Financial Cycles, Credit Bubbles and Stabilization Policies*

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Abstract

This paper analyzes the effects of several policy instruments to mitigate financial bubbles generated in the banking sector. We augment a New Keynesian macroeconomic framework by endogenizing boundedly-rational expectations on asset values of loan portfolios and allow for interbank trading. We then show how a financial bubble can develop from a financial innovation. By incorporating a loan management technology and a bank equity channel we can evaluate the efficacy of several policy instruments in counteracting financial bubbles. We find that an endogenous capital requirement reduces the impact of a financial bubble significantly while central bank intervention ("leaning against the wind") proves to be less effective. A welfare analysis ranks the policy reaction through an endogenous capital requirement as best.

JEL: E44, E52

Keywords: Financial bubbles, credit-to-GDP gap, endogenous capital requirement, stabilization policies

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1 Introduction

The run-up of financial bubbles followed by financial crashes is a (sadly) frequent phenomena in modern economies. The building up of the bubble as well as its crash usually sets a number of amplification mechanisms linked to the presence of financial frictions and spillovers effects in the real economy (especially in terms of consumption and investment decisions). Indeed, "procyclicality" is a relevant feature of financial cycles for macroeconomists and policymaking: hence the focus on business cycle fluctuations and financial crises (Borio et al. (2001), Danielsson et al. (2004), Kashyap and Stein (2004), Brunnermeier et al. (2009), Adrian and Shin (2010)).

In this paper we formalize the processes of bubble creation and asset price inflation to provide a setting for the analysis of monetary policy and efficacy of regulatory instruments. In particular, we consider a real (or rational) trigger of the bubble in form of a financial innovation and an (irrational or behavioral) extrapolation of past loan growth into the future asset price. We augment a standard New-Keynesian macroeconomic model with a loan management technology and endogenous equity holdings for banks to define policy instruments and measure their efficacy in counteracting financial bubbles. We consider several policy options (*i*) a conventional monetary policy reaction to changes in overall loans ("leaning against the wind"); (*ii*) a macroprudential measure that increases exogenously the target level of the capital requirement for bank equity and (*iii*) an endogenous capital requirement that reacts to the credit-to-GDP gap.

To investigate the role of stabilization policies we look through the lense of a general equilibrium model with supply side financial frictions which incorporates a bubble generating process in the loan market feeding back into the real sector via households' demand for deposits. We consider a model with bank monitoring and inside money creation features (see Goodfriend and McCallum (2007)) with interbank transactions in the form of securitization in the loan market, where a resale of loans triggers the build-up of the financial bubble. We contribute to the literature in several ways. First, we model the process of bubble creation in the loan market following Branch and Evans (2005) assuming that agents act as econometricians when forecasting and use this bounded rationality on banks when they evaluate the change in loan value. The repackaging of loans results in a higher value as it allows for mark-to-market of the bubble. In a financial system where balance sheets are continuously marked-to-market, asset price changes show up immediately in changes in net worth, and elicit responses from financial intermediaries who adjust the size of their balance sheets. Hence mark-to-market leverage is strongly procyclical (Adrian and Shin, 2008 and 2010) as the loan bubble feeds into bank's equity values featuring a banking sector transmission through endogenous bank capital (see also Gerali et al., 2011). Second, in the proposed setup we analyse the stabilizing effects of several policy options. We find that a "leaning against the wind" policy is less effective in reducing the size of financial bubbles than as an endogenous rule for the capital requirement reacting to the credit-to-GDP-gap. Raising the overall capital levels increases volatility, but improves welfare through lower spreads. We are to our knowledge the first to assess these measures in one single framework.

1.1 Motivation

Financial cycles, characterized by a build-up of an asset price bubble, are less frequent than average business cycles. However, when the bubble bursts, its economic consequences remain for a long period of time (see Reinhart and Rogoff (2011); Brunnermeier and Oehmke (2013)).

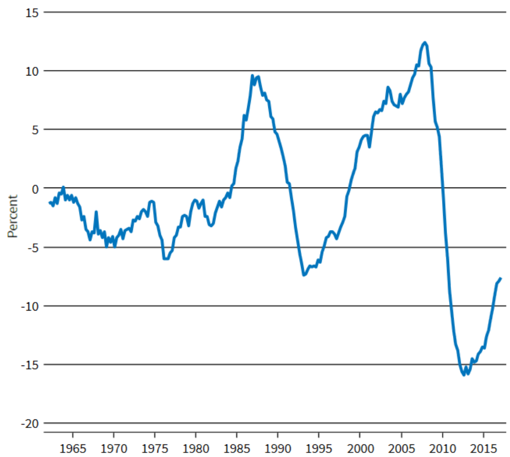
We define an asset price and credit bubble through three phases: the creation of the bubble (potentially triggered by financial innovation), a period of inflation and sudden burst (or implosion). During the boom the price of an asset deviates from its intrinsic value, i.e. it is not just determined by supply and demand forces; such a deviation features a positive feedback mechanism. In a burst asset prices suddenly fall inducing a negative feedback mechanism, sometimes even below the intrinsic value. These interactions can amplify economic fluctuations and possibly lead to serious financial distress and prolonged economic disruption.

To measure the financial cycle we employ the credit-to-GDP gap published by the Bank of International Settlements. The credit-to-GDP gap (according to the definition by the BIS) is the difference between the credit-to-GDP ratio and its long-run trend.[1] It reflects the build-up of excessive credit, i.e. of a credit bubble, in reduced form. Focusing on a credit measure, we can abstract from specific asset classes affected by the bubble such as housing, or stock markets. Figure 1 shows the developments of the credit-to-GDP gap in the U.S., Japan and for several European countries. For all countries plotted we see sizable swings in this measure.

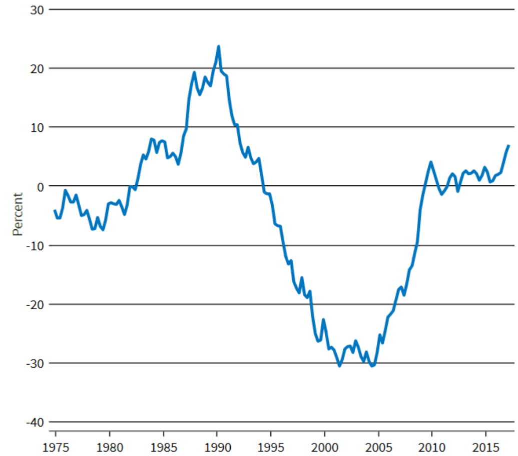
Panel (a) shows swings in a magnitude of 25% peak to trough for the United States in the last financial cycle. The coupling of low interest rates and financial innovation in the form of mortgage securitization fueled a housing prices bubble. Its burst in 2007 led to one of the longest and deepest economic downturn in U.S. history (for a summary, see Brunnermeier et al. (2009) and Brunnermeier and Oehmke (2013)). Panel (b) shows how the Japanese economy experienced a long-lasting financial cycle with a swing of 50% from peak to trough in the credit-to-GDP measure. Japan faced a very deep crisis after the end of the real estate and stock markets boom in the early 1990s leading to the so-called "lost decade" of the 1990s and enduring low growth during the 2000s. Several European countries have been recently dealing with major financial cycles, documented by swings in the credit-to-GDP gap for the U.K. in panel (d) (40% swing peak-to-trough) and Italy in panel (f) (30% swing peak-to-trough).

[1] In the BIS database the credit-to-GDP ratio is total credit to the private non-financial sector and captures total borrowing from all domestic and foreign sources as input data (https://www.bis.org/statistics/c_gaps.htm).

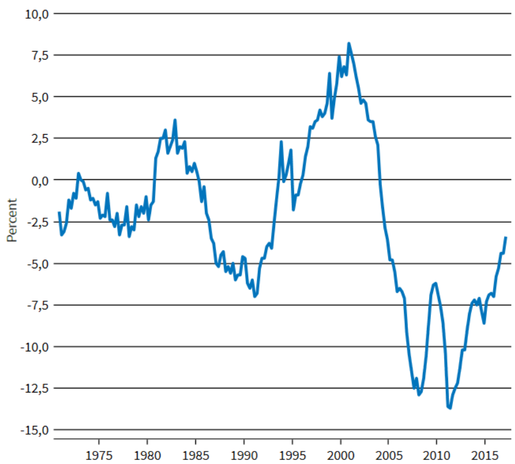
Figure 1: Credit-to-GDP Gap, Quarterly.



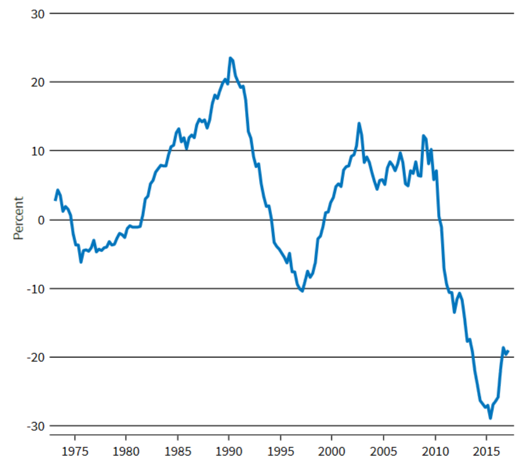
(a) United States



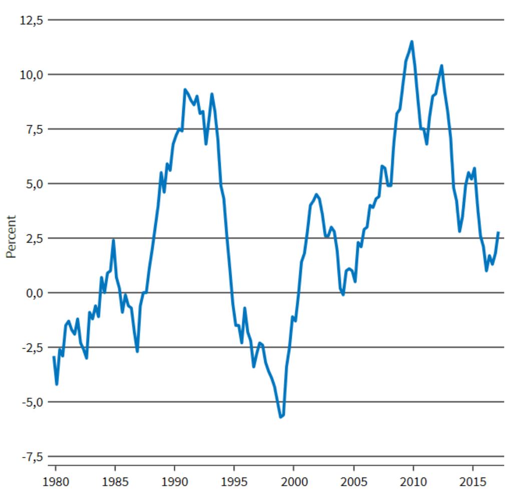
(b) Japan



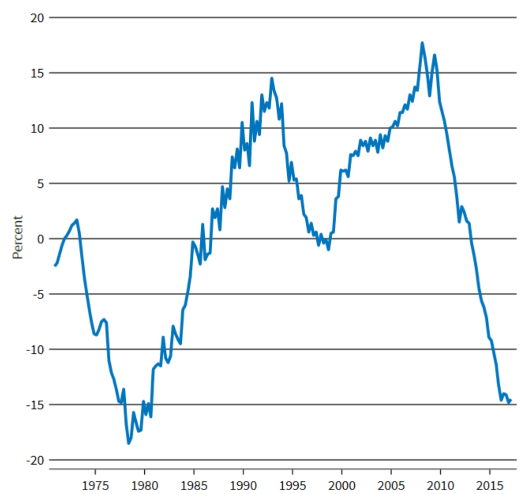
(c) Germany



(d) United Kingdom



(e) France



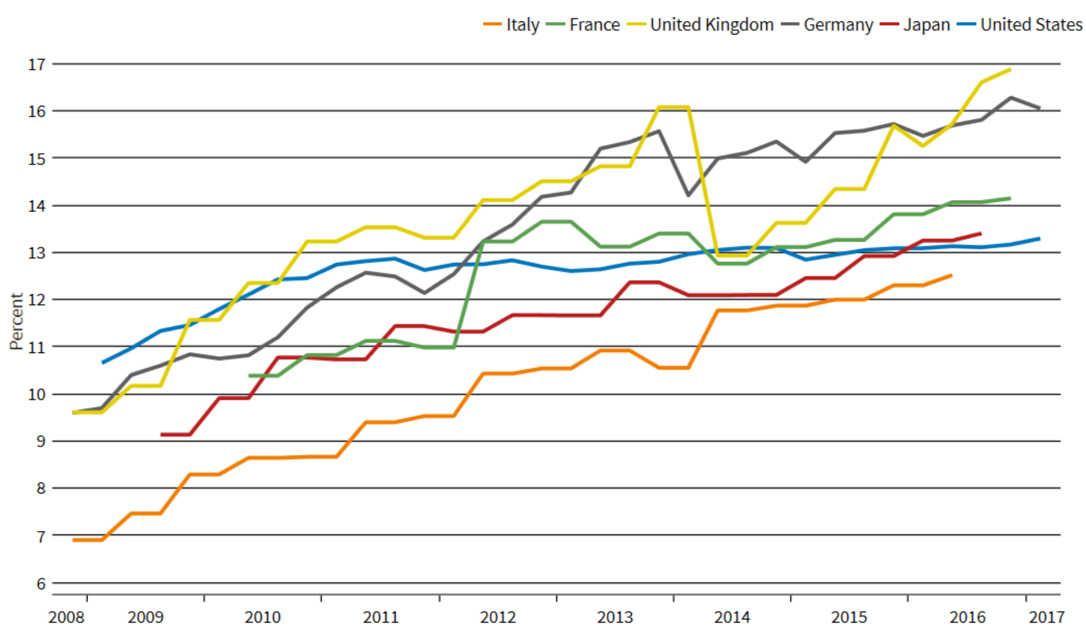
(f) Italy

Source: BIS. Based on total credit to the private non-financial sector, as % of GDP. Credit-to-GDP gaps is defined as the difference between the credit-to-GDP ratio and its long-term trend; in percentage points. Long-term trend is calculated using a one-sided Hodrick-Prescott filter with a lambda of 400,000.

