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Can LAW be justified to prevent financial instability?

A cost-benefit analysis of leaning against the wind (LAW) in Norway: Evidence from a Bayesian VAR model

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Abstract

Since the 2008 Global Financial Crisis, there has been an ongoing debate about how central banks can prevent future financial crises by mitigating the build-up of financial imbalances. We analyse the effect of incorporating financial stability considerations through monetary policy by "leaning against the wind" (LAW), which involves keeping a slightly tighter monetary policy for the purpose of mitigating financial instability. The benefits of LAW are lower probability and severity of a financial crisis in the future, while the cost is higher unemployment.

We model LAW as a one-time monetary policy shock using a structural Bayesian VAR model on Norwegian data, inspired by Robstad (2018). Then, we analyse the cost-benefit trade-off of LAW in Norway using a modified version of the framework in Svensson (2017a), and contribute to the literature by including house price growth as an indicator explaining the probability of a crisis. We find that LAW is clearly unjustified when using household credit growth as an indicator of financial instability. This conclusion also is robust to any reasonable changes in the underlying estimates and assumptions. When using house price growth, we actually find that LAW is justified in the benchmark model, although only by a very small margin. However, this conclusion is not at all robust, as reasonable changes to the underlying estimates and assumptions easily change the conclusion, making LAW unjustified. Hence, we cannot use this result to conclude that LAW is an advisable policy in Norway.

In sum, the numerical results do not find evidence that LAW is justified in Norway. Furthermore, Norway has a well-equipped macroprudential policy toolkit to counteract financial imbalances, arguably reducing the effect of and need for LAW. We therefore recommend that Norges Bank should not "lean against the wind", unless the Norwegian economy experiences extraordinary circumstances where the macroprudential policy tools clearly are insufficient to secure financial stability.

Keywords – Leaning against the wind (LAW), Monetary policy, Financial stability, Bayesian Vector Autoregression (BVAR), Macroprudential policy

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1 Introduction

In the period after the 2008 Global Financial Crisis (GFC), it has been a priority among monetary policymakers to reduce the risk of future financial crises. This stands in great contrast to the pre-crisis sentiment that financial stability is a concern of prudential regulators and supervisors only, and that the central bank should rather focus on price stability (Filardo and Rungcharoenkitkul, 2016). The somewhat narrow focus on stabilising prices must be seen in context with the inflation-targeting regimes that several central banks introduced in the late 1990s and early 2000s. However, after experiencing the consequences of the GFC, financial stability became a priority for most central banks, including Norges Bank. In 2018, financial stability was officially included as an objective in the Regulation on Monetary Policy in the Central Bank Act in Norway (Norges Bank, 2022b). The regulation explicitly states that the inflation targeting should be flexible in the sense that it should also "...counteract the build-up of financial imbalances".

Therefore, it is safe to say that there is a broad consensus that central banks should promote financial stability and mitigate the build-up of financial imbalances. Despite this, there has been an intense public and academic debate about how central banks should implement this in practice. There are two main categories of policy functions through which financial stability concerns can be implemented. One approach is to deal with financial (in)stability through macroprudential policy, which refers to policy tools used to reduce systematic risk in the financial system. Typical macroprudential policy tools include different types of capital requirements, loan-to-value (LTV) ratio restrictions and liquidity requirements. Another approach is for central banks to implement the financial stability objective through conventional monetary policy. This approach, known as "leaning against the wind" (LAW), involves using monetary policy to counteract the build-up of financial imbalances. In practice, this would imply maintaining a tighter monetary policy than indicated by considerations of inflation and output alone.

The general consensus is that macroprudential policy should be the first line of defence in promoting financial stability (Gerdrup et al., 2017). This view is often justified by the fact that macroprudential policy tools, in contrast to LAW, can be targeted more directly at the specific source of risk. The use of LAW, however, is far more controversial.

Several studies find that the costs in terms of higher unemployment and lower output exceed the benefits in terms of a lower probability and severity of a crisis.[1] Despite this, Øystein Olsen, former Governor of Norges Bank, has repeatedly emphasised that LAW is a policy tool used by Norges Bank, and that it is within their mandate (Olsen, 2016). Other advocates of LAW highlight that the macroprudential policy toolkit is weak in many countries,[2] and that the monetary policy through LAW, therefore, can play an important role in securing financial stability.

The conflicting views and debate about LAW make it an exciting topic from both an empirical and practical point of view. The most recent contribution to the public debate on this topic in Norway came in March this year when Norges Bank received criticism from Norges Bank Watch[3] (NBW) for their use of LAW in the period before the COVID-19 pandemic (Haram, 2022). They argued that LAW should only be used under exceptional circumstances, and not in the case of minor financial imbalances, referring to the Norwegian house price growth.

The fact that there is such a strong disagreement between Norges Bank, leading economists, and academicians regarding the effect and role of LAW, is an interesting starting point for further research. This has resulted in the following research question:

> *Can leaning against the wind (LAW) be justified as a policy tool to counteract financial imbalances in Norway?*

There are multiple approaches to quantifying the effect of LAW. Our starting point for evaluating LAW in this thesis is the framework created and used by Lars E. O. Svensson[4] in Svensson (2017a). In this framework, the benefits of LAW are lower probability and severity of a financial crisis in the future, while the cost is a higher unemployment deviation. LAW is justified if, and only if, the associated benefits exceed the associated cost.

[1] See for instance Ajello et al. (2016), Svensson (2017a) or Kockerols and Kok (2019).

[2] For instance, the U.S. have a very limited macroprudential policy toolkit, as its regulatory authorities are highly decentralised (Gourio et al., 2018).

[3] Norges Bank Watch is an independent group of experts appointed by the Centre for Monetary Economics at BI Norwegian Business School. Their mandate is to evaluate the monetary policy in Norway. In 2022, the group consists of Kjersti Haugland, Chief Economist at DNB Markets, Martin Blomhoff Holm, post-doc at the University of Oslo, and Sharon Zollner, Chief Economist at ANZ New Zealand.

[4] Lars E. O. Svensson is a Swedish economist and former Deputy Governor of Sveriges Riksbank (2007-2013). He has written a series of articles on the topic of LAW.

Svensson finds that the cost of LAW far outweigh the benefit of LAW in Sweden, suggesting that LAW is not justified. We conduct some changes to Svensson's framework to make it better suited to evaluate the effect of LAW in Norway specifically. Firstly, we substitute Svensson's estimates on the impact LAW has on key macroeconomic variables with our estimates. These estimates are the result of a Bayesian VAR (BVAR) model on Norwegian data, inspired by Robstad (2018). Secondly, we add house price growth as an additional indicator explaining crisis probability, alongside credit growth which is the conventional financial instability indicator used in the existing LAW literature. The latter change serves as a contribution to the literature and is especially interesting when evaluating the effect of LAW in Norway, considering the unique dynamics in the Norwegian housing market.

Having two different indicators of financial stability will result in two separate benchmark models throughout this thesis. Using our simplistic framework, we obtain conflicting conclusions about the effect of LAW in the benchmark models. Robustness tests further examine these contradictory results, changing some of the underlying assumptions and estimates. It is important to note that the effects associated with a LAW policy are far more complicated than the relatively simple and unrealistic framework used to evaluate it in this thesis.

2 Theory

In this chapter, we introduce the theory necessary to understand the methodology used to evaluate LAW. Firstly, we clarify the objectives of the central bank and illustrate how there may arise a trade-off between financial stability on one side and output and inflation objectives on the other side. Then, we discuss different policy tools available to counteract the build-up of financial imbalances. Finally, we review some of the theories on optimal monetary policy, and derive the indirect loss function used to evaluate LAW in this thesis.

2.1 Central Bank objectives and trade-offs

2.1.1 Norges Bank's purpose and objectives

The purpose of the Norwegian central bank (Norges Bank) is described in the Central Bank Act and determined by the political authorities. According to Section 1-2 in the Central Bank Act, the purpose of Norges Bank's activities is to maintain monetary stability, promote the stability of the financial system and an efficient and secure payment system and contribute to high and stable output and employment (Norges Bank, 2022b). In addition to this purpose, the operational objectives in the monetary policy are laid down by the government in a separate regulation to the Central Bank Act.[5] As of March 2018, the Regulation on Monetary Policy reads:

> *Monetary policy shall maintain monetary stability by keeping inflation low and stable. The operational target of monetary policy shall be annual consumer price inflation of close to 2 percent over time. Inflation targeting shall be forward-looking and flexible so that it can contribute to high and stable output and employment and counteract the build-up of financial imbalances.*

The regulation specifies three objectives in the monetary policy: (i) The central bank should try to maintain low and stable inflation around the target of 2 percent over time. Norges Bank has operated with such an inflation target in the monetary policy since 2001. However, this target is forward-looking and flexible, such that Norges Bank also can (ii) contribute to maintaining high and stable output and employment and to (iii) counteract

[5] Regulations in Norway normally supplement Acts.

the build-up of financial imbalances. Despite these clear objectives, the central bank is independent in its use of different instruments to achieve its objectives. In that sense, we can state that the central bank has instrument independence, not goal independence (Norges Bank, 2022b).

2.1.2 Trade-offs between monetary policy objectives

Having a monetary policy strategy that includes multiple objectives can create situations where there will be direct trade-offs between two or more of the objectives. For instance, the objective of maintaining inflation close to the inflation target of 2 percent can conflict with the objective of high and stable output and employment, at least in the short run. Another trade-off, which is the focus of this thesis, is the trade-off between financial stability on one side and output- and inflation objectives on the other side. To illustrate this, consider a situation in which weak output or inflation suggests lowering the policy rate. Still, the concern of financial stability could recommend not lowering the policy rate, or even increasing it.

This trade-off is further complicated by the fact that the objectives related to minimising the inflation and the output gap can be measured directly using the inflation rate and the estimated output gap, respectively. On the other hand, the objective of counteracting the build-up of financial imbalances (hereafter referred to as the "financial stability objective") is more challenging to measure. There is not yet established a robust indicator to measure financial imbalances. Both Gerdrup et al. (2017) and Kockerols et al. (2021) develop an indicator and include it in their alternative loss function. However, Norges Bank (2022b) states that any realistic modelling of these relationships will make the model cumbersome. Therefore, the consensus is that the financial stability objective should be addressed discretionary “outside the model”.

2.2 Counteracting the build-up of financial imbalances

We have seen the Central Bank Act stating that Norges Bank should counteract the build-up of financial imbalances. This objective has its foundation in research and experiences from past financial crises. Even though financial crises only occur rarely,[6] they involve significant costs to the economy. Moreover, upswings in the economy driven by credit growth are associated with deeper and more persistent recessions (Jordà et al., 2015). Thus, the financial stability objective itself is fairly uncontroversial, the issue of how the central bank should implement this objective has been a subject of debate. There are two main categories of policies regarding how the financial stability objective can be implemented, either (i) through macroprudential policy or (ii) through conventional monetary policy, better known as "leaning against the wind" (LAW).

2.2.1 Macroprudential policy

Macroprudential policy and supervision is the operation of monitoring, identifying and reducing systematic risk in the financial system, intending to make the system more resilient to financial instability (Rikheim et al., 2011). In this context, systematic risk means that macroprudential policy aims to protect the entire economy by reducing the risk in the financial system as a whole, as opposed to microprudential policy, which aims to protect consumers by reducing the risk in individual institutions (e.g., banks). The consensus among central bank economists is that macroprudential policy is the first-line defence against shocks to the financial system. Therefore it is often referred to as the third arm of the macroeconomic policy besides monetary policy and fiscal policy (Haldane, 2011).

In Norway, the responsibilities regarding the macroprudential policy and supervision are shared between Norges Bank, the Ministry of Finance (Finansdepartementet) and the Financial Supervisory Authority (Finanstilsynet). Together, these three institutions have a range of macroprudential policy tools at their disposal to reduce credit- and house price growth and thus prevent the build-up of financial imbalances. These tools include conventional policy instruments such as capital requirements, liquidity requirements, mortgage loan-to-value (LTV) restrictions, and supervision of financial institutions to ensure compliance with existing regulations.

The Ministry of Finance has the primary responsibility and final decision in determining the macroprudential policy, but it receives advice and recommendations from Norges

[6] Grytten and Hunnes (2010) finds that Norway has experienced nine financial crises in the period 1814-2010. If we include the 2020 Corona crisis, we get an average crisis frequency of ~ 20 years.

Bank and the Financial Supervisory Authority. Norges Bank provides quarterly advice on the use of the countercyclical capital buffer, while the Financial Supervisory Authority advises on multiple areas (e.g., the use of mortgage restrictions), as well as supervising financial institutions (Cunningham and Friedrich, 2016).

An important note is that simply implementing the macroprudential policy instruments does not necessarily reduce the systematic risk in the financial system. This is particularly true for traditional capital requirements, which may actually have a pro-cyclical effect on the economy, ultimately contributing to the build-up of financial imbalances. The reason is that the banks will easily fulfil their capital requirements in an upturn since the asset side of their balance sheet increases, making them more inclined to engage in loans with higher risk and still meet the capital requirements. The opposite will take effect in a downturn, as the banks' assets will decrease, and they must cut back on their lending to meet their capital requirements.

Despite this, capital requirements can still be used to reduce systematic risk in the financial system, as long as it is countercyclical. That is, banks should build up a capital buffer when financial imbalances build up – the so-called countercyclical capital buffer discussed above (Norges Bank, 2022b). The rate at which the buffer is set is decided by Norges Bank each quarter. In case of a downturn in the economy, where access to credit is significantly reduced, the buffer should be lowered. The purpose of the buffer is to prevent banks from tightening their lending too much during a downturn, effectively mitigating the potential pro-cyclical effects of banks' lending practices previously discussed.

Macroprudential policy is and will clearly continue to be a crucial part of Norges Bank's efforts to prevent financial instability. However, since financial crises are hard to predict and can have significant costs, some central bank economists have suggested that macroprudential policy alone is not enough to achieve the financial stability objective. They have advocated that also monetary policy could be used as a tool to counteract the build-up of financial imbalances by *leaning against the wind*.

2.2.2 Leaning against the wind (LAW)

Monetary policy can contribute to reducing the build-up of financial imbalances by "leaning against the wind" (LAW). LAW imply that the central bank will keep the policy rate higher than what the consideration of inflation and output alone would suggest. This policy intends to mitigate the risk of financial imbalances triggering or amplifying a potential financial crisis (Norges Bank, 2022b).

Since financial crises are infrequent events, occurring only every 20 years on average in Norway since 1814, the empirical foundation behind LAW is uncertain. However, the existing literature[7] indicates that LAW can contribute to reducing both the likelihood and severity of future financial crises. BIS (2016) emphasises that the benefits can be significant, especially if LAW is applied early in a period with high growth in credit and house prices. Nonetheless, the use of LAW is somewhat controversial, as it also entails a cost for the economy in terms of lower capacity utilisation, higher unemployment rate, and lower inflation. Another, more indirect cost of LAW is that the central bank extends the time horizon for which it must meet the inflation target. The latter could potentially make it more difficult to anchor the inflation expectations, which further would make the monetary policy less effective in influencing the economy (Billi and Vredin, 2014). In other words, LAW affects the economy in multiple ways, hence the debate about LAW is about whether the benefits outweigh the costs or not. A comprehensive framework for measuring this cost-benefit trade-off will be introduced in the methodology chapter.

Despite the uncertain empirical foundation behind the net effect of LAW, Øystein Olsen, former Governor of Norges Bank (2011-2022), has repeatedly emphasised that LAW is a tool used by Norges Bank and that it is within their mandate (Olsen, 2016). This view has been criticised by Norges Bank Watch, among others. In their 2022 report, Norges Bank Watch suggested that leaning should be saved only for exceptional circumstances when credit and/or house price growth has had extraordinary growth (Haugland et al., 2022). As an example of exceptional circumstances, Norges Bank Watch highlighted the situation in New Zealand's housing market in 2021, where house prices had a peak growth of 30 percent y-o-y. The view of Norges Bank Watch is in line with Kockerols et al. (2021), who find that there may be a role for LAW if financial imbalances increase markedly, as opposed to normal times when the costs of LAW far outweigh the benefits of a less likely and severe crisis.

[7] See, for instance, Gerdrup et al. (2017), Kockerols et al. (2021) or Schularick and Taylor (2012).

An element further complicating the debate and literature about LAW is that the calculations of costs and benefits are highly uncertain and sensitive to different assumptions. This is a result of financial crises occurring rather sporadically, and that countries have various structural factors in their economy, making the risk of financial instability different. Furthermore, alternative assumptions on the effects of a monetary policy shock on inflation and unemployment on the one side, and financial imbalance and crisis severity and probability on the other side, make the existing literature inconclusive.

Regardless of the net effect of LAW, the consensus among central bank economists is that macroprudential policy is the first-line defence to counteract the build-up of financial imbalances. This has also been the view of Norges Bank under Governor Olsen, who has underlined that LAW – if used – would only work as a supplement to macroprudential policy (Olsen, 2016).

2.3 Optimal monetary policy

We have seen that when the central bank has multiple objectives, there may arise trade-offs between some of these objectives. What then becomes the *optimal* monetary policy depends on (i) the relative importance of the objectives and (ii) the effect monetary policy has on the objectives (Haugland et al., 2022). To illustrate the considerations and trade-offs the central bank has to do in such a case, it is normal to use so-called *loss functions*, where the policy rate that minimises the loss function is considered optimal. In section 2.3.1, we will introduce a standard central bank loss function under flexible inflation targeting before we in section 2.3.2 derive the indirect loss function used for evaluating the effect of LAW in this thesis.

