the key policy rate	No	4	Baseline VAR specification using the actual key policy rate as the policy measure	5.2.2
Cumulated shock series, the output gap and the four-quarter change in the GDP deflator for Mainland Norway	No	4	Alternative timing assumption with the policy measure ordered first	5.3.1
The output gap, four-quarter change in the GDP deflator for Mainland Norway and the cumulated shock series using only real-time back data	No	4	Excluding the forecasts from the first stage regression	5.3.2
The output gap, four-quarter change in the GDP deflator for Mainland Norway and the cumulated shock series (omitting the meeting in December 2008)	No	4	Omitting the meeting in December 2008 from baseline shock series.	5.3.3
The output gap, four-quarter change in the GDP deflator for Mainland Norway, the cumulated shock series and the log of world commodity prices (Exogenous)	Yes	4	Extension of the baseline VAR I	5.3.4
The output gap, four-quarter change in the GDP deflator for Mainland Norway, the log of the import weighted exchange rate (I-44) and the cumulated shock series	Yes	4	Extension of the baseline VAR II	5.3.4
The output gap, four-quarter change in the GDP deflator for Mainland Norway, the log of real house prices and the cumulated shock series	Yes	4	Extension of the baseline VAR III	5.3.4
The output gap, four-quarter change in the GDP deflator for Mainland Norway and the cumulated shock series (including the four-quarter change in house prices)	No	4	Permutations of the first stage regression I	5.3.5
The output gap, four-quarter change in the GDP deflator for Mainland Norway and the cumulated shock series (including wage growth)	No	4	Permutations of the first stage regression II	5.3.5
The output gap, four-quarter change in CPI-ATE and the cumulated shock series	No	4	Alternative inflation measures I	5.3.6
The output gap, four-quarter change in HICP and the cumulated shock series	No	4	Alternative inflation measures II	5.3.6

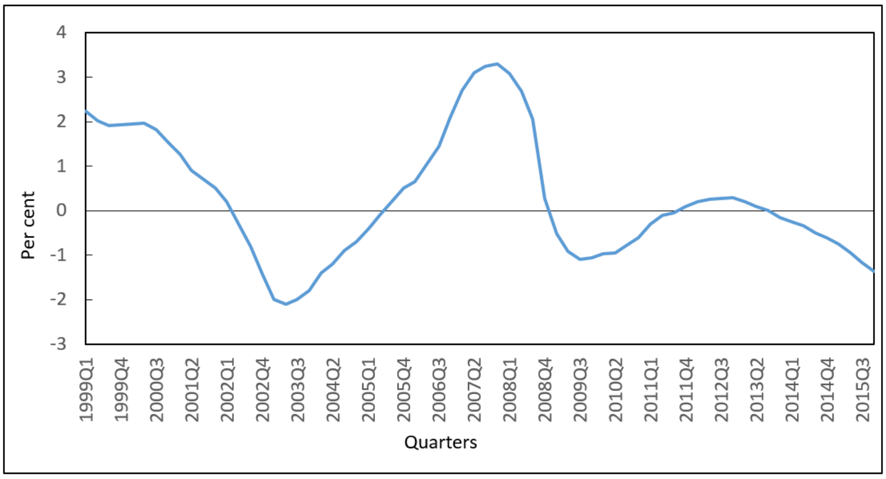
Notes: Estimated VAR models with different specifications. The table includes information regarding the variables included in the different VAR estimations, whether a trend is included, number of lags, and the specific section in the thesis where the model is presented. All the variables, except from world commodity prices, are added as endogenous variables in the VAR estimation.

Figure 15: GDP deflator Mainland Norway. 1999Q1 – 2015Q4.



