Leaning Against the Wind When Credit Bites Back*

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This paper analyzes the cost-benefit trade-off of leaning against the wind (LAW) in monetary policy. Our starting point is a New Keynesian regime-switching model where the economy can be in a normal state or in a crisis state. The setup 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 normal times when the severity of a crisis is endogenous (when "credit bites back"). Our qualitative results are robust to alternative specifications for the probability of a crisis. Our results hinge on the endogeneity of crisis severity. When the severity of a crisis is exogenous, we find that, if anything, it is optimal to lean *with* the wind.

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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

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protracted recessions, i.e., "credit bites back" (Jordà, Schularick, and Taylor 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, and can be considered the first line of defense against financial instability since such tools can be both more granular and targeted to the source of risk. However, there is great uncertainty regarding the effectiveness of macroprudential policy tools and the appropriateness of legal frameworks. 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 and also to shadow banks[1]; see Smets (2014) for a broader discussion.

Financial crises are rare events and have historically occurred every fifteen to twenty 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, Lansing, and Natvik (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 react to financial stability risks and deviate from the policy it would have chosen in the absence of such risks. The question of LAW is only relevant insofar as financial stability risk and

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

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 buildup 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. For the setup to be relevant for small open economies, we use the estimated model of Justiniano and Preston (2010a) 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, which will serve as a proxy for financial imbalances in the model, only affects the probability of a crisis and the severity of a crisis and does not affect economic developments in normal times. Parameters controlling the probability of crises and the severity of financial recessions are calibrated based on a sample of OECD countries.

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 Cúrdia and Woodford (2009, 2010) and Woodford (2012) 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) and Dynan (2012). 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.

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 setup, we use an infinite time horizon. Using a longer horizon can reduce the benefits of leaning, since credit growth eventually picks up after a monetary policy tightening aimed at mitigating financial stability risk. This point has been highlighted by Svensson (2016) and reflects that real credit, which determines the probability of a crisis, is assumed to return to a specific steady-state level in his application. We calibrate the effect of an interest rate increase on credit growth to reflect SVAR evidence for Norway. Like Ajello et al. (2015), we assume that the crisis probability is a function of credit growth over a five-year period. We follow Alpanda and Ueberfeldt (2016), Pescatori and Laséen (2016), and Svensson (2016) in assuming that a crisis can occur at any point in time. Unlike Ajello et al. (2015) and Alpanda and Ueberfeldt (2016), we assume that the 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 aggregate risks correctly, but not their own contribution to that risk.

We contribute to the literature by investigating 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 normal times when the severity of crisis is endogenous (when "credit bites back"). The LAW policy can be implemented by responding relatively more to fluctuations in output and/or by responding directly to household credit growth. Compared with a policy that does not take into account that a crisis can happen, a "benign neglect" policy, the LAW policy contributes to a lower loss and reduced tail risk in the economy. The costs are paid in terms of higher inflation volatility. Our qualitative results are robust to alternative calibrations of the probability of crisis. If, however, the severity of crisis is exogenous, or the effect of credit on crisis severity is very small, the optimal response is to lean *with* the wind. This nests the results found in the literature, e.g., Ajello et al. (2015), Alpanda and Ueberfeldt (2016), Pescatori and Laséen (2016), and Svensson (2016), who find no (or very small) net benefits of LAW policies, and typically assume either no or a very small effect from credit to crisis severity.

The rest of the paper is organized as follows. We begin by establishing empirical evidence to inform us about the link between credit and crisis probability and severity in section 2. This is used when we set up a model for analyzing LAW (section 3) and calibrating it (section 4). In section 5 we present some properties of the calibrated model, while the results of our LAW analysis are in section 6. We end with a section on sensitivity (section 7) and conclusions (section 8).

2. Can LAW Policies Make Sense?

We interpret LAW as monetary policy adjustments where the central bank reacts to financial stability risks and deviates from the policy it would have chosen in the absence of such risks. Two central assumptions must be fulfilled for LAW to be able to bring benefits.

Table 1. Estimated Effects of a Monetary Policy Shock on Real Credit in VAR Studies

Paper	Country	Peak Effect of MP Shock (%)
Goodhart and Hofmann (2008)[a]	Panel	Approx. −1.25
Assenmacher-Wesche and Gerlach (2008)[b]	Panel	Approx. −0.8
Musso, Neri, and Stracca (2011)[c]	US	Approx. −3
Musso, Neri, and Stracca (2011)[c]	EA	Approx. −2
Laséen and Strid (2013)[c]	SWE	Approx. −0.8
Robstad (2014)[c]	NOR	Approx. −0.8
Pescatori and Laséen (2016)[c]	CAN	Approx. −0.8

[a]Based on bank loans to the private sector.
[b]Based on total loans to private non-bank residents.
[c]Based on credit to households.

First, monetary policy must be able to affect the relevant financial variables. Second, financial crises cannot be purely exogenous events. The probability of a crisis and/or the severity of a crisis must be linked to financial imbalances. In this section, we evaluate to what extent these necessary conditions are fulfilled, both based on the existing empirical literature and estimates based on a sample of twenty OECD countries. In our setup, we use the five-year growth rate in real household credit as a measure of financial imbalances (similar to, e.g., Ajello et al. 2015).

2.1 The Effect of Monetary Policy on Credit

The empirical literature has established a clear link from monetary policy to credit. Table 1 provides an overview of VAR estimates of the peak effect on the level of real credit following a 1 percentage point increase in the nominal interest rate.

The peak effect of monetary policy on real credit is similar in magnitude across the different studies. This indicates that monetary policy may play a role in affecting credit developments. Papers focusing on (small) open economies (e.g., Laséen and Strid 2013, Robstad 2014, and Pescatori and Laséen 2016) suggest that the peak effect on real household credit following a monetary policy shock that raises the nominal interest rate by 1 percentage point is around 0.8 percent. The effect is estimated to be larger when considering the United States or the euro area as a whole (Musso, Neri, and Stracca 2011). In our paper, we will make use of the estimates in Robstad (2014), which are in the lower end of the estimates.

2.2 The Effect of Credit on the Probability of a Crisis

There is a general consensus in the literature that excessive credit accumulation is one of the main drivers of financial crisis (see, e.g., Reinhart and Rogoff 2008, Schularick and Taylor 2012, Anundsen et al. 2016, and Jordà, Schularick, and Taylor 2016). We estimate the probability of a crisis based on a panel of twenty OECD countries over the period 1975:Q1–2014:Q2.[2] These are the same data used in Anundsen et al. (2016). In contrast to Anundsen et al. (2016), who estimate the probability of being in a pre-crisis period, we reformulate the model and estimate the probability of a crisis start directly (similar to, e.g., Schularick and Taylor 2012). Our dependent variable takes the value of 1 if there was a crisis start in country i at quarter t and zero otherwise.[3] The probability of a crisis start is assumed to depend on the five-year growth in real household credit (L). Using the logit specification, the probability of a crisis start in country i in quarter t is given by

$$p_{i,t} = \frac{\exp(\mu_i + \mu_L L_{i,t})}{1 + \exp(\mu_i + \mu_L L_{i,t})}, \tag{1}$$

where μ_i are country fixed effects and μ_L is the coefficient on the cumulative credit growth. The estimates we get are shown in table 2.