2.3.1 The loss function under flexible inflation targeting

We assume that the central bank minimises a quarterly quadratic loss function, containing inflation and unemployment

$$L^* \equiv (\pi_t - \overline{\pi})^2 + \lambda(u_t - \overline{u})^2, \tag{2.1}$$

where π_t is the inflation rate in quarter t, $\overline{\pi}$ is the inflation target, $u_t - \overline{u}$ is the gap between the unemployment rate in quarter t and the long-run natural rate of unemployment, $\overline{u}$.[8] $\lambda > 0$ is a parameter explaining how much weight the central bank assigns to stabilising the unemployment gap relative to inflation-gap stabilisation.

Note that the deviations from the targets in the loss function are squared, which is the standard assumption for multiple reasons. Firstly, a quadratic loss function considers deviations from the target in both directions equally "costly". That is, a below-target inflation will create an equal loss as a corresponding above-target inflation (Norges Bank, 2022b). Secondly, a quadratic functional form makes minor deviations from the target less costly than larger deviations. For instance, an increase in inflation from 2.2 to 2.4 percent increase the loss less than an increase in inflation from 2.4 to 2.6 percent, even though the increase itself is the same.[9]

It is important to note that loss functions, as with all economic models, are simplifications of the real world, where we make assumptions about the functional form, relative weights of the objectives, and the effect the chosen monetary policy has on the objectives.

2.3.2 The indirect loss function

We assume that the central bank operates with a loss function as defined in equation 2.1 above. Furthermore, we introduce a simple Phillips curve that has the following form

$$\pi_t = z_t - \gamma(u_t - \overline{u}), \tag{2.2}$$

where z_t is a stochastic process, given exogenously, representing a cost-push shock to inflation. Furthermore, γ is a parameter measuring the inflation sensitivity to demand conditions, that is, it decides the slope of the Phillips curve. A high (low) γ implies that price-setting is sensitive (insensitive) to the state of the economy. The Phillips curve is illustrated in 2.1b.

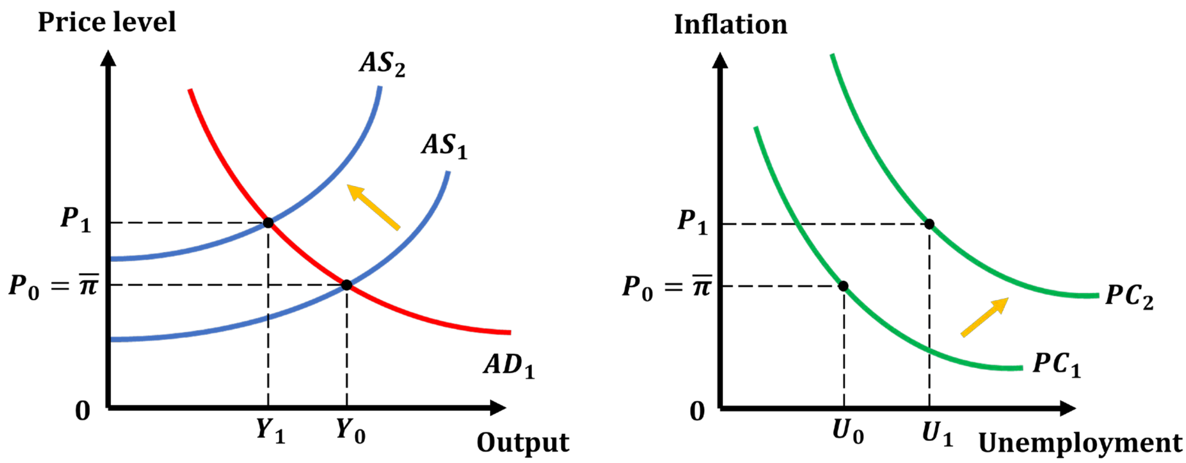
We further introduce u_t^* as the optimal unemployment rate under flexible inflation targeting when the possibility of a financial crisis is disregarded. We consider u_t^* as optimal in the sense that it stabilises both the inflation rate around the inflation target and the

[8] The natural rate of unemployment, $\overline{u}$, can change over time, reflecting changes in the labour market fundamentals or in the general economy. However, we assume that such changes will only occur slowly over time (e.g., through demographic or technological changes) which justifies a fixed $\overline{u}$.

[9] Assuming the same inflation target of 2 percent.

unemployment rate around the long-run sustainable rate (Svensson, 2017a).

In the case of an exogenous cost-push shock to the Phillips curve in equation 2.2, a trade-off arises between stabilising the inflation at the inflation target, $\overline{\pi}$, and stabilising the unemployment rate at the long-run natural rate of unemployment, $\overline{u}$. The central bank must therefore decide between stabilising inflation (pushing the AD-curve inward by increasing the policy rate) and stabilising the unemployment (pushing the AD-curve outward by lowering the policy rate). This trade-off is illustrated in Figure 2.1.



(a) AS-AD model **(b)** The Phillips Curve

Figure 2.1: A cost-push shock creates a trade-off for the central bank

What the optimal unemployment rate, u_t^*, would be in a situation with a cost-push shock depends on the specific characteristic of the cost-push shock. Moreover, the optimal unemployment rate will be exogenous and vary over time. Hereafter, we will refer to u_t^* as the *benchmark unemployment rate*, as in Svensson (2017a). We use this to define the *unemployment deviation*, $\tilde{u}_t$, as

$$\tilde{u}_t \equiv u_t - u_t^*. \tag{2.3}$$

Note that $\tilde{u}_t$ must not be confused with the conventional unemployment gap from the steady state defined in equation 2.1. It must rather be considered as the deviation from the optimal policy under flexible inflation targeting (Svensson, 2017a).

As shown algebraically in Appendix A, we can incorporate equation 2.2 into 2.1 to arrive at a simple quadratic (indirect) loss function where the loss can be explained only from the unemployment rate deviating from the benchmark unemployment rate

$$L_t = (\tilde{u}_t)^2 \equiv (u_t - u_t^*)^2. \tag{2.4}$$

The indirect loss function in equation 2.4 is the starting point for evaluating the effect of LAW in this thesis. The exact expressions are shown in detail in section 3.3.[10] Note that L_t is just a partial version of the true loss function derived by incorporating equation 2.2 into 2.1. Readers interested in details on the entire indirect loss function and its derivation are referred to Appendix A or Appendix C in Svensson (2016).

[10] The exact derivation from L_t to these expressions is described in detail by equation (1) to (12) in chapter 2 in Svensson (2017a).

3 Methodology

This chapter gives a walkthrough of the methodology used to evaluate the effect of LAW in this thesis. We start by explaining how we model a monetary policy shock (MP-shock) to key macroeconomic variables in the Norwegian economy using a structural Bayesian VAR (BVAR) model. Then, we explain how the estimates from this BVAR model are used to arrive at the marginal benefits (MB), the marginal cost (MC) and the net marginal cost (NMC) of LAW using the modified framework inspired by Svensson (2017a). Since this is an empirical exercise focusing on the effects of LAW in Norway, we highlight the use of estimation methods and assumptions that makes the methodology and framework representative and relevant for LAW in Norway. A sketch of our methodology and the overall framework to find the marginal benefits and cost of LAW is outlined in Figure 3.1.

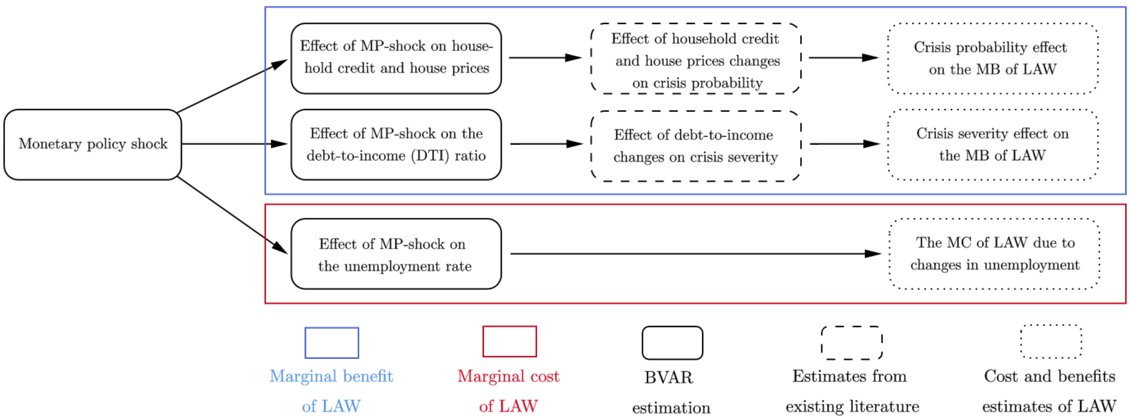


Figure 3.1: Our overall framework to find the net marginal cost of LAW

3.1 Modelling LAW as a monetary policy shock

We model LAW as a monetary policy shock where the central bank increases the policy rate by 1 percentage point in the first quarter, relative to the steady state policy rate level found by minimising the central bank loss function. Thereafter, the policy rate will further increase in the second quarter, before it gradually converges back to its steady-state level.[11] To model this monetary policy shock, we use a structural Bayesian VAR model similar to Robstad (2018). This is in contrast with Svensson (2017a), which uses estimates from both a DSGE model and a VAR model, with a constant 1 percentage point increase

[11] We only model a 1 percentage point increase in the first quarter. The movement after this is solely an effect of the BVAR model itself.

over the first four quarters. Note that a 1 percentage point increase in the policy rate is the standard way to model LAW,[12] despite that a 1 percentage point higher policy rate due to LAW is considered quite a large increase. In fact, Cunningham and Friedrich (2016) finds that the average increase in the policy rate in countries using LAW is just 0.3 percentage points. However, we choose to model LAW consistent with the existing literature and argue that using a 1 percentage point increase is both a practically and theoretically sound approach.

In section 3.1.1, we will explain the details of our BVAR model, before we in section 3.1.2, will discuss some of the assumptions behind the chosen model, as well as its advantages and disadvantages compared to alternative models. Finally, we will discuss the optimal lag length in the BVAR model in section 3.1.3.

3.1.1 The Bayesian VAR (BVAR) model

By modelling LAW using a structural BVAR model, we can study the effects on the endogenous variables in our model simultaneously, which is a great starting point to evaluate the benefits and costs of LAW. The BVAR model used in this thesis is based on the BVAR model created by Robstad (2018), but with some modifications. The starting point is the following reduced form VAR,

$$y_t = C_0 + C_1 t + A_1 y_{t-1} + \cdots + A_l y_{t-l} + u_t, \tag{3.1}$$

where y_t is a vector of endogenous variables, C_0 is a constant, $C_1 t$ is a linear time trend, l is the number of lags, A_l is the coefficient matrices on the lags and u_t is a vector of error terms at t. In line with Robstad, we have included inflation, the real exchange rate, real house prices, the nominal interest rate, and real household credit as variables in the model. We deviate from Robstad by substituting GDP (mainland Norway) with the unemployment rate, as well as adding the household debt-to-income ratio as an additional variable in the model. An overview of the variables used in our model is given in Table 3.1. Note that this is the raw data of the variables as described in Appendix B, and not

[12] This choice is also made by Laséen and Strid (2013), Gerdrup et al. (2017) and Kockerols et al. (2021) which demonstrates that a 1 percentage point increase in the policy rate is the preferred method to model LAW, despite that the literature differs in regards to the length of this policy rate increase.

necessarily the form the variables are used in the model.[13]

Table 3.1: Variables used in the BVAR model

Variable	Description	Source
Nominal interest rate	3-months NIBOR	Norges Bank & FRED
Unemployment rate	Seasonally adjusted unemployment rate	SSB
Price level	Seasonally adjusted CPI-ATE	SSB
Real credit level	Seasonally adjusted Household credit (C2)	SSB
Real house prices	Seasonally adjusted nominal house prices	SSB & Eiendom Norge
Real exchange rate	Seasonally adjusted I-44 for Norway	Norges Bank
Debt-to-income ratio	Seasonally adjusted household debt-to-income ratio	SSB & Norges Bank

The model defined in equation 3.1 cannot be used directly to interpret structural shocks because the error terms in this reduced form VAR also reflect the contemporaneous effects from the endogenous feedback from shocks in the economy. To fix this problem, we need a structural VAR model that represents the underlying structures of the economy to identify the effect of a monetary policy shock. To do so, we identify a Bayesian VAR model, where a monetary policy shock is identified using an identification procedure with sign restrictions, as in Uhlig (2005). This identified model can be described using

$$B_0 y_t = C_0 + C_1 t + B_1 y_{t-1} + \cdots + B_l y_{t-l} + \varepsilon_t, \tag{3.2}$$

where B_0 is the matrix of contemporaneous restrictions, $B_0^{-1} B_l = A_l$ and ε_t is a vector of structural shocks. To identify a monetary policy shock, we place direct restrictions on the signs of the contemporaneous effects of the impulse responses stemming from the structural shock. We will use 10 000 draws, and for each of these draws, the algorithm searches until it finds one solution of the B_0 restrictions that satisfies the given sign restrictions. Of these 10 000 draws, we will report the median impulse response, as well as the 16th and 84th percentile probability bands.

One advantage of using this type of identification scheme is that it allows for total simultaneity between the interest rate and the other included variables in the model, which makes the model consistent with the DSGE literature (Robstad, 2018). However, the identification procedure with sign restrictions has a weakness in that there can be several specifications of the B_0 matrix that satisfy the given sign restrictions. This represents a weakness in using sign restrictions as an identification procedure, as the

[13] See section 4.2 for the exact data transformations.

chosen specification does not necessarily capture the expected effect of the monetary policy shock. However, using 10 000 draws and reporting the median impulse response will deal with this issue.

The sign restrictions we will impose is that a 1 percentage point increase in the policy rate, on impact, will lead to a decrease in inflation, an increase in unemployment, and an exchange rate appreciation. Furthermore, we also include the restriction that a monetary policy shock does not increase real household credit growth, real house price growth, or the debt-to-income upon impact. Besides our additional restriction on the debt-to-income variable, these restrictions are the same as those recommended by Farrant and Peersman (2006) and Robstad (2018). The sign restrictions are summarised in Table 3.2 below.

Table 3.2: Sign restrictions in the BVAR model

Variable	Monetary policy shock
Interest rate	+
Unemployment rate	+
Inflation	-
Household credit	-
House prices	-
Exchange rate	-
Debt-to-income	-

3.1.2 Properties of the BVAR model

Vector autoregression (VAR) has been a recognised and popular method in empirical macroeconomics ever since the work of Sims (1980). Despite its popularity, some classical VAR models can experience problems with over-parameterisation and in-sample overfitting due to small sample sizes relative to the number of estimated parameters, which results in poor forecasts. This issue is especially apparent when working with forecasting of multivariate macroeconomic time series models which are characterised by relatively small data sets and a large number of parameters (Kotzé, 2022). VAR models with a large number of parameters significantly reduce the degrees of freedom, which again can reduce the efficiency of the estimated parameters and thus also hurt the forecasts provided by the model. The number of parameters that need to be estimated in a classical VAR model is calculated as

$$K^2 \cdot p + C, \tag{3.3}$$

where K denotes the number of variables, p is the number of lags in the model, and C is the vector of constants estimated in the model. For example, if we were to estimate a two-lag VAR model with the seven variables shown in Table 3.1, we would need to provide estimates for $7^2 \cdot 2 + 7 = 105$ parameters. This implies that we would need at least 27 years of quarterly data in order to estimate all variables using a classical VAR model. In our case, we have 113 observations, which would leave $113 - 105 = 7$ degrees of freedom, too low to provide any useful information as it will hurt the accuracy of the model.

One possible solution to this issue is to use the Bayesian approach to macroeconometric time series modelling by estimating a BVAR model. The difference between a BVAR model compared to a classical VAR model is that the parameters are not treated as fixed values but rather as random variables that each have prior probabilities. This reduces the issues related to over-parameterisation described above, and since this is a typical problem within the field of macroeconometrics, the popularity of Bayesian methods has increased.[14] Hence, the correct use of this method can make the in-sample overfitting less dramatic and improve the out-of-sample forecasting (Koop and Korobilis, 2010).

In addition, there are more advantages to using a BVAR model. When estimating parameters in complex models involving economic applications and interpretation, where the identification of particular parameters may prove difficult, Bayesian methods can provide a helpful synthesis between estimation and calibration techniques. Furthermore, Kotzé (2022) highlights that BVAR models are also quite powerful to use in forecasting, which allows us to read more insight into the information provided by the lags of each variable.

The assumptions for BVAR modelling are the same as for time series modelling in general and are described in detail in Appendix C. The by far most crucial assumption in empirical macroeconomics is that the time series must be stationary. Since several economic time series, including most of our time series, turn out to be non-stationary, we must find solutions to overcome the issue of non-stationarity. Specifically, we will convert some of our variables to log-differences and/or apply a band-pass filter on the time series which are non-stationary, as in Christiano and Fitzgerald (2003). These methods are described

[14] Svensson (2017a) does not mention it directly, but he also uses estimates from a BVAR model, as the estimates he retrieves from Sveriges Riksbank (2014) come from the BVAR model in (Laséen and Strid, 2013).

explicitly in chapter 4 and the transformed time series are shown in Appendix D.

3.1.3 Optimal lag length in the BVAR model

One crucial element in BVAR modelling, as for time-series models in general, is the decision about the number of lags to include in the model. As previously discussed, including excessive lags in the model will increase the number of parameters to be estimated, hence lowering the degrees of freedom. Low degrees of freedom will increase the standard errors of parameter estimates, which implies an increased forecast error. On the other hand, including too few lags can result in an estimation bias.