Germany and France (panel (c) and (e) resp.) experienced swings of a lesser extent and did not have major domestically-driven financial crises.

Several policy options can be considered for reducing the probability and severity of future financial crises. First, monetary policy can "lean against the wind" of asset prices and credit booms by adopting a higher policy interest rate than what would be implied by the inflation target and the stabilization of the output gap (BIS (2014) and (2015)). Second, in the aftermath of the global financial crisis new capital regulation was adopted increasing the risk-weighted capital requirements of banks. Policy switches to stricter capital requirements can be observed in the U.S. Japan and Europe. Figure 2 shows the ratio between Tier 1 capital (the sum of common stocks plus retained bank profits) over risk weighted assets where risk weighted asset assign the highest weight (50%) to loans. The ratio has been steadily increasing in the aftermath of the crisis. Other measures as a stricter LTV ratio and limits to leverage have similar macroeconomic effects, so that higher capital requirement serves as a proxy for several regulatory measures which stay fixed over the financial cycle.

Figure 2: Tier1 Capital to Risk Weighted Assets



Source: IMF

Finally, the countercyclical capital buffers (CCyB) are an integral part of the Basel III capital standards. The credit-to-GDP gap is a "common reference point under Basel III to guide the build-up of countercyclical capital buffers"Ȧll major economies have adopted regulations regarding the CCyB, but it has not yet been activated in the U.S., Japan, and major European economies with the exception of the U.K. In this paper we build a single setup in which these policy alternatives can be evaluated.

1.2 Related Literature

Modern economies experience financial cycles with episodes of large movements in asset prices that cannot be explained by changes in economic fundamentals. Such evidence has triggered a growing literature on financial bubbles in macroeconomic models. Brunnermeier and Oehmke (2013) analyse the amplification mechanisms of rational bubbles in asset prices. In models of rational bubbles, agents hold a bubble asset because its price is expected to rise in the future. The implied explosive nature of the price path in this class of models is consistent with the observed run-up phases to many financial crises. Bubbles in asset prices can emerge in an overlapping generation setting (Galí (2014), (2017)). Furthermore, and in contrast with the earlier literature on rational bubbles, the introduction of nominal rigidities allow the Central Bank to impact on the real interest rate and, through it, on the magnitude of the bubble. Bubbles in asset prices can arise and survive because of several class of frictions characterising the underlying economic model. A more recent strand of literature deals with these counterfactual implications by adding borrowing constraints. For example, in the model by Martin and Ventura (2012), entrepreneurs face financing constraints so they can borrow only a fraction of their future firm value. When such financing constraints are present, bubbles can have a crowding-in effect, and thus allow the productive set of entrepreneurs to increase investments. Lending is not intergenerational, but in our view can be more adequately explained through decisions made in the banking sector.

Bubbles in asset prices can also originate on heterogeneous beliefs (Scheinkman and Xiong (2003), Xiong (2013)). In a market in which agents disagree about an asset's fundamental and short sales are constrained, an asset owner is willing to pay a price higher than his own expectation of the asset's fundamental because he expects to resell the asset to a future optimist at an even higher price. Such speculative behavior leads to a bubble component in asset prices. The bubble component builds on the fluctuations of investors' heterogeneous beliefs. It is also possible to analyze welfare implications of belief distortions based on models with heterogeneous beliefs (Brunnermeier, Simsek and Xiong (2014)). These findings question the efficient markets notion that rational speculators always stabilize prices. They are consistent with models in which rational investors may prefer to ride bubbles because of predictable investor sentiment, heterogenous beliefs and limits to arbitrage (Brunnermeier and Nagel, 2004). Boswijk, Hommes and Manzan (2007) estimate a model with fundamentalist and chartist traders whose relative shares evolve according to an evolutionary performance criterion, showing that the model can generate a run-up in asset prices and subsequent mean-reversion to fundamental values. Finally, bubbles can originate from near-rational behaviour of agents. Lansing (2010) shows how near-rational bubbles can arise under learning dynamics when agents forecast a composite variable depending on the future asset price. Branch and Evans (2011) present a model where agents learn about risk and return and show how it gives rise to bubbles. DeLong et al. (1990) show how the pricing effects of positive feedback trading can both originate and amplify bubbles in asset prices. In our setup, we incorporate the notion of bounded-rationality through a Kalman filter recursion.

The control of bubble-burst episodes in the financial sector has put forth a series of proposals. Benes and Kumhof (2012) analyse in a DSGE setting the implication of the Chicago Plan. The plan is preventing banks from creating excessive inside money during credit booms, and then dismantle it during economic downturns, in order to soften credit cycles. More recent macroprudential policies try to influence the supply of credit taking a system-wide approach. In the absence of macroprudential policy the monetary authority reacts to an adverse change to financial conditions by using the policy rate to affect the refinancing conditions of financial intermediaries (Blinder et al. (2008), Carlstrom and Fuerst (1997)). Woodford (2012) finds a complementary role of macroprudential policy along with interest rate policy, Svensson (2012) argues in favor of a clear assignment to financial stability and price stability. Most of macroprudential tools discussed in the literature are targeted at the bank's regulatory capital to address potential vulnerabilities on the demand side of credit.[2] Studies which raise the importance of supply side features identify, instead, short term debt refinancing of banks as a major source of vulnerability and financial innovation in the form of new financial instruments used in the interbank market.[3] Endogenous capital requirements (Borio (2012)) have been proposed as a part of macroprudential policies. A key element is to address the procyclicality of the financial sector by building up buffers in good times, when financial vulnerabilities emerge, so as to be able to drain them in bad times, when financial strain materialises. If effective macroprudential frameworks were in place, capital and liquidity buffers could be drained to control the building up of the bubble. By setting up a comprehensive banking sector within our macroeconomic model, we can evaluate the efficacy of interest rate policy, fixed capital requirements and countercyclical requirements in one single framework.

The paper is organized as follows: Sections 2, 3 and 4 describe the model and its equilibrium. Section 5 gives the results of quantitative experiments. Section 6 shows the welfare analysis, before section 7 concludes.

[2] Examples for models with limited borrowing capacity of households are Bernanke, Gertler and Gilchrist (1999) and Kiyotaki and Moore (1997). Corrado and Schuler (2017), among others, analyse the effects of several macroprudential policy measures in a model with cash-in-advance households in which banks trade excess funds in the interbank lending market. They conclude that stricter liquidity measures along with a moderate capital requirement directly limit inside money creation, therefore reducing the severity of a breakdown in interbank lending.

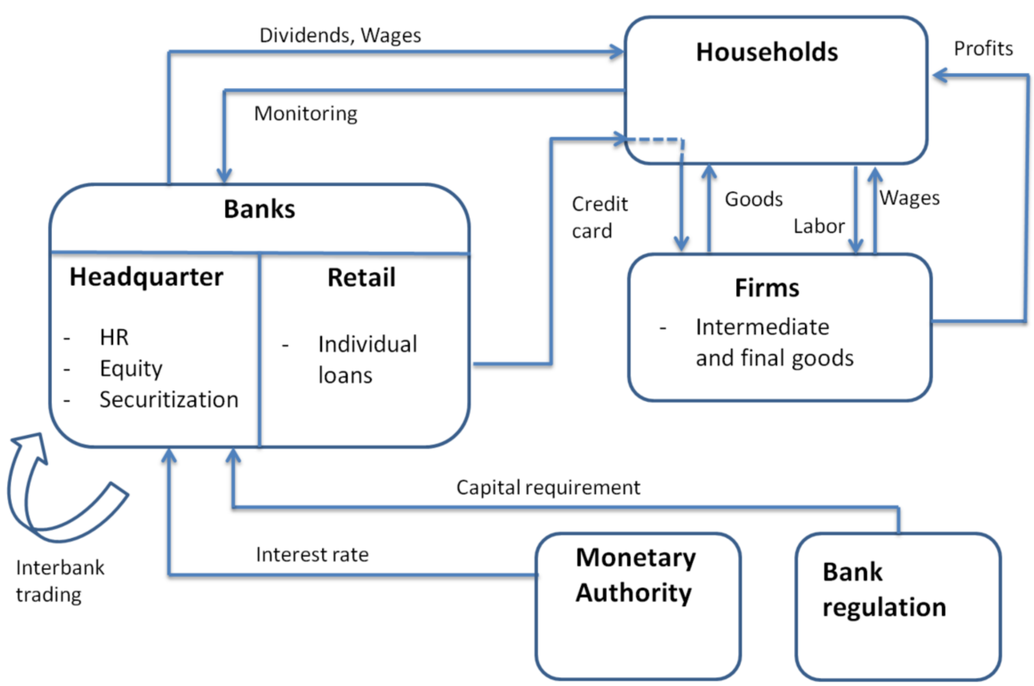
[3] Justiniano et al. (2015), Gertler and Karadi (2011) and Gertler and Kiyotaki (2010) focus on the role of endogenous leverage constraints for banks to trigger credit supply disruptions.

2 Non-financial sector

In this section we first describe the non-financial sector, and in the following the banking system including the central bank. The agents in this economy and their interconnections are summarized in a flow chart in Figure 3. The real part of the model comprizes of households in which one part consumes by spending money, and the other part works for firms and in the banking sector. Households can invest in bank shares and save in bonds.

There are monopolistically-competitive intermediate firms and a continuum of final good producing firms which together form the production sector.

Figure 3: Model Overview



2.1 Households

There is a mass one of infinitely-lived households with the utility described by

$$\max\ E_0 \sum_{t=0}^{\infty} \beta^t \left[log(c_t) + \phi_l log(1 - l_t^s - m_t^s) \right] \tag{1}$$

where c_t is consumption, l_t^s labor provided to the production sector and m_t^s labor provided to the banking sector. ϕ_l reflects the weight of leisure. Households only can acquire consumption goods by spending bank deposits D_t which means that they have to fulfill a money in advance constraint given by

$$P_t c_t \leq v D_t \tag{2}$$

Their budget is described by the following inequality which involves the interest payments on loans, L_t, and deposits, D_t:

$$\begin{aligned} c_t + \frac{B_{t+1}}{P_t} + \frac{D_{t+1}}{P_t} - \frac{L_{t+1}}{P_t} + \frac{Q_t^\Psi}{P_t}\Psi_t \quad \leq \quad & w_t(l_t^s + m_t^s) + (1+R_t^B)\frac{B_t}{P_t}... \\ & ... + (1+R_t^D)\frac{D_t}{P_t} - (1+R_t^L)\frac{L_t}{P_t} + \frac{Q_t^\Psi + \Pi_t^\Psi}{P_t}\Psi_{t-1} + \Pi_t^F \end{aligned} \tag{3}$$

Here B_t are savings in government bonds, w_t the real wage for production or banking labor, P_t the price level, and R_t^D, R_t^L, and R_t^B interest rates on the respective assets and liabilities. Q_t^Ψ represents the equity price and Ψ_t the equity investments. Π_t^Ψ relates to dividend payments for bank equity.

Optimal production and monitoring labor imply

$$\lambda_t w_t = \frac{\phi_l}{(1 - l_t^s - m_t^s)}. \tag{4}$$

The Euler equation with respect to bonds reads as

$$\begin{aligned} E_t \Lambda_{t,t+1}(1 + R_{t+1}^B) &= 1 \\ \Lambda_{t,t+1} &\equiv E_t \beta \left\{ \frac{\lambda_t P_{t+1}}{\lambda_{t+1} P_t} \right\} \end{aligned} \tag{5}$$

The Euler equation for the pricing of equity, Ψ_t, assuming no direct utility from equity holdings,[4] gives

$$1 = \beta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \frac{Q_{t+1}^\Psi + \Pi_{t+1}^\Psi}{Q_t^\Psi} \frac{P_t}{P_{t+1}} \right\} \tag{6}$$

For each household i the cash in advance constraint

$$P_t c_t(i) = v D_t(i) \tag{7}$$

generates an individual loan demand

$$L_t(i) = D_t(i) \tag{8}$$

[4] We abstract from the possibility that agents could draw prestige related to social status from owning banks and other wealth items, see Kumhof et al. (2015) for the alternative approach.

