Macroprudential Policies in a Low Interest-Rate Environment*

Margarita Rubio†
University of Nottingham

Fang Yao‡
Reserve Bank of New Zealand

January 31, 2017

Abstract

This paper analyzes the role of macroprudential policies in a low interest-rate environment, in which monetary policy can be occasionally restricted by a lower bound. We study this issue by using a DSGE model with housing and collateral constraints. The macroprudential instrument is a loan-to-value ratio (LTV) rule. We find that, when the steady-state interest rate is high, the two policies can work independently with different instruments and separate objectives. When the steady-state interest rate is low, however, monetary policy hits the zero lower bound more frequently and the macroprudential authority can act as a complementary macro-financial stabilizer for both real and financial cycles.

Keywords: Macroprudential, monetary policy, zero lower bound, collateral constraint, financial stability

JEL Classification: E32, E44, E58

*The views expressed in this paper are those of the authors and do not necessarily reflect the views of the Reserve Bank of New Zealand. Usual disclaimer applies. Part of this research was undertaken while Margarita Rubio was visiting the Reserve Bank of New Zealand. She would like to thank the Bank for its hospitality.

†University of Nottingham, Sir Clive Granger Building, University Park, Nottingham, NG7 2RD, UK. E-mail: margarita.rubio@nottingham.ac.uk.

‡Reserve Bank of New Zealand.

"*Central banks and governments around the world must be able to adapt policy to changing economic circumstances. The time has come to critically reassess prevailing policy frameworks and consider adjustments to handle new challenges, specifically those related to a low natural real rate of interest. While price level or nominal GDP targeting by monetary authorities are options, fiscal and other policies must also take on some of the burden to help sustain economic growth and stability.*" - "Monetary Policy in a Low R-star World" by John Williams, August 15, 2016

1 Introduction

In the post-Global Financial Crisis (GFC) world, there are new challenges to the conduct of macro-financial stabilization policies. One of the major changes in this new environment is a significant decline in the neutral real interest rate. In many advanced economies, estimated long-term neutral rates have declined to much lower levels compared to the pre-crisis period and show no sign of recovery (Laubach and Williams, 2015). This is challenging for policy makers for two reasons. First, low neutral rates limit the scope of conventional monetary policy in stabilizing the economy. Second, low interest rates raise concerns about financial imbalances and risks to financial stability (Borio, 2016).

The GFC has shown that the zero (or effective) lower bound (ZLB) on nominal interest rates is not just a theoretical concern. Economies encounter this lower bound with much higher probability than was previously believed. A critical implication of a low interest-rate environment is that, when central banks use conventional monetary policy to stabilize the economy, the nominal interest rate may indeed hit its lower bound. The ZLB constraint makes it more difficult for traditional monetary policy to stabilize the economy. The immediate consequence of the limited effectiveness of monetary policy is that business cycles may be more unstable. Moreover, persistently low interest rates may also have important implications for financial stability. In fact, low interest rates affect incentives of financial market participants, leading to excessive risk-taking behavior. For instance, the yield-chasing motive encourages agents to engage in speculative investment in assets, such as real estate. Low interest rates may increase the likelihood of asset bubbles and excessive leverage.[1]

In this paper, we argue that, in a low interest-rate environment, the case for using macroprudential policies becomes even stronger. On the one hand, greater financial instability due to low interest rates calls for macroprudential policies to contain financial risks. On the other hand, macroprudential policy

[1] See Cœuré (2015) for further discussion.

may also be useful to complement monetary policy, when it is subject to the lower bound.[2] To illustrate this point, we build a dynamic stochastic general equilibrium (DSGE) model with collateral constraints on borrowers and an occasionally binding ZLB for the interest rate. Monetary policy in the model is described by a standard Taylor rule, which is subject to an occasionally binding ZLB. Macroprudential policy is characterized by a rule on the loan-to-value ratio (LTV) that responds to deviations of credit and output from their respective steady states. We calibrate the model to match a low interest-rate environment by setting the steady-state interest rate equal to 2%.[3] We solve the model using the "occbin" toolkit proposed by Guerrieri and Iacoviello (2015).

Using this framework, we answer the following research questions: first, without an active role for macroprudential policy, what are the consequences of a steady-state interest rate falling from 4% to 2% for business and financial cycles? Second, can macroprudential policy contribute to both financial and macroeconomic stability in the low interest-rate environment?

Our simulation results show that, in a 2% steady-state interest-rate environment, the nominal interest rate hits the ZLB more frequently and stays there for longer periods than in a model with a 4% steady-state interest rate. This, in turn, leads to both volatile macroeconomic and financial cycles. There are two channels that give rise to more volatile macro dynamics: firstly, through collateral effects, negative productivity shocks drive down house prices and tighten the collateral constraint for the borrowers. This, in turn, negatively affects credit. This feedback loop between house prices and credit gives rise to a powerful financial accelerator, emphasized in Iacoviello (2005). Secondly, when the interest rate is restricted by the occasionally binding ZLB, it provides an additional amplification of the shock. In this case, the anticipation that the interest rate will be forced to stay at zero for certain periods reinforces the effects of the negative productivity shock. Inflation falls and pushes up the real cost of borrowing. This, in turn, depresses house prices and credit even further than under the collateral channel.

Having shown that, in a low interest-rate environment, the occasionally binding ZLB leads to more volatile real and financial cycles, we move on to study the effects of active macroprudential policy rules as a complement to a less effective monetary policy. In particular, we compute the optimal simple rule for the LTV by minimizing a loss function for the macroprudential regulator. We consider an LTV rule that responds to credit and output gaps. We find that, in the 4% interest-rate environment,

[2] In policy debates, the use of macroprudential policies to act as macroeconomic stabilizers is controversial, since these policies are designed for other goals. Nevertheless, the ZLB is an extreme case in which monetary policy is in real need for alternatives (Caruana, 2011).

