"Leaning against the Wind," Macroprudential Policy, and the Financial Cycle*

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Should monetary policy lean against financial stability risks? This has been a subject of fierce debate over the last decades. We contribute to the debate about "leaning against the wind" (LAW) along two lines. First, we extend the Svensson (2017) framework to address a critique that the framework does not consider the lower-frequency financial cycle. We then evaluate the costs and benefits of LAW in the extended framework for the euro area and find that the costs outweigh the benefits. Second, we assess the costs and benefits of monetary and macroprudential policy. We find that macroprudential policy has net marginal benefits in addressing risks to financial stability in the euro area, whereas monetary policy has net marginal costs. This would suggest that an active use of macroprudential policies targeting financial stability risks would alleviate the burden on monetary policy to "lean against the wind."

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1. Introduction

This article focuses on the long-running debate on whether and, if so, to what extent monetary policy should "lean against the wind" by addressing financial imbalances in addition to its inflation objectives.[1] In other words, it focuses on whether central banks should lean against the financial cycle by tightening monetary policy more than a pure inflation-targeting rule would prescribe in order to curtail asset prices and credit growth in economic upswings, and vice versa in downturns. Furthermore, it considers to what extent macroprudential policy, one of the key policy tools used more actively in the aftermath of the GFC, could help alter this tradeoff and potentially alleviate the need for monetary policy to "lean against the wind."

We contribute to this debate by analyzing the cost and benefits of monetary policy "leaning against the wind" in the euro area. Furthermore, we take the financial cycle into account in our assessment and, last but not least, we bring macroprudential policy into the picture. Our work is related to three different strands of the literature. First, it relates to the extensive literature on whether monetary policy should "lean against the wind." Second, it relates to the literature on financial crises, and third, to the literature on macroprudential policy.

The debate on whether to use monetary policy to address risks to financial stability, or to "lean against the wind," has been going on in policy and academic circles for at least two decades in two distinct stages. The first stage can be traced back to the empirical findings of Bernanke and Lown (1991) and Borio, Kennedy, and Prowse (1994), who documented a positive association between large fluctuations in equity and real estate prices and those in real economic activity. During this first stage, which lasted until the GFC, the prevailing view was that monetary policy should respond to fluctuations in asset

[1]See Taylor (2007) for a discussion of the implications of monetary policy for financial stability before the global financial crisis (GFC), and International Monetary Fund (2019) and Rajan (2013) highlighting the risks of low interest rates after the GFC.

prices only to the extent that they affect forecasts of inflation or the output gap.[2]

This view was based on two main arguments:[3] first, the early identification and precise measurement of price bubbles in real time was difficult, if not outright impossible; second, even if such price misalignments were observed, it was argued, monetary policy would not be able to deal with them adequately. This was because the interest rate adjustments necessary to contain asset price bubbles could, as a side effect, trigger bubbles in other asset classes and instabilities in aggregate demand.

This view was not shared by everyone. Cecchetti and others called for a more active role for monetary policy in addressing financial stability risks.[4] They argued that if expected inflation were to remain unaffected by an asset price bubble, which would be the case if the bubble did not last for too long, then reacting only to expected inflation would not prevent bubble-induced macroeconomic volatility.

Notably, in the pre-crisis stage, the debate neither centered on the role of excessive credit or risk-taking[5] in fueling asset price bubbles, nor did it consider the role of macroprudential policies.

This changed dramatically in the aftermath of the financial crisis, which ushered in the second stage of this debate. In this second stage, the focus first turned towards credit-fueled asset price bubbles.[6] These price misalignments are especially harmful because they generate feedback loops in financial markets that can considerably exacerbate systemic risk and financial instability.[7]

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[2]See, e.g., Bernanke and Gertler (1999, 2001) and Kohn (2006, 2008).

[3]See Constâncio (2018) and Filardo and Rungcharoenkitkul (2016).

[4]See Borio, English, and Filardo (2003); Borio and Lowe (2002b); Cecchetti et al. (2000); and Cechetti, Genberg, and Wadhwani (2002).

[5]Borio and Zhu (2012) highlighted the importance of bank risk-taking in the transmission of monetary policy. Di Maggio and Kacperczyk (2017) find evidence of risk-taking in a low interest rate environment for the U.S. money fund industry, and Lian, Ma, and Wang (2019) find that investors "reach for yield" when interest rates are low and propose mechanisms related to investor psychology.

[6]See Brunnermeier, Rother, and Schnabl (2017); Brunnermeier and Schnabel (2016); and Jordà, Schularick, and Taylor (2015a, 2015b) for the debate.

[7]Biljanovska, Gornicka, and Vardoulakis (2019) show that a rational bubble relaxes collateral constraints and, as a consequence, induces more borrowing and higher asset prices, and amplifies downturns. Models of boundedly rational

Second, the debate has focused on how to tackle such imbalances in the most effective manner. The severe consequences of credit-fueled asset price bubbles called for the development of new policy instruments tailored to containing systemic risk, i.e., macroprudential policy. A discussion has also emerged on whether monetary policy should coordinate with macroprudential policy to jointly safeguard financial stability. This coordination would be predicated on the strong mutual dependencies between the two policy functions and reflect uncertainty about whether macroprudential policy can fulfill all its objectives.

Broadly speaking, two opposing viewpoints have been put forward, calling for either (i) two separate policy functions, which would keep the pre-crisis, price-stability-oriented, monetary policy frameworks largely unchanged,[8] or (ii) fully merging monetary and macroprudential policy.[9]

The dominant view in the post-crisis stage still prescribes that monetary policy should not respond to financial stability concerns. The reason is now, however, different: the new macroprudential policies are deemed the most effective tool for ensuring financial stability, because they can directly restrain excessive leverage or risk-taking.[10]

According to Smets (2014), however, the need to incorporate to some extent financial stability concerns into monetary policy objectives hinges on (i) the effectiveness of macroprudential policies (e.g., the ability to manage the financial cycle); (ii) the extent to which monetary policy (including conventional and unconventional measures) can be a source of financial instability—for example, by incentivizing risk-taking; and (iii) the extent to which monetary policy

bubbles based on heterogeneous beliefs confirm the higher price volatility and the difficulty to predict them (Scheinkman and Xiong 2003; Xiong 2013). More recently, Schuler and Corrado (2019) analyzed policy in a model with boundedly rational bubbles and found that macroprudential policy is more effective in addressing the externality than monetary policy.

[8]See, e.g., Bean et al. (2010).

[9]See, e.g., Brunnermeier and Sannikov (2013).

[10]The following studies document the usefulness of macroprudential policies in moderating systemic risk and thus complementing monetary policy in the domain of financial stability: Angelini, Neri, and Panetta (2012); Angeloni and Faia (2013); Bean, Clerc, and Mojon (2012); Christensen, Meh, and Moran (2011); Darracq Pariès, Kok, and Rodriguez-Palenzuela (2011); Korinek and Simsek (2016); and Lambertini, Mendicino, and Punzi (2013).

can remain independent from financial stability concerns, especially in crisis times.[11]

The strand of literature on model-based evaluations of LAW is most closely related to our contribution. On the one hand, Svensson (2017) finds that it is not advisable to use LAW. In the Svensson framework, assuming an inflation-targeting central bank, the cost of LAW is measured by the increase in unemployment following a monetary policy tightening, and benefits are related to a lower probability and severity of financial crises. Svensson argues that LAW not only has a cost in terms of a weaker economy if no crisis occurs but also substantial costs in terms of higher unemployment going into the crisis due to the policy. The empirical analysis of Svensson concludes that the marginal costs of LAW far exceed the benefits. In other words, the cost of higher unemployment as a result of the monetary policy tightening far outweighs the benefits of the reduced probability and severity of financial crises.

On the other hand, there are a range of studies exploring whether optimal policy should be "leaning against the wind." Most of them find small positive effects of LAW by monetary policy using small-scale models. In one of these studies, Gerdrup et al. (2017) base their analysis on a standard small New Keynesian model with regime switching. Debt dynamics are implemented ad hoc and the optimal rule is found by optimizing over the coefficients of the policy rule. Ajello et al. (2019) analyze the tradeoff in a stylized two-period model and find that the optimal monetary policy response to financial conditions is very small. Laséen, Pescatori, and Turunen (2017) use a New Keynesian framework with endogenous systemic risk to scrutinize optimal policy responses. They find that benefits from LAW are small and can also be negative in the case where the policy is implemented and the financial sector is in a fragile state.

Related to this, Svensson's conclusions have been criticized by the Bank for International Settlements (BIS) and others for not properly accounting for systemic risk and the persistence of the financial cycle, which risks ignoring the long-lasting effects on the

[11] An extended monetary policy mandate including financial stability concerns, as a complement to macroprudential policies, can help prevent the buildup of excessive debt overhangs in pre-crisis periods. Thereby, it could alleviate the need for monetary policy to engage in post-crisis resolution policies.

real economy that financial crises may have.[12] Accounting for these elements, it is argued, would create a case for a more active use of monetary policy to lean against the financial cycle. For instance, Filardo and Rungcharoenkitkul (2016) use a stylized model of the economy with a Markov-switching financial cycle and a macroeconomic block. Optimal monetary policy in this environment dampens the financial cycle.

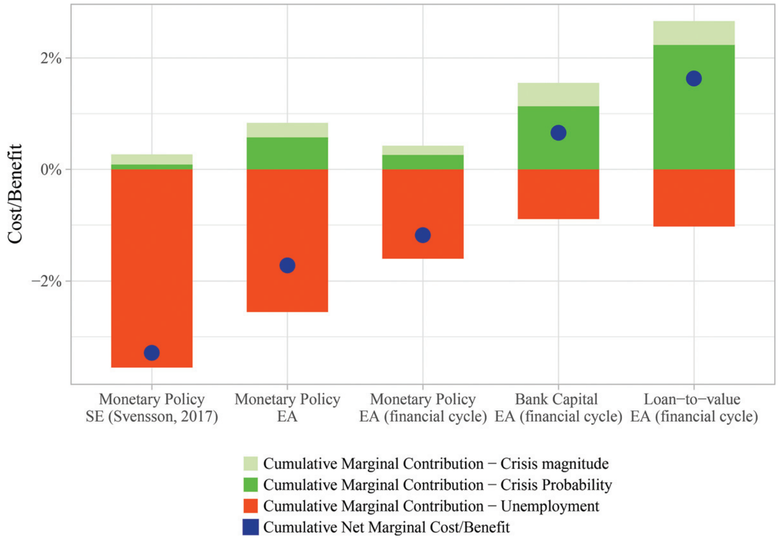
Contributing to this literature, we have recalibrated Svensson's model for the euro area. Furthermore, we account for the critique of the BIS by modifying the Svensson framework to take into account the financial cycle. We do this by making the probability of a crisis start dependent on a financial cycle early-warning indicator. To calibrate the Svensson model for the euro area and take into account the financial cycle, we change two parts of the framework. The dynamic stochastic general equilibrium (DSGE) model for the euro area of Darracq Pariés, Kok, and Rodriguez-Palenzuela (2011) is used to conduct the policy experiments, and the probability of crisis is estimated on the European financial crisis database by the European Systemic Risk Board (ESRB) (Lo Duca et al. 2017). Furthermore, we incorporate macroprudential policies into the framework to help assess whether such policies are more efficient for addressing financial stability risks than a LAW monetary policy.

Our findings suggest that (i) even when taking into account the more persistent financial cycle, LAW by monetary policy does not yield net benefits for the euro area, and (ii) the benefits of using macroprudential policies (in the form of capital and loan-to-value (LTV) ratio requirements) to address financial stability risks outweigh the costs.

These findings are summarized in figure 1. The figure shows that the recalibration of the model for the euro area and taking into account the financial cycle comes to the same conclusion as Svensson does for Sweden; namely, that LAW is associated with substantial net marginal costs (though slightly lower than the original Svensson result; see third bar from the left). Turning to macroprudential policy, we focus on two measures: a permanent 1 percentage point (pp)

[12] See, e.g., Adrian and Liang (2016); BIS (2016); Filardo and Rungcharoenkitkul (2016); Gourio, Kashyap, and Sim (2017).

Figure 1. Comparing the Cost and Benefits of Monetary and Macroprudential Policy "Leaning against the Wind"



increase in bank capital requirements and a permanent 1 pp tightening in LTV requirements. When modifying the model this way, we observe (fourth and fifth bar) that these measures are more effective in reducing the probability and severity of financial crises (marginal benefits) and that the negative impact on unemployment is lower (marginal costs) than a monetary policy that tries to address financial stability risks. Overall, the marginal benefits of macroprudential policy outweigh the marginal costs. These findings would suggest a meaningful role for macroprudential policies in complementing monetary policy and helping alleviate the burden on monetary policy to lean against financial stability risks.[13]

The article is structured as follows: Section 2 describes the Svensson framework underlying our analysis throughout. Section 3

[13]In the context of the euro area, the relative effectiveness of macroprudential policy to tackle the buildup of financial stability risks may be even more pronounced due to the fact that, in a monetary union, a single monetary policy is not well suited to deal with financial imbalances building up at the national level. Such imbalances are indeed better tackled with targeted national macroprudential measures (Darracq Pariès, Kok, and Rancoita 2019).

takes Svensson's analysis for monetary policy to the euro area and describes our extension of the Svensson model to consider the financial cycle. Section 4 analyzes macroprudential policy in the extended framework. Section 5 carries out robustness checks and section 6 discusses the results. Finally, section 7 concludes.

2. Svensson Framework

We base our calculations on the framework defined by Svensson (2017) and adapt it to the euro area. Before discussing the evaluation of the different policy options, we will explain in the following the underlying framework and the parameters used.

