Does Easing Monetary Policy Increase Financial Instability?*

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Abstract

We develop a model featuring both a macroeconomic and a financial stability objective that speaks to the interaction between monetary and macro-prudential policies. First, we find that interest rate rigidities in a monopolistic banking system have an asymmetric impact on financial stability: they exacerbate the effects of financial frictions in response to contractionary shocks to the economy, while they act as an automatic stabilizer in response to expansionary shocks. Second, when the policy interest rate is the only available instrument, a monetary authority subject to the same constraints as those of private agents cannot always achieve a (constrained) efficient allocation and faces a trade-off between macroeconomic and financial stability in response to negative shocks. This has important implications for the role played by U.S. monetary policy in the run up to the global financial crisis. Our model suggests that the weak link in the U.S. policy framework was not an excessively lax monetary policy stance after 2002, but rather the absence of an effective second policy instrument aimed at preserving financial stability.

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1 Introduction

The global financial crisis and ensuing great recession of 2007-09 have ignited a debate on the role of policies for the stability of the financial system or the economy as a whole (i.e., the so called macro-prudential policies). In advanced economies, this debate is revolving around the role of monetary and regulatory policies in causing the global crisis and how the conduct of monetary policy and the supervision of financial intermediaries should be altered in the future to avoid the recurrence of such a catastrophic event. In this paper we develop a simple model featuring both a macroeconomic and a financial stability objective that speaks to the interaction between monetary and macro-prudential policies.

The prime objective of macro-prudential policy is to limit build-up of system-wide financial risk, in order to reduce the probability and mitigate the impact of a financial crash.[1] Most commonly used prudential tools, however, are likely to interact with other policies. The overlap between different policy areas is one of the major challenges for policy-makers, who have to consider the unintended impact of their instruments on other policy objectives and the unintended impact of other policy-makers' instruments on their own policy objective (Svensson, 2012).

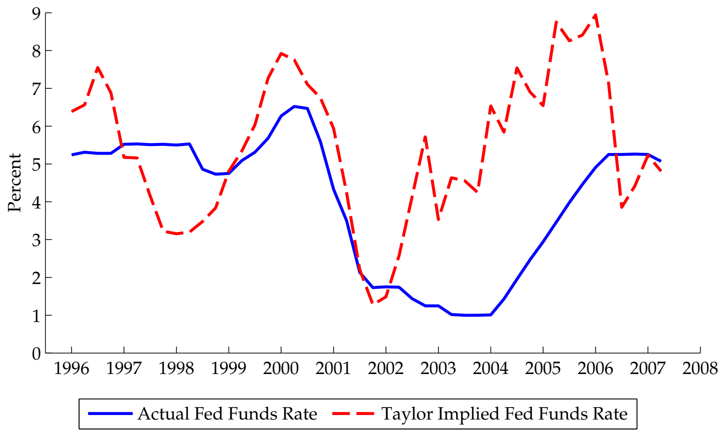
On the one hand, monetary policy can affect financial stability. For example, investors may be pushed to substitute low-yielding, safe assets for higher yielding, riskier assets (Rajan, 2005, Dell'Ariccia et al., 2011); investors may also be encouraged to take greater risks if they perceive that monetary policy is being used asymmetrically on asset prices (Issing, 2009); and asset price increases induced by falling interest rates might cause banks to increase their holdings of risky assets through active balance sheet management (Adrian and Shin, 2009, 2010). On the other hand, macro-prudential policy instruments can have an effect on macroeconomic stability. In fact, by affecting variables such as asset prices and credit, macro-prudential policy is likely to affect a key transmission mechanism of monetary policy (see e.g., Ingves, 2011). This overlap entails the possibility of the instruments having offsetting or amplifying effects on their objectives if they are implemented in an uncoordinated manner, possibly leading to worse outcomes than if the instruments had been coordinated (see Bean et al., 2010, Angelini et al., 2011, between others).

Against this background, some observers have assigned to monetary policy a central role in exacerbating the severity of the global financial crisis of 2007-09. In a paper that openly embraces this view, Taylor (2007) noticed that —during the period from 2002 to 2006— the U.S. federal funds rate was well below what a rule of thumb of good economic performance over the previous two decades would have predicted. Figure 1 displays the actual federal funds rate (solid line) and the counterfactual policy rate that

[1] See Bank of England (2009), IMF (2011), Borio (2011) for a discussion.

would have prevailed if monetary policy had followed a standard Taylor rule (dashed line). As a matter of fact, the interest rate implied by the Taylor rule is well above the actual federal funds rate, starting from the second quarter of 2002. Taylor (2007) shows that such counterfactual policy rate would have reduced the rapid growth of the housing market bubble; moreover, Taylor also supports the idea that the deviation from this rule-based framework has been a major factor in determining the likelihood and the severity of the crisis (Taylor, 2010).