The estimates suggest that the steady-state (annual) probability of a crisis is approximately 3.3 percent. Further, there is a positive effect of credit growth on the probability of a crisis. A plot of the estimated logit function as a function of cumulative real credit growth can be found in figure 8.

[2] Countries included are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Italy, Japan, Korea, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States.

[3] To avoid post-crisis biases, as discussed in, e.g., Bussiere and Fratzscher (2006), we omit observations for when a given country was in a crisis.

Table 2. Estimated Parameters in the Logit Model

	(1)
Five-Year Real Credit Growth	2.232**
	(1.099)
Constant	−4.792***
	(1.026)
Country Fixed Effects	Yes
Pseudo R-Squared	0.0424
AUROC	0.725
Observations	1,832

Note: Clustered standard errors are reported in parentheses below the point estimates, and the asterisks denote significance levels: * = 10 percent, ** = 5 percent, and *** = 1 percent.

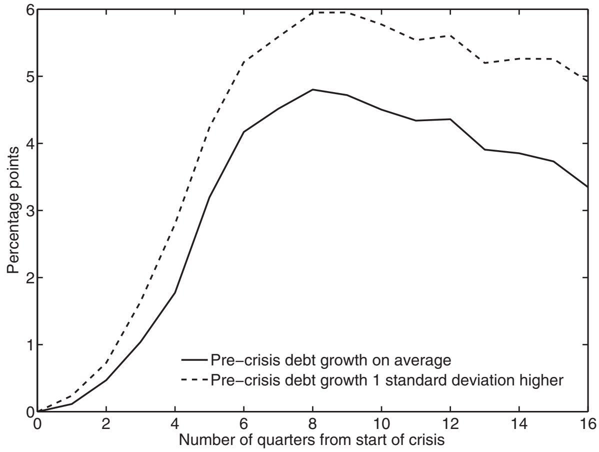
2.3 The Effect of Credit on the Severity of a Crisis

The empirical literature has found that credit accumulation in a boom is important for economic activity during the bust (see, e.g., Jordà, Schularick, and Taylor 2013, 2016 and Hansen and Torstensen 2016). In our framework we are interested in how credit accumulation in the boom affects the path for the output gap during busts. To this end, we use local projection methods (Jordà 2005) to estimate how the five-year growth in real household credit affects the path for the unemployment rate during a financial crisis. We add the unemployment rate to the data used in Anundsen et al. (2016).[4] To keep things simple, we estimate paths only for the unemployment rate during financial recessions (defined as recessions that coincide with a financial crisis within a two-year window).[5] The corresponding effects on the output gap are then calculated based on Okun's law.

[4]Data on unemployment rates were gathered from FRED (Federal Reserve Economic Data). 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; for others, we have used harmonized rates. Some include the entire population, while some include only the working-age population.

[5]Recession dates are based on Hansen and Torstensen (2016).

Figure 1. Change in Unemployment Rate from the Start of the Crisis (percentage points)



Notes: The solid line is the path for the unemployment rate conditional on the five-year growth in household real credit at the peak of financial recessions. The dashed line illustrates the path when the five-year growth in real household credit is one standard deviation higher at the peak.

Figure 1 and table 3 show the local projection results for the unemployment rate during a financial crisis conditional on pre-crisis cumulative credit growth. In figure 1, the solid black line shows the increase in unemployment during a financial crisis conditional on the average five-year growth in real credit at the peak of the cycle. The dashed line shows the corresponding path for the unemployment rate when the five-year growth in household real credit is one standard deviation higher at the peak.[6] The increase in the unemployment rate during a crisis is both higher and more protracted in this case. The difference between the two paths is also significant; see table 3. Our results are in line with the results in Jordà, Schularick, and Taylor (2013) and suggest that "credit bites back."[7]

[6]The average cumulative growth in real household credit at the peak is 11 percent in the data. The standard deviation is about 17 percent.

[7]The magnitude of this effect is, naturally, uncertain. Estimates may differ depending on the number of countries analyzed, the sample period, and the empirical approach used. For example, Jordà, Schularick, and Taylor (2016) document that the buildup of mortgage credit in the boom has become more important for real economic activity during recessions post–World War II.

Table 3. Local Projection for the Unemployment Rate during Financial Crises

Horizon	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Constant	0.0	0.3	0.7	1.1	2.5**	3.5***	3.8***	4.1***
	(0.2)	(0.3)	(0.5)	(0.8)	(1.0)	(0.9)	(0.9)	(0.9)
Five-Year Growth in Real Credit	0.7**	1.5**	3.5***	5.9***	6.0***	6.0***	6.2***	6.6***
	(0.3)	(0.5)	(0.9)	(1.5)	(1.6)	(1.5)	(1.5)	(1.6)
Horizon	**(9)**	**(10)**	**(11)**	**(12)**	**(13)**	**(14)**	**(15)**	**(16)**
Constant	3.9***	3.7***	3.6**	3.6*	3.1	3.0	2.8	2.4
	(1.0)	(1.1)	(1.4)	(1.7)	(1.9)	(2.0)	(2.1)	(2.1)
Five-Year Growth in Real Credit	7.1***	7.3***	6.9**	7.2**	7.4**	8.1**	8.8**	9.0**
	(1.8)	(2.0)	(2.4)	(2.9)	(3.2)	(3.4)	(3.6)	(3.6)
Observations	31	31	31	31	31	31	31	31

Notes: Cluster-robust standard errors are in parentheses. Asterisks denote significance: * = 10 percent, ** = 5 percent, and *** = 1 percent.

3. Model for Analyzing LAW

The previous section shows that LAW may bring benefits: monetary policy can affect credit, and credit has an impact on both the probability and the severity of a financial crisis. We therefore introduce a parsimonious framework in order to analyze to what extent monetary policy should conduct LAW policies within a flexible inflation-targeting regime. To achieve this, we add the possibility of large shocks (interpreted as financial stress) to household consumption demand controlled by a Markov process in an otherwise standard New Keynesian open-economy model. In line with the empirical evidence in the previous section, we will make both the probability and the severity of crises endogenous.

