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Financial Bubbles in Interbank Lending

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Financial Bubbles in Interbank Lendingⁱ

Abstract

As a result of the global financial crisis countercyclical capital requirements have been discussed to prevent financial bubbles generated in the banking sector and to mitigate the adverse effects of financial repression after a bubble burst. This paper analyses the effects of an endogenous capital requirement based on the credit-to-GDP gap along with other policy instruments. We develop a macroeconomic framework which endogenizes market expectations on asset values and allows for interbank transactions. We then show how a bubble in the banking sector relaxes financing constraints. In policy experiments we find that an endogenous capital requirement can effectively reduce the impact of a financial bubble. We show that central bank intervention (leaning against the wind") instead has only a minor effect.

JEL Code: E44, E52

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

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ⁱ We would like to thank Jeffrey Campbell, Michael Kumhof, Stephen Millard, Tommaso Proietti and Radek Sauer for helpful comments, as well as participants at the Monetary and Macroeconomics seminar at the Bank of England, and during presentations at the University of Rome Tor Vergata, the EEA-ESEM annual congress 2017, the EconPol Europe Founding Conference 2017, and ifo Macroeconomics Seminar 2018. We acknowledge research assistance by Tim Stutzmann. The usual disclaimer applies.

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Financial Bubbles in Interbank Lending*

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April 9, 2018

Abstract

As a result of the global financial crisis countercyclical capital requirements have been discussed to prevent financial bubbles generated in the banking sector and to mitigate the adverse effects of financial repression after a bubble burst. This paper analyzes the effects of an endogenous capital requirement based on the credit-to-GDP gap along with other policy instruments. We develop a macroeconomic framework which endogenizes market expectations on asset values and allows for interbank transactions. We then show how a bubble in the banking sector relaxes financing constraints. In policy experiments we find that an endogenous capital requirement can effectively reduce the impact of a financial bubble. We show that central bank intervention (“leaning against the wind”) instead has only a minor effect.

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1 Introduction

Financial cycles are less frequent than average business cycles. However, when speculative financial bubbles burst, their economic consequences are rather persistent (Reinhart and Rogoff (2011); Brunnermeier and Oehmke (2013)). A financial bubble consists of three phases: creation of the bubble (potentially triggered by financial innovation), 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 deviation features a positive feedback mechanism. In a burst the prices suddenly fall with negative feedback mechanism, sometimes below the intrinsic value. These interactions can amplify economic fluctuations and possibly lead to serious financial distress and prolonged economic disruption.

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 (financial innovation) and an (irrational or behavioral) extrapolation of past loan growth into the future asset price. Hence, the size of loan portfolio is not just determined by supply and demand. The loan size is also linked to expectations of future loan value with a positive feedback mechanism in the bubble variable coming from the pricing at the loan trading stage.

The model comprises of households who consume, work for firms and banks, and invest in bank shares: they face a deposit in advance constraint which introduces a spillover from the financial sector into the real economy. The commercial banking sector comprises of a bank headquarter and retail branches which interact with households giving out differentiated loans to households. The “wholesale” unit is responsible for the management of the capital position of the bank. We allow for interbank transactions (securitization) in the loan market where resale of loans triggers the build up of the financial bubble. The repackaging of loans means a higher value as it allows for a mark-to-market of the price expectations through sale. This also results in a higher level of bank capital. As the amount of outstanding loans are linked to optimal bank capital, rising equity capital allows to expand further on the amount of loans. Finally, there is a monetary authority setting interest rates for bank refinancing.

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. 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 We find that a “leaning against the wind” policy is not very effective

¹In the BIS database the credit-to-GDP ratio is total credit to the private non-financial

in reducing the size of financial bubbles while endogenous macroprudential measures, such as an endogenous rule reacting to the credit-to-GDP-gap, can target (pure) financial bubbles more effectively than interest rate policy. This result is also in line with the findings by Galì (2017) who shows that monetary policies that lean against the bubble are potentially destabilizing and likely to be dominated by inflation targeting policies.

The paper is organized as follows: The first section discusses the motivation and related literature. Section 2 to 6 describe the model. Section 7 shows quantitative experiments. Section 8 concludes.

1.1 Motivation

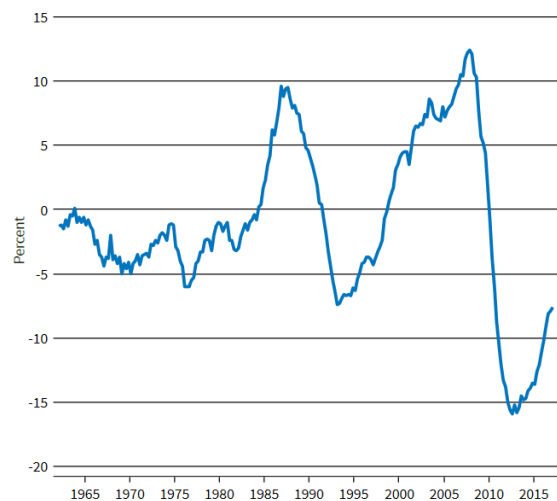
The run-up of financial bubbles followed by financial crashes is a (sadly) frequent phenomena in modern economies. The building up of the bubble as well as its crash usually sets a number of amplification mechanisms linked to the presence of financial frictions and spillovers effects in the real economy (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)).

Figure 1 shows various developments of the credit cycle (measured by credit-to-GDP gap) in Japan, the U.S. and Europe. For all countries plotted we see sizable swings in this measure. Credit expansion and contraction has significant effects on the demand side of the economy, and thus on economic cycles.

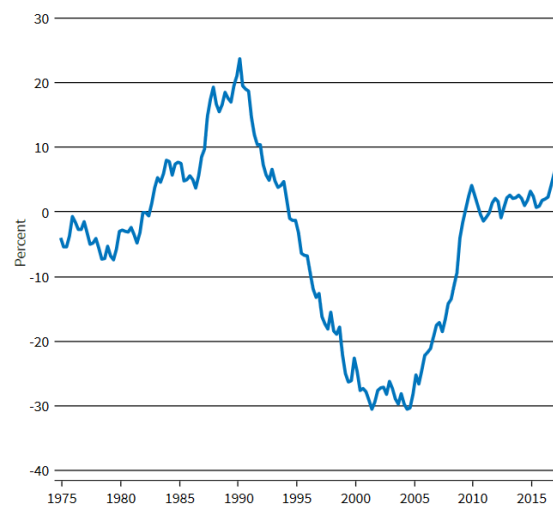
Japan faced a very deep crisis in the early 1990s caused by booming real estate and stock markets leading to the so-called “lost decade” of the 1990s and enduring low growth during the 2000s. To prick the bubble in real estate and in the stock market, the Bank of Japan implemented standard conventional policies by raising the official discount rate in May 1989, from 2.5% to 6.0%. In addition, the Bank of Japan forced the real estate sector to de-lever by reducing the amount of lending to the real estate sector where several real estate firms faced bankruptcy, leading to fire sales and a drop in real asset prices. Ultimately, the drop in real estate prices led to a decrease in the value of the collateral and to an overall lending decline with a debt overhang problem for the entire banking sector (see, for example, Hoshi and Kashyap (2004)). Only in very recent years Japan moved from conventional to macroprudential policies aiming at increasing the minimum Tier1 ratio of capital over risky assets from 4.5% (2013) to 6% (2017).

sector and captures total borrowing from all domestic and foreign sources as input data (https://www.bis.org/statistics/c_gaps.htm).

