Monetary and Macroprudential Policy Rules in a DSGE Model

By Chenjie Shao and Khaldoun Khashanah *

In this paper, we construct a dynamic stochastic general equilibrium (DSGE) model with a banking sector, analyzing the interaction between macrorpudential policy and monetary policy. Here capital requirement is our macroprudential policy tool. We find that an appropriate combination of macroprudential policy and monetary policy is beneficial compared to the case of only using monetary policy, when the economy is driven by technology shock. The absolute independence between macroprudential and monetary policymakers when making monetary policy decisions might be harmful in terms of excessive volatility of output. When financial shocks are the main drivers, it is also beneficial to introduce macroprudential policy. Different from the case of technology shocks, central banks taking full responsibility for both policies generates more sizable benefits than other cases. Hence, it yields a significant gain to introduce capital requirements as a macroprudential policy tool, particularly in terms of financial stability.

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After experiencing the worst financial crisis since the Great Depression, policymakers and researchers in the United States and Europe have become quite interested in macroprudential policy. Why has macroprudential policy become more important than ever? Since a quarter of a century ago, the financial markets have been liberalized globally. Particularly, in the U.S. banking sector, the old heavily controlled financial system was replaced by a new lightly regulated one. Borio and Shim (2007) suggest that the lightly regulated financial environment may have made it more likely that financial factors in general, and booms and busts in credit and asset prices in particular act as drivers of economic fluctuations. Moreover, the establishment of a monetary policy regime yielding low and stable inflation, underpinned by central bank credibility, may have made it less likely that signs of unsustainable economic expansion show up first in rising inflation and more likely that they emerge first as excessive increases in credit

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and asset prices (Borio and Shim (2007)). Hence, macroprudential policy is important, aiming at enhancing the resilience of the financial system so that the likelihood of financial instability is reduced. Compared with macroprudential policy, monetary policy may not be sufficiently concerned with financial stability.

Macroprudential policy is also differerent from the microprudential policy. Microprudential supervisors focus on single institutions and are accordingly liable to neglect risks outside their purview - risks that may be negligible for the individual institution but may nevertheless add up in the aggregate (Brunnermeier et al. (2009)). In contrast, macroprudential policy need to counter the risk aggregation during booms and mitigate credit contraction in economic downturns.

Macroprudential institutions were established all over the world after 2008, including the Financial Stability Oversight Council (FSOC) in the United States and the European Systemic Risk Board (ESRB) in the European Union. In U.K., the Bank of England is assigned full responsibility in macroprudential policymaking. That is to say, in U.K. and the Eurozone, central banks plays a dominant role in macrprudential policymaking while in the United States, the Federal Reserve needs to collaborate with other members in the FSOC. The differences in the institutional frameworks for the relationship between the macroprudential policymakers and the central banks might bring up a question: which institutional framework is better in handling crises similar to the 2008 financial crisis? Another important question is about the optimal interaction relationship between monetary policy and macroprudential policy. The relationship between the two policies is a little bit complicated. Both policies affect the credit demand by allocating spending and affect the credit supply by influencing the funding cost of consumers, financial intermediaries and firms. However, monetary policy aims at price stability while macroprudential policy targets financial stability. The similarities in transmission mechanisms and differences in policy goals might show the difficulties in finding out the best interaction relationship between the two policies.

In this paper we extend the dynamic stochastic general equilibrium (DSGE) model developed by Shao and Khashanah (2015) to analyze the macroeconomic effects of macroprudential policy. Here we mainly use loan-to-value (LTV) ratio as our macroprudential instrument. We choose it for two reasons. First, Cerutti et al. (2015) and Lopez et al. (2015) find that among the macroprudential instruments available, both emerging and advanced countries prefer loan-to-value-related measures. Second, the newly approved Basel III reform envisions a countercyclical capital buffer, along with a host of other instruments (Angelini et al. (2014)). Thus it is meaningful to assess the macroeconomic effect of LTV ratio so that more discretion is allowed in its application for macroprudential goals. Following Angelini et al. (2014) and De Nicolo et al. (2012), we assume that the macroprudential authority minimizes a loss function whose arguments are the variance of the loans-to-output ratio, of output and of bank profits. We use the volatility of bank profits to assess bank risk taking. Then we assess the robustness of our results to alternative parameterizations of the loss functions. We model the monetary policy in a standard way: the central bank sets the Taylor rule's parameters to minimize the variance of inflation and output. Similar to Angelini et al. (2014), there are three types of interaction between the macroprudential and monetary policymakers. In the "cooperative" case, the two policymakers jointly and simultaneously implement their policy rules in order to minimize a common loss function. In the "noncooperative" case each policymaker minimizes his own loss function, taking the other's policy rule as given. In the "augmented cooperative" case, the monetary policymakers also act as macroprudential policymakers. That is, the monetary policymakers implement an augmented Taylor rule considering financial stability.

We use the DSGE model by Shao and Khashanah (2015) for two reasons. Firstly, this framework considers bank-affiliated mortgage companies in the financial intermediation sector and classify households into three types: savers, borrowers and credit-constrained borrowers. Using loan-level data, Demyanyk and Hermet (2008) show that loan quality - adjusted for observed characteristics and subsequent house price appreciation - deteriorated monotonically, between 2001 and 2007. They also find evidence that securitizers were aware of the increasing riskiness of high-LTV borrowers, and adjusted mortgage rates accordingly. Hence, the root cause of the collapse of the MBS market lies in loans with deteriorating quality. Then a question might come up: how are banks able to issue such low quality loans under the regulations? Demyanyk and Loutskina (2012) showed that bank holding companies (BHCs) establish mortgage company (MC) subsidiaries to take advantages of inconsistent regulations across banks and MCs. Thus BHC-affiliated MCs (BMCs) could impose inferior lending standards to bank subsidiaries of the same BHC (Shao and Khashanah (2015)). MCs did not go extinct with subprime and continue to originate around 30% of the U.S. mortgages through 2010 (Demyanyk and Loutskina (2012)). Therefore it is important to consider the effects of BMCs behavior on the business cycle in macroprudential policymaking. Secondly, in the model, the supply of credit to the real economy is constrained by the availability of bank capital, which can only be accumulated gradually through retained earnings. Thus when there is a negative shock to bank capital, lowering the minimum LTV requirement could avert deleveraging and its repercussions on the real economy (Angelini et al. (2014)). We find that time-varying bank capital requirements can improve financial stability, while further analysis is needed.

There is a growing literature incorporating macroprudential policy in economic models. Some papers focus on the pros and cons of adopting Basel III, including Angelini et al. (2014), Bean et al. (2010) and Roger and Vlcek (2011)). There are also papers proposing macroprudential tools - LTV ratios - to improve social welfare (see Gruss and Sgherri (2009), Lambertini, Mendicino and Punzi (2011) and Funke and Paetz (2012)). Other authors suggest that it is necessary to strengthen the interaction of macroprudential and monetary policy for a sound financial system (see Borio and Shim (2007) and Angelini et al. (2014)). Closer to our analysis is the paper by Angelini et al. (2014), which focus on the interaction between optimal monetary and macroprudential polices in a DSGE model with a banking sector. Nevertheless, the macroeconomic effects of bank-affiliated mortgage companies were not considered. Our model provides a rationale for the use of macropurdential tools in situations similar to the 2008 financial crisis.

We contribute to the literature in two dimensions: on the origins of the Crisis and on the interaction between macroprudential and monetary policy in a DSGE model. First, we analyze the potential important contributing factors - deteriorating lending standards - to the recent crisis put forward by many academic researchers. Second, as far as we know, this article is the first DSGE model to analyze the interaction between monetary policy and macroprudential policy in conjunction with banks acting as "loan pushers" by establishing bank-affiliated mortgage companies, providing theoretical support to recent empirical findings by Dell'Arriccia, Igan and Laeven (2008), Demyanyk and Hermet (2008) and Demyanyk and Loutskina (2012).

The rest of the paper proceeds as follows. Section 2 presents the model and Section 3 discusses model calibration and Section 3 shows the results of simulations in different cases. In the following section, sensitivity analysis and further analysis are performed. We leave the final section for concluding remarks.

I. Model Framework

Our model is a variant of Gerali et al. (2010). There are three types of households: Savers, Borrowers and Credit-constrained Borrowers. All the three types of households work, consume and accumulate housing. There are mainly two differences among the households. First, Savers make deposits to banks, while Borrowers and Credit-constrained Borrowers borrow loans from banks at different rates. Second, Savers' discount factor is higher than the other two households'. Credit-constrained Borrowers discount factor is the lowest.

There exists three main agents in the producing sector: entrepreneurs, capital good producers and retailers. Capital good producers produce capital used by entrepreneurs to produce a homogeneous intermediate good. Retailers buy the intermediate goods from entrepreneurs in a competitive market, brand them at no cost and sell the final differentiated good at a price. Households obtain income by working for entrepreneurs. They supply their differentiated labor services through unions. Unions then set wages to maximize members utility subject to adjustment costs.