3.1 Core Model

As our core model, we will use the small open-economy model in Justiniano and Preston (2010a). The model builds on Galí and Monacelli (2005), Monacelli (2005), and Justiniano and Preston (2010b) and allows for habit formation, indexation of prices, labor market imperfections, and incomplete markets. The reader is referred to Justiniano and Preston (2010a, 2010b) for a detailed description of the model.

3.2 Financial Imbalances

Credit developments play no role in the model of Justiniano and Preston (2010a). Credit is, however, a key variable in our framework, so we add it alongside the core model.

Credit is meant to proxy for financial imbalances, and it will serve two purposes: it will determine endogenously (i) the probability and (ii) the severity of a financial crisis. We will assume that credit is "frictionless" in normal times, which means that there are no direct feedback effects from developments in credit to real economic activity in normal times.

Following Ajello et al. (2015), we let the five-year growth rate in real household credit represent the level of financial imbalances in the model. We denote it L_t, and it is given by

$$L_t = \sum_{s=0}^{19} (\Delta cr_{t-s} - \pi_{t-s}), \tag{2}$$

where Δcr_t is household credit growth and π_t is the inflation rate.

We assume that the growth rate in household credit depends on a vector of endogenous variables (X_t):

$$\Delta cr_t = \omega_X X_t + \epsilon_{\Delta cr,t}, \tag{3}$$

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

3.3 Financial Crises

We introduce the possibility of financial crises in the model through Markov switching. A financial crisis is here interpreted as a large, but low-probability, shock to domestic consumption demand. More formally, let $\hat{\epsilon}_{g,t}$ be a shock in the consumption Euler equation (see Justiniano and Preston 2010a for derivations):

$$\begin{aligned} c_t - hc_{t-1} &= E_t(c_{t+1} - hc_t) - \sigma^{-1}(1-h)(i_t - E_t\pi_{t+1}) \\ &\quad + \sigma^{-1}(\hat{\epsilon}_{g,t} - E_t\hat{\epsilon}_{g,t+1}), \end{aligned} \tag{4}$$

where c_t is consumption and i_t is the nominal interest rate. The parameter $\sigma > 0$ is the intertemporal elasticity of substitution and $h \geq 0$ measures the degree of habit in consumption. We will assume that the demand shock consists of two elements: $\hat{\epsilon}_{g,t} = \epsilon_{g,t} - z_t$. $\epsilon_{g,t}$ is a standard autoregressive demand shock, while z_t represents a financial shock:

$$z_t = \rho_z z_{t-1} + \Omega\kappa_t. \tag{5}$$

The parameter Ω is controlled by a Markov process. In normal times, $\Omega = 0$ and $z_t = 0$. In crisis times, $\Omega = 1$ and the crisis impulse κ_t matters for aggregate demand. The crisis impulse is modeled as a function of financial imbalances (L_t):

$$\kappa_t = (1 - \Omega)(\gamma + \gamma_L L_t) + \rho_\kappa \Omega\kappa_{t-1}. \tag{6}$$

The parameter γ controls a constant effect on output during a crisis, while the parameter γ_L controls the effect of the initial level of financial imbalances 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 (6) measures the potential size of the crisis shock, which depends endogenously on developments in financial imbalances (L_t). The probability of switching from normal times to the crisis regime is endogenous and given by $p_{C,t}$, defined as

$$p_{C,t} = \frac{\exp[\mu + \mu_L L_t]}{1 + \exp[\mu + \mu_L L_t]}. \tag{7}$$

The probability of returning to normal times is exogenous and equal to p_N.

3.4 Monetary Policy

The monetary authority has the following loss function:

$$W_0 = E_0 \sum_{t=0}^{\infty} \beta^t (\pi_t^2 + \lambda_y y_t^2 + \lambda_i (i_t - i_{t-1})^2), \tag{8}$$

where $0 < \beta < 1$ is the household's discount factor. λ_y and λ_i are the weights on the output gap and the change in the nominal interest rate (annualized), respectively.[8] We set $\lambda_y = 2/3$ and $\lambda_i = 1/4$.[9]

We restrict the central bank's interest rate policy to follow optimal simple Taylor-type rules. The exact form of the rules will be spelled out at the relevant stages.

4. Calibration

For calibration, we use the estimates of the parameter values in Justiniano and Preston (2010a).[10] Table 4 shows the calibrated

[8] Interest rate changes in the loss function are mainly included to make the dynamics of the interest rate under the optimized policy rules more in line with the interest dynamics under estimated Taylor rules. This term was not included in Gerdrup et al. (2016).

[9] These weights have been used by Norges Bank (see, e.g., Norges Bank 2012).

[10] We have used the median of the posterior in table 2 in their paper.

Table 4. Calibrated Parameters

Parameter	Value	Description
ω_x	0.31	Effect of Output on Credit Growth
ω_r	−0.45	Effect of Real Interest Rate on Credit Growth
$\sigma_{\Delta cr}$	0.014	Standard Deviation of Credit Shock
$\rho_{\Delta cr}$	0.2	Persistence of Credit Shock
ρ_z	0.5	Persistence of Crisis Shock (z_t)
ρ_k	0.8	Persistence in Crisis Impulse(κ_t)
γ	0.55	Exogenous Component in Crisis Severity
γ_L	1.75	Endogenous Component in Crisis Severity
μ	−4.79	Constant Term in the Equation for $p_{C,t}$
μ_L	2.23	Effect of Credit on $p_{C,t}$
p_N	0.125	Probability of Going from Crisis Regime to Normal Times Regime

values for the remaining parameters in the model. This section explains how these parameter values were chosen.

4.1 A "Benign Neglect" Policy Rule

In the baseline calibration, we consider an optimal simple rule based on the assumption that crises never happen. That is, using the loss function specified in equation (8), we search for the optimal simple rule in the original Justiniano and Preston (2010a) model.[11] We label this the "benign neglect" policy rule. It is restricted to take the following form:

$$i_t = \rho_i i_{t-1} + (1 - \rho_i)[\theta_\pi \pi_t + \theta_y y_t] + \epsilon_{i,t}, \tag{9}$$

where $\epsilon_{i,t}$ is a monetary policy shock, $0 < \rho_i < 1$ is the degree of interest rate smoothing, and θ_π and θ_y are the response coefficients for inflation and output, respectively.

The optimal parameters in the benign neglect policy rule are $\rho = 0.89$, $\theta_\pi = 6.51$, and $\theta_y = 1.35$. The policy rule features a high degree of interest rate smoothing, and the optimal response to

[11] 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, output, and interest rate changes.

inflation is relatively higher than the response to output. This rule will serve as a benchmark when we later evaluate policy rules that take the risk of financial crises into account.[12]

4.2 Credit Dynamics

The quarterly rate of household credit growth 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 household credit growth.[13] The point estimate of the effect of the output gap on credit growth is reported in table 4. Next, the effect of the real interest rate on credit growth is calibrated to match the response of a monetary policy shock from the structural VAR model in Robstad (2014),[14] given the calibrated effect of output on credit. This ensures that real credit declines about 0.7–0.8 percent in response to a monetary policy shock that raises the nominal interest rate by 1 percentage point at impact.