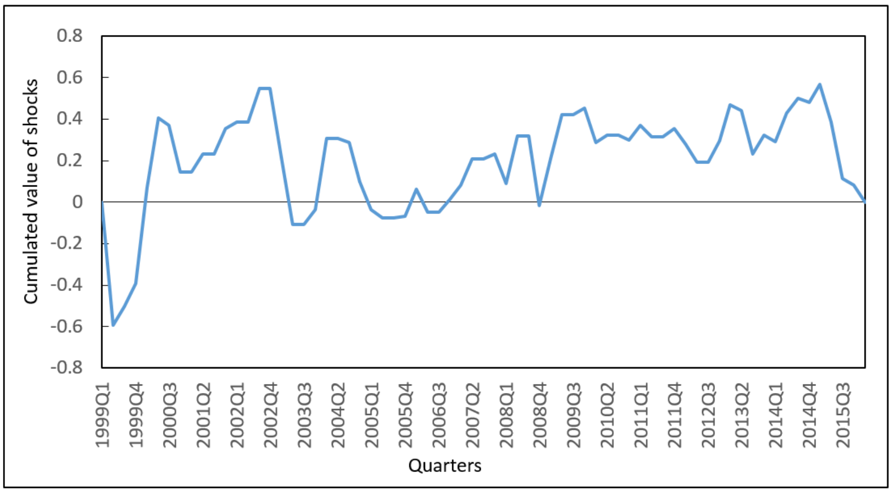
Notes: GDP deflator for Mainland Norway (S.A.). Four-quarter change.

Figure 16: The output gap for Norway. 1999Q1 – 2015Q4.



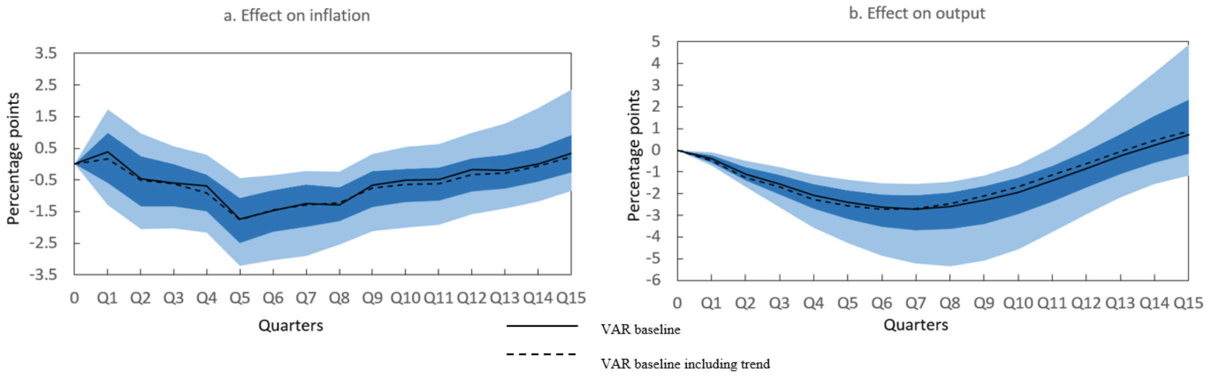
Notes: The percentage deviation between mainland GDP and projected potential mainland GDP for Norway.

Figure 17: Cumulated shock series. 1999Q1 – 2015Q4.



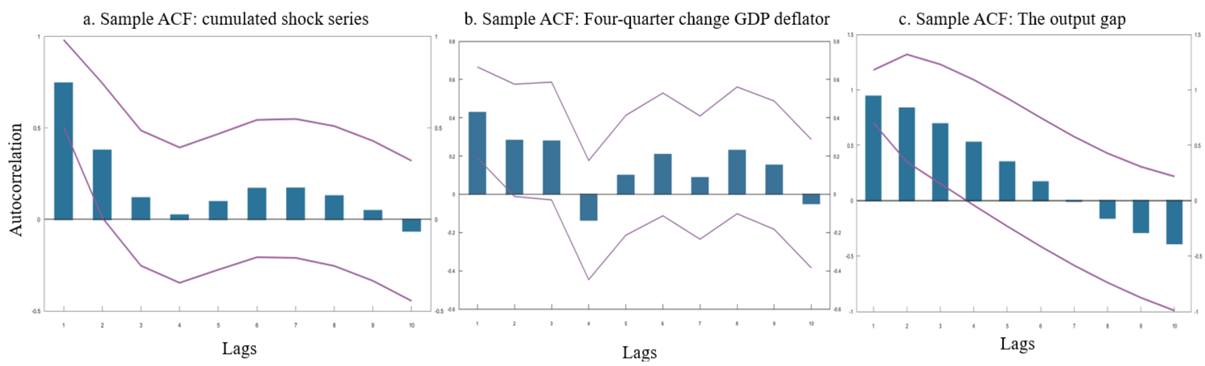
Notes: Value of baseline shock series cumulated.