To decide the optimal number of lags, we will test the model with different lags and compare the results using three different model selection criteria, namely the Akaike information criterion (AIC), the Hannan-Quinn information criterion (HQIC) and the Schwarz information criterion (SBIC). The results from these tests are shown in Table 3.3.

Table 3.3: Optimal lag length

Lag	AIC	HQIC	SBIC
0	13.7898	12.8602	13.9636
1	-9.1614	-8.5975	-7.7707*
2	-9.7743	-8.7170*	-7.1667
3	-9.5208	-7.9701	-5.6963
4	-9.3622	-7.3181	-4.3208
5	-9.8538*	-7.3163	-3.5955

The suggested lag lengths are the ones with the lowest value, indicated with an asterisk. The AIC suggests a lag order of five, the HQIC suggests a lag length of two, and the SBIC suggests a lag length of one. The model with two lags is the second best for both AIC and SBIC and is therefore used in this thesis.

3.2 Description of our framework

As mentioned in the introduction to this chapter, this thesis is inspired by the framework described in Svensson (2017a). More specifically, the underlying assumptions and formulas used to calculate the marginal benefits and costs associated with LAW are the same as the ones used by Svensson. Unlike Svensson, who uses a regression from Schularick and

Taylor (2012) to estimate the probability of a crisis, this thesis utilises a regression from Kockerols et al. (2021) to estimate the same probability. In addition, we include house price growth as an alternative approach to calculating the probability of a crisis.[15]

We will look more into the macroeconomic variables linking an MP-shock to the probability and severity of a crisis in section 3.2.1 before we in section 3.2.2 will discuss some of the main assumptions and benchmark numbers used in Svensson (2017a).

3.2.1 Variables linking MP-shock and LAW benefits

In the existing LAW literature, including Svensson (2017a), credit growth has dominated as the macroeconomic variable linking monetary policy and the probability of a financial crisis.[16] One of our main contributions is that we include house price growth as an alternative approach to estimating the probability of a crisis.[17] This is a logical contribution considering that Riiser (2005) finds that house price growth has predictive power for financial crises in Norway and that Norges Bank highlights house price growth as an important indicator for financial stability.

Having established the effect of a monetary policy shock on household credit and house prices, we will use the probability functions from the logit regressions in Kockerols et al. (2021) to estimate the effect of the two variables on the probability of a crisis start. Their article applies annual data for 20 OECD countries with a sample period from Q1 1975 to Q2 2014 in their regressions. They find that both five-year cumulative household credit growth and house price growth can be used as indicators of financial instability, hence used to calculate the probability of financial crises. These logit functions in Kockerols et al. (2021) are different from the one by Schularick and Taylor (2012), which utilise five annual lags of credit growth as opposed to the cumulative growth rates.[18]

Regarding the link between monetary policy and crisis severity, Svensson (2017a) uses the household debt-to-disposable income ratio (hereafter: debt-to-income). This is inspired by the work of Flodén (2014), who finds a statistically significant relationship between the

[15] This is the main reason why we substitute the way we estimate crisis probability. The regression in Schularick and Taylor (2012) does not allow for house price growth to be used in finding crisis probability.

[16] For instance, see Schularick and Taylor (2012), Gerdrup et al. (2017), or Kockerols et al. (2021).

[17] Anundsen et al. (2016) show that house price growth positively, and significantly, affects predicting financial crises. See section 3.2.2 for details.

[18] This logit regression model will be applied as a robustness test in section 5.3.3.

debt-to-income ratio in 2007 and the unemployment rate in the period after the Great Recession. More concretely, Flodén finds that a 1 percentage point lower debt-to-income ratio is associated with a 0.02 percentage points smaller increase in the unemployment rate. The estimate is a result of a linear regression using data on pre-crisis credit growth and household debt, as well as changes in unemployment, consumption, and house prices in the five-year period (2008-2012) after the financial crisis started. Furthermore, Flodén's estimates is comparable to other similar studies, such as Jordà et al. (2013) and Krishnamurthy and Muir (2017), making it a representative benchmark.

3.2.2 Assumptions and benchmark numbers

Following the framework outlined in Svensson (2017a), we need to discuss some fundamental assumptions and benchmark numbers.

The perhaps most important assumption that differentiates this framework from the preceding LAW literature is the fixed increase in the unemployment deviation by 5 percentage points (pp) in case of a crisis. This assumption distinguishes the framework from the preceding literature, which often used a fixed magnitude of a crisis. Svensson (2017a) describes this as the second and main cost of LAW.[19] The constant unemployment increase of 5pp is supported by IMF (2015) and Laséen and Strid (2013). To point out the importance of this assumption, we can use a simple example. If the fixed magnitude of a crisis is a 5pp unemployment deviation, the economy would be better off with a crisis if the non-crisis unemployment deviation rises above 5pp. Clearly, this does not make sense according to economic theory. In section 5.3.6, we will change this assumption to test the robustness of our results.

One considerable simplification using this framework, as well as in the alternative LAW literature, is that the correlation between the probability of a crisis and the prior growth in either credit or house prices is a reduced-form result. In reality, the probability of a crisis is a much more complex estimation process, where the financial system and its resilience are far more critical factors. In addition, there is a difference between "bad" and "good" growth that this framework does not recognise. The issue related to the simplicity of the probability calculations and the framework, in general, will be further debated in

[19] The first, and more obvious, cost of LAW is the increased unemployment deviation, regardless of a crisis. This deviation is estimated by our BVAR model and shown in section 5.1.2.

chapter 6 of this thesis.

As outlined at the start of this section, we use the regression estimates presented in Kockerols et al. (2021) to estimate the probability of a crisis. Using these estimates, the quarterly probability of a crisis start in quarter t is given by

$$q_t = \frac{exp(X_{i,t})}{1 + exp(X_{i,t})} = 1 - \frac{1}{1 + exp(X_{i,t})}, \tag{3.4}$$

where $X_{i,t}$ for household credit (HC) growth and house price (HP) growth are somewhat different and given by

$$X_{HC,t} = \underset{(1.026)}{-4.792^{***}} + \underset{(1.099)}{2.232^{**}} \cdot D^{\Delta 5Y}_{HC,t}, \tag{3.5}$$

$$X_{HP,t} = \underset{(1.005)}{-4.804^{***}} + \underset{(0.607)}{1.896^{***}} \cdot D^{\Delta 5Y}_{HP,t}. \tag{3.6}$$

$D^{\Delta 5Y}_{HC,t}$ and $D^{\Delta 5Y}_{HP,t}$ are the five-year cumulative credit growth and house price growth in a given quarter t, respectively. As shown in Kockerols et al. (2021) and illustrated by the asterisks in equation 3.5 and 3.6, both coefficients are significant on at least a 5% level.[20] This indicates that both variables have importance in predicting the probability of a crisis start.

Having estimated the probability of a crisis start, it is necessary to also find the benchmark probability of being in a crisis in a given quarter t, referred to as p_t. p_t is a part of the expressions used to calculate the marginal benefit and cost of LAW in section 3.3, and it is therefore important to define this variable. We let n denote the duration of a financial crisis in quarters and use a simple linear approximation[21] to define

$$p_t \approx \sum_{\tau=0}^{n-1} q_{t-\tau}, \tag{3.7}$$

which effectively states that the probability of being in a crisis in quarter t equals the accumulated probability of a crisis starting in the last n quarters, including the current quarter t. This indicates that p_t will gradually build up to its peak and steady-state effect, reached after n quarters.

[20] The asterisks indicate level of statistical significance: $^{*}p \leq 0.1, ^{**}p \leq 0.05, ^{***}p \leq 0.01$.

[21] Svensson (2017a) uses a Markov process to determine p_t, but the difference is relatively small, and will not significantly affect the final results.

Lastly, there are some essential assumptions regarding the probability and severity of a financial crisis. Firstly, we assume monetary neutrality, implying that there are no long-term effects from the MP-shock on the included variables. Furthermore, we assume that a crisis can not start in the first quarter and that the crisis duration is assumed to be $n = 8$ quarters. Finally, the non-crisis unemployment deviation is assumed to be zero, indicating a steady state as the starting point.

Table 3.4: Variable explanations and benchmark numbers

Variable	Explanation	Estimate
$d\bar{i}_1$	MP-shock to interest rate first quarter	1 pp
$E_1\Delta u_t$	Fixed crisis increase unemployment deviation	5 pp
$\tilde{u}_t^n$	Non-crisis unemployment deviation[22]	0 pp
n	Crisis duration (in quarters)	8
q_1	Probability of crisis start in first quarter	0.00
q_t	Probability of crisis start in quarter t	see section 5.1.1
p_t	Probability of being in a crisis in quarter t	see section 5.1.1

Table 3.4 summarise some of the most critical assumptions and benchmark numbers discussed in this section. Some of these will be altered to test the robustness of our results in section 5.3. Readers interested in a deeper discussion about the framework and benchmark numbers are referred to Svensson (2016) and (2017a) for further details.

3.3 Estimating the net marginal cost of LAW

As outlined in the introduction of this thesis, the potential benefit of LAW is related to (i) a lower probability of a financial crisis and (ii) a smaller crisis severity, while the cost of LAW is related to a higher unemployment deviation, regardless of a financial crisis.[23]

3.3.1 Benefit 1: Lower probability of a financial crisis

Having established the relationship between the growth variables and the probability of a crisis, we have all the components to set up the expression for the marginal benefit from a lower probability of a crisis, which is given by

[22] Even though this does not appear directly in the further analysis, it is an important assumption to derive the expressions in section 3.3. See chapter 2 in Svensson (2017a) for further details.
[23] Described as the first cost of LAW by Svensson (2017a).

$$MB_t^p = E_1(\Delta u_t)^2 \left(-\frac{dp_t}{d\bar{i}_1}\right), \tag{3.8}$$

where $-dp_t/d\bar{i}_1$ denotes the marginal reduction of the expected quarter-t loss from a lower probability of a crisis in quarter t.

3.3.2 Benefit 2: Smaller severity of a financial crisis

Combining the MP-shock effect on the debt-to-income ratio and its indirect effect on crisis the unemployment deviation will provide us with the interest rate effect on the magnitude of a crisis. From this, we can define the marginal benefit of smaller severity as

$$MB_t^{\Delta u} = 2p_t E_1 \Delta u_t \left(-\frac{dE_1 \Delta u_t}{d\bar{i}_1}\right), \tag{3.9}$$

where $-dE_1\Delta u_t/d\bar{i}_1$ denotes the marginal reduction in the expected quarter-t loss from a smaller magnitude of a crisis. Summarised, the total marginal benefit of LAW, MB_t, can be described by combining equation 3.8 and 3.9 from above

$$MB_t \equiv MB_t^p + MB_t^{\Delta u}. \tag{3.10}$$

3.3.3 Cost: Higher unemployment deviation

As already discussed, the (first) cost of LAW is represented by an increase in the non-crisis unemployment deviation. Having obtained the estimates on the unemployment deviation as a result of the MP-shock, we can now define the marginal cost of LAW as

$$MC_t = 2p_t E_1 \Delta u_t \frac{dE_1 u_t^n}{d\bar{i}_1}, \tag{3.11}$$

where $dE_1 u_t^n/d\bar{i}_1$ denotes the marginal increase in the expected quarter-t loss from a higher unemployment deviation in quarter t.

3.3.4 The net marginal cost of LAW

Combining the expressions for the marginal benefits given by equation 3.10 and the marginal cost given by equation 3.11, we can now calculate the net marginal cost (NMC) of LAW. The final cumulative NMC is found by subtracting the cumulative marginal benefit from the cumulative marginal cost, described as

$$NMC = \sum_{t=1}^{\infty} \delta^{t-1} NMC_t = \sum_{t=1}^{\infty} \delta^{t-1} MC_t - \sum_{t=1}^{\infty} \delta^{t-1} MB_t, \tag{3.12}$$

where δ^{t-1} is the discount factor. Discounting will not be used in our benchmark model. However, we will explore the effect of discounting as a robustness test in section 5.3.2.

The most crucial measure in our framework is the cumulative NMC for the whole period, namely after 40 quarters, indicating if LAW is justified or not. A negative NMC means that LAW would be justified in our framework, while a positive NMC suggests that LAW is unjustified. To quantify the NMC, our framework uses a scale based on percentage points. This scale will illustrate how strong the conclusion is, either for or against LAW. With opposite conclusions, the absolute value will be used to discuss the certainty of the two results.

4 Data

4.1 Data description

As stated in the previous chapter, the data used as input in our BVAR model is a combination of aggregated data series from multiple sources. Our starting point is the data used in Robstad (2018), but we make some replacements and additions. Firstly, we replace GDP with the unemployment rate, as we in this thesis are interested in finding the effect of a monetary policy shock on the unemployment rate. Unemployment data in Norway are usually retrieved from either Statistics Norway (SSB) or the Norwegian Labour and Welfare Administration (NAV). In this thesis, we prefer the unemployment data from SSB over NAV, as it is considered to be more precise and better represents the real unemployment rate in Norway.[24] Secondly, we add the household debt-to-income ratio to our data because we are interested in finding the effect of a monetary policy shock on this ratio. Finally, we extend the sample period of Robstad's data set by also including data from 2014 Q1 to 2021 Q4. A summary of the data with description and source can be found in Table 3.1 or in Appendix B.

An important detail is that we use the 3-month NIBOR rate as a proxy for the policy rate. The reasoning behind this choice is that this interest rate will vary more over time than the policy rate set by Norges Bank, making it a more suitable variable to model a monetary policy shock in a BVAR model. This is in line with the existing BVAR literature, for instance, Laséen and Strid (2013) and Robstad (2018).

We use a sample period for our data from 1994 Q1 to 2021 Q4. The reasoning behind the chosen sample period is that when using a BVAR model to identify a monetary policy shock, it is essential that there are no structural breaks in the monetary policy executed by the central bank. Even though the inflation targeting regime was not officially implemented before 2001, the deregulation of the credit markets was completed by the mid-1990s, making 1994 Q1 a reasonable start to our sample period (Norges Bank, 2022b). This is illustrated in Figure 4.1, where the dashed vertical line indicates the start of our

[24] The unemployment rate published by SSB intends to illustrate the total unemployment in Norway, coherent with international standards. Thus, this statistic is preferred over the statistics from NAV, which only report unemployment among those actively seeking employment through the NAV system.

sample period, and the dashed horizontal line represents the current inflation target of 2 percent.

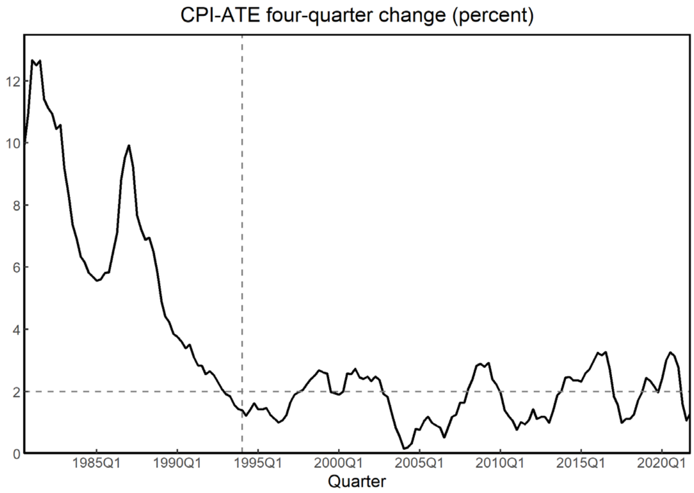


Figure 4.1: Norwegian core inflation (CPI-ATE) 1980 Q1 – 2021 Q4

Our choice of increasing the sample period to 2021 Q4, including also the COVID-19 pandemic, raises an interesting topic. Bobeica and Hartwig (2021), among others, show that the volatility of several macroeconomic time series increased drastically after March 2020. Furthermore, they find that this increased volatility can significantly impact the estimated parameters of different types of time series models, including BVAR's.

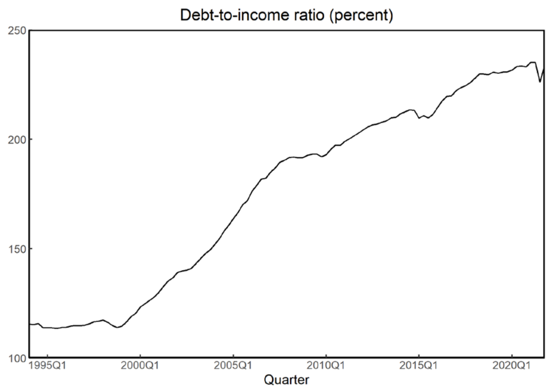
The increased post-COVID-19 volatility in our time series data can disturb our analysis in at least two ways. Firstly, a sudden increase in volatility in the time series data can increase the probability of the time series being non-stationary. The actions we conduct to mitigate potential issues related to stationarity are discussed in section 4.2. Secondly, the increased volatility in the time series can significantly impact the estimated parameters and the impulse responses in our BVAR model. To cope with this issue, one of the robustness tests we will conduct uses a sample period lasting only until 2019 Q4, excluding the volatility effects during and after COVID-19. The details and results from this robustness test are laid out in section 5.3.1.

