Preface

This thesis is the end-result of my two-year master`s degree in financial economics at NTNU. The work has been both challenging and interesting, and has greatly improved my understanding of monetary policy.

I wish to especially thank my supervisor at NTNU, Knut Anton Mork. He has been extremely helpful throughout this period. He helped me select an interesting theme for my thesis, and has given me valuable advice whenever needed. Also, I have enjoyed listening to his interesting stories from his long career in the banking industry.

All results, statements and any possible errors in this thesis are entirely my own, and cannot be assigned to NTNU. Microsoft Excel, Word, STATA, Eviews and MatLab has been used to present my results.

Abstract

The question whether central banks should emphasize financial stability when setting their policy rate has created an ongoing debate among policy makers and economists since the Global Financial Crisis. In this thesis, I examine whether Scandinavian central banks, with a main focus on Norway, should use monetary policy to support financial stability. In international literature, this type of policy is referred to as “Leaning Against the Wind”. This is done by central banks raising their policy rate above what is necessary for reaching the traditional inflation target and keeping output stable. The general idea is that this policy will benefit the economy through a reduced probability of a financial crisis in the future. But, increasing the policy rate also inflicts costs. In this context, the cost is expressed by an increase unemployment rate in the following period. This strategy is compared to a traditional one where financial stability is not considered.

The thesis begins with an empirical study to discover which financial variables can explain the occurrence of financial crises best. The data material is based on annualized observations from 1870 to 2013. I find lagged real debt growth 5 years before a financial crisis to be the best explanatory variable. As a second step, the result is used in a cost-benefit framework to examine how leaning as a policy affects the welfare in the economies. This is done by using a loss function, consisting of unemployment only. I take advantage of impulse responses from both the Norwegian and the Swedish central banks to investigate how an increase in the policy rate would affect both credit and unemployment. I also estimate these two effects in my own VAR-model to examine how using a different model affect the outcome.

I conclude that Leaning Against the Wind does not appear to be a desired policy for a Scandinavian central bank. The cost of leaning simply outweighs the potential benefits. I also discover that this result is quite sensitive to the assumptions made in the framework, the parameters from the central banks` DSGE models, and the effect of macroprudential policy. Replacing the parameters from the DSGE-models of the central banks to my own VAR-estimates based on Norwegian data worsened the argument for leaning, making the costs outweigh the benefits even more. The VAR-results implies that leaning has costs due to an increased unemployment rate, but also an additional cost as a total increase in the probability of a financial crisis.

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1. Introduction

The Global Financial Crisis

In the beginning of the 21st century, the U.S. economy experienced a long period of steady growth. There was a positive outlook regarding the future. People believed that the rise in housing prices would continue. Banks became sloppy, and many people were granted mortgages that were on the brink of what they could afford. Deregulation allowed financial institutions to pool these risky loans and sell them as securities to investors.

The turmoil in the housing market began in 2007. People started defaulting on their payments, and housing prices dropped significantly. When Lehman Brothers went bankrupt in 2008, a full-blown financial crisis spread around the world (Williams, 2012). The following month, the S&P 500-index fell by 17 percent. Confidence in the markets collapsed. The IMF estimated that 4000 billion dollars would be lost (Dattels & Kodres, 2009). The problems in the housing market triggered imbalances that were built up due to increased credit, poor risk assessments and complex financial instruments. Money and capital markets stopped because banks didn't want to lend money in the interbank market. Central banks all over the world cut their policy rates and provided gigantic liquidity to the banking industry.

The crisis was followed by a recession, where the unemployment rate doubled from 5 percent in the beginning of 2008 to 10 percent in 2009. It took more than 7 years for the economy to return to full employment. Businesses, even those with high credit ratings, had trouble financing their operations and had to reduce their activity. Households could not afford the cost of living. Importers and exporters faced problems in obtaining financing. Real economic activity was choked. Because of the high level of integration in the financial markets, the crisis affected the entire world. It is considered to be the worst financial crisis since the Great Depression (Eigner & Umlauft, 2015). Empirical evidence shows that excessive credit growth contributed to the severity of the crisis (Babecký et al., 2013).

Using the theoretical foundation of the New Keynesian models, central banks focused on providing price-stability and keeping output around its natural level before the Global Financial Crisis (GFC). In the years prior to the GFC, financial instability lurked beneath the surface of seemingly close-to-target inflation and output gaps. This instability remained largely undetected before the boom, and some studies claim that policies during this buildup created incentives for risk taking (Ziadeh, 2013 and Altunbas et al., 2010). The Global

Financial Crisis reminded the monetary policy world that price stability cannot ensure financial stability. While micro- and macroprudential policies are accepted as powerful tools in attenuating the buildup of financial risks,[1] the question of whether monetary policy should also be considered as a second line of defense remains hotly contested. The severe and costly outcome of the GFC created increased support for monetary policy as a tool not only to clean up after a crisis, but also to decrease the likelihood of crises occurring in the first place.

Norway, "Jappetiden," and the Banking Crisis of 1988-1992

In 1983, the coalition between the political parties Conservative, Christian and Center Parties changed monetary policy in Norway. Later that year, the advice from the commission on policy instruments, Virkemiddelsutvalget, and the increased credit growth was ignored and the policy rate was subsequently reduced by 1 percentage point (Skånland, 2004). The government, led by Kåre Willoch, deregulated several markets, which in turn contributed to an increased willingness to lend among Norwegian banks.

"Yuppie Age", Norwegian "Jappetiden[2]"— was a period in Norway from 1983 to 1987 that was characterized by economic optimism partly driven by the enormous revenues from the oil industry. The discovery of oil resulted in increased wealth for the population of Norway, and large amounts of capital were traded in the stock market. Simultaneously, a high inflation rate and favorable tax rules made it attractive to obtain large loans. In 1985, bank loans grew by 30 percent, and household consumption increased by 10 percent (Aamo, 2011). On the 21st of December 1990, this period came to an end when the Ministry of Finance alerted the prime minister that the banks were in deep trouble and reporting large deficits.

When this crisis took place, the banks had two privately funded deposit guarantees: Sparebankenes Sikringsfond and Forretningsbankenes Sikringsfond. However, their losses were too extensive to absorb. The banking crisis ended in 1991 with the Norwegian state having to take over as sole owner of the three largest commercial banks. Shareholders suffered huge losses. The macroeconomic consequences included a sharp reduction in GDP growth.

The crisis could have been limited with better supervision (Aamo, 2011). One of the causes of this banking crisis was revealed to be exploding credit growth. Poorly calculated credit ratings

[1] Dagher et al. (2015) claim that enforcing a 15 to 20 percent capital requirement on banks could have prevented more than 4 out of 5 of the financial crises in advanced economies since the 1970s.
[2] From the word YUP – "Young, upwardly mobile professional"

and a strong upswing in real estate markets were followed by a sharp decline. From 1978 to 1988 in mainland Norway, credit grew about 110 percent in comparison to GDP. In the aftermath of the crisis, credit grew slowly, and didn't return to its pre-crisis level until 2008 (Aamo, 2011).

Leaning Against the Wind

"Leaning Against the Wind" refers to a tighter monetary policy than what is justified for stabilizing inflation around an inflation target and resource utilization around a long-run sustainable rate. It has been promoted as a tool for countering increasing credit growth and rising asset prices in advanced economies since the Global Financial Crisis shook the world in 2007-2008. The mechanism behind leaning is increasing the policy rate, which in turn affects financial variables and reduces the risk of financial instability. Its supporters suggest that leaning induces financial stability (Olsen, 2015; Sveriges Riksbank, 2013). The benefits of leaning—namely, a reduced probability of costly financial distortions in the medium run—have allowed some central banks to justify the policy. Riksbanken, the Swedish central bank, did Lean Against the Wind quite aggressively between 2010 and 2014 (Svensson, 2014), stating concerns about risks associated with household indebtedness. Øystein Olsen, the governor of Norway's central bank, says "We have been leaning against the wind" (Olsen, 2015). However, the policy has its opponents. As pointed out in a detailed cost-benefit analysis by Svensson (2016), leaning has costs in terms of higher unemployment and lower inflation. This has a cost if no crisis occurs and makes the cost of a crisis higher if the economy is weakened by the increased policy rate.

2. Research Questions and Methodology

In this thesis, I seek to contribute to the discussion regarding central bank policy and financial stability: I want to examine whether it is reasonable for a Scandinavian central bank to Lean Against the Wind or not. In my attempt to answer this problem, I have chosen to combine an econometric analysis and a cost-benefit framework. The two questions that I seek to answer is:

1. What is the link between financial variables and the probability of a financial crisis in Scandinavia?
2. Given this link, what would be the cost and benefit of increasing the policy rate above what is justified for stabilizing inflation around an inflation target and resource utilization around a long-run sustainable rate?

The first question will be answered through my own econometric analysis, using data from Norway, Sweden and Denmark. The cost-benefit analysis will be done by using an existing framework, created by Lars Svensson. The main focus of the analysis will be towards the Norwegian economy. For the sake of comparison, I also include the corresponding Swedish dynamics, kindly provided to me by Svensson. To pursue this part, I begin by taking advantage of the results from the econometric analysis together with DSGE[3]-estimates from the central banks of Norway and Sweden. The reason for this, is the need to establish the link between monetary policy and the financial variables. I begin with parameters from the Swedish central bank (Riksbanken), before I include dynamics provided by Norges Bank later. They have some of the best researchers dedicated to studying the dynamic relationships in the economies, and I consider Norges Bank and Riksbanken to be the best source for model parameters. Therefore, the results presented in this thesis will mainly be relevant for Norway and Sweden.
As a final exercise, I check my result for robustness by providing parameters for the link between a monetary policy and financial variables through a different model. This is done by estimating a structural vector auto-regression (SVAR) model based on chosen time series variables from the Norwegian economy.

[3] Dynamic, Stochastic, General Equilibrium model.

2.1 The Role of Financial Variables as a Cause of Financial Crises

In this section, I detail my chosen methods for research question 1, studying how a variety of financial variables can affect the probability of financial crises.

2.1.1 Data and Methodology

Patterns in credit growth and financial crises indicate a possible link between the two. Therefore, I will examine whether a country's recent history of credit growth can help predict a financial crisis. More specifically, I am looking at the effect that the growth rate in real loans has on the probability of a financial crisis. I seek to provide empirical support for Minsky's (1977) argument that the financial system itself is prone to generate economic instability through endogenous credit booms. I am also considering other variables, in case credit doesn`t turn out to be the best predictor for the Scandinavian countries.

In my pursuit to explore this possible link, I use panel data from 1870 to 2013. All data is taken from the Scandinavian countries of Norway, Sweden, and Denmark with the aim of observing the dynamics that lead to a financial crisis in small, open economies.

My raw data is obtained from the "Macrohistory Database" at Macrohistory Lab Bonn (Jordà, Schularick, & Taylor, 2017). The database was created by Òscar Jordà, Moritz Schularick, and Alan M. Taylor, and covers 17 advanced economies from 1870 to 2013 on an annual basis. Bank loans are defined as total loans to households and non-financial corporations, measured in domestic currency. The dataset contains a total of 17 financial crises for the Scandinavian countries. Because we observe data obtained over multiple time periods for the same countries, we have a panel data set, although a somewhat narrow one.

In my empirical study, I will follow Schularick and Taylor (2012) in setting up both a linear probability model and a logit model using a financial crisis as a dependent binary variable. It takes the value of 1 if country *i* has a financial crisis in year *t*, and the value of 0 otherwise.

$$p_{it} = \beta_{0i} + \beta_1(L)DlogCREDIT_{it} + \beta_2(L)X_{it} + e_{it},$$

$$logit(p_{it}) = \beta_{0i} + \beta_1(L)DlogCREDIT_{it} + \beta_2(L)X_{it} + e_{it},$$

Where $logit(p) = \ln(\frac{p}{1-p})$ is the log of the odds ratio, and L is the lag operator. CREDIT is defined as total bank loans to households and non-financial corporations, deflated by the CPI.

The lag polynominal $\beta_1(L)$ contains lags from 1 to 5 years prior to the financial crisis. It can be interpreted as the growth rate of real loans in year t for country i.

The lag polynominal $\beta_2(L)$ allows me to control for other factors that might affect the outcome, in the form of additional variables in the vector X. It will contain real GDP growth, inflation, investment-to-GDP ratios, and short-term and long-term interest rates.

I begin by estimating five models to select my baseline model (the best fit):

- OLS Linear Probability
- OLS Linear Probability with country fixed effects
- OLS Linear Probability with country and year fixed effects[4]
- Logit
- Logit with country fixed effects

The Linear Probability Model

The linear probability model is popular when Y, the dependent variable, is binary. It takes the values of 0 or 1. It can be explained using a simple regression model, such as

$$p = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + u$$

This model assumes that the probability of something occurring is a linear function of the independent variables, $P(y = 1|x) = \beta_0 + \beta_1 X_1 + \cdots + \beta_k X_k$

A great advantage of the linear model is its ease of interpretation. In the example above, using $\beta_1 = 0.1$, a one unit increase in X_1 would lead to a 10 percentage point increased probability of Y being 1. In our case, $\beta_1$measures the change in probability of a financial crisis when real loan growth changes by one unit, holding other factors (other lags) fixed.

It is estimated using ordinary least squares. Ordinary least squares minimize the sum of the squared residuals—the distance between predicted and observed values. For OLS to provide us with the best linear unbiased estimators (BLUE), the Gauss-Markov assumptions must be met (Wooldridge, 2016), which are as follows:

[4] I have a sample consisting of many years, but few countries. Conditional FE can only be estimated using years in the panel if there is variation in the outcome variable. Using year effects would radically reduce the number of observations, and will thus not actually be considered here.

- The model is linear in its parameters. This means that the sensitivity of the dependent variable to the explanatory variables does not depend on the value of the explanatory variables.
- $E(U|X) = 0$. This means that the expected value of the error term, conditional on the regressors, equals zero.
- No heteroskedasticity. This means that the variance of the error term is constant and independent of the value of the explanatory variables.
- $Cov(u_t, u_s|X) = 0$ for $t \neq s$. Distinct error terms are uncorrelated. The Durbin-Watson test is used to check for serial correlation, and will only be reported if the assumption is broken.
- No perfect multicollinearity. Perfect multicollinearity means an exact linear relation among the explanatory variables.

I also assume that residuals are normally distributed. This is not crucial for the OLS-estimation, but is important when performing tests, especially if using a small dataset. If a sample is sufficiently large, the parameter estimates tend towards normality anyway. To test for normality in the residuals, I will use the Kolmogorov-Smirnov test. The null hypothesis is that the observations are normally distributed, and the alternative is that the observations are not normally distributed. This will also only be reported if the assumption is violated.

To test if the effect of a specific growth rate is significantly different from zero, I will perform a *t*-test, where the test statistic is given by

$$t = \frac{\beta_1^{\wedge}}{SE(\beta_1^{\wedge})}$$

To test whether all growth rates are jointly statistically significant, I will use the *F*-test. For a full outline of OLS and the *t*-/*F*-test, see Wooldridge (2016).

However, the linear probability model has some flaws:

- It allows for predicted probabilities outside the natural outcome (0-1).
- Heteroskedastic errors: OLS ignores the fact that the linear probability model is heteroskedastic with residual variance $p(1-p)$[5]. This heteroskedasticity could become somewhat problematic when we are dealing with a p close to 0 (which we are

[5] Var(u) = $p(1-p)$= $(\beta_0 + \beta_1 X_1)(1 - \beta_0 + \beta_1 X_1)$ for a univariate model: The variance of u depend on X.

in this situation). I will improve the OLS estimates by using heteroskedasticity robust standard errors when estimating the model.

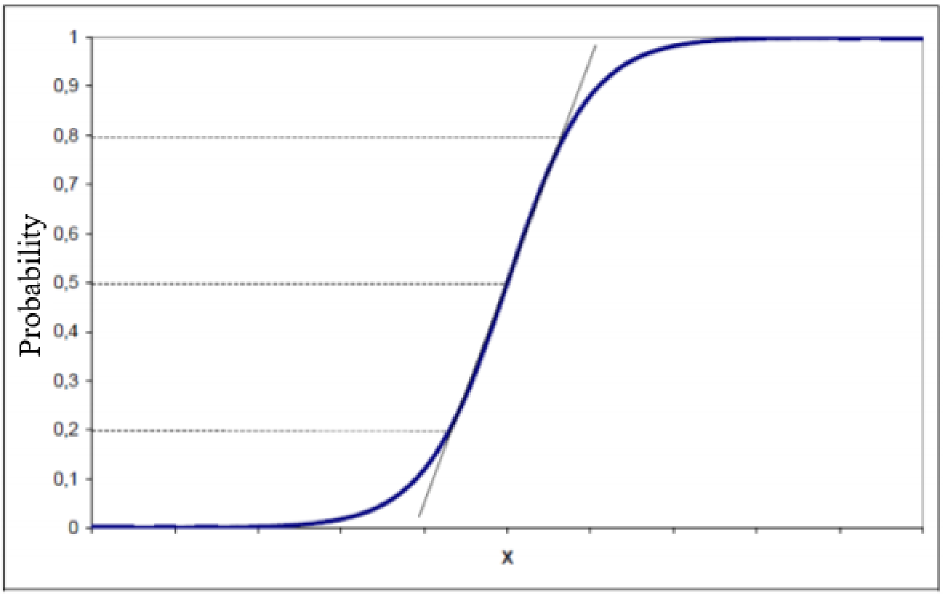
Logit

The logistic regression solves the above-mentioned problems with the linear probability model. It is popular when using a binary explanatory variable. It models the probability of the outcome being 1. The probability estimation of this model will lie between 0 and 1 (Wooldridge, 2016).

$$P(y = 1|x) = P(y = 1|x_1, x_2, \dots, x_k)$$

The logistic regression solves a function to maximize the probability of the observed Y-values (Tufte, 2000). It is estimated using "maximum likelihood estimation." Under the classical OLS assumptions, OLS is maximum likelihood aswell.

The most important assumptions for the logistic regression is that the dependent variable follows the S-curve. The S-curve shows the probability plotted against the logit-value.



$Figure: The\ S - curve\ (Tufte, 2000)$

Aldrich and Nelson (1984) mention 2 assumptions that underlie the logistic regression:

- The dependent variable can only take 2 values.
- No multicollinearity between the independent variables.

The logit-model is a non-linear regression model, using logistic distribution (Aldrich & Nelson, 1984). It assumes that the natural logarithm of the odds is a linear function of the independent variables.

$$Odds = p/(1-p)$$

The odds can be interpreted as the ratio between the probability of something occurring (p), and the probability that it won't occur $(1-p)$. The logistic regression coefficient output is the natural logarithm of the odds ratio (Peng, Lee, & Ingersoll, 2002).

To remove the lower limit of Y, we find the natural log of the odds (the "logit"):

$$L = \ln\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 x_1 + \cdots + \beta_n x_n + v$$

The logit shows a linear relationship between the independent variables. An increase in one of the independent variables will change the probability of Y=1. Positive coefficients can be interpreted as a positive relationship between the variables, and vice versa. The probabilities in a logit model will always be between 0 and 1 (Tufte, 2000).

Because of the non-linear coefficients, a logit model cannot be estimated using ordinary least squares (OLS). OLS finds the parameters that minimize the sum of the squared residuals, which is solved algebraically. Maximum likelihood estimation chooses the values of the coefficients that best describe the full distribution of the data. By running several iterations, the method selects the coefficients that yield the highest probability that the model fits reality (Kleinbaum, 1994). It does this by maximizing the natural logarithm of the likelihood function. The likelihood function is the joint probability distribution of the data, treated as a function of the unknown coefficients. So, the estimators are the values of the coefficients that maximize the likelihood function. Robust standard errors will be used for the logit models as well.

Interpreting Coefficients in Logit Regressions

The results from a logit estimation cannot be interpreted in the same way as the linear probability model. But, as previously mentioned, the direction of the coefficients can still be interpreted the same way.

The Odds Ratio

The odds ratio measures the relationship between the odds at different values of the independent variable.

$$Odds\ ratio = \frac{\frac{p_f}{1-p_f}}{\frac{p_s}{1-p_s}}$$

p_s is the probability that the dependent variable will be 1, by a selected value of the independent variable. p_f is the probability that the independent variable will be more than 1. If the independent variable increases by one unit, the odds ratio shows how the odds change due to this increase. If the odds ratio exceeds 1, the odds increase as the independent variable increases. Vice versa, an odds ratio below 1 tells us that the odds decrease as the independent variable increases.

Probabilities

The probabilities interpreted from a logit-model will change depending on where you are on the S-curve. At the middle of the curve, it is steep, and therefore a small change in the independent variable will make a greater difference than the same change would make at the bottom of the curve (Tufte, 2000). In other words, the maximum effect of a change in the independent variable is at the middle of the S-curve. The estimated effect of a change in an independent variable at different points on the S-curve can be found by taking the coefficients and multiplying them by the probabilities of the dependent variable being 1 and 0 (Tufte, 2000).

It is also common to look at the marginal effects of the coefficients evaluated at the means. This is an estimate of the change in probabilities at the point where the data is centered (Tufte, 2000).

The probability for the dependent variable being 1 can be calculated according to Kleinbaum (1994) by using the following equation:

$$P(Y=1) = \frac{1}{1+e^{(\beta_0+\beta_1 x_1+\cdots+\beta_n x_n)}}$$

Model Evaluation

- R^2 is used to evaluate the goodness of fit in the OLS-models
- Pseudo-R^2 is used for the logit-models. A higher value corresponds to a better fit, but the score is measured on a different scale than the R^2 from OLS (Brooks, 2014).
- Area under the ROC curve: The ROC, or Receiver Operating Characteristic, measures a model's predictive ability. The ROC curve plots the probability of true default (sensitivity) and false default (1 – specificity) for the entire range of possible cutoff points. A higher Area Under the ROC Curve (AUROC) indicates a superior predictive ability. It is essentially a test of whether the model's distribution signals are significantly different for crisis and non-crisis states. If the AUROC score is above 0.5, it has some prediction power compared to, for example, a coin toss. A perfect model would have an AUROC score of 1. As a general rule of interpretation, Hosmer and Lemeshow (2000) state that an AUROC curve above 0.8 demonstrates excellent discriminative ability.

2.2 A Cost-Benefit Analysis of Leaning Against the Wind

In the second part of the thesis, I use the results from the above analysis in a cost-benefit framework to examine how Leaning Against the Wind could affect the economy and the welfare of the Scandinavian people.

2.2.1 The Framework

Lars Svensson (2016) has developed a framework to analyze the trade-offs associated with Leaning Against the Wind. Using estimates from Schularick and Taylor (2012) and the effect of the policy rate on the unemployment rate reported by Ekholm (2013), he calculates the resulting effects on welfare from a 1 percent point increase in the policy rate over quarters 1-4. Leaning in this approach reduces the probability of a crisis, but at the short-term cost of increased unemployment.

I will combine his framework with my own results and calculations to perform the analysis. To facilitate the reader's understanding, the method will be explained alongside the analysis itself.

2.2.2 DSGE Models

To provide a link between leaning and financial stability using my selected baseline model from Part 1, I need an estimate of how the policy rate affects real debt over time. Furthermore, to calculate the dynamics of the loss function from a changed policy rate, we need to find its effect on unemployment and output. To do this, I use dynamic responses from two DSGE models, developed by the Norwegian and the Swedish central banks, respectively.

Based on the New Keynesian foundations, DSGE means Dynamic Stochastic General Equilibrium. Dynamic means that it models both short-run and long-run dynamics. It is stochastic in the sense that the economy is exposed to random disturbances, such as changes in preferences or technology (Bergo, 2005). It also contains shocks to monetary policy. The shocks are modelled as persistent processes, making the effects last for several periods. General equilibrium describes the fact that supply equals demand in all the markets, but the economy can deviate from the long-run steady state. Such fluctuations can, for instance, happen due to a sudden change in households' desire to save, a shock to technology, or an unexpected policy shock. As the effects of a shock die, the economy eventually reverts to previous levels. An example of a DSGE model for an open economy can be seen in Clarida, Gali, and Gertler (2001).

NEMO

The Norwegian Central Bank uses a range of different models to conduct monetary policy. NEMO is a macroeconomic model used to analyze the effects of a wide range of variables in a small, open economy. The model is meant to capture the dynamics of the Norwegian economy and see how it reacts to different kind of changes and readapts to the long-run equilibrium. This long-run equilibrium is decided by factors such as technology, the labor force, and capital (Bache, 2008).

The modelling framework can be used to optimize the policy rate, so that the economy can move towards equilibrium, and inflation can reach the inflation target (Olsen, 2011). A thorough derivation of the model can be seen in Alstadheim et al. (2010). NEMO is based on the New Keynesian framework, with nominal rigidities and imperfect competition. Its microfoundations originate from the assumption of optimizing behavior in households and firms. It also has the classical long-run characteristics, such as no trade-off between inflation and unemployment. RAMSES is a similar model used by the Swedish Central Bank

(Adolfson et al., 2013). It shares many similarities with NEMO, but is constructed to fit the Swedish economy.

To connect the policy rate with real debt growth, I begin by using the impulse response from RAMSES, kindly provided to me by Lars Svensson. As he did in his paper, I use Ekholm (2013) to make a connection between policy rate and unemployment. To extend my analysis to include estimated dynamics for the Norwegian economy, Norges Bank kindly sent me the impulse responses from NEMO. However, these impulse responses only contain the resulting dynamics in output and inflation from a change in the policy rate.

If one wants a very simple translation between output gaps and unemployment gaps, an Okun-coefficient is commonly used.

2.2.3 The Okun-coefficient

Arthur Okun (1962) reported an empirical relationship between unemployment and output. It is a strong and stable relationship (Ball et al., 2013). The relationship is estimated using the following equation:

$$U_t - U_t^* = \beta(Y_t - Y_t^*) + \varepsilon_t,$$

Where $U_t - U_t^*$ is the unemployment gap, and $Y_t - Y_t^*$ is the output gap.

For Norway, there is empirical support for β = -0.294, using a dataset from 1980 to 2011 (Ball et al., 2013). Longer time series show slightly higher coefficients, and therefore I chose to use a coefficient of -0.35.

2.2.4 Estimating impulse responses using a different model

Some economists suggest that DSGE estimates should be checked by using other econometric models (Bache, 2015). Because of this, I expand my analysis by estimating a VAR (vector autoregressive model) based on Norwegian data. The goal of this analysis is to find parameters for how a shock to monetary policy affects unemployment and credit growth.

Data

The dataset consists of time series for 6 variables from 1994 to 2013, for the Norwegian economy. All data is measured quarterly. I wish to thank Ørjan Robstad from the Norwegian central bank for providing me with the data[6][7]. The sample period is chosen because of the accomplished deregulation of the credit market by the mid-1990s (Robstad, 2014).

The following variables are included:

1) Nominal interest rate: 3-month Norwegian Interbank Offered Rate (NIBOR). On level form.

2) Unemployment rate: Unemployment rate statistics from Statistics Norway, seasonally adjusted. On level form.

3) Inflation/Price level: Seasonally adjusted CPI, adjusted for tax changes and excluding energy products (CPI-ATE). Converted to log-differences[8].

4) Real exchange rate: Trade-weighted nominal exchange rate index for 44 trading partners (I-44), adjusted for relative prices in Norway and abroad. Converted to log-differences.

5) Real credit: Credit to households, delated by the CPI-ATE and adjusted for population growth. Converted to log-differences.

6) Real house prices: Nominal house pries, deflated by the CPI-ATE. Seasonally adjusted. Converted to log-differences.

Unemployment and nominal interest rate are on level forms. The rest is log differenced, and can be interpreted as growth rates. A band-pass filter has been applied to the credit variable. This will remove low-frequency movements in real household credit growth, and induce stationarity (Robstad, 2014).

Vector Autoregressive Model

The following description will only be a brief summary of the most important features of a VAR model, presented in Brooks (2014).

To analyze the connection between a monetary policy shock and the unemployment rate, I chose to use a structural vector-autoregressive (SVAR) model. A VAR is a multivariate generalization of autoregressive models, popularized by Sims (1980). It is considered to be a

[6] Note that this is not the same dataset as used to estimate the probability models. The reason for this, is that I wanted quarterly data when estimating the VAR model.

[7] Unemployment is taken from SSB – Statistics Norway, and is measured by Arbeidskraftundersøkelsen (AKU).

[8] Some variables are converted to log difference because of non-stationary characteristics. This will be explained later.

standard workhorse for empirical research in macroeconomics, as stated by Killan (2013). This type of model is useful when working with several variables that is mutually affecting each other. All the variables in the model are kept endogenous. A given variable depend on its own historical values, and also on the values (present and historical) of the other variables included in the system. Another advantage is that forecasts often are just as good, or even better than "traditional structural models". A common critique of the VAR-models is that they are a-theoretical (they lack theoretical fundament).