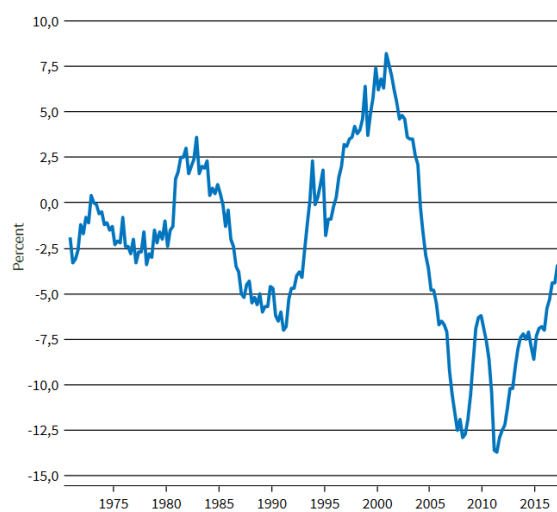
Figure 1: Credit-to-GDP Gap, Quarterly.



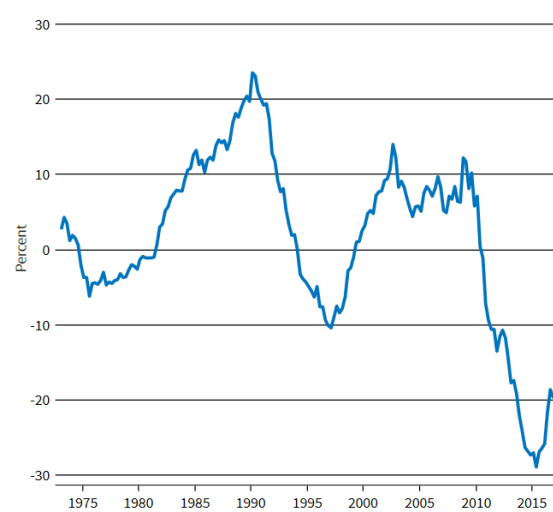
(a) United States



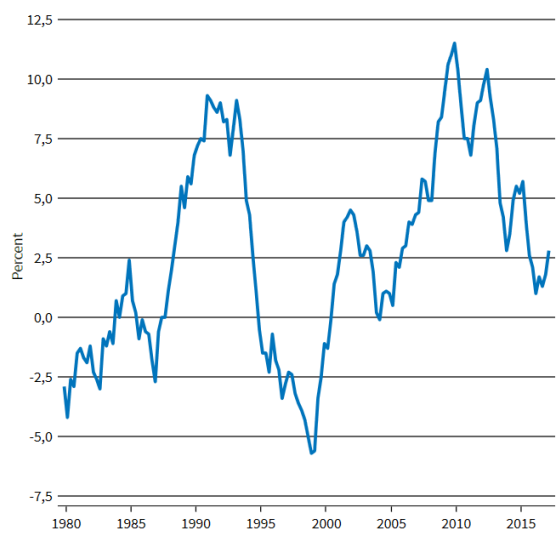
(b) Japan



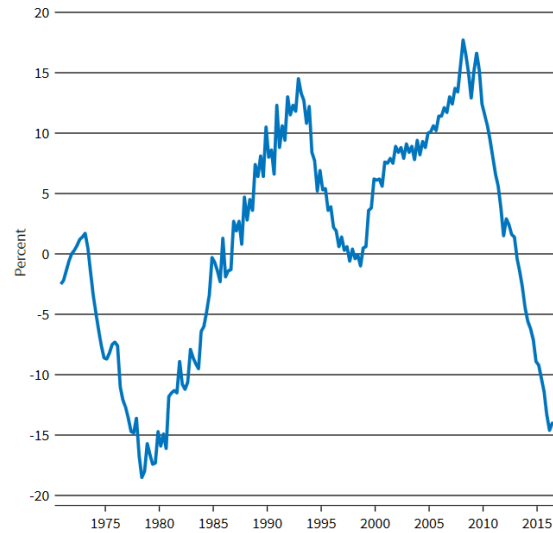
(c) Germany



(d) United Kingdom



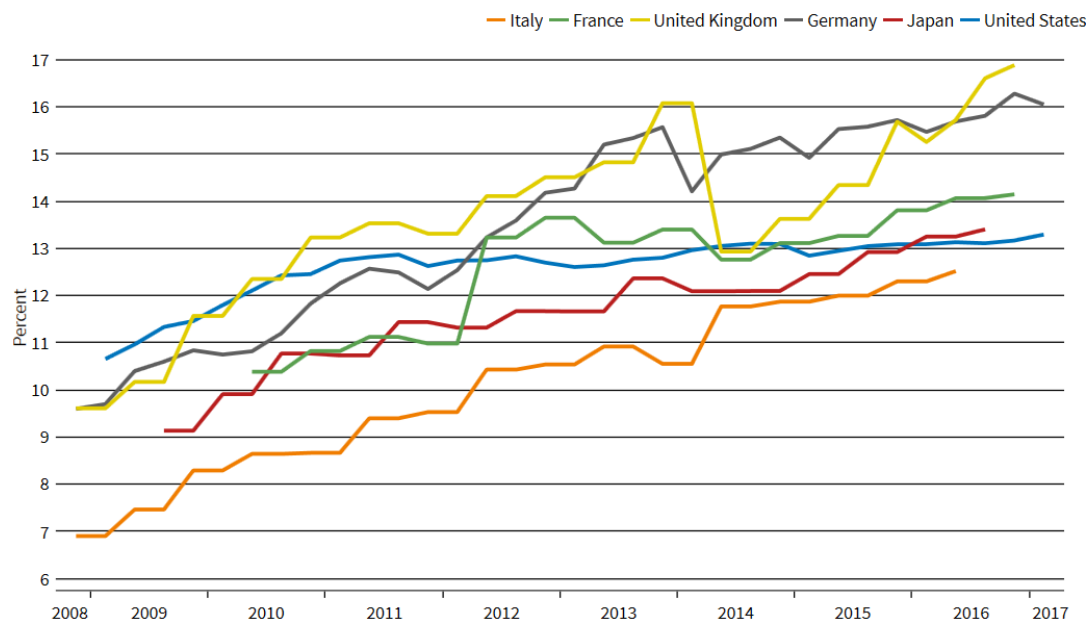
(e) France



(f) Italy

Source: BIS

Figure 2: Tier1 capital to risk weighted assets



Source: IMF

Policy switches to stricter capital requirements can also be observed in the U.S. and Europe. The coupling low interest rates and financial innovation in the form of mortgage securitization² had fueled the U.S. real estate prices bubble and the following burst in 2007 leading 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)).