Figure 18: VAR baseline with and without trend



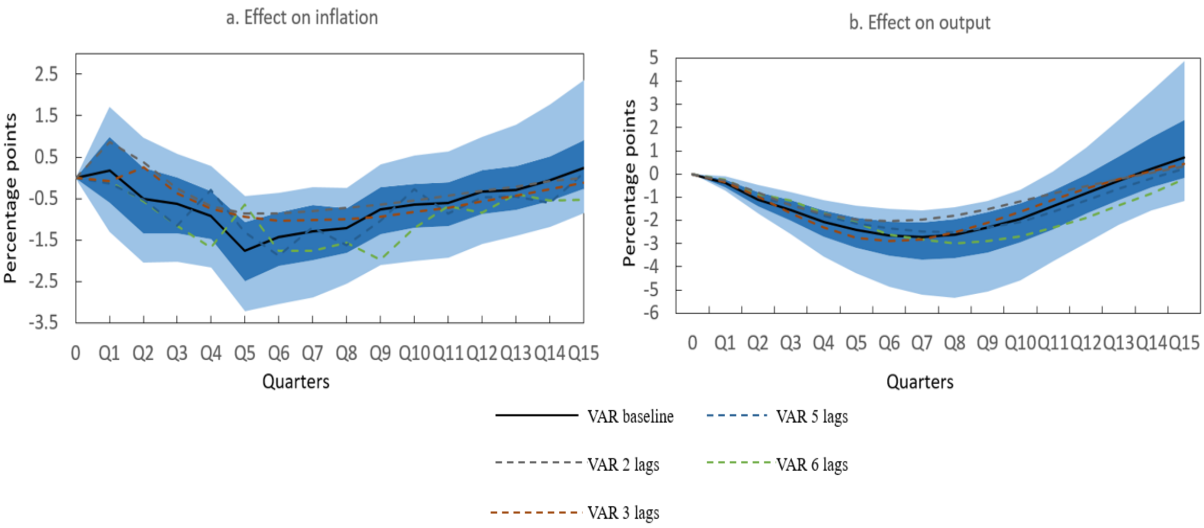
Notes: Impulse responses to a one percentage point contractionary monetary policy shock of the alternative specification (dashed line) and the baseline VAR (solid line) with the corresponding 68 and 95 per cent confidence intervals of the baseline VAR. The baseline specification employs the output gap, four-quarter change in the GDP deflator for Mainland Norway and our new cumulated quarterly shock series as endogenous variables. The alternative specification in addition includes a trend component. Both specifications use four lags.