4.2 Data transformations

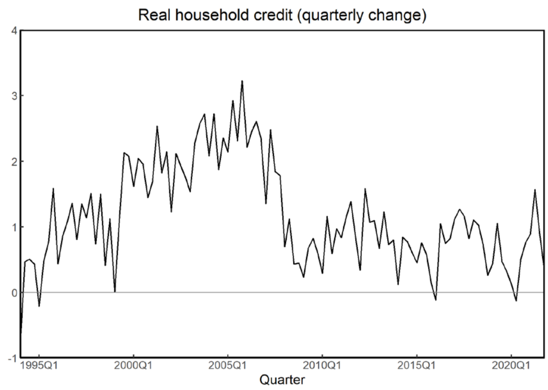
The most crucial assumption in order to use our data in the BVAR model is that the time series must be stationary. Before conducting any transformations, an Augmented

Dickey-Fuller test (ADF-test) for stationarity rejects the null hypothesis of a unit root (on a 5 percent significance level) for all time series in our dataset, besides the unemployment rate which is stationary. Therefore, we must conduct some transformations on our data before we can use it in the BVAR model.

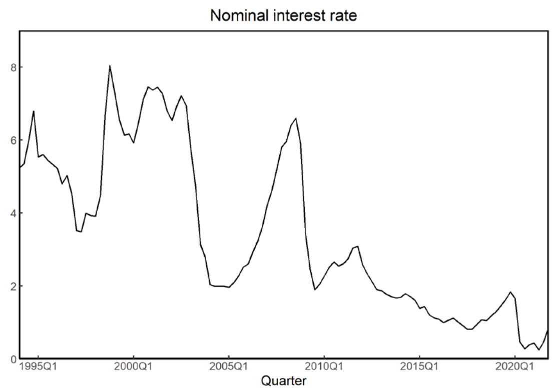
The nominal interest rate, unemployment rate, and debt-to-income ratio are kept in levels, while the other variables are converted to log-differences and must therefore be interpreted as growth variables. By taking the log-difference, inflation growth, exchange rate growth, and house price growth becomes stationary time series. In contrast, credit growth is still non-stationary on a 5 percent significance level. Furthermore, the debt-to-income ratio has an underlying upward linear trend, which clearly indicates a non-stationary process. At the same time, the nominal interest rate also has clear tendencies indicating a non-stationary time series. This is confirmed using an ADF-test where we can reject the null hypothesis of a unit root for all variables in our dataset except for the nominal interest rate, credit growth, and the debt-to-income ratio. These three non-stationary time series are plotted in Figure 4.2 below.



(a) Debt-to-income ratio



(b) Household credit growth



(c) Nominal interest rate

Figure 4.2: Non-stationary time series

The nominal interest rate is kept in levels because this gives the most logical interpretation for further analysis. To solve the non-stationarity issues of the credit growth variable, we follow the procedure of Robstad (2018) and apply a band-pass filter which removes low-frequency movements in real credit growth.[25] It is worth noting that the standard deviation of real house price growth is almost four times larger than for the filtered real credit growth series, indicating that the business cycle fluctuations are relatively small for real credit.[26] The same band-pass filter is applied to the debt-to-income ratio, and after this transformation, the ADF-test rejects the null hypothesis of a unit root for these two variables. All transformed and stationary time series used in our model are plotted in Figure D.1 in Appendix D. All the input variables and their respective transformations are summarised in Table 4.1 below.

Table 4.1: Data transformation for the variables used in the BVAR model

Variable	Transformation	Form	p-value[27]
Nominal interest rate	None	Levels	0.3820
Unemployment rate	None	Levels	0.0221
Inflation	Log-diff	Growth rate	0.0070
Household credit	Band-pass filter & Log-diff	Growth rate	0.0000
House price	Log-diff	Growth rate	0.0000
Exchange rate	Log-diff	Growth rate	0.0000
Debt-to-income ratio	Band-pass filter	Levels	0.0023

[25] Growth cycles longer than 8 years (32 quarters) are removed, just as suggested in Christiano and Fitzgerald (2003).

[26] See Appendix D for descriptive statistics of both the untransformed and transformed data series. This result is also robust to the case where the real credit growth is filtered using the same band-pass filter as for real credit (around 3.5 times larger).

[27] The p-value from the ADF-test after the final transformation.

5 Results

In this chapter, we start by calculating the benchmark probability of a crisis start, q_t, and the probability of being in a crisis, p_t, in a given quarter. Then we will present the impulse responses from our BVAR model and describe how we have used these estimates to compute the marginal benefits and cost of LAW. Finally, we will test the robustness of our findings by analysing how sensitive the results are to changes in some of the underlying estimates and assumptions.

5.1 Benchmark probabilities and BVAR model results

5.1.1 Probability calculations

As mentioned, this thesis will use both credit growth and house price growth as indicators of financial imbalances. Furthermore, we use both indicators to estimate the benchmark probability of a crisis start, q_t, and the probability of being in a crisis, p_t, in a given quarter t.

The benchmark annual growth rates will be the average growth rates from the last five years in our data, which are found to be 5.64% and 4.61% for credit growth and house price growth, respectively. These estimates are similar to the estimates reported in Norges Bank (2022a).[28] When using these numbers in equation 3.5 and 3.6, we get the estimates shown in Table 5.1 below.

Table 5.1: Probability calculations and crisis frequency

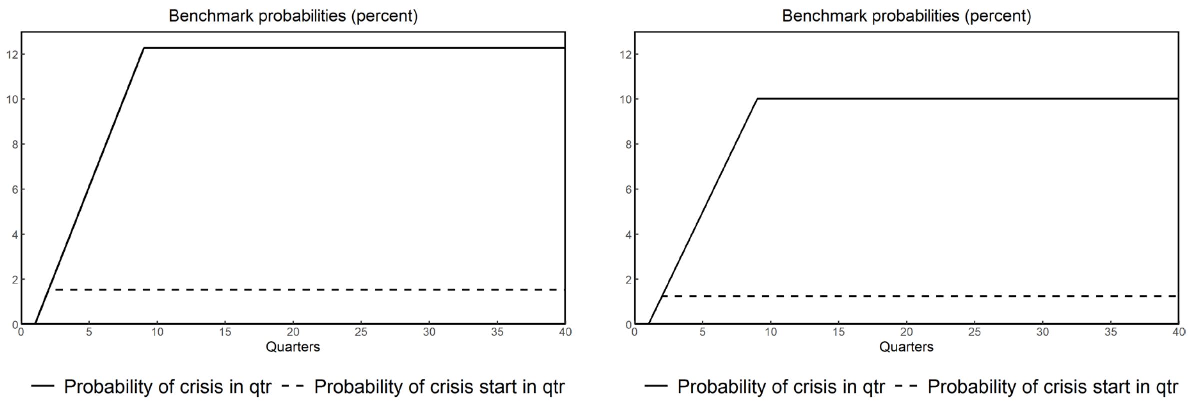
State	Variable	Household credit	House prices	Svensson (2017a)
Crisis start	q_t	1.53%	1.25%	0.80%
Being in a crisis[29]	p_t	12.26%	10.02%	6.42%
Frequency of crises		16.3	20.0	31.2

Having two different growth rates and probability estimation functions will result in two different benchmark probabilities and two different benchmark models throughout this thesis. Moreover, our probability estimates are relatively high, at least compared to

[28] The small and insignificant difference is caused by different calculation approaches.
[29] The estimated peak effect, see Figure 5.1.

probabilities used in the existing LAW literature.[30] Since our benchmark probabilities are significantly higher than in the existing LAW literature, we will further examine the importance of these estimates in a robustness test in section 5.3.5. However, our estimates of the crisis frequencies are more in line with the empirical and historical estimates reported in Taylor (2015) (globally) and Grytten and Hunnes (2010) (Norway) discussed in section 2.2.

Figure 5.1 illustrates the probability calculations from Table 5.1. The dotted lines represent q_t, and the solid lines represent the p_t in our two models. As mentioned, we will use a linear approximation, making p_t constant at the same level after 9 quarters.[31] A linear approximation is also used in Svensson (2016) for simplicity, and it will have no significant effect on the results compared to the more complicated Markov process used in Svensson (2017a). Note that the peak effects are a bit different for the two models, which again will be further examined in section 5.3.5.



(a) Household credit **(b)** House prices

Figure 5.1: Benchmark probabilities - linear approximation

5.1.2 Impulse response functions from BVAR model

Figure 5.2 reports the impulse responses to the 1 percentage point monetary policy shock we have used to model LAW. The black line represents the median impulse response from the 10 000 draws used in the BVAR model, while the blue area illustrates the 67% confidence interval.

[30] For instance, Svensson (2017a) uses $q_t \approx 0.80\%$ and Gerdrup et al. (2017) uses $q_t \approx 0.83\%$ when using credit growth.

[31] q_t equals zero in the first quarter and constant thereafter, assuming no crisis starts during the 40 quarters.

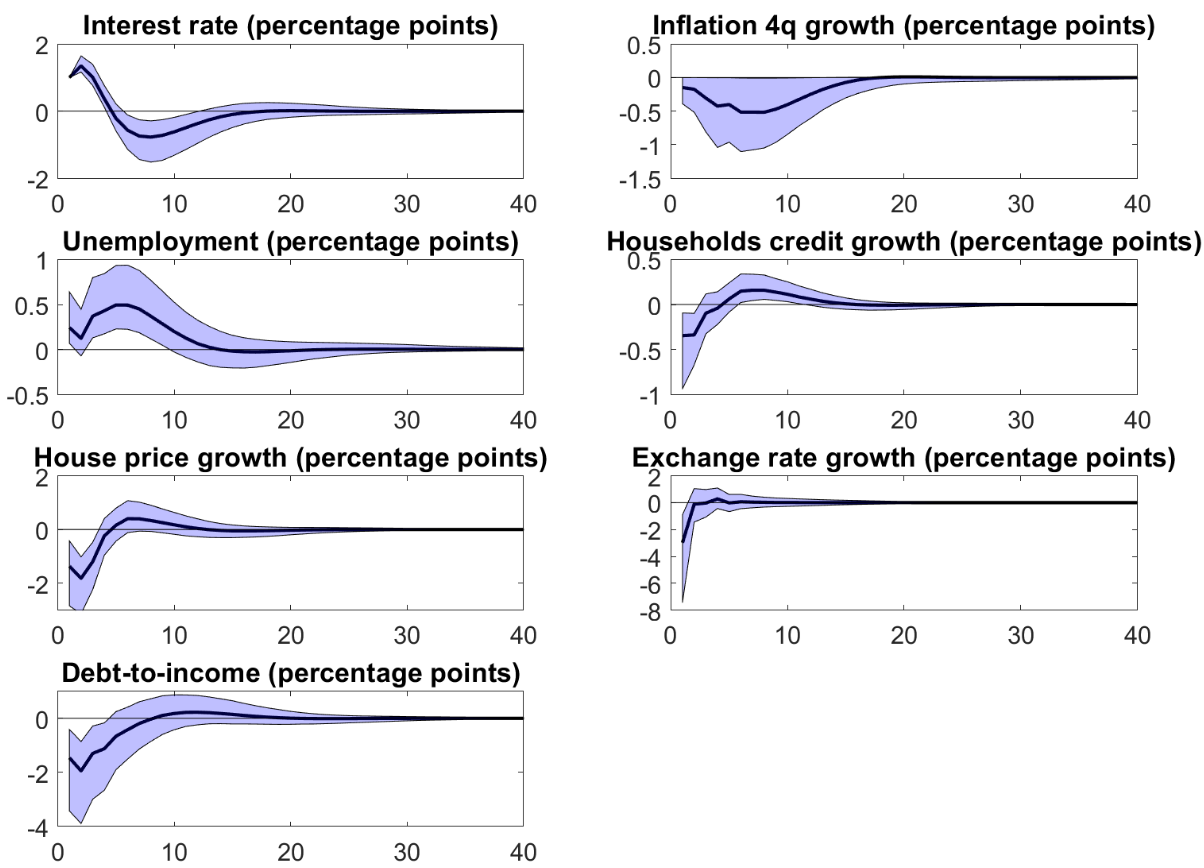


Figure 5.2: Impulse responses to a 1 percentage point monetary policy shock

The most important impulse responses for this thesis are the effects on household credit growth, house price growth, the debt-to-income ratio, and the unemployment rate (deviation), as these estimates will be used directly in the calculations of the benefits and cost of LAW. Note that this is the monetary policy shock effect over time and not the cumulative response reported in Robstad (2018). The exact estimates of the impulse response will be referred to when calculating the effects of LAW in the following sections.

5.1.3 The MP-shock effect on household credit and house prices

In order to calculate the first benefit of LAW, MB_t^p, described in section 3.3.1, we need estimates of the effect the monetary policy shock has on household credit growth and house price growth, respectively. As shown in Figure 5.2, the monetary policy shock has only a small negative effect on household credit growth, followed by an even smaller positive effect, before it converges back to baseline after around 12 quarters. To put this impulse response into context, we have reported the maximum cumulative effect of the impulse responses on household credit growth and house price growth from our BVAR model, as well as for similar BVAR studies, in Table 5.2.

Table 5.2: BVAR studies on house price and credit responses to a MP-shock

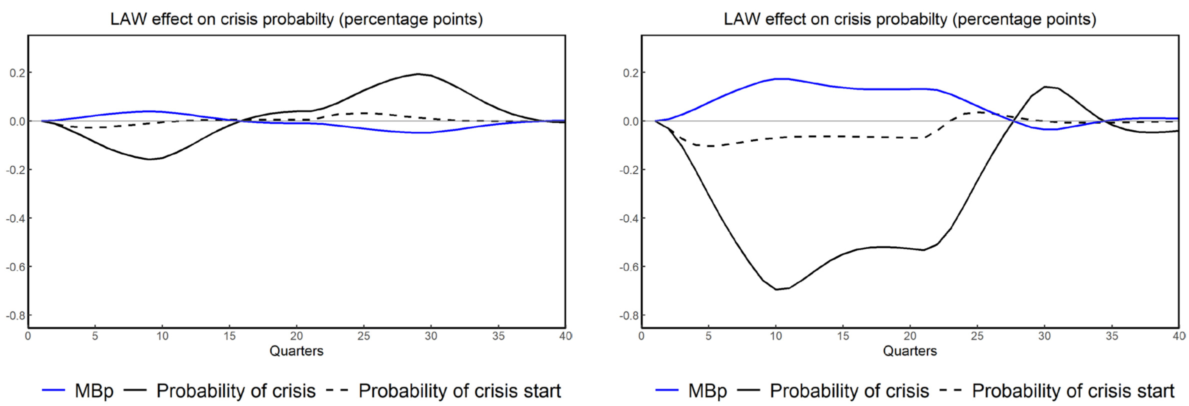
Paper	Country(ies)	Real house prices	Real household credit
This thesis	Norway	2.3-8.4	0.3-1.7
Robstad (2014): Choleski (interest rate last)	Norway	0-3	0-1
Robstad (2014): Choleski (house price rate last)	Norway	2-5	0.25-0.75
Robstad (2014): Long and short run restrictions	Norway	3-14	0.25-1.25
Robstad (2014): Sign restrictions	Norway	2-8	0.5-1.75
Bjørnland and Jacobsen (2010)	Norway	2-4	
Assenmacher-Wesche and Gerlach (2008)	Norway	0.5-3	(-2)-2
Assenmacher-Wesche and Gerlach (2008)	OECD	0.5-2	1-2
Carstensen et al. (2009)	OECD	5-15	
Goodhart and Hofmann (2008)	OECD	2-4	1-3
Jarocinski and Smets (2008)	US	2-4	
Alpanda and Zubairy (2014)	US	1-6	0.5-4
Vargas-Silva (2008)	US	1-3	
Musso et al. (2011)	US	1-3	1-3
Musso et al. (2011)	Euro area	0.5-1.5	0.5-1.5
Laseen and Strid (2013)	Sweden	1	1 (only mean reported)
Aoki et al. (2004)	UK	0.5-2	

Note: This table reports the max cumulative percentage point effect (absolute value) on house prices and household credit of a 1 pp monetary policy shock. The range indicates the 16th and 84th probability bands, respectively. Numbers from this thesis and Robstad's paper are exact, while the numbers from other papers are Robstad's visual approximations from the respective paper's impulse responses.

We observe that the effect on credit growth is smaller in our model than in the international studies. This is not a unique finding, considering that the sign restriction model in Robstad (2018) reports a similarly small effect, and Assenmacher-Wesche and Gerlach (2008) do not find any significant effect on real credit in their VAR study on Norwegian data. Since there are no indications that the short-run fluctuations in Norwegian credit are significantly larger compared to other countries in Table 5.2, this may suggest that short-run house price fluctuations in Norwegian house prices have smaller spillover effects on household credit in Norway.

The negative impulse response to the monetary policy shock is much more significant for house prices than for household credit. Figure 5.2 shows that the relatively large negative impact is followed by a slight positive increase before it converges back towards baseline after around 12 quarters. The impulse response is comparable to the estimates from Robstad's sign restriction model, but quite large relative to the effects on house prices in other countries. This is not a surprising result, as the Norwegian housing market has larger short-run fluctuations than the other countries and areas in Table 5.2. One aspect that can explain this fact is that the share of Norwegian mortgage loans that have a fixed interest rate is extremely low at about 10%, compared to the Scandinavian countries, the Euro area and the U.S. that average at 30-40%, 57% and 90%, respectively (Bjørlo and Winje, 2019) and (Albertazzi et al., 2020).

The movement from negative to positive growth in both household credit and house prices will result in a lower q_t in the earlier quarters before it, at some point, will turn and be above the benchmark probabilities reported in Table 5.1. The results are shown in figure 5.3, where we, not surprisingly, observe that the effect on the crisis probability is much higher when using house price growth compared to household credit growth. More concretely, the peak negative effect for p_t is more than five times higher when using house price growth. Compared to Svensson (2017a), the result from the household credit model is somewhat lower.[32] This is a consequence of the credit growth estimates in our BVAR model being lower than the house price growth estimates and not the probability functions estimate themself.