[3] Hamilton et al (2015) interpret the equilibrium level of the real federal funds rate as the long run or steady-state value of the real funds rate.

countercyclical macroprudential policies can lead to more stable financial cycles, while business cycles can be effectively managed by monetary policy, because the ZLB is rarely binding. In this case, the so-called "Tinbergen principle" applies: macroeconomic stability can be assigned to the monetary authority, while the macroprudential authority only takes care of financial stability. The two policies work independently with different instruments. By contrast, when the steady-state interest rate falls to 2% and monetary policy is occasionally restricted, the two policy spheres interdependent . In particular, macroprudential tools may materially contribute to the management of aggregate demand.[4] Our simulations show that, in the low interest-rate environment, a purely financial-stability focused macroprudential authority needs to use its instrument more aggressively to stabilize financial cycles than in normal times. Furthermore, we find that allowing macroprudential policy to respond directly to output strengthens economic stability, because a binding ZLB not only makes monetary policy ineffective, but also becomes an additional amplification channel of aggregate shocks.

Our paper is related to the strand of research that, following Iacoviello (2005), introduces a rule on the LTV interacting with monetary policy. For instance, Borio and Shim (2007) emphasize the complementary role of macroprudential policy to the monetary policy and its supportive role as a built-in stabilizer. Similarly, N'Diaye (2009) shows that monetary policy can be supported by countercyclical prudential regulation, and Angelini et al (2014) show interactions between LTV and capital requirements ratios and monetary policies. However, the literature above does not explicitly consider the impact of occasionally binding ZLB. For example, Antipa and Matheron (2014) study the interactions of macroprudential and unconventional monetary policies when the interest rate hits the zero lower bound. They find that macroprudential policies act as a useful complement to forward guidance policy during ZLB periods. Our paper abstracts from unconventional monetary policy, but we find a similar result regarding complementarity between LTV rules and monetary policy. Lewis and Villa (2016) study the interactions between monetary policy and a countercyclical capital buffer when monetary policy is constrained at the ZLB. Korinek and Simsek (2016) find that when the interest rate is limited by the ZLB, welfare can be improved by ex-ante macroprudential policies such as debt limits and mandatory insurance requirements. Our paper complements this literature and contributes by studying the interaction between LTV policy and monetary policy in a low interest-rate environment, in which the ZLB for the interest rate occasionally binds.

[4] Blanchard et al (2013) discuss this topic and also extend it to other situations in which monetary policy is unavailable for some individual countries such as currency unions or exchange rate pegs.

The rest of the paper continues as follows. Section 2 describes the model. Section 3 shows the dynamics of the model allowing for the ZLB constraint. Section 4 compares simulations for normal times and a low interest-rate environment. Section 5 analyzes macroprudential policy implementation. Section 6 concludes.

2 Model Setup

The economy features patient and impatient households, a final goods firm, a central bank which conducts monetary policy, and a macroprudential authority that sets financial regulation. Households work and consume both consumption goods and housing. Patient and impatient households are savers and borrowers, respectively. Borrowers are credit constrained and need collateral to obtain loans. The representative firm converts household labor into the final good. The central bank follows a Taylor rule for the setting of interest rates and the macroprudential regulator uses the LTV as an instrument for macroprudential policy.

2.1 Savers

Savers maximize their utility function by choosing consumption, housing and labor hours:

$$\max_{C_{s,t},H_{s,t},N_{s,t}} E_0 \sum_{t=0}^{\infty} \beta_s^t \left[\log C_{s,t} + j \log H_{s,t} - \frac{(N_{s,t})^{\eta}}{\eta} \right],$$

where $\beta_s \in (0,1)$ is the patient discount factor, E_0 is the expectation operator and $C_{s,t}$, $H_{s,t}$ and $N_{s,t}$ represent consumption at time t, the housing stock and working hours, respectively. $1/(\eta - 1)$ is the labor supply elasticity, $\eta > 0$. j represents the weight of housing in the utility function.

Savers maximize their utility subject to the following budget constraint:

$$C_{s,t} + b_t + q_t (H_{s,t} - H_{s,t-1}) = \frac{R_{t-1} b_{t-1}}{\pi_t} + w_{s,t} N_{s,t} + F_t, \tag{1}$$

where b_t denotes bank deposits, R_t is the gross return from deposits, q_t is the price of housing in units of consumption, π_t is the inflation rate, and $w_{s,t}$ is the real wage rate. F_t denotes lump-sum profits received from the firms. The first order conditions for this optimization problem are as follows:

$$\frac{1}{C_{s,t}} = \beta_s E_t \left(\frac{R_t}{\pi_{t+1} C_{s,t+1}} \right), \tag{2}$$

$$w_t^s = (N_{s,t})^{\eta-1} C_{s,t}, \tag{3}$$

$$\frac{j}{H_{s,t}} = \frac{1}{C_{s,t}} q_t - \beta_s E_t \frac{1}{C_{s,t+1}} q_{t+1}. \tag{4}$$

Equation (2) is the Euler equation, the intertemporal condition for consumption. Equation (3) is the labor-supply condition and Equation (4) represents the intertemporal condition for housing, in which, at the margin, the benefits from consuming housing equate costs in terms of consumption.

2.2 Borrowers

Borrowers solve the following optimisation problem:

$$\max_{C_{b,t},H_{b,t},N_{b,t}} E_0 \sum_{t=0}^{\infty} \beta_b^t \left[\log C_{b,t} + j \log H_{b,t} - \frac{(N_{b,t})^\eta}{\eta} \right],$$

where $\beta_b \in (0,1)$ is the discount factor for the borrower ($\beta_b < \beta_s$), subject to the following budget and collateral constraints:

$$C_{b,t} + \frac{R_{t-1} b_{t-1}}{\pi_t} + q_t (H_{b,t} - H_{b,t-1}) = b_t + W_{b,t} N_{b,t}, \tag{5}$$

$$E_t \frac{R_t}{\pi_{t+1}} b_t = k_t E_t q_{t+1} H_{b,t}, \tag{6}$$

where b_t denotes bank loans for borrowers. These are the converse of savers' deposits. k_t can be interpreted as a loan-to-value ratio.[5] The borrowing constraint limits borrowing to the present discounted value of their housing holdings. The first order conditions are as follows:

$$\frac{1}{C_{b,t}} = \beta_b E_t \left(\frac{R_t}{\pi_{t+1} C_{b,t+1}} \right) + \lambda_t R_t, \tag{7}$$

$$w_{b,t} = (N_{b,t})^{\eta-1} C_{b,t}, \tag{8}$$

[5] In standard housing models, the LTV is a parameter. However, in our model, this has a subindex t because it is the macroprudential instrument.

$$\frac{j}{H_{b,t}} = \frac{1}{C_{b,t}} q_t - \beta_b E_t \left(\frac{1}{C_{b,t+1}} q_{t+1} \right) - \lambda_t k_t E_t \left(q_{t+1} \pi_{t+1} \right). \tag{9}$$

where λ_t denotes the multiplier on the borrowing constraint.[6] These first order conditions can be interpreted analogously to the ones of savers.