Figure 1 A counterfactual path for the U.S. policy rate



Note. This chart replicates the counterfactual federal funds rate reported by Taylor (2007). The counterfactual path for the policy rate from 1996 to 2007 is obtained with a Taylor rule of the type: $i_t = r_t + \pi_t + 1.5(\pi_t - \pi) + 0.5(y_t - y_t^*)$, where r_t, long-run real value of the federal funds rate, is set to 2 percent, π_t is CPI inflation, π is target inflation (assumed at 2 percent), y_t is real GDP growth, and y_t^* is real potential GDP growth.

Despite the widely shared sentiment that the Federal Reserve is partly to blame for the housing bubble and its resultant economic impact, the issue is highly controversial.[2] "The best response to the housing bubble would have been regulatory, rather than monetary," said Bernanke (2010) in the remarks to the American Economic Association's annual meeting in Atlanta.

Such disagreement is also reflected in the substantially different institutional arrangements for the implementation of macro-prudential and monetary policies that emerged in different countries after the crisis (for a discussion see French et al., 2010, Yellen, 2011). At one extreme, the Bank of England has been assigned full responsibility for macro-prudential policy and monetary policy. At the other extreme, in the U.S., these functions remains relatively uncoordinated. Yet the interaction between macro-prudential and monetary policy has received surprisingly little attention in the

[2]Besides Taylor (2007, 2010), Borio and White (2003), Gordon (2005), and Borio (2006) support the idea that monetary policy contributed significantly to the financial boom that preceded the global financial crisis; in contrast, Posen (2009), Bean (2010), and Svensson (2010) provide arguments against this thesis.

literature.

To address some of the issues arising from the above discussion, we develop a simple model of consumption-based asset pricing and collateralized borrowing with monopolistic banking and real interest rates rigidities. The presence of a real and a financial friction give rise to both a traditional macroeconomic stabilization role for policy and a more novel financial stability objective. The macroeconomic stabilization objective arises from the presence of monopolistic competition in the banking sector and real interest rates rigidities. Due to monopolistic power, banks apply a markup on lending rates (Freixas and Rochet, 2008). Moreover, when banks cannot fully adjust their lending rates in response to macroeconomic shocks, the economy displays distortions typical of models with staggered price setting, generating equilibrium allocations that are not Pareto efficient (Hannan and Berger, 1991, Kwapil and Scharler, 2010, Gerali et al., 2010). The financial stability objective stems from the fact that the model endogenously generates financial crisis and embeds systemic risk. When access to credit is subject to an occasionally binding collateral constraint, a pecuniary externality arises (see, between others, Benigno et al., 2012, Bianchi, 2011, Bianchi and Mendoza, 2011, Jeanne and Korinek, 2010b). Atomistic agents do not internalize the effect of their individual decisions on a key market price entering the specification of the financial friction, thus driving a wedge between the competitive and the planner equilibria.

There are two main results. First, the analysis of our decentralized economy shows that real interest rate rigidities interact in an asymmetric fashion with the distortionary effects of the financial friction, depending on the sign of the shock hitting the economy. In response to positive shocks to the risk free interest rate, average lending interest rates raise, too. However, because of the stickiness, they are inefficiently lower than the flex-rates case, affecting next period refinancing needs and, therefore, the crisis probability through two mechanisms. On the one hand, lower average lending rates prompt consumers to borrow and consume more than the flex-rates case; on the other hand, interest rate repayments are lower. The net effect is that consumers face lower refinancing needs than the flex-rates case: the real rigidity, therefore, acts as an automatic macroprudential stabilizer. In contrast, when the risk free interest rate is hit by a negative shock, average lending interest rates decrease by less than the risk free rate. Through the same mechanisms described above, consumers face higher refinancing needs than the flex-rates case: the real rigidity, in this case, fosters financial instability.

Second, the model shows that a single policy authority, obeying the same financial constraints faced by private economic agents and with only one instrument (namely, the policy interest rate), cannot achieve a constrained efficient allocation depending on the sign of the shock hitting the economy. Specifically, in response to negative shocks, achieving the monetary policy objectives and maintaining financial stability entails a trade off because the two objectives require interventions on the policy rate of opposite direction. However, when two different instruments are at the policy maker's disposal (as, for example, a tax on debt and the policy interest rate), a constrained efficient allocation can be achieved in response to both positive and negative shocks to the risk free interest rate.