(a) Household credit

(b) House price

Figure 5.3: Change in crisis probability due to LAW

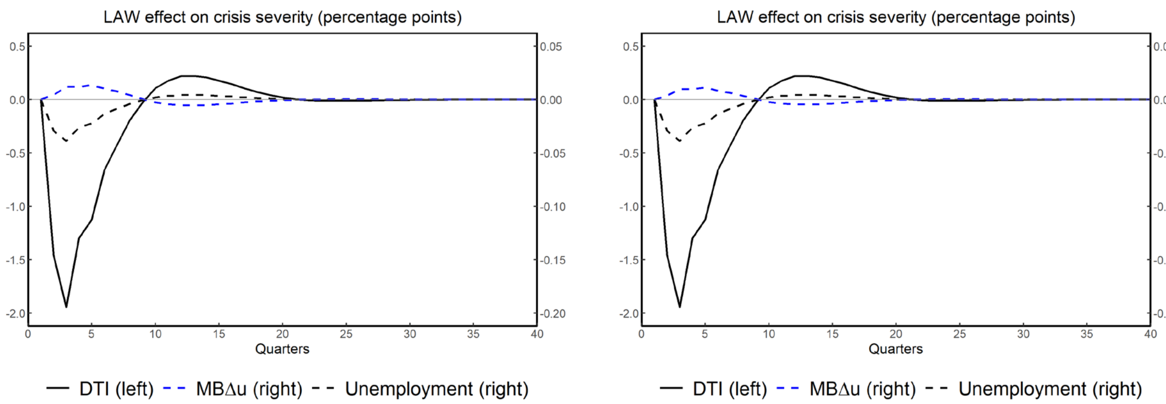
5.1.4 The MP-shock effect on debt-to-income

In order to calculate the second benefit of LAW, $MB_t^{\Delta u}$, described in section 3.3.2, we need estimates of the effect the monetary policy shock has on the debt-to-income (DTI) ratio. Figure 5.2 indicates that this ratio will drop about 2 percentage points in the first quarters after a monetary policy shock, followed by a small positive effect after quarter 10, before it eventually converges back to the baseline level after around 20 quarters. This

[32] In section 5.3.4 we use the exact same framework as in Svensson (2017a).

effect is comparable to the estimates in Fagereng et al. (2021), where they find that a one percentage point increase in the interest rate reduces the DTI ratio by 2-3 percentage points. The peak negative effect on the DTI ratio is somewhat lower in our model compared to the equivalent effect in Svensson (2017a). However, Svensson's estimates converge at a slower pace back to the baseline, resulting in a larger total cumulative effect.

A lower DTI ratio, as explained in section 3.2.1, is associated with a lower unemployment increase in case of a financial crisis, thus also a lower crisis severity. Because we use two different indicators for the crisis probability, we also have to report two different results for the marginal benefits of LAW that comes from a lower crisis severity. These are shown in Figure 5.4, together with the indirect effect on unemployment. Note that both black lines are the same in the two plots. The only difference is a marginally higher DTI effect in the household credit model. This small and barely noticeable difference comes from the difference in the p_t estimates, shown in Table 5.1.



(a) Household credit **(b)** House price

Figure 5.4: Change in crisis severity due to LAW

5.1.5 The MP-shock effect on the unemployment deviation

To calculate the cost of LAW, MC_t, described in section 3.3.3, we need an estimate of the monetary policy shock effect on the non-crisis unemployment deviation. The effect is here interpreted as the unemployment deviation from the baseline.[33] From Figure 5.2, we notice that the monetary policy shock leads to an increase in the non-crisis unemployment with a peak effect after 5-6 quarters before converging back to the baseline after about 20

[33] We assume a non-crisis unemployment deviation of zero. That is, the unemployment rate before the MP-shock is at its optimal rate in the sense that it minimises the indirect loss function in equation 2.4.

quarters. This peak effect is similar to the one reported in Svensson (2017a). However, two major differences are (i) that Svensson's estimates stay above the baseline for all quarters and (ii) that the unemployment deviation converges back to the baseline at a slower pace. Having estimated the effect of a monetary policy shock on the non-crisis unemployment deviation, it is straightforward to calculate the marginal cost of LAW using equation 3.11. Again, having two different p_t estimates will result in two different cost estimates. These effects are plotted as the red lines in Figure 5.5a and 5.6a.[34]

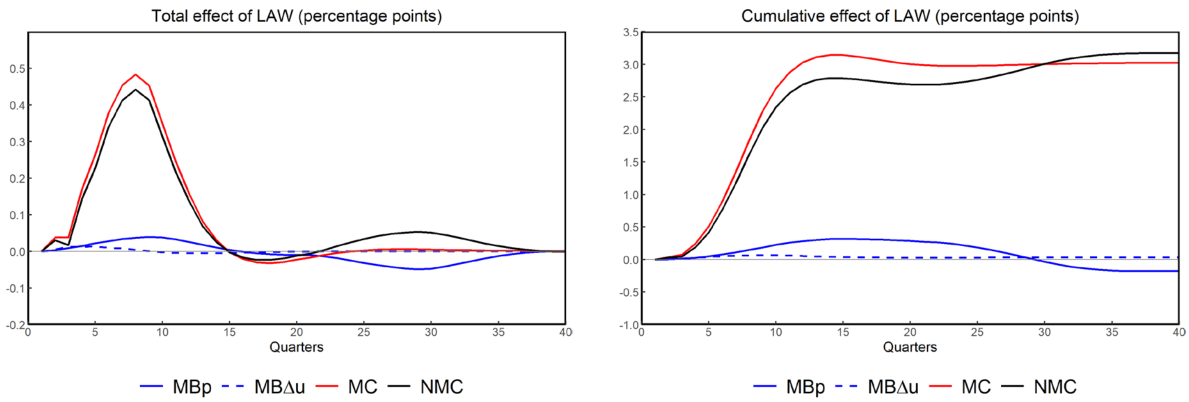
5.2 The benefits and cost of LAW

This section will use the results discussed in this chapter to calculate the marginal benefits (MB), marginal cost (MC) and net marginal cost (NMC) of LAW, both for separate quarters and cumulative over time. As outlined in section 3.3.4, the NMC is measured in percentage points, and the size (in absolute value) can indicate the certainty of our results in the two models.

5.2.1 Results using credit growth

When credit growth is used as the indicator of financial instability, the lines in Figure 5.5 display the marginal benefits (blue), marginal cost (red), and net marginal cost (black) of LAW. The NMC is initially high, as it follows the large marginal cost closely. Further, there are a few quarters with a negative NMC, before it becomes positive for the last quarters. This late effect is actually driven by a negative MB for the probability of a crisis. Overall, all calculations end with an effect of approximately zero after 40 quarters. The cumulative benefit from a lower crisis probability actually ends up as a cost (negative), while the cumulative benefit from a smaller crisis severity is essentially zero. In summary, there is a significant and positive NMC of approximately 3.4 percentage points associated with LAW in this model, which clearly makes LAW unjustified in our framework.

[34] As there are no intermediate calculations, there are no own plots for MC_t.



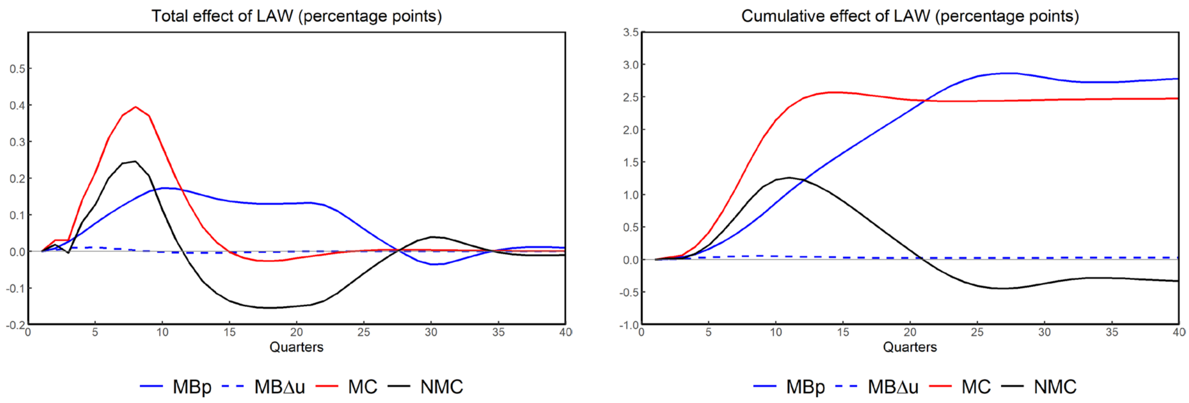
(a) The total MB, MC and NMC of LAW **(b)** The cumulative MB, MC and NMC of LAW

Figure 5.5: Benefits and cost of LAW using credit growth

5.2.2 Results using house price growth

When house growth is used as the indicator of financial instability, the lines in Figure 5.6 display the marginal benefits (blue), marginal cost (red), and net marginal cost (black) of LAW. The net marginal cost is positive for the first 11 quarters, followed by a substantial negative value for the next 16 quarters, before it varies around zero towards the end of the 40 quarters. In this model, the marginal benefit from a lower crisis probability clearly stays above the baseline for the majority of the observation period, only with a small negative effect around quarter 30. Overall, the cumulative benefit from a lower crisis probability ends above the marginal cost, while the benefit from a lower severity is still essentially zero. In summary, there is a relatively low negative net marginal cost of approximately -0.33 percentage points associated with LAW. In other words, this makes LAW justified in this model. However, the NMC is only about 10% (in absolute terms) of the effect in the credit model, clearly indicating a weaker effect and greater uncertainty about the conclusion.[35]

[35] A small part of this is affected by a higher p_t in the credit case, but changing the benchmark probabilities will not have a significant effect on the model. See section 5.3.5 for the details on this robustness test.



(a) The total MB, MC and NMC of LAW **(b)** The cumulative MB, MC and NMC of LAW

Figure 5.6: Benefits and cost of LAW using house price growth

5.3 Robustness tests

The results above involve uncertainty from at least two independent sources. Firstly, the estimates from the BVAR model involve some uncertainty, indicated by the wide confidence intervals for the key variables, especially unemployment. Secondly, the framework for evaluating LAW, described in section 3.2.2, contains a set of assumptions which can be challenged. Again, we focus on the cumulative NMC as the key measure.

In this section, we will perform various tests to check how robust the conclusion in our benchmark models is to changes in the BVAR estimates and the underlying assumptions. Some of the tests are inspired by Svensson (2017a), while others are chosen specifically for this thesis. Common for all the robustness tests is that they are considered to be sensible in an economic context. Repeatedly, we have to distinguish between the household credit model and the house price model. There will typically be two directions in these tests, one that increases the cumulative NMC and one that decreases it. As our framework concludes that LAW is either justified or unjustified, we will mainly focus on the direction that works against the current conclusion.[36] This is inspired by Svensson (2017a), who "stacks the cards in favour of LAW" in his framework using credit growth. In the household credit model, we will follow Svensson, while in the house price model will "stack the cards against LAW" to check how robust the conclusion is. All the robustness tests performed are plotted in one combined graph for each model in section 5.3.9.

[36] We will discuss changes in both directions when relevant.

5.3.1 Excluding COVID-19 in sample period

As discussed in section 4.1, having a sample period that includes the period during and after the COVID-19 pandemic can considerably impact the estimated parameters and impulse responses in our BVAR model. Therefore, one of our robustness tests will be to exclude the latter two years of observations in our data sample, using 2019 Q4 and not 2021 Q4 as the last data point. Using this slightly shorter and less volatile time series, we find a similar impulse response to the MP-shock for the two growth variables and the DTI effect. However, the shorter sample period results in a substantially different effect on the unemployment deviation than our initial response in Figure 5.2. More specifically, it has a somewhat higher peak effect and stays above the baseline considerably longer. These new impulse response functions are shown in Figure E.2 in Appendix E.

This lengthier effect on the unemployment deviation will significantly increase the marginal cost of LAW in both models. As a result, the conclusion that LAW is not justified is amplified in the household credit model. In addition, the conclusion has changed in the house price model, as LAW is now considered unjustified. In order for LAW to be justified in the house price model, the response needs to be approximately 85% of the reported median impulse response in Figure E.2.

5.3.2 Discounting

A fundamental assumption in the benchmark model is that the cumulative benefits and costs are not discounted. Since we operate with a time horizon as large as 40 quarters, a natural robustness test is to analyse the effect of LAW if we include discounting. Figure 5.5a and 5.6a illustrate that the cost of LAW is generally received earlier than the benefits. This indicates that discounting these numbers will work against LAW. Hence, it is only necessary to test it in the house price model, as discounting the household credit results will increase the cumulative NMC.

Svensson (2017a) suggests a quarterly discount factor of 0.995. Using this discount factor will slightly reduce the effect of LAW, although LAW is still justified in the house price model. For LAW to be considered unjustified, a quarterly discount factor of just below 0.980 is needed, which is unrealistically low.

5.3.3 Svensson's probability calculation and framework

Another logical robustness test is to use the same probability function as Svensson (2017a) uses in his paper, which is the probability function introduced by Schularick and Taylor (2012).[37] In this case, we use an annual credit growth rate of 12.0% to make p_t close to our estimate.[38] As illustrated in Figure 5.7, the cumulative NMC after 40 quarters is almost identical regardless of the probability calculation chosen. Hence, there are no significant differences between the two probability calculation approaches.

In addition, we have tested Svensson's variable estimates in our framework, except for house price growth, as it is not included in his analysis. The debt-to-income estimates lead to a slightly higher marginal benefit.[39] The impact of the probability in terms of credit growth is, just as above, practically unchanged with a slightly negative cumulative effect. The unemployment estimates vastly increase the marginal cost. In sum, this leads to a higher cumulative NMC in both models, solely because of the higher unemployment deviation estimates.[40] Hence, this result is only plotted for the house price model.

5.3.4 Change in the unemployment deviation

As shown in the above section, higher unemployment deviation estimates would consistently increase the marginal cost of LAW. Hence, we would need a lower unemployment deviation in the household credit model in order to change the conclusion. In the robustness test, we reduce the unemployment deviation used in the benchmark model to 50% of its initial response for all quarters. This will instinctively result in half the marginal cost reported in the benchmark scenario in Figure 5.5b. However, since this model has minimal marginal benefits, LAW is still not justified.

In the house price model, we increase the unemployment deviation response by 20%, making the total response 120% of the benchmark unemployment deviation in all quarters. Overall, this results in a positive cumulative NMC, indicating that LAW is no longer justified. In other words, a 20% increase in the unemployment deviation will overturn our

[37] This robustness test is only relevant for the household credit model, as Svensson (2017a) does not consider house prices in his crisis probability calculations.
[38] This result in $p_t = 12.29\%$, which is very close to $p_t = 12.26\%$ used in this thesis.
[39] The cumulative effect is over ten times higher but overall insignificant.
[40] The estimates on unemployment deviation come from a DSGE model, unlike our BVAR model.

conclusion regarding LAW. Such an increase is well within the confidence bands in Figure 5.2, indicating a quite realistic scenario.

5.3.5 Change in the probability of a crisis

To change the benchmark probabilities, we lower the initial annual growth rates, resulting in a lower q_t, which again lowers p_t. This will further affect both the marginal benefits and the marginal cost of LAW. In this case, we change the initial credit- and house price growth to zero.[41] This results in a q_t of roughly 0.85% in both models, significantly lowering the peak effects of p_t relative to Figure 5.1.

In our framework, this lowers both the marginal cost and marginal benefits of LAW, as p_t is part of all three main equations in 3.3. In total, this results in the same conclusion as in the benchmark models, but the magnitude (in absolute value) is somewhat smaller. The results are also robust to a higher q_t, implying that the benchmark probabilities in Table 5.1 have limited importance for the overall conclusion.

5.3.6 Change in household credit and house price growth

In the household credit model, we need to increase the impulse response to household credit growth in order to change our conclusion. A doubling of the impulse response functions for household credit for all quarters will increase the marginal benefit in the first quarters. However, the overall result is an even lower cumulative NMC at the end. This may sound surprising, but it is explained by some quarters having positive credit growth, which ultimately outweighs the initial negative growth. In other words, the negative MB_t^p in Figure 5.5b becomes even more negative. A lowering of the credit growth response will lower the overall NMC minimally.

In the house price model, we must reduce the impulse response to house price growth in order to overturn the conclusion. If we change the impulse response on house price growth to be 75% of the benchmark response, we find that the cumulative NMC becomes positive and LAW is no longer justified. The reduction to 75% of the initial response is clearly within the confidence bands reported in Figure 5.2, which again shows that our

[41] This is an unrealistic assumption, but it changes the initial probabilities to follow the estimates in both Svensson (2017a) and Gerdrup et al. (2017).

results in the house price model are quite sensitive to relatively minor changes. Increasing the house price growth response will increase NMC, making LAW even more justified.

5.3.7 Change in the fixed crisis unemployment increase

In theory, increasing the crisis severity represented by a constant increase in the unemployment deviation, Δu, should be favourable for LAW, as there are more significant benefits from avoiding the crisis. This theory is supported in the house price model, while the household credit model violates it. With an increase in Δu from 5 to 6 percentage points, the effect of LAW becomes even more justified in the house price model, while it is even less justified using the household credit model.

On the other hand, a change in Δu from 5 to 4 percentage points will result in a lower cumulative NMC in the credit model. However, this is as for the other robustness tests far from overturning the conclusion, as LAW clearly is unjustified. Moreover, $\Delta u = 4$pp will make the cumulative NMC positive in the house price model. In this case, the turning point is around 4.25 percentage points. Again, we observe that the conclusion in the house price model can be overturned with changes in the underlying assumptions.