2.3 Firms

2.3.1 Final Goods Producers

There is a continuum of identical final goods producers that operate under perfect competition and flexible prices. They aggregate intermediate goods according to the production function

$$Y_t = \left[\int_0^1 Y_t(z)^{\frac{\varepsilon-1}{\varepsilon}} dz \right]^{\frac{\varepsilon}{\varepsilon-1}}, \tag{10}$$

where $\varepsilon > 1$ is the elasticity of substitution between intermediate goods. The final good firm chooses $Y_t(z)$ to minimize its costs, resulting in demand of intermediate good z:

$$Y_t(z) = \left(\frac{P_t(z)}{P_t} \right)^{-\varepsilon} Y_t. \tag{11}$$

The price index is then given by:

$$P_t = \left[\int_0^1 P_t(z)^{1-\varepsilon} dz \right]^{\frac{1}{\varepsilon-1}}. \tag{12}$$

2.3.2 Intermediate Goods Producers

The intermediate goods market is monopolistically competitive. Following Iacoviello (2005), intermediate goods are produced according to the production function:

$$Y_t(z) = A_t N_{s,t}(z)^{\alpha} N_{b,t}(z)^{(1-\alpha)}, \tag{13}$$

where $\alpha \in [0,1]$ measures the relative size of savers and borrowers in terms of labor.[7] This Cobb-Douglas production function implies that labor efforts of constrained and unconstrained consumers are not perfect substitutes. This specification is analytically tractable and allows for closed form solutions

[6] Through simple algebra it can be shown that the Lagrange multiplier is positive in the steady state and thus the collateral constraint holds with equality.

[7] Notice that the absolute size of each group is one.

for the steady state of the model. This assumption can be economically justified by the fact that savers are the managers of the firms and their wage is higher than the wage received by borrowers.[8]

A_t represents technology and it follows the following autoregressive process:

$$\log(A_t) = \rho_A \log(A_{t-1}) + u_{At}, \tag{14}$$

where ρ_A is the autoregressive coefficient and u_{At} is a normally distributed shock to technology. We normalize the steady-state value of technology to 1.

Labor demand is determined by:

$$w_{s,t} = \frac{1}{X_t}\alpha\frac{Y_t}{N_{s,t}}, \tag{15}$$

$$w_{b,t} = \frac{1}{X_t}(1-\alpha)\frac{Y_t}{N_{b,t}}, \tag{16}$$

where X_t is the markup, or the inverse of marginal cost.[9]

The price-setting problem for the intermediate good producers is a standard Calvo-Yun setting. The intermediate good producer sells its good at price $P_t(z)$, and has a$1-\theta \in [0,1]$, probability of being able to change the sale price in every period. The optimal reset price $P_t^*(z)$ solves:

$$\sum_{k=0}^{\infty}(\theta\beta)^k E_t\left\{\Lambda_{t,k}\left[\frac{P_t^*(z)}{P_{t+k}} - \frac{\varepsilon/(\varepsilon-1)}{X_{t+k}}\right]Y_{t+k}^*(z)\right\} = 0. \tag{17}$$

where $\varepsilon/(\varepsilon-1)$ is the steady-state markup.

The aggregate price level is given by:

$$P_t = \left[\theta P_{t-1}^{1-\varepsilon} + (1-\theta)(P_t^*)^{1-\varepsilon}\right]^{1/(1-\varepsilon)}. \tag{18}$$

Using log-linearized versions of (17) and (18), we can obtain a standard forward-looking New Keynesian Phillips curve $\widehat{\pi}_t = \beta E_t\widehat{\pi}_{t+1} - \psi\widehat{x}_t + u_{\pi t}$, that relates inflation positively to future expected inflation and negatively to the markup ($\psi \equiv (1-\theta)(1-\beta\theta)/\theta$). $u_{\pi t}$ is a normally distributed cost-push shock.[10]

[8] It could also be interpreted as the savers being older than the borrowers, therefore more experienced.

[9] Symmetry across firms allows us to write the demands without the index z.

[10] Variables with a hat denote percent deviations from the steady state.

2.4 Equilibrium

The market clearing conditions are as follows:

$$Y_t = C_{s,t} + C_{b,t}. \tag{19}$$

The total supply of housing is fixed and it is normalized to unity:

$$H_{s,t} + H_{b,t} = 1. \tag{20}$$

2.5 Monetary Policy

Monetary policy is set as follows:

$$R_t^{TR} = \left(R_{t-1}^{TR}\right)^{\rho} \left((\pi_t)^{\left(1+\phi_\pi^R\right)} \left(\frac{Y_t}{Y}\right)^{\phi_y^R} R \right)^{1-\rho} \tag{21}$$

$$R_t = \max\left(R_t^{TR}, 1\right) \tag{22}$$

We consider a standard Taylor rule which responds to inflation and output, with interest-rate smoothing, where $\phi_\pi^R \geq 0$, $\phi_y^R \geq 0$ measure the response of interest rates to current inflation and output deviations from the steady state, respectively. R is the steady-state interest rate. However, we impose a ZLB constraint on the interest rate so that it cannot reach negative values when it follows the Taylor rule. Thus, R_t^{TR} is the policy rate implied by the Taylor rule while R_t is the actual rate, both expressed in gross terms.