The credit shock $\epsilon_{\Delta cr,t}$ in equation (3) is assumed to follow an AR(1) process with standard deviation $\sigma_{\Delta cr}$ and persistence $\rho_{\Delta cr}$. We calibrate $\sigma_{\Delta cr}$ and $\rho_{\Delta cr}$ to match (i) the standard deviation in household credit growth and (ii) the correlation between household credit growth and output in Norway.[15]

4.3 The Probability of a Crisis

The probability of a transition from normal times to crisis times ($p_{C,t}$) is assumed to depend on the five-year real growth in household credit (L_t) and is given by (7). We use the estimates documented in section 2.2 to calibrate the parameters μ and μ_L. The probability

[12]The benign neglect rule can be thought of as how policymakers saw the world prior to the global financial crisis from 2007/08.

[13]We regress household credit growth (C2 households) on the output gap (HP-filtered real GDP for mainland Norway using $\lambda = 3,000$). We estimate the model with 2SLS using two lags of the output gap as instruments for the current output gap.

[14]Figure 7 in this paper.

[15]The standard deviation of household credit growth and the correlation with the output gap is empirically (in the model) 1.54 (1.54) and 0.33 (0.38), respectively.

of going from a crisis regime to normal times, p_N, is assumed to be exogenous and calibrated to give an average duration of crisis of two years, requiring $p_N = 0.125$.

4.4 The Severity of a Crisis

In order to calibrate the effect on the output gap in a crisis and how it varies with the pre-crisis credit accumulation, we use the results established in section 2.3. These results indicate that the unemployment rate on average increases by about 5 percentage points during a crisis, while a one standard deviation higher credit accumulation before the crisis increases the unemployment rate by 0.75 percentage points the first two years of the crisis.

We use Okun's law with a parameter of -2 to map the unemployment rate to the output gap. Our results then suggest that the average fall in the output gap during a crisis should be approximately 10 percentage points, while one standard deviation higher credit accumulation before the crisis should make output fall by about 1.5 percentage points more over the first two years of a crisis. With a standard deviation in the five-year growth in real credit of 17 percent, this implies that output falls by $1.5/17 = 0.09$ percentage points more on average during a crisis if the five-year growth in real credit is 1 percentage point higher before the crisis, all else equal. This is in line with the effects of Jordà, Schularick, and Taylor (2013); see the discussion in Svensson (2016, appendix D).

To make the model match the empirical results, we perform local projections on simulated data from the model. The parameters γ and γ_L in equation (6) are then selected to match the results from the empirical projections.[16] The results are shown in figure 2.

[16] Since the output dynamics during a crisis in the model may differ from the implied dynamics illustrated in figure 1, we match the average difference between the output paths over horizon $h = 1, \ldots, H$ in order to capture that the severity of a crisis is both deeper and more protracted when credit growth is high in the boom preceding a crisis. Formally, we let y_h and y_h^L be the implied output paths based on the local projection in figure 1 when credit growth at the peak is on average and one standard deviation higher, respectively, and we let $\hat{y}_h$ and $\hat{y}_h^L$ be the counterparts based on simulations of the model. We choose γ and γ_L to minimize the following loss function: $L(\gamma, \gamma_L) = (\min_h y_h - \min_h \hat{y}_h)^2 + \frac{1}{H}(\sum_{h=1}^{H}(y_h^L - y_h) - \sum_{h=1}^{H}(\hat{y}_h^L - \hat{y}_h))^2$. We use $H = 8$ to be consistent with the assumption of an average duration of crisis of two years.

Figure 2. Output Dynamics during Crises in the Model

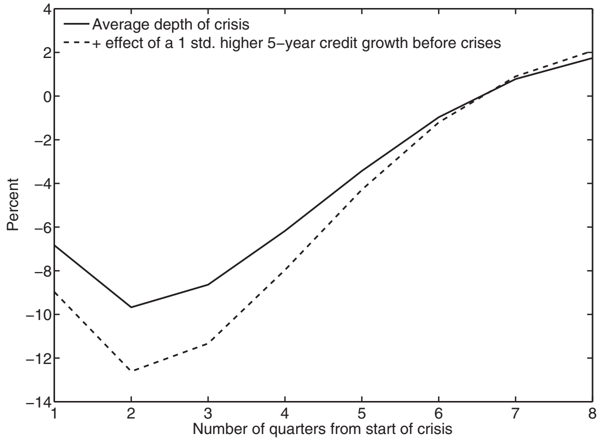


Figure 2 shows that, in the model, the output gap falls by approximately 10 percentage points during a crisis if the five-year real credit growth prior to the crisis is at its average level. Compared with the empirical results in figure 1, the model generates an output path that returns relatively quickly to the pre-crisis level. The average difference between the two paths illustrated in figure 2 is approximately 1.3 percent, somewhat lower than the calibration target of 1.5 percent.

5. Properties of the Calibrated Model

Before we turn to the analysis of policy rules that take the risk of a financial crisis into account, it is useful to consider some properties of the model under the benign neglect policy rule. We ask two questions. First, are there any potential benefits from LAW policies in this economy? Second, how strong is the impact of monetary policy on key variables?

To help answer the first question, table 5 shows statistics from simulations of two versions of the model. First we simulate the benchmark calibrated version, and then a version where crises never happen. The latter simulation can be interpreted as the case where macro stabilization policies have managed to remove crisis risk completely with no side effects to the rest of the economy.

Table 5. Simulations under the Benign Neglect Policy with and without the Possibility of Crises

	Benchmark	If Crises Never Happen
Std. Annual Inflation	1.66	1.59
Std. Output Gap	2.16	1.67
Std. Interest Rate (Ann. %)	3.96	3.17
Std. Real Exchange Rate	8.43	8.19
Std. Credit Growth	1.64	1.58
Loss	100	79.10
Frequency of Crisis (Ann. %)	3.23	0.00

Note: Model standard deviations and the frequency of financial crises are computed by generating 1,000 replications of length 1,000 quarters.

In the benchmark case, the average frequency of crises is about 3.2 percent. The volatility (measured by the standard deviation) of the output gap is reduced by almost one-quarter when crises are removed. The central bank loss is reduced by one-fifth. This implies that crisis risk is an important source of losses for the central bank, and worthy of further analysis. The next section analyzes whether LAW policies can reap any of the benefits from lower crisis risk.