5.3.8 Change in the crisis duration

Intuitively, a longer crisis duration will be favourable for LAW, as there are more significant benefits to avoiding the crisis. However, by increasing the crisis duration to $n = 12$ quarters in the household credit model, we actually find that the cumulative NMC marginally increases. Using $n = 12$ in the house price model would lower the cumulative NMC even more, reinforcing that LAW is justified.

The alternative is to test how decreasing the crisis duration to $n = 6$ quarters would affect our results. We find that this change has the opposite effect, as the cumulative NMC decrease in the household credit model, while it increases in the house price model. Nevertheless, the conclusion is the same using credit, while it ends up just overturning the result using house prices, making LAW unjustified.

5.3.9 Summary robustness tests

As we have seen throughout this section, none of the robustness tests overturns the result in the household credit model. This suggests that the effect of using LAW in this model is quite robust to changes in the underlying assumptions and estimates. All the cumulative NMC lines for the robustness tests conducted on the household credit model are reported in Figure 5.7. For a plot individually describing each of the robustness tests in this model, we refer to Figure F.3.

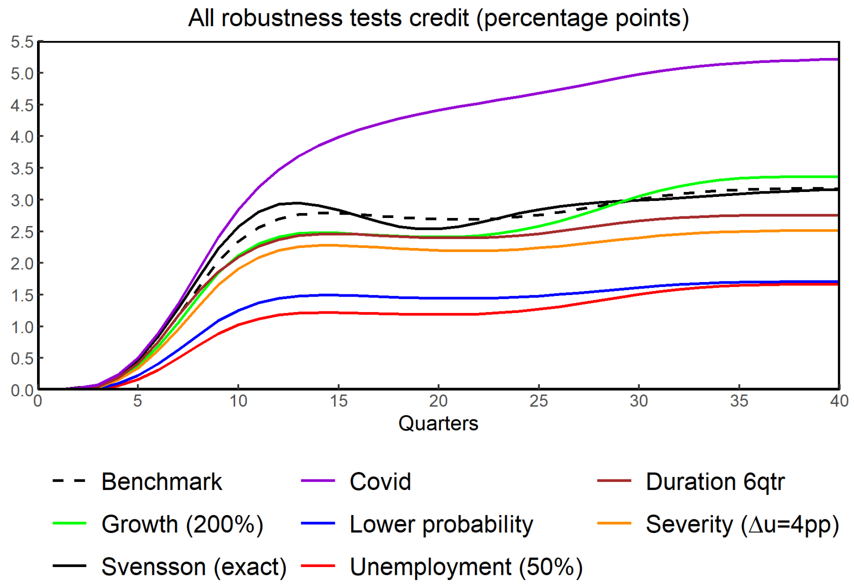


Figure 5.7: All robustness tests in the household credit model

Regarding the robustness tests for the house price model, we find that the result and conclusion about LAW change in several of the scenarios outlined in this section. This implies that the results are sensitive to relatively small and reasonable changes in the underlying assumptions and estimates. This observation is driven by the fact that the benchmark model has a low (in absolute terms) negative NMC. In other words, this makes the conclusion about LAW being justified relatively weak, at least compared to the conclusion in the household credit model above. Hence, we cannot unconditionally conclude that LAW is justified by using house price growth as an indicator of financial imbalances. All the cumulative NMC lines for the robustness tests conducted on the house price model are reported together in Figure 5.8. For a plot describing each of the robustness tests in this model, we refer to Figure F.4.

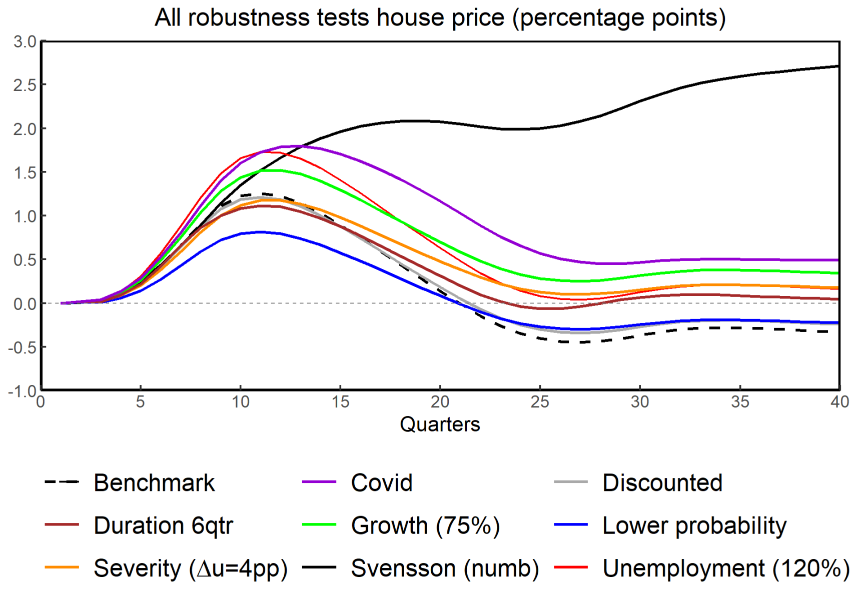


Figure 5.8: All robustness tests house price model

6 Discussion

In this chapter, we start by discussing our results from the previous chapter, as well as their robustness. Further, we debate the role of LAW compared to macroprudential policy tools in addressing financial stability in Norway. Finally, we look into the limitations and potential weaknesses of our analysis and come up with suggestions for further research.

6.1 Results and robustness

In chapter 5, we saw that LAW is unjustified in Norway when using household credit growth to estimate the probability of a financial crisis. This conclusion is in line with Svensson (2017a), and Kockerols and Kok (2019), who both find that the cost of LAW by far outweighs the benefits when using this framework in Sweden and the Euro area, respectively. However, by substituting household credit growth with house price growth to estimate the probability of a financial crisis, we actually observe that the benefits of LAW exceed the costs in our benchmark model, suggesting that LAW is justified. It should be mentioned that the conclusion in the household credit model is much stronger than the conclusion in the house price model. In fact, the effect is found to be about ten times stronger (in absolute terms). The weak conclusion in the house price model is highlighted by how sensitive this conclusion is to changes in the benchmark estimates and assumptions, which is something we will discuss later in this section.

The fact that the two indicators we use to estimate the crisis probability provide different conclusions about the effect of LAW (at least in the benchmark models) is a highly interesting starting point for our discussion. To fully understand the conflicting results, it is essential to reflect upon the methods used to arrive at these results. Both credit growth and house price growth are common indicators of financial stability (Norges Bank, 2022b). The only difference between the household credit model and the house price model is the indicator we have used for the probability estimates. The logistic regression used to estimate the crisis probability is based on five-year cumulative growth for the two indicators, respectively, using the same data set from 20 OECD countries in the period 1975Q1 - 2014Q2 (Kockerols et al., 2021). Since the background data is the same for the two equations, this suggests that the conflicting results are a consequence of the

Norwegian economy behaving differently than the average country in the OECD sample.

The impulse response functions from the BVAR model together with the estimates in Table 5.2 illustrate that Norwegian house prices are much more sensitive to an interest rate hike compared to other countries and areas such as Sweden, the UK, U.S., OECD and the Euro area. We explained this by the fact that Norwegian households have an exceptionally high share of mortgages with floating interest rates relative to all the countries and areas above. This characteristic of the Norwegian housing market will naturally make the house prices and the calculations for the crisis probability in Norway more sensitive to monetary policy changes. It is therefore not surprising that MB_t^p increases drastically when we substitute household credit growth with house price growth in the probability calculations, as illustrated by the differences between MB_t^p in Figure 5.5a and 5.6a. Moreover, we see that this effect on MB_t^p alone can explain that the cumulative net marginal cost of LAW goes from being positive to negative when we substitute credit growth with house price growth in the probability calculations.

A common critique of studies using complex estimation methods and a wide set of assumptions is that the results and subsequent conclusions are not robust to changes in these underlying assumptions. We addressed this issue by performing extensive robustness tests to check the validity of our findings. The robustness tests illustrate that LAW is not justified in the household credit model under any reasonable changes, as illustrated in Figure 5.7. Regarding the house price model, the robustness tests show that the cumulative net effect of LAW can be easily be overturned from negative to positive by performing plausible changes to the underlying assumptions and estimates, as illustrated in Figure 5.8. Thus, the benchmark result from the house price model cannot be used to conclude that LAW is an advisable policy in Norway. However, it should rather be used to illustrate that there exist situations, under reasonable assumptions, where LAW *can* be justified in Norway. Furthermore, this discovery is an excellent starting point for a discussion about (i) under which circumstances LAW well-functioning policy tool, and (ii) the role of LAW in relation to other policy tools used to secure financial stability.

6.2 Optimal method to address financial stability

In this section, we will discuss under which circumstances LAW can be a well-functioning policy tool. Additionally, we have until now only analysed LAW as an individual policy, but have not seen it in context with less controversial methods to handle financial instability. Hence, we will discuss the role of LAW in relation to the more traditional macroprudential policy tools.

6.2.1 LAW in relation with macroprudential policy

An important consideration when discussing the effects of monetary policy[42] and macroprudential policy is that the two policy functions in many ways are interdependent. That is, LAW will have an effect on macroprudential policy and vice versa. For example, a stricter macroprudential policy (e.g., larger capital requirements or more stringent mortgage LTV regulation) will likely work contractionary on economic activity and thus affect monetary policy decisions. Conversely, a change in the monetary policy will most likely also impact macroprudential policy decisions through two channels. Monetary policy changes will (i) affect the profitability of the financial institutions and (ii) the individual risk-taking behaviour in the economy, which both are effects that can trigger macroprudential policy changes, as highlighted by Kockerols and Kok (2019). The relationship between the two policy functions is in other words complex, and one should therefore be careful to evaluate them on an independent basis.

Carboni et al. (2013) emphasises that price stability – the main goal of monetary policy in Norway – and financial stability are usually mutually reinforcing targets. Hence, the interdependency between the two policy functions will usually work complementary. Be that as it may, the interdependency between the two policy functions can also create a situation where there arises a conflict between monetary and macroprudential policies. For example, if the monetary policy from Norges Bank is too expansionary and leads to an increased risk of financial instability, while the macroprudential policy at the same time is restrictive, this may conflict with the transmission channel of monetary policy. That is, the effect of the monetary policy can prove to be less effective. Despite this being a stylised example, it illustrates that there are advantages of having effective coordination

[42] Here, monetary policy in the sense of LAW.

between monetary and macroprudential policies.

Regardless of the interdependent, complementary or conflicting relationship between the two policy functions, it is likely that the effect of monetary policy on macroprudential policy is more significant than the effect of macroprudential policy on monetary policy. The logic behind this is that the monetary policy, by nature, works effectively through all parts of the economy, while macroprudential policies are often more narrow, and will thus only have a limited effect. As Jeremy Stein famously said it, LAW "gets into all the cracks" of the financial system.[43] It is therefore viable that in situations where there is limited availability of macroprudential policy tools, or limited effect of these tools, some LAW can be justified, which was also the key point made in Stein (2013).

If we relate the discussion about LAW and macroprudential policy to Norway specifically, it is important to highlight that Norway is known for having a well-equipped macroprudential policy toolkit and a strong Financial Supervisory Authority. The explanation behind this can be traced back to the Norwegian Banking Crisis that took place in the late 80s and early 90s. The consequences of this crisis highlighted the importance of having a well-functioning macroprudential regulation and supervision, and Norway has ever since worked systematically to promote financial stability (Gerdrup et al., 2004). In the period after the Banking Crisis, Norway increased its focus on financial stability by implementing both new microprudential and macroprudential policies, as well as increasing the supervision of the financial institutions. In addition, Norges Bank has worked systematically to increase awareness about the risks of financial imbalances, which can be exemplified by the fact that Norges Bank was the first central bank to publish a financial stability report in 1995.[44] Finally, Norway has been effective in implementing new macroprudential regulations. For instance, Norway was the first country to implement the countercyclical capital buffer (CCyB) as it was laid out in the Basel II regulation.

To conclude, we highlight the importance of viewing financial stability as an integral activity, not just as a sum of the individual policy functions. Norway is undoubtedly one of the more well-equipped countries when it comes to having a well-functioning macroprudential policy toolkit. This suggests that LAW is less needed in Norway, at least

[43] Jeremy C. Stein is an American macroeconomist and Harvard Professor who served as a member of the Federal Reserve Board from 2012 to 2014.

[44] Until 2012, the report was published semi-annually, but it is now only published once a year.

compared to countries that have a more immature or underdeveloped macroprudential policy toolkit. That being said, many of the macroprudential policy tools being used today are relatively new, such that more research should be conducted to accentuate which of these policies are the most effective.

6.3 Limitations and potential weaknesses

In this section, we will discuss some of the methods and assumptions in this thesis, and how these affect our results and conclusion about LAW. Firstly, we will look further into Svensson's framework and how we estimate the probability of a crisis. Then, we discuss our choice of a BVAR to model LAW, and its ability to reflect the impulse responses of an MP-shock on our variables. Lastly, we look closer into the data used in this thesis and debate how this affects the conclusions drawn in our analysis.

6.3.1 Svensson's framework

The framework presented in Svensson (2017a) has been criticised for its simplicity by Kockerols and Kok (2019), among others. This is not surprising, as Svensson himself emphasises that the framework is simple and depends on only a few relatively simple assumptions. However, this is not necessarily a weakness, according to Svensson, highlighting that the simple features of his framework ensure a transparent evaluation of LAW and that robustness tests can be used to check the validity of the results. Regardless of the criticism, this framework is among the most widely used methods to analyse LAW, indicating that it is a valid starting point for a cost-benefit analysis of LAW.

In section 3.1, we showed that the average LAW response is an increase in the policy rate of 0.3 percentage points (Cunningham and Friedrich, 2016), as opposed to the one-time increase of 1 percentage point used in this thesis and the vast majority of existing LAW literature.[45] Furthermore, LAW is often implemented gradually over time as a systematic policy, not necessarily as a one-time unsystematic policy as in this framework. Thus, using a one-time and relatively high interest rate hike of 1 percentage point to model LAW can cause an unrealistic and too large impulse response, which subsequently can result in a misleading conclusion regarding LAW.

[45] See footnote 12.

Another essential part of this framework is the choice of macroeconomic crisis indicators and how they affect the benefits and costs associated with LAW. In section 3.2.1 we justified the choice of household credit growth and house price growth as indicators explaining financial imbalances and crises in Norway. However, there may be other variables or a combination of variables, that is better suited to explain this relation. A possible variable can be the debt-to-income ratio itself, and the effect it has on the probability of a financial crisis, as opposed to the insignificant effect it has on the crisis severity in this thesis.

6.3.2 The probability of a crisis

As discussed under the assumptions in section 3.2.2, the way we estimate the crisis probability in this thesis represents a considerable simplification of the real world. The estimation method is a result of a logit regression for 20 OECD countries, indicating that these probability calculations are not made explicitly for Norway. In other words, these calculations do not necessarily represent a good prediction of the crisis probability in Norway. In practice, it would be difficult to create a distinct and robust probability calculation for Norway specifically, as this would require a more extensive data set than data from Norway alone can construct, at least to give precise and reasonable estimates.

In addition, house prices in Norway fluctuate substantially more compared to other countries, especially after 1990 (Knoll et al., 2017). Moreover, Norway has a quite high homeownership rate, at least compared to other OECD countries (Schembri, 2015). In our sample, we observe that house price growth has an almost four times higher standard deviation than household credit growth.[46] This illustrates how much more the house price growth fluctuates, which further influences the marginal benefit that comes from a lower probability of a crisis. Therefore, it is unsurprising that the house price model has a different impact than the household credit model in our framework. Being able to estimate the "true" crisis probability in Norway would take the different growth rate responses into consideration in the regression model. Such a logit regression would most likely result in a greater difference between the coefficients in equation 3.5 and 3.6. In other words, if this could be estimated, the marginal benefits of a lower probability of a financial crisis in Figure 5.3 would be much similar.

[46] See Table D.2 in Appendix D.

6.3.3 The BVAR model

All variable estimates in this thesis originate from our BVAR model. In addition to the nominal interest rate, the model includes six macroeconomic variables, which opens up the possibility of representing a relatively limited share of the total economy. Hence, the effect captured by the MP-shock may not represent the entire effect, as multiple other variables can potentially be included in the analysis. However, including more than 7 variables can work against its purpose, as the number of parameters that must be estimated increases exponentially with the number of variables used in BVAR models. This dimensionality curse can actually make an increased number of parameters reduce the efficiency of the estimated parameters.

Robstad (2018) tests different variable compositions and uses the best[47] to predict the house price and credit response. In all the models, the house price fluctuates more than the credit, just as in the benchmark model. In summary, the general development in the impulse responses is relatively similar. The uncertainty in our BVAR model is represented by the confidence interval in Figure 5.2. In addition, we have seen that relatively small changes in our sample period can lead to large changes in the impulse response functions. In section 5.3.1 we removed the eight COVID-19 quarters from our data, which resulted in the estimates shown in Figure E.2. In fact, the new impulse responses changed our benchmark conclusion using house price growth, indicating the large sensitivity in our BVAR model.