Stationarity

When doing my VAR analysis, it is important that all the variables are non-stationary, for reasons such as the possible persistence of shocks, or spurious regressions (Brooks, 2014). A stationary process is one where the statistical properties remains unchanged over time: It has a constant expectation and variance. In addition to this, the covariance between two selected observations only dependent on their actual distance in time, not the time itself. To test for stationarity, I use the Augmented Dickey Fuller (ADF)-test[9]. When the p-value of the test is less than 0.05 or when the test statistic is larger in absolute value than the selected critical value, the null hypothesis (unit root) can be rejected.

Choosing the optimal lag length

I use three information criterions to select the optimal lag length for my model; Schwartz, Hannan-Quinn and Aikake. They all consist of two separate parts, one that is a function of the variance-covariance matrix, and a second term that punishes models for its degrees of freedom. On the one side, we want a model with good explanatory power, but a simple model is also considered better than a model consisting of many variables.

The model

A typical structural VAR-model is given by

$$\pi_o y_t = \alpha + \sum_{i=1}^{j} \pi_i y_{t-i} + \varepsilon_t$$

[9] An assumption of the standard Dickey-Fuller test is that the residuals are white noise. This might not hold in my estimation, and I therefore use the ADF-test to get around this issue.

π_o is a matrix consisting of the contemporaneous effects between the variables. y_t is a vector consisting of the endogenous variables at time t, α is a constant, j is the number of lags, and ε_t is a vector of structural shocks. I assume no correlation between the error terms in in ε_t.

In order to correctly estimate the model, I express it on reduced form. The reason for this is that OLS-estimation on the structural VAR violates the assumption that the regressors are not correlated with the error term. This means multiplying each side of the structural VAR-model by the inverse of π_o. Using the rule that the product of a quadratic matrix and the inverse of the same matrix equals the identity-matrix, the VAR model on reduced form can be expressed as

$$y_t = c + \sum_{i=1}^{j} \varphi_i y_{t-i} + e_t$$

Where $\varphi_i = {\pi_o}^{-1}\pi_i$, and $c = \alpha {\pi_o}^{-1}$

The shocks e_t can be interpreted as a weighted average of the structural shocks, ε_t. The weights are given by the matrix π_o.

Impulse responses

VAR models are often difficult to interpret, but a solution is to calculate the impulse responses. The impulse response trace out the responsiveness of the dependent variables in the VAR to shocks to an error term. A shock is applied to a variable and its effect are noted on all variables. We can see how long a shock lasts and what the effects are on the variables in the system.

Sign restrictions

To study how a structural shock affects the variables in y_t, I need to separate the structural shocks from the shocks on reduced form. To identify these reduced shocks, restrictions are applied to the matrix of contemporaneous relationships. Three popular ways to do this is "Choleski identification" (recursive restrictions), non-recursive restrictions and sign restrictions. In this thesis, I chose to use sign restriction. The reason for this, is that I do not need to worry about unit roots since it is a Bayesian procedure (Uhlig, 2005). Also, it allows for full simultaneity between interest rates and the other variables in the VAR (Robstad, 2014).

By using this method, I need to put restrictions on the sign of the contemporaneous effect of the impulse reponse to the structural shocks. I follow Robstad (2014) in assuming that a policy shock that increases the interest rate will have the following effects on the selected variables on impact:

- Unemployment and exchange rate growth will be positively affected[10].
- Inflation, credit growth and house price growth will be negatively affected

I assume that the sign restrictions on impulse responses last for 1 period after the shock, as this approach is evidently more data-driven compared to longer restrictions.

To implement the sign restrictions, I first estimate the reduced-form VAR model using OLS, and select the optimal lag length. This model includes a constant. Then, the reduced form VAR is transformed to a SVAR model based on the above restrictions. Furthermore, the covariance matrix of the reduced form residuals is (randomly) factorized for getting a shock impact matrix, based on which impulse responses are computed and stored. The saved responses are checked against the initial restrictions. At the end, there are a number of different impulse responses satisfying the imposed restrictions[11]. The procedure is done in MatLab. I present the median impulse responses with 16% and 84% quantiles of the distribution (which represent 68% error bands) for the points on the impulse-response functions. I also represent the results for the ADF test[12].

[10] This implies that the real exchange rate appreciates.
[11] In this case, there is 1500 responses satisfying the restrictions that I imposed.
[12] The ADF-test will be conducted using EVIEWS.

3. A Presentation of The Raw Data

In this section, I will present a simple description of some key elements of the raw data that I have used for examining the first research question: The link between financial variables and financial crises.

Friedmann (1981) found that it was not money and credit separately, but rather the interaction between the two that mattered when looking at the effect of financial markets on the real economy. Because of this, I begin by looking at the relationship between credit and broad money for the individual countries, as shown in Figure 1. A feature that immediately catches the eye is the sharp increase in the amount of credit and bank assets relative to broad money following the Second World War. Figure 2 shows the aggregate for the Scandinavian countries.

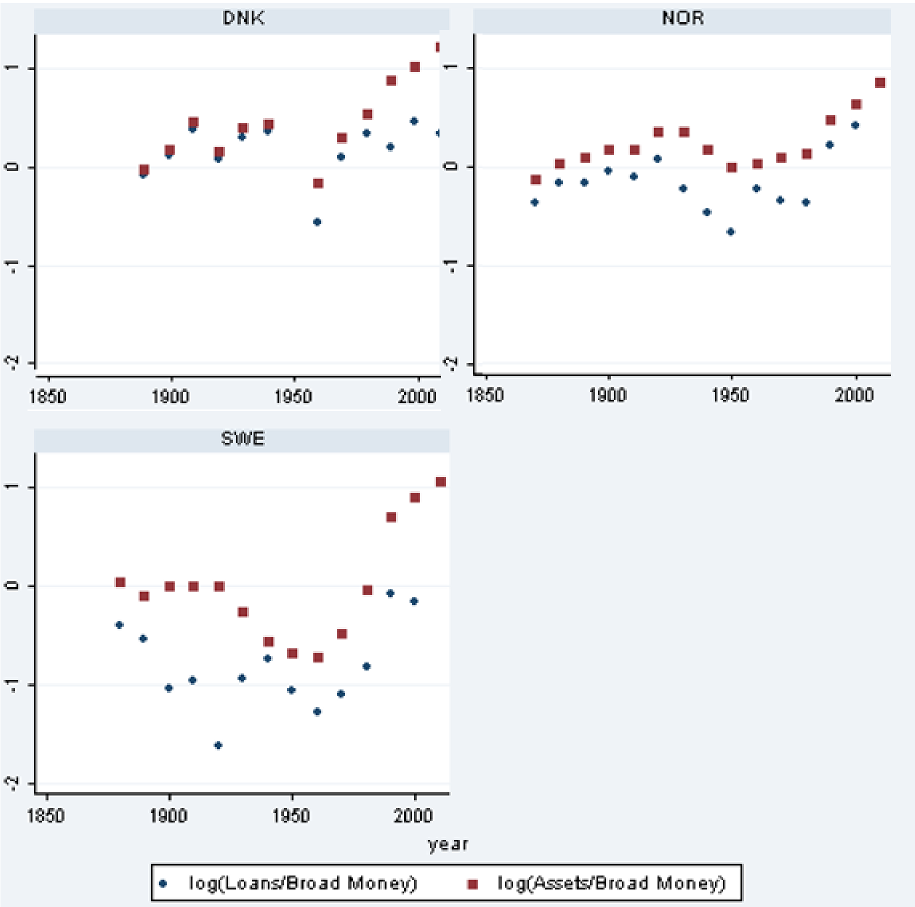


Figure 1: Credit relative to broad money by country (in decades).

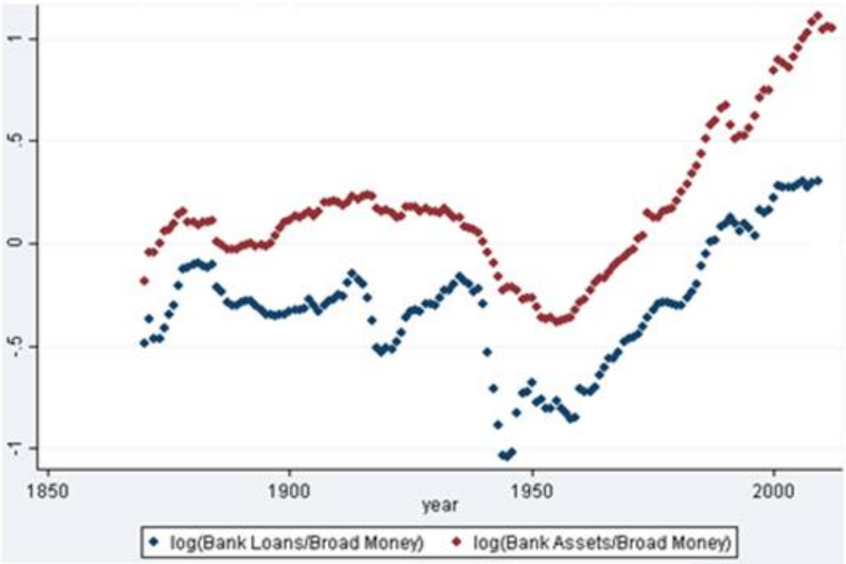


Figure 2: Aggregates relative to broad money since 1870 (in years).

Title	Pre- World War 2			Post- World War 2		
	N	Mean	s.d.	N	Mean	s.d.
Loans/ Broad Money	188	0.8106	0.3384	196	0.8936	0.4278
Assets/Broad Money	173	1.1232	0.2345	195	1.5661	0.8098
Broad Money/GDP	188	0.6354	0.1956	196	0.5172	0.0965
Δ log Real GDP	186	0.0186	0.0300	198	0.0238	0.0209
Δ log CPI	186	-0.0039	0.0527	198	0.0448	0.0336
Δ log Narrow Money	185	0.0236	0.0812	195	0.0618	0.0717
Δ log Broad Money	185	0.0363	0.0535	195	0.0771	0.0498
Δ log Loans	185	0.0423	0.0525	198	0.9835	0.0679
Δ log Assets	171	0.0386	0.0594	194	0.0974	0.0721
Δ log Loans/Broad Money	185	0.0094	0.0494	195	0.0204	0.0684

Δ log Assets/Broad Money	170	0.0041	0.0320	194	0.0213	0.0571

$Table\ 1: Annual\ summary\ before\ and\ after\ WW2.\ Wars\ are\ excluded.$

Some characteristics are already apparent in Table 1. The first two rows show that the values of loans and assets climbed relative to broad money after World War II (WW2). In the third row, we see that broad money fell relative to GDP in the second era under consideration.

Turning to the growth rates further down the table, it becomes obvious that the growth rate of broad money delinks from the growth in assets and loans after WW2. This changing relationship could potentially affect how the real economy responds to financial variables. Before WW2, the growth rate of broad money was 3.6%, loans were 4.2%, and bank assets were 3.8%. After WW2, the average broad money growth had a value of 7.7%, but the growth of loans (9.8%) and assets (9.7%) were higher. If we look at the growth rates of the relative relationship, the loans/money ratio had an annual growth rate of 0.94% before WW2 and 2.04% after. The asset/money growth rate rose from 0.41% before WW2 to 2.14% post WW2. There is significant evidence pointing towards the fact that the behavior of money and credit in Scandinavia has changed since the mid 20th century. Credit and bank assets have been decoupled from broad money, and are rapidly growing. This is consistent with the findings in Schuarick & Taylor (2012).

Financial Crises in the Scandinavian Countries

The next part will include an event study, aiming to discover the economy's response in the aftermath of a financial crisis. In my dataset, financial crises are defined as "*events where a country's banking sector experiences bank runs, sharp increases in default rates accompanied by large losses of capital that result in public intervention, bankruptcy or forced merger of financial institutions"* (Jordà, Schularick, & Taylor, 2017). In total, I identify 17 major banking crises in the three Scandinavian countries.

To construct the average global trend, I will calculate the mean of the predicted time effects from fixed country and year effects regressions for the dependent variable of interest. That is, for the variable Y_{it}, I estimate the regression $Y_{it} = a_i + b_t + e_{it}$, and then save the estimated year effects b_t to show the average global level of Y in year t.To provide a simple overview, I have summarized the key lessons of the event study by showing the cumulative level effects (relative to normal growth in non-crisis years, calculated five years after the event) of financial crises in the two eras of finance capitalism. This is shown in Table 2.

	Pre-WW2	Post-WW2
Log broad money	-0.2318*** (0.0457)	-0.2801*** (0.0571)
Log narrow money	-0.1445* (0.0745)	-0.3061*** (0.0825)
Log bank loans	-0.1042*** (0.039)	-0.4455*** (0.08)
Log bank assets	-0.3035*** (0.0525)	-0.4822*** (0.0803)
Log real GDP	0.0022 (0.027)	-0.1153*** (0.0225)
Log real investment	-0.2529** (0.1059)	-0.3501*** (0.0907)
Log price level[13]	-0.079 (0.0511)	-0.1217*** (0.0398)
Standard errors in parentheses. Significance levels denoted by *** p<0.01, ** p<0.05, * p<0.1		

Table 2: Cumulative log level effect for 5 years after a crisis versus the trend prior to the crisis

You can tell distinct differences in the dynamics of the economy following a financial crisis. Bank assets, broad money, and credit responded much more severely to financial crises after WW2. Bank loans declined more than 4 times in post-WW2 crises when compared to those before WW2. Before WW2, the level of bank loans five years after a crisis was 10 percent below normal. In the postwar period the decline was 44 percent. We can also notice negative inflation, reduced bank assets, and a drop in both output and real investment relative to the average trend.

[13] As an interesting side note, it appears that financial crises did not affect the business cycle (GDP) before World War II.

The effects on all variables are more negative in the second era. This provides additional motivation to study financial crises in modern economies, as crises severely affect all the variables in consideration. In despite of more advanced macroprudential policies and institutional safeguards, the effects of a financial crisis in the Scandinavian countries are more severe today.

The dynamics behind the numbers in table 2 can be seen in the following figures. The first three bars display the average global trend ("normal"). Moving one year ahead (and so on), the figure show the average response of the chosen variables following a crisis, calculated for the Scandinavian countries. The cumulative effect in table 2 is a sum of the bars from year 0-5.

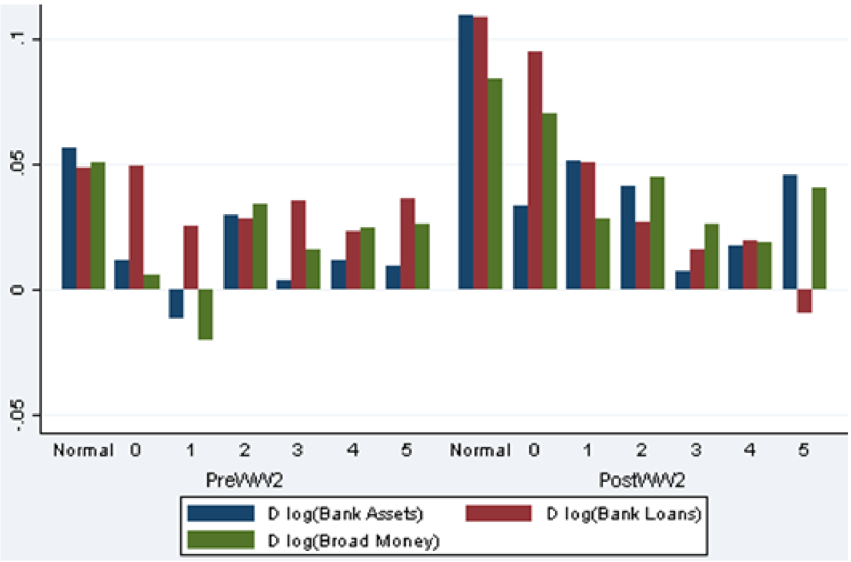


Figure 3: Growth rates of bank assets, bank loans, and broad money following a financial crisis

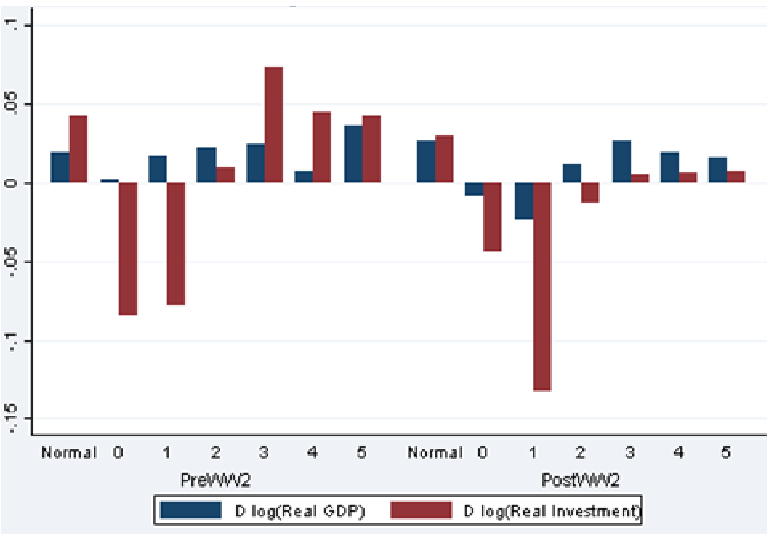


Figure 4: Growth rates of real variables following a financial crisis

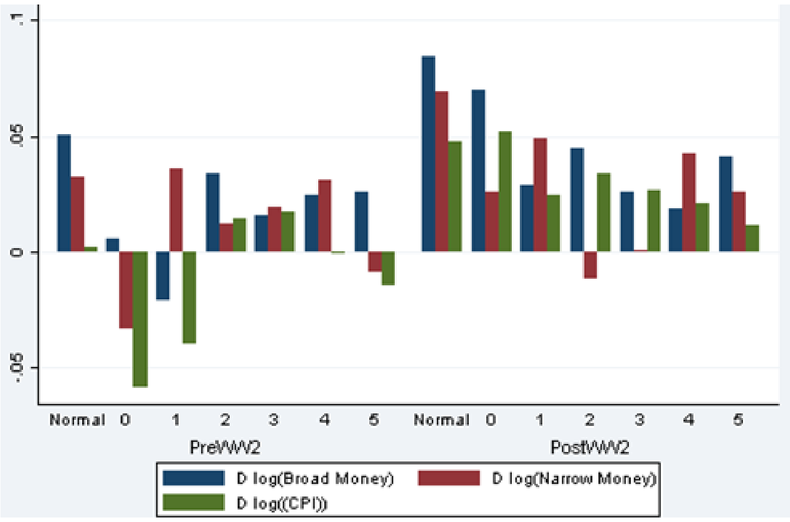


Figure 5:
Growth rates of money and inflation following a financial crisis

4. Theoretical Background

In this chapter, I will give a description of Norwegian monetary policy and a summary of the New Keynesian Theory, the theoretical baseline of monetary policy.

4.1 Norwegian Monetary Policy

The Norwegian government has delegated the implementation of monetary policy to Norges Bank. Since 2001, the Norwegian monetary policy has aimed for an inflation target around 2,5 percent as measured by the Consumer Price Index (Norges Bank, 2006).

This target reflects the viewpoint that low and stable inflation, with low and stable inflation expectations, is the best contribution that monetary policy can provide in order to reach the goal of steady progress in production and employment (Norges Bank, 2004). Low and stable inflation is a necessary condition for achieving stable exchange rate expectations, which is an anchor for the exchange rate.

The policy rate is the central bank's most important tool for monetary policy. The policy rate is the interest rate that the participants in the banking system receive on their deposits in the Norwegian Central Bank. It has a strong influence on the short-term rates in the money market and on banks' deposit and lending rates (Olsen, 2015). In normal circumstances, the Norwegian Central Bank has meetings to assess the policy rate every sixth week. Monetary policy is considered effective if the policy rate has broad impact on money market rates (Bache and Bernhardsen, 2009).

Norway's target, which is somewhat higher than that of other Scandinavian countries (2%) and of the Eurozone, was justified by the gradual increase in income from the petroleum industry that would probably entail a real appreciation. A higher inflation target, if attained, means that more of the real appreciation takes the form of an increase in domestic prices rather than a nominal appreciation of the currency. Also, 2.5 percent was the average inflation in Norway throughout the 1990s (Gjedrem, 2001). Monetary policy always works with a lag, which means that changes in policy rates should happen gradually (Norges Bank, 2004). The horizon for reaching the target is between 1 to 3 years. This means that expected inflation in one to three years should be 2.5 percent. However, the Norwegian Central bank can deviate from this; if the sole purpose of maintaining the inflation target requires interest rates that could create undesired effects for the real side of the economy, the central bank can diverge from its target policy.

It is normally accepted that the policy rate won't have a direct effect on the long-term interest rates. It is forces of demand and supply, expectations of future rates, and risk-premiums that affect the rates with longer maturities (Mork, 2004).

According to Norges Bank (2012), its monetary policy goals can be divided into three parts:

1) Inflation reaches its target. The interest rate is set in order to stabilize inflation around target, or brought back to target if a deviation occurs.

2) Inflation targeting is flexible, allowing the central bank to take the trade-off between inflation and the economic situation into account.

3) Monetary policy should dampen the risk of financial instability.

4.2 The New Keynesian Theory

4.2.1 Overview

The New-Keynesian model has become the baseline of modern monetary policy. It developed from the late 1970`s in response to the criticism of Neo-Keynesian economics. There was a growing need for macroeconomic models that were derived from the optimizing behavior of forward-looking agents but had sufficient friction to reflect real-world problems and tradeoffs. The model was developed as a framework for monetary policy analysis that is based on dynamic, optimizing, general equilibrium analysis in a stochastic context. The model is built on two core assumptions. The first one is rational expectations for households and firms. The second is that prices and wages are sticky in the short run (Bårdsen & Nymoen, 2001). It is widely used in simulation and forecasting purposes (Smets & Wouters, 2003).

Michael Woodford has been one of the most influential contributors to the New Keynesian Theory through his book *Interest and Prices* from 2003. The theoretical framework will be described through his work. To understand and interpret the technical parts, I am relying heavily on the guidance from Mork (2006).

Woodford (quote from *Interest and Prices*): "*Banks around the world have committed themselves more explicitly to relative straightforward objectives with regard to the control of inflation, and have found when they do so that not only is it easier to control inflation than previous experience might have suggested, but that price stability creates a sound basis for real economic performance as well.*"

Monopolistic Competition

To study price setting, firms needs to be able to make pricing-decisions. A key feature of the New Keynesian theory is monopolistic competition. Each of the differentiated goods is assumed to be produced by a distinct monopolistically competitive firm. A fundamental feature of monopolistic competition is that goods are similar to each other, but not completely identical. In this sense, the difference between monopolistic competition and perfect competition is that firms sell differentiated products, and thus have some pricing power (because each good is an imperfect substitute for the other goods). Each firm faces a given demand for their good, but it is still modeled as elastic to a degree because households are willing to manage without some individual good if the relative price becomes too high.

Nominal rigidities

If nominal prices or wages are resistant to change, we say that the situation has nominal rigidity. Sticky prices are a central point in New Keynesian economics. It is crucial for explaining how money can affect the real economy. In the framework, firms are subject to constraints on how often they are able to adjust prices of the goods and services they sell. Alternatively, it can be explained as an outcome of rational, profit-maximizing behavior, because firms may face some costs of adjusting those prices (menu costs). The result of these costs is that prices become sticky. Firms won`t change prices until the price change will provide sufficient revenues to cover the menu costs. The same kind of friction applies to workers in the presence of sticky wages.

4.2.2 The Model

This will only be a brief introduction to the model to provide some background. In *Interest and Prices*, several models (usually small DSGE models) and varying assumptions are used for each topic. For a full outline, see Woodford (2003).

The Two Key Equations for a New Keynesian model with Staggered Prices

The two main equations of the New Keynesian theory are the Phillips curve, and a forward-looking IS curve.

The IS curve represents aggregate demand in the goods market.

$$x_t = E_t(x_{t+1}) - \sigma(i_t - E_t\pi_t + \rho)$$

x_t denotes the output gap.

i_t is the nominal interest rate.

ρ is the real natural rate of interest (the rate of interest that is consistent with output being at the level without stickiness).

The IS relation is derived from intertemporal optimization under rational expectations. In the textbook version of the theory, the intertemporal tradeoff is mainly between present and future consumption (labor supply plays a role as well, but that's less important). In empirical implementations, present and future investment is equally important. The output gap is the difference between actual and potential output, where potential output is the output level in absence of nominal rigidities. Because of intertemporal substitution, a higher interest rate makes it relatively more expensive to consume today (Clarida et al., 1999). This will reduce demand and provide the economy with a lower output-gap.

The second equation is the New-Keynesian Phillips curve.

$$\pi_t = \beta E_t(\pi_{t+1}) + kx_t$$

- x_t denotes the output gap.
- π_t is the inflation rate.
- k denotes the slope of the curve.

The curve represents the supply side of the economy, and is derived from price setting behavior with nominal rigidities. Nominal rigidities are a key element of the model, and a main source of monetary policy non-neutrality (Gali, 2010). For reasons mentioned above, prices are not adjusted continuously in response to shocks, but are altered less frequently. The Calvo mechanism by Calvo (1983) is used as an approximation. Following this process, each firm has a probability of resetting its price each period. This probability is independent of the time since previous price-adjustment. It is not meant to be taken literally— firms don't really run lotteries about who will get to change prices each period. However, the Calvo assumption simplifies the math considerably. A very important further point is that, because of the stickiness, firms need to consider the future when setting prices. Again, they do that with rational expectations.

The New-Keynesian Phillips Curve contains supply shocks in the form of shocks to productivity and labor supply. However, the curve doesn't display the important tradeoff between stabilizing inflation and output. In the absence of cost-push shocks there is no tradeoff between inflation and the output gap. This is sometimes referred to as "the divine coincidence" (Blanchard and Gali, 2005). In reality, central banks do worry about those tradeoffs (Gjedrem, 2006). There are several possible situations where a tradeoff might occur in the New-Keynesian model:

- A sudden shock to costs can increase inflation. At the same time, firms might reduce both production and employment. This creates a conflict between stabilizing inflation and output in the short run.
- A positive demand-shock could cause tradeoffs[14], if the model is based on an open economy. Resulting from this, both prices and output tend to increase. The central bank could normally raise rates without facing a tradeoff, but there is a possibility that the resulting exchange rate could put additional downward pressure on inflation.
- Wage bargaining shocks affects wages negatively. This yields lower marginal costs and prices. Making a larger surplus associated with their employment relationships, firms might hire more workers. Unemployment decreases, and there is a positive rise in production. Confronted with higher output and lower inflation, the central bank now faces a tradeoff.
- A price mark-up shock is an increase in the elasticity of substitution between goods. This could be interpreted as a reduction in firms' market power. Firms will have to

[14] Normally, a demand-shock is not associated with tradeoffs in the NK framework.

lower prices, and this would in turn raise demand for goods. This makes firms employ more people to increase production, and the central bank is stuck with a dilemma.

In the literature, the tradeoff between stabilizing inflation and the real economy is often described as minimizing a loss function.

4.2.3 Welfare Maximization and the Loss Function

Minimizing the loss function can be viewed as the central bank`s attempt to maximize welfare. The trade-off between price stability and real economic stability is often described in the function, where both the deviation in output and inflation is included. These two variables follow from the model specification where the deviations from the flexprice equilibrium[15] are the results of staggered pricing. Because more than one factor is considered, the central bank might deviate from setting the policy rate in a way that only accounts for price stability. This is called flexible inflation targeting. Flexible inflation targeting is considered an effective way to achieve macroeconomic and financial stability (Bernanke & Gertler, 1999; Gilchrist & Leahy, 2002).

A simple loss-function from Woodford (2003) looks like this:

$$L = (\pi - \pi^*)^2 + \lambda x^2$$

In this equation, π denotes inflation, π^* denotes the inflation target, and x is the output gap. The deviations are measured quadratically[16], so the loss from large discrepancies is weighted as much worse than small ones. The trade-off between price stability and the real economy is expressed by the parameter λ. Lambda is not a parameter that the central bank can choose freely; it is rather derived from the underlying parameters of households' preferences and firms' behavior. The output gap is the deviation from the flexprice equilibrium. The relative weight of the output gap is intimately tied to the slope of the Phillips curve. If a shock makes inflation deviate from the optimal value of zero, the real effects are large as well, because not all prices are adjusted all the time.

The theory calls for central bank's policy to minimize the loss function subject to the IS and the Phillips equations. Unless a zero lower bound for nominal interest rates is binding, the Phillips equation is the only relevant constraint, meaning that minimizing the loss function

[15] The equilibrium price level when disregarding stickiness.