2.6 A Macroprudential Rule for the LTV

In standard models, the LTV ratio is a fixed parameter which is not affected by economic conditions. However, we can think of regulations of LTVs as a way to moderate credit booms. When the LTV is high, the collateral constraint is less tight. And, since the constraint is binding, borrowers will borrow as much as they are allowed to. Lowering the LTV tightens the constraint and therefore restricts the loans that borrowers can obtain. Literature on macroprudential policies has proposed rules for the LTV so that it reacts inversely to variables such that the growth rates of GDP, credit, the credit-to-GDP ratio or house prices. These rules provide a simple illustration of how a macroprudential policy could work in practice. We assume that the objective of the macroprudential regulator is to avoid situations that lead to an excessive credit growth; when there is a boom in the economy or house prices increase, agents borrow more. Therefore, we take deviations of credit and output from their respective steady states as leading indicators of credit growth and consequently consider a rule for the LTV, so that it responds to credit and output:

$$k_t = k_{SS} \left(\frac{b_t}{b}\right)^{-\phi_b} \left(\frac{Y_t}{Y}\right)^{-\phi_y}, \tag{23}$$

where k_{SS} is a steady state value for the LTV, and $\phi_b \geq 0$, $\phi_y \geq 0$ measure the response of the LTV to borrowing and output, respectively. This kind of rule delivers a lower LTV in booms, when credit and output are high, therefore restricting the credit in the economy and avoiding a credit boom derived from good economic conditions.[11]

2.7 Baseline Parameter Values

For simulations, we create two types of environments; one which we call "normal times," in which the steady-state annual interest is 4% as in the standard RBC models, and a second one called "low interest rate" in which the steady-state interest rate is 2%. For the "normal times" case, the discount factor for savers, β_s, is set to 0.99 to match a 4% interest rate in the steady state. The discount factor for borrowers in this scenario is set to 0.98.[12] For the "low interest rate" environment, we set β_s to 0.995. In order to keep the same difference across agents' discount factors in both scenarios, we set β_b to 0.985 in this case. The steady-state weight of housing in the utility function, j, is set to 0.1 in order for the ratio of housing wealth to GDP to be approximately 1.40 in the steady state, consistent with the US data, as in Iacoviello (2005). We set $\eta = 2$, implying a value of the labor supply elasticity of 1.[13] For the parameter controlling leverage, we set k_{SS} to 0.90, in line with the US data.[14] The labor income share for savers is set to 0.64, following the estimate in Iacoviello (2005). For the Taylor rule, we consider the standard values $\phi_\pi^R = 0.5$ and $\phi_y^R = 0.5$. For ρ we use 0 so that we rule out smoothing from the rule and it is comparable to the case in which the economy is hitting the ZLB.

We simulate the response of the model to a technology shock. We assume that technology, A_t, follows

[11] Funke and Paetz (2012) consider a non-linear version of this macroprudential rule for the LTV.

[12] Lawrance (1991) estimated discount factors for poor consumers at between 0.95 and 0.98 at quarterly frequency. We take the most conservative value.

[13] Microeconomic estimates usually suggest values in the range of 0 and 0.5 (for males). Domeij and Flodén (2006) show that in the presence of borrowing constraints this estimates could have a downward bias of 50%.

[14] See Iacoviello (2015).

an autoregressive process with 0.9 persistence and a normally distributed shock.[15] Table 1 presents a summary of the parameter values used:

Table 1: Parameter Values		
β_s	0.99/0.995	Discount Factor for Savers
β_b	0.98/0.985	Discount Factor for Borrowers
j	0.1	Weight of Housing in Utility Function
η	2	Parameter associated with labor elasticity
k_{SS}	0.9	Loan-to-value ratio
α	0.64	Labor share for Savers
X	1.2	Steady-state markup
θ	0.75	Probability of not changing prices
ρ	0	Smoothing parameter in Taylor rule
ϕ_π^R	0.5	Inflation parameter in Taylor rule
ϕ_y^R	0.5	Output parameter in Taylor rule

3 The Occasionally Binding ZLB

The GFC has caused us to re-think about existing models and re-shape them in order to appropriately reflect the changes that are occurring in the economy. For instance, standard solution methods for DSGE models did not take into account the possibility of having the interest rate constrained at the ZLB, which has been proven to be a crucial feature of the economy, especially after the recent financial crisis. Large enough shocks, under these traditional methods, bring the policy rate to negative levels, violating the ZLB. However, we now know that the ZLB constraint for the interest rate is not just a theoretical curiosity, partly due to falling neutral interest rates. Even absent of large shocks, we have seen many economies across the world interest rates hitting their lower bounds. Therefore, it is important to be able to introduce this constraint in monetary policy models.

Considering occasionally binding lower bounds poses a technical challenge to solving DSGE models. In this paper, we use the solution method proposed by Guerrieri and Iacoviello (2015), namely the "occbin" toolbox,[16] which implements a piecewise-linear approximation to solve DSGE models with

[15] The persistence of the shocks is consistent with the estimates in Iacoviello and Neri (2010).

[16] There are alternative solution methods in the literature. For example, Jones (2015) shows that if the Blanchard-Kahn conditions are satisfied for the linearized model under the non-zero lower bound regime, then the "occbin" method developed

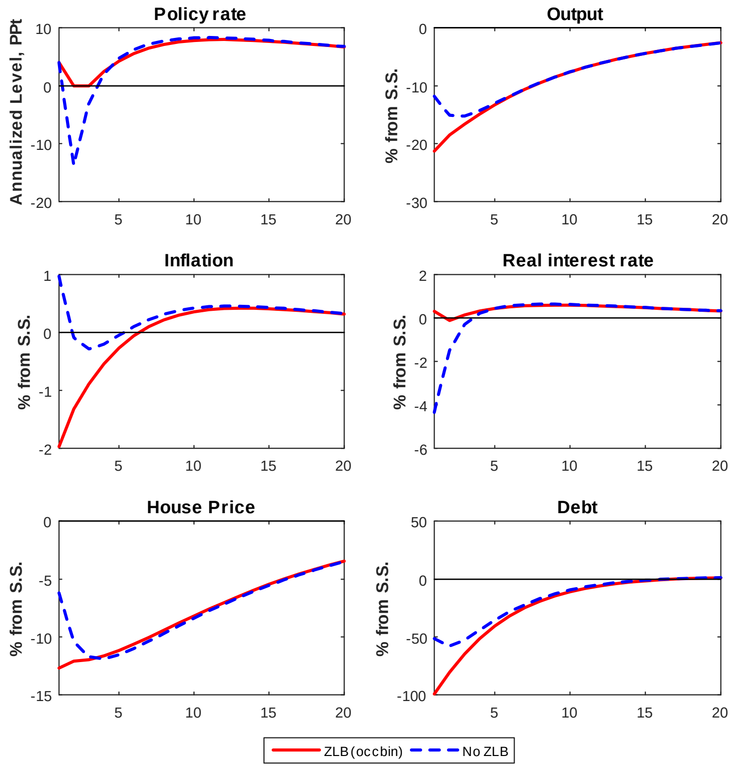

Figure 1: Impulse responses to a negative productivity shock

occasionally binding constraints. The key advantage of the toolbox is to solve for the rational expectations solution with unknown durations of each regime. For instance, in this method, the duration of the binding regime does not need to be fixed at a predetermined value but depends on the realization of shocks. In fact, how long a regime is expected to last affects the value of the endogenous variables contemporaneously. The "occbin" toolbox uses a guess-and-verify procedure to generate time-varying policy functions depending on the expected duration of regimes at each period.[17] In our case, the constraint that binds occasionally is the ZLB. Under one regime, the ZLB constraint is slack. Under the other regime, the constraint binds. Using this toolkit, we linearize the model under each regime around the non-binding steady state.

