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NORGES BANK RESEARCH

9 | 2016

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ISSN 1502-819-0 (online)
ISBN 978-82-7553-917-3 (online)

Leaning Against the Wind when Credit Bites Back*

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June 22, 2016

Abstract

This paper analyzes the cost-benefit trade-off of leaning against the wind (LAW) in monetary policy. Our starting point is a New Keynesian Markov-switching model where the economy can be in a normal state or in a crisis state. The set-up enables us to weigh benefits against costs for different systematic LAW policies. We find that the benefits of LAW in terms of a lower frequency of severe financial recessions exceed costs in terms of higher volatility in output and inflation in normal times when i) agents underestimate crisis risk, and ii) the severity of crises is endogenous (i.e. when "credit bites back"). Furthermore, we find that using an asymmetric rule that only includes positive credit growth can reduce the frequency of severe financial recessions even further, but that this comes at the cost of higher volatility in normal times. Finally, we find that LAW policies can lead to relatively higher output volatility in normal times when agents perceive crisis risk correctly because they are already internalizing the risk of lower future consumption by reducing consumption today.

Keywords: *Monetary policy; Financial stability; Leaning against the wind; Markov-switching; Endogenous crisis*

JEL classification: *E12; E52; G01*

1 Introduction

Since the global financial crisis, attention has been devoted to policies that promote financial stability. Empirical literature has found that periods of high credit growth can lead to deeper and more protracted recessions, i.e. that "credit bites back" (Jorda et al. (2013)). Macroprudential policy measures have been introduced in many countries to prevent and mitigate systemic risks related to high growth in credit and asset prices,

*This paper should not be reported as representing the views of Norges Bank. The views expressed are those of the authors and do not necessarily reflect those of Norges Bank. An earlier version of the paper was presented at the Riksbank-BIS Workshop "Integrating financial stability into monetary policy decision-making - the modelling challenges" in Stockholm 23 November 2015. It has also been presented at various seminars and workshops in Norges Bank. We are grateful to the participants at the various seminars and workshops, and Veronica Harrington and Lars Svensson for useful comments.

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and can be considered the first line of defence against financial instability since such tools can be both more granular and targeted to the source of risk. Monetary policy can still play a powerful role by "leaning against the wind" (LAW) as it is transmitted more broadly to all sectors in the economy, also to shadow-banks[1], see Smets (2014) for a broader discussion. Furthermore, there is great uncertainty regarding the effectiveness of macroprudential policy tools and the appropriateness of legal frameworks.

Financial crises are rare events and have historically occurred every 15-20 years on average, see Taylor (2015). LAW policies can potentially lead to a loss of central bank credibility since such events are hard to predict. Justifying tight monetary policy can be difficult since we cannot observe the possible gains in terms of a lower frequency and severity of crises. If interest rates are systematically kept higher than those implied by price stability, inflation expectations can fall and the inflation targeting regime could lose credibility. Many authors have furthermore shown that with long-term debt contracts, raising monetary policy rates to reduce the credit-to-GDP level can have perverse effects since GDP growth falls faster and stronger than credit, see Svensson (2014) and Gelain et al. (2015). However, gains can be high if leaning against excessive financial stability risks can reduce the probability and severity of crises longer down the road. The recent financial crisis showed that monetary policy, or economic policy in general, has limitations when it comes to cleaning up after a crisis has occurred.

This paper will investigate to what extent monetary policy should actively aim at mitigating the build-up of financial imbalances. The question of LAW is only relevant insofar as financial stability risk and inflation are not perfectly correlated. Negative shocks to inflation may give rise to a trade-off in monetary policy because bringing inflation back to target may have to be achieved at the expense of a build-up of financial imbalances. Small open economies are faced with such trade-offs when international interest rates fall, and the central bank has to reduce domestic interest rates to reduce the degree of currency appreciation and lower imported inflation. The open economy dimension also gives rise to a trade-off between stabilizing inflation and output when the economy is hit by a shock to aggregate demand (no divine coincidence between stabilizing inflation and output). This means that a central bank cannot clean up after a crisis has erupted by reducing interest rates without paying attention to inflation. To be relevant for small open economies, we use the estimated model of Justiniano and Preston (2010a,b) as the core model.

In our framework, LAW is motivated by agents underestimating financial stability risks. When aggregate credit is accumulated in the economy, agents do not incorporate the risk this poses to economic developments. We introduce regime-switching into an otherwise standard open economy New Keynesian model. This procedure enables us to analyze economic developments for an economy that occasionally experiences financial headwinds using a relatively parsimonious model. While the financial system and its interaction with economic developments is extremely complex, we simplify the mechanisms to highlight some important policy trade-offs. We model credit developments as a separate block "outside" the core model. Credit only affects the probability of switching to a crisis and the severity of a crisis and does not affect economic developments in nor-

[1]Or "it gets in all of the cracks," as Jeremy Stein puts it in a speech at the "Restoring Household Financial Stability after the Great Recession: Why Household Balance Sheets Matter," research symposium sponsored by the Federal Reserve Bank of St. Louis, February 7, 2013.

mal times. Parameters controlling credit developments, the probability of crisis and the severity of financial recessions are calibrated based on a sample of 22 OECD countries from 1970q1 to 2014q2.

When the economy makes the transition from a normal regime to a crisis regime, aggregate demand is reduced abruptly. The mechanisms behind this aggregate demand shock can be numerous. In Woodford (2012), Curdia and Woodford (2010) and Curdia and Woodford (2009), a similar term can be interpreted as credit spreads, the difference in equilibrium yield between long-term bonds issued by risky private borrowers and those issued by the government. Higher credit spreads make financial conditions worse for borrowers, reducing overall welfare. Aggregate demand can also fall as a result of strained balance sheets. When leverage is high, households, non-financial companies and financial institutions are at higher risk of defaulting. When agents try to de-lever, assets may be sold at fire-sale prices, creating debt-deflation type spirals, see e.g. Lorenzoni (2008), Bianchi (2011) and Bianchi and Mendoza (2013). Consumers reduce consumption in order to strengthen their balance sheets, see Mian and Sufi (2011). The underlying idea is the same as in Woodford (2012): *"The idea of the positive dependence on leverage is that the more highly levered financial institutions are, the smaller the unexpected decline in asset values required to tip institutions into insolvency - or into a situation where there may be doubts about their solvency - and hence the smaller the exogenous shock required to trigger a crisis. Given some distribution function for the exogenous shocks, the lower the threshold for a shock to trigger a crisis, the larger the probability that a crisis will occur over a given time interval."*

We contribute to the literature by investigating systematic LAW policies in a cost-benefit framework. We find that the benefits of LAW in terms of a lower frequency of severe financial recessions exceed the costs in terms higher volatility in output and inflation in normal times when i) agents underestimate crisis risks, and ii) the severity of crises is endogenous, i.e. when "credit bites back". The policy can be implemented by putting less weight on lagged interest rates (which means more aggressive interest rate changes) and by putting positive weight on credit in the Taylor rule. The LAW policy can alternatively be approximated by re-optimizing the weights in the traditional Taylor rule (lagged interest rate, output and inflation), but this policy will not react to shocks to credit. Furthermore, we find that using an asymmetric rule that only includes positive credit growth can reduce the frequency of severe financial recessions even further, but may also put central bank credibility at risk due to higher volatility in normal times and a somewhat lower average inflation. Finally, we find that LAW policies can lead to more output volatility when agents perceive crisis risk correctly. A positive credit shock leads in the latter case to lower output as agents update their perception of risk to include the risk of experiencing lower output and interest rates in later periods. Reacting by increasing interest rates to curb credit growth will lead to even lower output growth.

This paper is close in spirit to Ajello et al. (2015). They study the intertemporal trade-off between stabilizing current real activity and inflation in normal times and mitigating the possibility of a future financial crisis within a simple New Keynesian model with two states, and an endogenously time-varying crisis probability. While they use a two-period set-up, we use an infinite time horizon. Using a longer horizon can reduce the benefits of leaning, since credit growth and crisis probability eventually pick up after a monetary policy tightening aimed at mitigating financial stability risk. This point has been highlighted by Svensson (2016). Like Svensson (2016) and Alpanda and Ueberfeldt (2016)), we assume that a crisis can occur at any point in time. Unlike Ajello et al. (2015) and Alpanda and Ueberfeldt (2016)), we assume that crisis severity is endogenous. This will increase the benefit of leaning in monetary policy. Similar to Ajello et al. (2015) we will assume that private agents underestimate the probability of a crisis. This is in contrast to Alpanda and Ueberfeldt (2016), where agents are rational and perceive risks correctly. We will also investigate the importance of this assumption.