[16] This follows from a quadratic approximation of the welfare function. However, as the welfare function typically is concave, this approximation typically would seem appropriate.

subject to the Phillips curve yields the optimal values of inflation and the output gap. The IS relation can be solved next to get the nominal interest rate needed to attain these values.

The central bank cannot decide on the optimal present and future values of inflation and the output gap once and for all, but must be prepared to make changes as new information arrives.

The choice of time horizon for monetary policy implicitly provides insight into the central bank's loss function. If it puts considerable emphasis on inflation, and by doing so disregards the real economy, it will choose a short time horizon. Conversely, if the real economy is weighted as the most important factor, the central bank will choose a longer time horizon. The weight on output stabilization determines how quickly the inflation forecast is adjusted towards the inflation target (Svensson, 1997).

4.2.4 The Unemployment Gap

In addition to being an indicator of potential inflationary or deflationary pressures within an economy, the output gap is also related to the level of employment in an economy. Central banks commonly view full employment as corresponding with a zero-output gap and thus indicating that economy is operating at maximum efficiency. Therefore, when considering policy decisions, a country's central bank usually examines both inflation and unemployment.

One can use the unemployment gap instead of the output gap as a measure of resource utilization and an argument of the central bank's loss function. Potential output is well defined theoretically as the level of output that would result if all prices and wages were fully flexible. In reality, it is a kind of sophisticated moving average, and there are several challenges in estimating it empirically (Arnold & Tetlow, 2009; Sarwat & Mahmud, 2013; and Croitoru, 2016).

In contrast, the long-run sustainable unemployment rate (the long-run natural rate) is something that one can estimate fairly reliably with a variety of methods. This makes the unemployment gap a more reliable indicator of resource utilization. Svensson (2011) concludes that the gap between unemployment rate and an estimate of the sustainable rate is the best measure of resource utilization: "*The main reason is that the alternative of using the output gap requires estimating potential output, and during my period at the Riksbank I have become more skeptical about measures of potential output. Estimating the sustainable unemployment rate is less difficult and carries less risk of big mistakes. One can thus have a more open and transparent discussion about the sustainable unemployment rate than about* *potential output."* This argument is further extended in Svensson (2016), where he uses a quadratic loss function consisting of only unemployment: "*however, such a simple loss function can be seen as an indirect loss function resulting from the minimization of a loss function of both inflation and unemployment."*

5. Leaning Against the Wind

Leaning is a concept that captures several possible actions of the central bank: hiking more, cutting less, hiking earlier, using a higher policy rate than warranted to maintain stable prices (IMF, 2015). If it suspects growing financial instability, the central bank increases the policy rate. The transmission between monetary policy and macroeconomic conditions can be illustrated by the following figure:

Figure 6: From interest rates to financial stability (IMF, 2015).

In this paper, credit growth will be the main focus of the first link.

5.1 The Link Between Monetary Policy and Credit

The argument for leaning usually involves the effect that the policy rate has on the real debt growth. Economic theory states that monetary policy is neutral in the long run, which means that it cannot affect the long-run values of the real variables. However, there is existing empirical evidence showing that a temporary increase in the policy rate can decrease the real debt growth, and vice-versa. Diaz et al. (2015) demonstrates that a decrease in the monetary policy rate reduces debt by about 2 percent after 2,5 years, even in the presence of macroprudential policy. Riksbank (2014) found that real debt decreases under monetary policy tightening by about 1 percent after 2 years. In most of the studies, credit may return to its steady state value following a monetary policy shock, but the empirical literature is split on this question. A shock's impact on the long-run credit effects is sensitive to specification assumptions (IMF, 2015)

Some studies also find evidence that interest rates seem to affect the lending standards of banks. Maddaloni and Peydrò (2011) find that low short-term interest rates loosen standards for household and corporate loans. This softening—especially for mortgages—is amplified by securitization activity, weak supervision for bank capital, and low monetary policy rates for an extended period. Martin and Skeie (2011) find that higher interest rates tightens banks' lending standards.

5.2 The Link Between Credit Growth and Financial Crises

There are many variables that affect the financial stability of the economy: leverage of firms, bank risk taking, household debt, asset growth, and credit spreads (IMF, 2015).
Using an annualized dataset for 14 countries in the timespan 1870-2008, Schularick and Taylor examine how several key economic variables have developed throughout the history in their paper "Credit Booms Gone Bust: Monetary Policy, Leverage Cycles, and Financial Crises" from 2012. They find evidence that lagged credit growth during the 5 years prior to a crisis is a powerful predictor of a financial crisis. Their results are significant at the 1% level for both pre- and post-World War II data. Similar results have been found by the IMF staff (IMF, 2015). Ganioglu (2013) also finds support for the view that the probability of a financial crisis increases following periods with high credit growth.

In many of the New Keynesian models, the economy is at risk of experiencing a financial crisis, and the probability of this crisis is strongly determined by the credit conditions (Woodford, 2012). The effect of interest rates on the probability of a crisis might be even higher than what existing empirical evidence suggests, if their connection to other financial variables are also taken into consideration, such as risk-taking behavior, asset prices, and credit spreads (IMF, 2015).

5.3 Literature in Favor of LAW

Using the policy rate to target a specific financial variable has proven to be difficult. On the other hand, the policy rate's possible far-reaching effects have been used as an argument for leaning. Jeremy Stein, a governor on the Federal Reserve Board, took a clear stand on the issue. In a 2013 speech, he stated that monetary policy is a powerful tool against financial distress because it "gets in all the cracks" (Stein, 2013). If the underlying economic environment creates a strong incentive for financial institutions to take on more credit risk, it is unlikely that regulatory tools can completely contain this behavior. Dudley (2015) states that using macroprudential tools as a first line defense against financial instability is much easier said than done, and believes that using monetary policy to ensure financial stability understates its broad effects on the economy as a whole.

As mentioned, arguments are made in favor of leaning because of its possible desired effect on financial instability. Gerdrup et al. (2016) find that high interest rates could be an efficient tool for curbing financial instability if one considers the possible effect the interest rate setting has on the severity of a crisis. Gourio, Kashyap, and Sim (2016) find that leaning against the wind might be attractive, depending on several factors, including (1) the severity of the financial crisis; (2) the sensitivity of crisis probability to excess credit; and (3) the volatility of excess credit. Smets (2014) concludes that the new macroprudential policy should be the main tool for maintaining financial stability. However, monetary policy should also be used to keep an eye on financial stability, allowing the central bank to lean against the wind while maintaining its primary focus on price stability over the medium run.

Even when “Leaning Against the Wind” is considered a fruitful policy, questions also arise regarding its timing. Demertzis (2012) argues that short but aggressive cuts can be used as a response when early indicators of financial distress appear. Filardo and Rungcharoenkitkul (2016) find that leaning systematically over the whole financial cycle is found to outperform policies of “benign neglect” and “late-in-the-cycle.”

5.4 Literature Against Leaning

The opposing side argues that the focus of monetary policy should be on maintaining price stability, and that other types of policies are better suited for dealing with financial instability. Willams (2015) claims that monetary policy is poorly suited for dealing with financial stability concerns. Instead, given the scarcity of explicit macroprudential tools in the United States, microprudential regulations and supervision are used to achieve macroprudential goals. Yellen (2014) doesn’t see any need for monetary policy to deviate from a primary focus on attaining price stability and maximum employment. She goes on to say that increased risk-taking across the financial system should be met with a more robust macroprudential approach. In an independent evaluation of monetary policy in Norway, called Norges Bank Watch, in 2014, Mork, Freixas and Aamdal recommended that Norges Bank return to setting its policy rate mainly according to the standard criteria of flexible inflation targeting, with less regard to financial stability (Mork, Freixas & Aamdal, 2014).

Also, empirical evidence indicates that even if there is a link between the policy rate and financial variables, it is very weak. IMF (2015) estimates the welfare loss from a 1 percentage point increase in the policy rate, assuming a number of different crisis-durations and impacts (on unemployment) in their analysis. They find that with substantial slack in the macroeconomy the transmission from interest rates to financial risks is very weak (the 1 percentage point increase in the policy rate reduces real credit growth between 0.3-2 % after 1-4 years).

In a working note focusing on experiences with inflation targeting from the Norwegian Ministry of Finance (Finansdepartementet, 2017), several contributors mentioned the concept of Leaning Against the Wind. John Murray, the former Deputy Governor of the Bank of Canada, suggested a sharper separation of the Norwegian Central Bank`s responsibility for price stability and financial stability; "*Norges Bank should abandon the notion of leaning.*" Hilde Bjørnland, a professor in macroeconomics at BI (Norwegian Business School), emphasizes that the cost of leaning is that it will dampen economic activity. Therefore, the benefits of leaning could be outweighed by the cost. Knut Anton Mork, Professor II at NTNU and an economist for CARN Capital, refers to the wide range of research on this issue and recommends that monetary policy be focused around flexible inflation targeting. He also points towards the success of the Swedish Central Bank after 2014, when they reduced the weight of financial stability on their policy rate decisions.

One of the main reasons for estimating the link between credit growth and the Scandinavian countries is because I would like to get empirical evidence from small, open economies. Research suggests that countries of this type might have some additional concerns regarding financial stability and Leaning Against the Wind, as higher rates could appreciate the domestic currency. As pointed out by Unsal and Ozkan (2014), this could actually end up increasing debt levels.

A final and increasingly relevant argument against leaning is the effect the increased policy rate might have on the banking sector. Nelson, Pinter, and Theodoris (2015) use a DSGE model that includes a shadow banking sector and finds that a monetary contraction aimed at reducing the asset growth of commercial banks would cause a migration of activity towards the shadow banking sector. This casts some doubt on how monetary policy can be used in this way. They find that surprise monetary contractions tended to reduce the asset growth of commercial banks. The findings highlight the potential challenges associated with using monetary policy to lean against financial sector activity in pursuit of financial stability goals. However, it also raises questions about the ability of macroprudential policies to prevent financial instability. The term "shadow banking" often refers to those financial institutions that manage to escape strict regulation. Increased shadow banking activity and liquidity creation outside of the regulatory umbrella increases the fragility of the financial system as higher-risk financial intermediaries are subject to costly runs (Moreira & Savov, 2014).

5.4.1. The Analysis of Lars Svensson

Svensson (2016) has developed a framework to analyze the trade-offs associated with leaning against the wind. Using estimates from Schularick and Taylor (2012) and the effect of the policy rate on the unemployment rate as reported by Ekholm (2013), he calculates the resulting effects on welfare from a 1 percent point increase in the policy rate over quarters 1-4. Leaning in this approach reduces the probability of a crisis, but at the short-term cost of increased unemployment. Svensson makes a strong case against leaning.

He makes several important points:

- A higher policy rate increases unemployment and lowers inflation. This clearly reduces welfare in the absence of a financial crisis.
- The cost of a crisis is also higher if the economy is initially weakened because of the increased policy rate.
- Monetary policy is neutral in the long run. This means that it cannot affect the real debt in the long run. Furthermore, it has no accumulated effect on the probability of a crisis.

The main cost of leaning is increased unemployment, both in periods of financial distress and periods of stability. The rise in unemployment increases the value of the loss function, and hence reduces welfare.

The mechanism from which the possible benefits of leaning could be created is through the reduced probability of a crisis from reduced real debt growth, which in turn is a result of a higher policy rate. However, according to Svensson's empirical estimates, this benefit is far outweighed by the costs. In chapters 7-9, I report on my own attempts to duplicate Svensson's analysis.

6. Financial Variables and Financial Crises: An Empirical Study

I begin by presenting my initial results in Table 3. The purpose of this initial estimation is to select a baseline model for predicting financial crises for further examination. I will consider up to five annual lags of the selected independent variable. The methodology is explained in detail in chapter 2.1.

Table 3: Financial Crisis Prediction — OLS and Logit Estimates

Specification Estimation method Fixed effects	(1) OLS None	(2) OLS Country	(3) OLS Country+year	(4) Logit None	(5) Logit Country
L1.Δ log (loans/P)	0.117 (0.197)	0.113 (0.198)	0.048 (0.222)	3.735 (4.124)	3.786 (4.173)
L2.Δ log (loans/P)	0.507** (0.212)	0.505** (0.213)	0.555** (0.236)	12.46*** (4.516)	12.81*** (4.677)
L3.Δ log (loans/P)	0.211 (0.212)	0.209 (0.213)	0.217 (0.240)	6.525 (7.013)	6.637 (6.867)
L4.Δ log (loans/P)	-0.0616 (0.207)	-0.0641 (0.208)	-0.036 (0.237)	-3.625 (5.278)	-3.664 (5.106)
L5.Δ log (loans/P)	0.0109 (0.190)	0.00804 (0.190)	-0.356 (0.221)	2.007 (5.978)	1.920 (5.857)
Observations Groups	312 3	312 3	312 3	312 3	312 3
Sum of lag coefficients *SE* Test for all lags = 0 *p* value	0.784 0.295 2.631** 0.0239	0.772 0.297 2.565** 0.0272	0.428 0.318 2.333** 0.0438	21.10 8.460 18.13*** 0.0028	21.49 7.874 19.87*** 0.0031
Test for country effects = 0 *p* value Test for year effects = 0† *p* value		0.15 0.85 ----- -----	0.27 0.76 2.19*** 0.0001		0.58 0.76
R^2 / Pseudo R^2 Pseudolikelihood Overall test statistics *p* value AUROC *SE*	0.041 2.631** 0.024 0.762*** 0.0773	0.042 1.913* 0.06 0.768*** 0.0777	0.579 2.255*** 0.0001 0.993*** 0.0038	0.112 -44.67 18.13*** 0.0028 0.773*** 0.0740	0.138 -44 19.88*** 0.0092 0.780*** 0.0752
Reported statistic is *F* for OLS, chi-squared for logit. Reported statistic is R^2 for OLS, and Pseudo R^2 for logit. Robust standard errors in parentheses. Significance levels denoted by *** p<0.01, ** p<0.05, * p<0.1					

Model 1 is an OLS Linear Probability model with pooled data. In Model 2, I added fixed effects (country), but they don't have any statistical significance, with a *p* value of 0.85. Model 3 was also estimated using fixed effects for both year- and country-effects. The year-effects are statistically significant at the 1 percent level. The year-effects can be interpreted as a global time component that affects financial instability, and knowing this effect can improve the ability to predict financial crises.

The sum of the lag coefficients for models 1 and 2 is about 0.8, and the average real loan growth over five years has a standard deviation of 0.07. This means that one standard deviation increase in real loan growth will increase the probability of a crisis by 5.6 percentage points.

Because of the problems mentioned in the methodology chapter about the linear probability model, two logit models are estimated. Model 4 is a pooled logit model. In specification 5, I extended the model to include country fixed effects. This is done by including dummy variables in the regression. As in the OLS models, they are not statistically significant.

I chose specification 5 as my baseline model[17]. Real loan growth over the last 5 years is a significant explanatory variable for a financial crisis. Increased loan growth is associated with an increased likelihood that a financial crisis will occur. The 5 lag coefficients have a sum of about 21. These are jointly significant at the 1 percent level.

The Receiver Operating Characteristic (ROC) curve indicates that the selected baseline model has a significant predictive ability. The area under the ROC curve is 0.78 for the logit model with country fixed effects. This displays a great (but not perfect) discriminative ability.

[17] I consider the FE model to be more credible than the model without (model 4). It looks at the variation within the countries instead of the variation across. I wish to thank Luka Marcinko for helpful discussions regarding model selection.

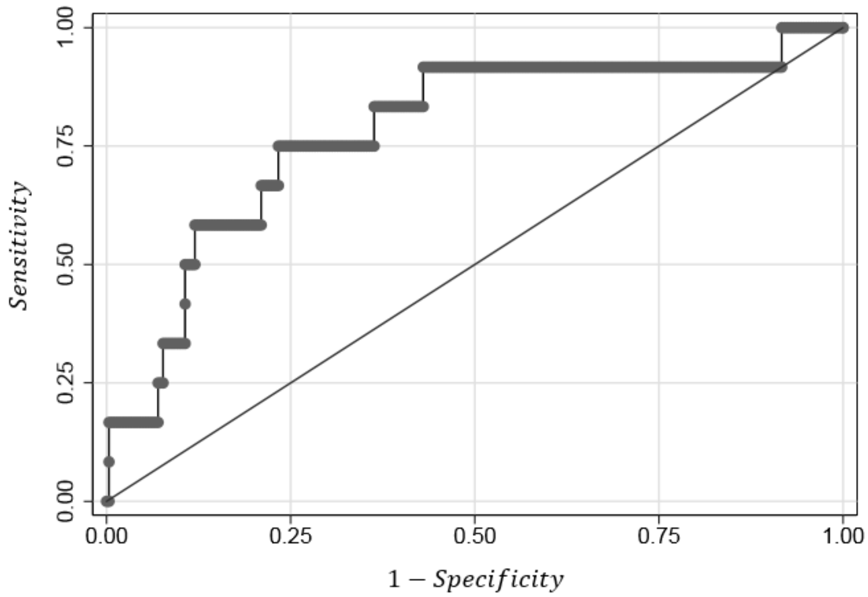


Figure 7: *ROC curve for the baseline model*

Unfortunately, all the above forecasts represented by the AUROC results might be misleading. This is because the models can look ahead into the sample as its forecasting abilities are generated. To challenge the model further, I limited the forecast sample to after 1983, and compared in-sample and out-of-sample forecasts. The first (in-sample) is based on the full sample, and the latter is based on rolling regressions, using lagged data only.

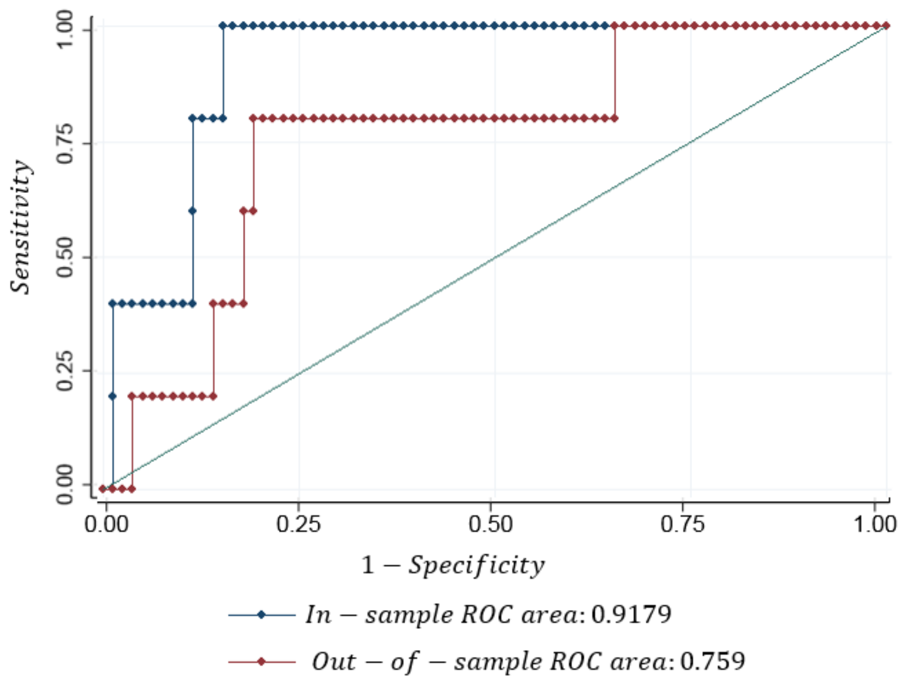


Figure 8: *In − sample vs out − of − sample ROC curves*

The out-of-sample AUROC still has a lot of predictive power and is statistically significant at the 5% level. The result adds some assurance to the predictive power of my baseline model.

I subjected the robustness of my results to further testing in Table 4. I used my baseline specification throughout the entire table and replaced lagged real loan growth with 4 selected variables: broad money, narrow money, loans/GDP, and loans/broad money.

Table 4: Baseline model with alternative specifications

Specification (Logit country effects)	(6) Baseline	(7) Replace loans with broad money	(8) Replace loans with narrow money	(9) Replace real loans with loans/GDP	(10) Replace real loans with loans/broad money
L1.Δ log (loans/P)	3.786 (4.173)	2.963 (5.7)	-1.407 (4.58)	3.636 (4.38)	1.429 (4.965)
L2.Δ log (loans/P)	12.81*** (4.677)	17.26*** (4.91)	6.51*** (1.82)	7.233 (4.496)	6.107 (4.031)
L3.Δ log (loans/P)	6.637 (6.867)	-1.39 (5.551)	-2.11 (3.73)	8.690 (6.455)	6.962* (4.193)
L4.Δ log (loans/P)	-3.664 (5.106)	7.34 (5.55)	0.63 (2.67)	-3.413 (5.636)	-4.352 (4.918)
L5.Δ log (loans/P)	1.920 (5.857)	9.08 (5.05)	0.56 (2.93)	0.216 (4.747)	-5.341 (4.011)
Marginal effects at each lag Evaluated at the means Sum	0.0845 0.286 0.148 -0.0817 0.0428 0.479	0.07 0.41 -0.033 0.17 0.22 0.837	-0.047 0.218 -0.07 0.021 0.018 0.14	0.097 0.193 0.232 -0.0911 0.005 0.436	0.433 0.185 0.211 -0.132 -0.162 0.146
Observations Groups	312 3	335 3	335 3	307 3	307 3
Sum of lag coefficients *SE* Test for all lags = 0†, χ^2 *p* value	21.49 7.87 19.87*** 0.003	35.26 8.5 23.07*** 0.0003	4.2 9.97 20.15*** 0.0012	16.36 6.93 7.47 0.188	4.8 9.15 8.185 0.146
Test for country effects = 0, χ^2 *p* value	0.53 0.76	0.24 0.88	0.75 0.68	0.52 0.76	0.35 0.83
Pseudo R^2 Pseudolikelihood Overall test statistics, χ^2 *p* value	0.138 -44 19.88 0.00925	0.14 -49 28.72*** 0.0002	0.068 -54 21.68*** 0.0029	0.089 -46 7.63 0.36	0.056 -47 9.81 0.19

AUROC *SE*	0.780*** 0.0752	0.79*** 0.0587	0.67*** 0.07	0.74*** 0.09	0.69*** 0.06

I began with the baseline model, as seen in specification 6. I also reported the results as marginal effects, evaluated at the means. Marginal effects are used to interpret the degree of influence in non-linear models such as the logit model. The sum of these over all 5 lags is equal to 0.47. This implies that a 1 percentage point reduction in annual real debt growth for 5 years reduces the annual probability of a financial crisis beginning by about 0.47 basis points per year, or 11.75 basis points per quarter. More interpretation of the results from my baseline model will be reported in the second part of my analysis.

Model 7 replaces real loans with broad money. This has a slightly higher R^2 and AUROC. According to these results, it seems that broad money could be considered just as good of an explanatory variable as real loans for the probability of a financial crisis. It seems as though both the liability and the asset side of banks' balance sheets do a pretty decent job at predicting financial crises, if I look at the entire sample. However, the separation of credit from broad money after World War II makes me want to test this further.

In specification 8, I use narrow money as a proxy for real loans. The explanatory power is almost cut in half when compared to the baseline model. In models 9 and 10, I use the ratios of loans/GDP and loans/broad money as explanatory variables. These are not statistically significant, and the re-specifications have lower R^2 and predictive power (AUROC) compared to the baseline model.

To conclude this section, it is evident that credit is not the only predictor of a financial crisis. However, only one model in the selected sample is as good as the baseline model. This result gave me some reassurance that my baseline model is good, but I needed to examine whether broad money could be just as good of an explanatory variable. In order to do this, I separated my sample and re-estimated the models using data from before and after World War II. The results are represented in Table 5.

$Table\ 5: Baseline\ model\ with\ pre - WW2\ and\ post - WW2\ samples.$

Specification (Logit country effects)	(11) Baseline Pre-WW2 Using loans	(12) Baseline Post-WW2 Using loans	(13) Pre-WW2 Replacing loans with broad money	(14) Post-WW2 Replacing loans with broad money
L1.Δ log (loans/P)	5.565 (9.480)	2.503 (8.937)	-6.4 (8.1)	13.15 (9.82)
L2.Δ log (loans/P)	6.232 (8.992)	38.01*** (8.890)	33.57*** (11.89)	8.45 (6.40)
L3.Δ log (loans/P)	6.053 (12.60)	27.01*** (8.866)	-22.68** (10.81)	17.18 (11.40)
L4.Δ log (loans/P)	-11.88* (6.902)	4.451 (17.43)	13.77* (7.32)	7.52 (10.23)
L5.Δ log (loans/P)	12.47* (6.778)	-32.11* (17.66)	14.23** (5.90)	-0.31 (9.53)
Observations Groups	155 3	183 3	155 3	180 3
Sum of lag coefficients *SE* Test for all lags = 0†, χ^2 *p* value	18.44 14.84 8.89 0.11	34.85 10.51 27.84*** 0.003	32.49 11.66 10.19* 0.07	45.99 22.49 9.53* 0.09
Test for country effects = 0†, χ^2 *p* value	0.009 0.9	6.8** 0.03	0.31 0.85	0.14 0.93
Pseudo R^2 Pseudolikelihood Overall test statistics, χ^2 *p* value AUROC *SE*	0.08 -26 9.51* 0.21 0.74*** 0.112	0.50 -11 27.87*** 0.0002 0.95*** 0.02	0.25 -26 18.75*** 0.009 0.84*** 0.07	0.23 -17 13.19* 0.068 0.79*** 0.14

The results for specification 14 reveal the suspicion I had after studying the raw data. The findings fit well with the picture of the changing dynamics in credit and money in the second era. After World War II, credit was delinked from broad money. None of the five lags of broad money are significant. Similar results are found for Model 11, where we examine the significance of real loan growth before the war. The result in Model 12 clearly indicates that real loan growth is the best variable of choice. When it comes to financial crises, I find that this indicates that credit is the main factor driving macroeconomic outcomes. This suggests that if central banks are concerned about financial stability, it might be better to use macroprudential tools that target credit rather than using monetary aggregates.

As a final step in this part of the analysis, I wanted to check for omitted variable bias. To do this, I expanded my baseline model to include additional control variables. I considered 4 extensions to my baseline model:

- 5 lags of real GDP growth
- 5 lags of inflation rate
- 5 lags of the nominal short-term interest rate
- 5 lags of the real short-term interest rate

Table 6: Robustness test

Specification (Logit country effects)	(6) Baseline	(15) Baseline plus 5 lags of real GDP growth	(16) Baseline plus 5 lags of inflation	(17) Baseline plus 5 lags of nominal short term interest rate	(18) Baseline plus 5 lags of real short term interest rate
L1.Δ log (loans/P)	3.786 (4.173)	2.163 (4.66)	6.121 (6.27)	2.943 (4.78)	2.29 (5.9)
L2.Δ log (loans/P)	12.81*** (4.677)	11.77*** (4.73)	19.03*** (4.76)	13.92*** (4.51)	16.85*** (5.1)
L3.Δ log (loans/P)	6.637 (6.867)	9.203 (7.98)	12.53 (8.8)	5.27 (8.26)	11.67 (7.14)
L4.Δ log (loans/P)	-3.664 (5.106)	-2.28 (5.47)	-11.19 (9.3)	-4.1 (5.29)	-5.95 (6.21)
L5.Δ log (loans/P)	1.920 (5.857)	0.91 (6.14)	-8.75 (6.96)	3.10 (5.38)	-7.45 (6.57)
Observations Groups	312 3	312 3	312 3	307 3	302 3
Sum of lag coefficients *SE* Test for all lags = 0†, χ^2	21.49 7.87 19.87***	21.76 7.98 23.07***	17.74 8.88 20.15***	21.13 8.66 24.8***	17.41 8.20 21.8***
Test for lags of added variable = 0, χ^2 *p* value		6.97 0.22	12.49** 0.029	4.8 0.4	11.61** 0.04

Pseudo R^2	0.138	0.147	0.181	0.142	0.17
AUROC	0.780***	0.80***	0.82***	0.73***	0.81***
SE	0.0752	0.05	0.07	0.09	0.06

One can easily see that, although some of the added control variables have some effect, credit growth remains the main predictor of financial crisis. None of the added variables has a considerable effect on the fit and predictive performance of the model. While testing for the significance of the lags of the added variable, we see that the lags of real GDP growth and short-term nominal interest rate are not statistically significant at the 5% level. The two strongest contributors are inflation and real short-term interest rate, but these do not increase the fit or the predictive power. The pseudo R^2 is slightly increased in the 4 extensions, but the greater fraction of the model's fit is always due to the credit variable.

Concluding remarks

I conducted this first part of my analysis, aiming to discover the best financial variable for explaining financial crises in the Scandinavian countries. After reading the famous paper of Schularick & Taylor, I decided to use real debt growth as a starting point, and estimated five different probability models using lagged real debt growth as the explanatory variable. I chose the logit model with country fixed effects as my baseline model, and went on to estimate this using alternative variables, to see if they could predict a financial crisis better than credit growth. Broad money seemed to be a decent variable of choice as well, but after separating my sample into eras before and after World War 2, there was no doubt that real debt growth had the best explanatory power for financial instability today. Adding lags of other control variables slightly increased the predictive power of the model, but I conclude that credit is the best choice when aiming to connect financial variables and financial crises in the Scandinavian countries.