More recently the European Union has been dealing with a major sovereign debt crisis which has been feeding into the financial sector. As also Borio (2012) notes fiscal policy intervention needs extra caution when economic booms and financial booms are coupled. The reason is that financial booms do not just enhance the balance sheets of financial institutions (Borio and Drehmann (2009)), they also enhance the fiscal accounts of public governments (Eschenbach and Schuknecht (2004), BIS (2010, 2012), Borio (2011), Benetrix and Lane (2011)). As potential output tend to be overestimated the sovereign inadvertently accumulates contingent liabilities. Furthermore, government bonds typically appear as risk neutral assets especially in the balance sheet of financial intermediaries. As the bubble busts balance sheet problems appear, especially in the financial sector, because of the dual risk-exposure coming from private lending and government assets. The response to the financial crises both in the U.S., Japan and Europe has been a general increase in capital requirement as

²Alan Greenspan testifying at the Financial Crisis Inquiry Commission in 2010 explained, "Whether it was a glut of excess intended saving, or a shortfall of investment intentions, the result was the same: a fall in global real long-term interest rates and their associated capitalization rates. Asset prices, particularly house prices, in nearly two dozen countries accordingly moved dramatically higher. U.S. house price gains were high by historical standards but no more than average compared to other countries."

shown in Figure 2.

1.2 Related Literature

There is a growing literature on financial bubbles in macroeconomic models. Brunnermeier and Oehmke (2013) analyse the amplification mechanisms of rational bubbles. 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 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 can also 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.

The control of bubble-burst episodes in the financial sector has triggered a series of proposals. Benes and Kumhof (2012) analyse in a DSGE setting the implication of the Chicago Plan. The key feature of this plan was the control of the credit functions in the banking system by ensuring that the creation of new bank credit can only take place through earnings that have been retained in the form of government-issued money, but not through the creation of new deposits by banks. 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)). In extreme situations, as when the Central Bank operates at the zero lower bound, interest rate policy may be complemented by unconventional tools (Bernanke and Reinhard (2004), Gertler and Karadi (2011), Curdia and Woodford (2010)).

Woodford (2012) and Svensson (2012) analyse the effectiveness of macroprudential policy along with an interest rate policy. While Woodford finds a complementary role of both,

Svensson argues in favor of a clear assignment to financial stability and price stability, respectively. 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.³ 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.⁴

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. There are several ways of intervening in this direction, through the design of macroprudential tools. Basel III, for instance, has designed a countercyclical capital buffer as opposed to “leaning against the wind policy” and other forms of capital and liquidity standards.⁵

The approach in this paper is placed in the literature of general equilibrium models with supply side financial frictions. We consider a model with bank monitoring and inside money creation features as in Goodfriend and McCallum (2007) with the added feature of 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 model the process of bubble creation 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 marked-to-market of the bubble through sale. 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 marked-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). In the proposed setup we analyse the stabilising effects of several policy options: (*i*) a conventional monetary policy reaction to

³Examples 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.

⁴Justiniano et al. (2015), Gertler and Karadi (2011) and Gertler and Kiyotaki (2010) focus on the role endogenous leverage constraints for banks to trigger credit supply disruptions.

⁵If effective macroprudential frameworks were in place, capital and liquidity buffers could be drained to control the building up of the bubble. But, if the authorities have failed to build up buffers in good times and financial problems emerge, the challenge is to act directly on financial institutions’ balance sheets (Borio (2012)).

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.

2 Model Overview

The model comprises of households who consume, work for firms and in the banking sector, and invest in bank shares and bonds. There are intermediate and final good producing firms which together form the production 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. A relaxation of financial constraints by looser regulation often stand at the beginning of credit booms (e.g. the Japan bubble, U.S. subprime boom, lending booms in some Eurozone countries). Furthermore, new technologies in loan production (IT) and selling (e.g. securitization) allow for an expansion of loans. Finally, the model includes a monetary authority which sets the riskless interest rate.

3 Households

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

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \left[\log(c_t) + \phi_l \log(1 - l_t^s - m_t^s) + \phi_e \log \left(\frac{Q_t^\Psi \Psi_t}{P_t} \right) \right] \quad (1)$$

where c_t is consumption, l_t^s labor provided to the production sector and m_t^s labor provided to the banking sector. Q_t^Ψ represents the equity price and Ψ_t the equity investments. ϕ_l reflects the weight of leisure and ϕ_e the weight of stock investments in utility. 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

$$P_t c_t \leq v D_t \quad (2)$$

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

$$c_t + \frac{B_{t+1}}{P_t} + \frac{D_{t+1}}{P_t} - \frac{L_{t+1}}{P_t} + \frac{Q_t^\Psi}{P_t} \Psi_t \leq w_t(l_t^s + m_t^s) + (1 + R_t^B) \frac{B_t}{P_t} \dots \quad (3)$$

$$\dots + (1 + R_t^D) \frac{D_t}{P_t} - (1 + R_t^L) \frac{L_t}{P_t} + \frac{Q_t^\Psi + \Pi_t^\Psi}{P_t} \Psi_{t-1}$$

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. Π_t^Ψ relates to dividend payments for bank equity.

4 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.

$$y_t = \left(\int_0^1 y_t(i)^{1-\epsilon} di \right)^{\frac{1}{1-\epsilon}} \quad (4)$$

The profit function of intermediate firm i is given by

$$\Pi_t^F(i) = y_t(i) - w_t l_t(i) \quad (5)$$

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

$$y_t(i) = A1_t l_t(i)^{1-\alpha} \quad (6)$$

In (6), $A1_t$ is a shock to productivity in goods production, similar to a standard TFP shock in the real-business-cycle literature, whose mean increase 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) pricing), i.e.

$$\sum_{k=0}^{\infty} \theta^k E_t \{ R_{t,t+k}^B y(i)_{t+k|t} (P_t^*(i) - \mathcal{M} M C_{t+k}) \} = 0 \quad (7)$$

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

5 Banking Sector

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).