Figure 19: Sample autocorrelation function included variables VAR baseline



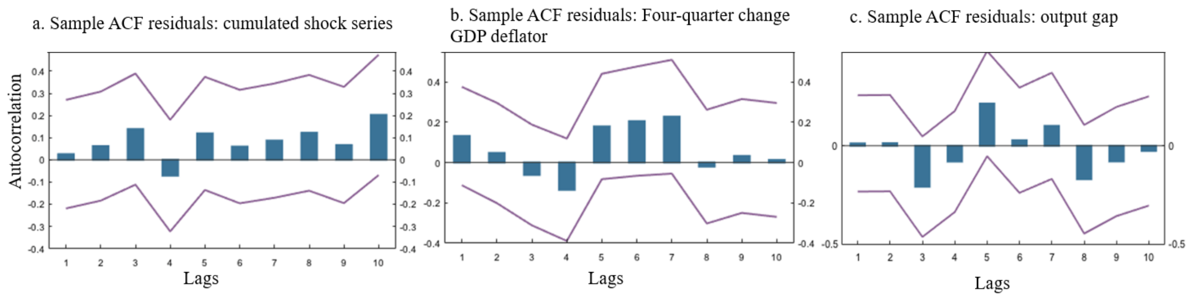
Notes: Figure 19 displays the sample autocorrelation functions for the cumulated quarterly shock series (a), four-quarter change in the GDP deflator for Mainland Norway (b) and the output gap (c). The blue columns indicate how correlated the respective variable is with its past values. The solid purple lines constitute the 95 per cent confidence intervals. If the confidence interval of a specific lag contains the value zero, the interpretation is that autocorrelation cannot be rejected on a five per cent significance level.

Figure 20: Lag length sensitivity



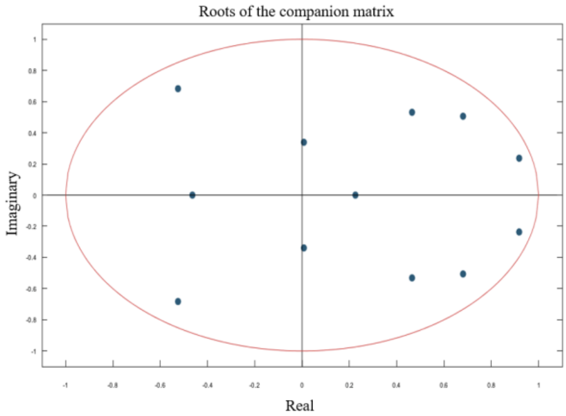
Notes: Impulse responses to a one percentage point contractionary monetary policy shock of the alternative specifications (coloured dashed lines) and the baseline VAR (solid line) with the corresponding 68 and 95 per cent confidence intervals of the baseline VAR. The baseline specification employs the output gap, four-quarter change in the GDP deflator for Mainland Norway and our new shock measure as endogenous variables with four lags. The alternative specifications employ the same variables as in the baseline specification, but with different lag structures.

Figure 21: Sample autocorrelation function residuals from baseline VAR



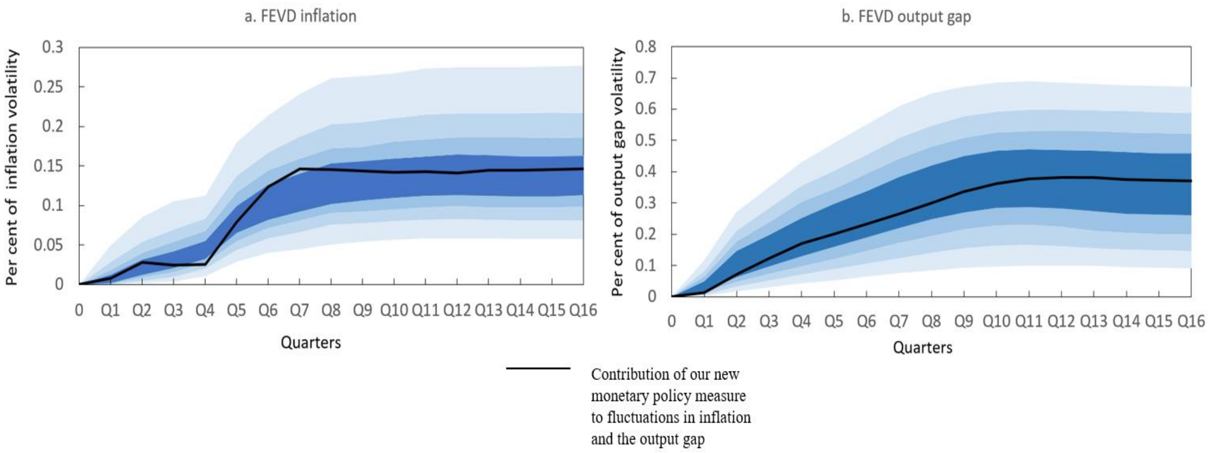
Notes: The figure displays the sample autocorrelation function residuals for the cumulated quarterly shock series (a), four-quarter change in the GDP deflator for Mainland Norway (b) and the output gap (c) after estimating the baseline VAR.