Household i obtains individual deposits $D_t(i)$ through loans $L_t(i)$ from each bank j, i.e.

$$L_t(i) = \int_0^1 L_t(i,j)dj \tag{9}$$

and

$$D_t(i) = \int_0^1 D_t(i,j)dj, \tag{10}$$

where the individual demands are determined by the interest rate ratio of the bank j vs. the aggregate interest rate level. Finally, optimal holdings of bank deposits, D_t, are determined by

$$\frac{1}{\lambda_t} = c_t + \frac{L_t}{P_t}\left[R_t^L - R_t^D\right], \tag{11}$$

which relates them to consumption and the marginal cost of holding loans, i.e. the aggregate interest spread.[5]

2.2 Firms

Production of consumer goods involves two stages with intermediate inputs. The final goods firm produces a composite good, y_t, by combining intermediate goods, $y_t(i)$, through a constant elasticity of substitution (CES) aggregator, i.e.

$$y_t = \left(\int_0^1 y_t(i)^{1-\epsilon} di\right)^{\frac{1}{1-\epsilon}} \tag{12}$$

The profit function of intermediate firm i is given by

$$\Pi_t^F(i) = y_t(i) - w_t l_t(i) \tag{13}$$

Intermediate goods are produced by employing labor, l_t, according to the following technology

$$y_t(i) = A1_t l_t(i)^{1-\alpha} \tag{14}$$

In 14, $A1_t$ is a shock to productivity in goods production, similar to a standard TFP shock in the real-business-cycle literature, whose mean increases over time at the trend growth rate of g.

There is a probability of θ that firms are not able to change the price in a given period. Thus firms setting the price have to solve the following multi-period problem (Calvo (1983)

[5]Subsequently, we leave out the respective subscript as each household is identical.

pricing), i.e.

$$\sum_{k=0}^{\infty} \theta^k E_t\{R^B_{t,t+k} y(i)_{t+k|t}(P^*_t(i) - \mathcal{M}MC_{t+k})\} = 0 \tag{15}$$

with P^*_t being the optimal price set in period t.

3 Banking Sector

The commercial banks feature a bank headquarter and retail branches which lend to households. We allow for interbank transactions in form of trades of securitized loan portfolios. We model productivity, i.e. efficiency in loan production, and lending constraints in form of equity capital in the financial sector. Technologies in loan production and selling allow for an expansion of loans. The financial sector comprizes of commercial banks which are active in the traditional banking business, i.e. handing out credit to households, and which are able to trade loan portfolios with each other. Thus the bank business involves a loan origination and trading stage. The loan origination stage combines the loan management technology of Goodfriend and McCallum (2007) with differentiated loan demand as in Gerali et al. (2011). Finally, the model includes a monetary authority which sets the riskless interest rate.

3.1 Loan origination

There is a mass 1 of commercial banks with a bank headquarter and retail branches.

Bank headquarter

The bank headquarter decides on the interest rate spread given the optimal amount of loans and the capital structure. The bank headquarter maximizes its profits, i.e.

$$max \sum_{t=0}^{\infty} \left[R^L_t \frac{L_t}{P_t} - R^D_t \frac{D_t}{P_t} - \frac{\kappa_e}{2}\left(\frac{e_t}{L_t} - \tau\right)^2 - w_t m_t \right], \tag{16}$$

where L_t is the overall loan portfolio, D_t are the household bank deposits and e_t bank equity. Banks face a quadratic cost related to a deviation from the optimal ratio of bank equity versus the loan portfolio, the capital requirement ratio τ.

At the headquarter level the individual bank balance sheet constraint has to hold, i.e.

$$L_t = D_t + e_t \tag{17}$$

Bank headquarters also decide on the amount of monitoring work which is remunerated by the real wage, w_t. It is implied by the size of the loan portfolio through following loan management technology

$$\frac{L_t}{P_t} = Q_t m_t^{1-\alpha}, \tag{18}$$

with Q_t being the efficiency in loan production, which can be subject to shocks following a AR(1) process

$$Q_t = \rho_3 Q_{t-1} + \epsilon_t^3 \tag{19}$$

where ϵ_t^3 is an i.i.d. shock. Optimal loan provision gives the external finance premium on the bank headquarter level, i.e.

$$R_t^L - R_t^D = \frac{v w_t m_t}{(1-\alpha)c_t} - \kappa_e \left(\frac{e_t}{L_t}\right)^2 \left(\frac{e_t}{L_t} - \tau\right). \tag{20}$$

Retail banks

Retail banks hand out differentiated loans to households (following the mechanisms a la Gerali et al. (2011)). Deposit demand for transaction purposes triggers demand for loans. Total loan demand, L_t, and total deposit demand, D_t, are derived from the money in advance condition. The differentiated loan demand function by households reads as

$$L_{j,t} = \left(\frac{R_t(j)^L}{R_t^L}\right)^{-\epsilon_L} L_t \tag{21}$$

for all j retail banks with ϵ_L being the elasticity of substitution between loans from different retail branches. This results in an effective loan rate of

$$R_t^L(j) = \frac{\epsilon_L}{\epsilon_L - 1} R_t^L, \tag{22}$$

where $\frac{\epsilon_L}{\epsilon_L - 1}$ represents the loan markup.

Profit, Dividends and Retained earnings

Bank profits, $\omega_{B,t}$, are given by the in-period return over equity and monitoring costs, i.e.

$$\omega_{B,t} = R_t^L \frac{L_t}{P_t} - R_t^D \frac{D_t}{P_t} - \frac{\kappa_e}{2}\left(\frac{e_t}{L_t} - \tau\right)^2 - w_t m_t. \tag{23}$$

The share of profits, ϕ_Ψ, which is paid out as dividends is given by

$$\Pi_t^\Psi = \phi_\Psi \omega_{B,t}. \tag{24}$$

The remaining share, $(1-\phi_\Psi)$, is booked as a profit to the bank's equity capital e_t. The law of motion for bank capital, e_t, which is our proxy for Tier 1 capital, is then

$$e_t = (1 - \delta_e)e_{t-1} + \phi_B(Q_t^\Psi - Q_{t-1}^\Psi)\Psi + (1 - \phi_\Psi)\omega_{B,t-1}, \tag{25}$$

where Ψ is the initial stock of bank equity and ϕ_B is the pass-through of equity price changes to bank capital. Stock price changes $(Q_t^\Psi - Q_{t-1}^\Psi)$ result from changes in profits in combination with the household Euler equation. The dying rate of bank capital, δ_e, captures sunk cost of bank capital management. $Q_t^\Psi \Psi$ represents the market capitalization of the bank.

3.2 Loan securitization and trading

We motivate our approach to the bubble formation through experimental evidence as described in Mauersberger and Nagel (2018). In their example they focus on the causes and effects of bubbles in a setup with identical subjects endowed with the same number of shares, in which money pays no interest. Information about fundamental values are the dividend payments of shares per period. There is a finite horizon after which shares a worthless. Trading is done via a call market with orders cleared at a single price. Everyone can choose to be a buyer or seller in this market.

After the start of the trading the contract prices rise above the fundamental value. As the fundamental value falls toward the end of the trading periods, the contract prices settle below the fundamental value.

In order to transfer this simple example into a macroeconomic environment we allow for securitization in the loan market where a fundamental financial innovation shock pushes loan creation activities of banks and the resale of loans triggers the build-up of the financial bubble.[6] Banks can securitize loans into tradable loan portfolios, and exchange them with each other. Banks use securitization to make additional profits. The repackaging of loans means a higher value as it allows for a mark-to-market of their price expectations. Higher profits result in a higher level of bank capital. As the amount of outstanding loans is linked to optimal bank capital, rising equity capital allows to expand further on the amount of loans. Thus, securitizing loans allows banks to leverage their asset origination.[7] The seller of a securitized loan can obtain additional cash which could be used to address further loan demand. The buyer of the securitized loan gets an additional loan asset with expected higher return.

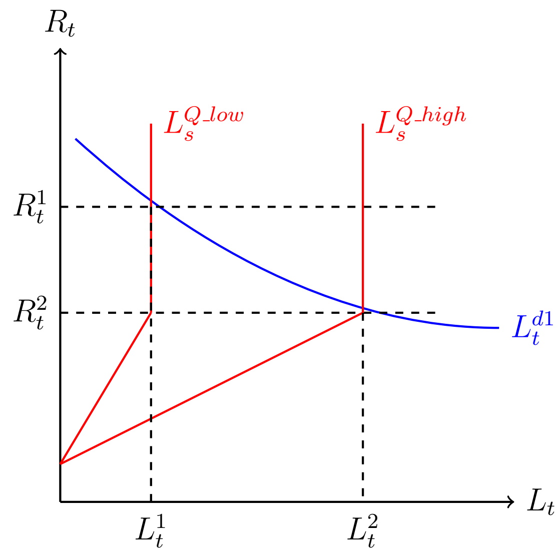
Initial financial innovation shock. We assume a financial innovation shock which is a productivity shock to the efficiency of the bank loan production function, Q_t, by which the size and thus the value of the loan, L_t, increases at banks. We can think of the productivity shock

[6]See Brunnermeier (2009) for a detailed treatment on loan securitization according to the "originate and distribute model" characterizing bank behavior before the financial crisis of 2007-08 in the US.

[7]See Goswani et al. (2009) for an analysis of macro-financial linkages of securitization.

to the efficiency in loan production, Q_t, as a new technology shock which allows to increase the loan output while reducing the monitoring need of banks. The mechanism is illustrated in Figure 4 which shows the loan demand and loan supply, and the interest rate at which the market clears. A higher efficiency in loan production allows for an outward shift in the loan supply curve.

Figure 4: Shock to loan production efficiency



Bubble creation through resale technology. The expectation formation plays a crucial role for the development of the financial bubble. In this respect we deviate from the fully informed agent paradigm. Several contributions to the literature support a deviation from the rational expectations assumption. As in Branch and Evans[8] (2005) we assume that banks act as econometricians when forecasting and implement boundedly-rationale beliefs $\mathcal{P}$ when they evaluate the change in value of loan portfolios. The estimation follows a Kalman filter recursion where the banking sector monitors past growth in value of loans, i.e.

$$lnL_t - lnL_{t-1} = g_t + v_t \tag{26}$$

with v_t being a short run fluctuation around g_t, the economy's growth rate. The short run fluctuation, v_t, differs conceptionally from shocks to Q_t, the efficiency of loan management. In their expectation formation process bank agents just monitor past changes in loan value. They do not consider the contribution of (aggregate) bank productivity measures when they form

[8] Branch and Evans (2005) compare the effectiveness of several prediction models for economic growth. The Constant Gain Method and specifically the Simple Method provide the best results with regards to the expectations formation of economic agents that adapt to continuous structural changes in the economy.

expectations about the growth in future value. g_t is a AR(1) process around the mean g, i.e.

$$g_t = (1 - \delta_g)g + \delta_g g_{t-1} + \eta_t \tag{27}$$

where η_t is an i.i.d. shock. The expectation operator of the not-fully informed agent reads as

$$\begin{aligned} \tilde{E}_t(lnL_{t+1} - lnL_t) &= \tilde{E}_t(g_{t+1} + v_{t+1}) \\ &= \tilde{E}_t(1 - \delta_g)g + \delta_g \tilde{E}_t g_t \end{aligned} \tag{28}$$

where $\tilde{E}_t$ is the expectation operator with an adaptive expectation formation. By replacing the expectation of g_t the expression becomes backward looking.[9] For the expectation of the growth trend of the economy, we assume that banks mix between monitoring last period's growth trend, g_{t-1}, and the growth in the value of loans:

$$\tilde{E}_t g_t = (1 - \kappa)\delta_g \tilde{E}_{t-1} g_{t-1} + \kappa(lnL_t - lnL_{t-1})$$

with κ being the weight on last period's growth trend. Replacing this into (28), multiplying out and collecting terms we derive the expectation of the future loan value:

$$\tilde{E}_t(lnL_{t+1}) = (1 - \delta_g)g + \delta_g^2(1 - \kappa)\tilde{E}_{t-1} g_{t-1} + lnL_t + \delta_g \kappa(lnL_t - lnL_{t-1})$$

As we are interested in the short-run amplification effect of the bubble in the value of loans on the financial cycle we set $\kappa = 1$. So when banks sell a loan portfolio through securitization they realize gains through expected future valuation changes, i.e.