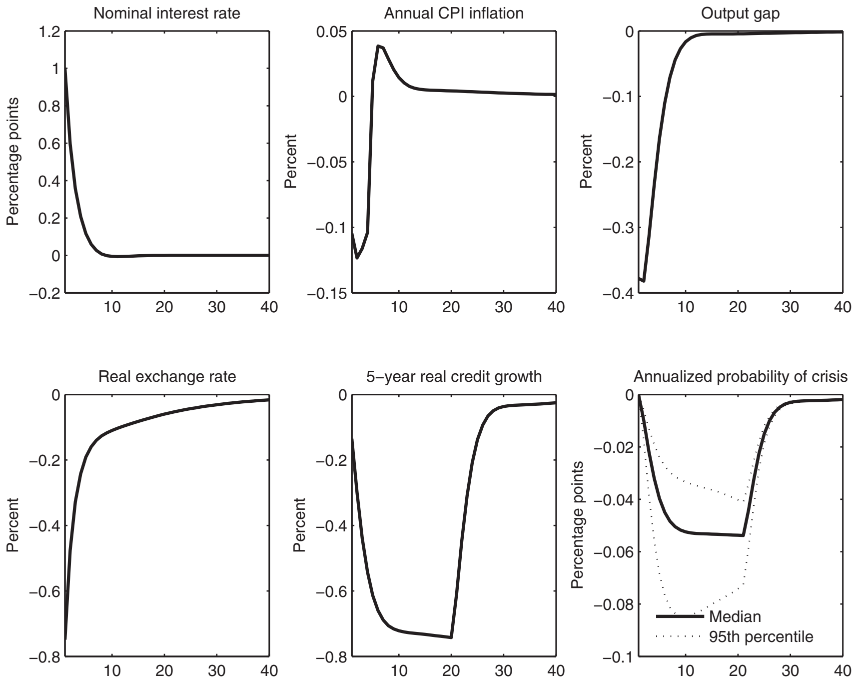
In order to shed light on the second question, we start by plotting the impulse response function (IRF) for key variables to a monetary policy shock; see figure 3.

A monetary policy tightening makes the output gap decline by almost 0.4 percent. Inflation also falls, but it increases in later periods due to the depreciation of the real exchange rate. The five-year real credit growth declines gradually, and the response is much more persistent than for the other variables. The peak impact is at almost –0.8, which was reported as the calibration target in section 4.2.

We also include the IRF for the probability of a crisis. Since this is a non-linear function of credit, the IRF depends on the initial situation of the economy when the monetary policy shock hits.[17]

[17] Here we have simulated the IRF from 50,000 model-generated initial states.

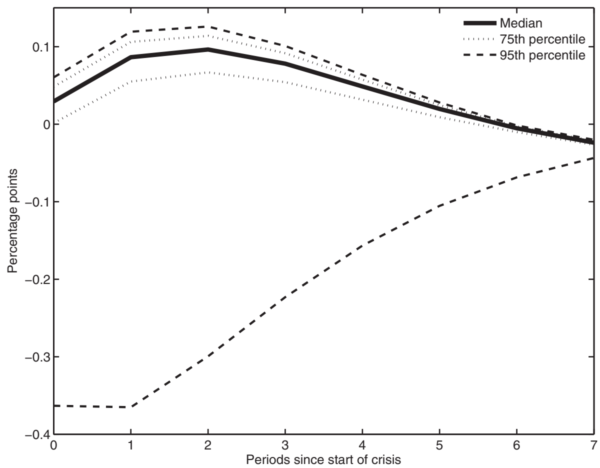
Figure 3. Impulse Response Functions under a Benign Neglect Policy Rule



Naturally, the shape of the IRF for the crisis probability resembles the shape of the IRF for the five-year real credit growth. An increase in the policy rate by 1 percentage point leads to a decline in the probability of a crisis of about 0.05 percentage points. This amounts to a decline in p_C from, e.g., 3.2 to 3.15 percent. A larger response can be expected when credit is initially at a higher level. The lower area of the 95th percentile gives a decline of more than 0.08 percentage points.

It is also relevant to check how monetary policy shocks can affect crisis outcomes. Figure 4 shows how a positive monetary shock is expected to affect the output gap if a crisis was to happen sometime in the two-year period after the shock. This also depends on the initial situation of the economy, so it has a distribution across different initial states. The median response tells us that a contractionary

Figure 4. The Effect of a Positive Interest Rate Shock on the Output Gap during a Crisis (percentage points)



Note: Distribution of crisis outcomes from simulations are based on 50,000 different initial states.

monetary policy shock, through reducing credit, will increase the level of the output gap during crises, i.e., reduce the severity. The largest effect comes in the third period of the crisis, where output is increased by almost 0.1 percentage point. Hence, if the typical fall in output in the third period of the crisis is 10 percentage points, the monetary policy shock lowers it to 9.9 percentage points.

Sometimes the sign shifts, implying that monetary policy makes the output gap even more negative during crises, explaining why the 95th percentile covers area below zero. That happens if a crisis occurs shortly after the monetary policy shock. In such cases the economy is initially weaker due to the monetary policy shock, while the effect of the shock on credit is still quite small.

In summary, monetary policy has the potential to reduce the expected cost of crises, both through a reduction in the probability of a crisis and the potential severity. There will, however, also be a cost associated with such a policy through increased volatility in normal times, especially when there is a trade-off between stabilizing traditional target variables and financial stability.

6. Systematic LAW with Simple Interest Rate Rules

We will now use the model extended with credit and crisis risk to evaluate whether it can be beneficial for the central bank to conduct systematic LAW policies. In particular, we will compare the outcomes under the benign neglect rule and a LAW specification of the following form:

$$i_t = \rho_i i_{t-1} + (1-\rho_i)[\theta_\pi \pi_t + \theta_y y_t + (1-\Omega)\mathbb{1}_{\Delta cr_t > 0}\theta_L(\Delta cr_t - \pi_t)] + \epsilon_{i,t}. \quad (10)$$

θ_L is the response coefficient on real credit growth. We assume an asymmetric response to credit, where $\mathbb{1} = 1$ if real credit growth is positive and zero otherwise. Furthermore, we assume that the central bank does not respond directly to credit growth during crises. The other coefficients have the same interpretation as those in (9).

The motivation for analyzing an asymmetric policy rule is that, in practice, it is natural to think about LAW policies in the context of high credit growth.[18] This means that the interest rate will be kept higher than what is justified by the (medium-term) outlook for inflation and output when credit growth is higher than some threshold. To be pragmatic, we set this threshold to zero (i.e., when real credit growth is above trend).

Table 6 compares the benign neglect policy rule established in section 4 with three different (optimized) policy rules that take the risk of a financial crisis into account.