5.1 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 profit function,

$$\Pi_t^B = \sum_{t=0}^{\infty} \left[R_t^L \frac{L_t}{P_t} - R_t^D \frac{D_t}{P_t} - \frac{\kappa_e}{2} \left(\frac{e_t}{L_t} - \tau \right)^2 - w_t m_t \right], \quad (8)$$

where L_t is the overall loan portfolio, and D_t are the total 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.

$$L_t = D_t + e_t \quad (9)$$

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

$$\frac{L_t}{P_t} = Q_t m_t^{1-\alpha}, \quad (10)$$

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

$$Q_t = \rho_3 Q_{t-1} + \epsilon_t^3 \quad (11)$$

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.

$$R_t^L - R_t^D = \frac{v w_t m_t}{(1 - \alpha) c_t} - \kappa_e \left(\frac{e_t}{L_t} \right)^2 \left(\frac{e_t}{L_t} - \tau \right). \quad (12)$$

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.⁶ The differentiated loan demand function by households reads as

$$L_{j,t} = \left(\frac{R_t(j)^L}{R_t^L} \right)^{-\epsilon_L} L_t \quad (13)$$

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

$$R_t^L(j) = \frac{\epsilon_L}{\epsilon_L - 1} R_t^L, \quad (14)$$

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.

$$\omega_{B,t} = R_t^L \frac{L_t}{P_t} - R_t^D \frac{D_t}{P_t} - \frac{\kappa_e}{2} \left(\frac{e_t}{L_t} - \tau \right)^2 - w_t m_t. \quad (15)$$

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

$$\Pi_t^\Psi = \phi_\Psi \omega_{B,t}. \quad (16)$$

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 , is then

$$e_t = (1 - \delta_e) e_{t-1} + \phi_B (Q_t^\Psi - Q_{t-1}^\Psi) \Psi + (1 - \phi_\Psi) \omega_{B,t-1}, \quad (17)$$

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. The dying rate of bank capital δ_e , captures sunk cost of bank capital management. $Q_t^\Psi \Psi$

⁶Deposit demand equivalently reads as

$$D_{j,t} = \left(\frac{R_t(j)^D}{R_t^D} \right)^{-\epsilon_D} D_t$$

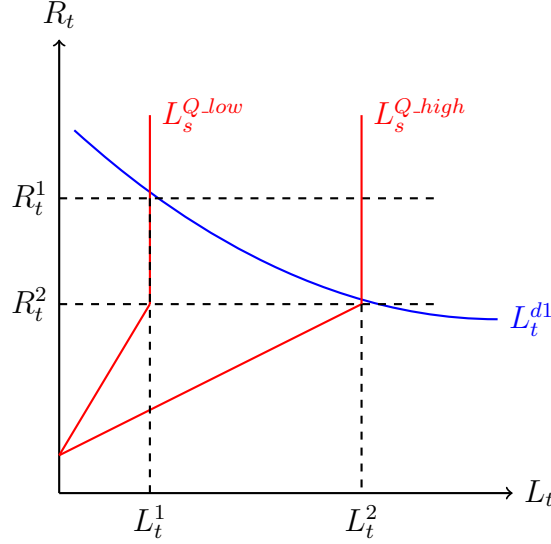
represents the market capitalization of the bank.

5.2 Loan securitization and trading

Banks are allowed to securitize loans into tradable loan portfolios, and exchange them with each other with their given value plus a profit.⁷

Initial financial innovation shock. We assume a financial innovation shock which is a

Figure 3: Shock to loan production efficiency



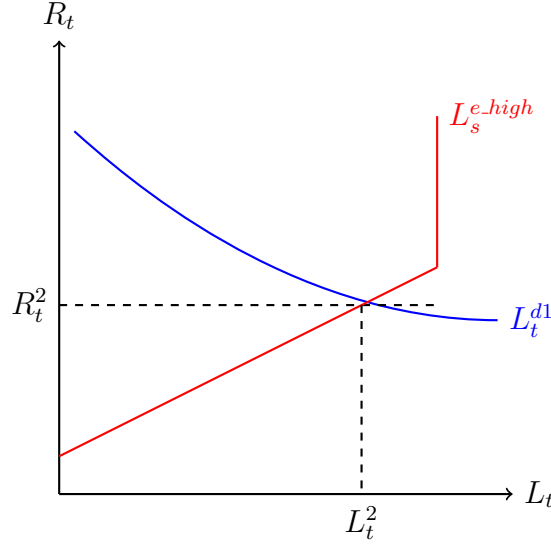
productivity shock to the efficiency of the bank loan production function, Q_t , by which the size and thus the value of the loan, L_t , increases at banks. We can think of the productivity shock to the efficiency in loan production, Q_t , as a new technology shock which allows to increase the loan output while reducing the monitoring need of banks. The mechanism is illustrated in Fig. 3 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.

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 Branch and Evans⁸ (2005) we assume that

⁷See 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.

⁸Branch and Evans (2005) evaluate the effectiveness of different prediction models for economic growth. They compare four different methods: Recursive Least Squares (RLS), Kalman-filter method, Constant Gain Least Squares and a special case of Constant Gain Least Squares which allows the constant gain to be equal for every variable (Simple Method). The Constant Gain Method and specifically the Simple Method turn out to provide the best results which allows the conclusion that this is a method worth considering with

Figure 4: Expansion of equity capital due to mark-to-market



agents act as econometricians when forecasting and implement this bounded rationality on banks 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.

$$\ln L_t - \ln L_{t-1} = g_t + w_t$$

with w_t being a short run fluctuation around g_t , the economy's growth rate. The short run fluctuation, w_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 expectations about the growth in future value. g_t is a AR(1) process around the mean g , i.e.

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

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

$$\begin{aligned} \tilde{E}_t(\ln L_{t+1} - \ln L_t) &= \tilde{E}_t(g_{t+1} + w_{t+1}) \\ &= \tilde{E}_t(1 - \delta_g)g + \delta_g \tilde{E}_t g_t \end{aligned} \tag{18}$$

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

regards to the expectations formation of economic agents that adapt to continuous structural changes in the economy.