To illustrate how the occasionally binding ZLB affects the dynamics in our model, we compute impulse responses to a productivity shock, using both the standard solution method and the "occbin" toolkit. In this case, the LTV is set to its steady state value of 0.9 and no active rule is allowed.

Figure 1 presents impulse responses to a negative productivity shock for the case in which the

by Guerrieri and Iacoviello (2015) yields the same path for the endogenous variables as his approach. This is the case of our model.

[17] See Guerrieri and Iacoviello (2015) for further explanation on the "occbin" toolkit and the solution method.

economy is not constrained by the ZLB (blue dashed line) as opposed to the occasionally binding ZLB case (red solid line).[18] The upper- left panel displays the annualized level of the policy rate. It starts from the steady state level of 4%. We see that, when there are occasionally binding constraints for the interest rate, the policy rate reaches the zero lower bound and stays there for a couple of periods before converging to the Taylor rule interest rate. The non-constrained interest rate, however, becomes negative. This discrepancy between the two rates makes the rest of the variables also behave differently. In particular, both output and inflation respond in a much stronger manner in the world in which the interest rate is constrained. The deeper output recession in the occasionally binding model is driven by two channels. Firstly, the negative impact of the productivity shock is amplified by the collateral channel of borrowers, even without a ZLB. As shown in blue dash lines, when the negative shock hits, house prices fall and tighten the collateral constraint for borrowers. This, in turn, negatively affects credit via the collateral constraint. This feedback loop between house prices and credit gives rise to a powerful financial accelerator, emphasized in Iacoviello (2005). Even though, in this case, the central bank can support the economy by cutting the interest rate dramatically, the economy suffers an output recession. Secondly, when the interest rate is restricted by the occasionally binding ZLB, the latter provides an additional amplification of the shock. In this case, the occasionally binding ZLB economy suffers an even stronger recession, because the combination of deflation and the binding ZLB of the nominal interest rate pushes up the real cost of borrowing. The rise in the real interest rate depresses house prices and credit further, triggering the collateral effect on the real economy. As shown by the red solid lines, in the occasionally binding economy, the interest rate falls to zero and stays there for a few periods. In the meantime, inflation falls sharply, pushing up the real interest rate. As a result, house prices, credit and output decrease by more than in the case where the ZLB is ignored.

With this example, we show that explicitly modelling the occasionally binding ZLB delivers an enhanced propagation mechanism via the collateral channel for both real and financial variables. The importance of the collateral channel is much greater when the steady-state interest rate is low. In the next section, we illustrate this point formally by simulating the model under different steady-state interest rates (high and low).

[18] For illustrative purposes, we consider a size of the shock large enough to make the ZLB bind.

4 A Low Interest-Rate Environment

In recent years, and especially in the post-crisis period, long-term interest rates have trended downwards persistently. The decline in interest rates has implications both for financial stability and the implementation of monetary policy. In this section, we explore the consequences of a low steady-state interest rate, when an occasionally binding ZLB is explicitly considered. To address this question, we simulate our model with the same productivity shock process under two levels of steady-state interest rates (high and low). The LTV in these experiments is fixed at the steady-state level.

In the first setting, which we call "normal times," we set the annualized steady-state interest rate to be 4%, as in the standard real business cycle literature.[19] As an alternative, to reflect post-crisis times, we construct a scenario, which we call the "low interest-rate" environment, in which the interest rate in the steady state is 2%. Both simulations are done using the "occbin" toolkit in order to allow for occasionally binding ZLB constraints, which is crucial for the propagation mechanism in the low interest-rate economy. Give the same size of shocks, we show that, in a low interest-rate environment, the interest rate is more likely to hit the ZLB and the economy is more volatile than the economy with a high interest rate.

Figure 2 shows the simulated economy under a productivity shock.[20] We consider the two scenarios; "normal times" and "low interest rate," and plot them together for comparison. The black solid line corresponds to the 2% steady-state interest rate, while the red dashed line indicates the 4% steady-state interest rate economy. We can observe that in "normal times" the economy never hits the ZLB, while in the "low interest-rate" setting, the constraint binds several times and for extensive periods. Furthermore, in "normal times" the economy is less volatile than in a "low interest-rate" environment. Having interest rates permanently low, as it is currently the case in many economies, has important implications for economic dynamics. First of all, when we are in a "low interest-rate" environment, even small business cycle shocks can make the interest rate hit the ZLB frequently. As a result, monetary policy becomes less effective, because it loses its ability to further stimulate the economy, when the interest rate reaches zero. In this case, it results in a more volatile macroeconomy, as we can see in the upper-right panel of figure 2.

Furthermore, low interest rates create an environment of amplified financial cycles. This can be clearly

[19] Since the seminal paper by Kydland and Prescott (1982), the literature on DSGE models had traditionally considered a calibrated value of the discount factor of 0.99, to pick up the value of the interest rate in the steady state. It was considered that a reasonable value of the steady-state interest rate was 1% in a quarterly model (4% annualized).

[20] We consider a 0.03% shock to technology for simulations.