This has important implications regarding the role played by U.S. monetary policy for the stability of the financial system in the run up to the global financial crisis. In particular, we show that Taylor's argument —i.e., that higher interest rates would have reduced both the probability and the severity of the crisis— is supported by our theoretical model only with the auxiliary assumption that the policy authority —addressing all distortions present in our model— has just one instrument at its disposal, namely the policy rate. However, Taylor's argument cannot be rationalized in the context of our model when the policy authority has two different instruments: in this case, in response to a negative shock, interest rates ought to be lowered as much as needed without concerns for financial stability. As suggested by Bernanke (2010) and Blanchard et al. (2010), this implies that the same monetary policy stance as the one adopted by the Federal Reserve during the 2002-06 period, accompanied by stronger regulation and supervision of the financial system, might have been more effective in reducing the likelihood and the severity of the crisis —relative to a tighter monetary policy stance with the same financial supervision and regulation observed during the 2002-06 period.

This paper is related to several strands of literature. The first is the branch of the New Keynesian literature that considers financial frictions and Taylor-type interest rate rules (see Angelini et al., 2011, Beau et al., 2012, Kannan et al., 2012, for example). These papers consider either interest rules augmented with macro-prudential arguments —such as credit growth or asset prices— or combination of interest and macro-prudential rules in order to allow monetary policy to "lean against financial winds". However, in this class of models, crisis and regular business cycle are not differentiated: macro-prudential regulation is therefore taken for granted, in the sense that it does not target a well defined market failure.

The second is a growing literature that interprets financial crises as episodes of financial amplification in environments where credit constraints are only occasionally binding. In this class of models the need for macro-prudential policies may stem from a fundamental market failure: a pecuniary externality originating from the presence of a key market price in the aggregate collateral constraint faced by private agents (see, between others, Benigno et al., 2012, Bianchi, 2011, Bianchi and Mendoza, 2011, Jeanne and Korinek, 2010b). However, in these models the financial friction is the only distortion in the economy. The question of how the pursue of financial stability may affect macroeconomic stability is therefore left unresolved.

The third is a vast literature on the relation between the degree of competition in the banking sector and banks' risk-taking behavior. On both theoretical and empirical grounds, the benefits of fostering competition in the banking sector are ambiguous from a financial stability perspective (see, for instance, Boyd and Nicolo, 2005, Martinez-Miera and Repullo, 2010, Vives, 2011).

Finally, few papers consider both frictions at the same time. Benigno et al. (2011) analyze a fully specified new open economy macroeconomics 3-period model that features the same financial friction analyzed here and Calvo-style nominal rigidities. The solution of the fully non-linear version of that model (i.e., without resorting to approximation techniques) shows that there is a trade off between macroeconomic and financial stability but it is quantitatively too small to warrant the use of a second policy instrument in addition to the interest rate. Kashyap and Stein (2012) use a modified version of the pecuniary externality framework of Stein (2012) where the central bank has both a price stability and a financial stability objective. Similar to our findings, a trade off emerges between the two objectives when the policy interest rate is the only instrument and it disappears when there is a second instrument (a non zero interest rate on reserves, in their case). However, they do not model the price stability objective explicitly. Woodford (2012), in contrast, sets up a New Keynesian model with credit frictions, where the probability of a financial crisis is endogenous (i.e., it is a regime switching process that depends on the model variables). Woodford characterizes optimal policy in this environment showing that —under certain circumstances— the central bank may face a trade off between macroeconomic and financial stability. However, he does not model financial stability explicitly.

In contrast, in our paper, both the macroeconomic and the financial stability objective are well defined and each objective originates from a friction that we model explicitly. The interaction between the macroeconomic and the financial friction delivers not only a stark trade off between macro and financial stability, but also asymmetric effects of aggregate demand shocks that are crucial for our main results. Specifically, such asymmetry helps rationalize the role of monetary policy and macro-prudential policy (or the lack of thereof) in the run up to the global financial crisis.

The rest of the paper is organized as follows. In section 2 we describe the model economy. Section 3 and 4 characterize the decentralized and the socially planned equilibrium of the economy, respectively. In section 5 we discuss the implications of our model in terms of the role played by U.S. monetary policy for the stability of the financial system in the run up to the global crisis. In section 6 we conclude.