Banks set up three substitutes: the loan branch, the deposit branch and the BMC branch. The deposit branch, namely, is the place where Savers make deposits. The loan branch supplies loans to Borrowers as well as entrepreneurs. The BMC branch provides riskier loans to Credit-constrained Borrowers with higher LTV ratios. Banks offer implicit guarantees to the creditors of the BMC branch and retain the residual values of BMCs as a return. When taking on a loan either from the loan branch or the BMC branch, agents face a borrowing constraint, tied to the value of future collateral holdings. Borrowers and Credit-constrained Borrowers borrow against their housing stock, while entrepreneurs borrow against their physical capital.

Following Gerali et al. (2010), the banking branches operates in a regime of monopolistic competition: banks set interest rates on deposits and on loans in order to maximize profits. The amount of loans issued by each branch can be financed through the amount of deposits and bank capital.

A. Households

The key differences between the three types of households are that Savers' discount factor β^P [1] is higher than Borrowers' discount factor β^I, while the Borrowers' discount factor β^I is higher than the Credit-constrained Borrowers' discount factor β^S [2].

Savers

The representative Saver maximizes the expected utility:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_t^P [\varepsilon_t^z log(c_t^P(i) - a^P c_{t-1}^P) + \varepsilon_t^h log h_t^P(i) - \frac{l_t^P(i)^{1+\phi}}{(1+\phi)}]$$

In which, c_t^P, h_t^P and l_t^P denote current consumption, housing services and hours worked, respectively. The parameter a^P is a habit coefficient and c_{t-1}^P represents aggregate consumption at time $t-1$. The parameters ε_t^h and ε_t^z capture exogenous shocks to the housing demand and consumption preferences, respectively. Both of them have an AR(1) representation with i.i.d. normal innovations. The budget constraint of Savers have to match (in real terms):

$$c_t^P(i) + q_t^h(h_t^P(i) - h_{t-1}^P(i)) + d_t^P(i) = w_t^P l_t^P(i) + \frac{(1+r_{t-1}^d)d_{t-1}^P}{\pi_t(i)} + T_t^P \quad (1)$$

The left side represents the flow of expenses. It is composed by current consumption c_t^P, accumulation of housing services $(h_t^P(i) - h_{t-1}^P(i))$, and deposits to be made this period d_t^P. The right side represents resources, in which $w_t^P l_t^P$, $\frac{(1+r_{t-1}^d)}{\pi_t} d_{t-1}^P$ and T_t^P denote wage earnings, gross bank interest income on last period and lump-sum transfers T_t^P, respectively.

Following Gerali et al. (2010), with the exception of a white noise for monetary policy, we assume that any generic shock ε_t in this model follows a stochastic AR(1) process as below

$$\varepsilon_t = (1 - \rho_\varepsilon)\bar{\varepsilon} + \rho_\varepsilon \varepsilon_{t-1} + \eta_t^\varepsilon$$

Where ρ is the autoregressive coefficient, $\bar{\varepsilon}$ is the steady-state value and η_t^ε is an i.i.d. zero mean normal random variable with standard deviation equal to σ_ε.

[1] We name Savers' and Borrowers' discount factors following Gerali et al. (2010).
[2] "S" is the first letter of the word "subprime".

Borrowers

Different from Savers, Borrowers only borrow loans from banks and do not own retail firms. The representative Borrower maximizes the expected utility:

$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_t^I [\varepsilon_t^z log(c_t^I(i) - a^I c_{t-1}^I) + \varepsilon_t^h log h_t^I(i) - \frac{l_t^I(i)^{1+\phi}}{(1+\phi)}]$

Similar to Savers, Borrowers utility also depends on current individual consumption c_t^I , housing services h_t^I and hours worked l_t^I. ε_t^h and ε_t^z are the same shocks as in the utility function of Savers.

The budget constraint for Borrowers is as follows (in real terms):

$c_t^I(i) + q_t^h(h_t^I(i) - h_{t-1}^I(i)) + \frac{(1+r_{t-1}^{bH})b_t^I}{\pi_t(i)} = b_t^I(i) + w_t^I l_t^I(i)$

As in Iacoviello (2005), the amount of funds received by Borrowers from the bank is subject to the borrowing constraint

$(1 + r_t^{bH})b_t^I(i) \leq m_t^I \mathbb{E}_t[q_{t+1}^h h_t^I(i)\pi_{t+1}]$ (2)

Where m_t^I represents shocks originated from the loan-to-value (LTV) ratios for mortgages. The total exposure toward the bank of the Borrowers would be less or equal to the expected value of their collaterals. As in Iacoviello (2005), we assume that in the neighborhood of the steady state the constraint always binds.

Credit-constrained Borrowers

As noted above, Borrowers and Credit-constrained Borrowers borrow loans from different bank branches. Borrowers borrow from the loan branch and Credit-constrained Borrowers borrow from the BMC branch at higher interest rates and higher average LTV ratios. Also the Credit-constrained Borrowers' discount factor is lower than Borrowers. The representative Credit-constrained Borrower maximizes the expected utility:

$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_t^S [\varepsilon_t^z log(c_t^S(i) - a^S c_{t-1}^S) + \varepsilon_t^h log h_t^S(i) - \frac{l_t^S(i)^{1+\phi}}{(1+\phi)}]$

In the meanwhile, Credit-constrained Borrowers financial decisions need to match the following budget constraint (in real terms):

$c_t^S(i) + q_t^h(h_t^S(i) - h_{t-1}^S(i)) + \frac{(1+r_{t-1}^{bS})b_t^S}{\pi_t(i)} = b_t^S(i) + w_t^S l_t^S(i)$

Similar to Borrowers, Credit-constrained Borrowers also need to match the following borrowing constraint imposed by the BMC branch:

$(1 + r_t^{bS})b_t^S(i) \leq m_t^S \mathbb{E}_t[q_{t+1}^h h_t^S(i)\pi_{t+1}]$ (3)

Where m_t^S is the loan-to-value (LTV) for risky mortgages. We assume that the LTVs follows the stochastic AR(1) process

$m_t^I = (1 - \rho_{mI})\bar{m}^I + \rho_{mI} m_{t-1}^I + \eta_t^{mI}$

$m_t^S = (1 - \rho_{mS})\bar{m}^S + \rho_{mS} m_{t-1}^S + \eta_t^{mS}$

Where η_t^{mS} and η_t^{mI} are i.i.d. zero mean normal random variables with standard deviation equal to σ_{mS} and σ_{mI}, respectively. And $\bar{m}^S$ and $\bar{m}^I$ are the calibrated steady-state values respectively.

B. Entrepreneurs

In our economy, we assume that the representative entrepreneur only cares about consumption c_t^E and maximizes the following utility function:

$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_t^E [log(c_t^E(i) - a^E c_{t-1}^E)]$

The intermediate output y_t^E is as below:

$y_t^E(i) = a_t^E [k_{t-1}^E(i) u_t(i)]^{\alpha} l_t^E(i)^{1-\alpha}$

Where a_t^E represents a stochastic total factor productivity shock. As in Iacoviello and Neri (2009), entrepreneurs uses a combination of the labor supplied by Savers, Borrowers and Credit-constrained Borrowers according to

$l_t^E = (l_t^{E,P})^{\mu_1} (l_t^{E,I})^{\mu_2} (l_t^{E,S})^{1-\mu_1-\mu_2}$.

As Borrowers, entrepreneurs also borrow from the loan branch of banks. Entrepreneurs flow budget constraint in real terms is the following:

$c_t^E(i) + w_t l_t^E(i) + q_t^k k_t^E(i) + \frac{(1+r_{t-1}^{bE})}{\pi_t} b_{t-1}^E(i) + \psi(u_t(i)) k_{t-1}^E(i) = \frac{y_t^E(i)}{x_t} + b_t^E(i) + q_t^k (1-\delta) k_{t-1}^E(i)$

Following Schmitt-Grohe and Uribe (2006), we specify that $\psi(u_t) = \xi_1(u_t - 1) + \frac{\xi_2}{2}(u_t - 1)^2$. While Borrowers use their housing stock as collateral, banks require entrepreneurs to lend against their physical capital. The borrowing constraint is thus

$(1 + r_t^{bE}) b_t^E(i) \leq m_t^E \mathbb{E}_t [q_{t+1}^k (1-\delta) k_t^E(i) \pi_{t+1}]$ (4)

Where m_t^E is the entrepreneurs loan-to-value ratio, which also follows the stochastic AR(1) process.

C. Loan and deposit demand

Following Gerali et al. (2010), the way that both types of Borrowers and Entrepreneurs decide the amount of loans to the monopolistic banking substitutes, is like a classical Dixit and Stiglitz (1997) aggregator.