The first policy rule we consider is labeled *LAW*. In this case, we optimize with respect to all the coefficients in the Taylor rule (10). Introducing endogenous financial crises changes the optimized parameters in several ways. First, the response to output relative to inflation increases and the degree of interest rate smoothing is reduced. Second, the coefficient on credit growth is positive, meaning that monetary policy should react systematically to credit growth.

[18]For example, Norges Bank (2016) states the following: Conditions that imply an increased risk of particularly 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 *buildup* of financial imbalances.

Table 6. Optimal Parameters in Simple Monetary Policy Rules

Parameter	Benign Neglect	LAW	C-LAW I	C-LAW II
ρ_i	0.89	0.88	0.89	0.86
θ_π	6.51	5.80	6.51	4.60
θ_y	1.35	1.45	1.35	1.24
θ_L	—	0.51	0.64	—

Notes: The optimal coefficients are obtained by minimizing the weighted sum of variances in (annualized) inflation, output, and the change in the nominal interest rate (annualized). The weight on the output gap and the change in the nominal interest rate is $\lambda_y = 2/3$ and $\lambda_i = 1/4$, respectively.

The two remaining policy rules we consider are constrained versions of the LAW policy rule. In the first version, we fix the parameters on the lagged interest rate, inflation, and output in the benign neglect policy rule and reoptimize with respect to credit growth only. We label this policy rule *C-LAW I*. In the second version, we set the coefficient on credit growth to zero and reoptimize with respect inflation, output, and the lagged interest rate (*C-LAW II*). These constrained versions of the LAW policy are meant to illustrate the relative importance of introducing credit growth as an additional element in the Taylor rule and changing the relative response to traditional target variables. While the first constrained version of the LAW policy responds relatively more to credit growth, the second version compensates for the inability to respond directly to credit by increasing the relative response to output. It also features a lower degree of interest rate smoothing.

Table 7 evaluates the different policy rules with regard to the variation in some key variables, the total central bank loss, and the frequency of crises (the unconditional crisis probability). First, comparing the benign neglect policy rule with the different LAW rules, the latter lead to reduced volatility in output but increased costs in terms of higher inflation volatility. The unconstrained LAW policy reduces the total loss by approximately 3.8 percent, and the unconditional probability of a crisis is reduced by 6 basis points. Comparing the two constrained versions of the LAW policy, the

Table 7. Standard Deviations of Endogenous Variables, Loss, and the Frequency of Crisis under Different Policy Rules

	Benign Neglect	LAW	C-LAW I	C-LAW II
Std. Annual Inflation	1.66	1.74	1.69	1.75
Std. Output	2.16	1.83	2.01	1.84
Std. Interest Rate (Ann. %)	3.96	3.94	3.90	3.97
Std. Real Exchange Rate	8.43	8.44	8.41	8.45
Std. Credit Growth	1.64	1.56	1.58	1.58
Loss Relative to Benign Neglect	100.00	96.23	97.62	96.88
Frequency of Crises (Ann. %)	3.23	3.17	3.16	3.21

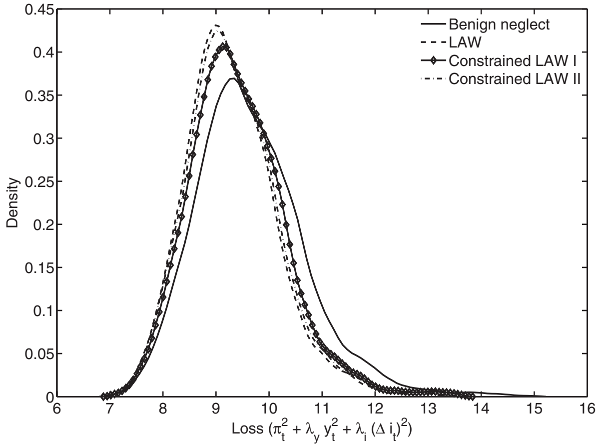
Note: Model standard deviations and the frequency of financial crisis are computed by generating 1,000 replications of length 1,000 quarters.

results may suggest that taking financial stability considerations into account by changing the relative response to traditional target variables generates a relatively large share of the benefits.

Figure 5 shows the distribution of losses under the different policy rules. While the difference in losses between the alternative LAW policies is small, it is clear that taking crisis risk into account when setting the policy rate reduces the magnitude and frequency of tail-risk events.

In order to illustrate the magnitude of the "degree of leaning" under the alternative LAW policies, we simulate the model under the benign neglect rule, while including the different LAW rules as "cross-checks." Table 8 shows the difference in the nominal interest rate implied by the respective LAW policies and the actual policy rule (benign neglect) for different states of the economy. Considering all states of the economy, the LAW policy implies an interest rate that is approximately 18 basis points higher on average. In periods with elevated financial stability risks (i.e., when $L > 0$), the LAW policy implies a 26 basis points higher interest rate on average. The interest rate is even higher (around 50 basis points) when the real economy is strong at the outset (i.e., $y > 0$). In periods when financial stability risks are elevated but the real economy is weak, the LAW policy implies a somewhat more expansionary policy than the

Figure 5. Distribution of Losses under Different Policy Rules



Note: The figure shows the distribution of losses under the alternative policy rules.

Table 8. Difference between the Interest Rate under Alternative LAW Policies and the Benign Neglect Policy Rule for Different States of the Economy (percentage points)

State	Frequency*	LAW	C-LAW I	C-LAW II
All States	1.00	0.18	0.20	0.00
$L > 0$	0.49	0.26	0.25	0.05
$L, y > 0$	0.28	0.48	0.35	0.27
$L > 0, y < 0$	0.21	−0.05	0.12	−0.23
$L < 0$	0.51	0.10	0.16	−0.05
$L, y < 0$	0.29	−0.11	0.08	−0.26
$L < 0, y > 0$	0.21	0.38	0.26	0.23

*The share of time spent in each state.

benign neglect policy. When financial stability risks are relatively low ($L < 0$), the LAW policy implies a 10 basis points higher interest rate. When both financial stability risks are low and the real economy is weak, the interest rate should be 11 basis points lower in the LAW case. The LAW policy rule calls for a higher interest rate (38 basis points) when the real economy is strong ($y > 0$), even though financial stability risks are low.