Figure 22: Eigenvalues of the companion form matrix



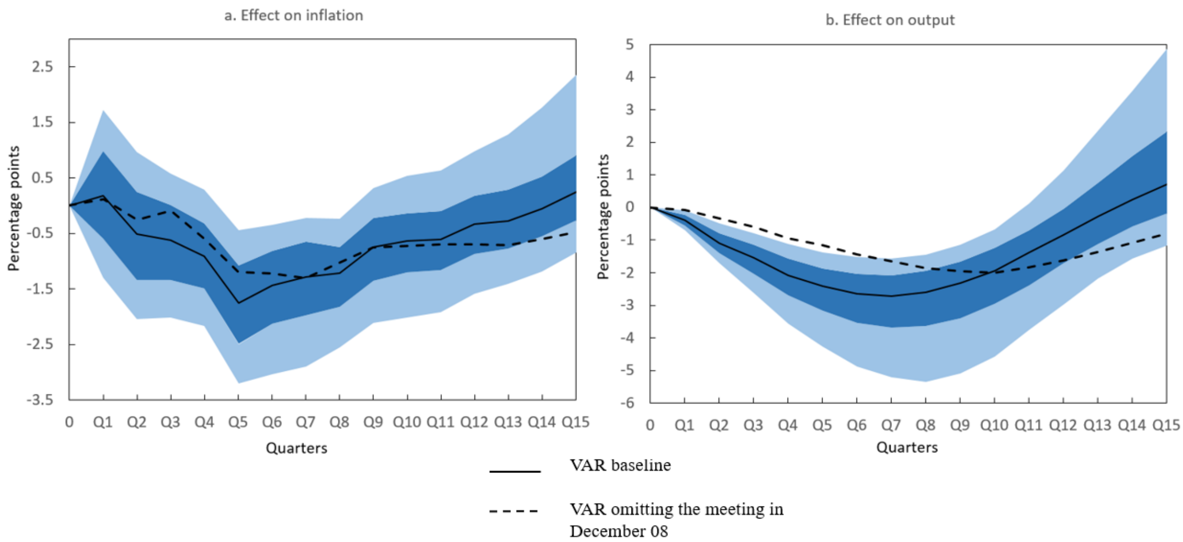
Notes: Figure 22 pictures the roots test applied to test if the eigenvalues of the companion form matrix in the baseline specification lie within the unit circle, in order to assess the stability of the VAR, i.e. a covariance-stationary process. The figure shows the eigenvalues with the real components on the x-axis and the complex components on the y-axis (StataCorp LP, 2016).