2 The model

The model includes monopolistic banking and real interest rate rigidities in the well known pecuniary externality framework of Jeanne and Korinek (2010a). Unlike Jeanne and Korinek (2010a), where consumers borrow directly from capital markets, in our set up consumers get loans from a stylized monopolistic banking sector. The financial friction is given by the presence of *collateralized borrowing.* Strictly speaking, the real frictions are two: the first is the presence of *market power* in the loan markets, exercised by monopolistically competitive banks; the second is *infrequent adjustment of interest rates* by banks.

The economy is populated by two sets of agents: a continuum of monopolistically competitive banks and a continuum of atomistic identical individuals ("consumers") who borrow from banks and consume. Each set of agents has a mass normalized to one. There are only three periods, denoted $t = 0, 1, 2$: the "short run", the "medium run", and the "long run".

At the beginning of period 0 consumers own an asset, whose available stock is normalized to 1. In order to consume they can either sell a fraction of the asset $(1 - \theta_{i,1})$ at market prices or borrow from banks $(b_{i,1})$. Note, however, that consumers can pledge the asset as a collateral to roll over their debt in period 1. They have a well defined demand function for loans which is decreasing in the lending interest rate (R_{L1}). Monopolistic banks freely borrow from outside lenders at the risk free interest rate $(R_t = R^*)$ and —given loans demand— optimally set their lending rates. The risk free interest rate can be hit by a temporary shock $(R^* \pm \upsilon)$ at the beginning of period 0. We assume that only a fraction of banks (μ) can reset their lending rates conditional on the shock, while the remaining banks $(1 - \mu)$ need to keep their lending rates fixed.[3] After the realization of the shock, which is observed by all agents, the credit market clears. At the end of the period households consume $(c_{i,0})$.

In period 1, consumers are endowed with the same stochastic endowment (e), they repay their debt $(b_{i,1}R_{L1})$, borrow an additional amount from banks $(b_{i,2})$, realize banks profits $(\pi_{i,1})$, and consume $(c_{i,1})$: notice that debt roll over is subject to a collateral constraint. If hit by a shock in period 0, the level of the risk free interest rate returns to its pre-shock value (R^*).

Period 2 represents the long run. Consumers get the same deterministic return on the asset that they own (y), repay their debt $(b_{i,2}R_{L2})$, realize banks profits $(\pi_{i,2})$, and consume $(c_{i,2})$.

2.1 Consumers

The utility of each consumer, indexed by $i \in [0, 1]$, is given by:

$$u(c_{i,0}) + u(c_{i,1}) + c_{i,2}, \tag{1}$$

[3] This assumption is justified by both theoretical and empirical findings (see, for example, Hannan and Berger, 1991, Neumark and Sharpe, 1992, Kwapil and Scharler, 2010, Gerali et al., 2010).

where, for simplicity, we assume a unitary discount factor. The period utility function, $u(\cdot)$, is a standard CES function:

$$u(c) = \frac{c^{1-\varrho}}{1-\varrho}. \tag{2}$$

The budget constraint can be written as:

$$\begin{cases} c_{i,0} = b_{i,1} + (1-\theta_{i,1})p_0, \\ c_{i,1} + b_{i,1}R_{L1} = e + b_{i,2} + (\theta_{i,1} - \theta_{i,2})p_1 + \pi_{i,1}, \\ c_{i,2} + b_{i,2}R_{L2} = \theta_{i,2}y + \pi_{i,2}. \end{cases} \tag{3}$$

Initially, each consumer owns $\theta_{i,0} = 1$ unit of the asset, where the price of the asset in period t is denoted by p_t. Consumers can buy or sell the asset in a perfectly competitive market, but they cannot sell it to the lenders and rent it back: as in Jeanne and Korinek (2010b), we assume that consumers derive some important benefits from owning the asset.[4] Note that, in a symmetric equilibrium, all consumers are identical and we must have $\theta_{i,0} = \theta_{i,1} = \theta_{i,2} = 1$.