The Svensson framework is based on a quadratic loss function of unemployment. Assuming a monetary policy that stabilizes both the inflation rate around an inflation target and the unemployment rate around its long-run sustainable rate, we define u_t^* as the optimal unemployment rate under flexible inflation targeting when the possibility of a financial crisis is disregarded. The loss from the unemployment rate deviating from the benchmark unemployment rate, u_t^*, can be represented by the quadratic (indirect) loss function:

$$L_t = (\tilde{u}_t)^2,$$

with $\tilde{u}_t = u_t - u_t^*$ being the unemployment deviation.[14]

For the purpose of evaluating the costs and benefits of different policy options, we consider two states of the economy after period 1. With a probability p_t the economy is in a crisis state and the crisis unemployment deviation, $\tilde{u}_t^c$, is conditional on being in a crisis state. For the noncrisis state, which occurs with probability $1 - p_t$, the unemployment deviation is denoted by $\tilde{u}_t^n$.

The expected quarter-t loss conditional on information available in quarter 1 can be written as

$$\mathbb{E}_1 L_t = \mathbb{E}_1(\tilde{u}_t)^2 = (1 - p_t)\mathbb{E}_1(\tilde{u}_t^n)^2 + p_t\mathbb{E}_1(\tilde{u}_t^c)^2.$$

The crisis unemployment deviation, $\tilde{u}_t^c$, is composed of two components: a crisis increase in the unemployment rate net of any policy reaction during the crisis, Δu, and the noncrisis unemployment

[14] See appendix A of Svensson (2017) for further details on the quadratic loss function.

deviation, $\tilde{u}_t^n$. Therefore, we can rewrite the expected quarter-t loss as

$$\begin{aligned}\mathbb{E}_1 L_t &= (1-p_t)\mathbb{E}_1(\tilde{u}_t^n)^2 + p_t\mathbb{E}_1(\Delta u_t + \tilde{u}_t^n)^2, \\ &= \mathbb{E}_1(\tilde{u}_t^n)^2 + p_t\left(\mathbb{E}_1(\Delta u_t + \tilde{u}_t^n)^2 - \mathbb{E}_1(\tilde{u}_t^n)^2\right), \\ &= \mathbb{E}_1(\tilde{u}_t^n)^2 + p_t\Big(\underbrace{\mathbb{E}_1(\Delta u_t)^2 + 2\mathbb{E}_1(\tilde{u}_t^n\Delta u_t)}_{cost\ \ of\ \ a\ \ crisis}\Big).\end{aligned}$$

The second term in the last two expressions deserves further explanation. This term describes the cost of a crisis as being the crisis deviation less the noncrisis deviation.

A policy action in this setup is discretionary and not a reaction to a shock or the realization of the crisis state. Furthermore, the monetary policy in the underlying DSGE model interacts with the discretionary policy actions. In other words, policymakers systematically react ignoring the possibility of a crisis state, but they consider whether to intervene nonsystematically given the possibility of a crisis state. Their discretionary policy intervention might have benefits in the case that the crisis state materializes but also costs in both states.

Any policy will have an impact on the quarter-t loss and we define the net marginal cost, NMC_t, as the derivative of the quarter-t loss function with respect to the policy measure, $\mathfrak{p}_1^i$, implemented to address risks to financial stability:

$$\text{NMC}_t = \frac{d\mathbb{E}_1 L_t}{d\mathfrak{p}_1^i}.$$

Taking the partial derivatives for each component of the rewritten quarter-t loss function yields

$$\text{MC}_t = 2(\mathbb{E}_1\tilde{u}_t^n + p_t\mathbb{E}_1\Delta u_t)\frac{d\mathbb{E}_1 u_t^n}{d\mathfrak{p}_1^i}, \tag{1}$$

$$\text{MB}_t^p = -\left(\mathbb{E}_1(\Delta u_t)^2 + 2\mathbb{E}_1(\tilde{u}_t^n\Delta u_t)\right)\frac{dp_t}{d\mathfrak{p}_1^i}, \tag{2}$$

$$\text{MB}_t^{\Delta u} = -2p_t\mathbb{E}_1(\tilde{u}_t^n + \Delta u_t)\frac{d\mathbb{E}_1\Delta u_t}{d\mathfrak{p}_1^i}, \tag{3}$$

$$\text{NMC}_t = \text{MC}_t - (\text{MB}_t^p + \text{MB}_t^{\Delta u}), \tag{4}$$

with MC_t being the marginal cost related to the change in the unemployment rate, MB_t^p being the benefits from a lower probability of a crisis, and $\mathrm{MB}_t^{\Delta u}$ being the benefit of a reduced severity of a crisis.

For the purpose of assessing whether a policy is favorable, we look at the discounted cumulated net marginal cost:

$$\begin{aligned}\mathrm{NMC} = \sum_{t=1}^{\infty} \delta^{t-1}\mathrm{NMC}_t &= \sum_{t=1}^{\infty} \delta^{t-1}\mathrm{MC}_t \\ &\quad - \left(\sum_{t=1}^{\infty} \delta^{t-1}\mathrm{MB}_t^{\Delta u} + \sum_{t=1}^{\infty} \delta^{t-1}\mathrm{MB}_t^{p} \right),\end{aligned}$$

with δ being the discount factor.

Here, we will look at the cumulated net marginal cost over time.

In order to evaluate policies in our framework, we need to define values of the static and dynamic components of the framework. Since we are taking partial derivatives, we need to define the constant values of the probability of a crisis, the noncrisis unemployment deviation, and the crisis increase in unemployment. For our analysis we rely on a calibration suitable for the euro area. Furthermore, we conduct a sensitivity analysis to the calibrated parameters (see table 1).

The probability of being in a crisis is determined, assuming a Markov process,[15] by the probability of a crisis start and the crisis duration. In order to calibrate the framework to the euro area, we assume the crisis duration to be eight quarters. This estimate, which coincides with the benchmark calibration of Svensson (2017), reflects the mean unfiltered peak-to-trough duration of the financial cycle in Europe as defined in Schüler, Hiebert, and Peltonen (2015).

As for the crisis increase in unemployment, Δu, we assume it to be 5 pp. This assumption rests on estimates from the International Monetary Fund (2015) and Sveriges Riksbank (2013) and is also used by Svensson in his analysis. A larger crisis increase in unemployment would lead to higher net marginal benefits because of the quadratic term in the marginal benefits of a lower probability of a crisis start (see equation (2)), and the otherwise linear influence of the crisis increase on the costs (see equation (1)).

[15]See appendix C in Svensson (2017) for further details on the Markov process.

Table 1. Sensitivity of Cost and Benefits of LAW by Monetary Policy Considering the Financial Cycle

Crisis Increase in Unemployment (pp)	Crisis Duration (Quarters)	Crisis Severity Coefficient on DTI Ratio	Discount Factor	Time Horizon	Cumulative Net Marginal Cost/Benefit
5	8	0.02	1.00	40	−1.46
1	8	0.02	1.00	40	−0.28
2	8	0.02	1.00	40	−0.56
3	8	0.02	1.00	40	−0.84
4	8	0.02	1.00	40	−1.13
5	8	0.02	1.00	40	−1.43
6	8	0.02	1.00	40	−1.73
7	8	0.02	1.00	40	−2.04
8	8	0.02	1.00	40	−2.35
9	8	0.02	1.00	40	−2.66
10	8	0.02	1.00	40	−2.99
5	**6**	0.02	1.00	40	−1.29
5	**7**	0.02	1.00	40	−1.36
5	**8**	0.02	1.00	40	−1.43
5	**9**	0.02	1.00	40	−1.48
5	**10**	0.02	1.00	40	−1.54
5	8	**0.01**	1.00	40	−1.47
5	8	**0.02**	1.00	40	−1.43
5	8	**0.03**	1.00	40	−1.38
5	8	**0.04**	1.00	40	−1.34
5	8	0.02	**0.95**	40	−1.12
5	8	0.02	**0.96**	40	−1.19
5	8	0.02	**0.97**	40	−1.26
5	8	0.02	**0.98**	40	−1.33
5	8	0.02	**0.99**	40	−1.39
5	8	0.02	**1.00**	40	−1.46
5	8	0.02	1.00	**20**	−2.23
5	8	0.02	1.00	**40**	−1.43
5	8	0.02	1.00	**50**	−1.71
5	8	0.02	1.00	**75**	−2.10
5	8	0.02	1.00	**100**	−2.35

With regard to the benefits of a less severe crisis, we rely on the conservative estimates found in Flodén (2014). These estimates, which Svensson uses in his framework, imply that the marginal benefit is equal to 0.02 times the policy effect on the household debt-to-income (DTI) ratio.

The marginal benefit of a lower probability of a crisis is the part we adapt in order to take into account the financial cycle (see section 3.1), and throughout our simulations we consider a discount factor of 1.[16]

All three parts rely on calibrated parameters, which we adjust to reflect the situation in the euro area wherever possible, and policy impulse responses. We also use Svensson's benchmark calibration in order to ensure comparability and because this calibration is very conservative and tilted in favor of LAW (see appendix A). The relevant policy impulse responses for marginal cost and severity of a crisis are unemployment [pp], and the DTI ratio [pp]. The relevant impulse response for the probability of a crisis will be explained along with the extensions we implemented to think about the financial cycle in the following section.

3. Calibrating the Model for the Euro Area and Incorporating the Financial Cycle

In order to calibrate the Svensson framework for the euro area, we employ the estimated closed-economy DSGE model of Darracq Pariès, Kok, and Rodriguez-Palenzuela (2011).[17] This euro-area DSGE model is in regular use for monetary and macroprudential policy analysis at the European Central Bank (ECB). Moreover, in terms of macrofinancial propagation mechanisms, the model is consistent with other comparable macroeconomic models for the euro area (Cozzi et al. 2020). Focusing on the impact of monetary policy shocks on the unemployment rate, the Darracq Pariès, Kok, and Rodriguez-Palenzuela (2011) model produces broadly comparable, if slightly weaker, impulse responses to euro-area-based empirical (mainly vector autoregression (VAR)-based) studies. The impulse

[16] A discount factor of 1 implies no discounting. In our sensitivity analysis we also vary the discount factor (see table 1).

[17] See appendix B for a description of the model.

response of the unemployment rate to a 1 pp policy rate shock in Darracq Pariès, Kok, and Rodriguez-Palenzuela (2011) peaks at a slightly higher level but is less persistent compared with recent empirical studies on monetary policy transmission in the euro area (Laine 2019; Rubio 2019). Furthermore, it is broadly consistent with recent estimates based on the ECB's new multicountry model (ECB-BASE; see Angelini et al. 2019).

In line with Svensson's approach, the results for monetary policy "leaning against the wind" are achieved by assuming the policy rate to be 1 pp above the flexible inflation targeting implied equilibrium rate for four quarters and to move endogenously thereafter.[18]

3.1 Financial Cycle

A critique of the Svensson framework, which we address in this paper, is that it is unable to capture the effect of the financial cycle on the costs and benefits of LAW (see Adrian and Liang 2016; BIS 2016; Filardo and Rungcharoenkitkul 2016; Gourio, Kashyap, and Sim 2017). BIS (2016) underlines that the financial cycle has a much lower frequency and that risks build up gradually. These features are not captured in Svensson's framework because of the shorter time horizons.

We take this critique into account by changing how the policy experiments are translated into the probability of a crisis start. Svensson (2017) uses the household debt growth as the determinant of the probability of a crisis occurring based on regressions in Schularick and Taylor (2012). This approach uses credit as an indicator which is also widely used as a basis for early-warning indicators.[19] Furthermore, Schularick and Taylor (2012) include 17 developed countries from 1870 onwards on a yearly basis which are not representative of the euro area.[20] In order to have an approach which considers the longer time horizons of the financial cycle and

[18]We achieve this by extracting the monetary policy shocks from a conditional forecast on the policy rate being fixed for four quarters.

[19]See, e.g., Borio and Lowe (2002a, 2004); Drehmann (2013).

[20]The financial crisis database underlying their calculations can be found at http://www.macrohistory.net/data.

is more suitable for the euro area, we rely on an early-warning indicator combining a set of long-term growth rates and estimated on euro-area data.[21]

This early-warning indicator, called systemic risk indicator (SRI), is designed to capture cyclical systemic risk, uses data from the monthly European financial crisis database by Lo Duca et al. (2017), and consists of a weighted average of the following normed variables:[22]

- two-year change in bank credit-to-GDP ratio,
- two-year growth rate of real total credit,
- three-year change in residential real estate price-to-income ratio,
- two-year change in the debt-service ratio,
- three-year growth rate of real equity prices, and
- current account-to-GDP ratio.

Before regressing the SRI on the crisis start dates, we have to construct the SRI from the impulse response functions (IRFs) of the DSGE model. Since the Darracq Pariès, Kok, and Rodriguez-Palenzuela (2011) model does not include an external sector or equity markets, we cannot include the three-year growth rate of real equity prices and current account-to-GDP ratio in the calculation of the SRI. Therefore, we take a reduced version of the SRI based on the other four variables: the two-year change in bank credit-to-GDP ratio, the two-year growth rate of real total credit, the three-year change in residential real estate price-to-income ratio, and the two-year change in the debt-service ratio. Table 2 shows the weights used in constructing the SRI. These are chosen to optimize the early-warning properties of the SRI for systemic financial crisis, using a constrained least squares regression. The variables used in the regression are normalized with their mean and standard deviation across time and geographies.

[21]See Rünstler and Vlekke (2018) or Schüler, Hiebert, and Peltonen (2015) for an analysis of the financial cycle in the euro area.

[22]See Detken, Fahr, and Lang (2018) and Lang et al. (2019) for a detailed description of the methodology and an evaluation of the SRI as an early-warning indicator.

Table 2. Weights Used in Calculating SRI

	Weight
Two-Year Change in Bank Credit-to-GDP Ratio	0.62
Three-Year Change in Residential Real Estate Price-to-Income Ratio	0.28
Two-Year Growth Rate of Real Total Credit	0.05
Two-Year Change in the Debt-Service Ratio	0.05

Having constructed the four-variable SRI, we run the following regressions:

$$Pr(p_{i,t}) = b_{0,i} + b_1(L)SRI_{i,t} + b_2X_i + \varepsilon_{i,t},$$

with $b_1(L)$ being the lag polynomial of 0 up to 20 quarters, and X_i being country fixed effects. The left-hand-side variable is the probability of a crisis start in the respective quarter.