The rest of the paper is organized as follows: In Section 2, we first describe the model and monetary policy rules. In Section 3, we show how we calibrate the channel from credit to the probability and severity of crisis. Baseline results are shown in Section 4. This section also illustrates some of the main trade-offs. The importance of endogenous crisis severity is shown in Section 5. In Section 6 we investigate how the cost-benefit analysis of LAW changes when we allow for the possibility of a non-linear Taylor rule where only positive credit growth induces the central bank to raise interest rates. The role of bias in agents' perceived crisis risk is investigated in Section 7. We conclude in Section 8.

2 Model framework

A parsimonious framework is here introduced to analyze to what extent monetary policy should actively aim at mitigating the build-up of financial imbalances in a flexible inflation targeting regime. To achieve this, we add the possibility of large shocks ("financial stress") controlled by a Markov process in an otherwise standard New Keynesian open economy model. Both the probability and the size of the financial shock is endogenous, and linked to a measure of financial imbalances (credit).

2.1 Core model

As our core model, we will use the small open economy model in Justiniano and Preston (2010a). The model builds on Justiniano and Preston (2010b), Gali and Monacelli (2005) and Monacelli (2005) and allows for habit formation, indexation of prices, labor market imperfections and incomplete markets. This section provides an overview of the key structural equations in the log-linear approximation of the model around a non-stochastic steady state. The reader is referred to Justiniano and Preston (2010a,b) for a more detailed description of the model.

The log-linear approximation of the domestic household's Euler equation is given by

$$c_t - hc_{t-1} = E_t(c_{t+1} - hc_t) - \sigma^{-1}(1-h)(i_t - E_t\pi_{t+1}) + \sigma^{-1}(\hat{\epsilon}_{g,t} - E_t\hat{\epsilon}_{g,t+1}) \qquad (1)$$

where c_t is consumption, i_t is the nominal interest rate, π_t is inflation and $\hat{\epsilon}_{g,t}$ is an exogenous shock to domestic demand. The parameter $\sigma > 0$ is the intertemporal elasticity of substitution and $h \geq 0$ measures the degree of habit in consumption. Goods market clearing implies

$$(1-\alpha)c_t = y_t - \alpha\eta(2-\alpha)s_t - \alpha\eta\psi_{F,t} - \alpha y_t^* \qquad (2)$$

where

$$\psi_{F,t} = (e_t + p^*) - p_{F,t} \tag{3}$$

Equilibrium domestic consumption depends on domestic output (y_t) and three sources of foreign variation: the terms of trade, $s_t = p_{F,t} - p_{H,t}$, world demand (y_t^*) and the law of one price gap ($\psi_{F,t}$), which is the difference between the world currency price (p^*) and the domestic currency price of imports. The parameter α is the share of foreign goods in the domestic consumption bundle (a measure of the degree of openness in the economy) and η is the elasticity of substitution between domestic and foreign goods.

The terms of trade and the real exchange rate (q_t) are linked by the following relationship:

$$q_t = e_t + p_t^* - p_t = \psi_{F,t} + (1-\alpha)s_t \tag{4}$$

The Phillips curve for domestic inflation is given by

$$\pi_{H,t} - \delta\pi_{H,t-1} = \theta_H^{-1}(1-\theta_H)(1-\theta_H\beta)mc_t + \beta E_t(\pi_{H,t+1} - \delta\pi_{H,t}) \tag{5}$$

where

$$mc_t = \phi y_t - (1-\phi)\epsilon_{a_t} + \alpha s_t + \sigma(1-h)^{-1}(c_t - hc_{t-1})$$

Domestic inflation, $\pi_{H,t} = p_{H,t} - p_{H,t-1}$, is determined by current marginal costs (mc_t), expectations about future inflation and lagged inflation (due to price indexation). The parameter θ_H is the Calvo-parameter (the fraction of firms that are not allowed to adjust prices optimally in any period t), ϕ is the inverse Frisch elasticity and β is the household's discount factor.

The Phillips curve for imported inflation is

$$\pi_{F,t} - \delta\pi_{F,t-1} = \theta_F^{-1}(1-\theta_F)(1-\theta_F\beta)\psi_t + \beta E_t(\pi_{F,t+1} - \delta\pi_{F,t}) + \epsilon_{cp,t} \tag{6}$$

where $\pi_{F,t} = p_{F,t} - p_{F,t-1}$ is the increase in the price of imports measured in domestic currency. $\epsilon_{cp,t}$ is a shock capturing inefficient variations in mark-ups. The CPI inflation rate, π_t, is given by

$$\pi_t = (1-\alpha)\pi_{H,t} + \alpha\pi_{F,t} = \pi_{H,t} + \alpha\Delta s_t \tag{7}$$

where $\Delta s_t = \pi_{F,t} - \pi_{H,t}$ is the change in terms of trade.

The uncovered interest parity condition (UIP) gives

$$(i_t - E_t\pi_{t+1}) - (i_t^* - E_t\pi_{t+1}^*) = E_t\Delta q_{t+1} - \chi a_t + \phi_t \tag{8}$$

and the flow budget constraint implies

$$c_t + a_t = \beta^{-1}a_{t-1} - \alpha(s_t + \psi_{F,t}) + y_t \tag{9}$$

where a_t is log real net foreign asset position as a fraction of steady state output. The foreign economy is modeled as a closed-economy variant of the model described in this section.

2.2 Credit dynamics

Credit plays no role in the equilibrium characterization of the core model outlined above. In our model framework, credit is assumed to be frictionless in normal times. This means that there are no direct feedback effects from developments in credit to real economic activity. Developments in credit will serve two purposes in our model: they will determine endogenously (i) the probability and (ii) the depth of a financial crisis.

Following Ajello et al. (2015), we let the 5-year cumulative growth rate in real private credit to the non-financial sector represent the level of financial imbalances in the model. The cumulative growth in real credit, L_t, is given by:

$$L_t = \sum_{s=0}^{19} \Delta log \frac{B_t}{P_t} \approx \Delta log \frac{B_t}{P_t} + \frac{19}{20} L_{t-1} \tag{10}$$

where B_t is the stock of nominal credit and p_t is the price level.

The growth rate of nominal credit depends on a vector of endogenous variables (X_t):

$$\Delta log B_t = \omega_X X_t + \epsilon_{B,t} \tag{11}$$

where ω_X is a vector of parameters. $\epsilon_{B,t}$ captures inefficient shocks to credit.

Inserting (11) into (10) gives us the following expression for the cumulative growth in real credit:

$$L_t = \rho L_{t-1} + \omega_X X_t - \pi_t + \epsilon_{B,t} \tag{12}$$

where $\pi_t = \Delta log \frac{P_t}{P_{t-1}}$ is the inflation rate and $\rho = 19/20$.

2.3 Financial crisis

We introduce the possibility of a financial crisis in the model through Markov switching. Financial crisis is here interpreted as large, but low-probability shocks to domestic demand. More formally, the demand shock, $\epsilon_{g,t}$, in the consumption euler equation (1) consists of two elements: $\hat{\epsilon}_{g,t} = \epsilon_{g,t} - z_t$, where $\epsilon_{g,t}$ is a standard autoregressive demand shock while z_t represents the financial shock:

$$z_t = \rho_{z,t} z_{t-1} + \Omega \kappa_t \tag{13}$$

In normal times, the parameter $\Omega = 0$ and so $z_t = 0$. But the economy may switch to a crisis regime. In that case $\Omega = 1$ and the impulse κ_t matters for the development in aggregate demand. The size of the crisis impulse, κ_t, is modeled as a function of the cumulative growth in credit:

$$\kappa_t = \frac{1}{\rho_\kappa}(1 - \Omega)(\gamma + \gamma_L L_t) + \rho_\kappa \Omega \kappa_{t-1} \tag{14}$$

The parameter γ can here be interpreted as controlling the effect on output during a crisis when $L_t = 0$ (i.e. when the economy initially is in steady state), while the parameter γ_L controls the marginal effect of additional credit on the severity of a crisis. When the economy is in normal times ($\Omega = 0$), the first term on the right-hand side in equation (14) measures the potential size of the crisis shock, which depends endogenously on developments in leverage (L_t). The parameter Ω is controlled by a Markov process. The transition probability matrix for the two regimes is given in Table 1. The probability of

From \ to	Normal times	Crisis times
Normal times	$1 - p_{C,t}$	$p_{C,t}$
Crisis times	p_N	$1 - p_N$

Table 1: Transition probabilities

a transition from normal times to crisis times, $p_{C,t}$, is endogenous and depends on the degree of leverage (L_t) in the economy:

$$p_{C,t} = \frac{exp[\theta_0 + \theta_L L_t]}{1 + \exp[\theta_0 + \theta_L L_t]} \tag{15}$$

2.4 Monetary policy

The monetary authority sets the nominal interest rate in order to minimize its objective function

$$W_0 = E_0 \sum_{t=0}^{\infty} \beta^t (\pi_t^2 + \lambda_y y_t^2) \tag{16}$$

where $0 < \beta < 1$ is the household's discount factor and $\lambda_y = 1$, that is, we attach equal weights to (annualized) inflation and output in the loss function. To simplify, we consider the limiting case when β goes to unity, which transforms the problem to a case where the policymaker minimizes the weighted sum of variances in inflation and output. The optimal policies are restricted to a family of simple Taylor-type rules of the form

$$i_t = \rho_i i_{t-1} + (1 - \rho_i)[\theta_\pi \pi_t + \theta_y y_t + \theta_B \Delta log(B_t)] + \epsilon_{i,t} \tag{17}$$

where $\epsilon_{i,t}$ is a monetary policy shock, $0 < \rho_i < 1$ is the degree of interest rate smoothing while ρ_π, ρ_y and ρ_B are the response coefficients for inflation, output and credit growth respectively.[2]

3 Calibration

3.1 Standard parameters (core model)

We use the estimated parameters in Justiniano and Preston (2010a) to calibrate the core model.[3]

[2] We also tried to include cumulative real credit growth (L) in the monetary policy rule. Similar to Gelain et al. (2015), a positive weight on the real "debt level" in the Taylor rule gave equilibrium indeterminacy. The intuition is that a shock that increases expected inflation moves real debt in the opposite direction. Reacting positively to real debt will in this case cause the real interest rate to decline further, pushing inflation further up.