An alternative approach could be to use a DSGE model instead of a BVAR model, which allows for an increased number of variables and more advanced assumptions. In their article, Gerdrup et al. (2017) uses a core (DSGE) model developed by Justiniano and Preston (2010). This model consists of a total of 47 estimated and 4 calibrated parameters. Such a high number of variables are not unusual when using DSGE models in the LAW literature. On the one hand, such models include a broader aspect of the economy when calibrating the impulse response from the shock. On the other hand, it can be challenging to obtain the true effects of the MP-shock. Svensson (2017b) criticise using DSGE models when evaluating LAW policies. The criticism can be summarised in that the model does not cover (i) the presence of an effective lower band, (ii) explicit modelling of the

[47] Ranked based on MRSE in out-of-sample forecasting.

financial sector, and (iii) the empirical moments and impulse response observed in the data (Kockerols et al., 2021). This illustrates that also DSGE models have drawbacks.

In summary, the impulse responses from our BVAR model are considered to represent a reasonable estimate of an actual monetary policy shock in Norway. However, the impulse response functions can easily be affected by relatively small changes in our data. An alternative could therefore be to use a DSGE model. However, this is a more complex approach and would not necessarily result in more precise or representative estimates.

6.3.4 Consequences of using aggregated data

The data used in this thesis are quarterly, aggregated macroeconomic data from Norway. Using such data, we get a broad and general impression of how the Norwegian economy, households and firms react to a LAW policy. One can argue that aggregated data gives the best representation of LAW, as the monetary policy shock will affect the economy as a whole and cannot be targeted to affect only a specific part of the population. However, aggregated data also limits us in the sense that we are not able to distinguish distinct segments of the population from each other.

When Norges Bank and Finanstilsynet try to mitigate the build-up of financial imbalances, they seek to protect both the overall financial system as well as individual financial institutions and individual households. Some households are more vulnerable to financial instability and economic crises, and these vulnerable households are often characterised by being both highly indebted and having a high unemployment risk. The issue with aggregated data is that we cannot separate the effect that LAW will have on these vulnerable households from the effect LAW will have on households with a more sound financial situation. Hence, it would be interesting to use disaggregated data to analyse how different subsegments of households (e.g., vulnerable versus not vulnerable households) would react to LAW. However, such data can be very difficult to obtain, and it is often hard to divide such data into more suitable subgroups.

There are a limited number of studies using disaggregated data to study how changes to key macroeconomic variables affect different segments of the economy. One of these, Fagereng et al. (2021), uses disaggregated data on Norwegian households to analyse how interest rate hikes affect the debt-to-income ratios for different household segments. They find that interest rate hikes, as expected, generally lower the household's debt-to-income levels. However, when looking only at vulnerable households which are both highly indebted and have high unemployment risk, they find no effect on the debt-to-income levels. Thus, their conclusion is that monetary policy does not seem to work effectively when the objective is to prevent financial imbalances to build up in the most vulnerable household segments of the population.

Despite the fact that this study is only analysing the effect of monetary policy on the debt-to-income ratio and not the other variables used in this thesis, it highlights two important topics. Firstly, it confirms that a shock to the interest rate can have contrasting effects on different household segments. Secondly, it illustrates that a non-targeted policy tool such as LAW may not be an effective way to address financial instability risk, despite aggregated metrics indicating that such a policy may have an effect.

6.4 Suggestions for further research

Even though this thesis has modified some of the underlying assumptions and benchmark numbers within the original framework from Svensson (2017a), it is still only a partial analysis of LAW. Specifically, we only use household credit growth and house price growth as variables linking LAW and the probability of a financial crisis, and financial stability. Although the latter contributes to the existing LAW literature, there are several other macroeconomic variables that can assist in estimating the crisis probability (e.g., the debt-to-income ratio). Hence, supplementary LAW research should experiment using the house price growth in combination with household credit and/or other variables. Finding the actual cause of financial instability would be the best way to implement and target policies to lower both the probability and severity of potential future financial crises.

Another interesting contribution would be to extend the analysis of LAW to capture a combined effect of monetary and macroprudential policy, in a similar fashion to the study conducted by Kockerols and Kok (2019)[48]. In addition, analysing a systematic LAW policy using house price growth as an indicator of financial stability could also be a fascinating

[48] Kockerols and Kok extend the framework from Svensson (2017a) such that it includes simultaneous shocks to monetary policy and macroprudential policy. They use a DSGE model, and model shocks to the macroprudential policy as an increased banking sector capital requirements by 1 pp, or a tightening in the LTV requirements by 1 pp.

and perhaps even more realistic approach. In other words, there are numerous ways to extend this thesis, especially considering our contribution to using house price growth.

The perhaps most relevant, but also most challenging extension would be to use disaggregated data to analyse the effect of LAW on different household segments. Even though LAW, as a policy tool, cannot target specific segments within the economy, using disaggregated data would provide interesting information about the effect LAW can have on different household segments. Lastly, a significant contribution to this thesis and the Norwegian LAW literature in general would be to realistically estimate the probability of a financial crisis in Norway.

7 Conclusion

In this thesis, we have analysed whether or not LAW can be justified as a policy tool to counteract financial imbalances in Norway. The motivation behind this thesis question is the long-standing debate and conflicting views on the effect and role of LAW among central banks, leading economists and academicians.

To answer our research question, we model LAW as a one-time monetary policy shock to the economy using a structural Bayesian VAR model on Norwegian data, inspired by Robstad (2018). Then, we put the estimates obtained from this model into a modified version of the framework used by Svensson (2017a) to quantify the benefits and costs of LAW. Our main contribution to the existing literature is the inclusion of house price growth as a financial stability indicator explaining crisis probability. Traditionally, only credit growth − which we also use − has been used to estimate the probability of a crisis.

We find that the cost far outweighs the benefits when using household credit growth to estimate the crisis probability. This conclusion is shown to be robust to reasonable changes in the underlying estimates and assumptions, and is in line with conclusions from the existing literature using this framework.[49] However, when we substitute household credit growth with house price growth, we actually find that the benefits of LAW now exceed the cost in the benchmark model, although the conclusion is much weaker than in the household credit model. To be precise, the conclusion in the household credit model is about ten times stronger (in absolute terms), compared to the house price model conclusion. Moreover, we find that the result in the benchmark house price model is not very robust, as reasonable changes in some of the underlying estimates and assumptions easily change the conclusion about LAW, making it unjustified. Hence, the result from the benchmark house price model cannot be used to conclude that LAW is a justified policy in Norway. We rather view this result as evidence that there exist certain situations under which LAW can be justified in Norway.

In sum, our numerical analysis suggests that using LAW to promote financial stability by slowing house price growth can in some cases be justified, but using it to slow household credit growth will turn out to be very costly. This highlights very well the drawback of

[49] See Svensson (2017a) and Kockerols and Kok (2019).

LAW as a policy tool to counteract financial instability, namely that LAW will affect the entire economy. In other words, LAW is not a targeted tool which can be used to address structural vulnerabilities in a specific part of the financial system alone (e.g., to slow only house price growth), as opposed to different types of macroprudential policy tools. This argument makes LAW even more difficult to justify.

In the case of an underdeveloped macroprudential policy toolkit, or the economy being in a situation where the narrow or slow nature of macroprudential policies does not work efficiently, it is easier to justify LAW as a policy tool to counteract financial instability. However, there is no evidence that either of these cases is relevant to the Norwegian economy. On the contrary, Norway has one of the most developed and well-functioning macroprudential policy toolkits. We argue that it is important to consider financial stability as an integral activity, not as LAW and macroprudential policy separately. Therefore, the well-functioning macroprudential policy toolkit suggests that the need for LAW in Norway is limited, at least compared to countries that have a more immature or underdeveloped macroprudential policy toolkit.

We also want to highlight that this thesis, as well as the vast majority of the existing LAW literature, uses aggregated data. Findings from Fagereng et al. (2021) indicate that a monetary policy shock can impact separate household segments in different ways. In fact, they find that an interest rate hike only lowers the debt-to-income ratio on the aggregated level, but not among households that are highly indebted and have a high unemployment risk. Hence, they conclude that monetary policy is not an effective tool to prevent financial instability among vulnerable households.

Despite that the conclusion in Fagereng et al. (2021) is not directly transferable to our thesis, it illustrates quite well that we must be careful not to conclude too quickly and only based on results on the aggregated level. However, if the financial stability in vulnerable households is unaffected by an MP-shock also in our study, this would further support our view that LAW is not a justified policy alone. The indication from Fagereng et al. (2021) is therefore yet another argument against the use of LAW in Norway.

To summarise, we do not find evidence that LAW is justified as a policy tool in Norway. The numerical estimates suggest that LAW is never justified in the household credit model, even if we perform reasonable changes in the underlying estimates and assumptions in favour of LAW. Despite the fact that the benchmark house price model has a conclusion in favour of LAW, this conclusion is very weak compared to the household credit model, and not robust to reasonable changes in the underlying estimates and assumptions. Furthermore, Norway has a well-developed macroprudential policy toolkit, which further weakens the case of LAW in Norway. Therefore, we recommend that Norges Bank should not "lean against the wind", unless the Norwegian economy suddenly finds itself in an extreme situation where the macroprudential policy clearly is insufficient to secure financial stability.

8 References

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Appendix

A Deriving the indirect loss function

We follow the method described by Svensson (2016) when deriving the indirect loss function. Our starting point for deriving the indirect loss function is a quadratic loss function that includes inflation and unemployment,

$$L^*(\pi_t, u_t) \equiv (\pi_t - \overline{\pi})^2 + \lambda(u_t - \overline{u})^2, \tag{A.1}$$

where π_t is the inflation rate in quarter t, $\overline{\pi}$ is the inflation target, $u_t - \overline{u}$ is the gap between the unemployment rate in quarter t and the long-run sustainable unemployment rate, $\overline{u}$. $\lambda > 0$ is a parameter explaining how much weight the central bank assigns to stabilising the unemployment-gap, and is constant relative to inflation-gap stabilisation. Furthermore, we introduce a simple Phillips curve that has the following form,

$$\pi_t = z_t - \gamma(u_t - \overline{u}), \tag{A.2}$$

where z_t is a stochastic process, given exogenously, that represents a cost-push shock to the Phillips curve. This cost-push shock causes a direct trade-off between inflation-stabilisation and unemployment rate stabilisation. To illustrate, a positive (negative) z_t, indicates that reaching the inflation target requires a positive (negative) unemployment gap.

If we combine A.1 and A.2, we can rewrite the quadratic loss function such that it also includes the Phillips curve,

$$\begin{aligned} L_t^0[(u_t - \overline{u}); z_t] \equiv L_t^*[z_t - \gamma(u_t - \overline{u}), u_t] &= [z_t - \gamma(u_t - \overline{u})]^2 + \lambda(u_t - \overline{u})^2 \\ &= (\gamma^2 + \lambda)(u_t - \overline{u})^2 - 2\gamma z_t(u_t - \overline{u}) + z_t^2 \\ &= (\gamma^2 + \lambda)\{(u_t - \overline{u})^2 - 2[u^*(z_t) - \overline{u}](u_t - \overline{u}) + (1 + \lambda/\gamma^2)[u^*(z_t) - \overline{u}]^2 \\ &= (\gamma^2 + \lambda)\{[u_t - u^*(z_t)]^2 + (\lambda/\gamma^2)[u^*(z_t) - \overline{u}]^2\}. \end{aligned} \tag{A.3}$$

We can write the expression in the last part of the final line of A.3 as,

$$u^*(z_t) - \overline{u} \equiv \frac{\gamma z_t}{\gamma^2 + \lambda}. \tag{A.4}$$

From A.3 follows that $u^*(z_t)$, which is given by A.4, is the unemployment rate that for a given z_t minimises the loss function in A.1 subject to the the Phillips curve in A.2. Moreover, it is clear that choosing u_t to minimise the *simple* loss function,

$$L_t(u_t; u_t^*) \equiv (u_t - u_t^*)^2, \tag{A.5}$$

where $u_t^* \equiv u^*(z_t)$, is equivalent to choosing u_t to minimise the loss function $L_t^0(u_t; z_t)$, that has the Phillips curve incorporated. As explained in 2.3.2, u_t^* is referred to as the benchmark unemployment rate. That is, the benchmark which we measure deviations from when evaluating the LAW in this thesis.

B RAW data

Nominal interest rate Norway: Three-month money market rate (NIBOR). *Source: Norges Bank and FRED*

Unemployment rate Norway: Seasonally adjusted 3-month moving average unemployment rate for people aged 15-74 years. *Source: Statistics Norway*

Prices Norway: Seasonally adjusted consumer price index adjusted for tax changes and excluding energy products (CPI-ATE). *Source: Statistics Norway*

Real household credit Norway: C2 for households chained and break adjusted, deflated by CPI-ATE and adjusted for population growth: *Source: Statistics Norway*

Real house prices Norway: Seasonally adjusted nominal house prices deflated by CPI-ATE. *Source: Statistics Norway and Eiendom Norge*

Real exchange rate: Trade-weighted nominal exchange rate index for 44 trading partners (I-44) deflated by CPI-ATE. *Source: Norges Bank*

Debt-to-income ratio: Seasonally adjusted household debt-to-income ratio. *Source: Norges Bank and Statistics Norway*[50]

Population Norway: Population (in thousands) from 15-74 years. *Source: Statistics Norway*

[50] More precise, the exact numbers are from Norges Bank (2022a).

C Assumptions for Bayesian Vector Autoregression

Bayesian Vector Autoregressions (BVARs) have the same set of assumptions as multivariate time series in general. Hanck et al. (2019) describes a general time series regression model which extends the ADL model such that multiple regressors and their lags are included. It uses p lags of the dependent variable and q_l lags of l additional predictors where $l = 1, ..., k$:

$$\begin{aligned} Y_t &= \beta_0 + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \cdots + \beta_p Y_{t-p} \\ &+ \delta_{11} X_{1,t-1} + \delta_{12} X_{1,t-2} + \cdots + \delta_{1q} X_{1,t-q} \\ &+ \delta_{k1} X_{k,t-1} + \delta_{k2} X_{k,t-2} + \cdots + \delta_{kq} X_{k,t-q} + u_t \end{aligned} \tag{C.6}$$

To estimate this model, we follow Hanck et al. (2019) and make the following assumptions:

1. The error term u_t has conditional mean zero given all regressors and their lags:

$$E(u_t \mid Y_{t-1}, Y_{t-2}, ..., X_{t-1}, X_{k,t-2}, ..., X_{k,t-1}, X_{k,t-2}, ...) \tag{C.7}$$

   This assumption is an extension of the conditional mean zero assumption used in AR and ADL models and guarantees that the general time series regression model stated above gives the best forecast of Y_t given its lags, the additional regressors $X_{1,t}, ..., X_{k,t}$ and their lags.

2. The Independent and identically distributed random variables (i.i.d) assumption for cross-sectional data are not (entirely) meaningful for time series data. We replace it with the following assumption, which consists of two parts:

   (a) The $(Y_t, X_{1,t}, ..., X_{k,t})$ have a stationary distribution, which is the "identically distributed" part of the i.i.d. assumption for cross-sectional data. If this does not hold, forecasts may be biased, and statistical inference can be strongly misleading.

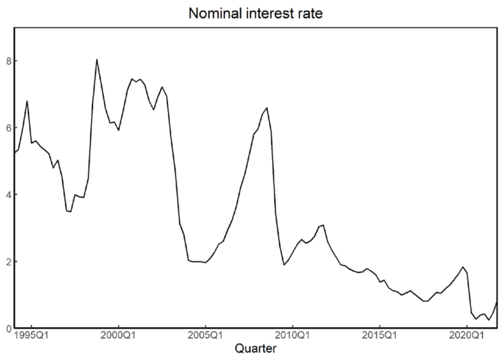
   (b) $(Y_t, X_{1,t}, ..., X_{k,t})$ and $(Y_{t-j}, X_{1,t-j}, ..., X_{k,t-j})$ become independent as j gets large, which is the "independent" distributed part of the i.i.d. assumption for cross-sectional data. This assumption ensures that the Weak Law of Large Numbers (WLLN) and the central limit theorem (CLT) hold in large samples.

3. Large outliers are unlikely: $E(X_{1,t}^4), E(X_{2,t}^4), ..., E(X_{k,t}^4)$ and $E(Y_{1,t}^4)$ have nonzero, finite fourth moments.

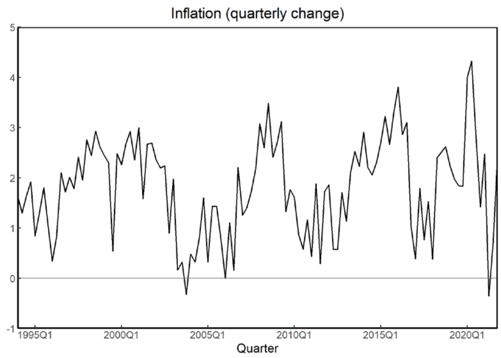
4. No perfect multicollinearity.

The by far most crucial assumption in empirical macroeconomics is that the time series must be stationary. Several economic time series, including most of our time series, turned out to be non-stationary. The methods and procedure used to overcome the issue of non-stationarity are described in detail in 4.2.