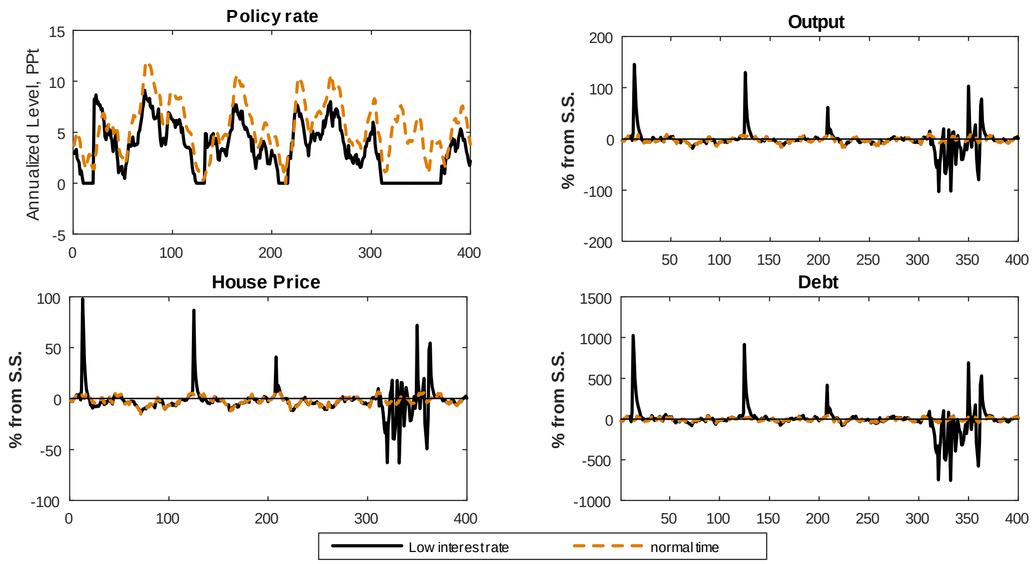

Figure 2: Simulated economy for productivity shocks. "Normal times" (4% SS interest rate) vs. "Low interest rate" (2% SS interest rate).

seen in the lower panels of figure 2, in which we observe that the volatility of debt and house prices is much higher for the "low interest-rate" economy as compared to the "normal time" economy. This is a consequence of the financial accelerator mechanism built into the model, interacting with constrained monetary policy. A model with collateral constraints presents a powerful financial accelerator, which allows for feedback loops between asset prices and credit. High house price increases the collateral value and relaxes the borrowing constraint for borrowers. This, in turn, creates aggregate demand effects from both borrowers and savers through both collateral and wealth effects. Such an environment, combined with less effective monetary policy which is occasionally binding at the ZLB, can produce both substantial financial expansions and catastrophic meltdowns.

As the previous simulations show, economies with financial frictions and low interest rates are particularly vulnerable when the conventional monetary policy is subject to the ZLB constraint. This circumstance calls for the need of other policies to stabilize the economy. A natural candidate that could help monetary policy in this situation is macroprudential policy.[21] Thus, a conclusion that we could extract from the simulation exercise is that, in a low interest-rate world, the case for using macroprudential policies is even stronger: first, it can be used to deal with financial instability which is a strong problem in this case. Second, it can act as a complement to monetary policy when it hits the ZLB to stabilize

[21] In the policy debate, other policy measures, such as unconventional monetary policy and fiscal policy, are also frequently mentioned. In this study, for the sake of scope and focus of the paper, we abstract the model from those alternative policies, even though they could also be interesting subjects in the low interest-rate environment.

the real economy. Indeed, we find that macroprudential policies are more needed in a "low interest-rate" economy than in "normal times."

For the rest of the paper, we use the "low interest-rate" environment as the benchmark calibration and study how active LTV rules can help monetary policy to stabilize the economy.

5 How Can Macroprudential Policy Help?

We have seen in the previous section that a "low interest-rate" environment calls for the use of macroprudential policy. In this paper, as in Angelini et al. (2014), we take the presence of the macroprudential regulator as given and study the effect of this policy on the economy and its interaction with monetary policy. As a first step, we demonstrate the effectiveness of macroprudential policy by studying the impulse responses with and without an active LTV policy rule responding only to credit. Then, we extend the class of the LTV rules to more variables and identify the optimal policy coefficients that minimize a loss function for the macroprudential regulator.

5.1 An LTV Rule responding to Credit

To develop some intuition, we first compare the impulse responses of the model with and without an active LTV rule. We take the monetary policy rule as given. We first study a simple LTV rule that responds only to credit:

$$k_t = k_{SS} \left(\frac{b_t}{b} \right)^{-\phi_b},$$

where we tentatively set the reaction parameter ϕ_b to 0.2.

Figure 3 presents impulse responses to a negative productivity shock in the model with a 2% steady-state interest rate. We compare the benchmark scenario in which there is no active LTV policy versus the case where the LTV responds countercyclically to credit. In both cases, interest rates are restricted by the occasionally binding ZLB.

First of all, without an active LTV policy, the interest rate immediately drops to the ZLB and stays there for a few periods. The economy suffers a deep recession, where both output and inflation fall. As discussed above, the effect of a negative productivity shock is amplified by the collateral channel and the rising real interest rate due to the binding ZLB. By contrast, when a countercyclical LTV rule can be used to help the economy, it relaxes the LTV by about 10 percentage points. As a result, the