Given that the lags of the SRI are highly autocorrelated and therefore multicollinear, we resort to regularization techniques for variable selection. This problem is particularly suitable for the use of regularization techniques because we want to focus on predictive power and interpretability. In order to achieve this, we use an elastic net regression to identify the relevant lags.[23] First, we use the elastic net to identify the relevant lags, and then we use the OLS coefficient estimates to parameterize the linking function. Using cross-validation for selecting the hyperparameters of the elastic net, the regularization finds lags 7 to 10 to be relevant. Table 3 shows the result of the maximum-likelihood regression for the selected variables.

[23]The elastic net is a regularization and variable selection method which combines and nests the least absolute shrinkage and selection operator (LASSO) and Ridge regularization techniques. The LASSO (Ridge) regularization means that you add the sum of absolute values (square of the absolute values) of the coefficients to the cost function of an otherwise standard ordinary least squares (OLS) regression. The elastic net combines the strengths of both approaches, namely the improved prediction power of Ridge regressions and the sparsity, or automatic feature selection, of LASSO regressions. See Zou and Hastie (2005) for a detailed description of the elastic net regularization technique.

Table 3. Start of Financial Crisis Prediction: Logit Estimates

	Dependent Variable: $Pr(p_{i,t})$			
	(1)	**(2)**	**(3)**	**(4)**
L0 SRI	0.450	−0.969***	−0.021	
	(0.284)	(0.366)	(0.561)	
L4 SRI		1.703***	−0.227	
		(0.340)	(0.841)	
L7 SRI				0.471
				(1.808)
L8 SRI			1.414***	1.234
			(0.540)	(3.005)
L9 SRI				−0.909
				(3.079)
L10 SRI				0.528
				(1.853)
AUROC	0.64	0.86	0.84	0.84
Observations	1,599	1,519	1,439	1,400
Log Likelihood	−83.819	−73.682	−67.228	−66.276
AIC	171.638	153.365	142.455	142.552

Notes: Standard errors are clustered at country level. Significance levels: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

From left to right, we add lags in time steps of four quarters, starting with the contemporaneous effect of the SRI on the probability of a crisis start. Column 4 shows the regression on the variables selected by the elastic net. The area under receiver operating characteristic (AUROC) for the specification without time lags is relatively low at 0.64. When adding the four-quarter lag (see column 2), we see that the AUROC increases up to a value of 0.86, and adding the eight-quarter lag leads to a slightly lower AUROC of 0.84. In comparison, the full specification in Schularick and Taylor (2012), including lags up to five years, has a slightly higher AUROC but features country fixed effects. The elastic net excluded country fixed effects in our case. The variables selected by the elastic net yield an AUROC of 0.84 and have the lowest log likelihood (see column 4). Their Akaike information criterion (AIC) value is at about the same level as for the specification in column 3.

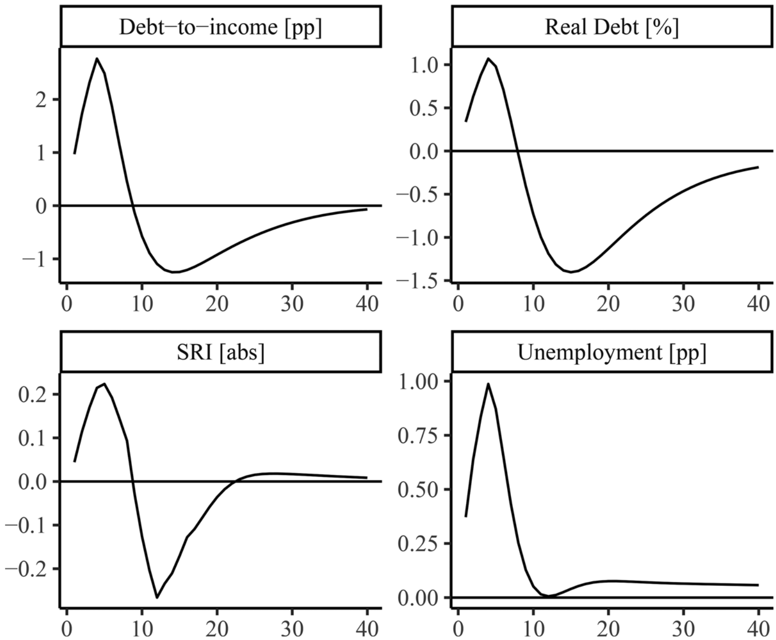
The functional form implies a quarterly probability of a crisis start of 0.5 percent versus the 0.8 percent used in Svensson's calculations. The difference is due to the different samples of the financial crisis databases used. Schularick and Taylor (2012) go back to 1870 and cover 17 developed countries, whereas Lo Duca et al. (2017) cover 22 European countries that experienced a financial crisis since 1970.

Coming back to the critique by the BIS and others, which was about monetary policy and its effect on the financial cycle, we will now discuss the results for "leaning against the wind" with our augmented version of the Svensson framework considering the financial cycle.

The IRFs for real GDP and real household and firm debt are then used to calculate the unemployment deviation (proxied by the GDP deviation times the Okun coefficient, with a value of 2), household debt growth, and the DTI ratio (total debt/GDP). These three series are used as inputs in the cost-benefit framework by Svensson (2017). The unemployment deviation drives the marginal costs, debt growth drives the probability of crisis, and the DTI ratio drives the severity of crisis.

Svensson's framework allows us to look at the cost over time. In order to establish whether a policy has net benefits or net costs, we look at the cumulative costs and benefits over 40 quarters.

Figure 2. Deviations from Steady State for a Temporary Monetary Policy Shock Using the Darracq Pariès, Kok, and Rodriguez-Palenzuela (2011) DSGE Model

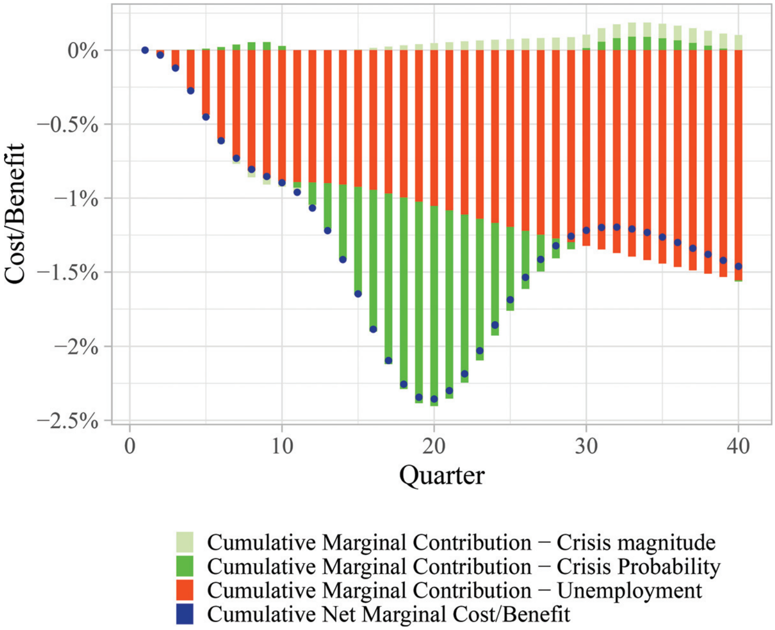


In the short run, an interest rate hike leads to an increase in debt levels (see figure 2). Such a short-term spike in debt levels is debatable, yet Gelain, Lansing, and Natvik (2018) and Korinek and Simsek (2016) confirm and explain how such a spike can come about.[24] Ultimately, the spike exacerbates the negative effects of monetary policy in the short run. Only in the medium turn does the DTI ratio decrease. The result of Svensson for "leaning against the wind" can be confirmed for the euro area, whereas the cumulated net marginal costs are slightly less negative.

We can see in figure 2 that monetary policy has a strong impact on the SRI. (See online version at http://www.ijcb.org for figures in

[24]An increase in interest rates can lead to a higher level of household debt, because higher interest rates also increase the debt service burden and lower the income of the borrowers, who then borrow more to smooth consumption.

Figure 3. Cumulative Net Marginal Cost/Benefit of LAW Considering the Financial Cycle



color.) It rises sharply in the beginning only to drop significantly to a low point after 2.5 years. The marginal benefits from a lower probability of a crisis are actually costs in the medium term because the SRI implies an increase in the probability of a crisis. Only towards the end of the 40-period horizon does the cumulated benefit of a lower probability of a crisis contribute to lowering the net cost. On top of this, there is a marginal cost in the form of the unemployment deviation. The marginal benefits of a less severe crisis are small compared with the marginal costs (see figure 3).

To conclude, even when considering the impact of monetary policy on the financial cycle, it is still inadvisable to use monetary policy to address financial stability risks. Nonetheless, the critique by the BIS is warranted in light of the results. The net marginal costs are lower when considering the financial cycle compared with the version without it, but the benefits of a lower probability of a crisis start are not enough to tip the balance.

4. Macroprudential Policy

Staying within the Svensson framework augmented to take into account the financial cycle, we next turn our attention to macroprudential policy. Are macroprudential policy instruments better able to address financial stability risks? Macroprudential policy interventions are represented here as an increase in banking-sector capital requirements[25] by 1 pp or a tightening in the LTV requirements[26] by 1 pp.[27]

We argue for one more additional change to the original framework to account for the financial cycle. We consider longer time horizons for which policy is activated to reflect the persistence and length of the financial cycle.[28] Furthermore, longer time horizons for the activation of macroprudential policy are more realistic, as they are usually implemented with a lag and are also typically adjusted more infrequently than monetary policy. The nature of the exercise implies that agents do not learn and are surprised every period again that the policymaker chooses to change macroprudential policy in a nonsystematic way. This assumption becomes more important the longer the time horizon we are considering.

Slight changes to the original DSGE model need to be incorporated for these simulations. For bank capital requirements, we

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[25]Cozzi et al. (2020) provide an overview for different DSGE models of the impact on real GDP of a 1 pp change in bank capital requirements.

[26]The Darracq Pariès, Kok, and Rodriguez-Palenzuela (2011) model implies that a 1 pp decrease in the average LTV ratio would have a fourfold peak impact on GDP. Furthermore, changes in the LTV regulation are usually announced as caps on new loans. Therefore, a change in the average LTV translates into a much larger change in the LTV cap on new loans. This is because new loans are a relatively small share of the stock and caps are usually applied at the top quantiles of the new loan LTV distribution.

[27]The marginal effect should be seen in combination with the level of capital requirements or LTV requirements, respectively. The Darracq Pariès, Kok, and Rodriguez-Palenzuela (2011) DSGE model would imply that the effects are larger the higher (lower) the level of capital (LTV) requirements are. This is because both bank capital and collateral constraints are externalities with an optimal level of 0 in the case of bank capital and the absence of collateral constraints. Other models such as Mendicino et al. (2018) incorporate tradeoffs for bank capital and would allow a more informative analysis about the influence of the bank capital level.

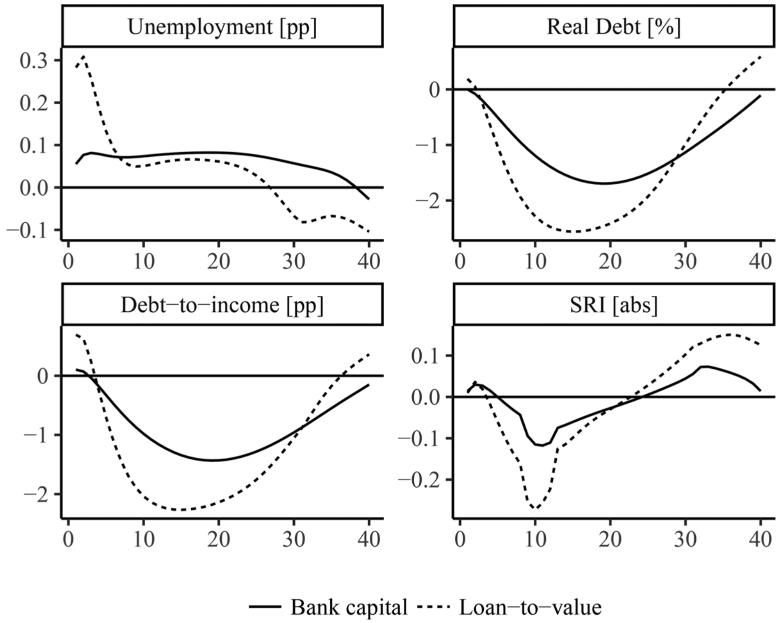
[28]The average length of the financial cycle in the euro area has been measured to 7.8 years; see Schüler, Hiebert, and Peltonen (2015).

assume an exogenous stationary AR(1) shock to the 11 percent bank capital requirements. With regard to the LTV requirements, we define LTV ratios for entrepreneurs and borrowing households as determined by a common LTV shock scaled to have the same absolute impact on both ratios. One has to bear in mind that a tightening of LTV requirements in the model does not fully represent how this tool is used in reality. In the model, we reduce the average LTV requirements, whereas in reality this tool is mostly used as a cap on LTV ratios. Therefore, a 1 pp reduction in average LTV corresponds to a lower cap of LTV ratios, depending on the distribution of LTV ratios.

Starting with bank capital requirements, we assume a 1 pp increase over the length of the financial cycle (7.8 years or 31 quarters). Figure 4 shows that the changes to debt levels are more pronounced and persistent than for LAW for four quarters. At the same time, the SRI is reduced significantly, reaching a low point 2.5 years after implementation of the policy. Unemployment increases slightly and goes down only towards the end of the 40 quarters considered here. These IRFs translate into considerable marginal costs (see figure 5). Nonetheless, the movements in the SRI are translated into marginal benefits outweighing the cost and tipping the balance in favor of using bank capital requirements to address financial stability risks. The benefits of a less severe crisis are not to be neglected either. The DTI ratio decreases significantly and translates into a significantly less severe crisis unemployment deviation.