⁹Compare to Milani (2005) who examines and tests whether agents in the economy have rational expecta-

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:

$$\tilde{E}_t g_t = (1 - \kappa) \delta_g \tilde{E}_{t-1} g_{t-1} + \kappa (\ln L_t - \ln L_{t-1})$$

with κ being the weight on last period's growth trend. Replacing this into (18), multiplying out and collecting terms we derive the expectation of the future loan value:

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

So when banks sell a loan portfolio through securitization they realize gains through expected future valuation changes, i.e.

$$\tilde{E}_t (\ln L_{t+1}) = \ln L_t + \ln(b_t) \quad (19)$$

where we assume δ_g and κ to be 1. Through the Kalman filter the expectation formation about future prices depends on the past changes in the value of the loan portfolio:

$$b_t = \frac{L_t}{L_{t-1}} \quad (20)$$

Thus the size of the bubble is determined by extrapolating the pace of loan growth which makes it backward looking. Using condition (19) and plugging it into the above loan production function results in:

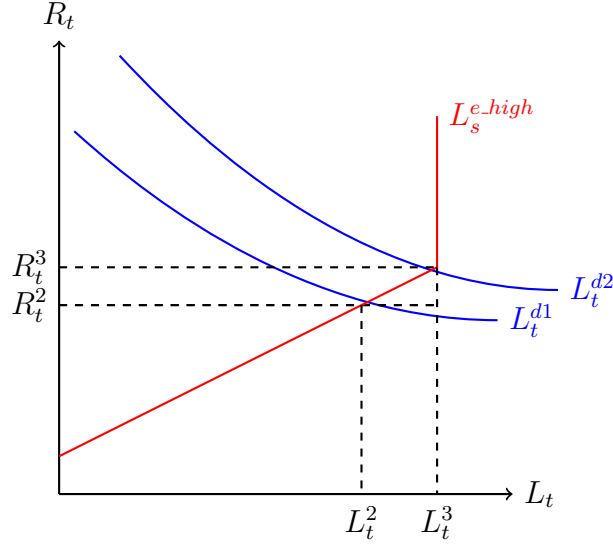
$$\frac{\tilde{E}_t \{L_{t+1}\}}{P_t} = Q_t m_t^{1-\alpha} + \frac{b_t}{P_t}. \quad (21)$$

Transmission to bank equity. The repackaging of loans results in a higher value, with the bubble term, b_t , being the profit of this transaction. The repackaging technology allows for a mark-to-market of the bubble through sale. This results in a higher level of bank equity by the bubble size, i.e. $e_t + b_t$. This is illustrated in Fig. 4. 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 , i.e.

$$e_{t+1} \uparrow \approx \tau L_{t+1} \uparrow \quad (22)$$

tions with regards to economic growth or whether it can be assumed that they 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. He finds that the adaptive learning method helps to improve the fit of the 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.

Figure 5: Increase in loan demand



We can separate two cases: 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} , will also expand as banks are able to lower the credit spread along with lower capital costs. 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 Fig. 5.

5.3 Discussion: From the standard model to the bubble model

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. 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. Second, this additional loan supply through the banking sector keeps consumption higher than given by what a household could fundamentally afford through its consumption-savings decision.

6 Monetary policy

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

$$R_t^p = (R_{t-1}^p)^\rho \left(\frac{\pi_t}{\pi^*} \right)^{(1-\rho)\phi_\pi} \left(\frac{y_t}{y_{t-1}} \right)^{(1-\rho)\phi_y} A3_t \quad (23)$$

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

7 Quantitative Results and Policy Experiments

We solve the model for its equilibrium, calculate non-stochastic steady states and linearize the model around the steady state. In the following 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.

7.1 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..

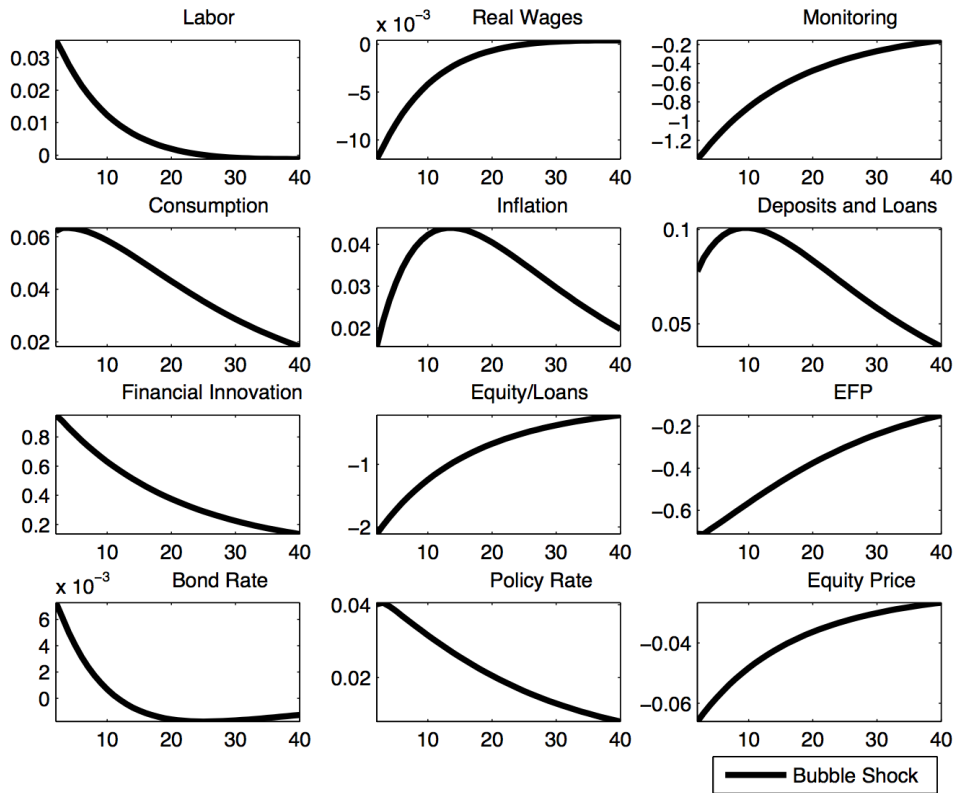
Table 3. Calibration of exogenous shocks

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.

Figure 6: 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.