7. A Cost-Benefit Analysis of Leaning Against the Wind

In this part of the analysis, I will use the framework for a cost-benefit analysis created by Lars Svensson. I take full responsibility for all calculations that are made, but I wish to make it clear that the framework was created solely by Svensson. The latest version with full mathematical derivations can be seen in Svensson (2017).

In the event of a financial crisis, the economy will experience an increased unemployment equal to the non-crisis unemployment rate u_t^n plus a fixed mark-up, Δu. The relationship can be described as

(1.1) $u_t^c = u_t^n + \Delta u > u_t^c$

The following notations will be used throughout the analysis:

- p_t : The probability of the economy being in a crisis in quarter *t.*
- q_t : The probability of a crisis starting at the beginning of quarter *t*.
- $E_1 u_t$: The expected unemployment rate.
- $E_1 u_t^n$: The expected unemployment rate when disregarding the possibility of a crisis.

If a crisis occurs, the unemployment rate increases by Δu, and becomes equal to the crisis unemployment rate during this first quarter.

If a financial crisis has a duration of *n* quarters, the likelihood of being in a crisis is approximately equal to the probability that a crisis began in any of the last *n* quarters. This implies that the probability of the economy being in a crisis in quarter *t* can described by the following equation:

(1.2)

$$p_t = \sum_{\tau=0}^{n-1} q_{t-\tau}$$

The quarter *t* expected unemployment rate will equal the weighted sum of the non-crisis expected unemployment rate, with probability 1-p_t, and the expected crisis unemployment rate with probability p_t

(1.3) $E_1 u_t = (1 - p_t)\, E_1 u_t^n + p_t E_1 u_t^c = (1 - p_t)\, E_1 u_t^n + p_t(E_1 u_t^n + \Delta u) = E_1 u_t^n + p_t \Delta u$

This means that the last term is the increase in the expected unemployment rate, because of the possibility that a crisis might occur.

The benchmark duration of a crisis in Svensson (2016) is 8 quarters, and the unemployment rate increased by 5 percentage points during those 5 years. Compared to my prior event study, where I found a cumulative output drop of 11.5 percent, this is a severe recession. It is also longer than the average financial crisis, according to Terrones et al. (2009). I will keep Svensson's assumptions for the sake of comparison, but it is worth noting that a recession of this magnitude is above normal.

Furthermore, i_t denotes a constant policy rate during the first 4 quarters. I will consider the effect on the expected future unemployment rate of increasing this rate during quarters 1-4. By (1.3) it is given by

(1.4)

$$\frac{dE_1 u_t}{di_1} = \frac{dE_1 u_t^n}{di_1} + \Delta u \frac{dp_t}{di_1}$$

The first term is the effect on $E_1 u_t^n$, the expected unemployment rate in times without a financial crisis. The last term adds the effect of the crisis— an increase of the expected unemployment rate. I begin by finding estimates for these relations separately.

The effect of the policy rate on the expected unemployment rate in non-crisis times

To calculate this, I use the dynamic effects following a monetary policy shock, presented in Ekholm (2013). This is the estimate from RAMSES, which will be used throughout the first part of the analysis. Later, I will extend the analysis to include the impulse response from NEMO.

The increase in the policy rate is 1 percentage point during the first 4 quarters, before it returns to the baseline level.

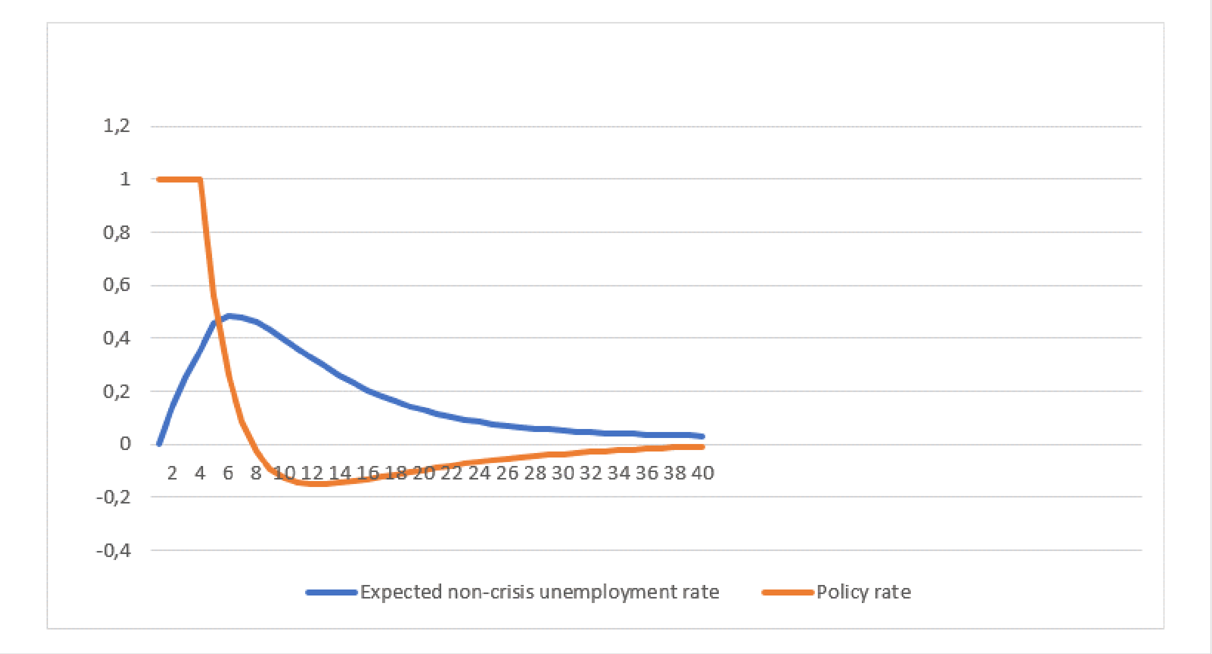


Figure 9: The effect of the policy rate on the expected non-crisis unemployment rate, according to Ekholm (2013). Measured in percentage points.

The blue line in Figure 9 shows the expected dynamics of the non-crisis unemployment rate. It increases gradually up to 0.48 percentage points in quarter 6, before falling slowly towards the baseline. If one assumes approximate linearity, this can be interpreted as the derivative of the expected non-crisis unemployment rate with respect to the policy rate.

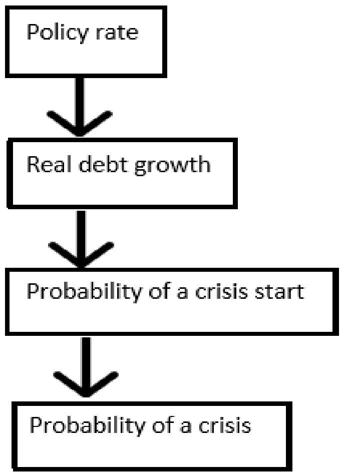
(1.5)

$$\frac{dE_1 u_t^n}{di_1} = \frac{\Delta E_1 u_t^n}{\Delta i_1} \ for \ t \geq 1$$

This is the first term of (1.4).

The effect of the policy rate on the probability of a financial crisis

I assume that the policy rate affects the probability of a crisis through its effect on real debt growth. The dynamics can be represented through the following figure:



The effect of the policy rate on real debt growth

The first link, between the policy rate and real debt growth, is given by Sveriges Riksbank (2014), who estimated how an increase in the repo rate affects the real debt ratio of households.[18] A 1 percentage point increase in the repo rate over 4 quarters reduces households' real debt.

The effect of real debt growth on the probability of whether a crisis will begin

I used my empirical results from the first part of the analysis to create a new equation that shows the quarterly relationship,

$$q_t = \frac{1}{4} * \frac{\exp(Xt)}{1 + \exp(Xt)},$$

Where

(1.6) $Xt = -4.85 + 3.786g_{t-4} + 12.81g_{t-8} + 6.637g_{t-12} + 3.664g_{t-16} + 1.92g_{t-20}$

(1.7) $g_t \equiv (\sum_{\tau=0}^{3} d_{t-\tau}/4)/(\sum_{\tau=0}^{3} d_{t-4-\tau}/4) - 1$

d_t is the level of real debt in quarter t.

[18] Svensson utilizes the results from Schularick and Taylor (2012) to find a reasonable estimate for the effect of credit growth on the probability of a crisis. Their estimate is calculated using data for households and non-financial corporations. In Sveriges Riksbank (2014), they only report the effect on household debt from an increased repo rate. In the second part of this analysis, the impulse response from Norges Bank's DSGE model will contain effects on both households and non-financial corporations.

To find the probability of whether a crisis will begin using our logit model, we will look at the logistic function

$$z = \frac{\exp(a + bg)}{1 + \exp(a + bg)} = \frac{1}{1 + \exp[-(a + bg)]}$$

where *z* is the annualized probability of a crisis beginning and *g* is the growth rate of real debt. The constants are a and b. In my logit specification, b is the sum of the coefficients.
The marginal effect of real debt growth on the probability of a crisis beginning can be found as the derivative of *z* with respect to *g*,

$$\frac{dz}{dg} = bz(1 - z)$$

This is the sum of the marginal effects in the baseline logit model from Table 4. From the table, this derivative has a value of 0.47. The sum of the coefficients can be calculated using the Xt equation above, which in this case is 21.49. This means that z = 0.0223, and the constant probability of a crisis beginning in a given quarter equals 2.23/4 = 0.557 percentage points. I will use this result later in my analysis.

If we consider a real debt growth of 0.05, we can solve for *a* using the logistic function:

$$0.0223 = \frac{1}{e^{-(a+0.05*21.49)}}$$

This means that a = -4.85.

Figure 10 shows the effect of a 1 percentage point higher policy rate during quarters 1-4 on real debt, real debt growth, the probability of a crisis beginning, and the probability of being in a crisis.

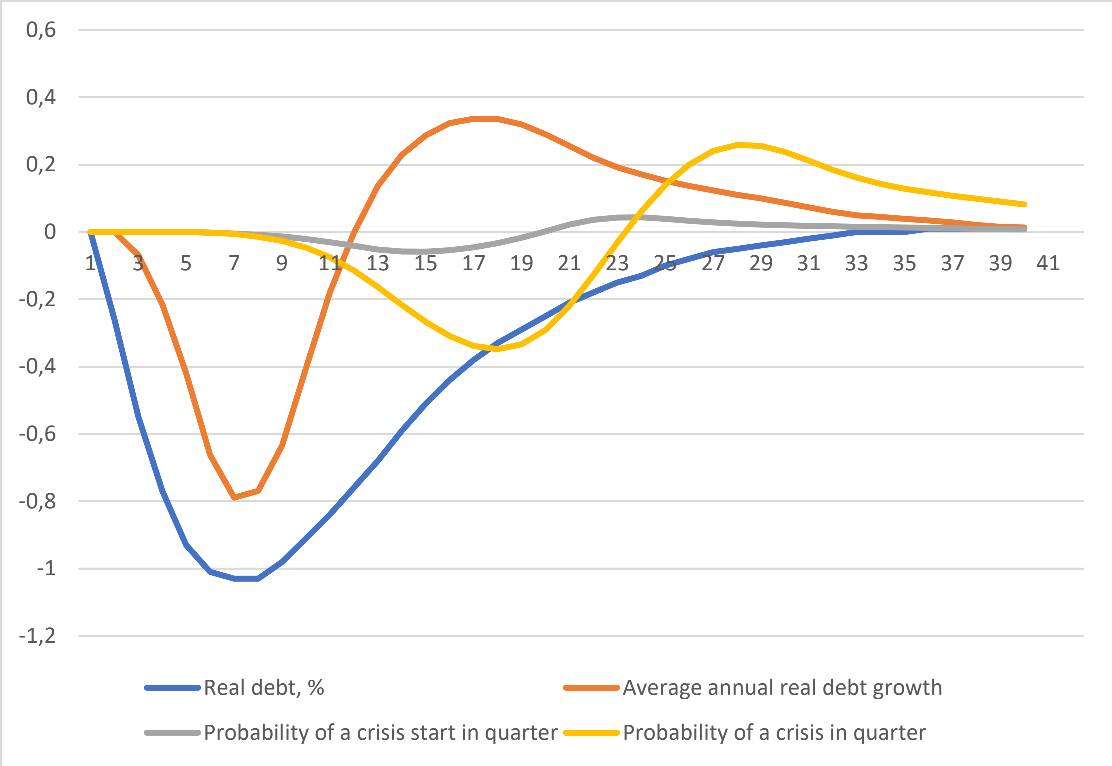


Figure 10: The effect of a 1 percentage point higher policy rate during quarters 1-4 on real debt, real debt growth, the probability of a crisis beginning, and the probability of being in a crisis. Measured in percentage points.

The blue line in figure 10 displays the effect from Sveriges Riksbank (2014). It can be interpreted as the derivative of real debt with respect to the policy rate for $t \geq 1$. Following the impulse response, the real debt is reduced by 1.03 percentage points in quarters 7 and 8. Because of the neutrality of money, real-debt returns to its long-run level after 32 quarters (8 years).

The orange line shows the effect on the average annual growth rate of real debt, defined by (1.7). It can be interpreted as the derivative of the annual real debt growth with respect to the policy rate. At first, it falls 0.8 percentage points in quarter 8. Because the real debt level converges to the baseline level, the corresponding growth rate becomes positive, peaking at 0.34 percentage points above normal level in quarters 17-18. It is important to note that the accumulated effect on the average annual real debt growth over the 40 quarters is 0.042 percentage points (barely noticeable).

$$\sum_{t=1}^{40} \frac{dg_t}{di_1} \approx 0$$

The gray line shows the dynamics of q_t, the probability of a crisis beginning for each quarter, resulting from (1.6). It can be interpreted as the derivative of the probability of a crisis beginning with respect to the policy rate. Because credit growth initially falls, the probability of a crisis beginning will decrease. This is a direct result from the logit regression. The 2-year lagged credit growth has a large negative sign, and will therefore lead to a decrease in the probability of a crisis beginning following the reduction in credit growth. The probability of a crisis beginning falls to 0.06 percentage points in quarters 14 and 15. Because average annual real debt growth moves above the baseline in quarter 12, the probability of a crisis beginning rises above the baseline. It has a positive peak of 0.04 percentage points in quarter 22. The accumulated effect over time on the probability of a crisis beginning is 0.002. This means that increasing the policy rate actually increases the probability of a crisis beginning over time, but by an amount insignificantly different from zero:

$$\sum_{t=1}^{40} \frac{dq_t}{di_1} \approx 0.$$

The dynamics of the probability of a crisis, p_t, is shown by the yellow line. It is defined by (1.2), and can be interpreted as the derivative of the probability of a crisis with respect to the policy rate. As mentioned, the duration of a crisis is 8 quarters, and the probability of a crisis is shown by the 8-quarter moving sum of the gray line. Based on the movements in q_t, the economy faces a reduced probability of being in a financial crisis after 2.5 years, but this is accompanied by an increased probability about 1.5 years later. It has a negative peak of -0.34 percentage points in quarter 18 and a positive peak of 0.25 percentage points in quarter 28. More importantly, the accumulated effect over the entire period is close to 0.

$$\sum_{t=1}^{40} \frac{dp_t}{di_1} \approx 0$$

The effect of the policy rate on the expected future unemployment rate

As mentioned, we assume a 5 percent increase in the unemployment rate following a crisis. Given the effect of the policy rate on the non-crisis unemployment rate and the probability of a crisis, we can find the total effect of the increased policy rate on the expected future unemployment rate. This is illustrated in Figure 11.

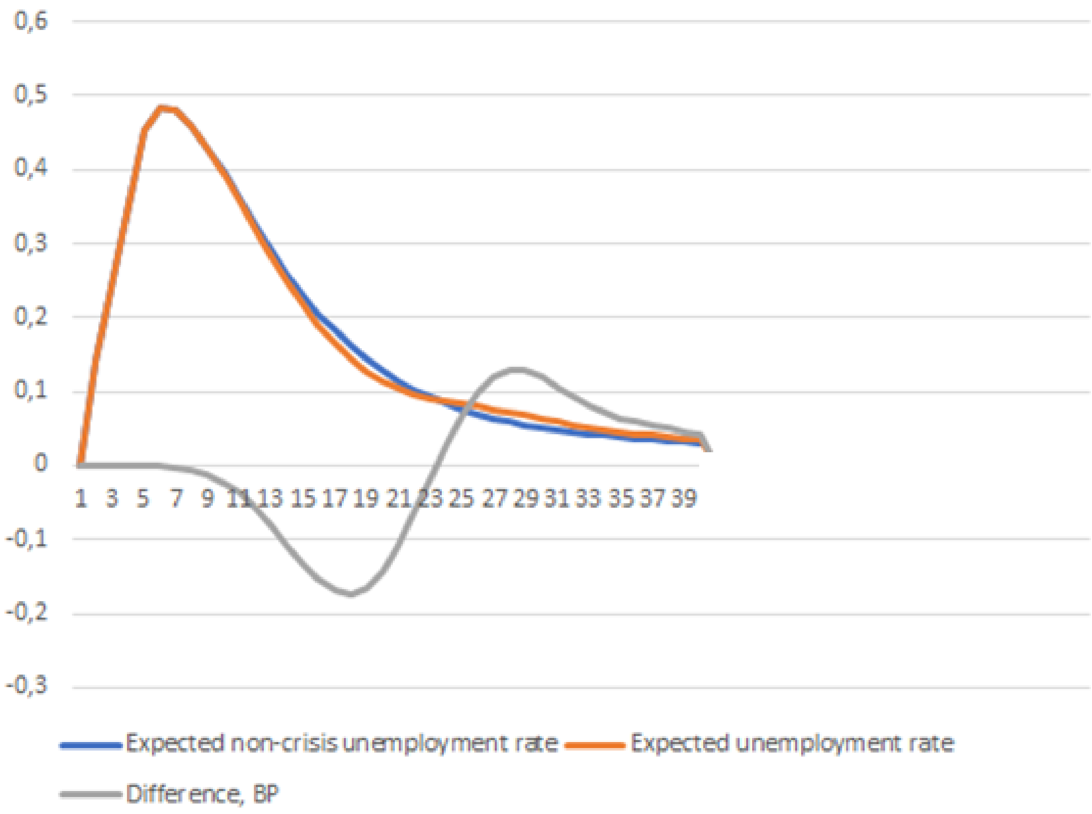


Figure 11: The effect of a 1 percentage point higher policy rate during quarters 1-4 on the expected unemployment rate and the expected non-crisis unemployment rate. Measured in percentage points.

The blue line is the effect of the policy rate on the non-crisis unemployment rate (from figure 9). The orange line includes the fact that a financial crisis affects the expected unemployment rate. This is calculated as the last term on the right side of (1.4),

$$\Delta u \frac{dp_t}{di_1}$$

This term is very small compared to the effect on $E_1 u_t^n$, which is shown by the first term on the right side of (1.4),

$$\frac{dE_1 u_t^n}{di_1}$$

Because of this, the blue and the orange lines coincide almost perfectly. The gray line displays the difference that accounting for a possible financial crisis has on the expected unemployment rate. The difference is measured in basis points, and has a negative peak after

4.5 years: $\frac{dp_{18}}{di_1} = -0.34$ percentage points in quarter 18, resulting in

$\Delta u \frac{dp_t}{di_1} = 5 * (-0.34) = -0.017\, percentage\ points = -1.7\, basis\ point.$

Compared to the blue line in quarter 18, which measures 16 basis points (0.16 percentage points), the effect of accounting for a possible financial crisis is small.

More importantly, the cumulated difference in the expected non-crisis unemployment rate and the expected unemployment rate over 40 quarters is approximately -1 basis point, meaning that

$$\Delta u \sum_{t=1}^{40} \frac{dp_t}{di_1} \approx 0$$

Which furthermore implies that

$$\sum_{t=1}^{40} \frac{dE_1 u_t}{di_1} = \sum_{t=1}^{40} \frac{dE_1 u_t^n}{di_1} + \Delta u \sum_{t=1}^{40} \frac{dp_t}{di_1} \approx \sum_{t=1}^{40} \frac{dE_1 u_t^n}{di_1}$$

To interpret the total picture, we can say that the effect of the policy rate on $E_1 u_t$ is approximately equal to its effect on $E_1 u_t^n$, the non-crisis unemployment rate. However, the effect on the unemployment rate is not sufficient to assess the net cost of such a policy, because it has possible welfare-enhancing effects as well. I will examine this in the following section.

Evaluating Leaning Against the Wind Using a Quadratic Loss Function

The following definitions will be used extensively:

(2.1) $u_t^{\sim} \equiv u_t - u_t^*$: The unemployment gap, defined as the gap between the optimal unemployment rate under flexible inflation targeting (when disregarding a possible crisis) and the current unemployment rate.

(2.2) $u_t^{\sim n} \equiv u_t^n - u_t^*$: The unemployment gap under the policy of leaning in non-crisis times.

(2.3) $u_t^{\sim c} \equiv u_t^c - u_t^*$: The unemployment gap under the policy of leaning in crisis times.

We begin by introducing a quadratic loss function containing only unemployment.

The expected intertemporal welfare loss is defined as

$$E_1 \sum_{t=1}^{\infty} \delta^{t-1} L_t = \sum_{t=1}^{\infty} \delta^{t-1} E_1 L_t$$

δ is a discount factor, satisfying $0 < \delta < 1$

The quarter *t* loss function is

$$L_t = (u_t^{\sim})^2$$

The quarter *t* expected loss, $E_1 L_t$ can be written as

$$E_1 L_t = E_1(u_t^{\sim})^2 = (1 - p_t^{-})(E_1 u_t^{\sim n})^2 + p_t^{-}(E_1 u_t^{\sim n} + \Delta u)^2$$

This implicitly tells us, that if the economy is operating on a non-crisis unemployment rate different from zero, this inflicts a loss. When the central bank increases the policy rate, we saw that unemployment deviated from this level, and hence, a loss occurs.

We first consider an initial situation without a crisis in the first quarter, where the expected future non-crisis unemployment gaps are zero:

(2.4) $E_1 u_t^{\sim n} = 0 \; for \; t \geq 1$

The expected quarter *t* loss when the possibility of a financial crisis is accounted for can be expressed as the difference between the costs and benefits of deviating from the zero-unemployment gap:

$Quarter \; t \; loss = Ct - Bt$, where

(2.5) $C_t \equiv (1 - p_t^{-})(E_1 u_t^{\sim n})^2 + p_t^{-}(E_1 u_t^{\sim n} + \Delta u)^2 \equiv C_t^n + C_t^c$

(2.6) $B_t \equiv (p_t^{-} - p_t)[(\Delta u)^2 + 2\Delta u E_1 u_t^{\sim n}]$

For a step-by-step mathematical derivation, see Appendix A.

p_t^{-} is defined as the benchmark probability of a crisis in quarter *t*, which is conditional on the initial situation. This makes $(p_t^{-} - p_t)$ the possible reduction in the probability of a crisis from the benchmark probability.

The benchmark probability of a crisis

The sum of coefficients in (1.6) and the marginal effects of 0.47 implies an annual probability of a crisis beginning as equal to 2.23 percent, or a quarterly probability of 2.23/4 = 0.557 percent. This is the benchmark probability of a crisis beginning.

Assuming that there is no financial crisis in the first quarter, I used (1.2) to find the benchmark probability of a crisis in quarter *t*,

(2.7)

$$p_t^- = \begin{cases} 0 & \text{for } t = 1 \\ (t-1)q & \text{for } 2 \le t \le n \\ nq & \text{for } t \ge n+1 \end{cases}$$

On the condition that the economy is not in a crisis state in quarter 1, for a given *q* and *n* (8 years), I followed (1.2) to find the probability of a crisis in quarter *t*. The blue solid line in Figure 12 shows how the probability rises linearly up to its steady state value in quarter 9, where it stays at 4.45 percent.

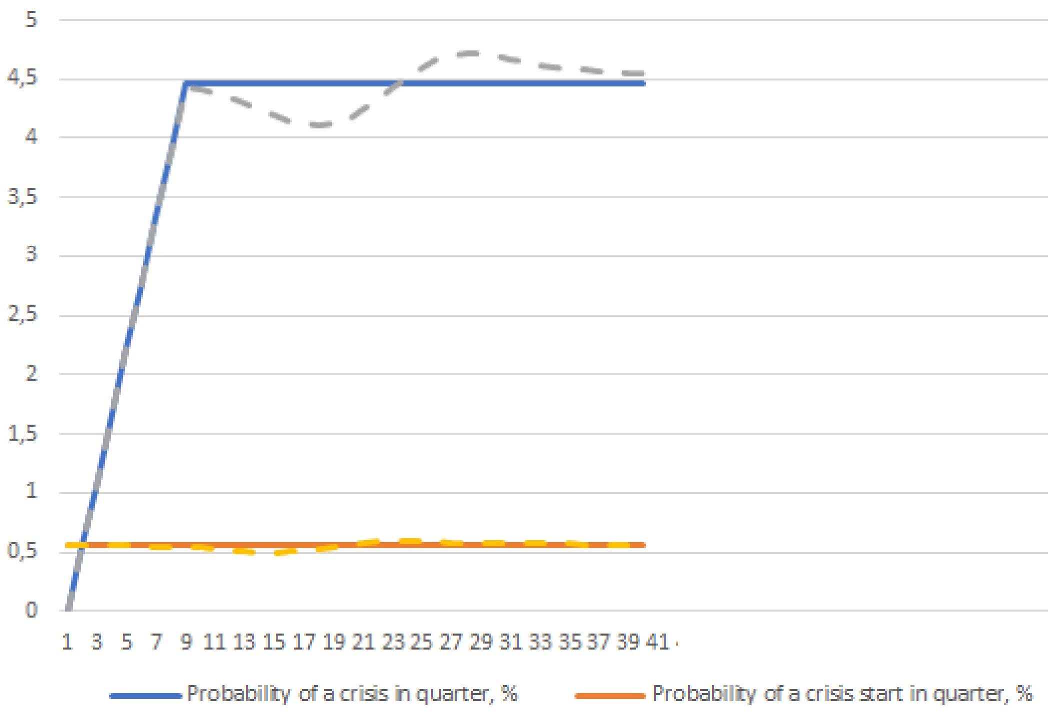


Figure 12: The probability of a crisis beginning and of a crisis for the benchmark (solid lines) and for a 1 percentage point higher policy rate during quarters 1-4 (dashed), conditional on no crisis occurring in quarter 1. Measured in percentage points.

The dotted gray line shows the following dynamics that result from a 1 percentage point higher policy rate throughout quarters 1-4. The increased policy rate reduces the probability of a crisis at first, down to 4.11 percent in quarter 18. Because credit growth eventually becomes positive, the probability peaks above the baseline up to 4.71 percent after 7 years. More importantly, the total effect is approximately zero for the 40 quarters.

A thought that naturally emerges so far is that if leaning inflicts losses on the economy through increased unemployment and has such a small effect on the probability of a crisis, how can the benefits outweigh the costs? In the following section, I will examine the costs and benefits of leaning separately.

The cost of deviating from a zero expected non-crisis unemployment gap

I begin by considering the cost, assuming that the probability of a crisis rests at the steady-state level, $p_t^- = p = 4.55$ percent.

At this point, the cost C_t is given by (2.5)

The blue line in Figure 13 shows how the probability-weighted non-crisis expected loss changes with deviations in $E_1 u_t^{\sim n}$,

$C_t^n = (1 - p_t^-)(E_1 u_t^{\sim n})^2 = 0.95544(E_1 u_t^{\sim n})^2$

The line has a minimum when the expected non-crisis unemployment gap is zero. Thus, if we neglect the probability of a crisis, the optimal policy is to set $E_1 u_t^{\sim n}$ equal to 0. In other words, sticking to inflation targeting and disregarding financial stability minimizes the cost.