Coming to LTV requirements, we find that decreasing the LTV requirements of both firms and households by 1 pp leads to a much stronger reaction of the macroeconomy than changing the bank capital requirements (see figure 4). Unemployment rises sharply and recedes to an elevated level. At the same time, debt and the DTI ratio decrease more, after an initial increase. Finally, the SRI reaches the bottom after 2.5 years but at a level more than twice as low as for the bank capital requirements. These IRFs imply a much higher marginal cost (see figure 6). Nevertheless, the benefits of a less severe crisis alone outweigh the marginal costs after 40 quarters. The probability of a crisis ultimately adds to the marginal benefits, although only slightly. In net cumulative terms, tightening the LTV requirements by 1 pp for 31 quarters is beneficial.

Figure 4. Deviations from Steady State for a 31-Quarter Activation of Macroprudential Policy Using the Darracq Pariès, Kok, and Rodriguez-Palenzuela (2011) DSGE Model



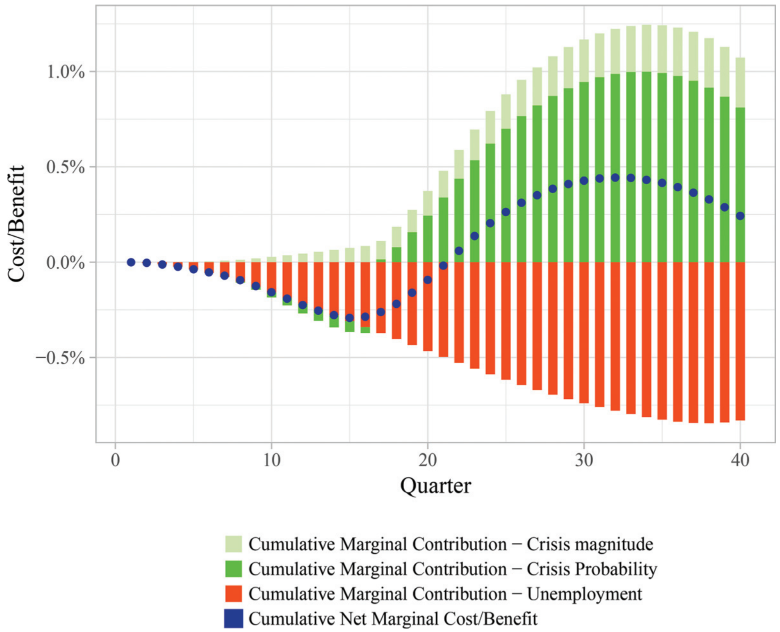
5. Robustness

5.1 Sensitivity to Calibrated Parameters

We calibrated the parameters so that they are suitable for the euro area. The results are of course conditional on the calibration we use. In order to underline the robustness of our results, we conduct a sensitivity test to the parameters. These parameters are the crisis increase in unemployment, crisis duration, crisis severity coefficient on DTI ratio, discount factor, and the time horizon. Table 1 shows the results for different calibrations, and we find that LAW by monetary policy considering the financial cycle has cumulated net marginal cost across all calibrations.

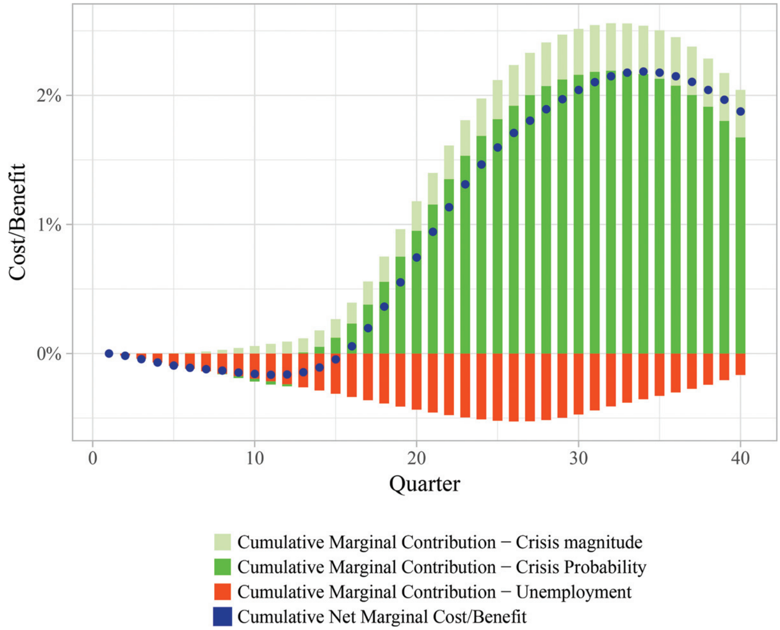
The parameter with the largest influence is the crisis increase in unemployment. We consider values from a 1 pp up to a 10 pp crisis

Figure 5. Cumulative Net Marginal Cost/ Benefit of Macroprudential Policy Considering the Financial Cycle (temporary increase of bank capital requirements—31 quarters)



increase in unemployment and find that the costs are larger for a higher crisis increase. This result is intuitive given the convex loss function. Regarding the crisis duration, we consider values between 6 and 10 quarters. Not surprisingly, we find that a longer crisis duration implies higher costs. Turning to the crisis severity coefficient on the DTI ratio, we consider values between 0.01 and 0.04. For this parameter a larger coefficient implies less cost. Given that the policy has net marginal benefits of reducing the crisis severity, this parameter amplifies the positive impact. For the discount factor we simulate values between 0.95 and 1 and find that a lower discount factor reduces the cumulated costs. Last but not least, we look at the time horizon and consider values between 20 and 100 quarters, and the costs outweigh the benefits across all time horizons with the least negative cost for a time horizon of 40 quarters.

Figure 6. Cumulative Net Marginal Cost/Benefit of Macroprudential Policy Considering the Financial Cycle (temporary increase of LTV requirements—31 quarters)

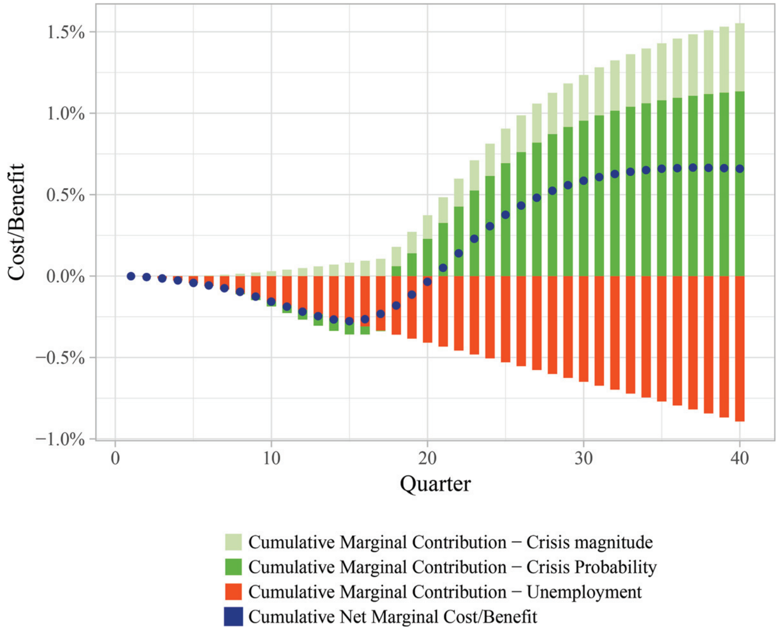


5.2 Permanent Policy Changes

It can be argued that in practice changes in macroprudential policy occur only quite infrequently. The contribution of the Svensson framework is that we can assess the cost and benefits of the *implementation* of a policy in contrast to a static level assessment. The DSGE model by Darracq Pariès, Kok, and Rodriguez-Palenquela (2011) is calibrated to reflect bank capital and LTV ratios in the euro area. Therefore, the investigation of whether a permanent change in bank capital or LTV requirements is advisable in order to tackle financial stability risks has merit.

Our results show that a permanent increase in bank capital requirements of 1 pp has net marginal benefits after 40 quarters (see figure 7). The results are driven by the permanent decrease in debt levels and a strong reduction in the SRI (see figure 8). The

Figure 7. Cumulative Net Marginal Cost/Benefit of Macroprudential Policy Considering the Financial Cycle (permanent increase of bank capital requirements)



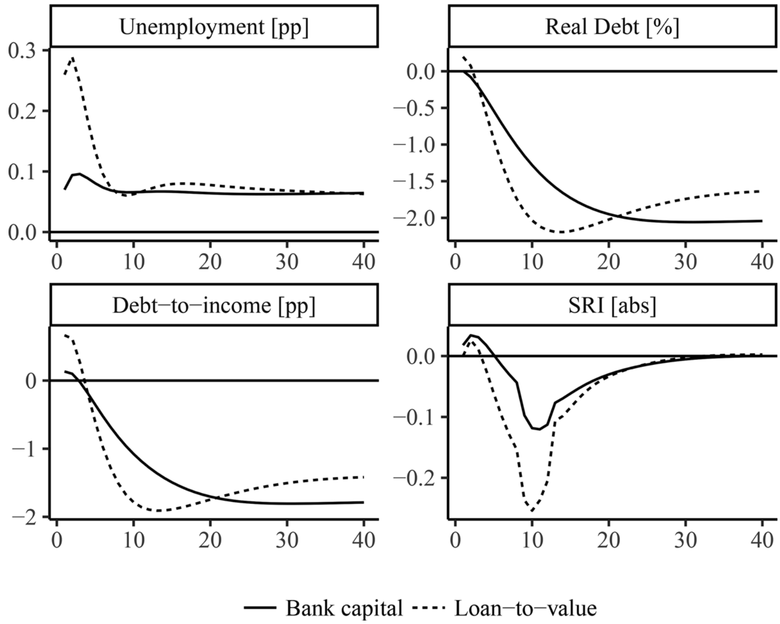
benefits outweigh the cost already after 23 quarters, and it is therefore advisable to use bank capital requirements in order to address financial stability concerns.

Similarly, a permanent decrease in the LTV requirements for entrepreneurs and borrowing households has net cumulated marginal benefits, outweighing marginal costs already after 18 quarters, and has cumulative net benefits after 40 quarters (see figure 9). These results are even more subject to the limitation that agents do not learn and are surprised every period about the macroprudential policy stance.

5.3 Short-Run Implementation of Macroprudential Policy

Having laid out in section 3.1 that a policy implementation over a longer horizon corresponds more naturally to the idea of the financial

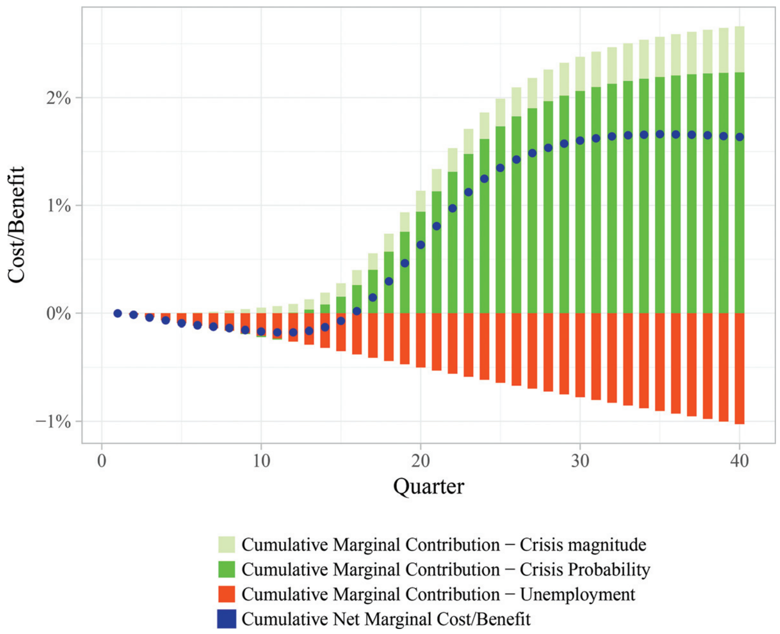
Figure 8. Deviations from Steady State for Permanent Macroprudential Policy Shocks Using the Darracq Pariès, Kok, and Rodriguez-Palenzuela (2011) DSGE Model



cycle, it is nonetheless worth exploring the results for shorter time spans of policy implementations.

As for monetary policy, we consider in the following a policy activation for four quarters. Starting with bank capital requirements, we find that a temporary increase in regulatory bank capital by 1 pp for four quarters has only marginal effects on the economy compared with LAW (see figure 10). Debt levels do go down and unemployment is slightly higher. The higher unemployment drives the marginal costs, which in this case dominate the cost-benefit analysis after 40 quarters (see figure 11). The erratic movement of the SRI in response to the policy leads to a cumulated cost of a higher probability of a crisis after around 20 quarters. In the end, the probability of a crisis has a cumulated benefit. The reduced debt levels only lead to comparatively very low cumulated marginal benefits due to a less severe crisis. In contrast to a longer time horizon of activation,

Figure 9. Cumulative Net Marginal Cost/Benefit of Macroprudential Policy Considering the Financial Cycle (permanent increase of LTV requirements)

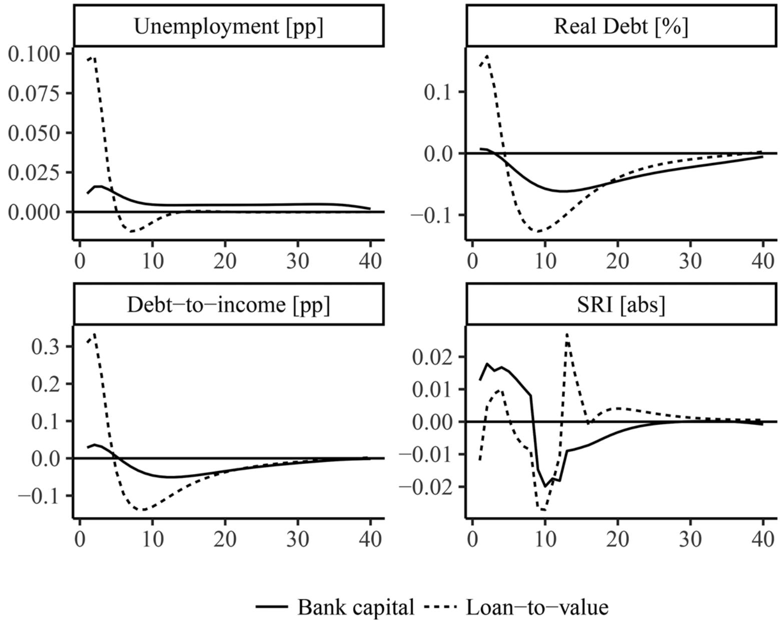


there are net marginal costs for the short-term use of bank capital requirements to address financial stability risks.