[3] We have used the median of the posterior in Table 2 in their paper.

3.2 Credit dynamics

The quarterly rate of credit growth, given by equation (11), is assumed to depend on the output gap and the real interest rate. The effect of output and the real interest rate on credit are calibrated in two steps. We first calibrate the effect of output on credit by estimating a simple reduced form equation for quarterly credit growth. We regress quarterly nominal credit growth (C2 households and C2 non-financial enterprises in mainland Norway) on the output gap (HP-filtered real GDP for mainland Norway using $\lambda = 3000$). We estimate the model with 2sls using two lags of the output gap as instruments for the current output gap. Results are displayed in Table A.1. Next, the effect of the real interest rate on credit growth is calibrated to match the response of a monetary policy shock from a structural VAR model, given the effect of output on credit in Table A.1.[4] The response of real credit following a standardized monetary policy shock in the structural VAR and in the model is shown in Figure 1, and the calibrated parameters are reported in Table A.4.

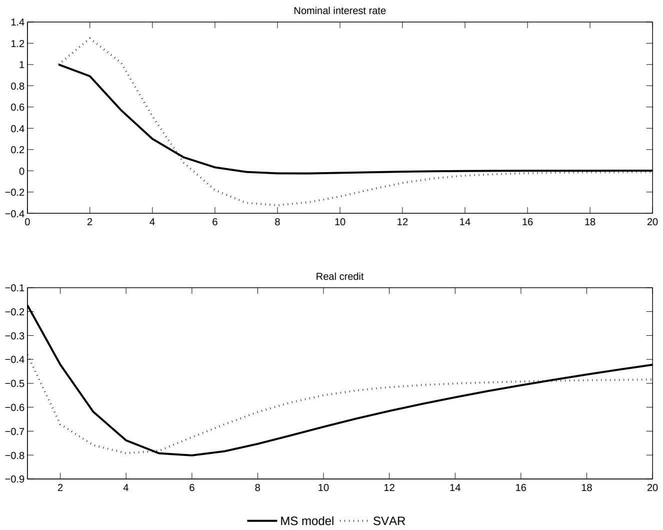

Figure 1: *Response of real credit to a monetary policy shock*

The credit shock $\epsilon_{B,t}$ in equation (11) is assumed to follow an AR(1) process with standard deviation σ_B and persistence ρ_B. We calibrate σ_B and ρ_B to match (i) the standard deviation in quarterly credit growth and (ii) the correlation between credit growth and output in Norway.

3.3 The probability and depth of financial crisis

The probability of switching into a crisis regime and the effect of credit on the severity of a crisis are estimated based on a sample of 22 OECD countries over the period 1975Q1

[4]We used a version of the structural VAR model in Robstad (2014), see Figure 7 in his paper. The VAR model is estimated on Norwegian data.

- 2014Q2[5]. We use the same data as in Anundsen et al. (2016). In addition, we have included the unemployment rate for all countries in the sample. Data on unemployment rates was gathered from FRED (Federal Reserve Economic Data).[6]

The probability of crisis

We estimate a simple logit model for the probability of crisis 1 to 3 years ahead (see Anundsen et al. (2016) for a detailed description of the empirical framework). If we let p_t denote the probability of being in a crisis 1 to 3 years ahead, then the probability of a crisis start in quarter t is approximately $pC_t = \frac{1}{8}p_t$. The probability of a crisis is here assumed to depend on the cumulative growth in real credit over a 5 year period (L_t).[7] The logit specification, is given by $p_t = \frac{\exp(\mu+\mu_L L_t)}{1+\exp(\mu+\mu_L L_t)}$. Estimates for μ and μ_L are given in Table A.2.

Cost of crisis

In order to calibrate the effect on output given a financial crisis we use local projection methods (see Jorda (2005), Jorda et al. (2013), Jorda et al. (2015)). We apply a version of the Bry and Boschan (1971) algorithm to find turning points in the business cycle. We then perform a local projection. Let $\Delta_h y_{i,t(p)+h} = y_{i,t(p)+h} - y_{i,t(p)}$ denote the absolute change in the unemployment rate for country i from the p^{th} peak of the business cycle to period $t(p)+h$, where $h = 1, 2, ..., 20$ is the number of quarters from the peak. Let $L_{i,t(p)}$ denote the cumulative growth in real credit at the peak of the business cycle. The local projection of the recession path is estimated for each horizon $h = 1, 2, ..., 20$ using the following specification:

$$\Delta_h y_{i,t(p)} = \sum_{i=1}^{I} \beta_{i,h} D_{i,t(p)} + \beta_h + \beta_h^L L_{i,t(p)} + \epsilon_{i,t(p)} \tag{18}$$

In equation (18), the parameter β_h is the recession path conditional on $L_{i,t(p)} = 0$, and the coefficients β_h^L measures to what extent leverage at the peak of the cycle affects the recession path. $D_{i,t(p)}$ are country fixed effects defined relative to the US.[8]

Figure 2 and Table A.3 shows the local projection results for the unemployment rate during a financial crisis. In Figure 2, the solid black line shows the increase in unemployment during the financial crisis conditional on cumulative growth in credit at the peak of the business cycle of 13% (average 5-year cumulative credit growth at the beginning of financial crisis in the OECD countries under consideration). The dashed red

[5]Countries included: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Korea, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the UK and US

[6]To get as long quarterly series on unemployment rates as possible, the definition of the unemployment rate differs somewhat between countries. For some countries, registered unemployment was used and for others we have used harmonized rates. Some include the entire population, while some include only the working age population.

[7]We subtracted the mean from this series such that "steady state" cumulative growth in credit is zero.

[8]That is, $D_{i,t(p)} = 1/I$ for $i = 1, ..., I-1$ where I is the US. This allows us to account for country fixed effects while still estimating an overall average constant path (see Jorda et al. (2015)).

line shows the corresponding path for the unemployment rate when cumulative growth in credit is 1 standard deviation higher at the peak (approximately 26%). As we can see, the increase in the unemployment rate during the crisis is higher and more protracted when cumulative growth in real credit is higher. The difference between the two paths are also highly significant, see Table A.3.

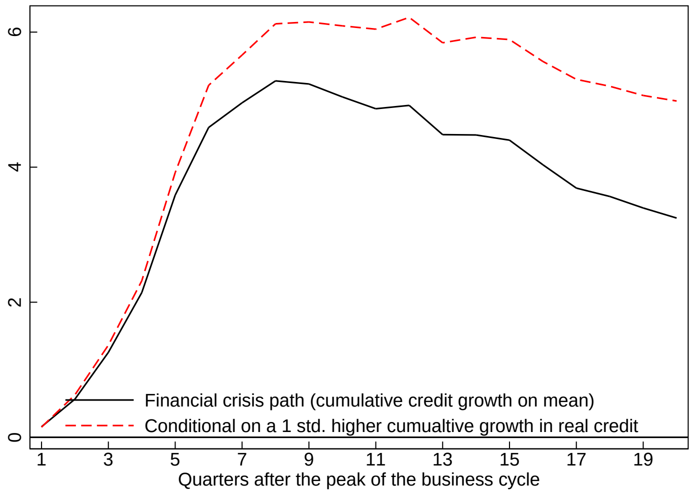

Figure 2: *Local projection for the unemployment rate. Absolute change in the unemployment rate from the start of the recession. Percentage points*

To use these estimates for calibration, we first transform the change in the unemployment rate in Figure 2 to the change in the output gap using Okun's law. Assuming an Okun's parameter of -0.5, the maximum fall in the output gap is approximately 10 percentage points after around two years, while the additional effect of a one standard deviation higher credit level before the crisis is approximately -2 percentage points.