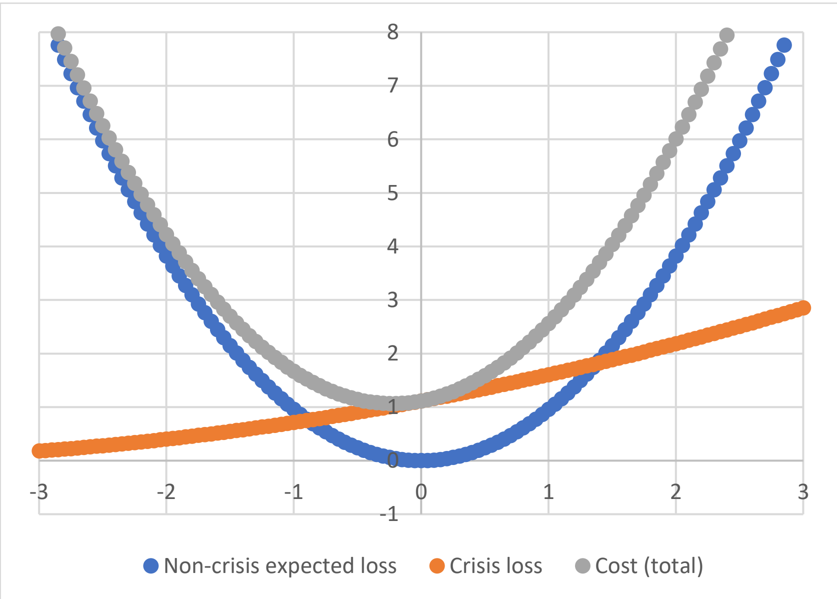


Figure 13: The probability-weighted quadratic expected non-crisis loss, expected crisis loss, and total cost as a function of the expected non-crisis unemployment gap.

The gray line shows the increased (added) loss when we account for the probability of a crisis.

$C_t^c = p_t^-(E_1 u_t^{\sim n} + \Delta u)^2 = 0.4456 * \ (E_1 u_t^{\sim n} + 5)^2$

For $E_1 u_t^{\sim n}$ = 0, the corresponding loss is 1.114. The loss has a minimum (zero) for an expected non-crisis unemployment gap of -5 percentage points.

The gray line shows the total cost of deviating from a zero expected non-crisis unemployment gap. It is the vertical sum of C_t^c and C_t^n.

The minimum value for the gray line is found at the point where the marginal cost equals 0. I can calculate the marginal cost by taking the derivative of the total cost, with respect to the non-crisis unemployment rate,

$$\frac{dC_t}{dE_1 u_t^{\sim n}} = \frac{d[(1-p_t^-)(E_1 u_t^{\sim n})^2] + [p_t^-(E_1 u_t^{\sim n}+\Delta u)^2]}{dE_1 u_t^{\sim n}} = 2 * (E_1 u_t^{\sim n} + p_t^- \Delta u)$$

$$= 2 * (E_1 u_t^{\sim n} + 0.2228)$$

The marginal cost of increasing the expected non-crisis unemployment rate (or the non-crisis loss that follows) is zero for $E_1 u_t^{\sim n} = -0.228$ percentage point. In this case, the total cost is 1.065.

When assessing only the cost of leaning, under the assumption that the probability of a crisis is zero, the optimal policy is to set $E_1 u_t^{\sim n}$ equal to 0. This is an intuitive result, because the benefit of leaning stems from the reduced probability of a crisis. Thus, if there is no crisis, the argument for leaning disappears. If we account for the fact that a financial crisis has a positive probability, it is optimal to reduce $E_1 u_t^{\sim n}$ to -0.228 percentage points below zero. This indicates that regarding costs, the best policy for the central bank is to slightly lower their policy rate, or lean *with* the wind.

The benefits of leaning against the wind

The benefits of leaning account for the fact that the increased policy rate might change the probability of a crisis. Increasing the rate will increase $E_1 u_t^{\sim n}$, together with reducing the probability of a financial crisis. The crisis-probability can thus be viewed as an implicit function of $E_1 u_t^{\sim n}$, $p_t = p_t(E_1 u_t^{\sim n})$, with the linear approximation

(2.8) $p_t(E_1 u_t^{\sim n})$ - $p_t^- = \frac{dp_t}{E_1 u_t^{\sim n}} * E_1 u_t^{\sim n}$, for t ≥ 1

Where $p_t(0) = \ p_t^-$ and the implicit derivative $\frac{dp_t}{E_1 u_t^{\sim n}}$ is given by

$$\frac{dp_t}{dE_1 u_t^{\sim n}} \equiv \frac{dp_t \big/ di_1}{dE_1 u_t^{\sim n} \big/ di_1}$$

Because of the result in (2.8), we can rewrite the benefit of deviating from a zero unemployment gap (2.6) as a function of $E_1 u_t^{\sim n}$, as

$$(2.9)\ B_t = [p_t^- - p_t(E_1 u_t^{\sim n})][(\Delta u)^2 + 2\Delta u E_1 u_t^{\sim n}] = -\frac{dp_t}{dE_1 u_t^{\sim n}} E_1 u_t^{\sim n}[(\Delta u)^2 + 2\Delta u E_1 u_t^{\sim n}]$$

I need to find a reasonable estimate for $\frac{dp_t}{dE_1 u_t^{\sim n}}$. I will follow Svensson (2016) and use the average of the derivatives $\frac{dE_1 u_t^{\sim n}}{di_1}$ and $\frac{dp_t}{di_1}$ from quarters 12 to 24. The numbers can be found from the calculation of Figures 9 and 10,[19] and my estimate is

$$\frac{dp_t}{dE_1 u_t^{\sim n}} = -0.0155$$

This will give the change in the unemployment rate a maximum (overestimated) effect on the probability of a crisis, which furthermore helps the argument for leaning. The average effect when considering all 40 quarters is lower than this estimate. Using this estimate instead would reduce the benefits of leaning.

[19] The blue line in Figure 9 shows $\frac{dE_1 u_t^{\sim n}}{di_1}$, and the yellow line in Figure 10 shows $\frac{dp_t}{di_1}$.

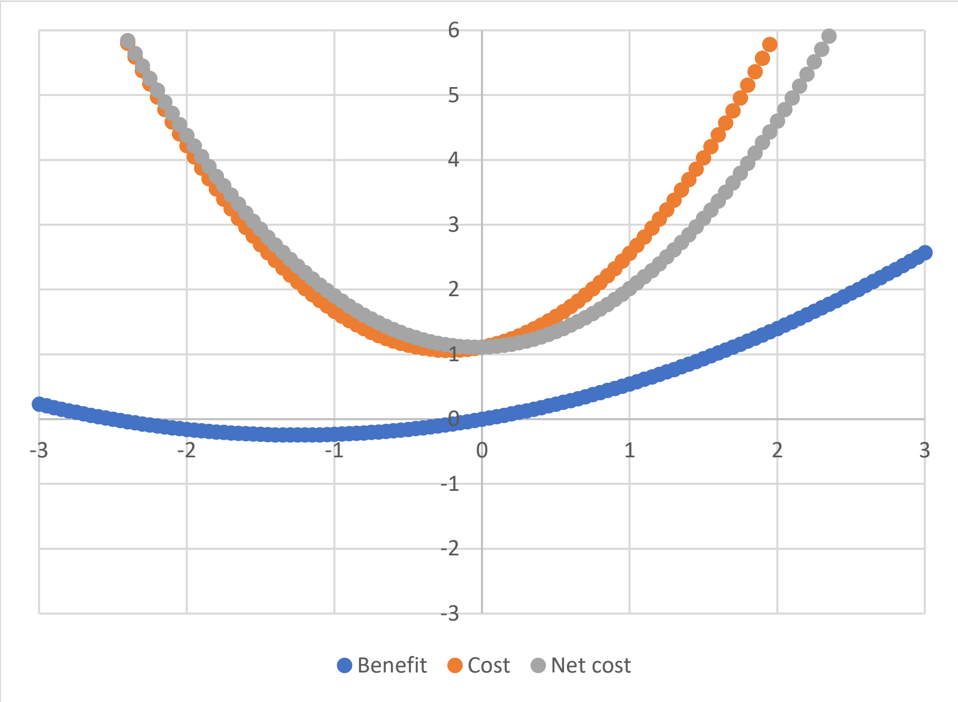


Figure 14: The probability-weighted quadratic cost, benefit, and net cost, as a function of the expected non-crisis unemployment gap.

The blue line shows the benefits of deviating from the starting point where $E_1 u_t^{\sim n}$ equals zero, given by (2.9)

$$B_t = 0.0156 * E_1 u_t^{\sim n}(25 + 10 * E_1 u_t^{\sim n})$$

When $E_1 u_t^{\sim n} = 0$, the benefits are also zero. Obviously, when there is no leaning, there are also no possible benefits. For my estimate of $\frac{dp_t}{dE_1 u_t^{\sim n}}$, the benefits are convex and increasing from $E_1 u_t^{\sim n} \geq -1{,}25$.

We see that for high values of the non-crisis expected unemployment gap the benefits are high. Unfortunately, this occurs for values where the costs outweigh the benefits. The orange line is the cost from Figure 13.

The most interesting part of this figure is the net cost, shown by the gray line. It is calculated by simply subtracting the benefits from the costs. It has a minimum for $E_1 u_t^{\sim n} = -0.05$. Here, the net cost is 1.113. The optimal policy is still to lean with the wind, but because we have accounted for the possible benefits, the optimal degree of leaning is less than in the previous part. For a sufficiently strong effect of the policy rate on the probability of a crisis, the curve for the net cost might have shifted so far to the right that the argument for leaning would have strengthened.

I can calculate the net marginal cost by taking the derivative of the net cost with respect to the non-crisis unemployment rate.

We calculated the marginal cost in the previous part,

$$MC_t = 2 * (E_1 u_t^{\sim n} + 0.2228)$$

The marginal benefit is found in a similar way, by taking the derivative of (2.9) with respect to the non-crisis unemployment gap,

$$\frac{dB_t}{dE_1 u_t^{\sim n}} = -\frac{dp_t}{dE_1 u_t^{\sim n}}[(\Delta u)^2 + 4\Delta u E_1 u_t^{\sim n}] = 0.0156(25 + 20 * E_1 u_t^{\sim n})$$

$$NMC_t = 2 * (E_1 u_t^{\sim n} + 0.2228) - [0.0156(25 + 20 * E_1 u_t^{\sim n})]$$

The net marginal cost for $E_1 u_t^{\sim n} = 0$ is 0.056, which indicates that when the non-crisis unemployment gap is zero, the marginal costs of Leaning Against the Wind exceed the marginal benefits. The effect of the policy rate on the probability of a crisis is not strong enough to justify any leaning.

The alternative assumption of a fixed loss level in a crisis

The framework of Svensson (2016) initially assumes that if the economy is weak when a financial crisis occurs, it is costlier for the economy. The dynamics of (1.1) provides the framework with the following assumption,

(1.1 revisited) $u_t^c = u_t^n + \Delta u > u_t^c$

The expectations of the crisis unemployment gap, $E_1 u_t^c$, has a higher value if u_t^n is higher.

$$E_1 u_t^c = E_1 u_t^n + \Delta u$$

I will now consider the results if the economy reaches a fixed unemployment gap following a crisis, no matter what the expectations are for the non-crisis unemployment gap. This furthermore means that the loss from a financial crisis is fixed and independent of the unemployment gap before the crisis occurs. This is not realistic in the real world – if the economy starts out with a 6% non-crisis unemployment gap, and the fixed loss level is 5%, this would yield the strange outcome that it would be better to have a financial crisis than to avoid it. However, some papers do consider this fixed loss level when evaluating the consequences of a financial crisis, such as Diaz Kalan, Lasèen, Vestin, and Zdzienicka (2015).

Here, the expected loss in quarter *t* can be written as

$$Expected\ quarter\ t\ loss = C_t - B_t$$

Where

(2.10) $C_t \equiv (1 - p_t^-)(\, E_1 u_t^{\sim n})^2 + p_t^-(\Delta u)^2$

(2.11) $B_t \equiv (p_t^- - p_t)[(\Delta u)^2 + (E_1 u_t^{\sim n})^2]$

For a derivation of these expressions, see Appendix B.

Figure 15 shows the resulting dynamics.

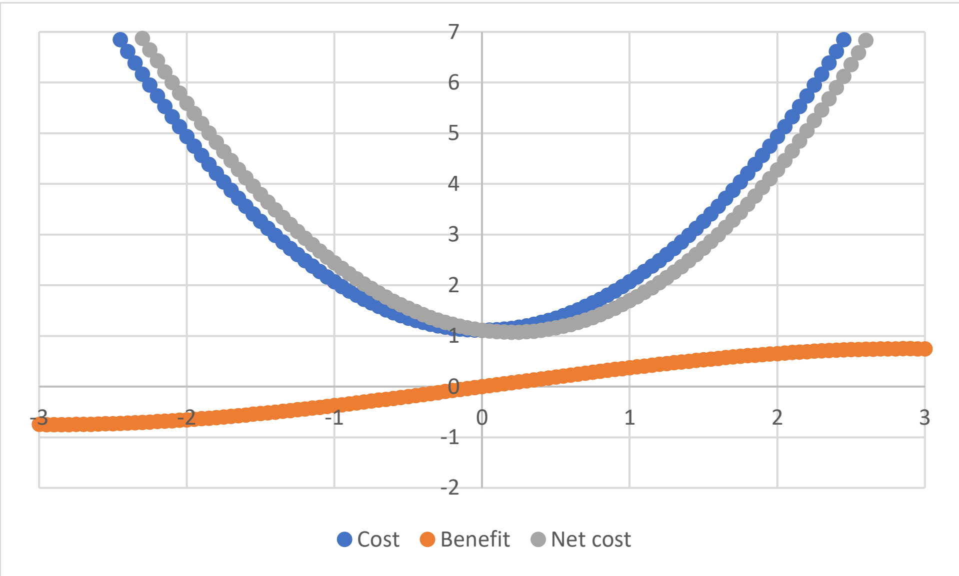


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Figure 15: The cost, benefit, and net cost, as a function of the expected non-crisis unemployment gap for a fixed loss level in a crisis.

The blue line shows the cost,

(2.12) $C_t = 0.95544 * (E_1 u_t^{\sim n})^2 + 1.114$

The cost has a minimum for $E_1 u_t^{\sim n} = 0$. At this point, the cost is 1.114. Because we have assumed that the crisis loss doesn't depend on the initial state, and therefore not on $E_1 u_t^{\sim n}$, the positive constant probability of a crisis doesn't induce any leaning.

The orange line shows the benefit,

(2.14) $B_t = 0.389 E_1 u_t^{\sim n} - 0.0156(E_1 u_t^{\sim n})^3$

The gray line shows the net cost. The net cost has a minimum for $E_1 u_t^{\sim n} = 0.2$. At this point, the cost is 1.074. This means that, using a fixed loss level, Leaning Against the Wind might be justified. However, the net gain from Leaning Against the Wind compared to $E_1 u_t^{\sim n} = 0$ is

0.04, which is nearly insignificant. Keep in mind that in this chapter we have assumed that monetary policy has an exaggerated effect on the probability of a crisis, and that the effect of a financial crisis does not depend on the initial state of the economy. These are both somewhat unrealistic assumptions. As mentioned in Svensson (2016), taking these assumptions into account might provide some insight into why some papers report evidence in favor of Leaning Against the Wind (such as Ajello, Laubach, Lopez-Salido, and Nakata (2015), and Diaz et al. (2015)), and some papers don't – the fixed loss level seems to be of crucial importance.

The Marginal Cost, Marginal Benefit, and Net Marginal Cost of Leaning Against the Wind

I return to assuming that if the economy is weaker, a financial crisis will have greater costs. When leaning, the increased policy rate in the first 4 quarters will change the expected unemployment gaps and crisis probabilities in all quarters. Therefore, we need to look at the costs and benefits in all 40 quarters.

I begin with the scenario where $E_1 \tilde{u_t^n}$ is 0 for all quarters to see how the intertemporal loss function is increased or decreased in response to an increase in the policy rate. Compared with the baseline unemployment rate from a flexible inflation targeting regime, increasing the policy rate can only be justified if the derivative of the intertemporal loss function with respect to the policy rate is negative. A positive value would suggest leaning with the wind, not against.

Recall that,

$$E_1 \sum_{t=1}^{\infty} \delta^{t-1} L_t = \sum_{t=1}^{\infty} \delta^{t-1} E_1 L_t$$

Which means that

$$\frac{d}{di_1} E_1 \sum_{t=1}^{\infty} \delta^{t-1} L_t = \sum_{t=1}^{\infty} \delta^{t-1} \frac{dE_1 L_t}{di_1}$$

I use the expression for the expected loss in quarter *t*, and find the derivative with respect to the policy rate, (3.1) $E_1 L_t = E_1(\tilde{u_t})^2 = (1-p_t)(E_1 u_t^{\sim n})^2 + p_t E_1(u_t^{\sim n} + \Delta u)^2$

(3.2) $\frac{dE_1 L_t}{di_1} = 2((E_1 u_t^{\sim n} + p_t \Delta u)\frac{dE_1 u_t^n}{di_1} - [(\Delta u)^2 + 2\Delta u E_1 u_t^{\sim n}](-\frac{dp_t}{di_1})$

This can be interpreted as expected marginal loss for a given quarter due to an increase in the policy rate. The first term on the right side can be interpreted as the marginal cost in quarter *t*, denoted as MC_t. The second term can be interpreted as the marginal benefit in quarter *t*, MB_t.

(3.3) $MC_t = 2((E_1 u_t^{\sim n} + p_t \Delta u)\frac{dE_1 u_t^n}{di_1}$

(3.4) $MB_t = [(\Delta u)^2 + 2\Delta u E_1 u_t^{\sim n}](-\frac{dp_t}{di_1})$

If $E_1 u_t^{\sim n}$ is zero, these two equations can be reduced to (3.5) and (3.6)

(3.5) $MC_t = 2(p_t \Delta u)\frac{dE_1 u_t^n}{di_1}$

This equation illustrates the loss from an increase in the policy rate. The increase in the policy rate exacts an extra cost, since the economy experiences a higher non-crisis and crisis unemployment rate. This reflects the fact that initial conditions matter when the economy suffers from a financial crisis.

(3.6) $MB_t = (\Delta u)^2(-\frac{dp_t}{di_1})$

Because of the positive values of the probability of a crisis, the increased unemployment rate following a crisis, and the derivative of the unemployment rate with the respect to the policy rate, we can easily see that the marginal cost will have a positive sign for all quarters. This makes the sign and magnitude of $\frac{dp_t}{di_1}$ crucial in deciding whether the benefits of leaning might outweigh the costs.

Figure 16 shows the marginal cost, marginal benefit, and net marginal cost of Leaning Against the Wind when the expected non-crisis unemployment rate equals zero.

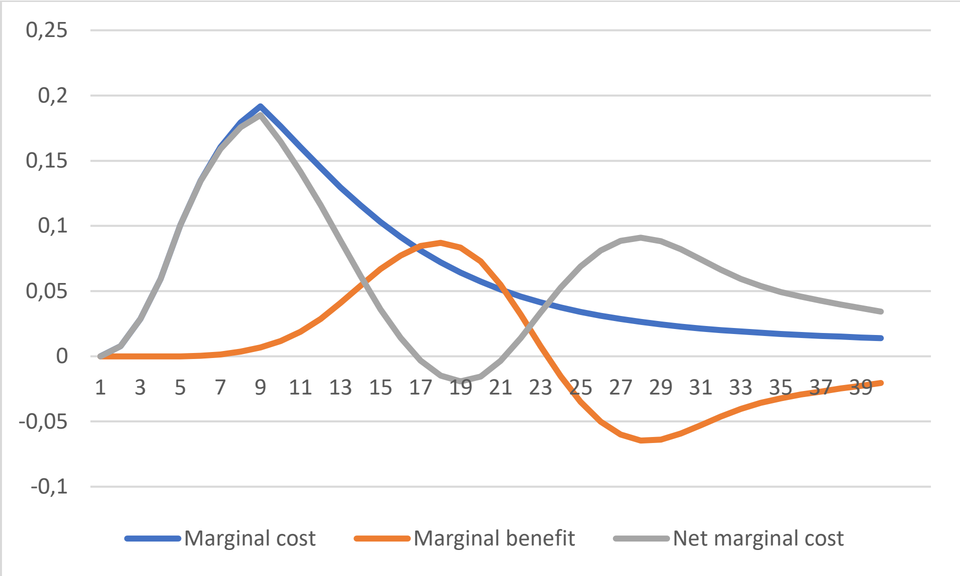

Figure 16: The marginal cost, the marginal benefit, and the net marginal cost of LAW when the expected non-crisis unemployment gap equals zero. Measured in percentage points.

The blue line shows the marginal cost for each quarter, according to (3.5). Because the probability of a crisis, p_t, is constant after quarter 9, it is proportional to the red line in Figure 9. The gradual increase in p_t from quarters 1-8 makes the marginal cost peak later than $\frac{dE_1 u_t^n}{di_1}$.

The orange line shows the marginal benefit from (3.6). It is proportional to the green line in Figure 10. The benefit has a positive peak in quarter 18.

The gray line shows the net marginal cost for a zero non-crisis unemployment gap over the 40 quarters considered. The accumulated sum is strictly positive, which means that the costs of Leaning Against the Wind outweigh the benefits. This means that increasing the policy rate will increase the intertemporal expected loss. The optimal policy is to lean with the wind, not against, when using the model from the Swedish central bank and the empirical results from the logit model based on the Scandinavian countries.

The next figure shows the cumulative effects of Leaning Against the Wind throughout the 40 quarters, based on the calculations from Figure 16. The net cumulative marginal cost has a slight drop, because the net marginal cost becomes negative in quarters 17-21. This is the only period where the costs are outweighed by the benefits, using our assumptions of a zero non-crisis unemployment gap.

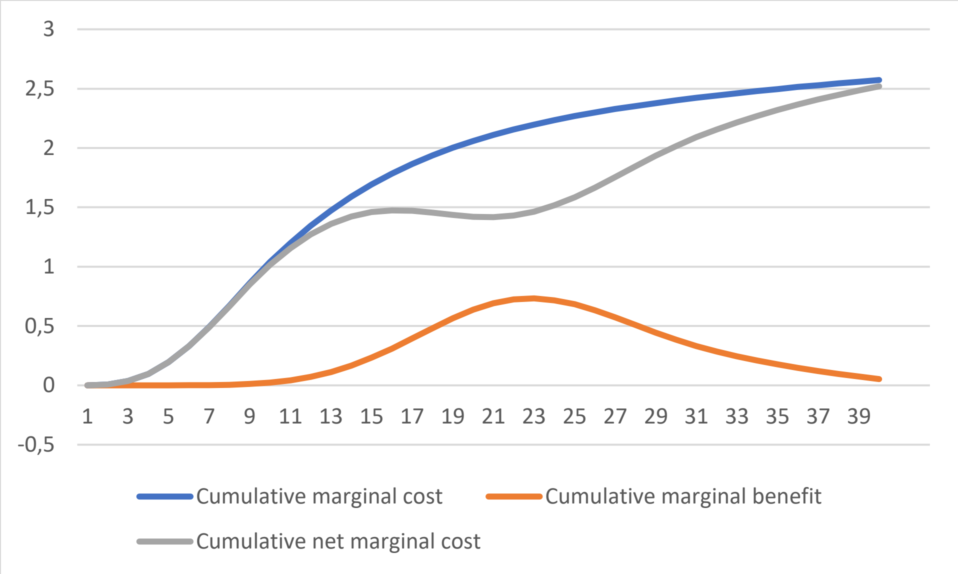

Figure 17: The cumulative marginal cost, marginal benefit, and the net marginal cost of LAW when the expected non-crisis unemployment gap equals zero. Measured in percentage points.

Concluding Remarks

An increase in the policy rate has a small effect on the probability of a crisis beginning, and consequently also on the probability of a financial crisis. This is affected both by the connections between the policy rate and credit (calculated from the DSGE model) and between credit and the likelihood of a financial crisis, as estimated in the logit model from part 6. The probability of a crisis falls in the medium run, between 2 and approximately 5 years from the initial interest rate hike. However, because credit growth rises above the baseline after about 3 years, this probability of a crisis moves above the baseline from quarter 20 and onwards. This makes the overall effect on the probability of a financial crisis approximately zero when taking the whole period into account. This significantly reduces the possible benefit from leaning.

By assessing the cost and benefit using this framework, it is clear that leaning provides the economy with a positive net loss. This is because it results in a positive unemployment gap for a long period, while at the same time having a very limited effect on the overall probability of a crisis. With the exception of 4 quarters in the medium run, the marginal cost is higher than the marginal benefit throughout the period. Leaning has not gained any support so far, and the results are very similar to the findings in Svensson (2016). If one assumes a fixed loss level in a crisis, the result indicates that some leaning might be justified, making this assumption crucial to the outcome.

The result so far is mainly relevant to the Swedish economy. I will now expand the analysis by investigating whether the same conclusion is applicable in Norway.

8. A Cost-Benefit Analysis with Norwegian Estimates

Using the same framework, it is possible to assess the effects of Leaning Against the Wind using a different impulse response. In the impulse response from RAMSES, the central bank increased the policy rate by 1 percentage point over quarters 1-4. In the impulse response from NEMO, the policy rate was increased up to 1 percentage point in quarter 2, before dipping below the baseline in quarter 6, and then rising back up over the following 34 quarters.

The model of the Norwegian central bank also calculates the resulting dynamics in credit and output. I will use these estimates to examine the costs and benefits of leaning, based on a model programmed to represent the dynamics in the Norwegian economy. To transform the response on the output gap to the unemployment gap, I will use an OKUN coefficient of -0.35. Figure 18 shows the movement in the (transformed) expected non-crisis unemployment rate following the increased policy rate.

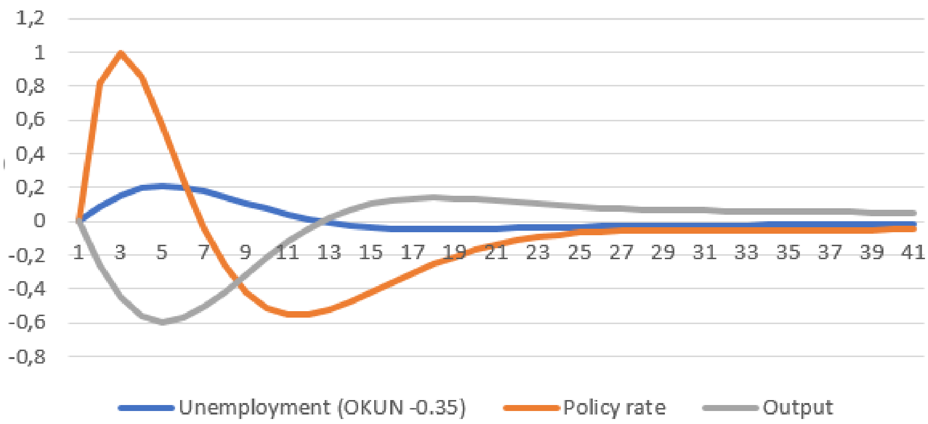

Figure 18: The effect of the policy rate on the expected non-crisis unemployment rate, according to Norges Bank. Numbers in percentage points.

The effect on unemployment differs from the Swedish model. Using the estimate from Norges Bank, unemployment rises by 0.2 percentage points, only half the corresponding value for Sweden. Some of this can be attributed to the fact that the average increase in the policy rate from quarters 1-4 is a little lower than in the Norwegian model.[20] However, it is still possible

[20] In the data from Norges Bank, the average annualized increase in the policy rate from quarters 1-4 is 0.8 percentage points. This weakens the direct comparison with Svensson (2016), but is still an interesting scenario.

to examine the cost and benefit from such a hike (some findings suggest that the kind of policy examined in Svensson (2016) is more than the average amount of leaning[21]). After crossing the baseline in quarter 13, it reaches negative 0.05 percentage point in quarter 18. Even though the effect is small, this could very well affect the net marginal cost of leaning, because the derivative of the unemployment rate with respect to the policy rate becomes negative after quarter 13. The effect is approximately zero after 6 years.

I use my results from the baseline logit regression together with the estimate from Norges Bank to calculate the effect that credit growth has on a financial crisis.

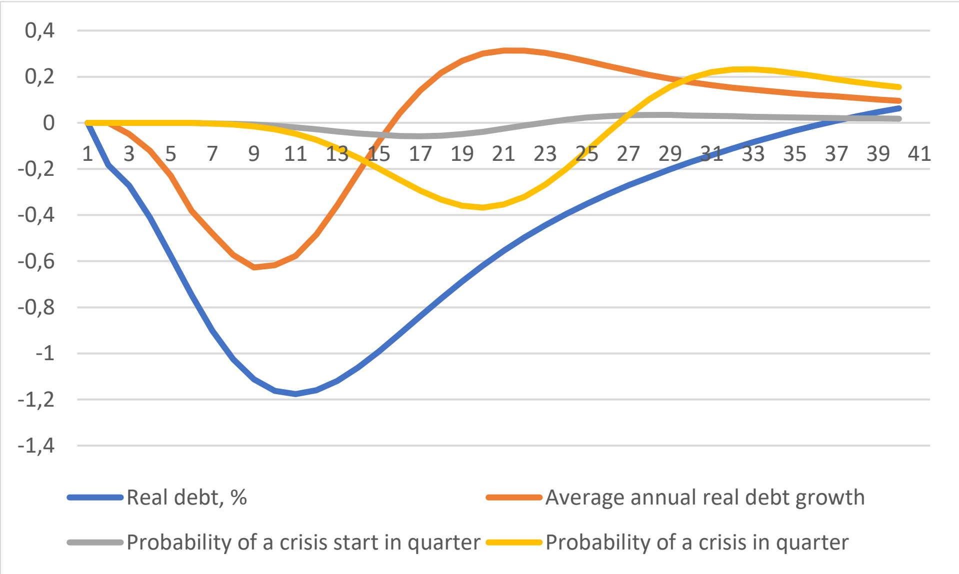

Figure 19: The effect of an increased policy rate on real debt, real debt growth, the probability of a crisis beginning, and the probability of being in a crisis.