$$\tilde{E}_t(lnL_{t+1}) = lnL_t + \delta_g ln(b_t) \tag{29}$$

In levels (real terms):

$$\frac{\tilde{E}_t L_{t+1}}{P_t} = \frac{L_t}{P_t} \delta_g b_t \tag{30}$$

where we assume κ to be 1 and g to be zero as we just consider business cycle fluctuations. Through the Kalman filter the expectation formation about future prices depends on the past

[9]Milani (2005) tests whether agents have rational expectations with regards to economic growth or show learning behaviour. The latter presumes that agents do not fully know the underlying economic model with all its parameters, so they forecast the future based on their observed values from previous periods. The adaptive learning method improves the fit of DSGE models. Similarly, Eusepi and Preston (2011) introduce a model in which agents do not have full knowledge of the economic processes, but predict future realisations by extrapolation from historical patterns in observed data. This results in a higher volatility and a higher persistence of macroeconomic variables which corresponds with the observed data.

changes in the value of the loan portfolio:

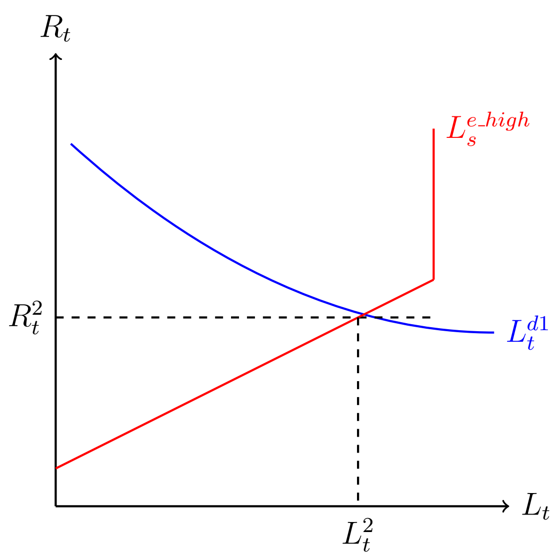
$$b_t = \frac{L_t}{L_{t-1}} \tag{31}$$

Thus the size of the bubble is determined by extrapolating the pace of loan growth which makes it backward looking. Using condition (30) and plugging it into the above loan production function results in:

$$\frac{\tilde{E}_t L_{t+1}}{P_t} = Q_t m_t^{1-\alpha} \delta_g b_t \tag{32}$$

The presence of a bubble creates an amplification effect in the value of the loan portfolio.

Figure 5: Expansion of equity capital due to mark-to-market



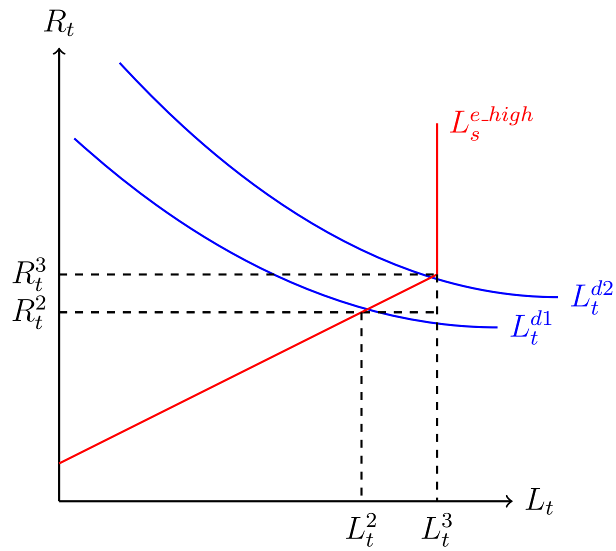
Transmission to bank equity. The repackaging of loans results in a higher value, with the bubble term, $\delta_g b_t$, being the profit of this transaction. The repackaging technology allows for a mark-to-market of the bubble through sale. This leads to a higher level of bank equity by the bubble size, illustrated in Figure 5. As the amount of outstanding loans is linked to optimal bank capital, rising equity capital allows the bank headquarter to expand further on the total amount of loans, L_t.The profit from the trading stage amounts to

$$\omega_{T,t} = \frac{\tilde{E}_t L_{t+1}}{L_t} = \delta_g b_t \tag{33}$$

of which the share of retained earnings is then booked to equity capital as in equation (25).

Wealth effect. An increase in equity feeds back to further loan expansion. We can separate two cases on the supply side of credit: first, if equity capital, e_t, is scarce, then the increase in equity capital leads to an expansion of loans in the next period, L_{t+1}, as the constraint is relaxed and banks can service more demand for credit. Alternatively, if equity capital is abundant, loans, L_{t+1}, expand as banks are able to lower the credit spread along with lower capital costs. On the demand side of credit higher dividend payments and appreciation of bank equity create wealth effects for the households. Through this effect we see a spill-over to the demand for credit which shifts outwards and absorbs the higher lending capacity of banks. This mechanism is illustrated in Figure 6.

Figure 6: Increase in loan demand



3.3 Monetary policy

The policy rate follows a Taylor (1993) rule which reacts to inflation, π_t, and fluctuations in output, y_t, i.e.

$$R_t^p = \left(R_{t-1}^p\right)^\rho \left(\frac{\pi_t}{\pi^*}\right)^{(1-\rho)\phi_\pi} \left(\frac{y_t}{y_{t-1}}\right)^{(1-\rho)\phi_y} A3_t \tag{34}$$

with $A3_t$ following a AR(1) process. We modify the Taylor rule for further experimentation in the quantitative section.

4 The Equilibrium

This section presents a closed form solution for the equilibrium. We consider equilibria with rational expectations at the side of households. Banks optimize intra-period with regard to their commercial lending and inter-period with regard to trading of loan portfolio governed by their price expectations described in section 3.2. We describe expectations for the special case where all banks hold the same subjective beliefs $\mathcal{P}$ and where these beliefs imply no uncertainty about future loan portfolio prices. Assuming no uncertainty allows to derive key insights into how the equilibrium price of the loan portfolio depends on banks' beliefs and their evolution over time. By imposing market clearing in the labor, goods, credit, stock and bond markets, the model can be solved for the equilibrium solution.

Theorem 1 (Equilibrium) *Households maximize their utility by choosing optimal sequences* $\{c_t, l_t^s, m_t^s, B_t, L_t, \Psi_t\}$. *The intermediate firm* i *chooses optimal prices* $P_t^*(i)$, *given its cost function with labor input* $\{l_t(i)\}$. *The final goods producing firm provides* $\{y_t\}$ *through a cost-minimal combination of intermediate goods* $y_t(i)$. *Commercial banks maximize profits by lending to households* $\{L_t\}$, *by receiving funds in the form of deposits* $\{D_t\}$, *and trade loan portfolios* $\{L_t\}$. *Retail banks provide loans* $L(i,j)$ *to households. Markets clear in each period* t, *i.e. for output* $y_t{=}c_t$, *bond holdings of the households clear as well as total stock holdings* $\Psi = \int_0^1 \Psi_t(i)$. *Labor markets clear, i.e.* $l_t^s{=}l_t$ *and* $m_t^s{=}m_t$.

We solve the model for its equilibrium, calculate non-stochastic steady states and linearize the model around the steady state. Upon log-linearizing and combining the relevant equilibrium conditions, we obtain a system of equations which characterize the dynamics of the economy in the neighborhood of the efficient, non-stochastic steady state. There are four forcing variables: productivity shocks $a1_t$, financial innovation shocks $a2_t$, and monetary shocks $a3_t$.We list below the main approximate equilibrium conditions, the remaining ones are relegated to Appendix A.

Output and Monitoring demand

$$\widehat{w}_t = -\eta\widehat{l}_t + a1_t$$
$$\tfrac{1}{\lambda}\widehat{\lambda}_t + c\widehat{c}_t + LR^L\left(\widehat{L}_t + \widehat{R}_t^L\right) + LR^D\left(\widehat{L}_t - \widehat{R}_t^D\right) = 0$$

Factor prices and quantities.

$$\widehat{\lambda}_t + \widehat{w}_t = \tfrac{l}{1-l-m}\widehat{l}_t + \tfrac{m}{1-l-m}\widehat{m}_t$$

Price inflation.

$$\widehat{\pi}_t = \beta E_t\widehat{\pi}_{t+1} + \vartheta\widehat{mc}_t$$
with $\vartheta = \frac{(1-\theta)(1-\beta\theta)}{\theta}\frac{1-\eta}{1-\eta-\eta\epsilon}$

Loan spread.

$$R^L R_t^L = \tfrac{\epsilon_L}{\epsilon_L-1}\left[cR^D R_t^D + \tfrac{vw_t m_t}{(1-\alpha)c}\left(\hat{w}_t + \hat{m}_t - \hat{c}_t\right) - \tfrac{\kappa_e e}{L^2}\left(2\tfrac{e}{L} - \tau\right)\widehat{e}_t - \tfrac{\kappa_e e}{L^2}\left(3\tfrac{e}{L} - 2\tau\right)\widehat{L}_t\right]$$

Bank Profit

$$\omega\widehat{\omega}_t = R^L L\left(\widehat{R}_t^L + \widehat{L}_t\right) - R^D L\left(\widehat{R}_t^D + \widehat{D}_t\right) - \tfrac{\kappa_e e}{L}\left(\tfrac{e}{L} - \tau\right)\left(\widehat{e}_t - \widehat{L}_t\right) - wm\left(\widehat{w}_t + \widehat{m}_t\right) + \delta_g\widehat{b}_t$$

Monetary policy rule.

$\widehat{R}_t^P = (1-\rho)\left(\phi_\pi \widehat{\pi}_t + \phi_c \widehat{c}_t\right) + \rho \widehat{R}_{t-1}^P + a3_t$

Financial Bubble.
$\widehat{L}_{t+1} = (1-\alpha)\widehat{m}_t + \widehat{b}_t + a2_t$
with $\widehat{b}_t = \widehat{L}_t - \widehat{L}_{t-1}$

Equilibrium with a financial bubble. We incorporate two main features which characterize a bubble into a DSGE model with banks: first, the size of loan portfolio is not just determined by supply and demand in the loan market. Instead of just matching consumption through the money in advance condition, the loan size is also linked to expectations of future loan value, which allows for a bubble component in pricing. Second, there is a (positive) feedback mechanism in the bubble variable coming from the pricing at the loan trading stage. The feedback mechanism leads to an excessive growth of loans over GDP while the bubble is growing.

5 Quantitative Results and Policy Experiments

In the following section we describe the benchmark calibration for the simulation of the model, before we show impulse responses for a financial bubble shock. Finally, we employ the simulated model for several policy experiments.

5.1 Benchmark Calibration

The model is calibrated to quarterly frequencies matching endogenous aggregates and interest rates to observable data. We assume zero average inflation. The household discount factor is set to 0.99 implying an annual real rate of interest of 4% for the riskless bond rate R^B.

Table 1. Parameters

β	discount factor	0.997
η	concavity in production	0.34
α	concavity in loan management	0.38
ϕ_l	weight of leisure in utility	0.7
ϵ	Dixit-Stiglitz parameter	6
τ	equity target level	0.11
v	velocity of money	0.31
θ	share of firms without price reset	0.77
$\mathcal{M}$	price markup	1.2
$\mathcal{M}_{\mathcal{L}}$	loan rate markup	1.4
ϕ_π	weight of inflation in policy function	1.5
ϕ_y	weight of output in policy function	0.5
ρ	smoothing in policy function	0.25
ω_Ψ	share of dividends in bank profits	0.68
δ_e	equity depreciation	0.025
κ_e	leverage deviation cost	4
ϕ_B	equity price pass-through	0.35
ϵ_L	elasticity loan demand	3.5

The share of intermediate firms which cannot reset their price in a given period is $\theta = 0.77$. The Dixit-Stiglitz parameter, ϵ, is set to 6 generating a mark-up of 20%. The velocity of money v is set to 0.31 on the basis of average GDP to M3 after the U.S. subprime crisis. The capital requirement ratio τ is set to 11%. For further experimentation we change τ to 15%. We assume a coefficient equal to 0.34 for the concavity of labor in the the production function of the intermediate product; for loan management we choose a coefficient of equal to 0.65.