Given the Dixit-Stiglitz framework, demand for a banking branchs loans is affected by the interest rates charged by the branch. Thus the demand function for a representative agent seeking to borrow an amount of b_t^Q (Q = H, E, S) can be expressed as follows:

$$\min_{b_t^Q(i,j)} \int_0^1 r_t^{bQ}(j) b_t^Q(i,j) dj$$

subject to

$$[\int_0^1 b_t^Q(i,j)^{\frac{(\varepsilon_t^{bQ}-1)}{\varepsilon_t^{bQ}}} dj]^{\frac{\varepsilon_t^{bQ}}{(\varepsilon_t^{bQ}-1)}} \geq \bar{b_t^Q}(i)$$

The solution is the demand function of loans for the Borrowers, entrepreneurs and Credit-constrained Borrowers:

$$b_t^Q(j) = (\frac{r_t^{bQ}(j)}{r_t^{bQ}})^{-\varepsilon_t^{bQ}} b_t^Q \qquad (5)$$

Similarly, demand for deposits of a representative Saver is obtained by maximizing the revenue of total savings

$$\max_{d_t^P(i,j)} \quad \int_0^1 r_t^d(j) d_t^P(i,j) dj$$

Subject to

$$[\int_0^1 d_t^P(i,j)^{\frac{(\varepsilon_t^d - 1)}{\varepsilon_t^d}} dj]^{\frac{\varepsilon_t^d}{(\varepsilon_t^d - 1)}} \leq \bar{d}_t(i)$$

The demand function of deposits can be derived as

$$d_t^P(j) = (\frac{r_t^d(j)}{r_t^d})^{-\varepsilon_t^d} d_t \qquad (6)$$

where d_t represents aggregate deposit.

D. Labor market

As Gerali et al. (2010), we assume that there are three unions for each labor type m, one for Savers, one for Borrowers and one for Credit-constrained Borrowers (indexed by Q). Each union (Q, m) has to maximize a weighted average of its members utility, with indexation τ_w denoting a weighted average of lagged and steady-state inflation:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_t^Q [U_{c_t^Q(i,m)} [\frac{w_t^Q(m) l_t^Q(i,m)}{P_t} - \frac{\kappa_w}{2} (\frac{w_t^Q(m)}{w_{t-1}^Q(m)} - \pi_{t-1}^{\tau_w} \pi^{1-\tau_w})^2 \frac{w_t^Q}{P_t}] - \frac{l_t^Q(i,m)^{1+\phi}}{(1+\phi)}]$$

in which we have

$$l_t^Q(i,m) = l_t^Q(m) = (\frac{w_t^Q(m)}{w_t^Q})^{-\varepsilon^l} l_t^Q$$

The wage inflation $\pi_t^{w^Q}$ is defined as:

$$\pi_t^{w^Q} = w_t^Q / w_{t-1}^Q \pi_t$$

E. Banks

In Gerali et al. (2010), banks have two main units: wholesale and retail units. There are two branches in the retail unit: a loan branch and a deposit branch.

Following Demyanyk and Loutskina (2012), we add a BMC branch to the Retail units, which lend loans to Credit-constrained Borrowers with higher LTV ratios and higher loan rates. The wholesale unit operates under perfect competition and manage the capital position of the group. The loan branch provides loans to Borrowers and to firms while Savers make deposits to the deposit branch. All the three branches enjoy some market power to adjust interest rates on loans and deposits in response to shocks.

Wholesale unit

The wholesale unit obeys the balance sheet identity that the loans are equal to the sum of deposits and bank capital. That is, $B_t = D_t + K_t^b$. As Gerali et al. (2010), we impose a quadratic cost on this wholesale activity related to the capital position of the bank. The capital-to-assets ratio, $\frac{K_t^b}{B_t}$, is also set equal to 0.09. Following Angelini et al. (2014), here we introduce risk weights w_t to distinguish between the capital-asset ratio and leverage. The risk weights are modeled as:

$$w_t^i = (1-\rho_i)\bar{w}^i + (1-\rho_i)\chi_i(Y_t - Y_{t-1}) + \rho_i w_{t-1}^i \qquad i = H, E, S,$$

where y is output. The parameters χ_H, χ_E, χ_S, ρ_H, ρ_E, and ρ_S are set at, respectively, 1, 1, 1, 0.94, 0.92, 0.93. The weights $\bar{w}$ are fixed at 1. Capital requirements ν_t are set by the macroprudential authority (see the following section).

The problem for wholesale bank is to maximize profits, subject to a balance sheet constraint.

$$\max_{B_t^j, D_t^j} \quad \mathbb{E}_0 \sum_{t=0}^{\infty} \lambda_t^P [(1+R_t^b)(B_t(j) - D_t(j)) - K_t^b(j) - \frac{\kappa_{Kb}}{2}(\frac{K_t^b(j)}{B_t} - \nu)^2 K_t^b(j)]$$

Subject to

$B_t(j) = D_t(j) + K_t^b(j)$

The first order conditions deliver a condition between wholesale rates and the degree of leverage.

$$R_t^b = R_t^d - \kappa_{Kb}(\frac{K_t^b}{B_t} - \nu_B) K_t^b / {B_t}^2$$

Following Angelini et al. (2014), we replace total loans B_t with the sum of risk-weighted loans to entrepreneurs b_t^E, to households b_t^h and to credit-constrained households b_t^S. Therefore we replace the first-order condition above with:

$$R_t^b = R_t^d - \kappa_{Kb}(\frac{K_t^b}{w_t^E b_t^E + w_t^H b_t^H + w_t^S b_t^S} - \nu_B) K_t^b / {B_t}^2 \qquad (7)$$

Retail unit

Retail unit activity is carried out with a monopolistic market power.

Loan branch

The problem for retail loan banks is to choose $r_t^{bH}(j), r_t^{bE}(j)$ to maximize:

$$\max_{r_t^{bH}(j), r_t^{bE}(j)} \mathbb{E}_0 \sum_{t=0}^{\infty} \lambda_t^P [r_t^{bH}(j) b_t^H(j) + r_t^{bE}(j) b_t^E(j) - R_t^b (b_t^H(j) + b_t^E(j)) \\ - \frac{\kappa_{bH}}{2} (\frac{r_t^{bH}(j)}{r_{t-1}^{bH}(j)} - 1)^2 r_t^{bH} b_t^H - \frac{\kappa_{bE}}{2} (\frac{r_t^{bE}(j)}{r_{t-1}^{bE}(j)} - 1)^2 r_t^{bE} b_t^E]$$

Subject to demand schedules:

$$b_t^H(j) = (\frac{r_t^{bH}(j)}{r_t^{bH}})^{-\varepsilon_t^{bH}} b_t^H$$

and

$$b_t^E(j) = (\frac{r_t^{bE}(j)}{r_t^{bE}})^{-\varepsilon_t^{bE}} b_t^E$$

The first order conditions yield

$$1 - \varepsilon_t^{bH} + \varepsilon_t^{bH} \frac{R_t^b}{r_t^{bH}} - \kappa_{bH} (\frac{r_t^{bH}}{r_{t-1}^{bH}} - 1) \frac{r_t^{bH}}{r_{t-1}^{bH}} + \beta_P \mathbb{E}_t [\frac{\lambda_{t+1}^P}{\lambda_t^P} \kappa_{bH} (\frac{r_{t+1}^{bH}}{r_t^{bH}} - 1) (\frac{r_{t+1}^{bH}}{r_t^{bH}})^2 \frac{b_{t+1}^H}{b_t^H}] = 0 \tag{8}$$

and

$$1 - \varepsilon_t^{bE} + \varepsilon_t^{bE} \frac{R_t^b}{r_t^{bE}} - \kappa_{bE} (\frac{r_t^{bE}}{r_{t-1}^{bE}} - 1) \frac{r_t^{bE}}{r_{t-1}^{bE}} + \beta_P \mathbb{E}_t [\frac{\lambda_{t+1}^P}{\lambda_t^P} \kappa_{bE} (\frac{r_{t+1}^{bE}}{r_t^{bE}} - 1) (\frac{r_{t+1}^{bE}}{r_t^{bE}})^2 \frac{b_{t+1}^E}{b_t^E}] = 0 \tag{9}$$

Deposit branch

Retail deposit branches perform a similar operation with respect to deposits. They collect deposits $d_t^P(j)$ from households and then pass the raised funds to the wholesale unit, which pays them at rate r_t. Since the rate r_t is so low that they have to set the deposit rate r_t^d higher than r_t, the problem for retail deposit banks is to choose $r_t^d(j)$ to minimize the loss:

$$\min_{r_t^d(j)} \mathbb{E}_0 \sum_{t=0}^{\infty} \lambda_t^P [r_t^d(j) d_t(j) - r_t d_t - \frac{\kappa_d}{2} (\frac{r_t^d(j)}{r_{t-1}^d(j)} - 1)^2 r_t^d d_t]$$

Subject to deposits demand

$$d_t^P(j) = (\frac{r_t^d(j)}{r_t^d})^{-\varepsilon_t^d} d_t$$

With $d_t^P(j) = D_t(j)$; the term containing κ_d is the quadratic adjustment costs for changing the deposit rate.