The blue line in Figure 19 demonstrates how real debt reacts to the temporary increase in the policy rate. It drops until it reaches -1.18 percentage points in quarter 10. The red line displays the corresponding average annual real debt growth, peaking negatively at -0.63 percentage points in quarter 9, almost a year later than in Figure 10 (the corresponding figure with Swedish estimates). This makes the effects on the probability of a crisis and whether a crisis begins shift further in time. The gray line indicates that there is at best a 0.06 percentage point reduced probability for a crisis beginning after about 4 years. The yellow line shows that the increased policy rate provides the economy with a 0.37 percentage point increased probability of a crisis after 5 years. About 3 years later, it reaches a positive peak of 0.23 percentage

[21] See Friedrich, Hess & Cunningham (2015). A typical leaning-policy is on average 0.3 percentage point above what is needed to stabilize inflation and output.

points. The accumulated effect of the policy rate on the probability of a financial crisis over the 40 quarters is a still approximately zero.

The Effect on Expected Future Quadratic Losses of Leaning Against the Wind

I continue to use the assumption that the economy suffers a 5 percentage point increase in the unemployment rate following a financial crisis.

We look at the initial situation with an expected non-crisis unemployment gap equal to zero for all quarters, and examine how the increased policy rate affects the intertemporal loss, taking all future quarters into account. I use the result that $\frac{dE_1 u_t^n}{di_1} \approx 0$ in quarters 25-40. In the Swedish model, we knew with certainty that the marginal cost of leaning would be positive for all quarters, because of how the unemployment rate responded to the policy rate shock. In the Norwegian model, this effect becomes slightly negative after 3 years. This is a quite common phenomenon in DSGE models, and it makes the marginal cost of leaning negative for a distinct period. The total effect on the expected loss on welfare is no longer as heavily determined by the value and sign in front of $\frac{dp_t}{di_1}$. We revisited (3.2) to improve our intuition.

$$(3.2\ revisited) \frac{dE_1 L_t}{di_1} = 2((E_1 \tilde{u}_t^n + p_t \Delta u) \frac{dE_1 u_t^n}{di_1} - [(\Delta u)^2 + 2\Delta u E_1 \tilde{u}_t^n](-\frac{dp_t}{di_1})$$

To simplify, (3.2) can be rewritten as

$$NMC_t(E_1 \tilde{u}_t^n) = MC_t(E_1 \tilde{u}_t^n) - MB_t(E_1 \tilde{u}_t^n)$$

The marginal cost, the marginal benefit, and the net marginal cost of Leaning Against the Wind when it is assumed that the expected non-crisis unemployment gap equals zero is shown in Figure 20.

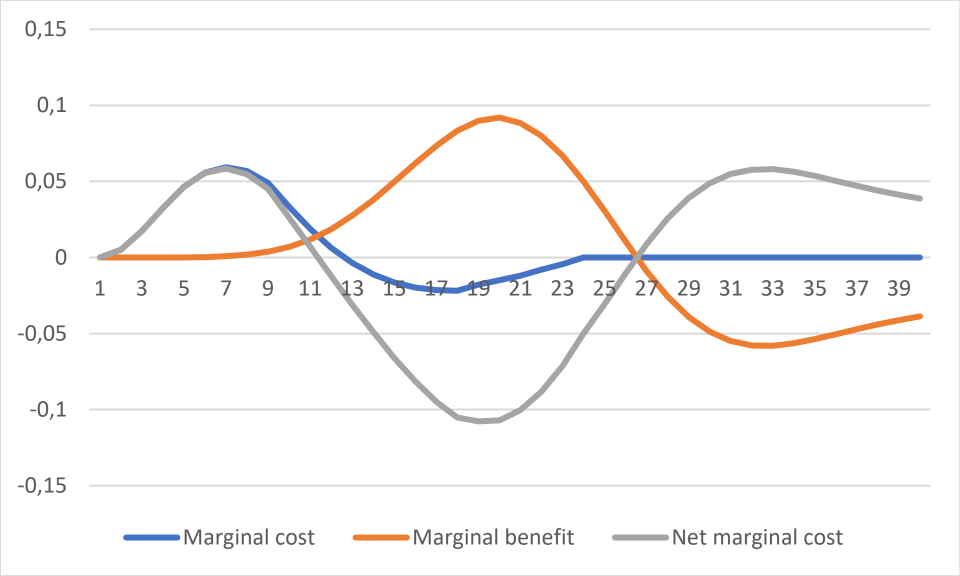

Figure 20: The marginal cost, the marginal benefit, and the net marginal cost of LAW when the expected non-crisis unemployment gap equals zero. Measured in percentage points.

The marginal benefit follows the same pattern as before, mainly due to the similar response in credit. However, because of the dissimilar properties of the DSGE models, the results exhibit different dynamics for the marginal cost. The marginal cost becomes negative after 13 quarters for the Norwegian economy, because the derivative $\frac{dE_1 \tilde{u_t}^n}{di_1}$ is negative. The negative net marginal cost is still not sufficient to justify leaning, but this illustrates a key point: the economy accepts a decrease in welfare in the short run for a better outcome in the medium run. However, in the long run, the total effect seems to vanish, because of the long-run neutrality of money.

To assess whether Leaning Against the Wind should be the preferred policy, we need to look at its cumulative effect over the entire 40 quarters.

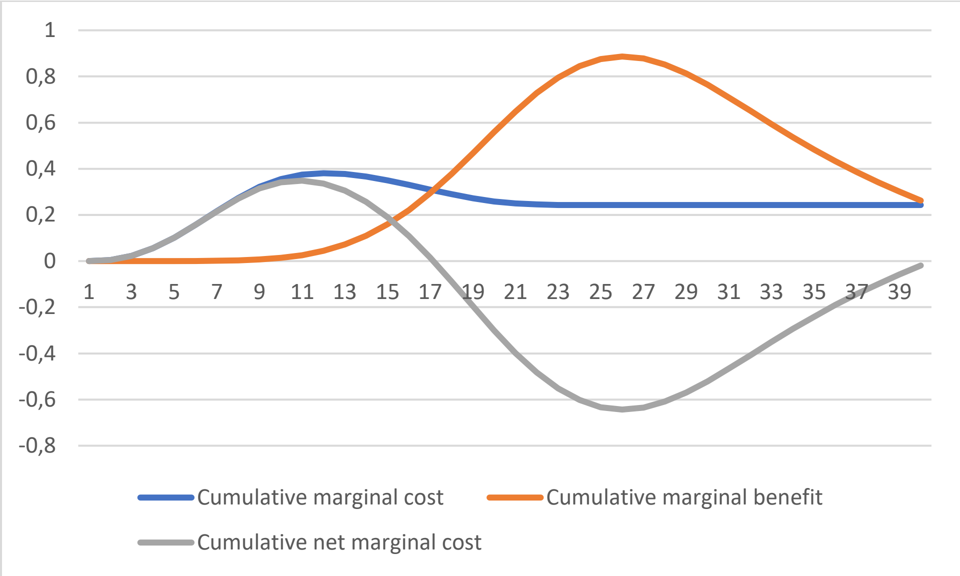

Figure 21: The cumulative marginal cost, marginal benefit, and the net marginal cost of LAW when the expected non-crisis unemployment gap equals zero. Measured in percentage points.

The cumulative marginal benefit is exactly equal to the cumulative marginal cost over the 40 weeks, which implies that there is no argument for or against Leaning Against the Wind. There is no change in welfare from the increased policy rate. In the remaining part of the analysis, I present the dynamic effects for each quarter, as presented in figure 20, before summing up the cumulative effects, such as in figure 21. This will make the interpretation clearer.

Sensitivity Analysis

The results using the Norwegian model weren't as clear cut against leaning as the ones using the Swedish model, where I concluded that there was absolutely no existing argument for Leaning Against the Wind. Because of this, I am curious to whether my results stand up to further sensitivity testing. I will examine the following:

- The sensitivity to the initial state of the economy.
- The sensitivity to the effect of the policy rate on the non-crisis unemployment rate.
- The sensitivity to the effects of effective macroprudential policy:
  - A higher probability of a crisis beginning due to higher credit growth.
  - A larger increase in the unemployment rate in the event of a crisis.

In Svensson (2016), leaning doesn't yield a negative net marginal cost in any of these scenarios.

The sensitivity to the initial state of the economy.

In Figure 22, I consider a scenario where the central bank decides to lean, increasing the unemployment gap equal to a small 0.1 percentage point for all quarters.

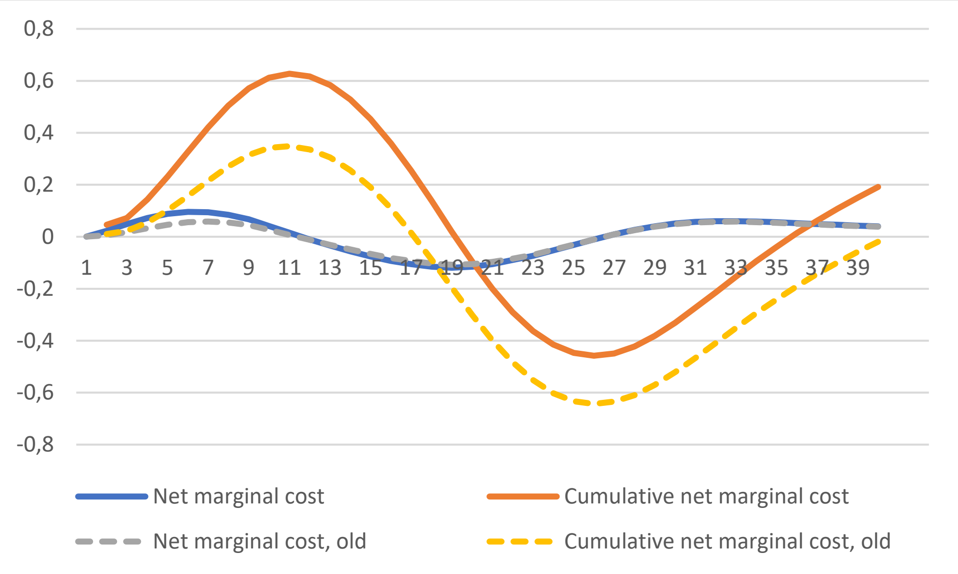

Figure 22: The marginal cost, the marginal benefit, and the net marginal cost of LAW when the expected non-crisis unemployment gap equals 0,1 percentage point for all quarters. Measured in percentage points.

The marginal cost is given by (3.3) if the expected non-crisis unemployment gap differs from zero, and it increases compared to the baseline scenario where $E_1 \tilde{u_t}^n = 0$. The net marginal cost shifts up and more than doubles for the increased non-crisis unemployment gap, because the crisis unemployment rate is higher in the absence of leaning. Because of the dynamics in (3.4), the marginal benefit is almost unchanged because $E_1 \tilde{u_t}^n$ has such a small impact on it ($(\Delta u)^2 = 25 > 2\Delta u E_1 \tilde{u_t}^n$). The net marginal cost is slightly higher through almost the entire period. The assumption of an initial weaker economy strengthens the argument against leaning.

In contrast to the findings of Filardo and Rungcharoenkitkul (2016), leaning systematically over the whole cycle does not increase the welfare of the economy within this framework. If the leaning was more aggressive, the resulting effect would be an even higher cumulative net marginal cost. This is because the expected non-crisis unemployment gap has a quite small impact on the marginal benefit.

A more realistic situation could be one where the expected non-crisis unemployment gap is positive for the first few quarters because the central bank decides to lean shortly against increasing real debt growth. In Figure 23, I look at a positive unemployment gap of 0.1 percentage points for the first 8 quarters, before it falls back to baseline in quarter 12 and onwards.

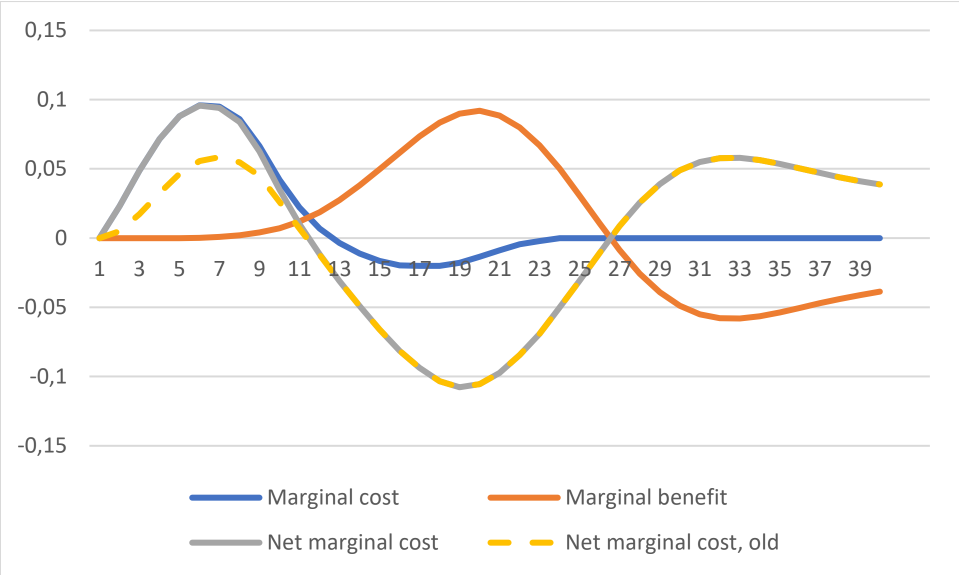

Figure 23: The marginal cost, the marginal benefit, and the net marginal cost of LAW when the expected non-crisis unemployment gap equals 0,1 percentage point for quarters 1-8, before falling to zero in quarter 12 and onwards. Measured in percentage points.

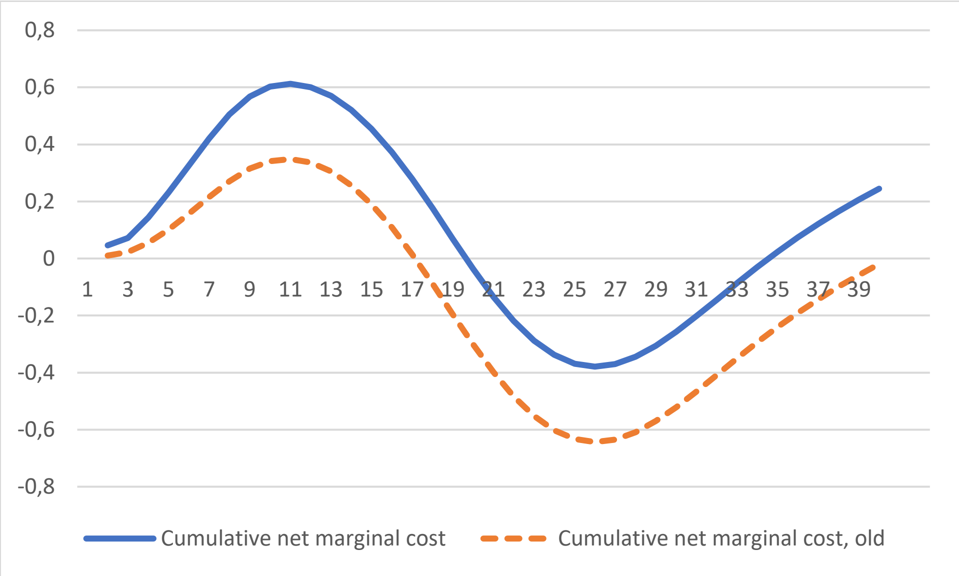

Figure 24: The marginal cost, the marginal benefit, and the net marginal cost of LAW when the expected non-crisis unemployment gap equals 0,1 percentage point for quarters 1-8, before falling to zero in quarter 12 and onwards. Measured in percentage points.

This policy increases the marginal cost the first 12 quarters, before the net marginal cost returns to the baseline assumption of $E_1 \tilde{u}_t^n = 0$. This makes the cumulative net marginal cost higher throughout the entire period. By looking at Figure 24, it is evident that when accounting for the weakened state of the economy in this framework, a deviation from a zero expected non-crisis unemployment gap yields more costs than benefits. This should be intuitive when considering that disregarding this effect either yielded arguments for or against leaning.

The sensitivity to the effect of the policy rate on the non-crisis unemployment rate

Equation (3.3) tells us that the marginal cost of leaning depends on how sensitive the non-crisis unemployment rate is to the policy rate. The original dynamics are given in Figure 18. If the unemployment rate was a little less sensitive to the increased policy rate, the costs of leaning would be reduced. In the following figure, I assume that the effects of the policy rate on the non-crisis unemployment rate are reduced by 50 percent.

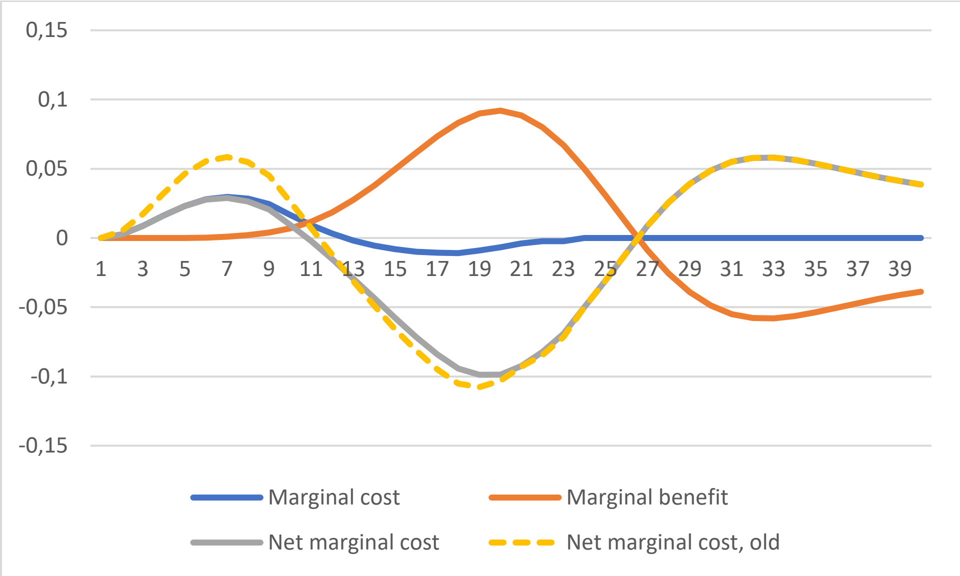

Figure 25: The marginal cost, the marginal benefit, and the net marginal cost of LAW when the effect of the policy rate on the expected non-crisis unemployment rate is reduced to half of the original estimate. Measured in percentage points.

The marginal cost shifts down by a half compared to the previous model, and (3.4) tells us that the marginal benefits remain unaffected[22]. Surely, the resulting initial effect on the net marginal cost is a reduction. In contrast to RAMSES, NEMO provides the economy with a negative unemployment gap for several quarters. This makes the net marginal cost slightly higher than in the original scenario for quarters 13-20. As Figure 26 shows, if leaning didn't provide the economy with such a large loss (because of the increased unemployment), there is no doubt that it would be a policy under consideration. The benefit from leaning outweighs the cost over the 40 quarters, and provides some argument for using the policy. However, keep in mind that the conclusion changes when using the empirical estimates.

[22] The marginal benefit is not affected by the effect of the policy rate on the non-crisis unemployment rate.

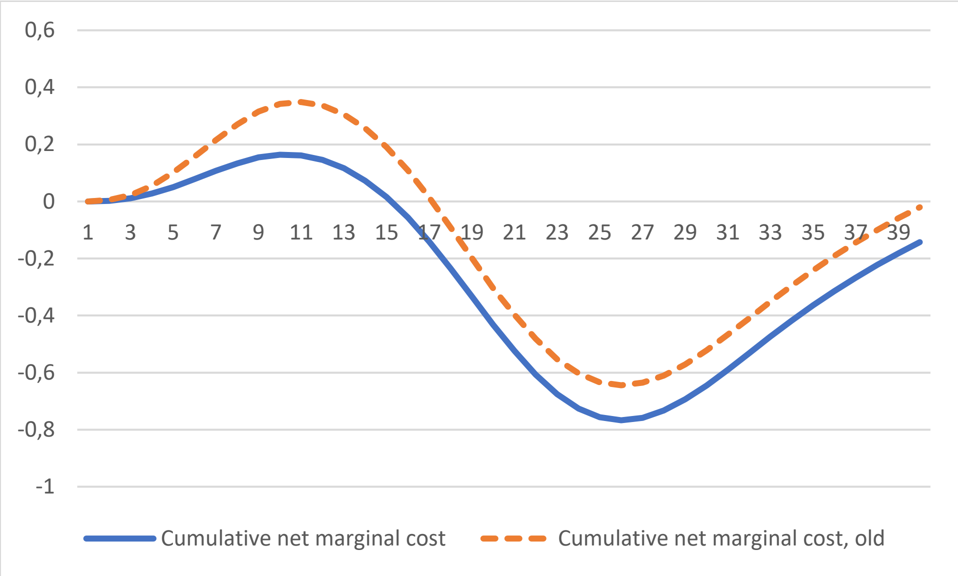

Figure 26: The cumulative net marginal cost when the effect of the policy rate on the expected non-crisis unemployment rate is reduced to half of the original estimate. Measured in percentage points.

Less Effective Macroprudential Policy

An argument that often arises in this debate is the possible role of monetary policy as a second line of defense against financial instability in situations where macroprudential policy turns out to be insufficiently effective. I will examine this by assuming that less efficient macroprudential policy manifests itself in terms of either higher credit growth, or an increase in the severity of a financial crisis (a larger jump in the unemployment rate).

A higher probability of a crisis beginning due to a higher credit growth

We return to assuming an expected non-crisis unemployment gap equal to zero. So far I have used my estimate from the logit regression, together with a steady state real debt growth of 5 percent. The resulting annual probability of a crisis beginning is 2.23 percent. In the following section, I will consider a scenario where the annual probability of a financial crisis is 3.23 percent. Using (1.6), and the logistic function, this corresponds to a constant annual real debt growth of 6.78 percent.[23] Resulting from the increased credit growth, the quarterly probability of a crisis beginning, expressed by q_t, is now equal to 0.8 percent, which by (1.2) leads to a

[23] This works both ways; one can also assume a given increase in annual credit growth and calculate the corresponding probability of a crisis beginning in any given quarter. But keep in mind that the credit growth is driving the probability of a financial crisis, not the other way around.

higher probability of a financial crisis, p_t (3.23 percent). Figure 27 displays how the policy rate affects credit growth, and the corresponding crisis dynamics in this scenario.

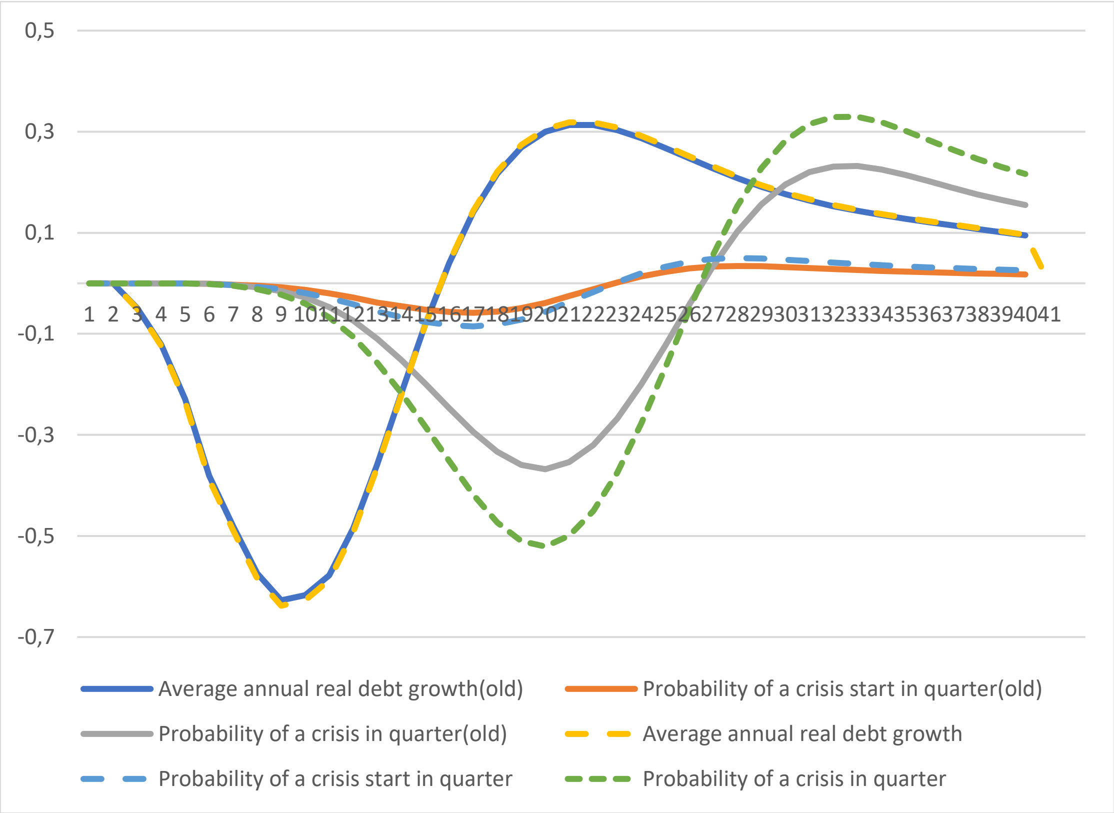

Figure 27: The effect of higher credit growth on average annual credit growth, the probability of a crisis beginning, and the probability of a crisis for all quarters (dotted lines) vs. normal credit growth (solid lines). Measured in percentage points.

The green dotted line shows that the probability of a crisis decreases by more than 0.5 percentage point in quarter 20. The heightened credit growth increases the effect of a monetary shock on the probability of a financial crisis by more than 40 percent. To compare, the increase in credit growth compared to the baseline level (5 percent) is about 36 percent. This difference in magnitudes is due to the non-linearity of the logit model.[24] The green dotted line peaks above the gray line, indicating that the economy faces an even higher probability of a crisis after 6.5 years. The cumulative effect is also 40 percent stronger, indicating that this will affect the benefits from leaning in a positive way. This is examined in Figure 28.

[24] The relationship between credit growth and the probability of a financial crisis is positive in my baseline estimation. Because of the non-linearity of logit models, this relationship increases with the initial level of credit growth, making the link between policy rates and financial instability stronger.

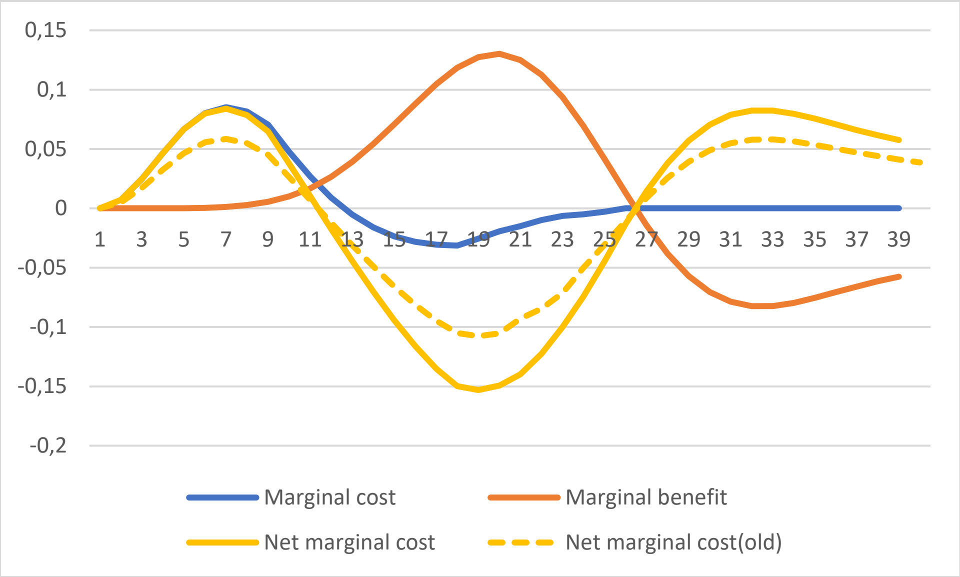

Figure 28: The effect of an increase in the annual probability of a crisis by 1 percent on the marginal cost, marginal benefit, and the net marginal cost of Leaning Against the Wind. Measured in percentage points.