Table 2. Implied Steady-States

R^P	policy rate	0.0084
R^B	bond rate	0.0101
R^D	deposit rate	0.0067
R^L	loan rate	0.0169
c	consumption	0.6244
$\frac{l}{c}$	production work	0.4900
$\frac{D}{c}$	deposits	2.0145
$\frac{L}{c}$	loans	2.0145
w	wage	0.9588
$\frac{m}{c}$	monitoring work	0.0246
ω_B	bank's profits	0.0239
ϕ_Ψ	share of bank's profits paid as dividends	0.7690
e	equity	0.2215
Π^Ψ	bank's dividends	0.0184
Q^Ψ	equity price	1.8258

We set total labor supplied in steady state to 1/2 of hours, similar to Goodfriend and McCallum (2007). The share of working time devoted to banking services is 2%. This implies that a share of 49% of total time is in the production sector and 1% in the banking sector. Following Gerali et al. (2011) we calibrate the banking parameters to replicate data averages for commercial bank interest rates and spreads. We calibrate the steady states to $R^B = 4\%$ p.a. and $R^{IB} = 3.36\%$ p.a. This implies an annualized return for $R^D = 2.6\%$ p.a. and a loan rate $R^L = 6.7\%$ p.a. From the derivation of the implied steady states of the model we have that 76% of profits are paid as dividends assuming that equity depreciates at 10% p.a.. δ_g, is calibrated to 10%, which implies the share of loans traded in each period.

Table 3. Calibration of exogenous shocks

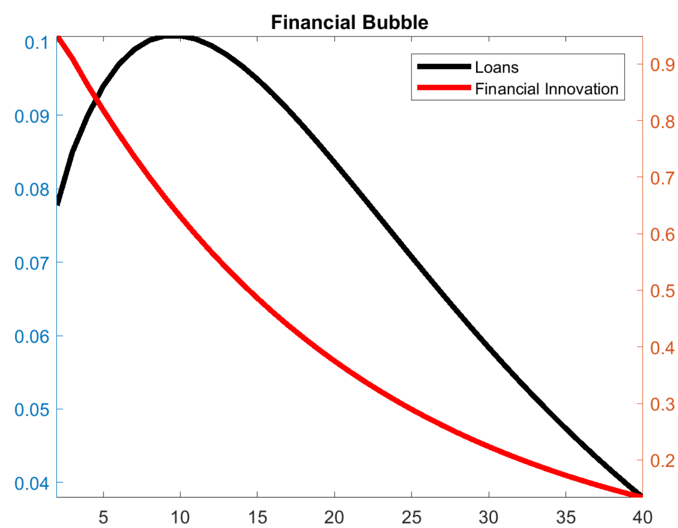
Persistence		
ρ_1	productivity	0.95
ρ_2	monetary policy	0.9
ρ_3	financial innovation	0.9
Volatility		
σ_1	productivity	0.72%
σ_2	monetary policy	0.82%
σ_3	financial innovation	1%

The technology shocks are assumed to be quite persistent, with a standard deviation equal to 0.72% and an autoregressive parameter 0.95. The shock to the policy rate has a standard deviation equal to 0.82%, and an autoregressive parameter of 0.9, and for the financial innovation shock we assume a higher standard deviation of 1% and an autoregressive parameter equal to 0.9. Shocks to the TFP have a relatively prolonged effect on macroeconomic variables, while a monetary policy shock rapidly dies out and the economy reaches again the steady state. The bubble shock is modeled as being somewhat persistent due to its effects on loan creation. Monetary policy coefficients on inflation and the output are 1.5 and 0.5. The rest of the parameters, implied steady states and interest rates used in the calibration are given in Tables 1-3.

5.2 Impulse response for the Financial Bubble

In our modelling approach we combine a fundamental shock with a bubble in the value of loans. Figure 7 shows the bubble reaction of the loan variable in response to the financial innovation shock.

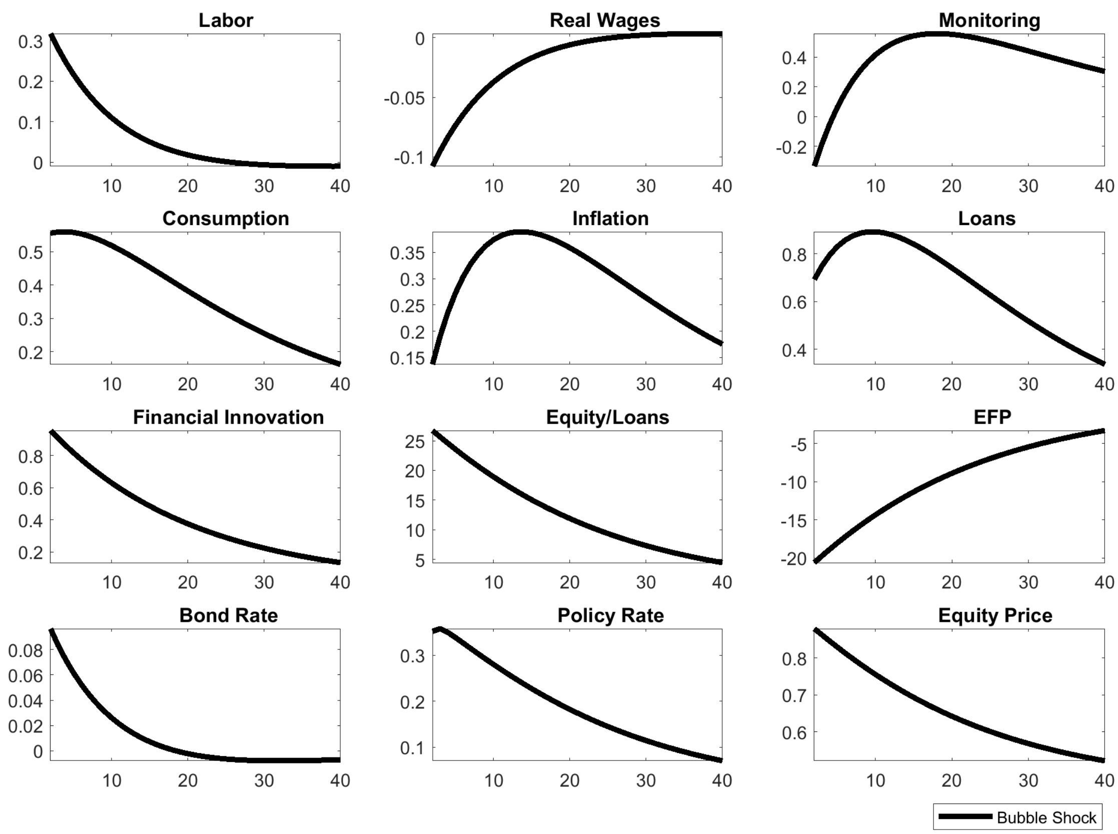
Figure 7: Simulated financial bubble



Note: The simulation shows the bubble reaction of the loan variable (axis LHS) in response to the financial innovation shock (axis RHS) .

The full impulse response of the economy to a financial innovation shock is shown in Figure 8. The financial innovation shock leads to a reduction in monitoring needs to service given transaction money demand. Simultaneously, the bank spread (external finance premium, or EFP) is lowered. The amount of loans handed out by banks and the equity price rise on impact. Then they further increase due to the positive feedback mechanism of the financial bubble. The financial bubble has a direct impact on inflation and due to staggered pricing also real effects on consumption in addition to the initial financial innovation shock.

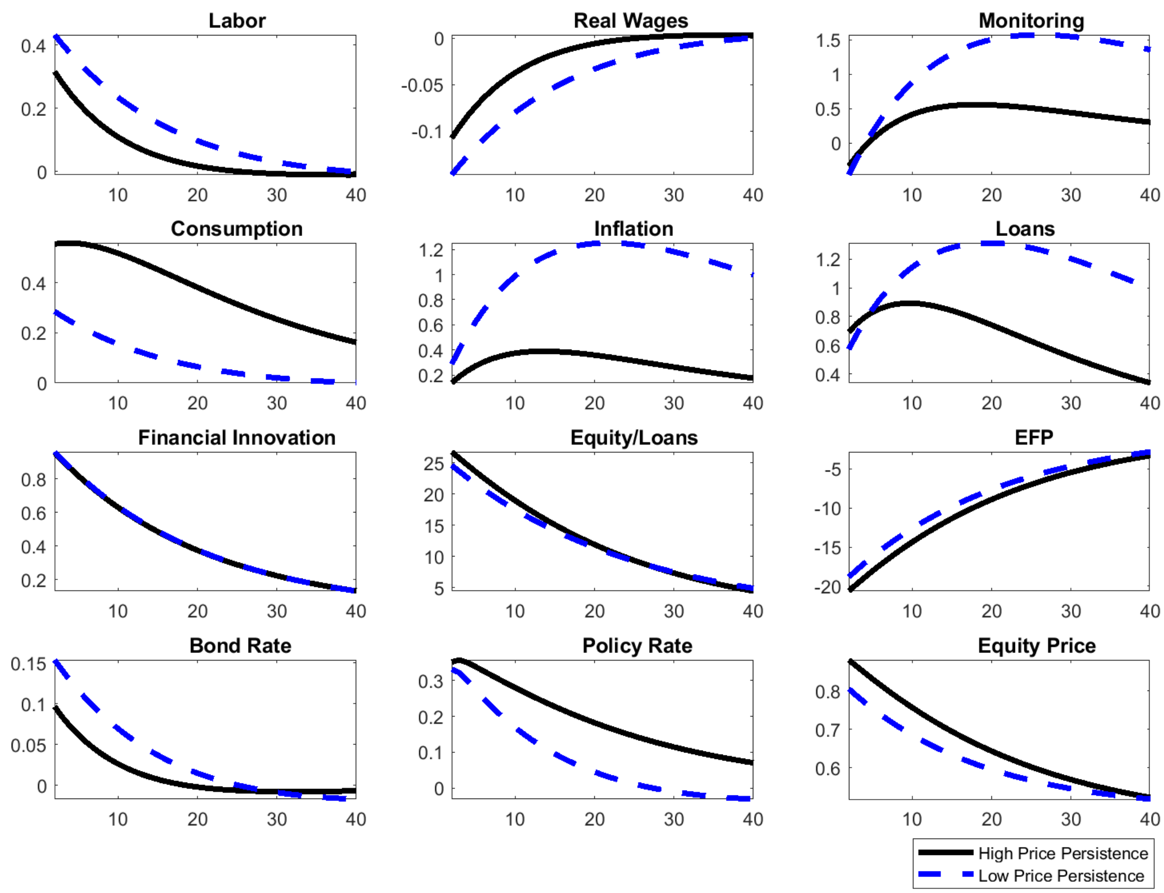
Figure 8: Impulse responses to a financial bubble shock



Note: All interest rates are shown as absolute deviations from the steady state, expressed in percentage points. All other variables are percentage points deviations from the implied steady state value.

We illustrate the effect of the staggered pricing mechanism (as in Calvo (1983)) under a financial innovation shock (Figure 9). We find that with higher price persistence less adjustment is channeled through inflation and real effects are higher. Hence, the effects of a financial bubble differ for economies depending on the degree of price flexibility. In particular, the assumption of sticky prices makes monetary policy non-neutral, allowing it to influence the size of the bubble; on the other hand, price stickiness makes it possible for aggregate bubble fluctuations to influence aggregate demand and, hence, output and employment.