The parameter γ in equation (14) can be interpreted as controlling the effect on output during a crisis when $L_t = 0$, while the parameter γ_L controls the marginal effect of additional credit on the severity of a crisis in the model. Looking at the local projection specification in equation (18), γ is comparable to $\{\beta_h\}$, while γ_L is comparable to $\{\beta_h^L\}$.

To calibrate γ and γ_L, we perform local projections on simulated data from the model (a synthetic local projection). Let $\hat{\theta}_h(\gamma, \gamma_L)$ and $\hat{\theta}_h^L(\gamma, \gamma_L)$ denote the estimated constant term and the estimated effect of credit on a crisis, respectively, from the synthetic local projection (comparable to β_h and β_h^L in equation (18)) for a given γ and γ_L. Similarly, let $\hat{\beta}_h$ and $\hat{\beta}_h^L$ be the empirical counterparts (these are the coefficients in Table (A.3) divided by the Okun parameter). Over a grid of γ and γ_L, we choose the combination that minimizes the following loss function:

$$L(\gamma, \gamma_L) = (\min_h \{\hat{\beta}_h\} - \min_h \{\hat{\theta}_h(\gamma, \gamma_L)\})^2 + (\min_h \{\hat{\beta}_h^L\} - \min_h \{\hat{\theta}_h^L(\gamma, \gamma_L)\})^2 \qquad (19)$$

That is, we choose γ and γ_L such that the quadratic difference between the maximum depth from the empirical and synthetic local projection when $L_t = 0$ and when $L_t > 0$ is minimized. Figure 3 plots the average output path during crisis in the model together with the empirical local projection when the level of credit before the crisis is at its mean and when the level of credit is one standard deviation higher. The model seems to capture both the average depth of financial crisis and the marginal effect of credit well.

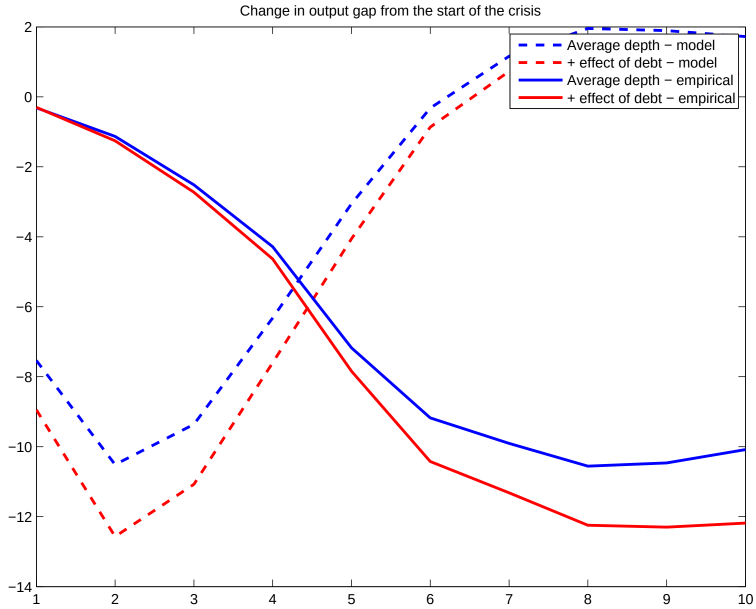

Figure 3: Calibration of crisis severity

4 Should monetary policy lean against the wind?

In our framework, LAW policies are restricted to cases where the central bank systematically responds to developments in credit. The optimality of LAW policies is analyzed within a simple class of Taylor-type rules given in equation (20). The objective function of the central bank, however, is to minimize volatility in output and inflation. Thus, the central bank determines the coefficients θ_i, θ_π, θ_y and θ_B in order to minimize the loss function (16).[9] We assume equal weights on (annualized) inflation and output in the loss function.

4.1 Benchmark: OSR when crises never happen

As a benchmark, we find the optimal simple rule when a crisis never happens (i.e. when the probability of crisis is equal to zero). The optimal parameters in the benchmark case are reported in the second column in Table 2. The optimal rule features a high degree of interest rate smoothing, characterized by a high coefficient on the lagged interest rate. The optimal response to inflation is relatively higher than the response to output, while the coefficient on credit growth is zero to the second decimal. Thus, in a world where a crisis cannot happen, monetary policy should not respond to movements in credit. This is not surprising, given that credit is frictionless during normal times in our model framework.

[9]We restrict ourselves to the limiting case when $\beta = 1$.

4.2 Endogenous crisis and "myopic" agents

We now consider an economy in which a crisis can occur at any point in time following a Markov process. Agents in the model are assumed to be "myopic" in the sense that they underestimate the likelihood of switching to a crisis regime. For simplicity, we assume that the agents' perceived probability of a crisis is zero. The central bank (or the authority that delegates the policy rule to the central bank) is assumed to know the true process for the probability and severity of crises when evaluating the loss function.

In our framework, LAW policies refer to cases where the central bank responds systematically to credit developments. In the following sections, policy rules that include credit growth are referred to as LAW policies. In order to compare the cost-benefit trade-off of leaning against credit developments in a world where a crisis can happen, we will compare the optimized LAW policy with an alternative (re-optimized) policy rule that does not include credit growth (i.e. a constrained version of the LAW policy). We label this the "No LAW" policy rule. It is, however, important to keep in mind that this alternative policy also takes into account that a crisis can happen (i.e. takes tail risk into account). In some sense, this policy can also be interpreted as a LAW policy. For example, if credit and output were perfectly correlated, we could achieve the same loss by increasing the relative weight on output as we would by reacting directly to credit. The LAW and the No LAW policies will therefore only differ insofar as the financial cycle is not aligned with the business cycle.

Optimal simple rules when crises happen endogenously

The optimal parameters in the Taylor rule when a crisis happens and agents ignore the possibility of a crisis are reported in Table 2. The third column reports the optimal parameters when the central bank can respond to all four variables (the LAW policy), while the forth column shows the constrained version where the coefficient on credit growth is set to zero (the No LAW policy).

Table 2: Optimal parameters in simple rules

Parameter	Benchmark	LAW	No LAW
θ_i	0.84	0.55	0.50
θ_π	6.92	3.28	3.37
θ_y	2.45	1.39	1.29
θ_L	0.00	0.18	-

Notes: The optimal coefficients are obtained by minimizing the weighted sum of variances in (annualized) inflation and output.

The optimal policy rule changes in several ways when we include the possibility of an endogenous financial crisis. First, the LAW policy features a lower degree of interest rate smoothing, implying that monetary policy becomes more aggressive. Second, the relative weight on output stabilization increases. Finally, the coefficient on credit growth turns positive, meaning that monetary policy should react systematically to developments in credit. The No LAW changes in a similar way as the LAW policy, but features a lower degree of interest rate smoothing. This implies that the No LAW policy to some degree compensates for the inability to respond to credit by becoming more active.[10]

The optimal interest rate response to a credit shock

Our findings suggest that monetary policy should respond systematically to developments in credit when crises occur endogenously, but by how much? In other words, what is the optimal interest rate response to an exogenous shock that increases credit growth in the economy - affecting both the probability and the severity of a crisis?

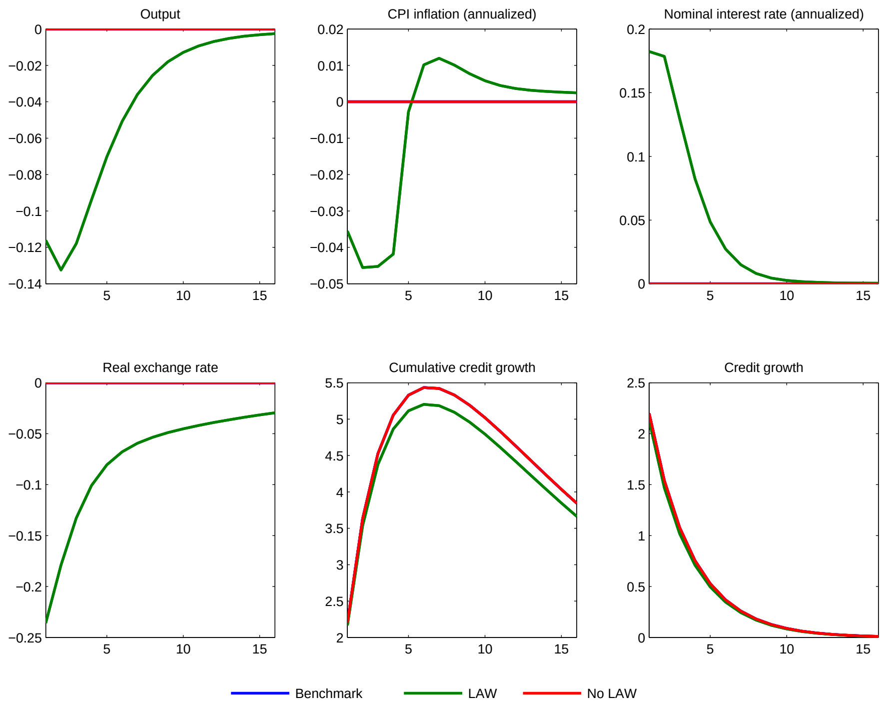

Figure 4: Shock to credit growth in normal times

To illustrate the optimal interest rate response under the LAW policy, Figure 4 plots the impulse responses following a one standard deviation shock to credit growth. Credit growth increases to around 2-2.5 per cent before declining. This causes cumulative credit growth to increase gradually over time, affecting both the probability and the potential severity of a crisis. As credit is frictionless during normal times in our framework, this has no real economic effects under the benchmark monetary policy rule or under the No LAW policy rule. Under the LAW policy, the optimal response to the exogenous shock

[10]How the optimal parameters in the Taylor rule change when we constrain the coefficient on credit growth to zero generally depends on the underlying loss function. For example, if we included interest rate volatility, or changes in the interest rate, in the loss function, the No LAW policy generally compensates for the inability to respond to credit growth by putting relatively more weight on output stabilization in the monetary policy rule (in addition to becoming more active). We can also note that our results seem to be robust (at least qualitatively) to different formulations of the underlying loss function.

in credit is to increase the policy rate by around 15-20 basis points (annualized). This causes a decline in cumulative credit growth of nearly 0.5 percentage points, at the cost of a decline in output and inflation.