Because the marginal cost of leaning is proportional to p_t, the marginal cost will increase. On the other hand, higher credit growth will increase the effect that the policy rate has on the probability of a crisis, $\frac{dp_t}{di_1}$. Keep in mind the aforementioned changing sign in front of this expression for the Norwegian economy. By (3.6), this makes the marginal benefit higher from quarters 12-26, reducing the net marginal cost. This comes directly from the reduced probability of a crisis due to leaning. However, because $\frac{dp_t}{di_1}$ changes sign in quarter 26, the result is an increased probability of a crisis, further reducing the possible benefits of leaning. The total effect is displayed in Figure 29.

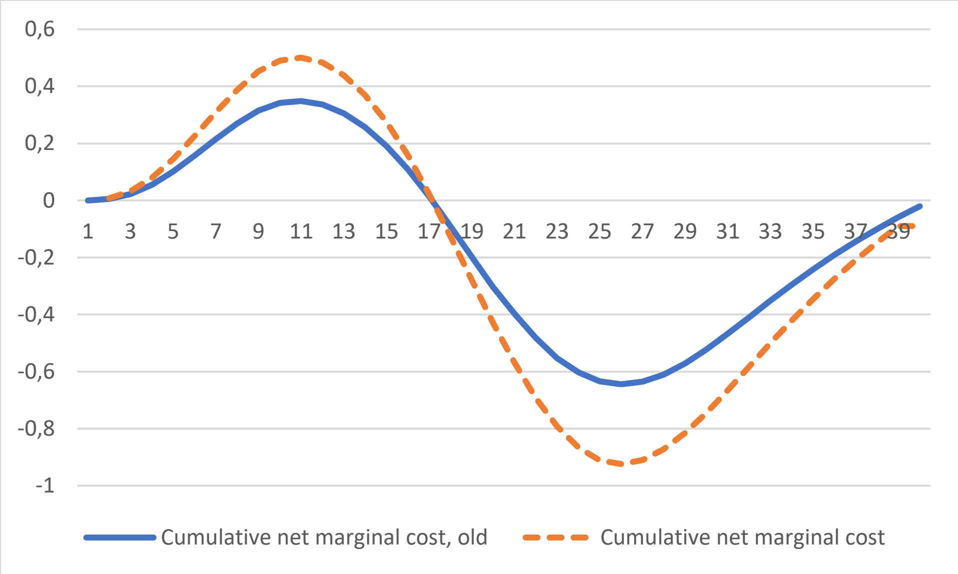

Figure 29: The effect of an increase in the annual probability of a crisis by 1 percent on the cumulative net marginal cost of Leaning Against the Wind. Measured in percentage points.

The increase in the accumulated marginal benefit is slightly higher than the effect on the accumulated marginal cost. Because of this, the argument for leaning could be justified. This means that if a less effective macroprudential policy (or anything else) increases the credit growth and the probability of a crisis beginning, the benefits of leaning increase more than the costs, and the case for LAW is stronger. The corresponding result when examining lower credit growth would intuitively be the complete opposite.

A larger crisis increase in the unemployment rate

From (3.5) and (3.6), the crisis increase in the unemployment rate has a large effect on both the benefits and the costs of leaning. I consider an increase in Δu from 5 percentage points to 6 following a financial crisis. Figures 30 and 31 show that less effective macroprudential policy, to the extent that it implies a larger crisis increase in the unemployment rate, does provide some argument for leaning. In fact, the more severe an effect a financial crisis has on the unemployment rate, the more the benefits of leaning increase.

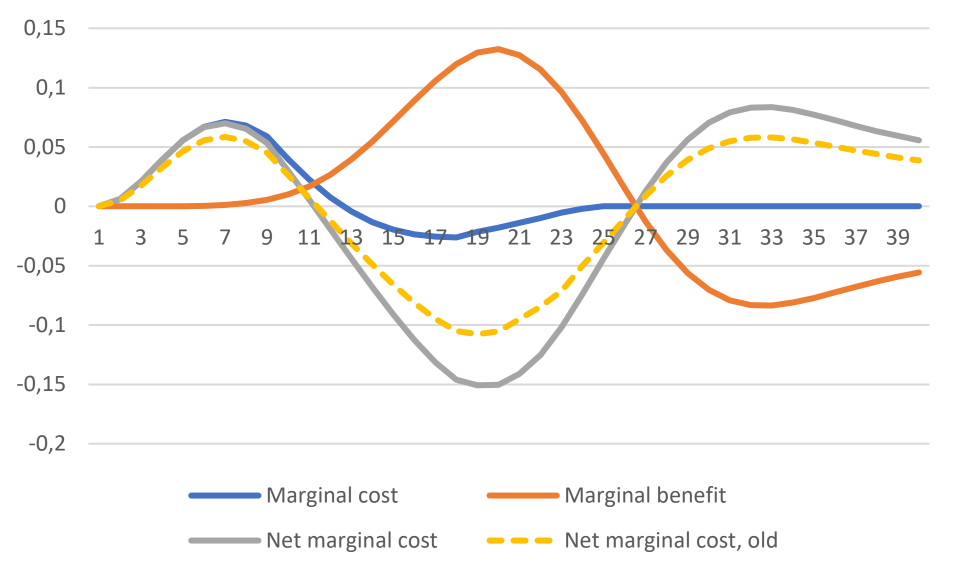

Figure 30: The marginal cost, the marginal benefit, and the net marginal cost of LAW when the crisis increase in the unemployment rate is equal to 6 percent. Measured in percentage points.

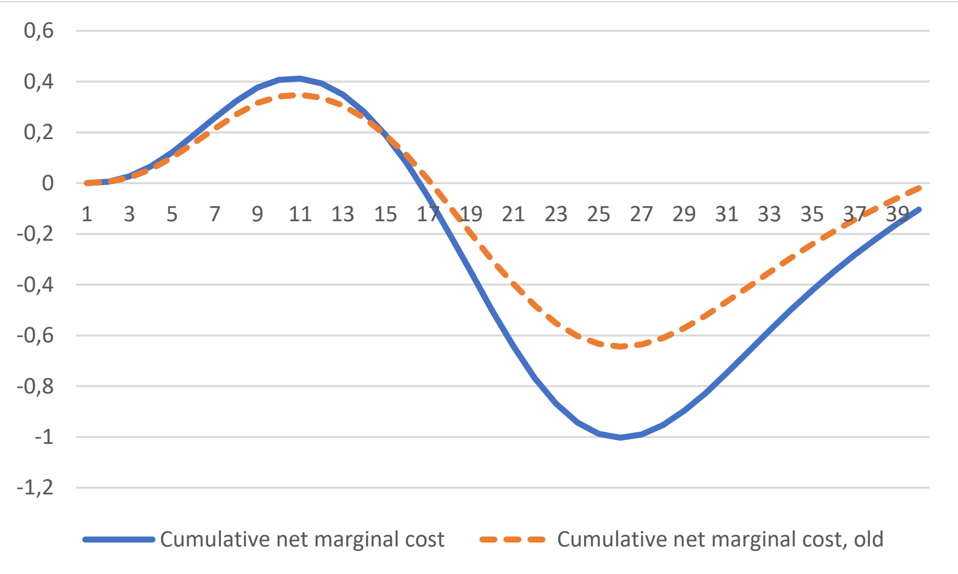

Figure 31: The cumulative net marginal cost of LAW when the crisis increase in the unemployment rate is equal to 6 percent. Measured in percentage points.

Household vs Firm Credit

I want to examine if changing the definition of credit could affect the outcome. I find good reasons for doing this;

* Sveriges Riksbank (2014) report how the policy rate affect loans to households only. Svensson uses this together with estimates from Schularick & Taylor, who defines credit as

loans to household and non-financial corporations. He assumes that this difference won't have any definitive effect on the outcome.

* Beck et. Al. (2012) find that who gets the credit matter; Firm credit is positively associated with economic growth, whereas household credit is not. Investigating whether a specific type of credit can be attributed as a better predictor of financial instability has interest in itself. Is financial instability the result of households "biting off more credit than they can chew", or does it stem from over-leveraged corporations? If the dynamics differ, leaning against a specific credit cycle might be more fruitful (or less) than the other[25]. Correspondingly, this can indicate the direction policymakers should focus macroprudential tools that target credit.

Therefore, I re-estimate my baseline model with the two series separately.

Table 7: Baseline model with separated series of real loans

Specification (Logit country effects)	(6) Baseline with loans to households and non-financial corporations	(7) Baseline with loans to households	(8) Baseline with loans to non-financial corporations
L1.Δ log (loans/P)	3.786 (4.173)	-11.96 (7.61)	19.64*** (6.52)
L2.Δ log (loans/P)	12.81*** (4.677)	17.08*** (6.871)	8.14 (6.58)
L3.Δ log (loans/P)	6.637 (6.867)	23.57 (7.96)	12.26 (9.17)
L4.Δ log (loans/P)	-3.664 (5.106)	-12.17 (8.16)	-2.87 (5.75)
L5.Δ log (loans/P)	1.920 (5.857)	1.302 (11.79)	9.78 (8.06)

[25] One cannot lean directly against only one form of credit: The policy rate would obviously affect loans to both households and firms. But, if the central bank is worried about a specific trend in credit (f. ex. a sharp increase in household debt), difference in the findings could suggest whether leaning might be more or less justified regarding a specific situation.

Marginal effects at each lag Evaluated at the means	0.0845 0.286 0.148 -0.0817 0.0428	-0.2 0.29 0.4 -0.207 0.02	0.299 0.124 0.186 -0.044 0.149
Sum	0.479	0.30	0.714
Observations Groups	312 3	312 3	312 3
Sum of lag coefficients	21.49	17.82	46.95
SE	7.87	11.51	10.75
Test for all lags = 0†, χ^2	19.87***	17.08***	27.59***
Pseudo R^2	0.138	0.24	0.22
Probability of a crisis start in a given quarter	0.557 percentage point	0.43 percentage point	0.375 percentage point

It seems like both credit to households and non-financial corporations can predict financial instability equally well. The coefficients exhibit slightly different dynamics (the first coefficient is negative in the logit-model with loans to households), but the overall picture tells the same story: real loan growth to both households and non-financial corporations affects the probability of financial crises in Scandinavia. There is a very small difference in the pseudo R^2, and both the sum of the marginal effects and the corresponding probability of a crisis start is quite equal. Because of the negative sign in front of the first lag in real loans to households, the probability of a crisis will move above baseline at first, but the resulting dynamics are very similar to that of the original scenario.

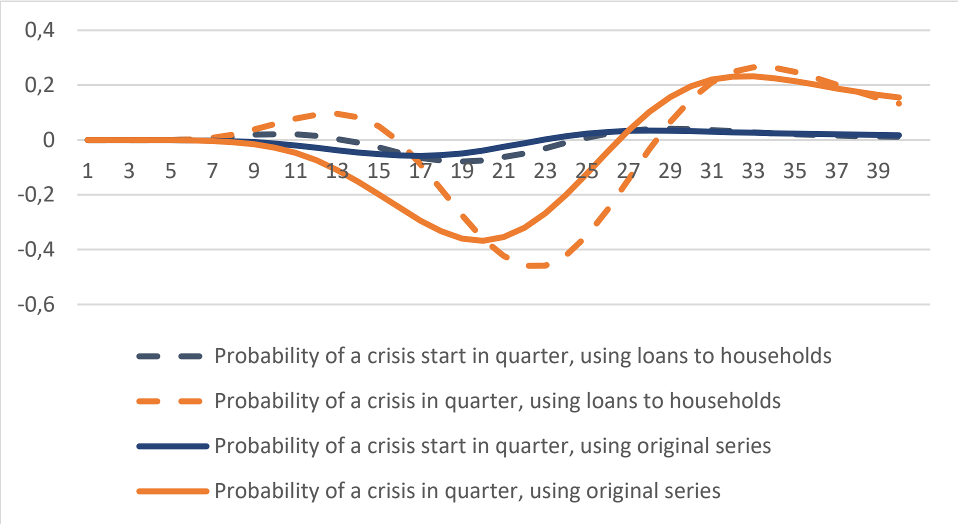

Figure 32: The effect of an increased policy rate on the probability of a crisis start, and the probability of being in a crisis: Real debt to households' vs original series

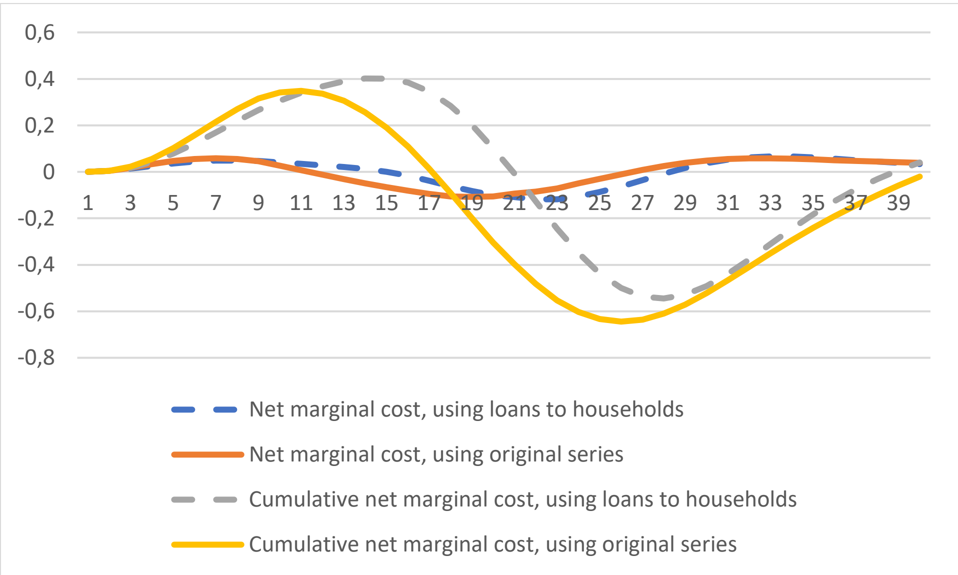

Figure 33: The cumulative net marginal cost of LAW, when the expected non-crisis unemployment gap equals zero: Comparing real debt to households' vs original series. Measured in percentage points.

First of all, figure 33 indicate that the assumption of Svensson seems to be empirically solid – there is not much of a difference in the cumulative net marginal cost from leaning, if one uses loans to households only. There is a shift in there the cumulative net marginal cost peaks, because of the aforementioned negative first-lag in the logit equation. Nevertheless, the interpretation of the outcome is unchanged. Both credit to households and firms appear to have identical effect on the probability of a crisis, which indicate that when focusing on credit growth, policy makers should emphasize both. But when it comes to leaning, the increased policy rate still leaves the economy with a cumulative net marginal cost of zero.

Concluding Remarks

The case against leaning does not seem as conclusive for the Norwegian economy as it does for the Swedish. The main reason for this is the effect of the policy rate on the output/unemployment rate from the two different DSGE models. As before, the cost stems from unemployment being above normal levels for a brief period. Initially, the marginal cost increases in a similar fashion as for the Swedish model, but the estimated effect on Norwegian unemployment in the long run provides the framework with a negative marginal cost after about 3.5 years. This is because the economy is predicted to experience unemployment-levels under normal. However, the cumulative marginal cost is still negative, because the initial increase in unemployment is far greater than the long-run effects[26].

The effect on real debt, real debt growth, and the corresponding crisis-probabilities is very much alike in the two models. The reason for this is twofold: First of all, I am using the same logit-estimation. Also, the effect on real debt resulting from the increased policy rate is very similar in Sveriges Riksbank (2014) and the numbers provided to me by Norges Bank. Both predicts a reduction in credit growth by about 1 percentage point after approximately 2 years, before it returns back to baseline in the long run. This makes the probability of a crisis start, and for the economy to be in a financial crisis decrease at first, before it eventually moves slightly above normal levels. Even though the crisis-probabilities shifts a little in time, the cumulative effect of leaning on the probability of a financial crisis is equal in both models.

In contrast to Svensson (2016), I find a distinct positive total marginal benefit from leaning. This occurs especially in the medium run, where the impact on the probability of a financial crisis peaks. The benefit turns negative after about 6 years. This is due to the fact that real debt growth is above baseline, and correspondingly, the probability of a financial crisis increases compared to normal level. This makes the “benefit” from leaning in these respective quarters negative. However, the positive effect that the economy gets from leaning in the medium run outweighs this long-run negative effect from the increase in credit growth.

Even in the presence of the benefits, the cumulative marginal cost from leaning is exactly equal to the cumulative marginal benefit, calculated over the entire 10-year period in

[26] Keep in mind that «long run» in this context refers to the later periods in the framework.

consideration. The effect of leaning on the economy does not seem to be positive. Also, I conclude that in this framework, leaning systematically over the entire cycle is a worse policy than a shorter hike, because the non-crisis unemployment rate is kept higher for a longer period of time, inflicting even greater costs.

The conclusion that leaning is a no-good policy appears to be quite sensitive to several factors. On the one hand, accounting for the effect on the initial state of the economy strengthens the case against leaning. This is robust for both leaning systematically over the whole cycle or hiking for a shorter period. If the effect of the policy rate on the expected unemployment gap was slightly weaker, this would decrease the cost of leaning, making the cumulative net marginal cost negative.

The effectiveness of macroprudential policy seems to be of importance as well. In this case, this results in a higher credit growth (and an increased probability of a crisis) or a more severe crisis. When considering increased credit growth, the accumulated net marginal cost of leaning is negative. This means that a less effective macroprudential policy could increase the argument for leaning. This is somewhat intuitive; if macroprudential policies fail, the broad effects of monetary policy might succeed instead. Also, if the crisis increase in the unemployment rate is larger, the argument for leaning is strengthened.

A crucial point when considering costs and benefits over such a long period of time seems to be how the unemployment rate reacts to the change in policy rate. This means that the conclusion is very sensitive to the dynamics from the different DSGE models. If the unemployment gap never becomes negative, the conclusion is clear cut because of the small estimated effect of credit growth on the probability of a financial crisis. However, if unemployment dips below the baseline for several years, the costs of leaning are drastically reduced.

Due to this result, I am interested in how changing from DSGE to a VAR model might affect the conclusion. In the next chapter, I use my own VAR estimates together with the probability-model in a final cost-benefit analysis.

9. A Cost-Benefit Analysis using a Norwegian VAR-model

In this chapter, I replace the parameters from the DSGE models with my own results from the structural vector autoregressive model, based on Norwegian data. I begin by presenting my results for model choice and stationarity. The main goal was to examine how credit and unemployment responded to an increase in the policy rate, and to further use this in the cost-benefit framework.

Figures for the impulse responses and the raw data used in the VAR can be seen in appendix C.

Choosing the optimal lag length

Lag	LogL	AIC	SC	HQ
0	-630.2498	17.43150	17.61976	17.50652
1	-401.8902	12.16137	13.47917*	12.68046*
2	-349.2379	11.70515	14.15249	12.68645
3	-317.6742	11.82669	15.40357	13.25214
4	-260.7354	11.25302	15.95945	13.12861
5	-207.8161	10.78948	16.62545	13.11522
6	-169.5261	10.72674	17.69225	13.50262
7	-120.9131	10.38118*	18.47623	13.60720

Table 8: Information criterions to choose the optimal number of lags

Schwartz and Hannan-Quinn criterions select two lags as the optimal length[27]. Because of this, I set my lag length to 2. In case of 1, there would be a risk of having autocorrelated residuals. The model is linear, and the responses are normalized with respect to the standard deviation of the policy shock.

[27] As mentioned in the methodolgy chapter, the information criterions might differ in their conclusion, because they differ in the way they "punish" more complex models.

Stationarity-tests

As mentioned, stationarity is important in time series econometrics. Because of this, an Augmented Dickey Fuller test is performed on each variable. The result is presented in table 9.

Variable	ADF test statistic (5% significance level)	Test statistic	p-value	Interpretation
Inflation growth rate	-2,9	-3,14	0,027	Stationary
Unemployment	-2,9	-3,31	0,017	Stationary
Real credit growth	-2,9	-3,8	0,0043	Stationary
Real house price growth	-2,9	-4,21	0,0012	Stationary
Real exchange rate growth	-2,9	-8	0	Stationary
Interest rate	-2,9	-2,34	0,15	Non-stationary (contains a unit root)

Table 9: Augmented Dickey Fuller test for a unit root

I will keep interest rate on level form, even if its exhibits non-stationarity. This is because of the interpretation that will be used further in the analysis. It is also kept on level form in Robstad (2014). However, due to this result, I will perform a stability test to the entire VAR-system. At the end of the day, it is the stability of the system that matters.

The following figure display the inverse roots of the characteristic AR polynomial. The estimated VAR is stationary if all roots have modulus less than one and lie inside the unit circle. This is the equivalent to the roots of the lag polynomial lying outside the unit circle, stated as a necessary and sufficient stability condition in Brooks (2014).

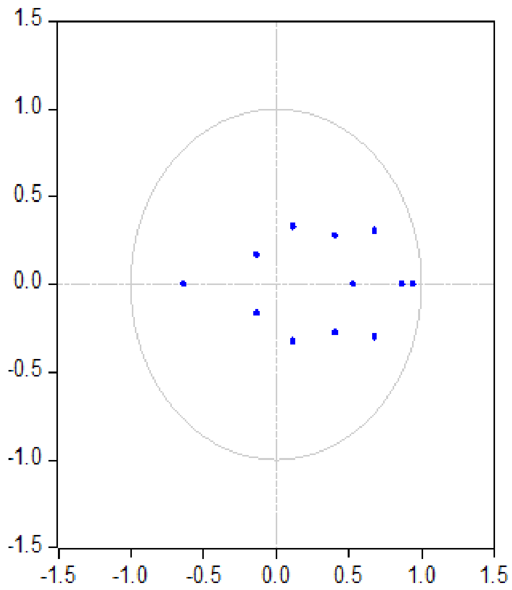

Figure 34: Inverse roots of the characteristic polynomial: Checking stability

Figure 34 shows that the system is stable. Now that I have obtained the necessary information to re-do the cost-benefit analysis, I am ready to examine whether changing from DSGE to VAR modelling has an impact on the argument for Leaning Against the Wind.

The effect of the policy rate on unemployment, credit growth and crisis probabilities

To pursue this part, one needs parameters for the policy shock, and the resulting dynamics in credit and unemployment. These results are taken from the VAR model, and presented in this part. As mentioned, all the variables in a VAR is endogenous by construction. An exogenous monetary policy shock is given to the system to find the estimates.

We begin by considering how an increase in the policy rate affects the non-crisis unemployment rate. This is the main element needed to assess the cost of leaning.

Figure 35: The effect of the policy rate on the non-crisis unemployment rate. Results from VAR-estimation.

Figure 35 display the dynamics of the non-crisis unemployment rate following a monetary policy shock. The policy rate increase up by 0.85 percentage point in quarter 2, before turning negative after 1 year. This makes the unemployment rate move 0.52 percentage point above baseline in quarter 5 and 6, before slowly returning to normal levels. These dynamics is similar to Ekholm (2013), which is used in Svensson (2016). This is the result from the Swedish DSGE-model.

The next figure shows how the increased policy rate affects the real debt growth of households[28], and the corresponding crisis-probabilities.

[28] As demonstrated earlier, it is no problem to use credit growth for households into a probability model based on households and non-financial corporations.

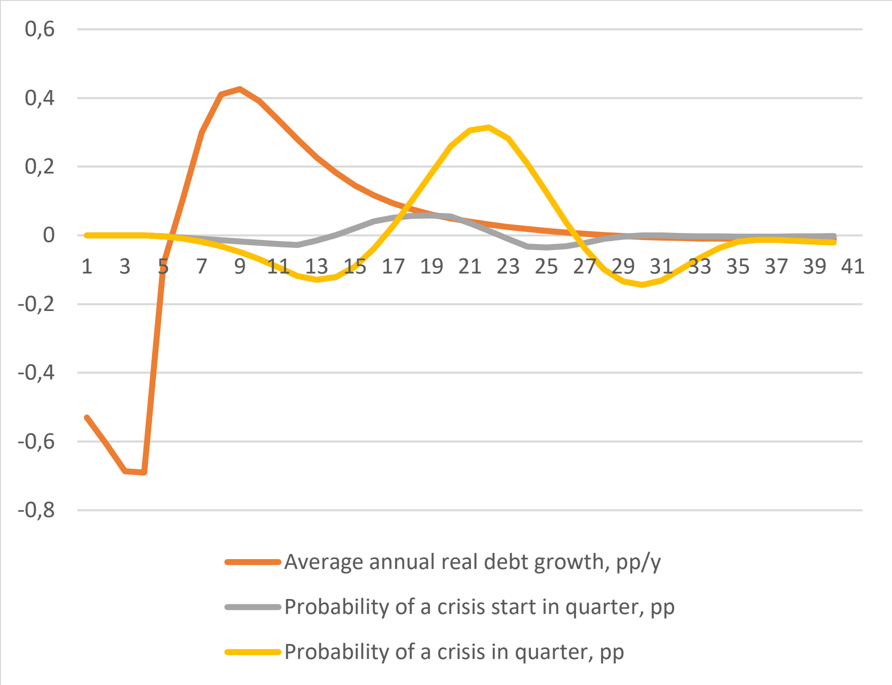

Figure 36: The effect of an increased policy rate on real debt growth, the probability of a crisis beginning, and the probability of being in a crisis. Results from VAR-estimation.

From the orange line in figure 36, one can see that average annual real debt growth decreases because of the monetary policy shock. Real debt growth drops by 0.69 percentage point in quarters 3 and 4, before the economy experiences higher-than-normal growth for about 6 years. Intuitively, this will reduce the probability of a financial crisis after about 2 years (because real debt growth drops immediately, and the first three coefficients in the logit model is positive), before the economy has an increased probability of being in a crisis from between years 4 and 7. This effect is shown by the yellow graph. The cumulative sum of the effect on the probability of a crisis is positive for the entire period[29], which indicate that the possible benefits from leaning will be slim. The total increase in the credit growth is larger than the initial decrease, which leads to an overall increase in the crisis probabilities.

The Cost, Benefit and Net Cost of Leaning Against the Wind

The next step is to assess the cost and benefit of leaning through the use of a loss function. The framework, assumptions and calculations will be identical to the previous chapters, and will therefore not be reviewed here. Figure 36 shows the marginal cost, marginal benefit and

[29] The sum of the yellow curve is 0.23 percentage point for the whole period.

net marginal cost of leaning when using parameters from the VAR-model.

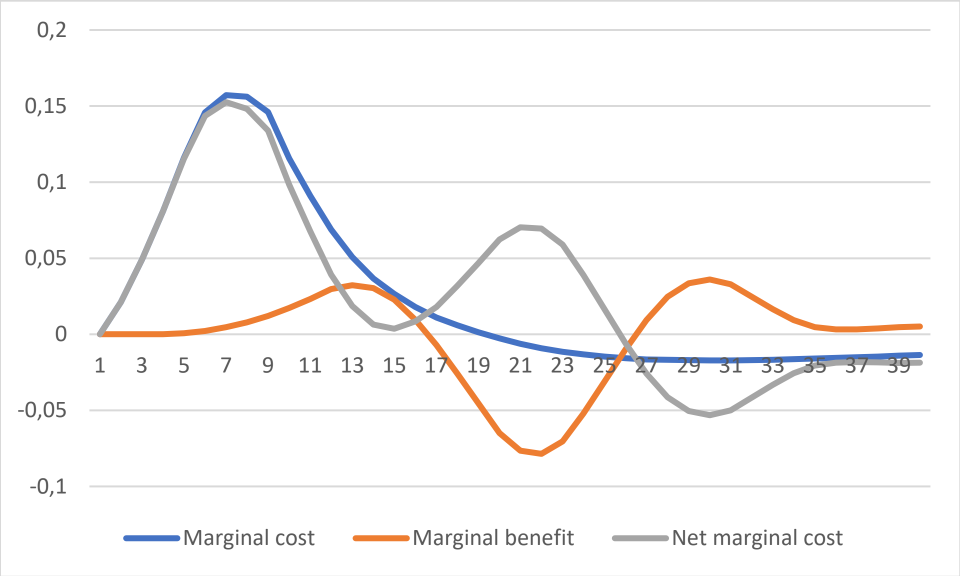

Figure 37: The marginal cost, the marginal benefit, and the net marginal cost of LAW when the expected non-crisis unemployment gap equals zero. Results from VAR-estimation. Measured in percentage points.