A four-quarter policy of a 1 pp tighter LTV requirement has a more persistent although weak effect on unemployment, debt levels, and the SRI (see figure 10). The benefits of a lower probability of a crisis start drive the results. In the short term, the cumulative costs outweigh the benefits, but after eight quarters the implementation has cumulated net marginal benefits (see figure 12). Therefore, even a short-term implementation of LTV requirements has net benefits in the long run, although the benefits are much larger for longer activation time spans.

We conclude that both macroprudential tools, if changed, should stay at their new respective levels in order to generate substantial benefits for the economy.

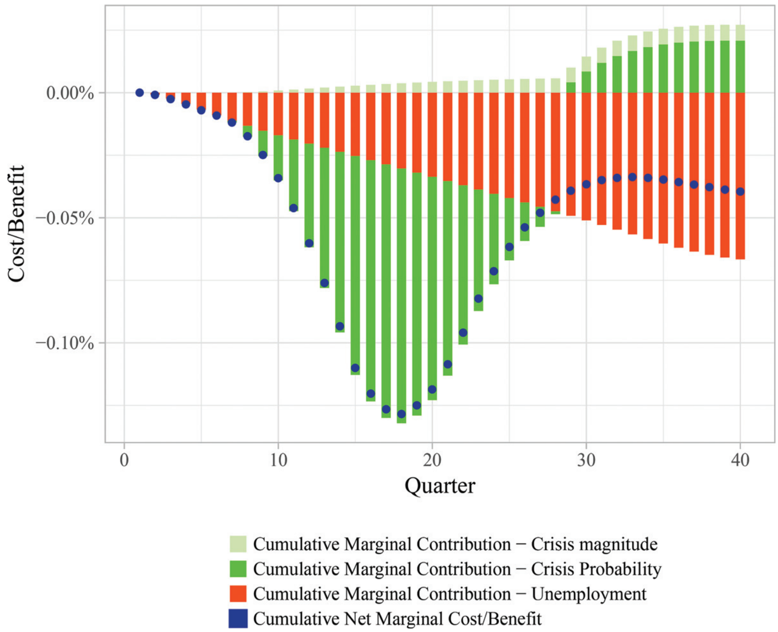
Figure 10. Deviations from Steady State for a Four-Quarter Activation of Macroprudential Policy Using the Darracq Pariès, Kok, and Rodriguez-Palenzuela (2011) DSGE Model



6. Discussion

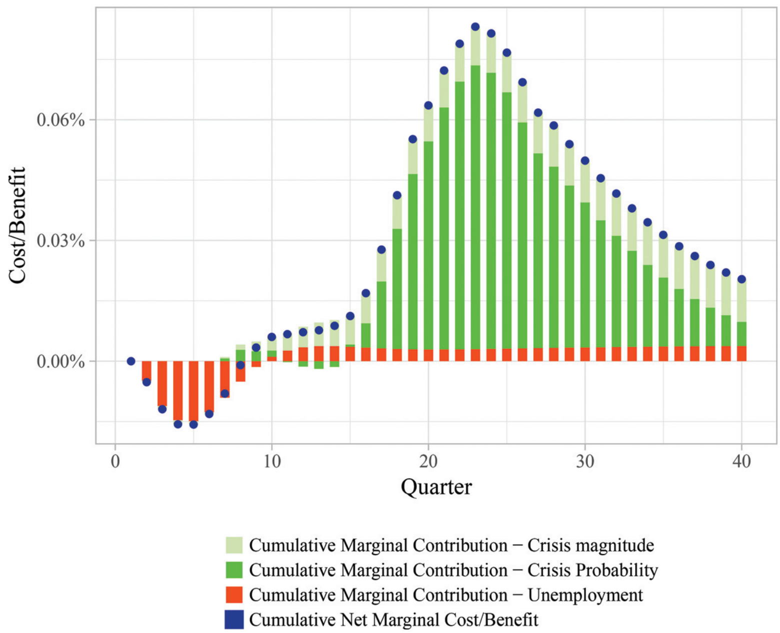
As already highlighted in the introduction, the finding that macroprudential policies are better suited to addressing financial stability risks than monetary policy is supported by a range of studies. This notwithstanding, our findings are obviously driven by the specific, and arguably simplistic, features of the Svensson framework. While we accommodate some of the criticism of the original Svensson approach (by studies such as Adrian and Liang 2016; Filardo and Rungcharoenkitkul 2016; and Gourio, Kashyap, and Sim 2017) by taking into account the longevity of financial cycles as compared with business cycle fluctuations, we acknowledge that further work is warranted to substantiate and improve the robustness of the finding that macroprudential policy is the preferred tool over monetary

Figure 11. Cumulative Net Marginal Cost/ Benefit of Macroprudential Policy Considering the Financial Cycle (temporary increase of bank capital requirements—four quarters)



policy to lean against the buildup of financial cycles. In particular, monetary policy is discretionary in the Svensson framework and imposes a cost in normal times by construction. A systematic policy response which takes into account the possibility of a crisis would be more balanced and consider the tradeoffs optimally. Gerdrup et al. (2017) highlight in a setting with endogenous crisis that a systematic (but not optimal) LAW policy rule is slightly beneficial. Nonetheless, the model they use lacks the level of sophistication regarding the debt dynamics featured in the model underlying our analysis. The debt dynamics are a crucial part of determining the benefits. The ideal experiment would consider endogenous crisis and optimal policy, but this is beyond the scope of this article. Another dimension we do not explore is systematic macroprudential policy

Figure 12. Cumulative Net Marginal Cost/Benefit of Macroprudential Policy Considering the Financial Cycle (temporary increase of LTV requirements—four quarters)



such as the countercyclical capital buffer (CCyB). Optimal macroprudential policy could further improve the benefits and reduce the costs over the discretionary policy. As for optimal monetary policy, optimal macroprudential policy also is out of the scope of this article.

As Jeremy Stein has observed, there may be situations where LAW is warranted, as it "gets into all the cracks" of the financial system.[29] In other words, in some circumstances, either due to the nature of financial stability risks or due to the potentially limited

[29]See "Overheating in Credit Markets: Origins, Measurement, and Policy Responses," speech by U.S. Federal Reserve Governor Jeremy C. Stein 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, St. Louis, Missouri, February 7, 2013.

effectiveness of the targeted macroprudential tools, some LAW may improve welfare.[30]

Furthermore, it has to be kept in mind that macroprudential policy and monetary policy are to a large extent interdependent. These interdependencies imply the potential for a tradeoff between the two policy functions, as the transmission of macroprudential instruments is likely to affect the monetary policy transmission mechanism. It is to be expected that a monetary policy change will often affect the macroprudential policy stance (e.g., through its effect on bank profitability and risk-taking behavior in the economy). Vice versa, changes in macroprudential policy, such as an adjustment of capital buffer requirements or changes to borrower-based measures (e.g., LTV ratios), are likely to affect general economic activity (via credit provisioning, asset prices, and the impact of economic activity on overall financing conditions) and thus may influence the monetary policy stance. As highlighted by inter alia Carboni, Darracq Pariès, and Kok (2013), price stability and financial stability are complementary and will often be mutually reinforcing.[31] In general, it is thus likely that in many instances there will be strategic complementarities between the two policy functions and that actions in one area will be supportive of the other policy area. However, there can also be potential for conflict between monetary and macroprudential policies; for instance, there can be situations where monetary policy would be too loose and risk creating financial imbalances, whereas macroprudential policy can be too restrictive, hampering the smooth transmission of monetary policy. Overall, while these considerations do not contradict the findings of this paper suggesting that targeted macroprudential policies are preferable to LAW, these considerations still underline the need to ensure an appropriate institutional framework with effective coordination mechanisms among the different policy functions, with clear delineations of responsibility.

[30]See also Smets (2014).

[31]See Angelini, Nicoletti-Altimari, and Visco (2012), Goodhart et al. (2007), and IMF (2015).

7. Conclusion

This paper analyzes the cost and benefits of monetary and macroprudential policy in addressing risks to financial stability for the euro area. This question is especially relevant today given the risk that the prolonged period of very accommodative monetary policy increases systemic risk.

In a first step we extend the Svensson framework to take into account the financial cycle and evaluate LAW by monetary policy in the euro area. We find that monetary policy has cumulated net marginal costs in addressing risks to financial stability. For the extended framework we reestimate the probability of a crisis start making use of the SRI, and determine with these estimates the benefits of a given policy in reducing the probability of a crisis. Thereby, we can answer one of the critiques of the BIS that the original Svensson framework does not consider the financial cycle and confirm the result by Svensson regarding LAW.

Turning to macroprudential policy, we argue for longer time horizons for which policy is activated and find that both a 1 pp increase in bank capital requirements and a 1 pp decrease in LTV requirements has cumulated net marginal benefits after 40 quarters. Furthermore, we assess permanent changes in macroprudential policy and find that the benefits are even greater. As a robustness check, we conduct the analysis for short-term implementation of macroprudential policies and find that these policies are less beneficial and show cumulative marginal costs in the case of an increase in bank capital requirements for four quarters.

To conclude, our analysis suggests that macroprudential policy is better suited to addressing risks to financial stability. The benefits outweigh the costs to a large degree for policy implementation with a longer time horizon.

Appendix A. Monetary Policy “Leaning against the Wind” in the Euro Area

In the following we will explain in detail which parts of the model are driven by which parameters and go step by step through the original Svensson framework applied to the euro area.

We conduct the policy evaluation in the Svensson framework with only minimal changes in order to compare the results for Sweden and the euro area. After all, Sweden is a small open economy and the euro area is large enough to be modeled as a closed economy. Therefore, monetary policy will have different effects on the macroeconomy.

The policy experiment in Svensson (2017) is conducted using the RAMSES DSGE model for Sweden.[32] The IRFs for real GDP and real household and firm debt are then used to calculate the unemployment deviation (proxied by the GDP deviation times the Okun coefficient, with a value of 2), household debt growth, and the DTI ratio (total debt/GDP). These three series are used as inputs in the cost-benefit framework by Svensson (2017). The unemployment deviation drives the marginal costs, debt growth drives the probability of crisis, and the DTI ratio drives the severity of crisis.

We contrast the results of Svensson with those of the euro area using the same calibration. The quarterly probability of a crisis start is assumed to be $q_t = 0.8\%$ and based on estimates from Schularick and Taylor (2012). Using a simple linear approximation,[33] these values imply a steady-state probability of being in a crisis of around $p_t = 6\%$.

With regard to the benefits of a less severe crisis, we rely on the conservative estimates found in Sveriges Riksbank (2014). These estimates, which Svensson uses in his framework, imply that the marginal benefit is equal to 0.02 times the policy effect on the household DTI ratio. The change in the crisis severity is to be seen in conjunction with the baseline crisis severity of an increase in unemployment of 5 pp. Taken together with the eight quarters crisis duration, 10 pp-years of unemployment deviation determine the severity of the crisis in the model without policy intervention.

Underlying the quarterly probability of a crisis start is a logistic function that links the policy impact via debt growth to the probability of a crisis.[34] The constant crisis probability is therefore

[32]See Adolfson et al. (2013).

[33]The linear approximation is the sum of the quarterly probabilities of a crisis start over eight quarters: $p_t \approx \sum_{i=0}^{n-1} q_{t-i}$.

[34]The function is taken from the estimates found in Schularick and Taylor (2012).

dependent on the steady-state growth of debt. Again we rely on the benchmark calibration and assume a 5 percent per annum growth in debt. In a first step the trend growth is added to the IRF from the DSGE model and then the transformed growth is the input for the logistic function linking debt growth and the probability of a crisis start:

$$X_t = -3.89 - 0.398 \cdot g_{t-4} + 7.138 \cdot g_{t-8} + 0.888 \cdot g_{t-12} + 0.203 \cdot g_{t-16} + 1.867 \cdot g_{t-20}, \tag{A.1}$$

with X_t being the annual probability of a crisis start and g_{t-i} being the annual growth rate of (average annual) real debt lagged by i quarters. The real debt growth rate is a transformation of the IRF of real household and firm debt. First, the trend growth is added to the IRF and second the growth rate is calculated according to $g_t = log(\sum_{i=0}^{3} d_{t-i}/4) - log(\sum_{i=0}^{3} d_{t-4-i}/4)$, with d_t being the IRF of real household and firm debt including the trend growth of 5 percent. The annual probability is then transformed into the quarterly probability: $q_t = \frac{1}{4 \cdot (1+exp(-X_t))}$. The probability of being in a crisis and the change in the probability of being in a crisis due to policy can be calculated using a Markov process.[35]

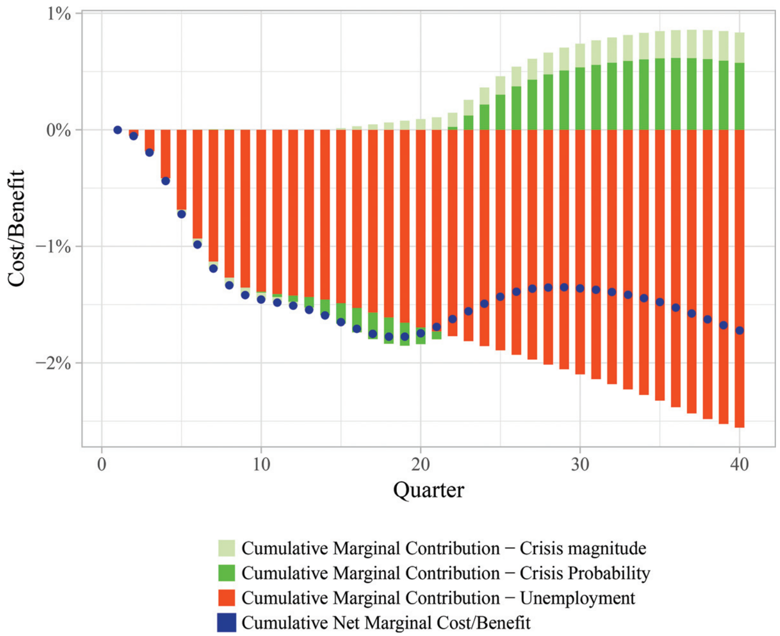
We use as before the IRFs from Darracq Pariès, Kok, and Rodriguez-Palenzuela (2011) as inputs to the Svensson framework. Now we are using the original calibration and therefore we do not use the SRI as an input but debt growth drives the probability of crisis.