After imposing a symmetric equilibrium, the first order condition derive

$$1 - \varepsilon_t^d + \varepsilon_t^d \frac{r_t}{r_t^d} - \kappa_d (\frac{r_t^d}{r_{t-1}^d} - 1) \frac{r_t^d}{r_{t-1}^d} + \beta_P \mathbb{E}_t [\frac{\lambda_{t+1}^P}{\lambda_t^P} \kappa_d (\frac{r_{t+1}^d}{r_t^d} - 1) (\frac{r_{t+1}^d}{r_t^d})^2 \frac{d_{t+1}}{d_t}] = 0 \qquad (10)$$

BMC branch

The problem for BMC is to choose $r_t^{bS}(j)$ to maximize the profit:

$$\max_{r_t^{bS(j)}} \mathbb{E}_0 \sum_{t=0}^{\infty} \lambda_t^P [r_t^{bS}(j) b_t^S(j) - R_t^b b_t^S(j) - \frac{\kappa_{bS}}{2} (\frac{r_t^{bS}(j)}{r_{t-1}^{bS}(j)} - 1)^2 r_t^{bS} b_t^S]$$

Subject to demand schedules:

$$b_t^S(j) = (\frac{r_t^{bS}(j)}{r_t^{bS}})^{-\varepsilon_t^{bS}} b_t^S$$

The first order condition for optimal BMC loan rate is

$$1 - \varepsilon_t^{bS} + \varepsilon_t^{bS} \frac{R_t^b}{r_t^{bS}} - \kappa_{bS} (\frac{r_t^{bS}}{r_{t-1}^{bS}} - 1) \frac{r_t^{bS}}{r_{t-1}^{bS}} + \beta_P \mathbb{E}_t [\frac{\lambda_{t+1}^P}{\lambda_t^P} \kappa_{bS} (\frac{r_{t+1}^{bS}}{r_t^{bS}} - 1) (\frac{r_{t+1}^{bS}}{r_t^{bS}})^2 \frac{b_{t+1}^S}{b_t^S}] = 0 \qquad (11)$$

Aggregate activities

Bank capital is accumulated each period out of retained earnings according to:

$$K_t^{b,n}(j) = \frac{(1 - \delta^b) K_{t-1}^{b,n}(j)}{\varepsilon_t^{Kb}} + w_b J_{t-1}^{b,n}(j)$$

As Gerali et al. (2010), $K_t^{b,n}$ is bank equity in nominal terms, $J_{t-1}^{b,n}$ are overall profits made by the three branches of the bank in nominal terms. $(1-w^b)$ is about the dividend policy of the bank, and δ^b is used to measure the resource used when managing bank capital as well as conducting the overall banking intermediation activity.

Overall profits of bank are the sum of earnings from the bank substitutes. After deleting the intra-group transactions, their expression is:

$$J_t^b(j) = r_t^{bH}(j)b_t^H(j) + r_t^{bS}(j)b_t^S(j) + r_t^{bE}(j)b_t^E(j) - r_t^d(j)d_t^P(j) - \frac{\kappa_{Kb}}{2}(\frac{K_t^b(j)}{B_t(j)} - \nu_B)^2 K_t^b(j) - Adj_t^B(j) \qquad (12)$$

F. Retailers

As in Gerali et al. (2010), the retail goods market is assumed to be monopolistically competitive. They buy the intermediate goods and combine them with no additional costs, into an undifferentiated homogeneous final goods. They maximize profits by

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \lambda_t^P [P_t(j)y_t(j) - P_t^w y_t(j) - \frac{\kappa_P}{2}(\frac{P_t(j)}{P_{t-1}(j)} - \pi_{t-1}^{\tau_P}\pi^{1-\tau_P})^2 P_t y_t]$$

In the above retailers face an adjustment cost κ_p to change the price and τ_p that represents the weight of the past inflation with respect to the steady state. Below is the final goods demand constraint:
$y_t(j) = (\frac{P_t(j)}{P_t})^{-\varepsilon_t^y} y_t$

G. Capital goods producers

As in Christiano et al. (2005), in the competitive capital producer sector, the capital producers buy undepreciated capital $k_t - (1 - \delta k_{t-1})$ from entrepreneurs at price P_t^k and buy a fraction i_t of final goods from retailers. Using these inputs the capital producer maximizes the following function

$$\max_{i_t} \mathbb{E}_0 \sum_{t=0}^{\infty} \lambda_t^E [q_t^k i_t [1 - \frac{\kappa_i}{2}(\frac{i_t \varepsilon_t^{qk}}{i_t} - 1)^2] - i_t]$$

Where κ_i and ε_t^{qk} measure cost for adjusting investment and the shock to the productivity of investment goods, respectively.

H. Monetary policy

The central bank sets the short term interest rate following a Taylor rule of the type:
$$r_t = r*(1-\phi_R)+(1-\phi_R)*((\pi_t-\pi)*\phi_\pi+(y_t-y_{t-1})*\phi_y)+\phi_R*r_{t-1} \qquad (13)$$
where ϕ_R, ϕ_Y and ϕ_π measure the inertia in the adjustment of policy rate, response to output growth and inflation deviations.

I. Aggregation and market clearing

In the final goods market, the equilibrium condition is given by the following resource constraint
$$y_t = c_t + q_t^k[k_t-(1-\delta)k_{t-1}] + k_{t-1}\psi(u_t) + \delta_b k_{t-1}^b + Adj_t \qquad (14)$$
Where $c_t = c_t^P + c_t^I + c_t^E + c_t^S$ is aggregate consumption, $k_t = \gamma^E k_t^E(i)$ is the aggregate stock of physical capital and k_t^b is aggregate bank capital (γ^s,$s \in P, I, S, E$ is the measure of each subset of agents). The term Adj_t includes real adjustment costs for prices, wages and interest rates. In the housing market, equilibrium is given by
$$h + \varepsilon_t^h = \gamma^P h_t^P + \gamma^I h_t^I + \gamma^S h_t^S \qquad (15)$$
Where h denotes the fixed exogenous housing supply stock and ε_t^h refers to the housing demand shock ε_t^h.

II. Monetary Policy and Macroprudential Policy under Different Policy Regimes

A. Policy Regimes

Built upon Kannan et al. (2009) and Angelini et al. (2014), in this section we introduce four cases to be used in the following simulations.

Monetary Policy Case

In this baseline case, the policy regime is same as the monetary policy rule used above. In order to stabilize inflation and output, the monetary policy authority selects the parameters of the monetary policy rule (13) by minimizing the following loss function:

$$L^{mon} = \sigma_\pi^2 + k_{Y,mon}\sigma_Y^2 + k_R\sigma_{\Delta R}^2, \qquad k_{Y,mon} \geq 0, k_R \geq 0, \qquad (16)$$

where σ^2 are variances of inflation, output, and the policy rate changes. The weights k characterize the authority's preferences over these variables. A positive

k_R is necessary because without cost for adjusting the policy rate, optimal policies might generate excessive volatility in the policy rate. The loss function (16) could be obtained by taking a second-order approximation of the utility function of households and entrepreneurs (Woodford (2003) and Angelini et al. (2014)).

Augmented Cooperative Case

With the baseline case as a benchmark, we investigate gains by incorporating information extracted from potential financial instability indicators such as loans-to-output ratio (B/Y) and bank risk taking (defined as choices that increase the volatility of bank profits (Nicolo et al. (2010))). Loans-to-output ratio is chosen because it measures leverage and when leverage is higher, the economy is more vulnerable to shocks (as in Iacoviello (2005) and Angelini et al. (2014)). Hence the second case is an augmented Taylor rule in which monetary policy also reacts to the growth of loans-to-output ratio (B/Y), with a form as follows:

$$r_t = r * (1 - \phi_R) + (1 - \phi_R) * ((\pi_t - \pi) * \phi_\pi + (y_t - y_{t-1}) * \phi_y + (B_t/Y_t - B/Y) * \phi_{B/Y}) + \phi_R * r_{t-1} \qquad (17)$$

The objectives of monetary policy are not only stabilizing inflation and output, but also minimizing systemic risk or enhancing the resilience of the financial system. Hence, the policy makers selects the parameters of the augmented monetary policy rule (17) by minimizing the following loss function:

$$L^{augmon} = \sigma_\pi^2 + \sigma_{B/Y}^2 + \sigma_{BankProfits}^2 + k_{Y,mac}\sigma_Y^2 + k_R\sigma_{\Delta R}^2 + k_\nu\sigma_{\Delta\nu}^2, \quad k_{Y,mac} \geq 0, k_R \geq 0, \qquad (18)$$

As in Angelini et al. (2014), we assume that the monetary authority sets a time-varying capital requirement following the rule:

$$\nu_t = (1 - \rho_\nu)\bar{\nu} + (1 - \rho_\nu)\chi_\nu(\frac{B_t}{Y_t} - \frac{\bar{B}}{\bar{Y}}) + \rho_\nu\nu_{t-1}$$

where $\bar{\nu}$ is the steady state of ν_t. A positive χ_ν implies the countercyclicality of the capital requirements. Our macroprudential approach is in line with the findings of Hanson et al. (2011) that asset deductions by banks would likely yield a damaging credit crunch while lowering capital requirements might avert such danger.