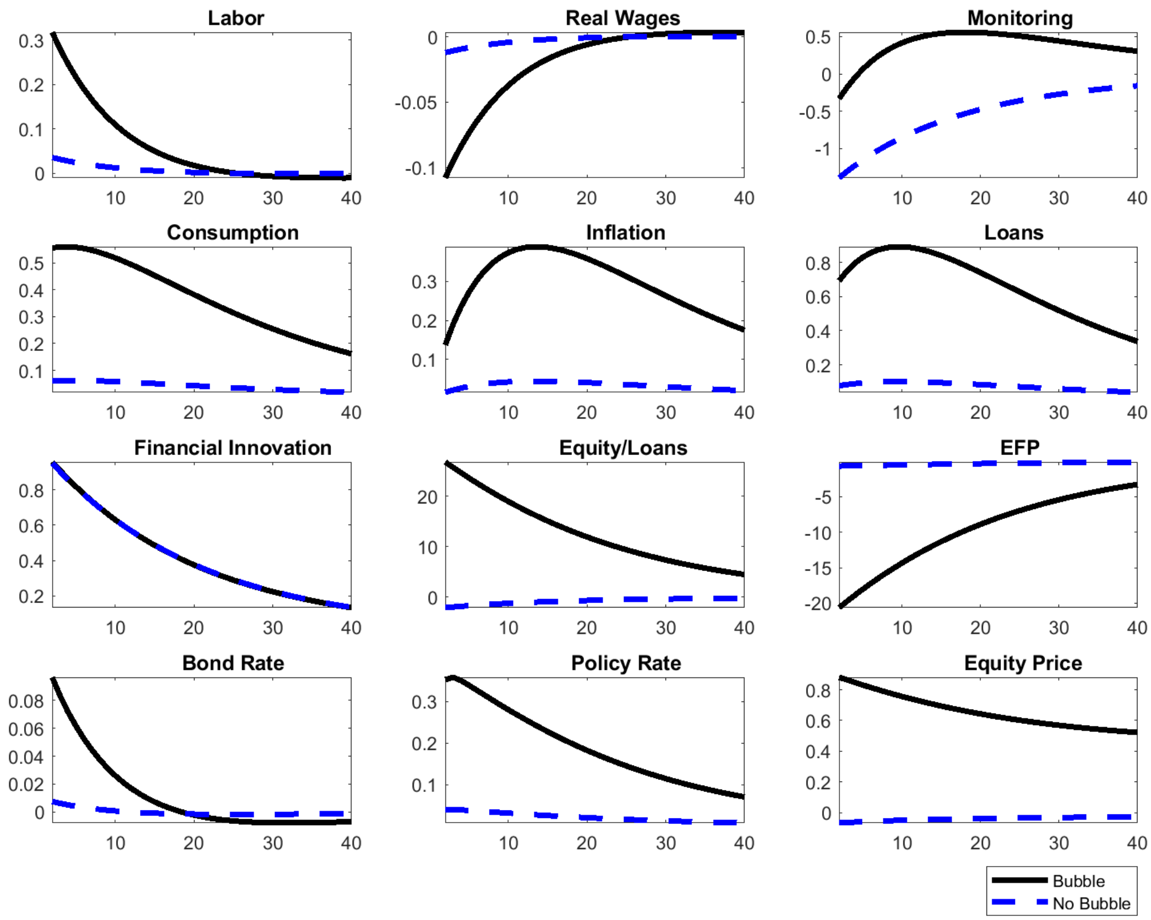
Figure 9: Impulse responses to a financial bubble shock with high and low price inertia



Note: All interest rates are shown as absolute deviations from the steady state, expressed in percentage points. All other variables are percentage points deviations from the implied steady state value.

We assess the impact in the economy of a financial innovation shock with and without a bubble in the value of loans (Figure 10). In the no-bubble economy the shock leads a reduction in monitoring needs. Simultaneously, the bank spread is lowered. The amount of loans handed out by banks and the equity price rise on impact. In the bubble-economy loans increase even more due to the positive feedback mechanism of the financial bubble generating the need to hire more monitoring workers in the banking sector. The spread is further compressed down by the expansion in the supply of loans while equity prices increase further. Hence, the presence of a bubble generates an amplification effect in the financial sector (via loans and equity) and in the real sector (via consumption funded by transaction money demand).

Figure 10: Impulse responses to a financial bubble shock versus no bubble shock



Note: All interest rates are shown as absolute deviations from the steady state, expressed in percentage points. All other variables are percentage points deviations from the implied steady state value.

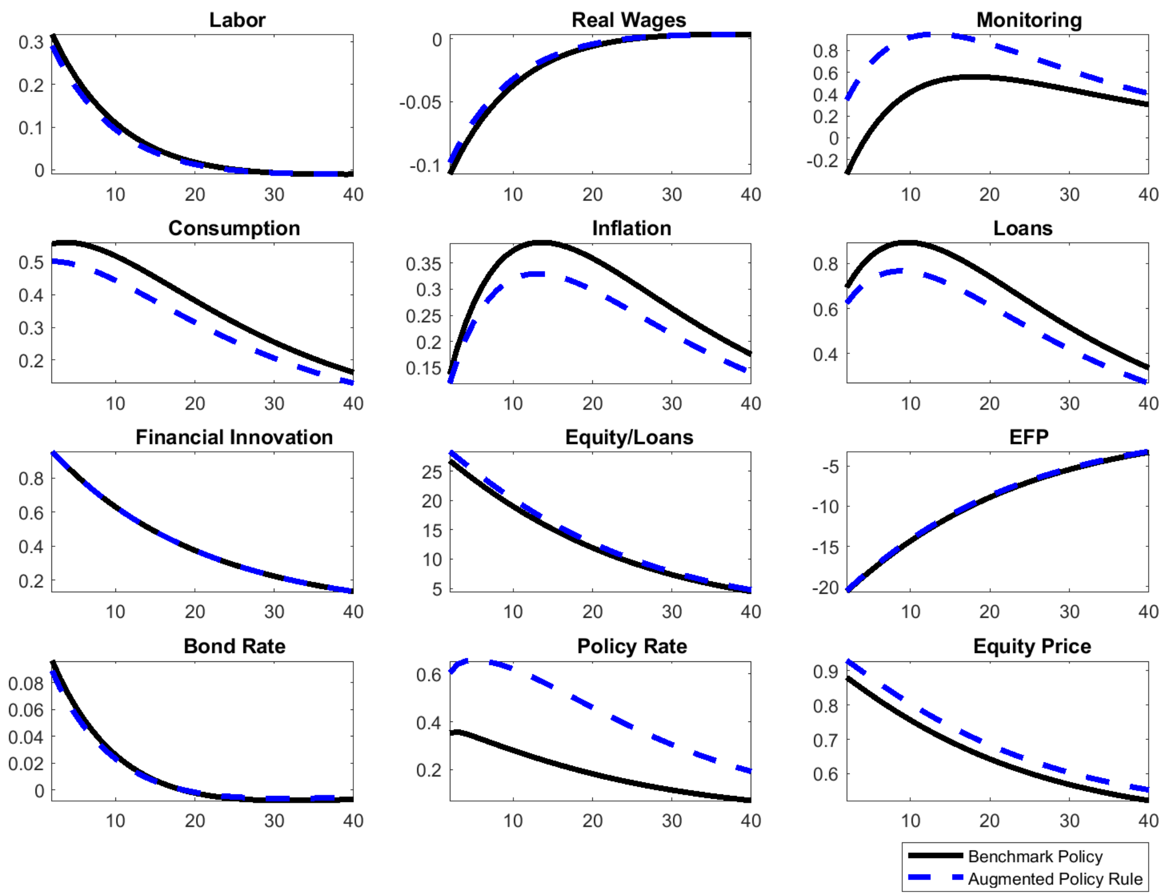
5.3 Policy experiments

We test how effective several monetary and macroprudential policies are in this setup. In Figure 11 we study the effect of monetary policy reacting to changes in overall loans, L_t. This would modify the Taylor rule of the monetary authority as follows:

$$R_t^p = \left(R_{t-1}^p\right)^\rho \left(\frac{L_t}{L}\right)^{\phi_L(1-\rho)} \left(\frac{\pi_t}{\pi^*}\right)^{(1-\rho)\phi_\pi} \left(\frac{y_t}{y_{t-1}}\right)^{(1-\rho)\phi_y} A3_t. \quad (35)$$

We see in the impulse response that the modified Taylor rule has some effect on inflation and consumption as the policy reaction doubles. A reaction to overall loan growth barely affects bank leverage, the credit margin (external finance premium, EFP) or the equity price. We conclude that a “leaning against the wind” policy has some effect in reducing the size of the financial bubble.

Figure 11: Impulse response of financial bubble shock with different monetary policy reaction



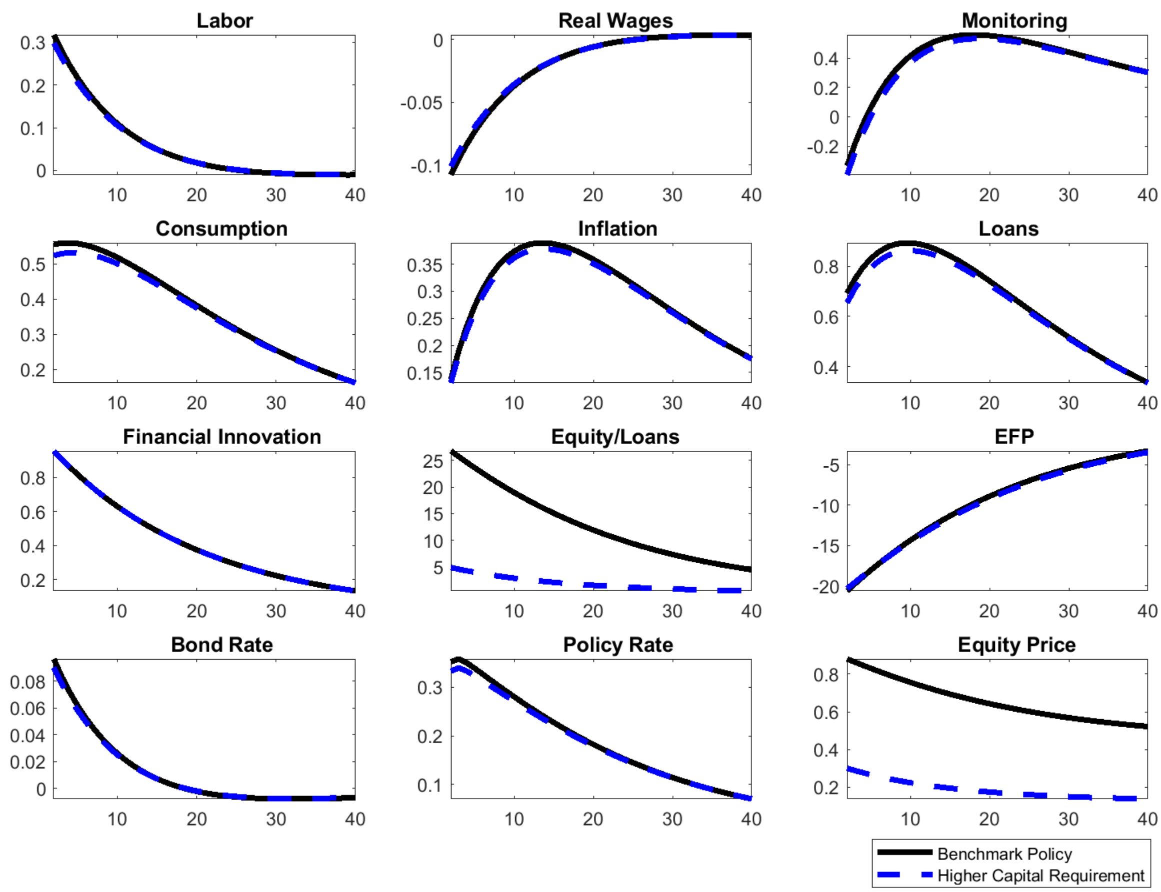
Note: All interest rates are shown as absolute deviations from the steady state, expressed in percentage points. All other variables are percentage points deviations from the implied steady state value.

The next experiment uses a macroprudential measure by increasing the target level of the capital requirement ratio, τ, from a level of 11% towards 15%, which affects the profits at the headquarter level:

$$\Pi_t^B = \sum_{t=0}^{\infty} \left[R_t^L \frac{L_t}{P_t} - R_t^D \frac{D_t}{P_t} - \frac{\kappa_e}{2} \left(\frac{e_t}{L_t} - \tau \right)^2 - w_t m_t \right] \tag{36}$$

The increased capital requirement ratio leads to a slight reduction of the impact of the shock as demonstrated in Figure 12. The response of inflation and consumption is dampened. This works through the equity price which increases by less during a financial shock. On the other hand, the negative impact on the spread between the loan and deposit rate is reduced, meaning that the financial sector can better absorb the bubble shock.