The benefit from the LAW policy is twofold. First, by reducing the accumulation of credit in the economy, the probability of a crisis decreases. Second, since the severity of a crisis is endogenous, lower credit growth will also affect the depth of a crisis should it occur. To illustrate the potential benefit arising from the latter, we will now impose a crisis following a shock to credit growth. Figure 5 shows the responses to the same shock as in Figure 4, but this time a crisis occur exogenously after 8 quarters (illustrated by the shaded areas). Comparing the LAW policy with the No LAW policy, it is evident that the LAW policy has a small (albeit economically insignificant) effect on the severity of the crisis. The reduction in cumulative credit growth following the LAW policy is thus not enough to give any significant benefits during the crisis. Comparing the two alternative policy rules with the benchmark policy rule, however, it is evident that taking into account the fact that a crisis can happen can have significant benefits.

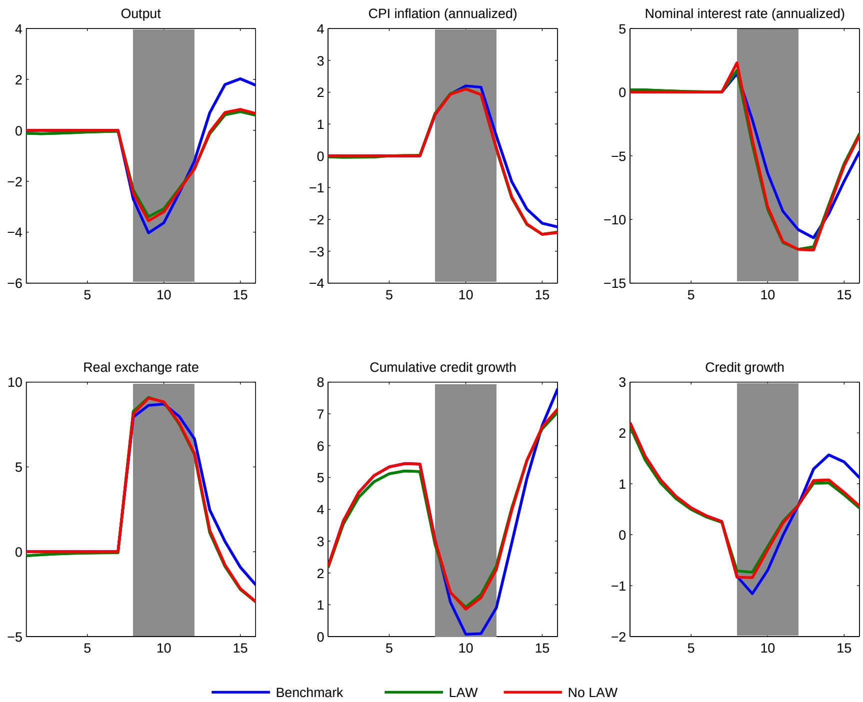

Figure 5: Shock to credit growth followed by a financial crisis after two years

Costs and benefits: Evaluation of the LAW policy

While the previous section illustrated that the potential benefit of the optimal LAW policy (in terms of a reduction in the severity of crises) seems to be small, we need to evaluate the costs and the benefits of the LAW policy in a more dynamic perspective. Taking into account the different shocks that might hit the economy at any point in time, how does the LAW policy affect the variation in inflation and output over time and thus the total loss? And does the LAW policy affect the average frequency of financial crises?

Table 3 reports the model-implied standard deviations of key endogenous variables as well as the total loss and the average frequency of crisis (the unconditional annual probability of a crisis) under the different policy rules. First, comparing the benchmark rule with the re-optimized rules, it is evident that taking into account the fact that crises can happen reduces volatility in output, while the cost in terms of higher inflation volatility is moderate. The LAW policy (No LAW policy) reduces the total loss by 34 per cent (27 per cent) compared with the benchmark policy rule. Lower volatility in credit growth also reduces the annual unconditional probability of a crisis by around 0.3 percentage points.

Table 3: Evaluating LAW policies

	Benchmark	LAW	No LAW
Standard deviation			
Inflation	0.696	0.727	0.718
Output	1.648	1.276	1.360
Interest rate	1.247	1.332	1.383
Real exchange rate	8.282	8.243	8.272
Credit growth	3.118	2.946	3.082
Loss	3.440	2.284	2.508
Frequency of crisis	4.932	4.656	4.716

Notes: Model standard deviations and the frequency of financial crisis are computed by generating 1000 replications of length 100 quarters.

Comparing the LAW policy with the No LAW policy rule, it is evident that responding systematically to credit developments contributes to somewhat lower volatility in output over time and slightly higher volatility in inflation. Thus, the lower volatility during crisis periods following the LAW policy more than compensates for the cost of higher volatility in normal times. The LAW policy contributes to a decline in the total loss by around 10 per cent compared with the No LAW policy, and the average frequency of crisis is marginally lower. Figure 6 plots the distribution of losses under the alternative interest rate policies. Comparing the LAW and the No LAW policy, it is evident that responding systematically to credit developments shifts the distribution of the loss function slightly to the left. The importance of taking tail risks into account in monetary policy decisions, however, is seen by comparing the benchmark policy rule (that ignores the possibility of crisis) with the two alternative rules (which both take into account that a crisis can happen).

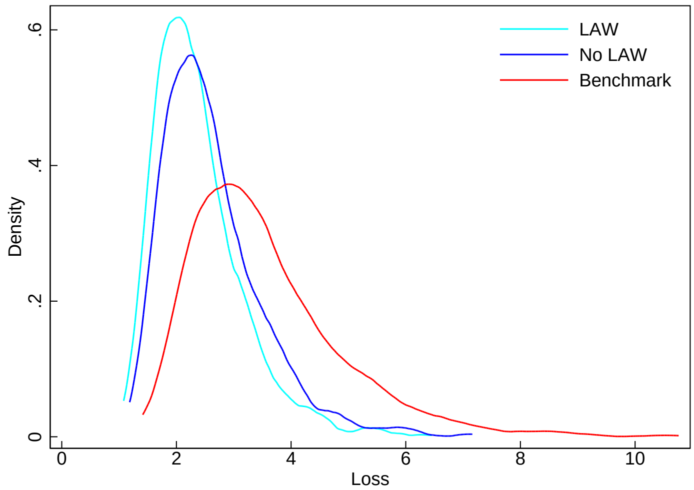

Figure 6: Distribution of losses

5 LAW policies and the endogeneity of crisis severity

A critical assumption in the evaluation of LAW policies is to what extent credit affects the severity of a crisis. While empirical evidence suggests that "credit bites back" (e.g. Jorda et al. (2013)), papers analyzing the optimality of LAW policies have typically assumed that the depth of a crisis is exogenous (e.g. Ajello et al. (2015) and Alpanda and Ueberfeldt (2016)). This implies that the only channel through which monetary policy can affect the crisis risk is through the probability of a crisis.

We have so far assumed that the size of the crisis shock has both an exogenous and an endogenous component that we calibrated to match a reduced form relationship between credit at the onset of the crisis and the development in the unemployment rate during the crisis. To investigate the importance of the assumption of endogenous crisis severity for the optimal interest rate response to credit growth, Table 4 reports re-optimized parameters in the Taylor rule under alternative assumptions about crisis severity.

Panel A reports the baseline results, while Panel B reports the re-optimized parameters under the assumption that the depth of a crisis only depends on developments in credit.[11] In this extreme case, where the severity of a crisis is completely endogenous (no exogenous term), the optimal coefficient on credit growth increases markedly compared with the benchmark. Considering a one standard deviation shock to credit growth, the optimal policy response is now to increase the interest rate by almost 80 basis points (see Figure B.1), and the reduction in accumulated credit now contributes to a less severe crisis (see Figure B.2). A larger reduction in the average frequency of crises is achieved compared to the baseline in Panel A, and the relative decline in the total loss of LAW relative to No LAW is now higher (around 20 percentage points).