Noncooperative Case

Macroprudential policy authority and monetary policy authority minimizes his own loss function, taking the other's policy rule as given. Hence, the solution of such interaction yields (ρ_R^{n*}, χ_π^{n*}, χ_Y^{n*}; ρ_ν^{n*}, χ_ν^{n*}) so that :

$$(\rho_R^{n*}, \chi_\pi^{n*}, \chi_Y^{n*}) = \text{arg min } L^{mon}(\rho_R, \chi_\pi, \chi_Y; \rho_\nu^{n*}, \chi_\nu^{n*})$$

$$(\rho_\nu^{n*}, \chi_\nu^{n*}) = \text{arg min } L^{mac}(\rho_R^{n*}, \chi_\pi^{n*}, \chi_Y^{n*}; \rho_\nu, \chi_\nu)$$

$$L^{mac} = \sigma_{B/Y}^2 + \sigma_{BankProfits}^2 + k_{Y,mac}\sigma_Y^2 + k_\nu\sigma_{\Delta\nu}^2 \qquad (19)$$

subject to the constraint given by the model. The superscript n denotes the case of noncooperation. That is to say, the policy chosen by each authority is optimal taking the other's as given. Also in all four policy regimes, households and firms are passive, taking policies as given.

Cooperative Case

The macroprudential policy authority and the monetary policy authority jointly and simultaneously implement the policy rules to minimize a common loss function as below:

$$L = L^{mon} + L^{mac} = \sigma_{B/Y}^2 + \sigma_{BankProfits}^2 + (k_{Y,mon} + k_{Y,mac})\sigma_Y^2 + k_\nu\sigma_{\Delta\nu}^2 + \sigma_\pi^2 + k_R\sigma_{\Delta R}^2, \qquad (20)$$

where the superscripts mon and mac denote the monetary and the macroprudential authorities. The solution of this problem yields parameters (ρ_R^{c*}, χ_π^{c*}, χ_Y^{c*}; ρ_ν^{c*}, χ_ν^{c*}) such that:

$$(\rho_R^{c*}, \chi_\pi^{c*}, \chi_Y^{c*}; \rho_\nu^{c*}, \chi_\nu^{c*}) = \text{arg min L}(\rho_R, \chi_\pi, \chi_Y; \rho_\nu, \chi_\nu)$$

subject to the model. The superscript c denotes the case of cooperation.

We compare the outcomes of the four cases along different dimensions. In the baseline simulations, the parameters are set at $k_{Y,mon} = 0.5$, $k_r = 0.1$ (equation (16) and equation (17)) and $k_{Y,mac} = 0.5$, $k_\nu = 0.1$ (equation (18)). The figures for the monetary policy rule's parameters are broadly in line with the values in the literature or used in calibration exercises (see, Angelini et al.(2014), Ilbas (2012) and Ehrmann and Smets (2003)).

After calibrating the model, we check robustness of the results using alternative values for the parameters in the loss functions.

III. Model Calibration

The parameters values for our model calibration are specified in Table 1. We set the Savers discount factor at 0.99 following Iacoviello and Neri (2009). As for Borrowers and entrepreneurs discount factors β^I and β^E, both of them are set at 0.975, in the range suggested by Iacoviello (2005) and Iacoviello and Neri (2009). The Credit-constrained Borrowers discount factor is 0.96, lower than the Borrowers. The Saver discount factor pins down the steady-state interest rate at $r^d = 0.0101$ on a quarterly basis. This implies an annual interest rate equal of 4.04 percentage points. The inverse of the Frisch elasticity of labor supply is assumed to be one, as typical in the macro literature. The mean value of the weight of housing in households utility function ε^h is set at 0.2, following Gerali et al. (2010) and Iacoviello and Neri (2009).

As for the loan-to-value (LTV) ratios, we set m^I at 0.8 in line with evidence for mortgages in US, as pointed out by Calza et al. (2007) and Demyanyk and Hermert (2008). The calibration of m^E is set as 0.5, between the value of 0.89 estimated by Iacoviello (2005), in which only commercial real estate can be collateralized, and the value of 0.32 given by Christensen et al. (2007). We set m^S at 1 in line with evidence for mortgages LTV ratios in US, as indicated in the Global Financial Stability Report in 2011. The capital share is assumed to be 0.25 and the depreciation rate as 0.025 as in Gerali et al. (2010). In the labor market we set ε^l at 5. In the goods market, we assume a markup of 20 percent, a value commonly used in the literature, and set a value of 6 for ε^y . For the parameter μ_1 and μ_2 that measures the degree of substitutability between hours worked between the three household sectors, we set μ_1 equal to 0.8, as in Iacoviello and Neri (2010) and Gerali et al. (2010). We assume that the Borrower and Credit-constrained Borrower groups have equal size so that $\mu_2 = 0.1$. For monetary policy, we set $\phi_\pi = 1.5$ and $\phi_r = 0.9$, which are standard values in the literature.

For the banking parameters, we calibrate them close to the average quarterly banking rates from 1988 to 2007. BMCs originated riskier mortgages with higher interest rates, so we set the steady-state interest rate of the BMC branch as around 2 percentages higher that of the loan branch, following Chomsisenghet and Pennington-Cross (2006). Analogously, we calibrate ε_t^{bH}, ε_t^{bS} and ε_t^{bE} according to the steady-state relation between the marginal cost and the loan rates. The steady state ratio of bank capital K_t^b to total loans $(B_t^H + B_t^E + B_t^S)$ is set to 0.09, as in Gerali et al. (2010). The parameters δ^b is set at the value of 0.0907 to pin down the ratio of bank capital to total loans $\bar{\nu}$ at 0.09.

Table 2 reports the steady-state values for the benchmark calibration. For our dynamic analysis, we log-linearize around the deterministic steady state. We solve the resulting linear system of rational expectation equations using dynare.

A. Simulation Results

In this section, we simulate the model under different policy regimes, following two shocks respectively: a technology shock and a negative financial shock.

The Performance of Policy Rules to Technology Shocks

Here we consider technology shocks, which can be interpreted as the main drivers of cyclical fluctuations in normal times (Table 3.) We firstly consider the case in which the macroprudential authority does not take output volatility into account ($k_{Y,mac} = 0$ in Tabel 3). In the monetary-policy-only regime, the monetary policy rate responds positively to inflation and output growth, indicating that strict inflation targeting is far from the optimal status, as in Angelini et al. (2014).

In the noncooperative case, the central bank's reaction to output remains around 1; in the capital requirement rule, the reaction to the LTV ratio becomes much stronger, but the autoregressive coefficient decreases substantially, causing a threefold change in the long-run coefficient. As a result, the variances of the policy rate and of capital requirements decrease by 16.87% and 80.3%, respectively. Also the variances of the output and of the loans-to-output ratio increase by, respectively, 2.5% and 9.25%.

Table 3 also reports results for the case in which there is no macroprudential policy and the central bank follows an optimized Taylor rule (15) to minimize its loss function (16). The optimized monetary-policy-only rule is countercyclical. Compared with the cooperative case, output becomes much less volatile (by 20.93%) and inflation far more volatile (by more than 15.66%). Not surprisingly, fluctuations in the loans-to-output ratio are now much larger (by 774.49%). There are also results for the case in the optimized augmented Taylor rule regime. The variance of the loans-to-output ratio decreases by 12.29%. This represents the main difference between the augmented cooperative case and the cooperative case, as the variances of the key target variables remain less unaffected. Altogether, the exercise shows the pros and cons of introducing time-varying capital requirements.