7.2 Impulse response for the Financial Bubble

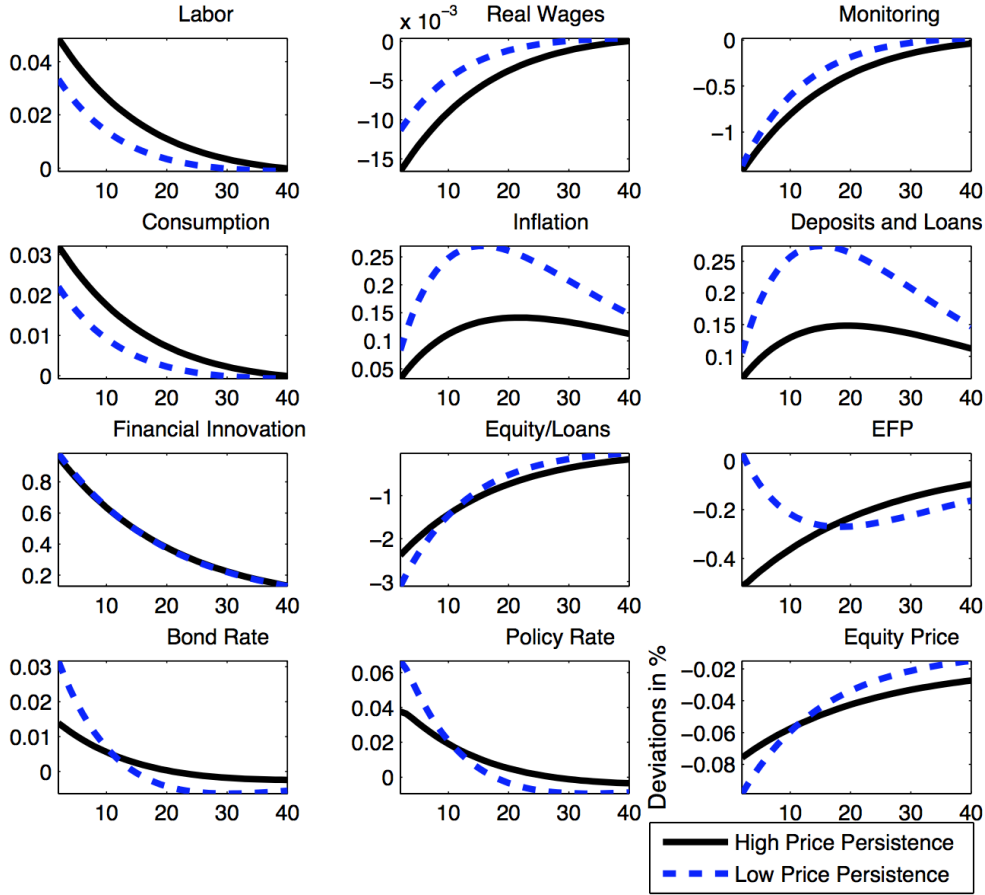
We first show the impulse response to a financial innovation shock in Fig. 6 and then the impulse under a variation of price persistence.

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) and the equity price are lowered. The amount of loans handed out by banks 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.

We illustrate the effect of the staggered pricing mechanism (as in Calvo (1983)) under the financial bubble shock (Fig. 7). 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 7: 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.

7.3 Policy experiments

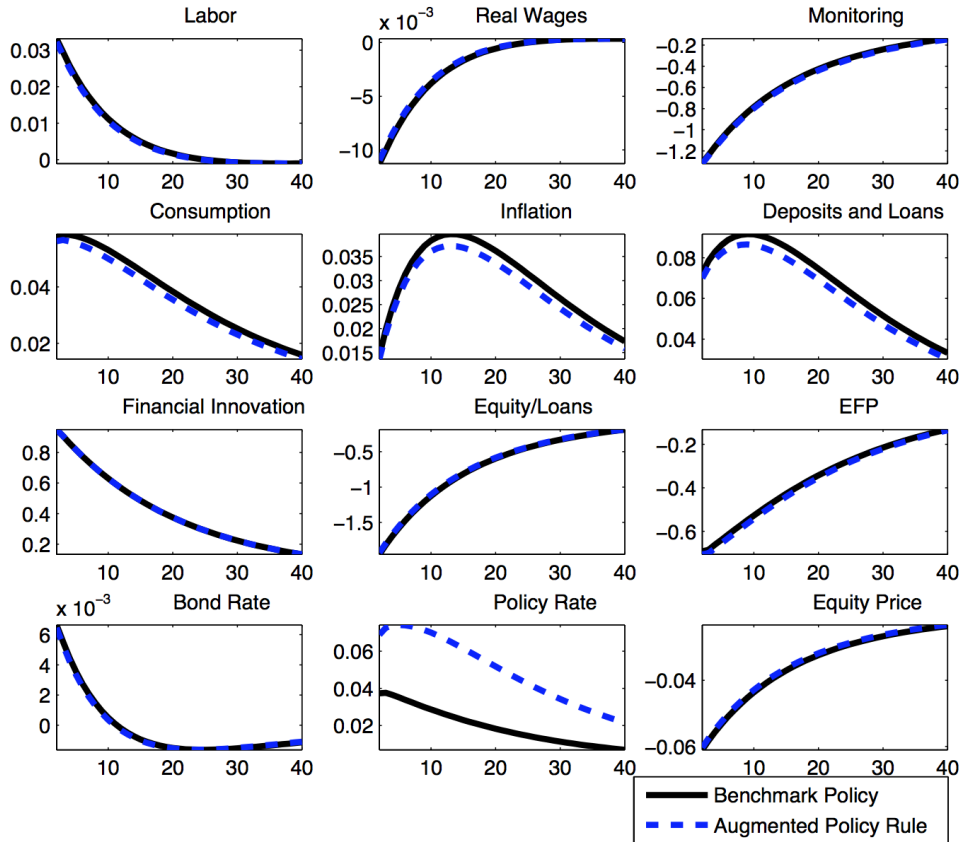
We test how effective several monetary and macroprudential policies are in this setup:

In Fig. 8 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 towards

$$R_t^p = (R_{t-1}^p)^\rho \left(\frac{L_t}{L} \right)^{\phi_L(1-\rho)} \left(\frac{\pi_t}{\pi^*} \right)^{(1-\rho)\phi_\pi} \left(\frac{y_t}{y_{t-1}} \right)^{(1-\rho)\phi_y} A3_t. \quad (24)$$

We see in the impulse response that the modified Taylor rule has little effect on inflation and consumption although the policy reaction doubles. A reaction to overall loan growth barely affects bank leverage, the credit margin (EFP) or the equity price. We conclude that a “leaning against the wind” policy is not effective in reducing the size of financial bubbles.

Figure 8: Impulse response 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.