The increased unemployment rate provides the economy with a substantial marginal cost from leaning. The marginal benefit is positive after 1.5 years, because the probability of a financial crisis is below normal. Recall from figure 36, that this probability turns positive after approximately 4 years, which turns the marginal benefit negative. In the following period, the economy experiences both an increased likelihood of being in a financial crisis as well as operating with a higher unemployment rate. Under these circumstances, the "benefit" can be considered as an additional cost that stems from the credit growth and the resulting increased probability of a crisis. In a similar way, the negative marginal "cost" between 5 and 10 years is an added benefit because the economy now operates at higher employment. However, this benefit is way smaller than the initial increase in the unemployment rate.

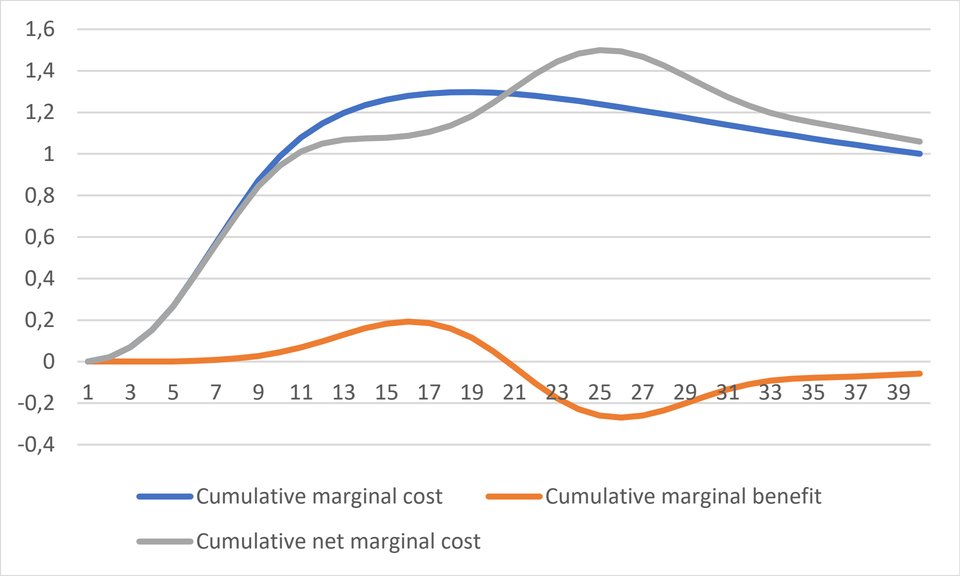

Figure 38: The cumulative net marginal cost of LAW, when the expected non-crisis unemployment gap equals zero. Results from VAR-estimation. Measured in percentage points.

Figure 38 sums up the cost-benefit analysis, using a Norwegian VAR model combined with a probability model based on Scandinavian data. The orange line indicate that the cumulative benefit actually is negative for the 10-year period. This is a direct result from the total crisis probability being higher than in the absence of leaning. The cumulative net marginal cost is positive for the entire period, which implies that it is not optimal for policy makers to lean.

Concluding remarks

The purpose of this chapter was to examine if switching to a different model would change the outcome. Replacing the DSGE model with a VAR makes the case against leaning more conclusive. In fact, the result from using a VAR model shifts more in the direction of the findings in Svensson (2016). One of the main arguments for leaning is that the increased policy rate reduces the probability of being in a financial crisis. My results indicate that this is simply not true, given the existing data. Increasing the policy rate will reduce the likelihood of a crisis at first, but eventually the economy ends up with a higher crisis-probability. The total effect over the entire period is actually that the overall probability is higher than in the absence of leaning. This means that leaning has no benefit. On the other hand, the response in unemployment is approximately equal to the findings in Ekholm (2013) [30], making the cumulative net cost of leaning positive.

[30] This makes me curious about the preciseness of the OKUN-coefficient in such a framework.

10. Summary and Further Considerations

The question whether central banks should emphasize financial stability when setting their policy rate has created an ongoing debate among policy makers and economists since the Global Financial Crisis. In this thesis, I set out to contribute to this discussion through a specific study of the costs and benefits of Leaning Against the Wind in Scandinavia. I began by establishing the link between a number of key financial variables and the probability of a financial crisis. I discovered real debt growth as the single best predictor, based on my dataset from Jorda, Schularick & Taylor (2017). The result stood its ground through a number of robustness tests. My empirical result was then put into a cost-benefit framework created by Lars Svensson (2016), where I used impulse responses from both the Norwegian and the Swedish central banks to investigate how an increase in the policy rate would affect welfare in the economy, measured by the use of a loss function, consisting of unemployment only. My immediate conclusion is that there is not sufficient evidence to justify any leaning. The cost, measured through an increase in the unemployment rate, outweighs the benefit, a brief reduction in the probability of a financial crisis. This holds for both Norway and Sweden, even though the conclusion is a little less clear-cut for the Norwegian economy. Changing the parameters from the DSGE-models of the central banks to my own VAR-estimates based on Norwegian data worsened the argument for leaning, making the costs outweigh the benefits even more. The VAR-results implied that leaning had costs due to an increased unemployment rate, but also an additional cost as a total increase in the probability of a financial crisis. My conclusion is similar to the findings of Svensson (2016).

An interesting extension to this framework would in my opinion to expand the effects of the policy rate to other financial variables, as well as credit. This could possibly strengthen the connection between monetary policy and financial stability. Stein (2013) emphasize the broad effects of monetary policy, because it “gets in all the cracks”. Including more of these cracks in the same framework would certainly be interesting. As a result, the possible benefits (and costs) could change.

In my analysis, I studied how real debt growth could affect the probability of a financial crisis in the Scandinavian Countries, using a dummy variable that determines whether or not a country experienced financial distress. As an advantage, I could simply use the existing dataset and the well-defined crisis-dates. On the other hand, this makes me implicitly assume that the only connection between leaning and financial stability is the reduction of a financial crisis. Increasing the policy rate might also affect the occurrence and development of smaller recessions. If that is the case, this will not be captured by my estimation. This could possibly increase the benefits from leaning.

In all, given the existing empirical evidence and the assumptions in this framework, I find it hard to disagree with John Murray – Norges Bank should abandon the notion of leaning.

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Appendix

Appendix A: From the Loss Function to the Cost and Benefit of Leaning Against the Wind

In this appendix, I provide the mathematical derivation of costs and benefits of leaning, from the quarter-t loss function, defined as

(A.1) $L_t = (\tilde{u_t})^2$

The quarter-t expected loss, $E_1 L_t$, can be written as

(A.2) $E_1 L_t = E_1(\tilde{u_t})^2 = (1 - p_t)E_1(\tilde{u_t}^n)^2 + p_t E_1(\tilde{u_t}^c)^2$

Because $\tilde{u_t}^c = \tilde{u_t}^n + \Delta u$, it follows that

(A.3) $E_1 L_t = (1 - p_t)E_1(\tilde{u_t}^n)^2 + p_t E_1(\tilde{u_t}^n + \Delta u)^2$

The expected square of a random variable is equal to the square of the expected random variable plus its variance[31];

$E_1(\tilde{u_t}^n)^2 = (E_1\tilde{u_t}^n)^2 + Var_1\tilde{u_t}^n,$

(A.4) $E_1(\tilde{u_t}^n + \Delta u)^2 = (E_1\tilde{u_t}^n + \Delta u)^2 + Var_1\tilde{u_t}^n,$

where $Var_1\tilde{u_t}^n$ is the variance of the non-crisis unemployment gap, conditional on information available in quarter 1.

Therefore, the quarter-t expected loss can be written as

(A.5) $E_1 L_t = E_1(\tilde{u_t})^2 = (1 - p_t)(E_1\tilde{u_t}^n)^2 + p_t E_1(\tilde{u_t}^n + \Delta u)^2 + Var_1\tilde{u_t}^n$

If there is no crisis in quarter 1 and the expected future non-crisis unemployment gaps are zero for t ≥ 1, the situation is optimal if the probability of a crisis in future quarters is assumed to equal zero. In this case, we can express (A.5) as

(A.6) $E_1 L_t = (E_1\tilde{u_t}^n)^2 + Var_1\tilde{u_t}^n$

But, the likelihood of a financial crisis is not zero. Let $\bar{p_t}$ denote the benchmark probability of a crisis in quarter t for t ≥ 1, conditional on the initial situation (what the expected non-crisis unemployment gaps are), and the corresponding current and expected future policy rates.

[31] For a random variable X, $E(X)^2 = E[EX + (X-EX)]^2 = (EX)^2 + E(X-EX)^2 = (EX)^2 + VAR(X)$

If we add and subtract $(1 - p_t^-)(E_1 u_t^{\sim n})^2 + p_t^-(E_1 u_t^{\sim n} + \Delta u)^2$ from (A.5), the expected quarter-t loss when accounting for the possibility of a crisis can be written as

(A.7) $E_1 L_t - Var_1 u_t^{\sim n} = [(1 - p_t^-)(E_1 u_t^{\sim n})^2 + p_t^-(E_1 u_t^{\sim n} + \Delta u)^2] - (p_t^- - p_t)[(\Delta u)^2 + 2\Delta u E_1 u_t^{\sim n}]$

Here, it is used that the crisis loss increase satifies

$$(E_1 u_t^{\sim n} + \Delta u)^2 - (E_1 u_t^{\sim n})^2 = (\Delta u)^2 + 2\Delta u E_1 u_t^{\sim n}$$

If we assume a linear relationship between the policy rate and the expected non-crisis unemployment gap together with additive shocks, the conditional variance is independent of policy. Therefore, in this case, it is enough to consider the terms on the right side of (A.7)

To simplify, we define

$Quarter\ t\ loss \equiv Ct - Bt$, where

(A.8) $C_t \equiv (1 - p_t^-)(E_1 u_t^{\sim n})^2 + p_t^-(E_1 u_t^{\sim n} + \Delta u)^2 \equiv C_t^n + C_t^c$

(A.9) $B_t \equiv (p_t^- - p_t)[(\Delta u)^2 + 2\Delta u E_1 u_t^{\sim n}]$

Appendix B: The Cost and Benefit with a Fixed Loss Level in a Crisis

Generally, the framework of Svensson (2016) assumes that a crisis is followed by an increased unemployment gap:

$u_t^{\sim c} = u_t^{\sim n} + \Delta u,$

so that the expected crisis unemployment gap becomes higher is the non-crisis unemployment gap is higher,

$E_1 u_t^{\sim c} = E_1 u_t^{\sim n} + \Delta u$

In this appendix, I provide a mathematical derivation for the cost and benefit if the economy reaches a fixed level of unemployment (gap) following a crisis. Then, the unemployment gap in the event of a financial crisis satisfies

(B.1) $E_1 u_t^{\sim c} = \Delta u$

The crisis unemployment gap is assumed to be random with mean Δu and conditional variance equal to that of the non-crisis unemployment gap, mentioned in appendix A.

The expected loss in a crisis can be written

(B.2) $E_1 (u_t^{\sim c})^2 = (\Delta u)^2 + Var_1 u_t^{\sim c} = (\Delta u)^2 + Var_1 u_t^{\sim n}$

Recall,

$E_1 (u_t^{\sim n})^2 = (E_1 u_t^{\sim n})^2 + Var_1 u_t^{\sim n}$

Therefore, the expected loss in quarter-t can be expressed as

$E_1 L_t = (1 - p_t) E_1 (u_t^{\sim n})^2 + p_t[(\Delta u)^2 + Var_1 u_t^{\sim n})]$

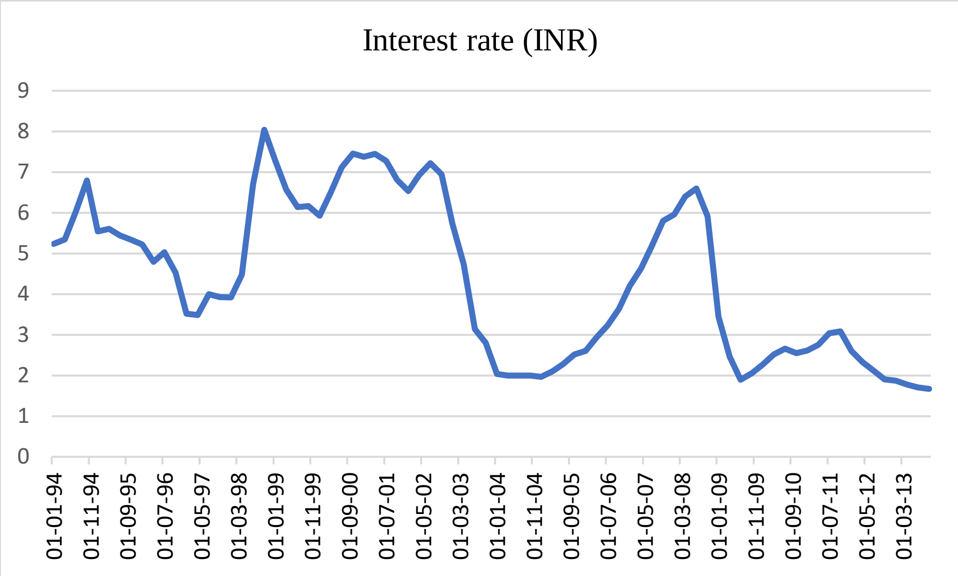
(B.3) $E_1 L_t = (1 - p_t)(E_1 u_t^{\sim n})^2 + p_t (\Delta u)^2 + Var_1 u_t^{\sim n}$

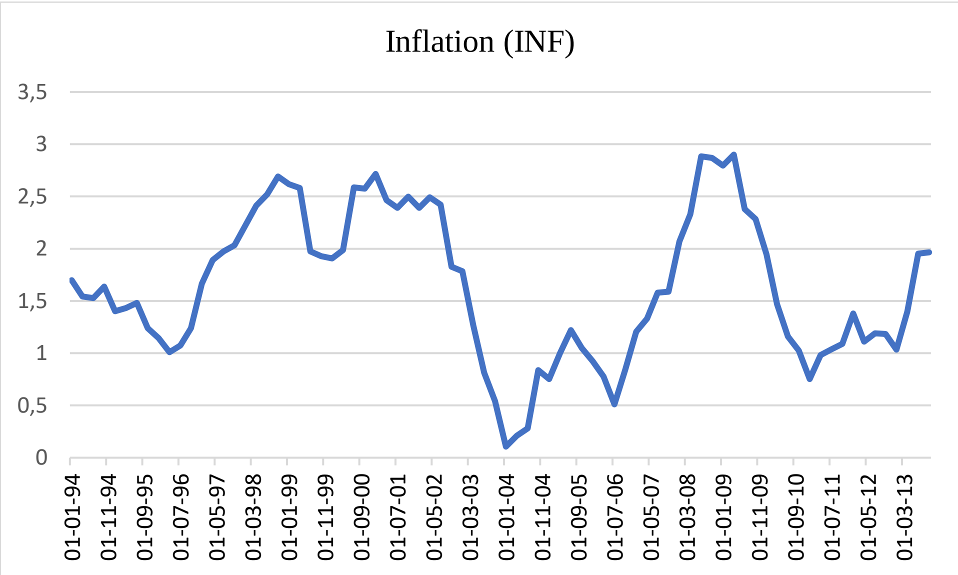
Then, we add and subtract $(1 - p_t^-)(E_1 u_t^{\sim n})^2 + p_t^- (\Delta u)^2$, and rewrite (B.3) as

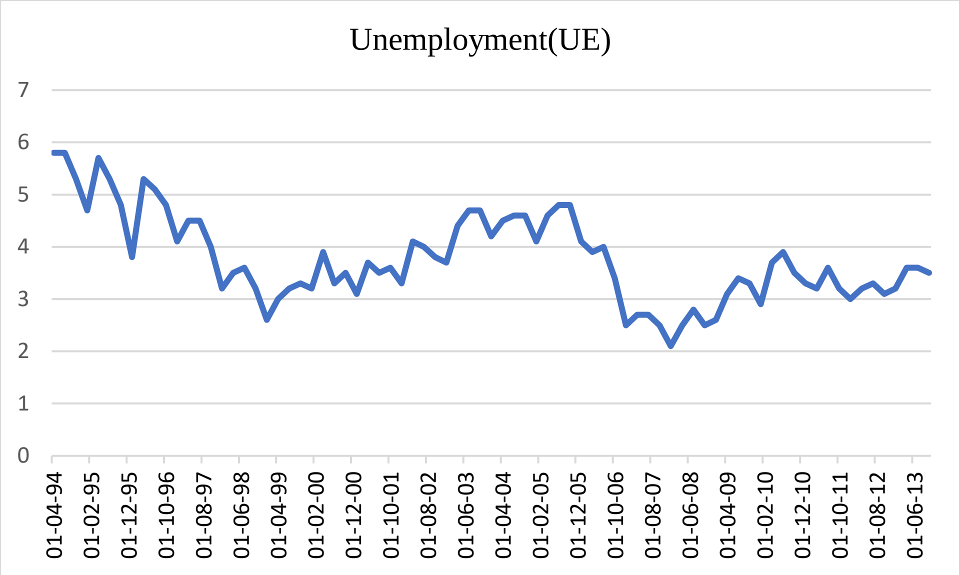
$E_1 L_t - Var_1 u_t^{\sim n} = [(1 - p_t^-)(E_1 u_t^{\sim n})^2 + p_t^- (\Delta u)^2] - (p_t^- - p_t)[(\Delta u)^2 - (E_1 u_t^{\sim n})^2]$

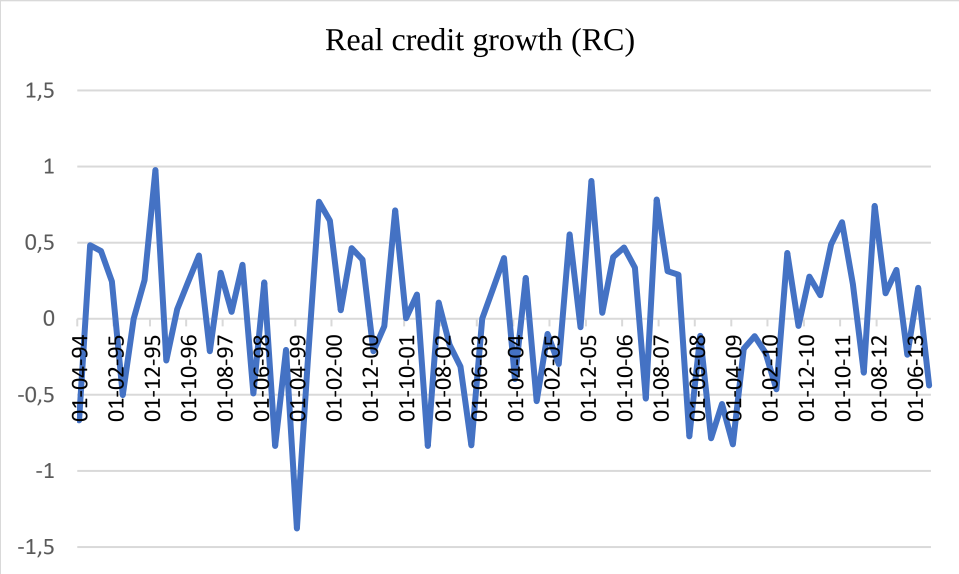
$\equiv Ct - Bt$

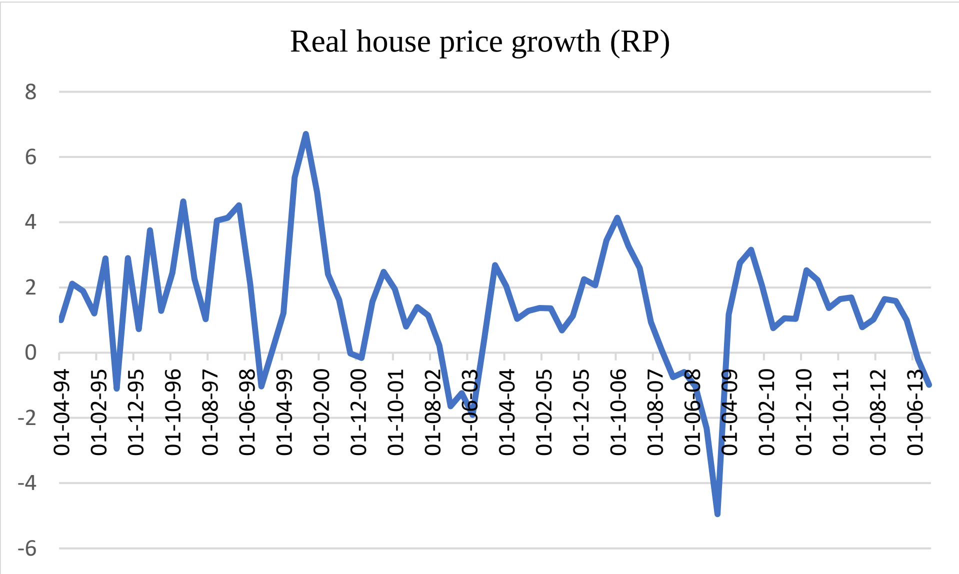
Appendix C: The VAR Model (Figures)

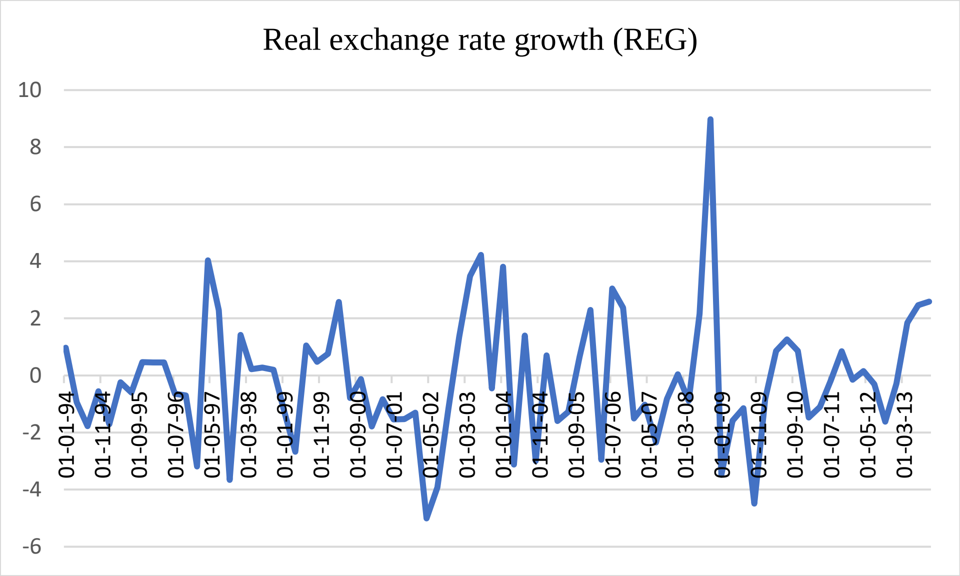




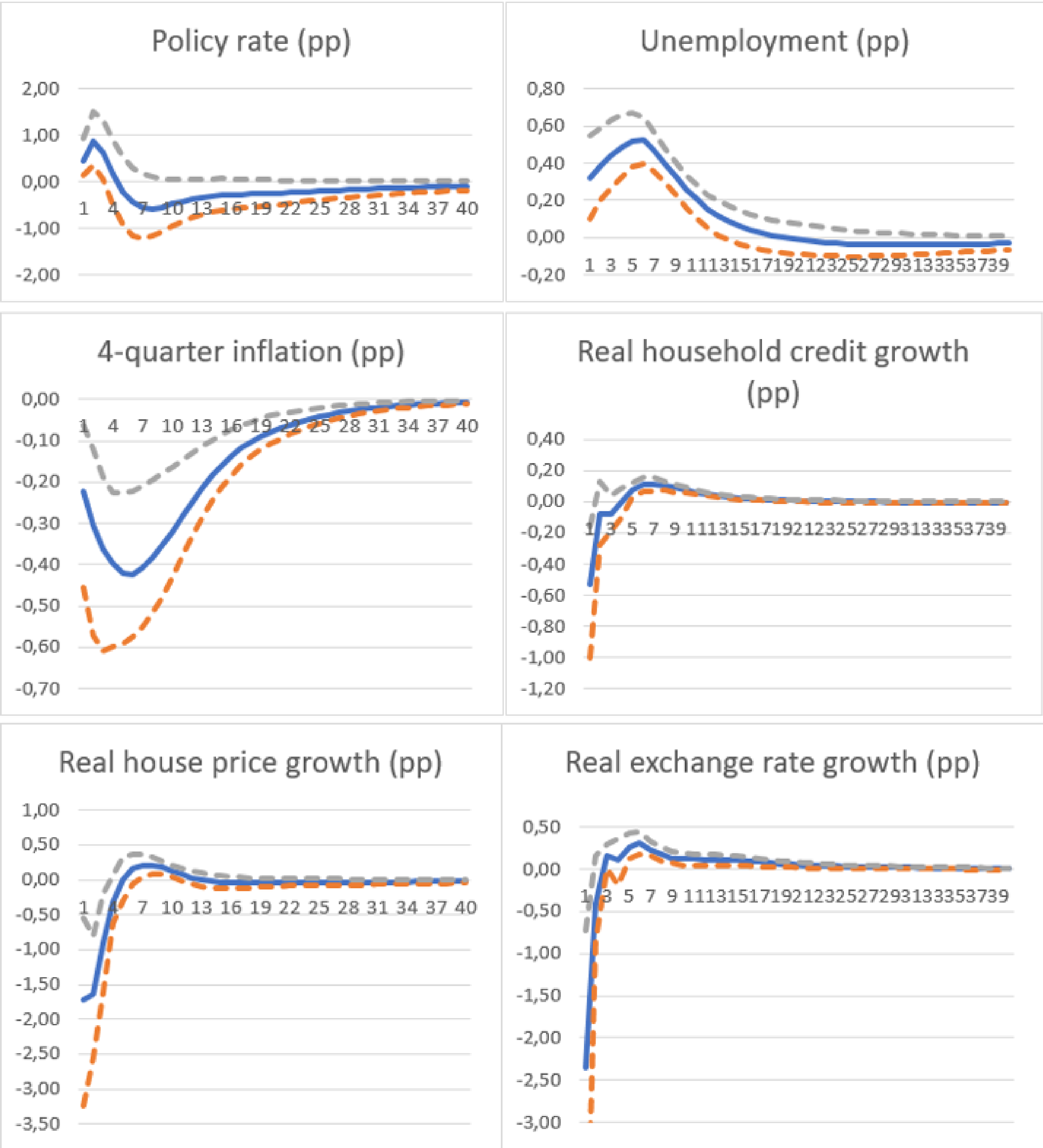

Unemployment(UE)
7
6
5
4
3
2
1
0
01-04-94
01-02-95
01-12-95
01-10-96
01-08-97
01-06-98
01-04-99
01-02-00
01-12-00
01-10-01
01-08-02
01-06-03
01-04-04
01-02-05
01-12-05
01-10-06
01-08-07
01-06-08
01-04-09
01-02-10
01-12-10
01-10-11
01-08-12
01-06-13


Real credit growth (RC)
1,5
1
0,5
0
-0,5
-1
-1,5
01-04-94
01-02-95
01-12-95
01-10-96
01-08-97
01-06-98
01-04-99
01-02-00
01-12-00
01-10-01
01-08-02
01-06-03
01-04-04
01-02-05
01-12-05
01-10-06
01-08-07
01-06-08
01-04-09
01-02-10
01-12-10
01-10-11
01-08-12
01-06-13


Real house price growth (RP)
8
6
4
2
0
-2
-4
-6
01-04-94
01-02-95
01-12-95
01-10-96
01-08-97
01-06-98
01-04-99
01-02-00
01-12-00
01-10-01
01-08-02
01-06-03
01-04-04
01-02-05
01-12-05
01-10-06
01-08-07
01-06-08
01-04-09
01-02-10
01-12-10
01-10-11
01-08-12
01-06-13



The median impulse responses with 16% and 84% quantiles of the distribution for the points on the impulse-response functions is presented in the following figure. The impulse responses show the percentage point deviations for each individual variable.


Policy rate (pp)
2,00
1,00
0,00
-1,00
-2,00
1 4 7 10 13 16 19 22 25 28 31 34 37 40
Unemployment (pp)
0,80
0,60
0,40
0,20
0,00
-0,20
1 3 5 7 9 11131517192123252729313335373 9
4-quarter inflation (pp)
0,00
-0,10
-0,20
-0,30
-0,40
-0,50
-0,60
-0,70
1 4 7 10 13 16 19 22 25 28 31 34 37 40
Real household credit growth (pp)
0,40
0,20
0,00
-0,20
-0,40
-0,60
-0,80
-1,00
-1,20
Real house price growth (pp)
1,00
0,50
0,00
-0,50
-1,00
-1,50
-2,00
-2,50
-3,00
-3,50
1 4 7 10 13 16 19 22 25 28 31 34 37 40
Real exchange rate growth (pp)
0,50
0,00
-0,50
-1,00
-1,50
-2,00
-2,50
-3,00