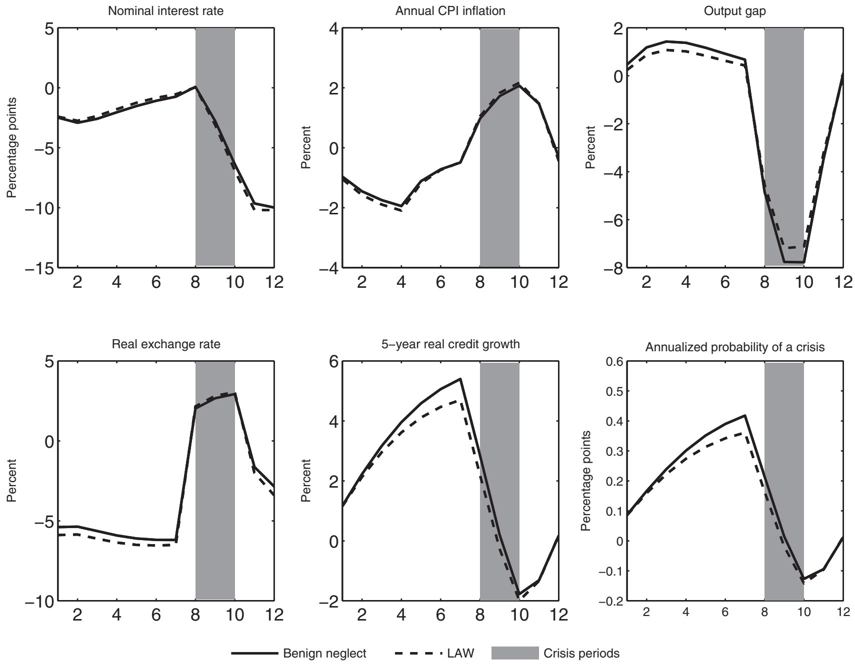
6.1 A Persistent Decline in Foreign Interest Rates and Financial Stability

The persistent decline in foreign interest rates in recent years has caused a trade-off for many small open economies. In this section we illustrate the dynamics of the economy in normal times and in crisis times when the central bank reacts to the decline in foreign interest rates using the benign neglect rule or the LAW rule. To counter the effects of lower foreign interest rates on the real exchange rate, inflation, and output, a central bank will respond by reducing the domestic policy rate. Lower interest rates might in turn fuel the housing market and increase the accumulation of household credit. This may increase the risk of a financial crisis. In such a scenario, a LAW rule that reduces the interest rate less than what is justified only by the medium-term outlook for inflation and output might deliver better outcomes over time.

Figure 6 shows IRFs of a large and persistent negative shock to the foreign interest rate under the benign neglect rule and the LAW rule. Both policy rules imply a big reduction in the nominal interest rate, but the LAW rule keeps the rate slightly higher. The appreciation of the real exchange rate is greater under the LAW rule and the drop in the inflation rate is larger. On the other hand, the LAW rule stabilizes output more than the benign neglect rule. Together with the higher interest rate, this dampens growth in household credit and reduces both the probability and the potential severity of a financial crisis. Following the negative shock to the foreign interest rate, we impose a crisis after eight quarters (illustrated by the shaded area in figure 6). The LAW policy reduces the severity of a crisis in terms of output. First, it contributes by restraining credit growth prior to the crisis. Second, it responds relatively more to the decline in output and features a lower degree of interest rate smoothing.

The IRFs show what happens when the crisis occurs on a prespecified date. Figure 7 shows the entire distribution for GDP under the two policy rules following the negative shock to the foreign interest rate. The width of the distribution is caused by both (i)

Figure 6. Impulse Responses of a Large and Persistent Negative Shock to Foreign Interest Rates



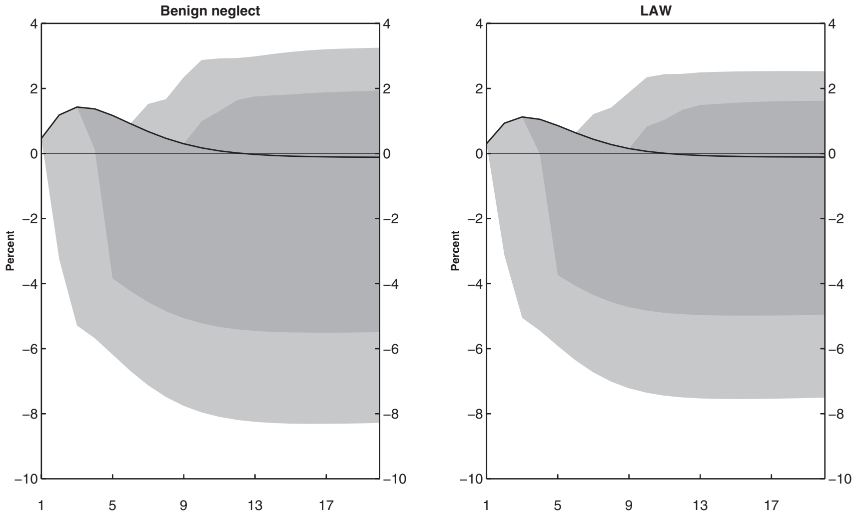
Note: Shaded area indicates a crisis (exogenously imposed after eight quarters).

uncertainty about when the crisis hits and (ii) uncertainty about the severity of the crisis. By following the LAW policy, one reduces the negative tail risk in output by dampening the effect of lower international interest rates on the probability and the potential severity of a crisis.

7. Sensitivity

The parameters governing the probability and the effect of credit accumulation on the severity of a crisis estimated in section 2 are highly uncertain. In this section, we examine how sensitive the optimized response to credit growth in the Taylor rule is to these key parameters.

Figure 7. Distribution of the Output Gap Following a Large, Persistent Negative Shock to Foreign Interest Rate, when Crisis Risk Is the Only Source of Uncertainty after the Interest Rate Shock



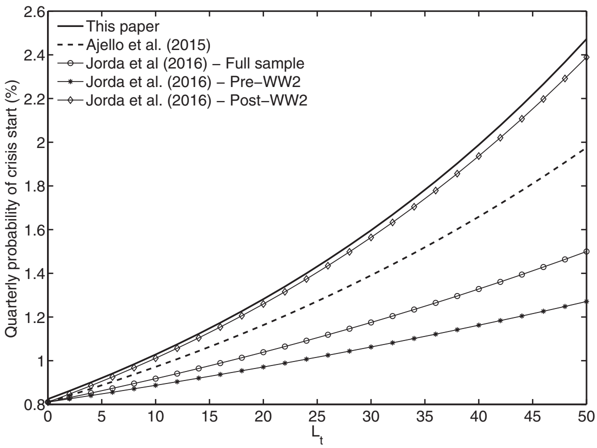
Note: The dark gray area shows the 95th percentile, while the light grey area shows the 99th percentile of the distribution.

7.1 LAW Policies and the Effect of Credit on the Probability of a Crisis

Figure 8 compares the logit function used in this paper with Ajello et al. (2015) and estimates of the effect of mortgage credit on the probability of a crisis for different sample periods reported in Jordà, Schularick, and Taylor (2016).[19] While the steady-state probability used in this paper and the one in Ajello et al. (2015) are similar, the effect of credit on the probability of a crisis is higher in

[19]When plotting the probability functions reported in Jordà, Schularick, and Taylor (2016) (table 4, column 2) we have set the constant term equal to the one used in Ajello et al. (2015). The regressions in Jordà, Schularick, and Taylor (2016) are based on the five-year moving average growth rate in mortgage credit, and not the cumulative growth. This has also been corrected for when plotting the probability functions.