As it is evident from the budget constraint, in order to consume in period 0, consumers need to either sell a fraction of their assets $(1-\theta_{i,1})$ or borrow from banks $(b_{i,1})$. Moreover, each consumer, in period 1, faces a collateral constraint of the form:

$$b_{i,2} \leq \theta_{i,1}p_1, \tag{4}$$

where $\theta_{i,1}$ is the quantity of domestic collateral held by the consumer at the beginning of period 1. The microfoundation of collateral constraint follows the spirit of Kiyotaki and Moore (1997). However, while in Kiyotaki and Moore (1997) borrowing capacity is an increasing function of the future value of the collateral asset, we assume that borrowing capacity is an increasing function of the current value of the collateral asset. The same modelling choice has been used by Mendoza (2010), Jeanne and Korinek (2010b) and Mendoza and Smith (2006) and is justified by the work of Cordoba and Ripoll (2004) and Kocherlakota (2000) who show that collateral constraints specified with next-period price of collateral asset do not yield quantitatively significant financial amplification.

Consumers maximize (1) subject to the budget constraint (3) and the collateral constraint (4). The utility maximization problem of the representative consumer (i.e., variables without the subscript i) can be written as:

$$\begin{aligned} \max_{b_1,b_2,\theta_1,\theta_2} \mathcal{V} &= u\Big(b_1 + (1-\theta_1)p_0\Big) + \mathbb{E}\Big[u\Big(e + b_2 + (\theta_1 - \theta_2)p_1 + \pi_1 - b_1 R_{L1}\Big) + \\ &\quad + \theta_2 y + \pi_2 - b_2 R_{L2}\Big] - \lambda(b_2 - \theta_1 p_1). \end{aligned} \tag{5}$$

[4] Consumers can be interpreted as households owning durable consumer assets (such as their homes, for example).

The first order conditions read:

$$\begin{aligned}
&p_0 = \tfrac{p_1(u'(c_1)+\lambda)}{u'(c_0)},\\
&p_1 = \tfrac{y}{u'(c_1)},\\
&u'(c_0) = R_{L1}\mathbb{E}\big[u'(c_1)\big],\\
&u'(c_1) = R_{L2} + \lambda.
\end{aligned} \tag{6}$$

The first two equations represent the asset pricing conditions for the economy in period 0 and 1. The second two equations are the Euler equation of consumption in period 0 and 1. By substituting for the CES utility function, we can derive the following optimal expressions for consumption:

$$\begin{aligned}
c_0 &= \Big(R_{L1}\mathbb{E}\big[\,(R_{L2}+\lambda)\,\big]\Big)^{-\frac{1}{\varrho}},\\
c_1 &= (R_{L2}+\lambda)^{-\frac{1}{\varrho}}\,.
\end{aligned} \tag{7}$$

In order to allow for market power in the banking sector, we model the market for loans in a Dixit and Stiglitz (1977) framework.[5] That is, we assume that units of loan contracts bought by households are a composite constant elasticity of substitution basket of slightly differentiated financial products —each supplied by a bank j— with elasticity term equal to ζ (which will be a major determinant of spreads between bank rates and the risk free rate).

In particular, the household i, in order to obtain a loan of a given size $b_{i,t}$, needs to take out a continuum of loans $b_{ij,t}$ from all existing banks j, such that:

$$b_{i,t} \leq \left(\int_0^1 b_{ij,t}^{\frac{\zeta-1}{\zeta}}\, dj\right)^{\frac{\zeta}{\zeta-1}} \tag{8}$$

where $\zeta > 1$ is the elasticity of substitution between differentiated loans (or banking services, in general). Demand by household i seeking an amount of real loans equal to $b_{i,t}$ can be derived by minimizing the total repayment due to the continuum of banks j over $b_{ij,t}$. Aggregating over symmetric households, the minimization problem yields downward-sloping loans demand curves of the kind:

$$b_{j,t} = \left(\frac{R_{Lj,t}}{R_{Lt}}\right)^{-\zeta} b_t. \tag{9}$$

where the aggregate interest rate on loans is given by:

$$R_{Lt} = \left(\int_0^1 R_{Lj,t}^{1-\zeta} dj\right)^{\frac{1}{1-\zeta}}. \tag{10}$$

[5] Benes and Lees (2007) and Gerali et al. (2010) take a similar approach.

2.2 Banks

There is a continuum of monopolistically competitive domestic banks indexed by $j \in [0,1]$ owned by households. Microeconomic theory typically considers market power as a distinctive feature of the banking sector (Freixas and Rochet, 2008).[6] In particular, we assume that each bank j supplies slightly differentiated financial products, and no other bank produces the same variety: each bank has, therefore, some monopoly power over its products. However, each firm competes with all the remaining firms, since consumers consider each firm's brand as a substitute —however imperfect— to all other available brands. As banks have market power over the supply of their products, they set prices to maximize their profits, keeping into account the elasticity of demand for their varieties.