Figure 1 depicts the impulse responses to a negative technology shocks. It offers some insights in the dynamics of the key variables of the model. In the cooperative case, the monetary policy rate performs in a similar way as that in the augmented cooperative case. It slightly increases in response to the shock, and then gradually returns to steady state. In the noncooperative case, monetary policy is slightly tightened, which is supported by tightening capital requirements. In each case, the responses of the key target variables – inflation and output – remain virtually the same. The loans-to-output (LTO) ratio in the noncooperative case goes in similar direction with that in the augmented cooperative case, while the LTO ratio in the cooperative case is initially significantly increased. It is obvious that compared with monetary-policy-only case, the cooperative, augmented cooperative and noncooperative cases strengthen financial stability in a more efficient way. A potential interpretation of this result is that our capital requirement tools are able to appreciate how aggressive risk-taking by banks and bank-affiliated mortgage companies and have countercyclical effects.

The Performance of Policy Rules to Financial Shocks

In this section, we consider the case in which the economy is hit by a sudden fall in bank capital in equation (7). Then banks have to reduce the supply of credit and increase lending rates. In table 4, under cooperation, the capital requirements rule is countercyclical since the reaction to the LTO ratio is much less than that in the case with technology shocks). In the noncooperative case both monetary policy and macroprudential policy become less responsive to loans-to-output ratio while in the augmented cooperative case both policies remain basically the same as in the cooperative case. No major differences between the two cooperative case and augmented cooperative case can be found in terms of volatility of key variables including inflation, output, policy rate and the loans-to-output ratio.

Comparison between the cooperative and monetary-policy-only cases shows that, monetary policy alone is not enough to stabilize the economy. Similar to the results in Angelini et al. (2014), in the noncooperative case, the variabilities of output and the monetary policy rate are significantly less than in the monetary-policy-only case while the performance of inflation volatility is contrary to that in Angelini et al. (2014). In both the cooperative and augmented cooperative cases, the social losses are significantly reduced in terms of monetary policy and macroprudential policy. In addition, we experimented a simulation causing shocks to the LTV ratios. The results are similar to those obtained with the shock to bank capital. This is because in our model banks react to a shock to their capital by modifying the supply of credit and lending rates.

Figure 7 shows the impulse responses to the negative financial shock. In the cooperative, augmented cooperative and noncooperative cases, the behavior of most key variables are very similar (except for capital requurirements, LTO ratio and capital asset ratio). On one hand, the macroprudential authority responds to the shortfall in bank capital by lowering capital requirements. Output and the loans-to-output ratio fall below their steady state while loan rates increases. On the other hand, in the monetary-policy-only case, the financial shock affects the loans-to-output more significantly, thus causing the sharper rise in the lending rate, greater fall in the capital asset ratio and the substantial contraction in credit supply.

Summary

In the two simulations discussed above, the significant benefits generated by an active management of capital requirements are presented. When technology shocks are the main drivers of the economy, macroprudential policy might make a great contribution to financial stability. Compared with the monetary-policy-only case, the volatility of output show a substantial fall in the noncooperative and augmented cooperative cases. When financial shocks hit the economy, capital requirements are more beneficial in terms of enhanced inflation stabilization than the monetary-policy-only case, regardless of how macroprudential policymakers interact with central bank.

B. *Robustness Check & Further Analysis*

Robustness Check

In this section we did robustness check to solve the puzzle of whether the results hold for alternative calibrations of the model. As pointed out in Angelini et al. (2014), it is debatable whether macroprudential policy should care about the volatility of output per se or only to the extent that it is related to excessive credit growth or deleveraging. Hence, we concentrate on the parameter of $k_{Y,mac}$, which is the weight on output in the loss function of the macroprudential authority, to make sure that the results are robust to different positive values of $k_{Y,mac}$. Obviously the results (reported in Tables 3 and 4) appear robust to the check.

Multiple shocks

In reality, economies are influenced by various types of shocks at the same time. Therefore, we considered a multishock scenario, taking into account all the shocks used in the Appendix.

In the cooperative case, the variances of the loans-to-output ratio and output are smaller than those in the monetary-policy-only case, by, respectively, 19.1% and 2.3%. In the meanwhile, the variances of the policy rate and inflation are reduced by, respectively, 40.75% and 11.9%. In the augmented cooperative case, the performance of key variables are similar to that in the cooperative case. All three cases (cooperative, noncoopreative and augmented cooperative) are countercyclical.

Comparison with Angelini's Model

A natural question is whether there is any difference between the analysis results of our model and Angelini's framework using U.S. data. In the version of

Angelini's model, after causing a technology shock, the variance of output Y under cooperation (see Table 5) is 0.0257 while that of output Y under augmented cooperation is a little lower (0.0247). The social loss under cooperation is also slightly more than that under augmented cooperation. Obviously the augmented cooperative case outperforms the cooperative one. Compared with the monetary-policy-only case, both output and inflation under augmented cooperation become less volatile. Therefore, in the version of Angelini's model, it is not significantly beneficial to introduce macroprudential policy in terms of output and inflation variance. This is different from our analysis results, in which it is significantly beneficial to introduce time-varying capital requirements in terms of output and inflation volatility and under monetary-policy-only case, output is significantly much more stable than the noncooperative case. The differences in the results should be caused by the introduction of BMC branch in our model. The prosperity in the real economy helps banks gain more bank capital so that both bank loan branch and BMC branch are able to issue more loans to firms and households.

In the case of a financial shock, the analysis results of Angelini's framework are also partly different from ours (see Table 6). Under noncooperation, the output is more volatile than the monetary-policy-only case. This is different from the analysis in our model, in which the variance of output is less than that in the monetary-policy-only case. The differences between the two results might be caused by both the feedback loop between the banking sector and the housing market through BMC market and banks' loan pushing activities, which leads to irrational exuberance by lending much more loans to firms. A more heavily regulated environment would definitely affect the volatility of output. This partly reflects the elusive nature of systemic risk since it can arise and propagate in various ways as the financial markets evolve.

IV. Conclusions

In this paper, it is shown that time-varying capital requirements, by interacting with monetary policy, might help strengthen financial stability. Three types of interaction has been considered: cooperative, noncooperative and augmented cooperative. In the cooperative case, monetary and macroprudential policymakers minimize a weighted average of their two objective functions simultaneously. In the noncooperative case, each policymaker minimizes his own objective function. In the augmented cooperative case, monetary policymakers also serve as macroprudential policymakers by minimizing an augmented monetary policy objective function. On one hand, the cooperative case captures a situation in which the central bank is assigned a pivotal role in macroprudential policy, as in the new European financial supervisory framework (Angelini et al. (2014)). On the other hand, the augmented cooperative case captures a situation in which the central bank takes financial stability into consideration in monetary policymaking. Moreover, the noncooperative case captures a situation in which the central bank and macrorpudential authority are independent from each other, as in the U.S.A. financial supervisory framework. We also consider the case in which there is only monetary policy and macroprudential authority does not exist.

We find that when technology shocks are the main drivers of the economy, macrorpudential policy yields some benefits relative to the monetary-policy-only case, while its effect on output volatility is muted. In the noncooperative case, the volatility of the policy rate and loans-to-output ratio are greater than that in the cooperative case and that in the augmented cooperative case. Therefore macroprudential policy might damage macroeconomic stability if used improperly. On the other hand, when the economic fluctuations are mainly driven by financial shocks, countercyclical capital requirements reduce the volatility of output and the loans-to-output ratio, regardless of whether or not the central bank and the macroprudential authority cooperate and how they cooperate with each other. Hence, an efficient interaction between time-varying capital requirements and monetary policy is useful to maintain financial stability. The results above are robust to a series of changes to the baseline case, including alternative parameteriations of the two policymakers preferences and to shocks other than technology and financial ones.

However, the simulations in this paper are very stylized. We have not established that the results above hold generally, as they depend upon a whole series of assumptions, methodological choices, and model specificities. Some potentially important factors (include financial externalities) are omitted, though the model captures some relevant features of the U.S. economy. Also we do not have good proxies for systemic risk, the very issue that macrorpudential policy should address. Improving modeling is important for future research in terms of model complexity, nonlinearities and alternative macroprudential instruments.