Panel C reports the re-optimized coefficients when the severity of a crisis is exogenous. Under the assumption of an exogenous crisis severity, in which the only way for monetary

[11] In this case, we set the parameter γ in equation (14) to zero and re-calibrated γ_L such that the average depth of crisis in the model matched the average depth of crisis from the local projection.

policy to affect crisis risks is through the probability of a crisis, the optimal response to credit developments is zero. Thus, in the case of an exogenous crisis severity, we find no net benefits of leaning against the wind. This corroborates the results found in the literature, e.g. Svensson (2016), Ajello et al. (2015) and Alpanda and Ueberfeldt (2016), who find no (or very small) net benefits of LAW policies.

Table 4: Optimal parameters in simple rules under different assumptions on the cost of crisis

	LAW	No LAW
Panel A: Baseline		
θ_i	0.55	0.50
θ_π	3.28	3.37
θ_y	1.40	1.29
θ_L	0.18	-
Loss	2.28	2.51
Frequency of crisis	4.66	4.72
Panel B: Depth depends only on credit		
θ_i	0.37	0.31
θ_π	2.91	2.70
θ_y	1.14	0.81
θ_L	0.65	-
Loss	4.28	6.01
Frequency of crisis	4.40	4.59
Panel C: Exogenous depth		
θ_i	0.49	0.49
θ_π	3.53	3.53
θ_y	1.56	1.56
θ_L	0.00	-
Loss	3.83	4.83
Frequency of crisis	5.01	5.01

Notes: The table shows optimal coefficients in the policy rule under different assumptions regarding the endogeneity of crisis severity. The optimal coefficients are obtained by minimizing the weighted sum of variances in (annualized) inflation and output.

6 A non-linear LAW policy

So far, we have assumed a symmetric response to credit developments. In practice, however, it may be more natural to think about LAW policies in the context of high credit growth. For example, Norges Bank (2016) states the following:

> "*Conditions that imply an increased risk of particulary adverse economic outcomes should be taken into account when setting the key policy rate. This suggests, among other things, that monetary policy should therefore seek to mitigate the **build-up** of financial imbalances*".

Leaning only against the build-up of financial imbalances implies that monetary policy is asymmetric. This means that interest rates are kept higher than what is justified by the (medium-term) outlook for inflation and output when developments in credit (or other financial indicators) are higher than some threshold. Intuitively, a symmetric LAW policy will have a smaller effect on the average frequency of crisis (since the interest rate responds to both positive and negative credit growth) than a non-linear LAW policy. Some effect is, however, expected also for linear LAW policies since the probability of a crisis is not a linear function. A policy that only leans against high credit growth may become more attractive by reducing the average frequency of financial crises even further.

In this section, we consider a non-linear policy where the central bank only responds to "high" credit growth. To achieve this, we introduce three possible regimes in the model.

1. Normal times. No leaning against the wind
2. Normal times. Leaning against the wind
3. Crisis times

Whether credit growth is positive or negative determines whether the economy is in the leaning state or not, conditional on the economy being in normal times (i.e. there is no leaning during a crisis). The non-linear policy rule is thus given by:

$$i_t = \rho_i i_{t-1} + (1-\rho_i)[\theta_\pi \pi_t + \theta_y y_t + (1-\Omega)\Upsilon\theta_B \Delta log(B_t)] + \epsilon_{i,t} \tag{20}$$

where $\Upsilon = 1$ if credit growth is positive and zero otherwise.

Table 5: Optimal parameters in the non-linear LAW policy

Parameter	Non-linear LAW	Linear LAW	No LAW
θ_i	0.57	0.55	0.50
θ_π	3.64	3.28	3.37
θ_y	1.46	1.40	1.29
θ_L	0.74	0.18	-

Notes: The optimal coefficients are obtained by minimizing the weighted sum of variances in (annualized) inflation and output.

Table 5 reports the optimal parameters in the non-linear LAW policy. Compared with the linear LAW policy, it features an even stronger response to developments in credit. A one standard deviation shock to credit growth now implies an increase in the interest rate of around 100 basis points (see Figure B.3). Table 6 compares standard deviations, the loss and the frequency of crises of the alternative policies. Interestingly, the non-linear LAW policy reduces the annual frequency of crises markedly, by nearly 0.6 percentage points. This contributes to a lower total loss, but the policy comes at a cost of increased volatility in normal times. Overall, the non-linear LAW policy leads to only marginal changes in volatility in output and inflation and the total loss, compared with the linear LAW policy rule.

Table 6: Evaluation of the non-linear LAW policy

	Non-linear LAW	Linear LAW	No LAW
Inflation	0.71	0.73	0.72
Output	1.29	1.28	1.36
Interest rate	1.32	1.33	1.38
Real exchange rate	8.13	8.24	8.27
Credit growth	2.89	2.95	3.08
Loss	2.26	2.28	2.51
Frequency of crisis	4.08	4.66	4.72

Notes: Model standard deviations and the frequency of financial crisis are computed by generating 1000 replications of length 100 quarters.

While a non-linear LAW may seem attractive in terms of reducing the average crisis frequency, it may also come at the cost of reducing central bank credibility. This is not analyzed further in this paper apart from documenting that the ergodic mean of inflation is somewhat lower with the non-linear LAW policy compared with the linear LAW policy rule, see Table A.5.

7 Role of perceived probability of crises

There are many potential sources of real-world frictions (or externalities) that lead agents to take on excessive risks. Similar to Ajello et al. (2015), we have modeled such frictions in a parsimonious way by assuming that agents underestimate the likelihood of a crisis. An interesting question in this context, is how important this assumption is for the optimality of the LAW policies analyzed above. In other words, what happens to the cost-benefit trade-offs of LAW policies when we let the private agents be fully rational (as in Alpanda and Ueberfeldt (2016))?

"Endogenous leaning"

The dynamics in the model economy changes when the agents know the true process for the probability and severity of a crisis, independently of the monetary policy rule. To illustrate this, Figure 7 plots the impulse responses following a one standard deviation shock to credit growth in two different models. The blue lines shows the impulse responses when the perceived probability of crisis is zero, while the green line shows the impulse responses when the perceived probability is positive and endogenous. The coefficient on credit growth in the Taylor rule is zero in both cases, i.e. monetary policy does not systematically respond to credit. Interestingly, a trade-off between stabilizing output and inflation following a shock to credit is now introduced, despite the fact that credit is "frictionless". The reason for this is that agents (to some degree) internalize the increased crisis risk. As both the probability and severity of a crisis increase as a result of the positive credit shock, expected output drops. With forward-looking agents and consumption smoothing, this causes a fall in output today. Similarly, an expected fall in interest rates and an expected depreciation of the real exchange rate causes a depreciation and higher inflation today. Monetary policy balances the trade-off between higher inflation and lower output by increasing the policy rate. The cumulative growth in credit is reduced significantly. In some sense, rational agents “lean against the wind” on their own.

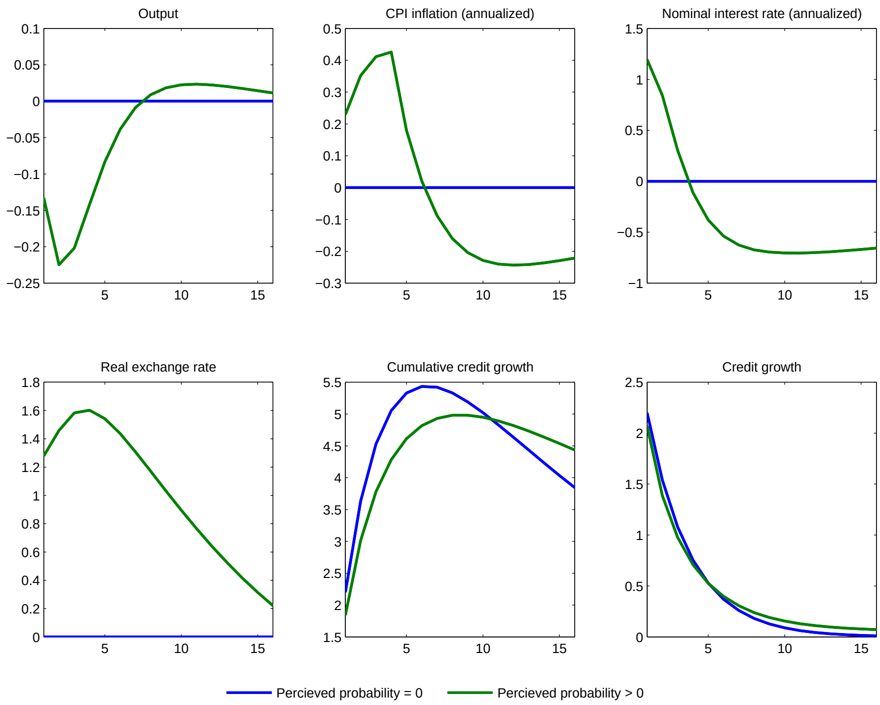

Figure 7: An exogenous shock to credit growth in normal times when agents internalize crisis risks

Cost-benefit trade-off when agents internalize crisis risks

LAW policies may be less desirable when agents internalize crisis risks. On the one hand, LAW policies will reduce both the probability and the severity of a crisis. A LAW policy may also contribute to lower inflation volatility in normal times since the effects on the exchange rate and inflation following a positive shock to credit is dampened by the higher interest rate. This, however, comes at the cost of higher output volatility. Table 7 reports the standard deviations of key variables as well as the total loss under the LAW and No LAW policies found in Section 4.2 when agents underestimate the probability of a crisis and when they internalize it. Comparing the losses under the two assumptions regarding the perceived probability, it is evident that the net benefit of the LAW policy is reduced once agents internalize the crisis risk. While the LAW policy reduces inflation volatility, the relative gain in terms of lower output volatility is reduced. There is still a small net benefit of reacting to credit developments, but it is relatively smaller.