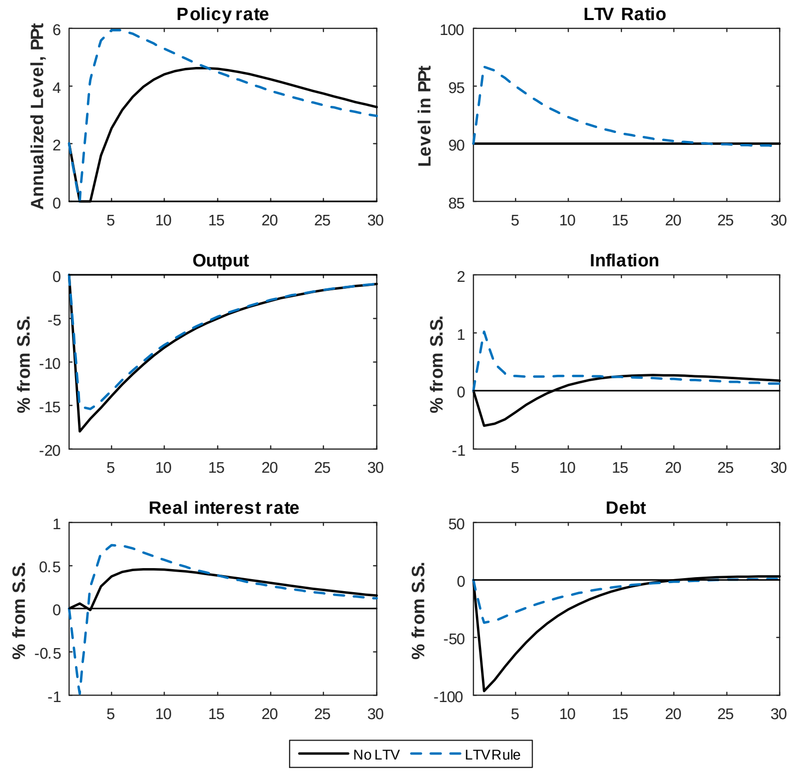

Figure 3: The effect of an active LTV rule with ZLB

provision of credit is supported by the LTV loosening. Interestingly, under the LTV policy, the ZLB binds just for one period. This comes from the general equilibrium effect on inflation. With the support of macroprudential policy, inflation increases instead of falling, which lifts the interest rate out of the ZLB more quickly. As a result, the real interest rate falls, providing the real economy with the kind of support that would have been achieved by monetary policy, should an occasionally binding ZLB not exist.

The main message that we obtain is that, when monetary policy is limited by an occasionally binding ZLB, a countercyclical LTV rule can help to stabilize the economy by both mitigating the collateral effect and lifting the interest rate out of the ZLB.[22] Next, we study the optimal setting of the LTV rule by minimizing a loss function of the macroprudential authority.

[22] Wu and Zhang (2016) integrate shadow rates into Iacoviello model. They find that when the ZLB is reached, alternative policy measures can be used, so that shadow rates are not limited by ZLB.

5.2 Optimal Simple Rules for the LTV

In the following section, we assess the optimal combination of parameters in the LTV rule, which minimizes a loss function of the macroprudential authority. In our search for optimized LTV policy parameters, we take monetary policy as given.[23] As in Angelini et al (2014), we assume that the macroprudential authority cares about the variability of credit, as a proxy for financial stability, and the variability of the instrument. This gives rise to a loss function in the following form:

$$L = \sigma_b^2 + \Lambda \sigma_{LTV}^2, \tag{24}$$

where σ_b^2 and σ_{LTV}^2 are variances of credit and the LTV, respectively. Λ is the relative weight that the macroprudential authority assigns to the targets. We use $\Lambda = 10$ in our policy experiences.[24] We use the loss function of the macroprudential regulator to evaluate different combinations of the policy coefficients in the simple rule described by equation (23). Then, searching over a grid of parameters, the solution of this problem is represented by the following expression:

$$\left(\phi_b^*, \phi_y^*\right) = \arg\min L\left(\phi_b, \phi_y\right),$$

subject to the model equations.

As a first approach, we consider a rule in which the macroprudential regulator only responds to credit deviations from the steady state, that is, we impose $\phi_y = 0$. Then, we extend the rule to allow the macroprudential instrument to also respond to output. The motivation for the extension of the rule is that when the economy reaches the ZLB, monetary policy loses its effectiveness to stabilize the economy. Thus, we study whether macroprudential policies could be used as a complement to monetary policy for macroeconomic stabilization.

Table 2 displays the optimized parameters for the proposed macroprudential rules and the corresponding variances of key variables.[25] We take the case when there are no macroprudential policies as a benchmark, and compare it with the model in which the active LTV rules is at work. We do these exercises for both the "normal times" (4% steady-state interest rate) and the "low interest-rate"

[23] In this paper, we do not address the optimal coordination between macroprudential policy and monetary policy, as in Angelini et al (2014).

[24] Given credit is much more volatile than the LTV, in order to obtain an internal solution of the minimisation, we set a large weight to the LTV. The value doesn't drive our results in Table 2. I show the robustness in an Apendix.

[25] In optimal simple rule simulations, we use $\phi_y^R = 0$ in the Taylor rule, so that monetary policy focuses purely on price stability, while macroprudential policy is in charge of macro stability. This separation brings cleaner numerical results.

environment (2% steady-state interest rate). Comparing these two environments helps us to make the point that the macroprudential policy implementation should be different in a world in which long-term interest rates are low and the economy hits the ZLB frequently.

Table 2: Optimized Parameters

	ϕ_b^*	ϕ_y^*	σ_b^2	σ_y^2	Loss
Benchmark (No LTV)					
Normal times	-	-	31.16	2.4	1.2899
Low interest rate	-	-	85.46	8.11	4.3749
LTV Rule with Credit					
Normal times	0.55	-	3.85	1.93	0.1699
Low interest rate	0.69	-	11.51	6.76	0.8347
Extended LTV Rule					
Normal times	0.55	0	3.85	1.93	0.1699
Low interest rate	0.11	0.8	9.46	5.13	0.5905

For comparison, we first report the value of the loss function and the corresponding volatility of output and credit in the economy in which no active LTV policy is in place. As seen in the first panel of the table, driven by the same size of productivity shocks, the economy in normal times is significantly less volatile than that in a low interest-rate environment. As we discussed before, in the low interest-rate world, the ZLB is binding more frequently. Lacking an effective stabilization policy, the economy becomes more volatile in both the real and financial sector. This finding motivates the need for macroprudential policies to enhance economic stability, especially in the low interest-rate environment.

When we introduce an active LTV rule responding to credit only, as seen in the middle panel of Table 2, we see that financial stability is improved dramatically without compromising macroeconomic stability. In normal times, the macroprudential policy delivers a much lower variability of credit and it also helps with macroeconomic stability. In the 2% interest-rate world, however, the optimized LTV rule has to respond to credit more aggressively, and it dampens mostly the volatility of credit, but the effect on the variability of ouptut is much muted. This result indicates that, when monetary policy is restricted by the occasionally binding ZLB, purely credit-focused macroprudential policy might be less helpful for the real economy. This finding points to a more active role for macroprudential policy in stabilizing the real economy.