Svensson's framework allows us to look at the cost over time. In order to establish whether a policy has net benefits or net costs, we look at the cumulative discounted costs and benefits over 40 quarters. We apply a discount factor of 1, relying on the benchmark calibration of Svensson. Equations (1), (2), and (3) determine the benefits and cost of the policy.

For monetary policy we can see that the marginal costs are driving the results (see figure A.1). Monetary policy has a relatively strong impact on the real economy, and the benefits are not sufficient to outweigh these high costs over time. An interest rate increase

[35] See appendix C in Svensson (2017) for a detailed explanation of the Markov process.

Figure A.1. Cumulative Net Marginal Cost/Benefit of LAW



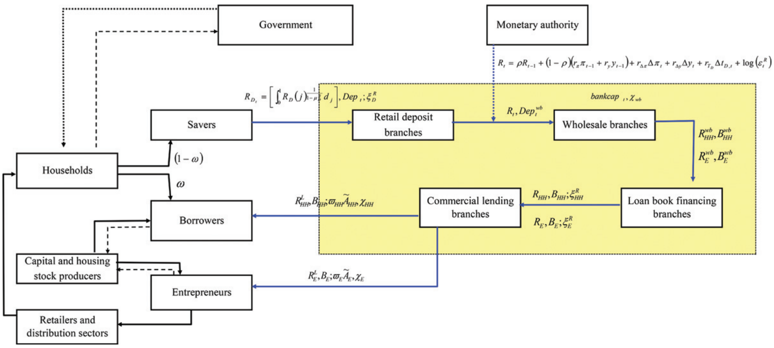
does lower debt and DTI in the long term but not enough to tip the balance between costs and benefits over the horizon of 40 quarters (see figure 2).

Appendix B. Euro-Area DSGE Model

In this section we describe the model found in Darracq Pariès, Kok, and Rodriguez-Palenzuela (2011).

The real side of the economy is modeled as a three-agent, two-sector economy, producing residential and nonresidential goods. Residential goods are treated here as *durable* goods. A continuum of entrepreneurs, with unit mass, produce nonresidential and residential intermediate goods under perfect competition and face financing constraints. Retailers differentiate the intermediate goods under imperfect competition and staggered price setting, while competitive distribution sectors serve final nonresidential consumption as well as

Figure B.1. Structure of the Model



residential and nonresidential investments. A continuum of infinitely lived households, with unit mass, is composed of two types, differing in their relative intertemporal discount factor. A fraction $(1-\omega)$ of households are relatively *patient*, the remaining fraction ω being *impatient*. Households receive utility from consuming both nonresidential and residential goods, and disutility from labor. Impatient households are financially constrained. The labor market structure is characterized by homogeneous labor supply and monopolistically competitive unions, which gives rise to staggered wage setting.

The banking sector collects deposits from patient households and provides funds to entrepreneurs and impatient households. Three layers of frictions affect financial intermediaries. First, wholesale banking branches face capital requirements (which can be risk insensitive or risk sensitive) as well as adjustment costs related to their capital structure. Second, some degree of nominal stickiness generates some imperfect pass-through of market rates to bank deposit and lending rates. Finally, due to asymmetric information and monitoring cost in the presence of idiosyncratic shocks, the credit contracts proposed to entrepreneurs and impatient households factor in external financing premiums which depend indirectly on the borrower's leverage. Figure B.1 provides an overview of the financial contracts linking the banking sector to the real economy.

Finally, a government sector collecting taxes and providing lump-sum fiscal transfers and a monetary authority applying a standard Taylor-rule close the model.

B.1 Households

B.1.1 The Saver's Program

The patient agents, $s \in [\omega, 1]$, are characterized by a higher intertemporal discount factor than the borrowers, and thus act as net lenders in equilibrium. They own the productive capacities of the economy. Each patient agent receives instantaneous utility from the following instantaneous utility function:

$$\mathcal{W}_t^s = \mathbb{E}_t \left\{ \sum_{j \geq 0} \gamma^j \left[\begin{array}{c} \frac{1}{1-\sigma_X} \left(X_{t+j}^s \right)^{1-\sigma_X} - \frac{\varepsilon_{t+j}^L \overline{L}_{S,C}}{1+\sigma_{LC}} \left(N_{Ct+j}^s \right)^{1+\sigma_{LC}} \\ - \frac{\varepsilon_{t+j}^L \overline{L}_{S,D}}{1+\sigma_{LD}} \left(N_{Dt+j}^s \right)^{1+\sigma_{LD}} \end{array} \right] \varepsilon_{t+j}^{\beta} \right\},$$

where X_t^s is an index of consumption services derived from nonresidential final goods (C^s) and residential stock (D^s), respectively.

$$X_t^s \equiv \left[\left(1 - \varepsilon_t^D \omega_D\right)^{\frac{1}{\eta_D}} \left(C_t^s - h_S C_{t-1}^s \right)^{\frac{\eta_D - 1}{\eta_D}} + \varepsilon_t^D \omega_D^{\frac{1}{\eta_D}} \left(D_t^s \right)^{\frac{\eta_D - 1}{\eta_D}} \right]^{\frac{\eta_D}{\eta_D - 1}},$$

with the parameter h_S capturing habit formation in consumption of nonresidential goods. We introduce three stochastic terms in the utility function: a preference shock ε_t^{β}, a labor supply shock ε_t^L (common across sectors), and a housing preference shock, ε_t^D. The latter affects the relative share of residential stock, ω_D, and modifies the marginal rate of substitution between nonresidential and residential goods consumption. All the shocks are assumed to follow stationary AR(1) processes.

Households receive disutility from their supply of homogeneous labor services to each sector, $N_{C,t}^s$ and $N_{D,t}^s$. The real compensation of hours worked in each sector are denoted $w_{C,t}^s$ and $w_{D,t}^s$. The specification of labor supply assumes that households have preferences over providing labor services across different sectors. In particular, the specific functional form adopted implies that hours worked are perfectly substitutable across sectors. $\overline{L}_C$ and $\overline{L}_D$ are level-shift terms needed to ensure that the patient agent's labor supply is equal to one in steady state.

The saver maximizes its utility function subject to an infinite sequence of the following budget constraint:

$$\begin{aligned} &C_t^s + Q_{D,t}T_{D,t}\left(D_t^s - (1-\delta)\,D_{t-1}^s\right) + Dep_t^s \\ &\quad = \frac{(1+R_{D,t-1})}{(1+\pi_t)} Dep_{t-1}^s + (1-\tau_{w,t})\left(w_{C,t}^s N_{C,t}^s + w_{D,t}^s N_{D,t}^s\right) \\ &\qquad + \Pi_t^s + TT_t^s, \end{aligned}$$

where $Q_{D,t}T_{D,t}$ is real price of housing stock in terms of nonresidential goods, TT_t^s are real government transfers, and Π_t^s are real distributed profits. $\delta \in (0,1)$ is the residential good depreciation rate. π_t is the nonresidential good inflation rate. $R_{D,t-1}$ is the nominal interest rate paid on the one-period real deposits Dep_t^s.

In equilibrium, all savers have identical consumption plans. Therefore, we can drop superscripts s. We also allow for a time-varying labor income tax, given by $1-\tau_{w,t} = \left(1-\overline{\overline{\tau}}_w\right)\varepsilon_t^W$.

B.1.2 The Borrower's Program

Each impatient agent $b \in [0,\omega]$ receives utility from the same type of function as in the case of patient households but with a lower discount factor $\beta < \gamma$:[36]

$$\mathcal{W}_t^b = \mathbb{E}_t\left\{\sum_{j\geq 0}\beta^j\left[\begin{array}{c}\frac{1}{1-\sigma_X}\left(\widetilde{X}_{t+j}^b\right)^{1-\sigma_X} - \frac{\varepsilon_{t+j}^L \overline{L}_{B,C}}{1+\sigma_{LC}}\left(N_{C,t+j}^b\right)^{1+\sigma_{LC}} \\ -\frac{\varepsilon_{t+j}^L \overline{L}_{B,D}}{1+\sigma_{LD}}\left(N_{D,t+j}^b\right)^{1+\sigma_{LD}}\end{array}\right]\varepsilon_{t+j}^{\beta}\right\},$$

where $\widetilde{X}_t^b$ is given by

$$\widetilde{X}_t^b \equiv \left[\left(1-\varepsilon_t^D\omega_D\right)^{\frac{1}{\eta_D}}\left(\widetilde{C}_t^b - h_B\widetilde{C}_{t-1}^b\right)^{\frac{\eta_D-1}{\eta_D}} + \varepsilon_t^D\omega_D^{\frac{1}{\eta_D}}\left(\widetilde{D}_t^b\right)^{\frac{\eta_D-1}{\eta_D}}\right]^{\frac{\eta_D}{\eta_D-1}}.$$

As regards savers, $\overline{L}_{B,C}$ and $\overline{L}_{B,D}$ are level-shift terms needed to ensure that the impatient agent's labor supply equals one in steady state.

[36]Variables related to the saver are denoted with a superscript b, as opposed to s, used for the savers.

Borrowers' incomes and housing stock values are subject to common idiosyncratic shocks $\varpi_{HH,t}$ that are iid across borrowers and across time. $\varpi_{HH,t}$ has a log-normal cumulative distribution function (CDF) $F(\varpi)$ with $F'(\varpi) = f(\varpi)$, and a mean of $E(\varpi) = 1$. The variance of the idiosyncratic shock $\sigma_{HH,t}$ is time varying. The value of the borrower's house is given by

$$\varpi_{HH,t}\widetilde{Q}_{D,t}T_{D,t}(1-\delta)\widetilde{D}^b_{t-1}.$$

Lending in this economy is only possible through one-period state-contingent debt contracts that require a constant repayment of $\frac{\left(1+R^L_{HH,t}\right)}{1+\pi_t}B_{HH,t-1}$ independent of $\varpi_{HH,t}$ if the borrower is to avoid costly loan monitoring or enforcement, where $R^L_{HH,t}$ is the nominal lending rate.

The borrower can default and refuse to repay the debt. Savers cannot force borrowers to repay. Instead lending must be intermediated by commercial banks that have a loan enforcement technology allowing them to seize collateral expressed in real terms,

$$\varpi_{HH,t}\tilde{A}^b_{HH,t} = (1-\chi_{HH})\varpi_{HH,t}\widetilde{Q}_{D,t}T_{D,t}(1-\delta)\widetilde{D}^b_{t-1},$$

at a proportional cost $\mu_{HH}\varpi_{HH,t}\tilde{A}_{HH,t}$ when the borrower defaults.

$\mu_{HH} \in (0,1)$ determines the deadweight cost of default; $0 < \chi_{HH} \leq 1$ represents housing exemptions. It defines the maximum loan-to-collateral ratio (often called the loan-to-value ratio) that the bank is willing to grant against each component of the collateral. Conditional on enforcement, the law cannot prevent the bank from seizing $\varpi_{HH,t}\tilde{A}_{HH,t}$. Suppose first that the borrower does not have access to any insurance against the $\varpi_{HH,t}$ shock. Whenever $\varpi_{HH,t} < \overline{\varpi}_{HH,t}$, the borrower prefers to default and lose

$$\varpi_{HH,t}\tilde{A}^b_{HH,t} < \frac{\left(1+R^L_{HH,t}\right)}{1+\pi_t}B_{HH,t-1} = \overline{\varpi}_{HH,t}\tilde{A}^b_{HH,t}$$

when the bank enforces the contract. On the other hand, when $\varpi_{HH,t} \geq \overline{\varpi}_{HH,t}$, the borrower prefers to pay $\frac{\left(1+R^L_{HH,t}\right)}{1+\pi_t}B_{HH,t-1}$ rather than lose $\varpi_{HH,t}\tilde{A}_{HH,t} \geq \frac{\left(1+R^L_{HH,t}\right)}{1+\pi_t}B_{HH,t-1}$.

To be able to use a representative-agent framework while maintaining the intuition of the default rule above, we assume that borrowers belong to a large family that can pool their assets and diversify away the risk related to $\varpi_{HH,t}$ after loan repayments are made. As in Lucas (1990) and Shi (1997), the family maximizes the expected lifetime utility of borrowers with an equal welfare weight for each borrower. The payments from the insurance scheme cannot be seized by the bank. As a result, despite the insurance, the bank cannot force the borrower to repay $\frac{\left(1+R^L_{HH,t}\right)}{1+\pi_t}B_{HH,t-1}$ when $\varpi_{HH,t} < \overline{\varpi}_{HH,t}$. Like the individual borrowers, the family cannot commit to always repay the loan (or make up for any lack of payment by a borrower), even though from an ex ante perspective it is optimal to do so. Ex post, from the perspective of maximizing the expected welfare of the borrowers, for any given $R^L_{HH,t}$ it is optimal to have borrowers with $\varpi_{HH,t} < \overline{\varpi}_{HH,t}$ default and borrowers with $\varpi_{HH,t} \geq \overline{\varpi}_{HH,t}$ repay $\frac{\left(1+R^L_{HH,t}\right)}{1+\pi_t}B_{HH,t-1}$.

Given the large family assumption in particular, households' decisions are the same in equilibrium. Therefore, we can drop the superscript b.