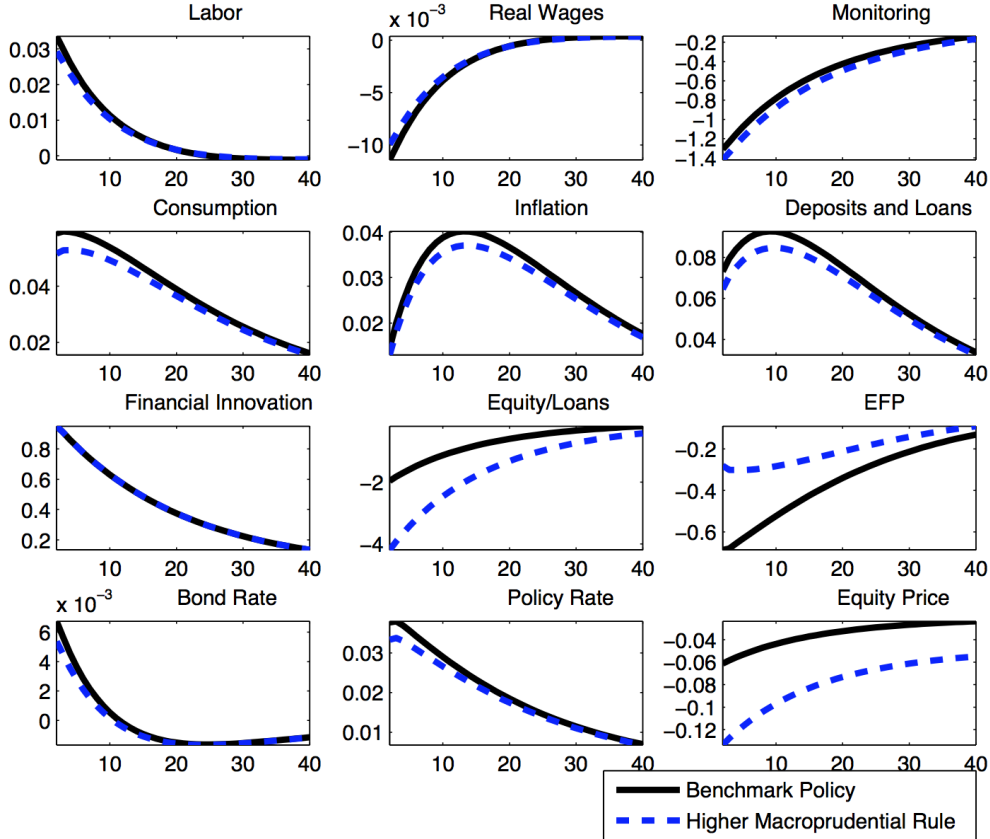
The next experiment uses a macroprudential measure by increasing the target level of

the capital requirement ratio, τ , from a level of 11% towards 15%.

$$\Pi_t^B = \sum_{t=0}^{\infty} \left[R_t^L \frac{L_t}{P_t} - R_t^D \frac{D_t}{P_t} - \frac{\kappa_e}{2} \left(\frac{e_t}{L_t} - \tau \right)^2 - w_t m_t \right] \quad (25)$$

The increased capital requirement ratio leads to a reduction of the impact of the shock as demonstrated in Fig. 9. The response of inflation and consumption is dampened. This works through the equity price which is lowered during a financial shock (almost twice as much compared to the base case). 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 9: Impulse response with higher equity requirement

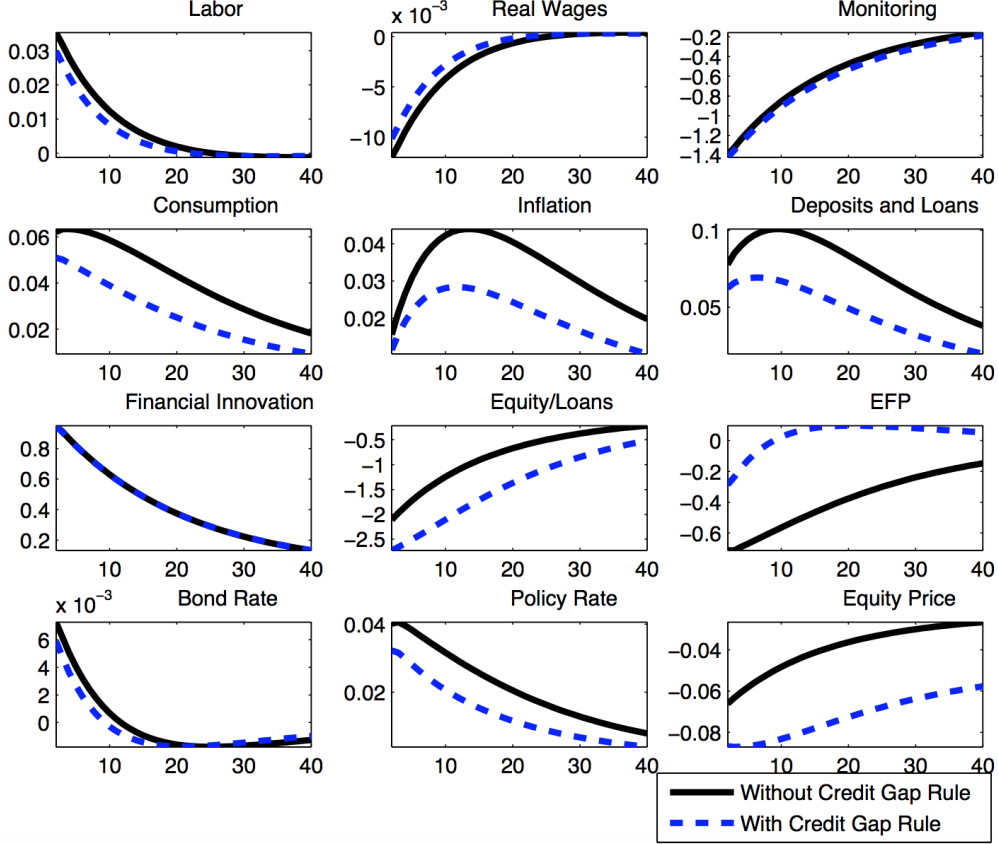


Note: All interest rates are shown as absolute deviations from the steady state, expressed in percentage points. All other variables are percentage points deviations from the implied steady state value.

Finally, in Fig. 10 we introduce an endogenous capital requirement, τ_t , set by regulator along the following rule reacting to the credit-to-GDP gap:

$$\tau_t = \bar{\tau} + \kappa_t \left(\frac{L_t}{Y_t} - \frac{L}{Y} \right) \quad (26)$$

Figure 10: Impulse response with endogenous 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.

Under the rule reacting to the credit-to-GDP gap we see a reaction 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 (external finance premium, EFP) is much lower. The stabilization comes from the combination of a lower equity price and a smaller response of deposits and loans. 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 while at the same time other variables do not move let us conclude that an endogenous requirement is effective in precisely working in the required way without adversely affecting other macroeconomic variables.

Supporting this reasoning, Table 4 shows that under and 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	0.1638	1	0.1078	1
Equity	2.72132	0.5188	6.7513	0.2133
Equity Prices	0.08529	0.4408	0.2185	0.1688
Loans	0.4477	0.9711	0.3326	0.7545

8 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 determined by supply and demand, 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 demonstrate how a bubble in the banking sector relaxes financing constraints on the liability side as it increases the value on the asset side of bank balance sheets. Through higher bank lending, the financial bubble generates (temporary) income effects at the side of the households.