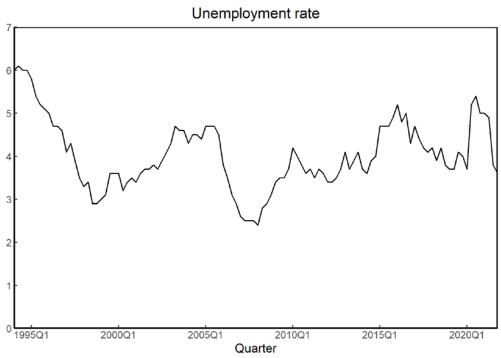
D Transformed time series used in the BVAR model



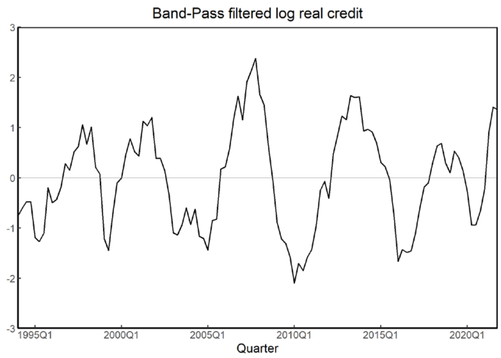
(a) Nominal interest rate



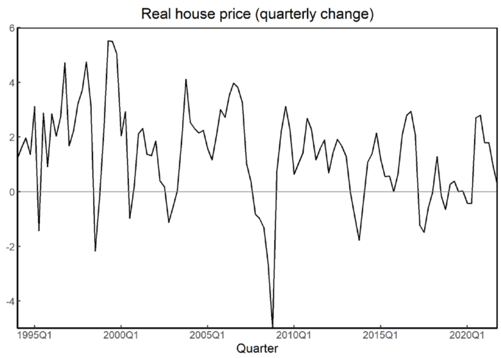
(b) Inflation



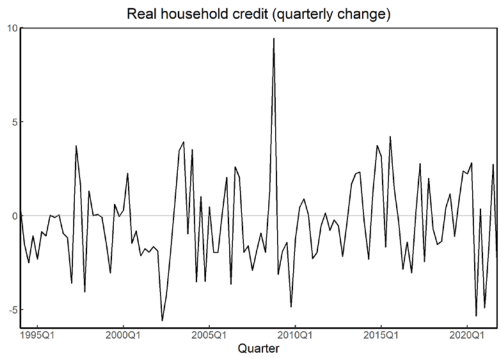
(c) Unemployment rate



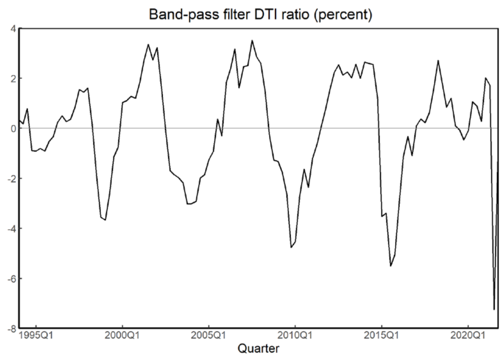
(d) Household credit



(e) House prices



(f) Exchange rate



(g) Debt-to-income ratio

Figure D.1: The post-transformed time series used as input in the BVAR model

Table D.1: Descriptive statistics input time series (raw data)

Variable	Obs	Mean	Std. dev.	Min	Max
Interest rate	113	3.46	2.22	0.25	8.04
Unemployment rate	113	4.05	0.82	2.40	6.10
Debt-to-income	113	175.12	43.30	113.60	235.21
Inflation (2015 = 100)	113	88.78	12.92	68.91	114.40
Exchange rate (1995 = 100)	113	1.13	0.17	0.91	1.54
House price (2003 = 100)[51]	113	1.65	0.64	0.59	2.70
Credit level	113	5.29	2.097	2.34	8.66

Table D.2: Descriptive statistics transformed time series

Variable	Obs	Mean	Std. dev.	Min	Max
Interest rate	113	3.46	2.22	0.25	8.04
Unemployment rate	113	4.05	0.82	2.40	6.10
Debt-to-income	113	-0.007285	2.150365	-7.240345	3.513566
Inflation (2015 = 100)	112	0.018075	0.009699	-0.003527	0.043243
Exchange rate (1995 = 100)	112	-0.004375	0.023496	-0.055846	0.094405
House price (2003 = 100)	112	0.013536	0.017496	-0.049761	0.055207
Credit level	112	0.000098	0.004651	-0.012948	0.011402

Table D.3: Descriptive statistics transformed time series, excluding COVID-19

Variable	Obs	Mean	Std. dev.	Min	Max	p-value[52]
Interest rate	105	3.67	2.15	0.81	8.04	0.3298
Unemployment rate	105	4.01	0.82	2.40	6.10	0.0211
Debt-to-income	105	-0.035092	2.121049	-5.665354	3.459824	0.0112
Inflation	104	0.017750	0.009092	-0.003222	0.038052	0.0308
Exchange rate	104	-0.004036	0.022702	-0.055846	0.094405	0.0000
House price	104	0.013673	0.017837	-0.049761	0.055207	0.0000
Credit level	104	0.000093	0.004649	-0.013117	0.009847	0.0001

[51] To be precise, it is January (M1) 2003 that is set equal to 100.
[52] Can be compared to the p-value in Table 4.1.

E Impulse response function excluding COVID-19 years

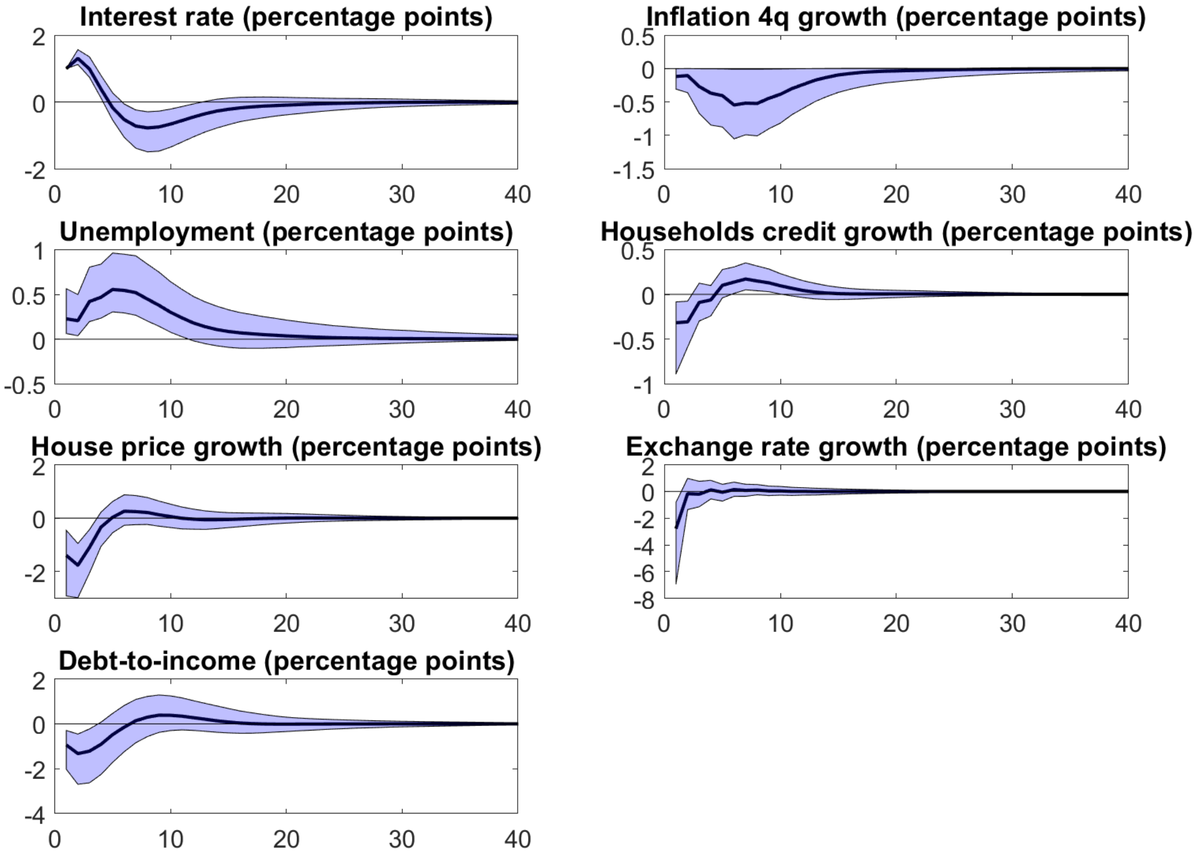
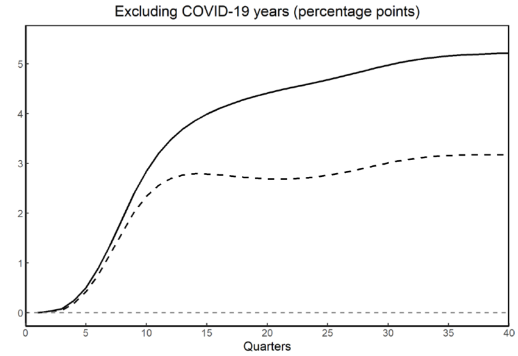
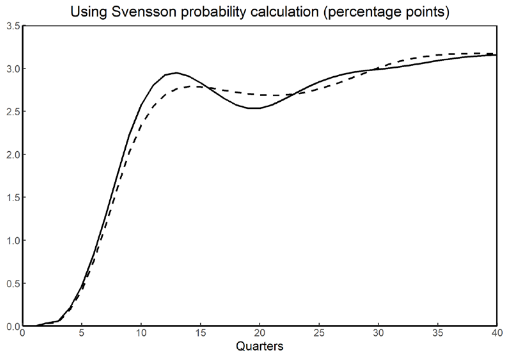


Figure E.2: Impulse responses excluding COVID-19 years

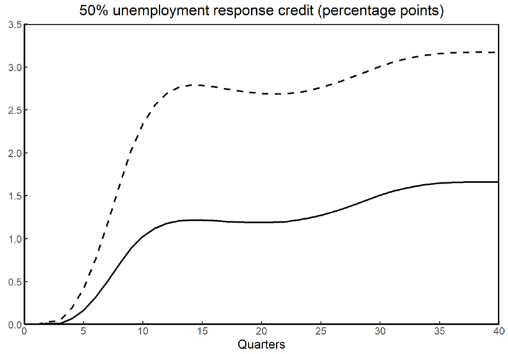
F Individual robustness plots



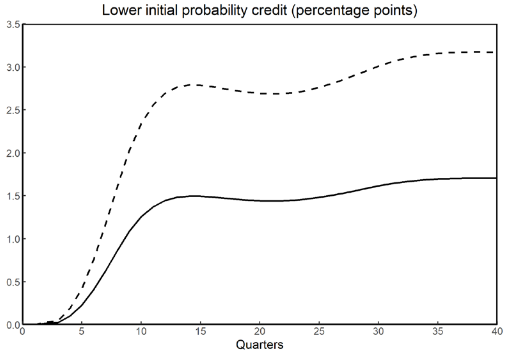
(a) Excluding COVID-19 years



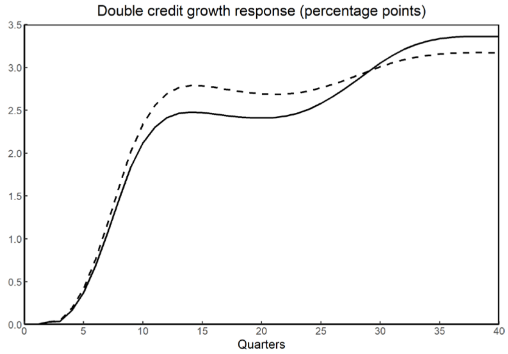
(b) Svensson framework



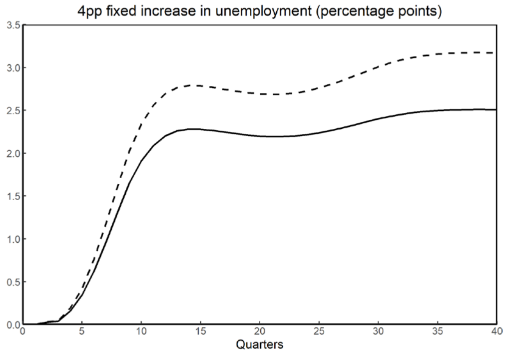
(c) Lower unemployment



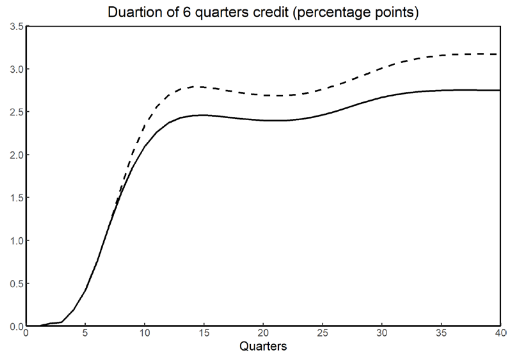
(d) Lower q_t



(e) Higher household credit growth

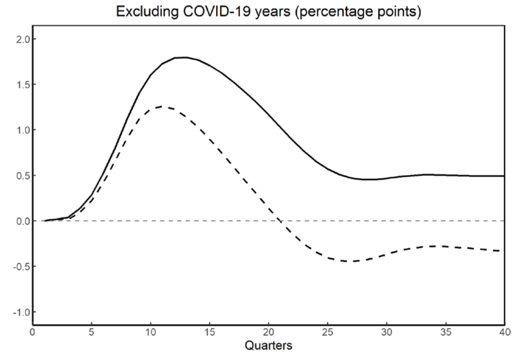


(f) Lower $\Delta u = 4pp$

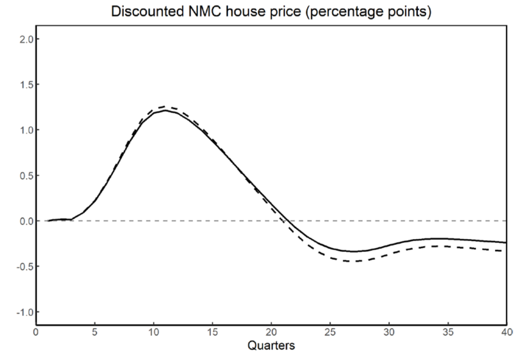


(g) Shorter crisis duration ($n = 6$)

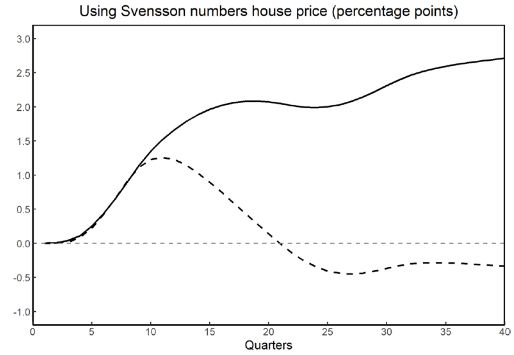
Figure F.3: All robustness tests when using household credit growth



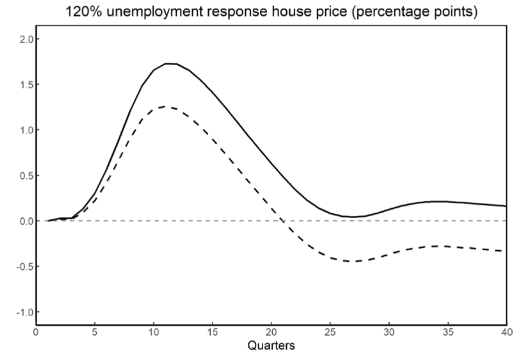
(a) Excluding COVID-19 years



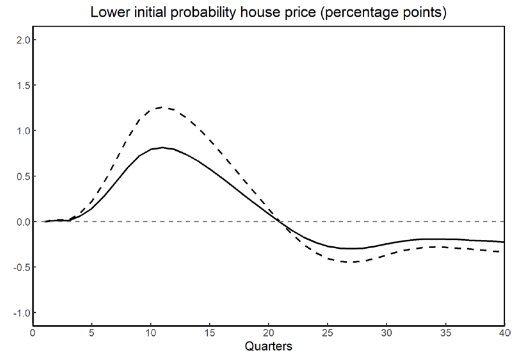
(b) Discounted



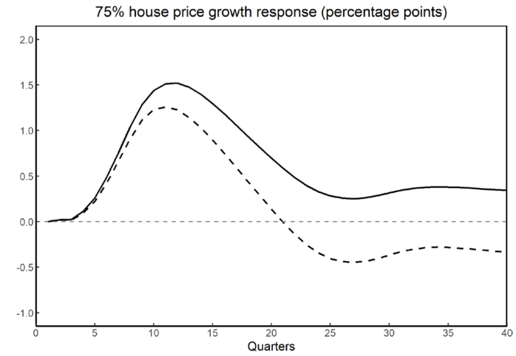
(c) Svensson estimates



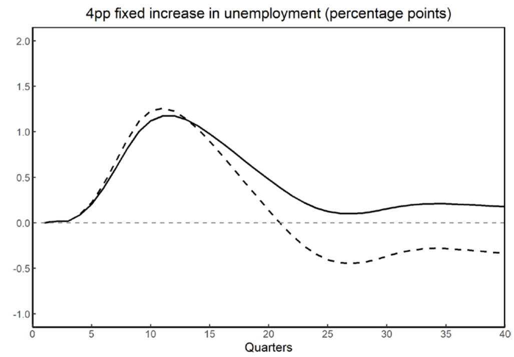
(d) Higher unemployment



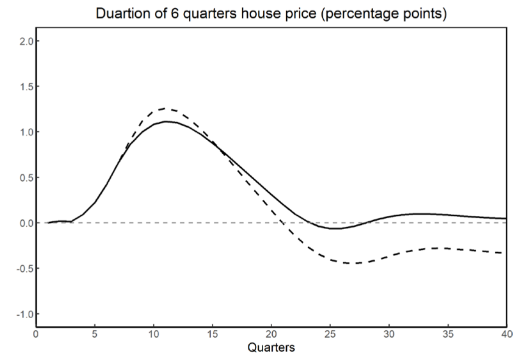
(e) Lower q_t



(f) Lower house price growth



(g) Lower $\Delta u = 4pp$



(h) Shorter crisis duration ($n = 6$)

Figure F.4: All robustness tests when using house price growth