Table 7: Evaluation of LAW policies when private agents internalize crisis risks

	Perceived probability = 0		**Perceived probability > 0**	
	LAW	No LAW	LAW	No LAW
Standard deviation				
Inflation	0.73	0.72	0.71	0.72
Output	1.28	1.36	1.23	1.25
Interest rate	1.33	1.38	1.42	1.46
Real exchange rate	8.24	8.27	8.35	8.62
Credit growth	2.95	3.08	2.68	2.78
Loss	2.28	2.51	2.17	2.26
Frequency of crisis	4.66	4.72	4.65	4.72

Notes: Model standard deviations and the frequency of financial crisis are computed by generating 1000 replications of length 100 quarters.

8 Summary

Whether to use monetary policy to curb high growth in credit and asset prices to contain the risk of financial instability, i.e. to "lean against the wind" (LAW), has been the subject of a contentious debate. In this paper we have investigated to what extent monetary policy should actively aim at mitigating the build-up of financial imbalances. LAW is motivated by agents underestimating financial stability risks. We introduce regime-switching into an otherwise standard open economy New Keynesian model to highlight some important policy trade-offs. Credit affects the probability of switching to a crisis and the severity of a crisis, but does not affect economic activity in normal times. Credit is in this sense frictionless in normal times. When the economy makes a transition from a normal regime to a crisis regime, aggregate demand is reduced abruptly.

We find that the benefits of LAW in terms of lower frequency of crisis and lower volatility during a crisis exceed the costs in terms of higher volatility in output and inflation in normal times when i) agents underestimate crisis risk, and ii) the severity of crises is endogenous. The conclusions are close to Ajello et al. (2015), who also have agents underestimating crisis risk. Our results are similar to Svensson (2016) only when we assume that the severity of crises is exogenous. However, we find evidence that the severity of crises (in terms of higher unemployment) can be linked to the amount of accumulated credit at the onset of crises based on a sample of 22 OECD countries from 1970q1 to 2014q2.

The LAW policies can be implemented by putting less weight on lagged interest rate (which means more aggressive interest rate changes) and by putting positive weight on credit in the Taylor rule and/or by re-optimizing weights on output and inflation. Furthermore, we find that using an asymmetric rule where the central bank only responds to positive credit growth, can reduce the frequency of crisis even further, but may also put central bank credibility at risk due to higher volatility in normal times and a somewhat lower average inflation. Finally, we find that LAW policies can lead to more output volatility when agents perceive the crisis risk correctly. A positive credit shock leads in the latter case to lower output as agents update their perception of risk to include the risk of experiencing lower output and interest rates in later periods. Reacting by increasing interest rates to curb credit growth will lead to even lower output growth today.

References

Ajello, A., T. Laubach, D. Lopez-Salido, and T. Nakate (2015, February). Financial stability and optimal interest-rate policy. Working paper, Federal Reserve Board.

Alpanda, S. and A. Ueberfeldt (2016). Should Monetary Policy Lean Against Housing Market Booms? Working paper 19/2016, Bank of Canada.

Anundsen, A., K. Gerdrup, F. Hansen, and K. Kragh-Sorensen (2016). Bubbles and crisis: The role of house prices and credit. *Journal of Applied Econometrics*. Forthcoming.

Bianchi, J. (2011). Overborrowing and systemic externalities in the business cycle. *American Economic Review 101*, 3400–3426.

Bianchi, J. and E. G. Mendoza (2013). Optimal time-consistent macroprudential policy. Working Paper 19704, National Bureau of Economic Research.

Bry, G. and C. Boschan (1971). *Cyclical Analysis of Time Series: Selected Procedures and Computer Programs*. National Bureau of Economic Research, Inc.

Curdia, V. and M. Woodford (2009). Credit frictions and optimal monetary policy. *BIS Working Papers* (278).

Curdia, V. and M. Woodford (2010). Credit spreads and monetary policy. *Journal of Money, Credit and Banking 42*, 3–35.

Gali, J. and T. Monacelli (2005). Monetary policy and exchange rate volatility in a small open economy. *The Review of Economic Studies 72*(3), 707–734.

Gelain, P., K. J. Lansing, and G. J. Natvik (2015, February). Leaning Against the Credit Cycle. Working Paper 2015/04, Norges Bank.

Jorda, O. (2005). Estimation and inference of impulse responses by local projections. *American Economic Review 95*(1), 161–182.

Jorda, O., M. Schularick, and A. M. Taylor (2013). When credit bites back. *Journal of Money, Credit and Banking 45*(s2), 3–28.

Jorda, O., M. Schularick, and A. M. Taylor (2015). Leveraged bubbles. *Journal of Monetary Economics,*. Forthcoming.

Justiniano, A. and B. Preston (2010a). Can structural small open-economy models account for the influence of foreign disturbances? *Journal of International Economics 81*(1), 61 – 74.

Justiniano, A. and B. Preston (2010b). Monetary policy and uncertainty in an empirical small open-economy model. *Journal of Applied Econometrics 25*(1), 93–128.

Lorenzoni, G. (2008). Inefficient credit booms. *Review of Economic Studies 75*(3), 809–833.

Mian, A. and A. Sufi (2011). House prices, home equity-based borrowing, and the US household leverage crisis. *American Economic Review 101*, 2132–2156.

Monacelli, T. (2005). Monetary policy in a low pass-through environment. *Journal of Money, Credit and Banking 37*(6), 1047–1066.

Norges Bank (2016). Monetary policy report with financial stability assessment 1/16. Technical Report 1.

Robstad, Ø. (2014). House prices, credit and the effect of monetar policy shocks in Norway: Evidence from Structural VAR models. Working paper 5/2014, Norges Bank.

Smets, F. (2014, June). Financial Stability and Monetary Policy: How Closely Interlinked? *International Journal of Central Banking 10*(2), 263–300.

Svensson, L. (2014). Inflation targeting and "leaning against the wind". *International Journal of Central Banking 10*(2), 103–114.

Svensson, L. E. (2016, January). Cost-benefit analysis of leaning against the wind: Are costs larger also with less effective macroprudential policy? Working Paper 21902, National Bureau of Economic Research.

Taylor, A. M. (2015, March). Credit, Financial Stability, and the Macroeconomy. NBER Working Papers 21039, National Bureau of Economic Research, Inc.

Woodford, M. (2012, April). Inflation targeting and financial stability. Working Paper 17967, National Bureau of Economic Research.

Appendix A: Tables

Table A.1: A reduced form equation for quarterly credit growth

	(1)
Output gap	0.395***
	(0.0994)
Constant	0.000
	(0.00119)
R-Squared	0.101
Observations	178

Notes: Asterisks denote significance levels: * = 10%, ** = 5% and *** = 1%.

Table A.2: Estimated parameters in the logit model

	(1)
Cumulative growth in real credit	3.773***
	(0.553)
Constant	-2.027***
	(0.251)
Country fixed effects	Yes
Pseudo R-Squared	0.0941
Observations	3087

Notes: Clustered standard errors are reported in parenthesis below the point estimates, and the asterisks denote significance levels: * = 10%, ** = 5% and *** = 1%.