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Table 1—: Benchmark Calibration

Parameter	Value	Description
β^P	0.99	Discount factor of Savers
β^I	0.975	Discount factor of Borrowers
β^S	0.96	Discount factor of Credit-constrained Borrowers
β^E	0.975	Discount factor of Entrepreneurs
ϕ	1	Inverse of the Frischs elasticity
μ_1	0.8	Share of Savers in the households
μ_2	0.1	Share of Borrowers in the households
ε^h	0.2	Weight of housing in the Savers utility function
α	0.25	Capital share
δ	0.025	Physical capitals depreciation rate
ε^y	6	Elasticity of substitution in the goods market
ε^l	5	Elasticity of substitution in the labor market
m^I	0.8	Borrowers LTV ratio
m^S	1	Credit-constrained Borrowers LTV ratio
m^E	0.5	Entrepreneurs LTV ratio
ν_B	0.09	Steady-state capital/loans ratio
ϕ_π	1.5	Taylor-rule coefficient on inflation
ϕ_r	0.9	Taylor-rule coefficient on nominal interest rate
ε^d	21.1033	Elasticity of substitution on bank deposit rate
ε^{bH}	2.2767	Elasticity of substitution on the rate of loan to Borrowers
ε^{bE}	2.4216	Elasticity of substitution on the rate of loan to entrepreneurs
ε^{bS}	1.7826	Elasticity of substitution on the rate of loan to Credit-constrained Borrowers

Table 2—: Steady State under the Calibration

Variable	Interpretation	Value
C/Y	Ratio of total consumption to GDP	0.87
I/Y	Ratio of investment to GDP	0.105
K/Y	Ratio of capital to GDP	4.2
B/Y	Ratio of total loans to GDP	2.885
B^H/B	Share of loans to Borrowers over total loans	15%
B^S/B	Share of loans to Credit-constrained Borrowers over total loans	15.3%
B^E/B	Share of loans to Entrepreneurs over total loans	69.7%
K^b/B	Ratio of bank capital to total loans	0.09
K^b/Y	Ratio of bank capital to GDP	0.26
$4 * r$	Annual policy rate	3.85%
$4 * r^d$	Annual bank deposit rate	4.04%
$4 * r^{bH}$	Annual bank rate on loans to Borrowers	6.86%
$4 * r^{bS}$	Annual bank rate on loans to Credit-constrained Borrowers	8.768%
$4 * r^{bE}$	Annual bank rate on loans to entrepreneurs	6.56%

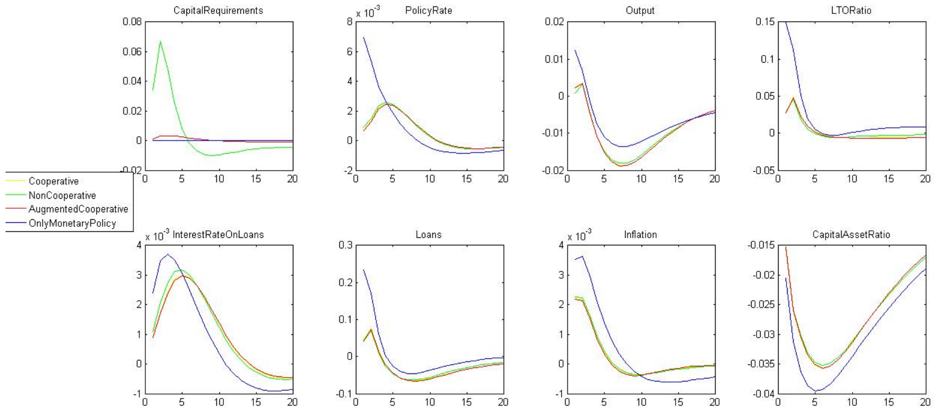

Figure 1: Impulse response to a negative technology shock

Note: The y-axis measures percent deviation from the steady state and the x-axis measures periods after causing the shock.

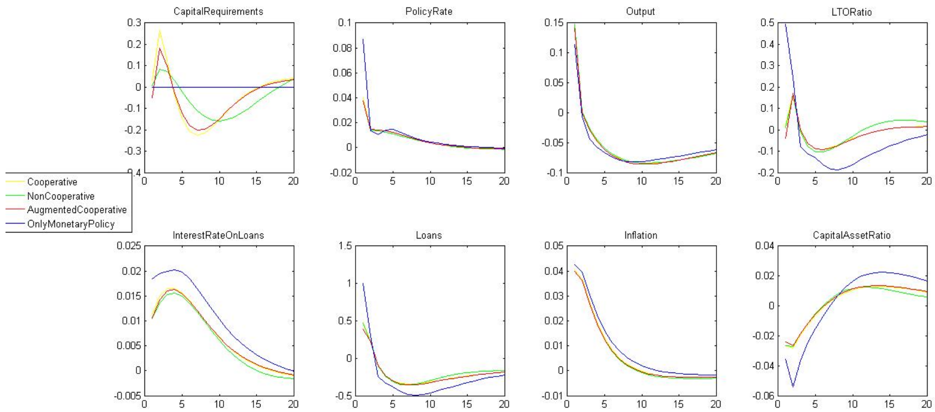

Figure 2: Impulse response to a negative financial shock

Note: The y-axis measures percent deviation from the steady state and the x-axis measures periods after causing the shock.

Table 3—: Interaction Between Monetary and Countercyclical Capital Requirements: Technology Shocks

Weight	Case	π	Y	δR	B/Y	$\Delta\nu$	Social loss
$k_{Y,mp} = 0$	Cooperative	0.0029	0.0343	0.0018	0.0605	0.1120	0.0927
	NonCooperative	0.0029	0.0353	0.0017	0.0705	0.0178	0.0930
	Augmented Cooperative	0.0029	0.0331	0.0022	0.0647	0.1032	0.0947
	Only monetary policy	0.0036	0.0270	0.0158	0.5965	-	0.6152
	Noncoop./coop. (%)	-0.1032	2.8080	-2.5366	16.5261	-85.0740	0.3255
	Only monetary policy/coop. (%)	22.4363	-21.2525	787.8241	886.1770	-	563.6821
	Augmented./coop. (%)	0.4474	-3.6848	25.0282	6.9934	-13.6680	2.1807
$k_{Y,mp} = 0.1$	Cooperative	0.0031	0.0351	0.0024	0.0694	0.1349	0.1073
	NonCooperative	0.0032	0.0386	0.0024	0.1116	0.0284	0.1410
	Augmented Cooperative	0.0030	0.0338	0.0026	0.0754	0.1165	0.1106
	Only monetary policy	0.0036	0.0270	0.0158	0.5965	-	0.6152
	Noncoop./coop. (%)	2.6580	9.8024	-3.6795	60.7325	-78.92	31.3632
	Only monetary policy/coop. (%)	15.3322	-23.0327	543.9084	759.0880	-	475.6670
	Augmented./coop. (%)	-2.1070	-3.6841	7.5634	8.5506	-13.6360	3.0510
$k_{Y,mp} = 0.5$	Cooperative	0.0029	0.0317	0.0021	0.0613	0.1089	0.1084
	NonCooperative	0.0033	0.0363	0.0040	0.2218	0.0577	0.2676
	Augmented Cooperative	0.0029	0.0343	0.0018	0.0605	0.1120	0.1100
	Only monetary policy	0.0036	0.0270	0.0158	0.5965	-	0.6152
	Noncoop./coop. (%)	14.7968	9.5083	96.3143	261.9480	-47.032	146.793
	Only monetary policy/coop. (%)	23.5846	-18.5011	663.8215	873.59	-	479.867
	Augmented./coop. (%)	0.9378	3.4940	-13.9670	-1.2764	9.7472	1.3253

Coefficients in Different Policy Regimes

		ϕ_π	ϕ_Y	ϕ_R	χ_ν	ρ_ν
$k_{Y,mp} = 0$	Cooperative	1.84	-0.32	0.79	0.19	0.78
	NonCooperative	1.83	-0.29	0.77	1.92	0.38
	AugmentedCooperative	1.86	-0.33	0.80	0.20	0.78
$k_{Y,mp} = 0.1$	Cooperative	1.45	-0.58	0.79	2.45	0.65
	NonCooperative	1.83	-0.28	0.77	1.92	0.38
	AugmentedCooperative	1.85	-0.33	0.79	0.19	0.78
$k_{Y,mp} = 0.5$	Cooperative	1.83	-0.30	0.78	0.19	0.78
	NonCooperative	1.82	-0.28	0.76	1.92	0.38
	Augmented Cooperative	1.84	-0.32	0.79	0.19	0.78
	Only monetary policy	1.70	-0.21	0.19	-	-

Table 4—: Interaction Between Monetary and Countercyclical Capital Requirements: Financial Shocks