By pooling the borrowers' resources, the representative family has the following aggregate repayments and defaults on its outstanding loan:

$$H(\overline{\varpi}_{HH,t})\tilde{A}_{HH,t} = \left[(1 - F_t(\overline{\varpi}_{HH,t}))\overline{\varpi}_{HH,t} + \int_0^{\overline{\varpi}_{HH,t}} \overline{\varpi} dF_t\right]\tilde{A}_{HH,t}.$$

On the commercial lending bank side, the profit made on the credit allocation is given by

$$G(\overline{\varpi}_{HH,t})\tilde{A}_{HH,t} - \frac{(1 + R_{HH,t-1})}{1 + \pi_t}B_{HH,t-1} \geq 0$$

with

$$G(\overline{\varpi}_{HH,t}) = (1 - F_t(\overline{\varpi}_{HH,t}))\overline{\varpi}_{HH,t} + (1 - \mu_{HH})\int_0^{\overline{\varpi}_{HH,t}} \overline{\varpi} dF_t.$$

$R_{HH,t-1}$ is the interest rate at which the commercial lending bank gets financing every period, while $R^L_{HH,t}$ is the state-contingent lending rate. Competition among banks will ensure that profits are null in equilibrium. The zero-profit condition could also be seen as the borrowing constraint in this model. Notice that this constraint always binds as long as it can be satisfied.[37] In contrast, the hard borrowing constraint in Iacoviello (2005) or Kiyotaki and Moore (1997) may not bind, even though authors using that framework assume it always binds to allow the use of perturbation methods.[38] The caveat is that if a new shock significantly lowers the value of $\tilde{A}_{HH,t}$, it may be impossible to find a default threshold that allows the bank to break even on the loan with the risk-free rate. This should not be a major concern except for very low aggregate shock values.[39]

With the assumption of perfectly competitive banks, we can represent the problem of borrowers as if they choose default thresholds as a function of the aggregate states directly, subject to the bank's participation constraints.

Each borrower maximizes utility function with respect to $\widetilde{C}_t$, $\widetilde{D}_t$, $B_{HH,t}$, $\overline{\varpi}_{HH,t}$, $N_{C,t}$, $N_{D,t}$, subject to an infinite sequence of real budget constraints:[40]

$$\begin{aligned}&\widetilde{C}_t + \widetilde{Q}_{D,t} T_{D,t} \left(\widetilde{D}_t - (1-\delta)\, \widetilde{D}_{t-1} \right) + H(\overline{\varpi}_{HH,t}) \tilde{A}_{HH,t} \\ &\quad = B_{HH,t} + \widetilde{TT}_t + \widetilde{w}_{C,t} \widetilde{N}_{C,t} + \widetilde{w}_{D,t} \widetilde{N}_{D,t}\end{aligned}$$

and the zero-profit condition for the commercial lending banks.

B.2 Labor Supply and Wage Setting

The labor market structure is modeled following Schmitt-Grohe and Uribe (2006). In both countries, households of each type (patient, impatient) provide homogeneous labor services, which are transformed by monopolistically competitive unions into differentiated labor inputs. As a result, all household of the same type supply the same amount of hours worked in each sector, in equilibrium.

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[37] If the constraint were slack, the lender could always reduce the borrower's expected repayments while still respecting the constraint by reducing $\overline{\varpi}_{HH,t}$.

[38] This may be a reasonable assumption for small shocks, but it can be a bad approximation for larger shocks that may be of concern to policymakers.

[39] In our calibrations, the balanced growth path value of the LTV $G(\overline{\varpi}_{HH,t})$ is around 0.5. This suggests that we would need shocks that cause extremely large movements in the LTV on impact before we violate the upper bound on the LTV. See the appendix in Bernanke, Gertler, and Gilchrist (1999) for a discussion of the same issue in their model.

[40] We use the nonresidential goods price level as a deflator.

We assume that in each sector $j \in \{C, D\}$ there exist monopolistically competitive labor unions indexed representing the patient and impatient households. Unions differentiate the homogeneous labor provided by households, N_{jt} from savers and $\widetilde{N}_{jt}$ from borrowers, creating a continuum of measure one of labor services (indexed by $z \in [0, 1]$) which are sold to labor packers.

Then perfectly competitive labor packers buy the differentiated labor input and aggregate them through a constant elasticity of substitution (CES) technology into one labor input per sector and households type. Finally, the labor inputs are further combined using a Cobb-Douglas technology to produce the aggregate labor resource $L_{C,t}$ and $L_{D,t}$ that enters the production functions of entrepreneurs (see later). We specify the details of the labor packers' profit-maximization problem below.

For $i \in \{B, S\}$, $L_{j,i,t}$ measures aggregate labor input for household type i and sector j,

$$L_{j,i,t} = \left[\int_0^1 L_{j,i,t}(z)^{\frac{1}{\mu_w}} \mathrm{d}z \right]^{\mu_w},$$

while $W_{j,i,t}$ denotes the aggregate nominal wage for type i and sector j,

$$W_{j,i,t} = \left[\int_0^1 W_{j,i,t}(z)^{\frac{1}{1-\mu_w}} \mathrm{d}z \right]^{1-\mu_w}.$$

Each union thus faces the following labor demand (originating from sector-specific labor packers):

$$L_{j,i,t}(z) = \left(\frac{W_{j,i,t}(z)}{W_{j,i,t}} \right)^{-\frac{\mu_w}{\mu_w - 1}} L_{j,i,t},$$

where $z \in [0, 1], \mu_w = \frac{\theta_w}{\theta_w - 1}$ and $\theta_w > 1$ is the elasticity of substitution between differentiated labor services, which we assume to be constant across types and sectors. Clearly, our structure gives rise to four different wages in equilibrium, each corresponding to a specific worker type (patient, impatient) in a specific sector (C, D). Unions set wages on a staggered basis. Every period, each union faces a constant probability $1 - \alpha_{wji}$ of being able to adjust its nominal wage.

If the union is not allowed to reoptimize, wages are indexed to past and steady-state inflation according to the following rule:

$$W_{j,i,t}(z) = [\Pi_{t-1}]^{\gamma_w^{j,i}} \left[\overline{\Pi}\right]^{1-\gamma_w^{j,i}} W_{j,i,t-1}(z),$$

where $\Pi_t = \frac{P_t}{P_{t-1}}$ and $\gamma_w^{j,i}$ denotes the degree of indexation in each sector, for each type. Taking into account that unions might not be able to choose their nominal wage optimally in the future, the optimal nominal wage $\widehat{W}_{j,i,t}(z)$ is chosen to maximize intertemporal utility under the budget constraint and the labor demand function.

B.3 Nonfinancial Corporate Sectors

B.3.1 Entrepreneurs

Entrepreneurs are also more impatient than household savers and have a discount factor $\beta_E < \beta$. They receive utility from their consumption of nonresidential goods. They are in charge of the production of intermediate residential and nonresidential goods, and operate in a perfectly competitive environment. They do not supply labor services. Their intertemporal utility function is given by

$$\mathcal{W}_t^E = \mathbb{E}_t \left\{ \sum_{j \geq 0} (\beta_E)^j \frac{\left(C_{t+j}^E - h_E C_{t+j-1}^E\right)^{1-\sigma_{CE}}}{1-\sigma_{CE}} \varepsilon_{t+j}^{\beta} \right\}.$$

Nonresidential intermediate goods are produced with capital and labor, while residential intermediate goods combine capital, labor, and land. In every period of time, savers are endowed with a given amount of land, which they sell to the entrepreneurs in a fixed quantity. We assume that the supply of land is exogenously fixed and that each entrepreneur takes the price of land as given in its decision problem. Entrepreneurs make use of Cobb-Douglas technology as follows:

$$Z_t(e) = \varepsilon_t^A \left(u_t^C(e) K_{t-1}^C(e)\right)^{\alpha_C} L_t^C(e)^{1-\alpha_C} - \Omega_C \qquad \forall e \in [0,1]$$

$$Z_{D,t}(e) = \varepsilon_t^{A_D} \left(u_t^D(e) K_{t-1}^D(e)\right)^{\alpha_D} L_t^D(e)^{1-\alpha_D-\alpha_{\mathcal{L}}} \mathcal{L}_t(e)^{\alpha_{\mathcal{L}}} - \Omega_D,$$

where ε_t^A and $\varepsilon_t^{A_D}$ are exogenous technology shocks and $\mathcal{L}_t(e)$ denotes the endowment of land used by entrepreneur e at time t.

Capital is sector specific and is augmented by a variable capacity utilization rate u_t. MC_t and $MC_{D,t}$ denote the selling prices for intermediate nonresidential and residential products.

Entrepreneurs' fixed capital is subject to common multiplicative idiosyncratic shocks $\varpi_{E,t}$. As for households, these shocks are independent and identically distributed across time and across entrepreneurs with $E(\varpi_{E,t}) = 1$, and a log-normal CDF $F^E(\varpi_{E,t})$. Here again, the variance of the idiosyncratic shock $\sigma_{E,t}$ is time varying.

As for borrowers, entrepreneurs only use debt contracts in which the loan rates can be made contingent on aggregate shocks but not on the idiosyncratic shock $\varpi_{E,t}$. Entrepreneurs belong to a large family that can diversify the idiosyncratic risk after loan contracts are settled, but cannot commit to sharing the proceeds of this insurance with banks. Banks can seize collateral $\varpi_{E,t}\tilde{A}_{E,t}$ when the entrepreneur refuses to pay at a cost of $\mu_E \varpi_{E,t}\tilde{A}_{E,t}$. The value of the collateral that the bank can seize is

$$\varpi_{E,t}\tilde{A}_{E,t} = \varpi_{E,t}(1-\chi_E)(1-\delta_K)(Q_t^C K_{t-1}^C + Q_t^D K_{t-1}^D).$$

We assume that the capital utilization rate is predetermined with respect to the idiosyncratic shock to facilitate aggregation. χ_E reflects the ability to collateralize capital. This specification relates to models where only capital serves as collateral as in Gerali et al. (2010) or Kobayashi, Nakajima, and Inaba (2007).

Aggregate repayments or defaults on outstanding loan to entrepreneurs are

$$H^E(\overline{\varpi}_{E,t})\tilde{A}_{E,t} = \left[(1-F_t^E(\overline{\varpi}_{E,t}))\overline{\varpi}_{E,t} + \int_0^{\overline{\varpi}_{E,t}} \overline{\varpi} dF_t^E\right]\tilde{A}_{E,t}.$$

On the commercial lending bank side, the profit made on the credit allocation is given by

$$G^E(\overline{\varpi}_{E,t})\tilde{A}_{E,t} - \frac{(1+R_{E,t-1})}{1+\pi_t}B_{E,t-1} \geq 0$$

with

$$G^E(\overline{\varpi}_{E,t}) = (1-F_t^E(\overline{\varpi}_{E,t}))\overline{\varpi}_{E,t} + (1-\mu_E)\int_0^{\overline{\varpi}_{E,t}} \overline{\varpi} dF_t^E.$$

$R_{E,t-1}$ is the interest rate at which the commercial lending bank gets financing every period, while $R^L_{E,t}$ is the state-contingent lending rate to entrepreneurs.

Overall, each entrepreneur maximizes its utility function with respect to C^E_t, K^C_t, K^D_t, u^C_t, u^D_t, B^E_t, $\overline{\varpi}_{E,t}$, $L_{C,t}$, $L_{D,t}$, subject to an infinite sequence of real budget constraints

$$\begin{aligned}
&C^E_t + Q^C_t(K^C_t - (1-\delta_K)K^C_{t-1}) \\
&\quad + Q^D_t(K^D_t - (1-\delta_K)K^D_{t-1}) + H^E(\overline{\varpi}_{E,t})\tilde{A}_{E,t} \\
&= B_{E,t} + MC_t Z_t + MC_{D,t}Z_{D,t} - W^r_{C,t}L_{C,t} - W^r_{D,t}L_{D,t} - p_{lt}\mathcal{L}_t \\
&\quad - \Phi\left(u^C_t\right)K^C_{t-1} - \Phi\left(u^D_t\right)K^D_{t-1} + TT^E_t
\end{aligned}$$

together with the participation constraints for the banks. We assume the following functional form for the adjustment costs on capacity utilization: $\Phi(X) = \frac{\overline{\overline{R^k}}(1-\varphi)}{\varphi}\left(\exp\left[\frac{\varphi}{1-\varphi}(X-1)\right]-1\right)$. Following Smets and Wouters (2007), the cost of capacity utilization is zero when capacity is fully used ($\Phi(1)=0$). p_{lt} denotes the relative price of land deflated by nonresidential goods price.

B.3.2 Retailers and Distribution Sectors

Retailers differentiate the residential and nonresidential goods produced by the entrepreneurs and operate under monopolistic competition. They sell their output to the perfectly competitive distribution sectors, which aggregate the continuum of differentiated goods. The elementary differentiated goods are imperfect substitutes with elasticity of substitution denoted $\frac{\mu_D}{\mu_D-1}$ and $\frac{\mu}{\mu-1}$ for the residential and the nonresidential sectors, respectively. The distributed goods are then produced with the following technology: $Y_D = \left[\int_0^1 Z_D(d)^{\frac{1}{\mu_D}}\mathrm{d}d\right]^{\mu_D}$ and $Y = \left[\int_0^1 Z(c)^{\frac{1}{\mu}}\mathrm{d}c\right]^{\mu}$. The corresponding aggregate price indexes are defined as $P_D = \left[\int_0^1 p_D(d)^{\frac{1}{1-\mu_D}}\mathrm{d}d\right]^{1-\mu_D}$ for the residential sector and $P = \left[\int_0^1 p(c)^{\frac{1}{1-\mu}}\mathrm{d}c\right]^{1-\mu}$ for the nonresidential sector. The distribution goods serve as final consumption goods for households and are used by capital and housing stock producers.

Retailers are monopolistic competitors which buy the homogeneous intermediate products of the entrepreneurs at prices MC_t for the nonresidential intermediate goods and $MC_{D,t}$ for the residential intermediate goods. The intermediate products are then differentiated and sold back to the distributors. Retailers set their prices on a staggered basis à la Calvo (1983). In each period, a retailer in the nonresidential sector faces a constant probability $1 - \xi_C$ (resp. $1 - \xi_D$ in the residential sector) of being able to reoptimize its nominal price. The demand curves that retailers face in each sector follow $Z_D(d) = \left(\frac{p_D(d)}{P_D}\right)^{-\frac{\mu_D}{\mu_D - 1}} Y_D$ and $Z(c) = \left(\frac{p(c)}{P}\right)^{-\frac{\mu}{\mu - 1}} Y$.