Figure 12: Impulse response of financial bubble shock with higher capital requirement



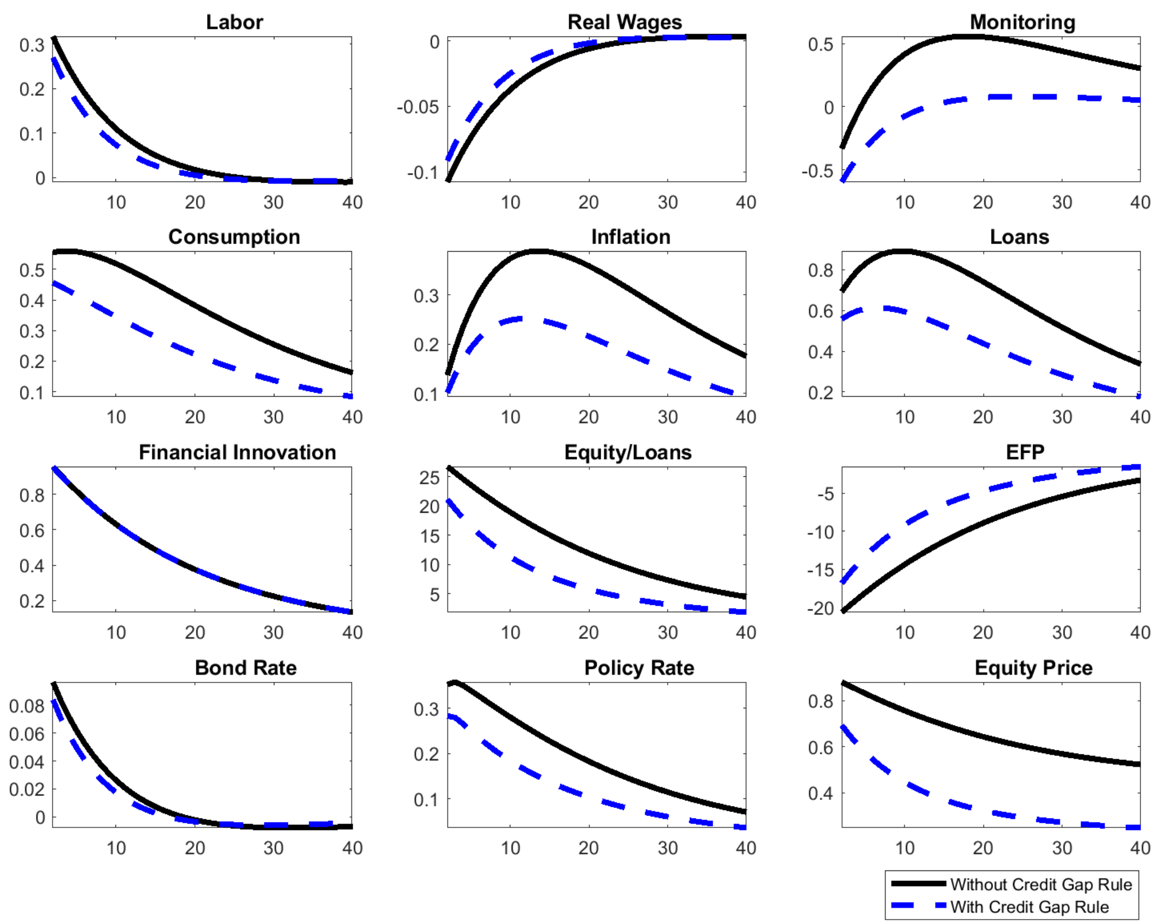
Note: All interest rates are shown as absolute deviations from the steady state, expressed in percentage points. All other variables are percentage points deviations from the implied steady state value.

Finally, in Figure 13 we introduce an endogenous capital requirement, τ_t, set by a regulator along the following rule reacting to the credit-to-GDP gap:

$$\tau_t = \overline{\tau} + \kappa_t \left(\frac{L_t}{Y_t} - \frac{L}{Y} \right) \tag{37}$$

Under the rule reacting to the credit-to-GDP gap we study the behavior of the financial bubble compared to the base case. While the equity price falls more than in the base case (but less than under the exogenous increase in target capital), the reaction of the spread (EFP) is dampened. The stabilization comes from the combination of a lower equity price and a limited response of monitoring. The endogenous increase in the necessary bank equity holdings counteract the initial cost reduction from the financial innovation shock. The side effects of the financial bubble are reduced, inflation and consumption react significantly less. The visible impact on the target variables, inflation and consumption, and the limited reaction of other variables let us conclude that an endogenous requirement is effective in precisely working in the required way without adversely affecting other macroeconomic variables.

Figure 13: Impulse response of financial bubble shock with endogenous capital requirement



Note: All interest rates are shown as absolute deviations from the steady state, expressed in percentage points. All other variables are percentage points deviations from the implied steady state value.

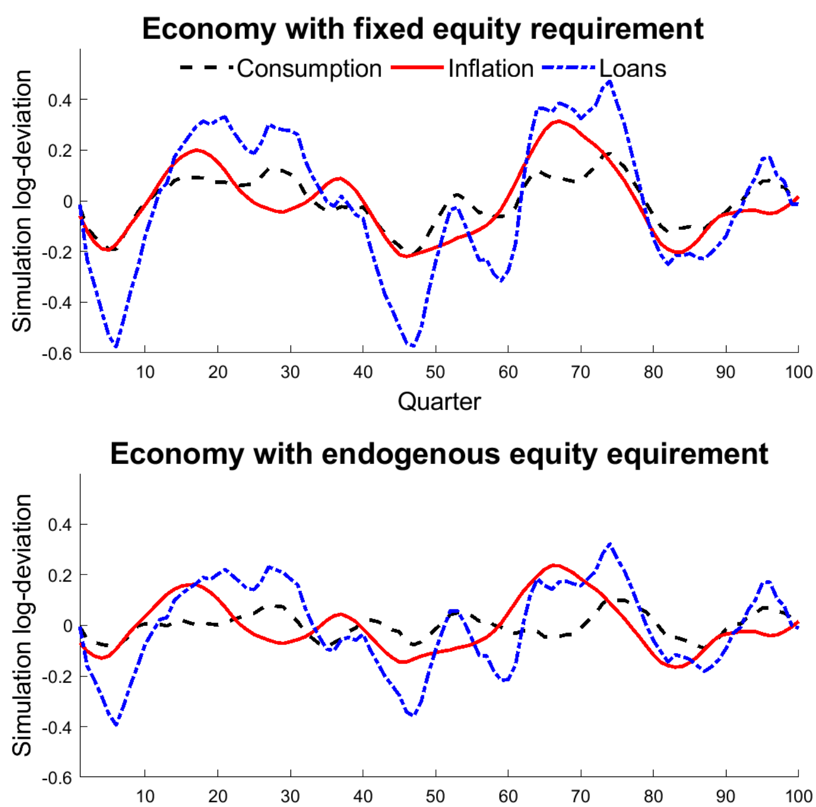
Supporting this reasoning, Table 4 shows that under an endogenous macroprudential rule the volatility of consumption and loans is sensibly attenuated while the volatility of equity and equity prices increases.

Table 4. Model Moments

	Benchmark		Endogenous Capital Requirement	
	S.D.	Corr.	S.D.	Corr.
Consumption	0.16497	1	0.11331	1
Equity	4.42854	0.63471	7.34583	0.43092
Equity Prices	0.13782	0.59156	0.23655	0.38796
Loans	0.44273	0.94411	0.32735	0.69627

This is illustrated in Figure 14 which gives a simulation of the main variables consumption, inflation and loans. We see that the amplitude of the cycle is much smaller in case of the endogenous equity requirement. In particular, credit booms and busts are attenuated. Furthermore, the simulation shows a stabilising effect of the endogenous rule on the real economy and on inflation.

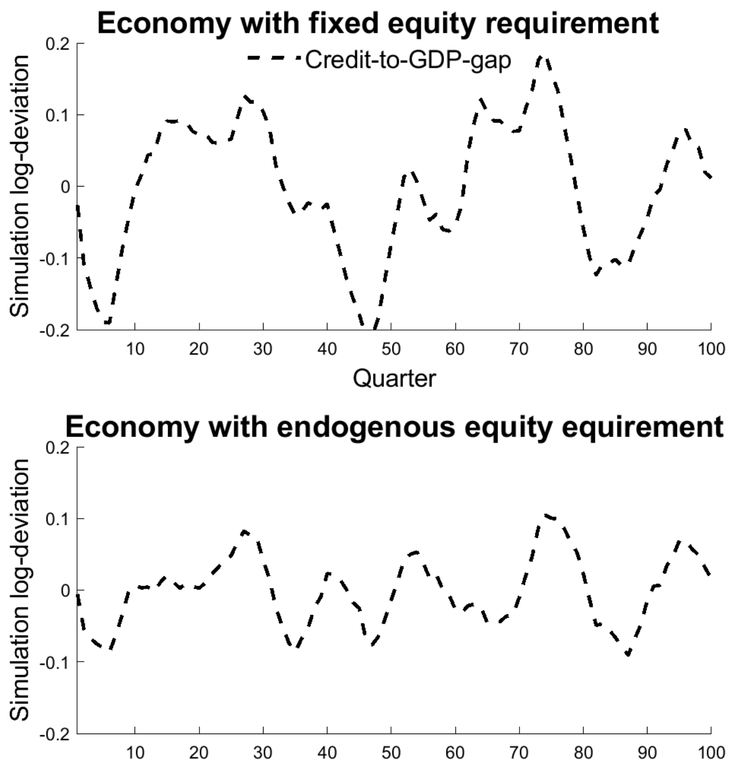
Figure 14: Simulation of consumption, inflation and loans with and without an endogenous capital requirement



Note: Two-year moving average of deviations in total credit-to-GDP.

Relating to the motivation of this paper in section 1.1. we also show how an endogenous requirement (countercyclical capital buffer) helps in dampening financial cycles. The amplitude of the credit-to-GDP gap is reduced from more than 30% peak-to-trough to 20% peak-to-trough. Financial cycles also become shorter as the countercyclical buffer is a self-correcting mechanism of excessive deviations in the credit-to-GDP measure.

Figure 15: Simulation of credit-to-GDP gaps with and without an endogenous capital requirement



Note: Two-year moving average of deviations in total credit-to-GDP.

6 Welfare

We have approximated welfare by employing a second-order Taylor expansion to utility and derived the loss function using the labor demand function, the marginal cost function and the

Table 5. Welfare

	Output volatility	Inflation volatility	Welfare loss
Benchmark	0.16497	0.05174	0.05996
Monetary Policy Reaction	0.14301	0.05109	0.05229
Higher Capital Requirement*	0.17271	0.05216	0.05263
Credit-Gap Rule	0.11331	0.04168	0.04149

**Note:* Welfare is calculated on the basis of the different steady-states implied by the higher capital requirement.

money in advance constraint.[10] The loss function reads as

$$\mathfrak{L}_t = \varphi\sigma_{\tilde{y}}^2 + \varpi\sigma_{\pi}^2,$$

with φ and ϖ resulting from model parameters. We use the approximation to quantify the welfare rankings which result from the monetary and macroprudential rules. Table 5 shows the welfare losses for the different regimes. A higher capital requirement is slightly procyclical, but incorporating changes to the steady state improves the welfare result.[11] The endogenous regimes, i.e. the policy reaction to loan growth and the credit-gap rule, also perform better in terms of welfare. The credit-to-GDP gap rule is more effective than the monetary policy as it targets precisely bank leverage. The endogenous capital requirement reduces the welfare loss by 43%, while the monetary policy reaction just by 14%.

7 Conclusions

In this paper we set up a framework for the causes and effects of a financial bubble. With this model we shed light on recent policy debates on monetary and macroprudential instruments.

The financial bubble features the deviation of the value of an asset from its equilibrium value, as well as a positive feedback mechanism for the value deviation. The analytical framework shows how a financial bubble can develop from the bank supply side with households following standard behavioral functions. We augment a standard New-Keynesian macroeconomic model

[10]The full derivation can be found in section C of the Appendix.

[11]We take into account lower credit spreads (EFP) in steady state in higher capitalized economies (see Gambacorta and Shin (2016)) through a loan production function which incorporates different equity levels through the loan production efficiency Q. We arrive at a welfare gain of up to 0.01 in consumption units. The welfare gain is calculated through incorporating equity implicitly into the Cobb-Douglas function for loan management. As through a higher equity requirement the spread and monitoring reaches minimal levels this gives us an upper bound to the possible gains in well-capitalized economies. The welfare gain outweighs the welfare losses of 0.00272. The overall effect is an improvement in the welfare loss, which would be at 0.05263, i.e. roughly the value of the welfare loss in case of a monetary policy reaction.

with a loan management technology and endogenous equity holdings for banks to define policy instruments and measure their efficacy in counteracting financial bubbles.

We test several measures on whether they can effectively reduce the impact of a financial bubble. We find that a macroprudential rule which reacts to the credit-to-GDP gap proves to be the most effective measure to prevent a bubble from growing. This lies in its nature of increasing costs which counteract the fall in monitoring need following a financial innovation. A central bank intervention against the financial bubble ("leaning against the wind") is less effective. Our welfare analysis shows that volatility increases, but overall welfare improves when introducing a higher fixed capital requirement. An endogenous requirement reduces welfare losses more than double compared to a monetary policy reaction. We thereby provide a comprehensive rationale for the use of countercyclical capital buffers.