Figure 23: Forecast error variance decompositions



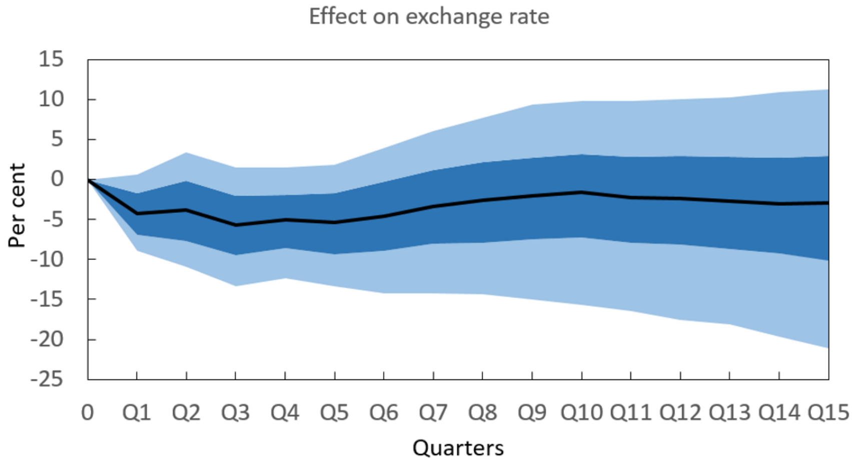
Notes: The forecast error variance decompositions (FEVDs) show how much of the forecast error variance, for inflation and the output gap, that is due to variations in the structural monetary policy shocks, ε_{MP}, at different horizons $t+s$, given the information available at time t (Bjørnland & Thorsrud, 2014). The FEVDs are pictured together with the 0.3, 0.5, 0,7 and 0.9 percentiles.

Figure 24: Policy rate meeting December 2008



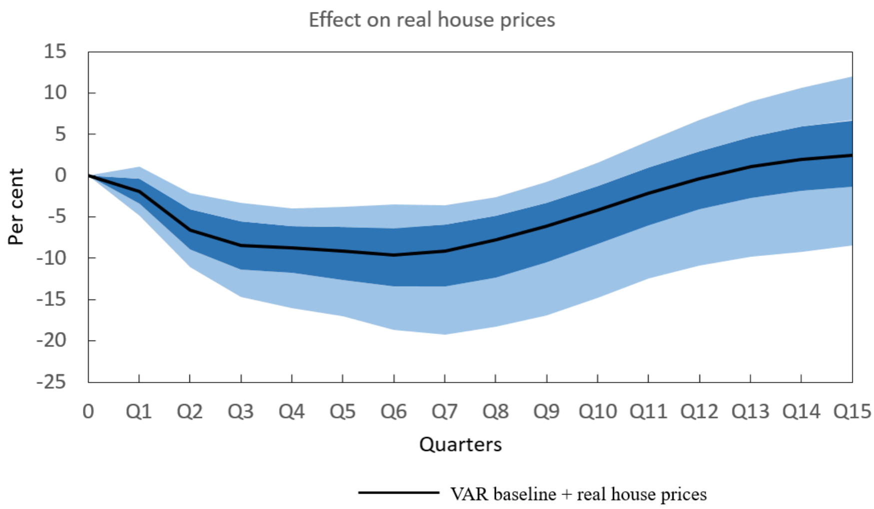
Notes: Impulse responses to a one percentage point contractionary monetary policy shock of the alternative specification (dashed line) and the baseline VAR (solid line) with the corresponding 68 and 95 per cent confidence intervals of the baseline VAR. The baseline specification employs the output gap, four-quarter change in the GDP deflator for Mainland Norway and our new cumulated quarterly shock series as endogenous variables with four lags. The black dashed line is obtained from using the shock series from our preferred baseline approach, but treating the policy measure as missing in December 2008, before cumulating the shock series.

Figure 25: Impulse response of the exchange rate



Notes: Impulse response to a one percentage point contractionary monetary policy shock on the exchange rate with its corresponding 68 and 95 per cent confidence intervals. The specification used includes the output gap, four-quarter change in the GDP deflator for Mainland Norway, the log of I-44 and our new cumulated quarterly shock series as endogenous variables with four lags. In addition, we include a trend component.

Figure 26: Impulse response of real house prices



Notes: Impulse response to a one percentage point contractionary monetary policy shock on real house prices, with its corresponding 68 and 95 per cent confidence intervals. The specification used includes the output gap, four-quarter change in the GDP deflator for Mainland Norway, the log of real house prices and our new cumulated quarterly shock series as endogenous variables with four lags. In addition, we include a trend component.