Weight	Case	π	Y	δR	B/Y	$\Delta\nu$	Social loss
$k_{Y,mp} = 0$	Cooperative	0.000011	0.000726	0.000003	0.003525	0.000006	0.003835
	NonCooperative	0.0030	0.0350	0.0018	0.0730	0.0180	0.0954
	Augmented Cooperative	0.000011	0.000732	0.000003	0.003406	0.000007	0.003784
	Only monetary policy	0.0036	0.0268	0.0156	0.5899	-	0.6084
	Noncoop./coop. (%)	26755	4715	59367	2018	255942	2387
	Only monetary policy/coop. (%)	32327	3495	518166	17017	-	15765
	Augmented./coop. (%)	0	0.826	0	-3.3759	0	-1.3299
$k_{Y,mp} = 0.1$	Cooperative	0.000012	0.000746	0.000003	0.003566	0.000006	0.004027
	NonCooperative	0.0034	0.0366	0.0040	0.2369	0.0587	0.2685
	Augmented Cooperative	0.000011	0.000754	0.000003	0.0034	0.000007	0.0039
	Only monetary policy	0.0036	0.0268	0.0156	0.5899	-	0.6111
	Noncoop./coop. (%)	28483	4803	133100	6542	977466	6569
	Only monetary policy/coop. (%)	29625	3496	518166	16441	-	15077
	Augmented./coop. (%)	-8	1.07	0	-3.365	16.67	-2.88
$k_{Y,mp} = 0.5$	Cooperative	0.000012	0.000719	0.000003	0.003643	0.000006	0.004375
	NonCooperative	0.0033	0.0358	0.0029	0.1434	0.0361	0.1863
	Augmented Cooperative	0.000011	0.000726	0.000003	0.003525	0.000006	0.004263
	Only monetary policy	0.0036	0.0268	0.0156	0.5899	-	0.6218
	Noncoop./coop. (%)	27033	4882	96866	3835	600650	4159
	Only monetary policy/coop. (%)	29625	3631	518166	16091	-	14113
	Augmented./coop. (%)	-8	0.97	0	-3.239	0	-2.56

Coefficients in Different Policy Regimes

		ϕ_π	ϕ_Y	ϕ_R	χ_ν	ρ_ν
$k_{Y,mp} = 0$	Cooperative	1.84	-0.32	0.79	0.19	0.78
	NonCooperative	1.60	1.16	0.84	8.15	0.94
	AugmentedCooperative	1.86	-0.33	0.80	0.20	0.78
$k_{Y,mp} = 0.1$	Cooperative	1.84	-0.32	0.79	0.19	0.78
	NonCooperative	1.44	1.19	0.79	8.18	0.94
	AugmentedCooperative	1.85	-0.33	0.79	0.20	0.78
$k_{Y,mp} = 0.5$	Cooperative	1.83	-0.31	0.78	0.19	0.78
	NonCooperative	1.49	1.17	0.81	8.35	0.94
	Augmented Cooperative	1.84	-0.32	0.79	0.19	0.78
	Only monetary policy	1.29	0.70	0.31	-	-

Table 5—: Interaction Between Monetary and Countercyclical Capital Requirements in Angelini's framework: Technology Shocks

Weight	Case	π	Y	δR	B/Y	$\Delta\nu$	Social loss
$k_{Y,mp}=0$	Cooperative	0.0031	0.0257	0.0107	0.0718	0.0204	0.0748
	NonCooperative	0.0039	0.0358	0.0125	0.0958	0.0672	0.0997
	Augmented Cooperative	0.0030	0.0247	0.0104	0.0725	0.0214	0.0755
	Only monetary policy	0.0041	0.0265	0.0067	0.0891	-	0.0931
	Noncoop./coop. (%)	26.4573	39.0385	17.5269	33.5749	229.2879	33.2812
	Only monetary policy/coop. (%)	31.4443	2.8565	-36.7963	24.1356	-	24.4371
	Augmented./coop. (%)	-3.044	-3.9019	-2.3794	1.0522	4.7703	0.8832
$k_{Y,mp}=0.1$	Cooperative	0.0031	0.0259	0.0107	0.0716	0.0203	0.0747
	NonCooperative	0.0038	0.0351	0.0126	0.0945	0.0661	0.0983
	Augmented Cooperative	0.0030	0.0249	0.0105	0.0724	0.0211	0.0754
	Only monetary policy	0.0041	0.0265	0.0067	0.0891	-	0.0931
	Noncoop./coop. (%)	22.2151	35.6647	17.1458	32.0839	224.8612	31.6735
	Only monetary policy/coop. (%)	30.6826	2.1538	-37.2314	24.4391	-	24.6987
	Augmented./coop. (%)	-2.9620	-3.7016	-2.7817	1.1316	3.7545	0.9614
$k_{Y,mp}=0.5$	Cooperative	0.0032	0.0266	0.0111	0.0709	0.0204	0.0741
	NonCooperative	0.0039	0.0359	0.0130	0.0962	0.0662	0.1001
	Augmented Cooperative	0.0031	0.0257	0.0107	0.0718	0.0204	0.0748
	Only monetary policy	0.0041	0.0265	0.0067	0.0891	-	0.0931
	Noncoop./coop. (%)	24.1021	35.1744	16.7914	35.6847	224.575	35.1885
	Only monetary policy/coop. (%)	27.8828	-0.4252	-39.1559	25.5865	-	25.6849
	Augmented./coop. (%)	-2.7095	-3.1905	-3.7334	0.0343	1.0027	

Coefficients in Different Policy Regimes

		ϕ_π	ϕ_Y	ϕ_R	χ_ν	ρ_ν
$k_{Y,mp}=0$	Cooperative	2.08	1.90	0.71	5.86	0.91
	NonCooperative	2.25	3.18	0.85	10.09	0.92
	AugmentedCooperative	2.21	2.05	0.72	6.47	0.92
$k_{Y,mp}=0.1$	Cooperative	2.05	1.88	0.71	5.75	0.91
	NonCooperative	2.23	3.15	0.85	10.10	0.92
	AugmentedCooperative	2.18	2.02	0.72	6.34	0.92
$k_{Y,mp}=0.5$	Cooperative	1.96	1.78	0.70	5.36	0.90
	NonCooperative	2.17	3.03	0.84	10.13	0.92
	Augmented Cooperative	2.08	1.90	0.71	5.86	0.91
	Only monetary policy	1.10	0.37	0.25	-	-

Table 6—: Interaction Between Monetary and Countercyclical Capital Requirements in Angelini's Framework: Financial Shocks

Weight	Case	π	Y	δR	B/Y	$\Delta\nu$	Social loss
$k_{Y,mp} = 0$	Cooperative	0.000011	0.000687	0.000137	0.007144	0.000024	0.007125
	NonCooperative	0.000012	0.000715	0.000173	0.00385	0.0515	0.003862
	Augmented Cooperative	0.000011	0.000731	0.000172	0.007142	0.000026	0.007153
	Only monetary policy	0.000027	0.000567	0.000055	0.0102	-	0.0102
	Noncoop./coop. (%)	9.0909	4.0757	26.2774	-46.1086	214412.5	-46.0011
	Only monetary policy/coop. (%)	145.4545	-17.4672	-59.854	42.9591	-	43.1767
	Augmented./coop. (%)	0	6.4046	25.5475	-0.028	0	0.01398
$k_{Y,mp} = 0.1$	Cooperative	0.000011	0.000679	0.000131	0.007146	0.000024	0.007157
	NonCooperative	0.000012	0.000708	0.000167	0.003836	0.0509	0.003848
	Augmented Cooperative	0.000011	0.000722	0.000164	0.007141	0.000026	0.07152
	Only monetary policy	0.000027	0.000567	0.000055	0.0102	-	0.0102
	Noncoop./coop. (%)	9.0909	4.2710	27.4809	-46.3196	212054.2	-46.2345
	Only monetary policy/coop. (%)	145.4545	-16.4948	-58.0153	42.9191	-	43.0767
	Augmented./coop. (%)	0	6.3328	25.1908	-0.06997	8.3333	-0.06989
$k_{Y,mp} = 0.5$	Cooperative	0.000011	0.000649	0.000111	0.007156	0.000023	0.007167
	NonCooperative	0.000012	0.00068	0.000145	0.003789	0.0486	0.0038
	Augmented Cooperative	0.000011	0.000687	0.000137	0.007144	0.000024	0.007155
	Only monetary policy	0.000027	0.000567	0.000055	0.0102	-	0.0102
	Noncoop./coop. (%)	9.0909	4.7766	30.6306	-47.0514	210930.4	-46.9653
	Only monetary policy/coop. (%)	145.4545	-12.6348	-50.4505	42.7194	-	42.8771
	Augmented./coop. (%)	0	5.8552	23.4234	-0.1677	4.3478	-0.1674

Coefficients in Different Policy Regimes

		ϕ_π	ϕ_Y	ϕ_R	χ_ν	ρ_ν
$k_{Y,mp} = 0$	Cooperative	2.13	-0.44	0.30	0.27	0.77
	NonCooperative	2.12	-0.43	0.3	5.16	0.12
	AugmentedCooperative	2.15	-0.47	0.31	0.28	0.77
$k_{Y,mp} = 0.1$	Cooperative	2.12	-0.43	0.30	0.27	0.77
	NonCooperative	2.12	-0.42	0.30	5.16	0.12
	AugmentedCooperative	2.15	-0.47	0.31	0.28	0.77
$k_{Y,mp} = 0.5$	Cooperative	2.10	-0.40	0.30	5.15	0.11
	NonCooperative	2.10	-0.40	0.30	5.15	0.11
	Augmented Cooperative	2.13	-0.44	0.30	0.27	0.77
	Only monetary policy	1.62	0.26	0.18	-	-