Table A.3: Local projections for the unemployment rate conditional on financial crisis

	(1)	(2)	(3)	(4)	(5)
Constant	0.162**	0.502***	1.150***	1.968***	3.253***
	(0.0606)	(0.0985)	(0.160)	(0.223)	(0.289)
Cumulative growth in credit	-0.0463	0.487	0.824	1.344	2.568
	(0.516)	(0.839)	(1.359)	(1.902)	(2.462)
Observations	34	34	34	34	34

	(6)	(7)	(8)	(9)	(10)
Constant	3.964***	4.246***	4.433***	4.314***	3.988***
	(0.400)	(0.388)	(0.346)	(0.318)	(0.302)
Cumulative growth in credit	4.800	5.440	6.499**	7.064**	8.093***
	(3.410)	(3.301)	(2.944)	(2.706)	(2.574)
Observations	34	34	34	34	34

	(11)	(12)	(13)	(14)	(15)
Constant	3.687***	3.611***	3.121***	3.030***	2.911***
	(0.307)	(0.365)	(0.446)	(0.492)	(0.531)
Cumulative growth in credit	9.064***	10.03***	10.46**	11.13**	11.46**
	(2.614)	(3.106)	(3.800)	(4.188)	(4.522)
Observations	34	34	34	34	34

	(16)	(17)	(18)	(19)	(20)
Constant	2.506***	2.080**	1.934**	1.730*	1.514
	(0.606)	(0.692)	(0.783)	(0.905)	(0.995)
Cumulative growth in credit	11.77**	12.38*	12.55*	12.82	13.33
	(5.164)	(5.897)	(6.671)	(7.705)	(8.478)
Observations	34	34	34	34	34

Notes: Clustered standard errors are reported in parenthesis below the point estimates, and the asterisks denote significance levels: * = 10%, ** = 5% and *** = 1%.

Table A.4: Calibrated parameters

Parameter	Value	Description
ω_x	0.395	Effect of output on credit growth
ω_r	-0.44	Effect of real interest rate on credit growth
σ_B	0.22	Standard deviation of credit shock
ρ_B	0.7	Persistence of credit shock
ρ	0.95	Coefficient on lagged L
ρ_z	0.5	Persistence of crisis shock (z_t)
ρ_k	0.8	Persistence in crisis impulse (κ_t)
γ	0.4	Exogenous component in crisis severity
γ_L	1.8	Endogenous component in crisis severity
θ_0	-2.027	Constant term in the equation for $p_{C,t}$
θ_L	3.773	Effect of credit on $p_{C,t}$
p_N	0.125	Probability of going from crisis regime to normal times regime

Table A.5: Difference between ergodic mean in asymmetric and symmetric LAW policy

Variable	Difference
Inflation	-0.01
Output	-0.16
Interest rate	0.88
Real exchange rate	-0.46
Credit growth	-0.15
Cumulative credit growth	-2.99

Notes: The table shows the difference between the ergodic mean in the asymmetric and the symmetric LAW policy.

Appendix B: Figures

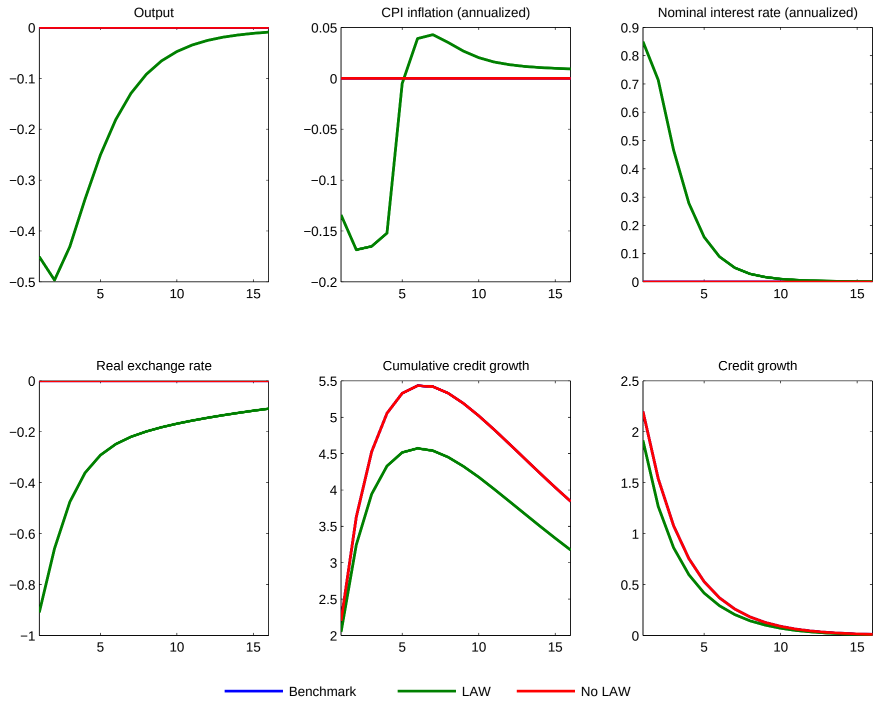

Figure B.1: Impulse responses: Shock to credit growth in normal times. Depth of a crisis depends only on the credit level

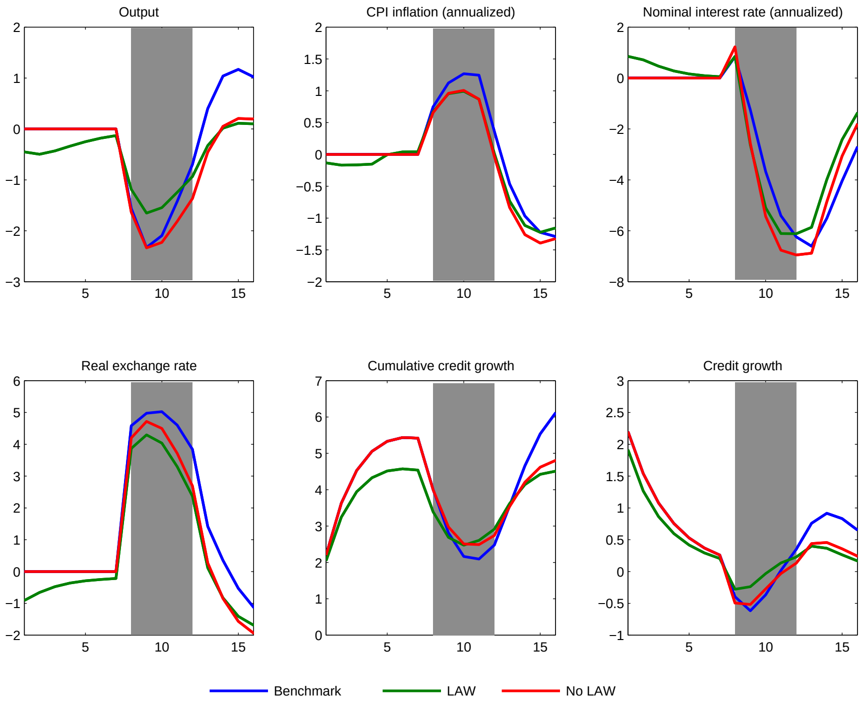

Figure B.2: Impulse responses: Shock to credit growth and an exogenous crisis after 2 years. Depth of a crisis depends only on the credit level

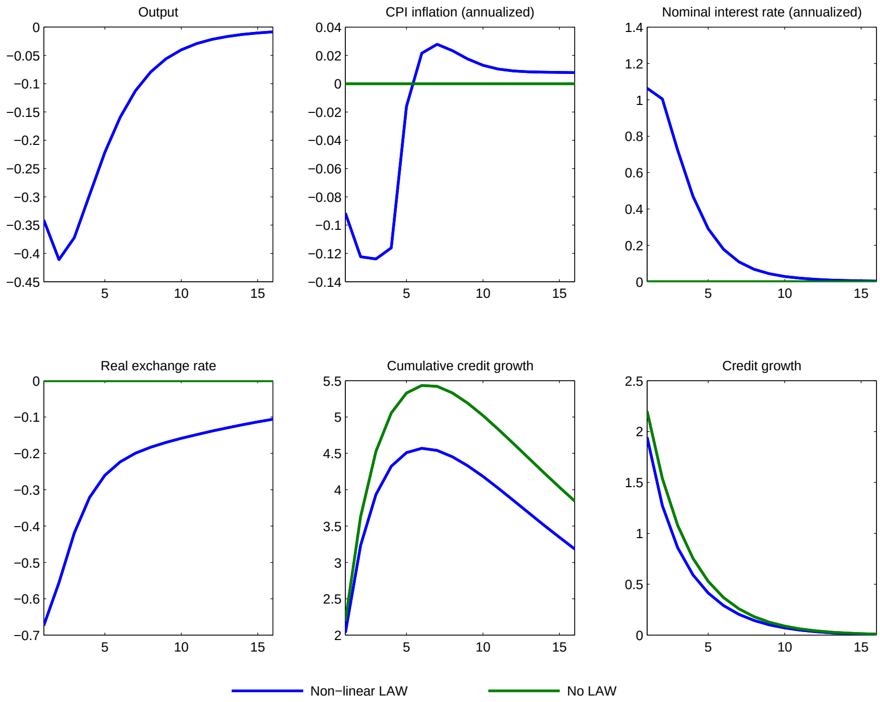

Figure B.3: Impulse responses: Shock to credit growth in normal times. Non-linear LAW policy