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. A central bank intervention against the financial bubble (“leaning against the wind”) has only a minor effect. We thereby provide a rationale for the use of counter-cyclical capital buffers.

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A Linearised model

Let \hat{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

$$\hat{\lambda}_t + \hat{w}_t = \frac{l}{1-l-m} \hat{l}_t + \frac{m}{1-l-m} \hat{m}_t \quad (27)$$

2) Demand for production labor

$$\hat{w}_t = -\eta \hat{l}_t + a1_t \quad (28)$$

3) Monitoring demand

$$\frac{1}{\lambda} \hat{\lambda}_t + c \hat{c}_t + LR^L (\hat{L}_t + \hat{R}_t^L) + LR^D (\hat{L}_t - \hat{R}_t^D) = 0 \quad (29)$$

4) Production

$$\hat{c}_t = (1 - \eta) \hat{l}_t + a1_t \quad (30)$$

5) Supply of banking services

$$\hat{c}_t = (1 - \alpha) \hat{m}_t + a2_t \quad (31)$$

6) Money in advance constraint

$$\hat{c}_t + \hat{P}_t = \hat{D}_t \quad (32)$$

7) Inflation

$$\hat{\pi}_t = \hat{P}_t - \hat{P}_{t-1} \quad (33)$$

8) Calvo (1983) pricing

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \vartheta \hat{m}c_t \quad (34)$$

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

9) Marginal cost

$$\hat{m}c_t = \hat{w}_t - \frac{1}{1-\eta} (\eta \hat{c}_t) + (1-\eta) \hat{l}_t \quad (35)$$

10) Bond holding

$$\widehat{B}_t = 0 \quad (36)$$

11) Stock holding

$$\widehat{\Psi} = 0 \quad (37)$$

12) Loans

$$\widehat{L}_t = \widehat{D}_t \quad (38)$$

13) Equity

$$e(1 - \delta_e)\widehat{e}_{t-1} - e\widehat{e}_t + \phi_B Q(\widehat{Q}_t^\Psi - \widehat{Q}_{t-1}^\Psi)\Psi + (1 - \phi_\Psi)\omega_B \widehat{\omega}_{B,t-1} \quad (39)$$

14) Bond rate

$$\widehat{R}_t^B = \widehat{\pi}_t + \widehat{\lambda}_t - E_t \widehat{\lambda}_{t+1} \quad (40)$$

15) Equity price

$$E_t \left(\lambda \widehat{\lambda}_{t+1} + Q^\Psi \widehat{Q}_{t+1}^\Psi + \Pi^\Psi \widehat{\Pi}_{t+1}^\Psi - \widehat{\pi}_{t+1} \right) - \left(\lambda \widehat{\lambda}_t + Q^\Psi \widehat{Q}_t^\Psi \right) = 0 \quad (41)$$

16) Loan spread

$$R^L R_t^L = \frac{\epsilon_L}{\epsilon_L - 1} \left[\begin{array}{l} R^D R_t^D + \frac{vw_t m_t}{(1-\alpha)c} (\widehat{w}_t + \widehat{m}_t - \widehat{c}_t) \\ - \frac{\kappa_e e}{L^2} \left(2 \frac{e}{L} - \tau \right) \widehat{e}_t - \frac{\kappa_e e}{L^2} \left(3 \frac{e}{L} - 2\tau \right) \widehat{L}_t \end{array} \right] \quad (42)$$

17) Deposit rate

$$\widehat{R}_t^D = \widehat{R}_t^P \quad (43)$$

18) Policy feedback rule

$$\widehat{R}_t^P = (1 - \rho) (\phi_\pi \widehat{\pi}_t + \phi_c \widehat{c}_t) + \rho \widehat{R}_{t-1}^P + a 3_t \quad (44)$$

19) Bank Profit

$$\begin{aligned} \omega_B \widehat{\omega}_{B,t} &= R^L L \left(\widehat{R}_t^L + \widehat{L}_t \right) - R^D L \left(\widehat{R}_t^D + \widehat{D}_t \right) - \\ &\quad \frac{\kappa_e e}{L} \left(\frac{e}{L} - \tau \right) \left(\widehat{e}_t - \widehat{L}_t \right) - wm (\widehat{w}_t + \widehat{m}_t) \end{aligned} \quad (45)$$

20) Dividends:

$$\widehat{\Pi}_t^\Psi = \widehat{\omega}_B \quad (46)$$

21) EFP:

$$efp_t = R^L \widehat{R}_t^L - R^D \widehat{R}_t^D \quad (47)$$

There are 21 equations and 21 variables.

B Calculating Steady States

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

$$1 + R^B = \frac{1}{\beta} \quad (48)$$

R^D

$$R^D = (1 - rr) R^P \quad (49)$$

R^L

$$R^L = \chi_{\epsilon_L} \left[R^D + \frac{vwm}{(1 - \alpha)c} \right] \quad (50)$$

c

$$c = A1l^{1-\eta} \quad (51)$$

D

$$D = \frac{c}{v} \quad (52)$$

w

$$w = (1 - \eta) l^{-\eta} \quad (53)$$

L

$$L = D \quad (54)$$

m

$$m = \left(\frac{L}{Q} \right)^{\frac{1}{1-\alpha}} \quad (55)$$

λ

$$\lambda = \frac{\phi_l}{w(1-l-m)} \quad (56)$$

ω_B

$$\omega_B = (R^L - R^D) L - wm \quad (57)$$

ϕ_Ψ

$$\begin{aligned} e &= \frac{(1 - \phi_\Psi)}{\delta_e} \omega_B \\ \tau &= \frac{e}{L} = \frac{(1 - \phi_\Psi)}{\delta_e} \frac{\omega_B}{L} \\ \tau \delta_e L &= \omega_B - \phi_\Psi \omega_B \\ \phi_\Psi &= 1 - \frac{\tau \delta_e L}{\omega_B} \end{aligned} \quad (58)$$

e

$$e = \frac{(1 - \phi_\Psi)}{\delta_e} \omega_B \quad (59)$$

Π^Ψ

$$\Pi^\Psi = \phi_\Psi \omega_B \quad (60)$$

Q^Ψ

$$\begin{aligned} 1 &= \beta E_t \left\{ \frac{Q^\Psi + \Pi^\Psi}{Q^\Psi} \right\} \\ Q^\Psi &= \frac{\beta \Pi^\Psi}{(1 - \beta)} \end{aligned} \quad (61)$$

$R^L - R^D$

$$R^L - R^D = \frac{R^D}{\epsilon_L - 1} + \frac{\epsilon_L}{\epsilon_L - 1} \left[\frac{vw_t m_t}{(1 - \alpha)c} \right] \quad (62)$$

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