B.3.3 Capital and Housing Stock Producers

Using distributed residential and nonresidential goods, a segment of perfectly competitive firms, owned by the patient households, produce a stock of housing and fixed capital. At the beginning of period t, those firms buy back the depreciated housing stocks from both household types $(1 - \delta)D_{t-1}$ and $(1 - \delta)\widetilde{D}_{t-1}$ as well as the depreciated capital stocks $(1 - \delta_K)K^C_{t-1}$, $(1 - \delta_K)K^D_{t-1}$ at real prices (in terms of consumption goods) $Q_{D,t}T_{D,t}$, $\widetilde{Q}_{D,t}T_{D,t}$, Q^D_t, Q^C_t, respectively. Then they augment the various stocks using distributed goods and facing adjustment costs. The augmented stocks are sold back to entrepreneurs and households at the end of the period at the same prices.

B.4 The Banking Sector

The banking sector is owned by the patient households and is segmented in three parts. Following Gerali et al. (2010), each banking group is first composed of a wholesale branch which gets financing in the money market and allocates funds to the rest of the group, facing an adjustment cost on the overall capital ratio of the group. The wholesale branch takes the bank capital and the dividend policy as given in its decision problem and operates under perfect competition. The second segment of the banking group comprises a deposit branch, which collects savings from the patient households and places them in the money markets, as well as two loan book financing branches, which receive funding from the wholesale branch and allocate those funds to the commercial lending branches. In this second segment, banks operate under monopolistic competition and face nominal rigidity in their interest rate settings. The third segment of the banking group is formed by two commercial lending branches which provide loan contracts to impatient households and entrepreneurs. The commercial lending branches are zero-profit competitive firms.

B.4.1 Wholesale Branch

The perfectly competitive wholesale branches receive deposits Dep_t^{wb}, from the retail deposit banks, with an interest rate set at the policy rate R_t. Taking as given the bank capital $Bankcap_t$ in real terms, they provide loans $B_{E,t}^{wb}$ and $B_{HH,t}^{wb}$ at interest rates $R_{E,t}^{wb}$ and $R_{HH,t}^{wb}$ to the loan book financing branches for lending to entrepreneurs and households, respectively. When deciding on deposits and loans, the wholesale banks are constrained by an adjustment cost on bank's leverage. This friction is meant to capture the capital requirement pressures on the bank's behavior. For this reason, we assume that wholesale banks target a capital ratio of 11 percent and the quadratic cost is supposed to illustrate the various interactions between banks' balance sheet structure, market disciplining forces, and the regulatory framework.[41] On the one hand, this reflects that, due to pecuniary and reputational costs, banks are keen to avoid getting too close to the regulatory minimum capital requirement and hence tend to operate with a substantial buffer over that minimum capital ratio.[42] On the other hand, bank capital is costly relative to other sources of financing (like deposits and bond issuance), implying that banks tend to economize on the amount of capital they hold.[43]

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[41]The 11 percent capital ratio target corresponds to the average (risk-adjusted) total capital ratio of the around 100 largest euro-area banks for the period 1999–2008, according to Datastream (Worldscope).

[42]There is a rich literature providing evidence that banks operate with substantial capital buffers; for some recent studies see, e.g., Ayuso, Pérez, and Saurina (2004), Berger et al. (2008), Bikker and Metzemakers (2004), Gropp and Heider (2010), and Stolz and Wedow (2005).

[43]For example, ECB estimates of the cost of equity, the cost of market-based debt (i.e., bond issuance), and the cost of deposits for euro-area banks show that the former was on average around 6.7 percent in the period 2003–09. During

Under the Basel I-like capital requirement regime, the bank's static profit-maximization problem can be formulated as follows where all quantities are expressed in real terms:

$$\max_{B_t^w, Dep_t^w} R_{HH,t}^{wb} B_{HH,t}^{wb} + R_{E,t}^{wb} B_{E,t}^{wb} - R_t Dep_t^{wb}$$
$$- \frac{\chi_{wb}}{2} \left(\frac{Bankcap_t}{0.5 B_{HH,t}^{wb} + B_{E,t}^{wb}} - 0.11 \right)^2 Bankcap_t$$

subject to the balance sheet identity

$$B_{HH,t}^{wb} + B_{E,t}^{wb} = Dep_t^{wb} + Bankcap_t.$$

As in Gerali et al. (2010) the derived lending spreads emphasize "the role of bank capital in determining loan supply conditions." For example, if the spread between the lending rate and the policy rate is positive, the bank would have an incentive to increase profits by raising loan volumes. But expanding lending would increase its leverage, which is penalized by regulatory rules and market disciplining forces. In the model, these penalties take the form of a cost to the bank which increases as the capital ratio moves away from its target. The bank's decision problem is therefore finely balanced between boosting its profits via increased leverage and retaining control of its capital structure. Moreover, a key point to notice for our Basel I-type specification is that the bank's target capital ratio is insensitive to changes in borrower risk over time. In addition, reflecting the risk weighting of the Basel I regulatory framework, household loans are given a (fixed) risk weight of 50 percent whereas the risk weight attached to corporate loans is 100 percent.

The decision problem of the wholesale bank leads to the following condition on the spread between the lending rate and the policy rate:

$$R_{HH,t}^{wb} - R_t$$
$$= -\chi_{wb} \left(\frac{Bankcap_t}{0.5 B_{HH,t}^{wb} + B_{E,t}^{wb}} - 0.11 \right) \left(\frac{Bankcap_t}{0.5 B_{HH,t}^{wb} + B_{E,t}^{wb}} \right)^2 0.5$$

the same period, banks' cost of raising debt in the capital markets was around 5 percent, while their average cost of deposit funding was close to 2 percent.

$$R^{wb}_{E,t} - R_t$$
$$= -\chi_{wb}\left(\frac{Bankcap_t}{0.5B^{wb}_{HH,t} + B^{wb}_{E,t}} - 0.11\right)\left(\frac{Bankcap_t}{0.5B^{wb}_{HH,t} + B^{wb}_{E,t}}\right)^2.$$

When the leverage of the bank increases beyond the targeted level, banks increase their loan-deposit margins.

The capital base of the wholesale branch is accumulated out of retained earnings from the bank group profits

$$Bankcap_t = (1 - \delta^{wb})Bankcap_{t-1} + \nu^b \Pi^b_t,$$

where δ^{wb} represents the resources used in managing bank capital, Π^b_t is the overall profit of the bank group, and ν^b is the share of profits not distributed to the patient households.

B.4.2 Imperfect Pass-Through of Policy Rate on Bank Lending Rates

The retail deposit branch and the loan book financing branches are monopolistic competitors and set their interest rates on a staggered basis with some degree of nominal rigidity à la Calvo (1983).

Retail Deposit Branch. The deposits offered to patient households are a CES aggregation of the differentiated deposits provided by the retail deposit branches: $Dep = \left[\int_0^1 Dep(j)^{\frac{1}{\mu^R_D}} \mathrm{d}j\right]^{\mu^R_D}$, expressed in real terms. Retail deposits are imperfect substitutes with elasticity of substitution $\frac{\mu^R_D}{\mu^R_D - 1} < -1$. The corresponding average interest rate offered on deposits is $R_D = \left[\int_0^1 R_D(j)^{\frac{1}{1-\mu^R_D}} \mathrm{d}j\right]^{1-\mu^R_D}$.

Retail deposit branches are monopolistic competitors which collect deposits from savers and place them in the money market. Deposit branches set interest rates on a staggered basis à la Calvo (1983), facing each period a constant probability $1 - \xi^R_D$ of being able to reoptimize their nominal interest rate. When a retail deposit branch cannot reoptimize its interest rate, the interest rate is left at its previous period level:

$$R_{D,t}(j) = R_{D,t-1}(j).$$

The retail deposit branch j chooses $\hat{R}_{D,t}(j)$ to maximize its intertemporal profit.

$$\mathbb{E}_t \left[\sum_{k=0}^{\infty} \left(\gamma \xi_D^R\right)^k \frac{\Lambda_{t+k}}{\Lambda_t} \left(R_{t+k} Dep_{t+k}(j) - \hat{R}_{t,D}(j) Dep_{t+k}(j) \right) \right],$$

where $Dep_{t+k}(j) = \left(\frac{\hat{R}_{D,t}(j)}{R_{D,t}}\right)^{-\frac{\mu_D^R}{\mu_D^R - 1}} \left(\frac{R_{D,t}}{R_{D,t+k}}\right)^{-\frac{\mu_D^R}{\mu_D^R - 1}} Dep_{t+k}$ and Λ_t is the marginal value of nonresidential consumption for the households savers.

A markup shock $\varepsilon_{D,t}^R$ is introduced on the interest rate setting.

Loan Book Financing Branches. As for the retail deposit branches, loan book financing branches provide funds to the commercial lending branches, which obtain overall financing through a CES aggregation of the differentiated loans: $B_{E,t} = \left[\int_0^1 B_{E,t}(j)^{\frac{1}{\mu_E^R}} \mathrm{d}j\right]^{\mu_E^R}$ as regards commercial loans to entrepreneurs and $B_{HH,t} = \left[\int_0^1 B_{HH,t}(j)^{\frac{1}{\mu_{HH}^R}} \mathrm{d}j\right]^{\mu_{HH}^R}$ as regards commercial loans to households. Loans from loan book financing branches are imperfect substitutes with elasticity of substitution $\frac{\mu_E^R}{\mu_E^R - 1}$ and $\frac{\mu_{HH}^R}{\mu_{HH}^R - 1} > 1$. The corresponding average lending rate is

$$R_E = \left[\int_0^1 R_E(j)^{\frac{1}{1-\mu_E^R}} \mathrm{d}j\right]^{1-\mu_E^R} \text{ and}$$

$$R_{HH} = \left[\int_0^1 R_{HH}(j)^{\frac{1}{1-\mu_{HH}^R}} \mathrm{d}j\right]^{1-\mu_{HH}^R}.$$

Loan book financing branches for each segment of the credit market are monopolistic competitors which levy funds from the wholesale branches and set interest rates on a staggered basis à la Calvo (1983), facing each period a constant probability $1 - \xi_E^R$ and $1 - \xi_{HH}^R$ of being able to reoptimize their nominal interest rate. If a loan book financing branch cannot reoptimize its interest rate, the interest rate is left at its previous-period level:

$$R_{HH,t}(j) = R_{HH,t-1}(j)$$
$$R_{E,t}(j) = R_{E,t-1}(j).$$

In each sector $i \in \{E, HH\}$, the loan book financing branch j chooses $\hat{R}_{i,t}(j)$ to maximize its intertemporal profit.

$$\mathbb{E}_t \left[\sum_{k=0}^{\infty} \left(\gamma \xi_i^R\right)^k \frac{\Lambda_{t+k}}{\Lambda_t} \left(\hat{R}_{i,t}(j) B_{i,t+k}(j) - R_{i,t}^{wb}(j) B_{i,t+k}(j) \right) \right],$$

where $B_{i,t+k}(j) = \left(\frac{\hat{R}_{i,t}(j)}{R_{i,t}}\right)^{-\frac{\mu_i^R}{\mu_i^R - 1}} \left(\frac{R_{i,t}}{R_{i,t+k}}\right)^{-\frac{\mu_i^R}{\mu_i^R - 1}} B_{i,t+k}$.

As for deposit rates, we add markup shocks $\varepsilon_{HH,t}^R$ and $\varepsilon_{E,t}^R$ to the staggered nominal lending rate settings.

Commercial Lending Branches. Commercial lending branches are delivering credit contracts for entrepreneurs and household borrowers. Those branches are perfectly competitive and in equilibrium have zero profits. Details on the credit contract and the decision problems for the commercial lending branches are provided in the sections on entrepreneurs and household borrowers.

B.5 Government and Monetary Authority

Public expenditures $\overline{\overline{G}}$ are subject to random shocks ε_t^G. The government finances public spending with lump-sum transfers.

Monetary policy is specified in terms of an interest rate rule targeting inflation, output, and their first difference as well as changes in the relative price of housing. Written in deviation from the steady state, the interest rate rule used has the following form:

$$\begin{aligned} r_t = {} & \rho r_{t-1} + (1-\rho)\left(r_\pi \pi_{t-1} + r_y y_{t-1}\right) \\ & + r_{\Delta\pi} \Delta\pi_t + r_{\Delta y} \Delta y_t + r_{T_D} \Delta t_{D,t} + \log\left(\varepsilon_t^R\right), \end{aligned}$$

where lowercase letters denote log-deviations of a variable from its deterministic steady state.

B.6 Comparing RAMSES Model for Sweden and the Euro-Area Model

The main differences between the DSGE model used for our euro-area calculations and the model used by Svensson for Sweden are the banking sector, labor market, housing sector, and the open economy. Darracq Pariès, Kok, and Rodriguez-Palenzuela (2011) feature a well-developed banking sector which intermediates deposits from patient households to firms and impatient households. Furthermore, loans to households are backed by housing. RAMSES features an open economy, has more sophisticated labor market dynamics featuring unemployment, and only incorporates risky loans between firms and households.

Appendix C. Acronyms

AIC	Akaike information criterion
AUROC	area under receiver operating characteristic
BIS	Bank for International Settlements
CCyB	countercyclical capital buffer
CDF	cumulative distribution function
CES	constant elasticity of substitution
DSGE	dynamic stochastic general equilibrium
DTI	debt-to-income
ECB	European Central Bank
ESRB	European Systemic Risk Board
GDP	gross domestic product
GFC	global financial crisis
IRF	impulse response function
LASSO	least absolute shrinkage and selection operator
LAW	“leaning against the wind”
LTV	loan-to-value
OLS	ordinary least squares
pp	percentage point
SRI	systemic risk indicator
VAR	vector autoregression

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