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A Linearised model

Let $\widehat{x}$ denote the deviation of a variable x from its steady state. The model can then be reduced to the following linearised system of equations:

1) Supply of production and monitoring labor

$$\widehat{\lambda}_t + \widehat{w}_t = \frac{l}{1-l-m}\widehat{l}_t + \frac{m}{1-l-m}\widehat{m}_t \tag{38}$$

2) Demand for production labor

$$\widehat{w}_t = -\eta\widehat{l}_t + a1_t \tag{39}$$

3) Monitoring demand

$$\frac{1}{\lambda}\widehat{\lambda}_t + c\widehat{c}_t + LR^L\left(\widehat{L}_t + \widehat{R}_t^L\right) + LR^D\left(\widehat{L}_t - \widehat{R}_t^D\right) = 0 \tag{40}$$

4) Production

$$\widehat{c}_t = (1-\eta)\,\widehat{l}_t + a1_t \tag{41}$$

5) Loan provision:

$$\widehat{L}_{t+1} = (1-\alpha)\widehat{m}_t + \delta_g b_t + a2_t \tag{42}$$

6) Money in advance constraint

$$\widehat{c}_t + \widehat{P}_t = \widehat{D}_t \tag{43}$$

7) Inflation

$$\widehat{\pi}_t = \widehat{P}_t - \widehat{P}_{t-1} \tag{44}$$

8) Calvo (1983) pricing

$$\widehat{\pi}_t = \beta E_t\widehat{\pi}_{t+1} + \vartheta\widehat{mc}_t \tag{45}$$

with $\vartheta = \frac{(1-\theta)(1-\beta\theta)}{\theta}\frac{1-\eta}{1-\eta+\eta\epsilon}$

9) Marginal cost

$$\widehat{mc}_t = \widehat{w}_t - \frac{1}{1-\eta}\left(\eta\widehat{c}_t\right) + (1-\eta)\,\widehat{l}_t \tag{46}$$

10) Bond holding

$$\widehat{B}_t = 0 \tag{47}$$

11) Stock holding

$$\hat{\Psi} = 0 \tag{48}$$

12) Loans

$$\widehat{L}_t = \widehat{D}_t \tag{49}$$

13) Equity

$$e(1-\delta_e)\widehat{e}_{t-1} - e\widehat{e}_t + \phi_B Q(\widehat{Q}_t^{\Psi} - \widehat{Q}_{t-1}^{\Psi})\Psi + (1-\phi_{\Psi})\omega_B\widehat{\omega}_{B,t-1} = 0 \tag{50}$$

14) Bond rate

$$\widehat{R}_t^B = \widehat{\pi}_t + \widehat{\lambda}_t - E_t\widehat{\lambda}_{t+1} \tag{51}$$

15) Equity price

$$E_t\left(\lambda\widehat{\lambda}_{t+1} + Q^{\Psi}\widehat{Q}_{t+1}^{\Psi} + \Pi^{\Psi}\widehat{\Pi}_{t+1}^{\Psi} - \widehat{\pi}_{t+1}\right) - \left(\lambda\widehat{\lambda}_t + Q^{\Psi}\widehat{Q}_t^{\Psi}\right) = 0 \tag{52}$$

16) Loan spread

$$R^L R_t^L = \frac{\epsilon_L}{\epsilon_L - 1}\left[\begin{array}{c} R^D R_t^D + \frac{v w_t m_t}{(1-\alpha)c}\left(\hat{w}_t + \hat{m}_t - \hat{c}_t\right) \\ -\frac{\kappa_e e}{L^2}\left(2\frac{e}{L} - \tau\right)\widehat{e}_t - \frac{\kappa_e e}{L^2}\left(3\frac{e}{L} - 2\tau\right)\widehat{L}_t \end{array}\right] \tag{53}$$

17) Deposit rate

$$\widehat{R}_t^D = \widehat{R}_t^P \tag{54}$$

18) Policy feedback rule

$$\widehat{R}_t^P = (1-\rho)\left(\phi_\pi\widehat{\pi}_t + \phi_c\widehat{c}_t\right) + \rho\widehat{R}_{t-1}^P + a3_t \tag{55}$$

19) Bank Profit

$$\begin{aligned} \omega\widehat{\omega}_t \;=\; & R^L L\left(\widehat{R}_t^L + \widehat{L}_t\right) - R^D L\left(\widehat{R}_t^D + \widehat{D}_t\right) - \\ & \frac{\kappa_e e}{L}\left(\frac{e}{L} - \tau\right)\left(\widehat{e}_t - \widehat{L}_t\right) - wm\left(\widehat{w}_t + \widehat{m}_t\right) + \delta_g\widehat{b}_t \end{aligned} \tag{56}$$

20) Dividends:

$$\widehat{\Pi}_t^{\Psi} = \widehat{\omega}_B \tag{57}$$

21) EFP:

$$efp\ efp_t = R^L \widehat{R}_t^L - R^D \widehat{R}_t^D \tag{58}$$

22) Bubble

$$\widehat{b}_t = \widehat{L}_t - \widehat{L}_{t-1} \tag{59}$$

There are 22 equations and 22 variables.

B Calculating Steady States

There is no technological progress $A1_t = A1 = 1$ and no price change i.e. $P_t = P = 1$.

$$1 + R^B = \frac{1}{\beta} \tag{60}$$

R^D

$$R^D = (1 - rr)\, R^P \tag{61}$$

R^L

$$R^L = \chi_{\epsilon_L} \left[R^D + \frac{vwm}{(1-\alpha)c} \right] \tag{62}$$

c

$$c = A1 l^{1-\eta} \tag{63}$$

D

$$D = \frac{c}{v} \tag{64}$$

w

$$w = (1 - \eta)\, l^{-\eta} \tag{65}$$

L

$$L = D \tag{66}$$

m

$$m = \left(\frac{L}{Q} \right)^{\frac{1}{1-\alpha}} \tag{67}$$

λ

$$\lambda = \frac{\phi_l}{w(1-l-m)} \tag{68}$$

ω_B

$$\omega_B = \left(R^L - R^D\right) L - wm \tag{69}$$

e

$$e = \frac{(1-\phi_\Psi)}{\delta_e}\omega_B \tag{70}$$

ϕ_Ψ

$$\begin{aligned} \tau &= \frac{e}{L} = \frac{(1-\phi_\Psi)}{\delta_e}\frac{\omega_B}{L} \\ \phi_\Psi &= 1 - \frac{\tau\delta_e L}{\omega_B} \end{aligned}$$

Π^Ψ

$$\Pi^\Psi = \phi_\Psi \omega_B \tag{71}$$

Q^Ψ

$$\begin{aligned} 1 &= \beta E_t \left\{ \frac{Q^\Psi + \Pi^\Psi}{Q^\Psi} \right\} \\ Q^\Psi &= \frac{\beta \Pi^\Psi}{(1-\beta)} \end{aligned} \tag{72}$$

$R^L - R^D$

$$R^L - R^D = \frac{R^D}{\epsilon_L - 1} + \frac{\epsilon_L}{\epsilon_L - 1}\left[\frac{v w_t m_t}{(1-\alpha)c}\right] \tag{73}$$

C Welfare

Defining $\hat{x}_t$ as the log deviation from the steady state ($\hat{x}_t = x_t - x$), each variable can be restated as a second order approximation of its relative deviation from the variable's steady state, which reads as:

$$\frac{X_t - X}{X} \simeq \hat{x}_t + \frac{1}{2}\hat{x}_t^2$$

From the problem, above household utility is described by additive functions of consumption and leisure

$$U_t = log(c_t) + \phi_l log(1 - l_t^s - m_t^s) \tag{74}$$

Taking the deviation from the steady state we get

$$U_t - U = \frac{1}{c}(c_t - c) - \frac{\phi_l}{1 - l^s - m^s}(l_t^s - l^s) - \frac{\phi}{1 - l^s - m^s}(m_t^s - m^s)$$

$$-\frac{1}{2}\frac{1}{c^2}(c_t - c)^2 + \frac{1}{2}\frac{\phi_l}{(1 - l^s - m^s)^2}(l_t^s - l^s)^2 + \frac{1}{2}\frac{\phi_l}{(1 - l^s - m^s)^2}(m_t^s - m^s)^2$$

Simplifying further

$$= \hat{c}_t - \frac{1}{2}\hat{c}_t^2 - \frac{\phi_l}{1 - l^s - m^s}(l^s \hat{l}_t^s + m^s \hat{m}_t^s) + \frac{1}{2}\frac{\phi_l}{(1 - l^s - m^s)^2}c(l^{s2}\hat{l}_t^{s2} + m^{s2}\hat{m}_t^{s2})$$

Now we rewrite m^s and l^s in terms of output. Production labor demand l_t is given by

$$l_t = \left(\frac{Y_t}{A1_t}\right)^{\frac{1}{1-\eta}} \int_0^1 \left(\frac{p_t(i)}{P_t}\right)^{-\frac{\epsilon}{1-\eta}} di$$

and according to the lemmas in Galì (2008)

$$\int_0^1 \left(\frac{p_t(i)}{P_t}\right)^{\frac{-\epsilon}{1-\eta}} di \simeq 1 + \frac{1}{2}\left(\frac{\epsilon}{1-\eta}\right)\frac{1}{\Theta}var_i\{p_t(1)\}$$

Log-linearizing the above condition

$$(1-\eta)\hat{l}_t = \hat{y}_t - a1_t + (1-\eta)log \int_0^1 \left(\frac{p_t(i)}{P_t}\right)^{-\frac{\epsilon}{1-\eta}} di$$

Loan management demand m_t is given by $\frac{L_t}{P_t} = Q_t a2_t m_t^{1-\alpha}$, together with the money in advance constraint $c_t \leq \frac{vL_t}{P_t}$ we derive the log-linearized expression for m_t

$$\hat{m}_t = \frac{1}{1-\alpha}\hat{c}_t - a2_t$$

Substitution by $\hat{c}_t = \hat{y}_t$

$$U_t - U =$$

$$\hat{y}_t - \frac{1}{2}\hat{y}_t^2 + \frac{1}{1 - l^s - m^s}\left[\frac{\phi_l}{1-\eta}(l^s[\hat{y}_t - a1_t + (1-\eta)log \int_0^1 \left(\frac{p_t(i)}{P_t}\right)^{-\frac{\epsilon}{1-\eta}} di) + \phi_l m^s(\frac{1}{(1-\alpha)}\hat{y}_t)\right]$$

$$= \hat{y}_t - \frac{1}{2}\hat{y}_t^2 - \phi_l[\nu(\hat{y}_t + \frac{\epsilon}{2\Theta}var_i\{p_t(i)\}) - \frac{1}{2}\nu^2(\hat{y}_t - a1_t)^2] - \phi_l[\mu\hat{y}_t - \frac{1}{2}\mu^2(\hat{y}_t - a2_t)^2] + t.i.p.$$

where $\nu = \frac{l^s}{(1-l^s-m^s)(1-\eta)}$ and $\mu = \frac{m^s}{(1-l^s-m^s)(1-\alpha)}$, $\Theta \equiv \frac{1-\eta}{1-\eta+\eta\epsilon}$ and t.i.p. are terms which are not affected by monetary policy. Using Woodford's (2003) result

$$\sum_{t=0}^{\infty} \beta^t var_i\{p_t(i)\} = \lambda \sum_{t=0}^{\infty} \beta^t \pi_t^2$$

Finally, we collect all terms on the rhs:

$$U_t - U = (1 - \phi_l(\nu + \mu) - \frac{1}{2}\phi_l(\nu^2 + \mu^2))\hat{y}_t - \frac{1}{2}(1 - \phi_l(\nu^2 + \mu^2))\hat{y}_t^2 - \frac{1}{2}\frac{\nu\phi_l\epsilon}{\Theta\lambda}\pi^2 + t.i.p.$$

Under $\phi_l = 0.65$ to yield roughly 1/2 of available time working in either goods production or banking, similar to Goodfriend and McCallum (2007), $\nu + \mu$ cancels out from the first expression.

The welfare measure is therefore approximated by:

$$\mathcal{W} = E_0 \sum_{t=0}^{\infty} \beta^t (U_t - U) = -\frac{1}{2} E_0 \sum_{t=0}^{\infty} \beta^t \left[(1 - \phi_l(\nu^2 + \mu^2))\tilde{y}_t^2 + \frac{\nu\phi_l\epsilon}{\Theta\lambda}\pi_t^2 \right] + t.i.p.$$

Restating gives

$$\mathcal{W} = E_0 \sum_{t=0}^{\infty} \beta^t (U_t - U) = -\frac{1}{2} E_0 \sum_{t=0}^{\infty} \beta^t \left[\varphi \tilde{y}_t^2 + \varpi \pi_t^2 \right] + t.i.p.,$$

with

$$\varphi = 1 - \phi_l(\nu^2 + \mu^2)$$

and

$$\varpi = \frac{\nu\phi_l\epsilon}{\Theta\lambda}.$$

The welfare function can be expressed in terms of a quadratic loss function

$$\mathfrak{L}_t = \varphi\sigma_{\tilde{y}}^2 + \varpi\sigma_{\pi}^2.$$