Figure 8. Relationship between Five-Year Real Credit Growth (L) and the Probability of a Crisis Start



our paper. However, Jordà, Schularick, and Taylor (2016) document that the effect of mortgage credit on the probability of a crisis has increased substantially over time. Estimates used in other papers analyzing LAW policies have typically been based on the long-run historical data in Schularick and Taylor (2012) (e.g., Ajello et al. 2015 and Svensson 2016), which starts in 1870, while we use data from the 1970s. As seen in figure 8, the effect of mortgage credit on the probability used in our paper is close to the effect estimated on the post–World War II sample in Jordà, Schularick, and Taylor (2016).

To illustrate how sensitive the optimized response to credit growth in the Taylor rule is to the underlying assumption about the probability of crisis, table 9 shows optimized parameters for different specifications of the crisis probability. We use the specification reported in Ajello et al. (2015) which features a lower effect of credit on the probability of a crisis. We also examine two cases when the probability of crisis is exogenous: one where the steady-state probability is relatively high (approximately 3.2 percent annually[20]) and one where the probability is relatively low (1 percent).

[20] We have used the steady-state probability reported in Ajello et al. (2015) to facilitate comparison.

Table 9. Optimal Simple Rules for Different Crisis Probabilities

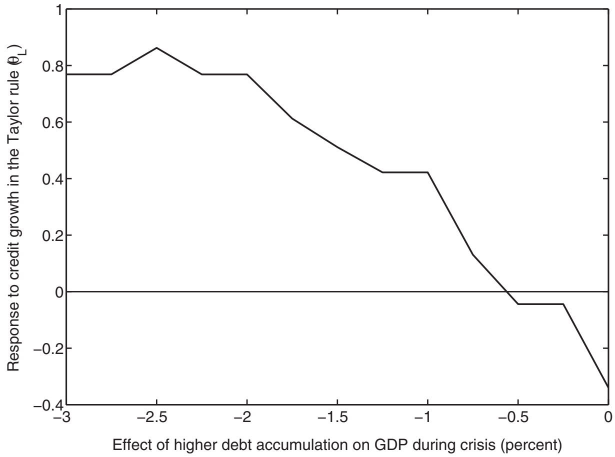
	LAW	Ajello et al. (2015)	Exogenous (3.2% Ann.)	Exogenous (1% Ann.)
ρ_i	0.88	0.87	0.88	0.91
θ_π	5.80	5.17	5.31	6.48
θ_y	1.45	1.30	1.30	1.46
θ_L	0.51	0.28	0.21	−0.03
Loss*	96.23	96.92	98.13	99.77

*Relative to the loss simulated under the benign neglect policy rule (using the same parameters in the logit function for the probability of a crisis).

It is clear that the optimal response to credit growth (and the potential benefit of LAW) depends on the assumed process for the probability of a crisis. First, it depends on the crisis probability level. The coefficient on credit growth is low when the crisis probability is low, both in the case of an endogenous and exogenous crisis probability. In the case of a 1 percent annual exogenous probability of a crisis, the coefficient on credit growth is slightly negative. However, even in this case the relative coefficient on output is somewhat higher than in the benign neglect rule. Second, the steepness of the logit function matters. In Ajello et al. (2015), the crisis probability increases less with accumulated credit growth than in our paper. This is reflected in the coefficient on credit being higher in our benchmark calibration (LAW rule) than that implied by Ajello et al. (2015); see table 9.

While the logit function in our benchmark calibration and the alternative functions shown in this section are linear, or close to linear, introducing more non-linearities may increase the benefits of leaning against the wind to the extent that monetary policy can influence these imbalances. For example, Anundsen et al. (2016) document that the effect of household credit on the likelihood of a crisis increases substantially when it coincides with extreme imbalances (or bubble-like behavior) in the housing market. While such non-linearities (or threshold effects) might be very important, they are difficult to incorporate in the model in a simple way.

Figure 9. The Relationship between the Marginal Effect on GDP during Crisis of a One Standard Deviation Higher Five-Year Growth in Household Real Credit and the Optimal Response to Credit Growth in the Taylor Rule



Note: The optimal policy rules are found by searching over an interval of the marginal effect of credit on GDP during a crisis (in steps of –0.25 percent).

7.2 LAW Policies and the Effect of Credit on the Severity of Crisis

The effect of credit accumulation on the decline in GDP during a crisis was calibrated to match the empirical results established in section 2.3. More precisely, our calibration implies that GDP declines by approximately 1.5 percentage points more on average during a crisis if the five-year growth in real household credit before the crisis is one standard deviation higher. In order to illustrate the sensitivity of our results regarding this calibration, figure 9 plots the relationship between the effect of a one standard deviation higher cumulative real credit growth on GDP during crisis (horizontal axis) and the optimal response to credit growth in the Taylor rule.[21] The optimal response to credit is an increasing function of the effect of credit on GDP during a crisis. If we assume that the severity of a crisis is

[21] The other coefficients in the Taylor rule are also reoptimized in this exercise.

exogenous (this implies that the effect of pre-crisis credit growth on GDP during a crisis equals zero), the optimal coefficient on credit growth is negative instead of positive, implying that monetary policy should, if anything, lean *with* the wind. Thus, in a case where the severity of a crisis is exogenous or the effect of credit on GDP during a crisis is sufficiently small, we find no role for monetary policy to respond countercyclically to credit growth.

8. Conclusion

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 buildup 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. A transition from a normal regime to a crisis regime involves an abrupt reduction in aggregate demand.

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 normal times when the severity of crisis is endogenous (i.e., "when credit bites back"). The LAW policy can be implemented by responding relatively more to fluctuations in output and by responding directly to household credit growth. Compared with a benign neglect policy, the LAW policy rules contribute to a lower loss and reduced tail risk in the economy. The costs are paid in terms of somewhat higher inflation volatility and interest rate volatility. Our qualitative results are robust to alternative specifications for the probability of a crisis. We also show that the optimal interest rate response to credit growth is higher when the severity of a crisis is sensitive to changes in accumulated credit growth. When the severity of a crisis is exogenous, then it is, if anything, optimal to lean *with* the wind. This nests the results found in the literature, e.g., Ajello et al. (2015), Alpanda and Ueberfeldt (2016), Pescatori and

Laséen (2016), and Svensson (2016), who find no (or very small) net benefits of LAW policies, and typically assume either no or a very small effect from credit to crisis severity. This difference underlines the importance of the assumptions concerning the process which determines the severity of a crisis.

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