In the bottom panel of the table, we experiment with an extended version of the LTV rule that responds to both credit and output. Results show that, in normal times, since monetary policy already does its job properly, there is no need for the LTV rule to respond to output directly. The optimized rule is the same as the one responding only to the credit. In this case, the so-called "Tinbergen principle" applies. Macroeconomic stability would be effectively managed by the monetary authority, while the macroprudential authority only needs to worry about financial stability. The two policies work independently, with different instruments, targeting separate objectives. When the economy is closer to the ZLB, however, the optimized rule responds more strongly to output than to credit. This is because monetary policy is often constrained by the binding ZLB. As discussed above, the binding ZLB becomes a more important distortion in the economy than the financial accelerator. In this case, macroprudential policy has to lend a helping hand to monetary policy, to assist macroeconomic stabilization. As a result, the whole economy improves in terms of the volatilities in both the macroeconomic and the financial sector, as opposed to the benchmark and the LTV rule responding only to credit.

In summary, in a low interest-rate environment, there are two reasons that strengthen the role of macroprudential policy. First, the low interest-rate world is more prone to financial instability, and that calls for the use of macroprudential policies to bring a more stable financial system. Second, monetary policy not only loses its effectiveness to bring macroeconomic stability, but also becomes an additional amplification mechanism, when it is constrained by the ZLB. In this case, macroprudential policies can act as a complement to monetary policy by not only responding to credit but also to output.

6 Concluding Remarks

In this paper, we build a DSGE model in which interest rates are permanently low and monetary policy is constrained by the ZLB. In this context, we study the implementation of macroprudential policies, represented by an LTV rule. In particular we answer the following research questions: Are macroprudential policies more relevant in a low interest-rate environment? Can macroprudential policies complement monetary policy when the latter binds at the ZLB occasionally?

In order to address these issues we first simulate the economy both for "normal times" and for a "low interest-rate" environment. We find that when interest rates are persistently low, the ZLB occurs frequently, leading to greater macroeconomic volatility and financial instability. In this context, the economy calls for the use of active macroprudential policies to contain financial stability and to act as a complement to the less effective monetary policy. Then, we study what would be the best way to implement a countercyclical LTV rule, which minimizes the loss function of the macroprudential regulator. We find that in a low interest-rate environment, macroprudential policies need to be more aggressive in responding to credit. Furthermore, when the LTV is allowed to respond to output, it will respond to output more strongly than to credit, because a binding ZLB not only makes monetary policy ineffective in economic stabilization, but also presents an additional amplification mechanism on top of the collateral channel. Therefore, in this environment, macroprudential policies can act as a complement to monetary policy.

References

[1] Angelini, P., Neri, S., Panetta, F., (2014), The Interaction between Capital Requirements and Monetary Policy, Journal of Money, Credit and Banking, 46 (6).

[2] Antipa, P. & Matheron, J., 2014. "Interactions between monetary and macroprudential policies," Financial Stability Review, Banque de France, issue 18, pages 225-240, April.

[3] Blanchard, O., Dell'Ariccia, G., Mauro, P., (2013), Rethinking Macro Policy II: Getting Granular, IMF Discussion Note, SDN 13/03.

[4] Borio, C., Shim, I., (2007), What can (macro-) policy do to support monetary policy?, BIS Working Paper, 242.

[5] Borio, C., (2016), Towards a financial stability-oriented monetary policy framework?, BIS speech, SP160914, September 2016.

[6] Caruana, J, (2001), Monetary policy in a world with macroprudential policy, Speech by Mr Jaime Caruana, General Manager of the BIS, at the SAARCFINANCE Governors' Symposium 2011, Kerala, 11 June 2011.

[7] Cœuré, B., (2015), How binding is the zero lower bound?, Speech at the conference Removing the zero lower bound on interest rates, organised by Imperial College Business School / Brevan Howard Centre for Financial Analysis, CEPR and the Swiss National Bank, London, 18 May 2015.

[8] Domeij, D., Flodén, M., (2006) The Labor-Supply Elasticity and Borrowing Constraints: Why Estimates are Biased. Review of Economic Dynamics, 9, 242-262.

[9] Funke, M., Paetz, M., (2012), A DSGE-Based Assessment of Nonlinear Loan-to-Value Policies: Evidence from Hong Kong, BOFIT Discussion Paper No. 11/2012.

[10] Guerrieri, L., Iacoviello, M. (2015) Occbin: A Toolkit to Solve Models with Occasionally Binding Constraints Easily, Journal of Monetary Economics, 70, 22-38.

[11] Hamilton, J., Harris, E., Hatzius, J., West, K., (2015), The Equilibrium Real Funds Rate: Past, Present, and Future. Presented at the U.S. Monetary Policy Forum, New York.

[12] Iacoviello, M., (2005), House Prices, Borrowing Constraints and Monetary Policy in the Business Cycle, American Economic Review, 95 (3), 739-764.

[13] Iacoviello, M., (2015), Financial Business Cycles, Review of Economic Dynamics, 18 (1), 140-164.

[14] Iacoviello, M. , Neri, S., (2010), Housing Market Spillovers: Evidence from an Estimated DSGE Model, American Economic Journal: Macroeconomics, 2, 125–164.

[15] Korinek, A., Simsek, A., (2016), Liquidity Trap and Excessive Leverage, American Economic Review, 106 (3), pp. 699-738.

[16] Kydland, F., Prescott, E., (1982). Time to Build and Aggregate Fluctuations, Econometrica 50 (6), 1345–1370.

[17] Laubach, T., Williams, J., (2015), Measuring the Natural Rate of Interest Redux. FRB San Francisco Working Paper 2015-16, October, forthcoming in Business Economics.

[18] Lawrance, E., (1991), Poverty and the Rate of Time Preference: Evidence from Panel Data, The Journal of Political Economy, 99 (1), 54-77.

[19] Lewis, V., Villa, S., (2016), The Interdependence of Monetary and Macroprudential Policy under the Zero Lower Bound, National Bank of Belgium WP, 310.

[20] N'Diaye, P., (2009), Countercyclical macro prudential policies in a supporting role to monetary policy, IMF Working Paper.

[21] Svensson, L., (2003), What Is Wrong with Taylor Rules? Using Judgment in Monetary Policy through Targeting Rules, Journal of Economic Literature, American Economic Association, vol. 41(2), pages 426-477, June.

[22] Williams, J., (2016), Monetary Policy in a Low R-star World, FRBSF Economic Letter, 2016-23.

[23] Wu, J., Zhang, J., (2016), A Shadow Rate New Keynesian Model, mimeo.