Each bank j collects fully insured deposits $d_{j,t}$ from foreign investors at the risk-free interest rate $R_t = R^*$, where R^* is exogenous and given. We assume further that outside lenders have infinite supply for deposits (as in Jeanne and Korinek, 2010b), so that banks can satisfy whichever demand for loans. Finally, banks use deposits to produce loans to consumers with the following constant return to scale production function:

$$b_{j,t} = d_{j,t} \tag{11}$$

In each period, bank j maximizes its profits over both prices and quantities:

$$\max_{R_{Lj,t},b_{j,t}} b_{j,t}R_{Lj,t} - d_{j,t}R_t,$$

subject to the demand schedule in (9) and to the production function in (11). The first order condition implies that the optimal lending rate applied by banks is a positive gross markup ($\mathcal{M}$) over the marginal cost:

$$R_{Lt}(j) = \frac{\zeta}{\zeta - 1}R_t = \mathcal{M}R_t. \tag{12}$$

Notice that, together with households optimality conditions (6), equation (12) defines the equilibrium of the economy. That is, once the lending rate has been set by banks, households make their consumption (and, therefore, borrowing) decisions and the loans market clears.

We also assume that the banking sector displays short-run interest rate stickiness. In particular, we assume that banks cannot immediately adjust their lending rates in

[6] The presence of market power can be justified by the existence of switching costs, due to asymmetric information problems which typically lead to long-term relationships between banks and borrowers (see Diamond (1984) for example). Empirically, the presence of market power in the banking sector, as well as its determinants over the business cycle, are well documented. See for example Berger et al. (2004) and Degryse and Ongena (2008).

response to macroeconomic developments. The presence of interest rate stickiness in the banking sector can be justified by the presence of adjustment costs of and monopolistic power. For example, Hannan and Berger (1991) show that, in the presence of fixed adjustment costs, banks re-set their lending rates only if the costs of changing the interest rate are lower than the costs of maintaining a non-equilibrium rate (see also Neumark and Sharpe, 1992). Empirically, it is a well documented fact that the adjustment of banks lending rates to changes in the risk-free rate is only partial and heterogeneous, in particular in the short run. For example, Kwapil and Scharler (2010) show that interest rate pass-through of consumer loans in the U.S. can be as low as 0.3, implying that interest rates charged on consumer loans are smoothed heavily by banks. We therefore implement interest rate stickiness by means of a simple one-period real rigidity —while we assume that in the long-run interest rates are fully flexible.

In particular we assume that, if the risk free interest rate is hit by a temporary shock (υ) in period 0, only a fraction μ of the banks can update this information by resetting their prices, whereas the remaining $1-\mu$ banks cannot. This entails that, following a shock to the risk free interest rate, the average lending rate will be in general different from the one desired by banks: remembering that consumers are price takers and that their loans demand depends on the average interest rate in the economy, this friction will lead to a distortion in the competitive equilibrium and will create the scope for monetary policy intervention to restore efficiency. Moreover, given that the incomplete pass-through of changes in the risk free rate on lending rates is a realistic assumption only in the short run, we assume that from period 1 interest rates are again fully flexible.

Finally, notice that shocks to the interest rate in period 0 are observed by all agents before they take their decisions. We will consider three different scenarios: no shock to the risk free interest rate ($\upsilon = 0$), a temporary increase of the risk free rate ($\upsilon > 0$), and a temporary reduction of the risk free rate ($\upsilon < 0$). We can interpret these three scenarios as the result of a realized temporary "shock" to the risk free interest rate at the beginning of period 0. Specifically, the shock υ can be interpreted as a demand shock —such as a preference shock or a government spending shock— in a closed economy or as a foreign demand shock in a small open economy (see Harrison and Oomen (2010) and Cook and Devereux (2011), for example).

2.3 Shocks and parameter values

To be able to solve and simulate the model we need to make assumptions about few key parameters: the distribution of the stochastic endowment (e), the return of the asset (y), households preferences (ϱ), the degree of monopolistic competition in the banking sector (ζ), the risk free interest rate (R^*), the degree of interest rates stickiness (μ), and the size of the shocks to the interest rate (υ). Table 1 summarizes the parameter values assumed.

Table 1 Calibration of model's parameter

General			
Average Endowment	$\bar{e}$	1.3	Jeanne and Korinek (2010a)
Asset return	y	0.8	Jeanne and Korinek (2010a)
Risk free rate	R^*	1.015	Average 3M US T-Bill
Elasticity of Subst. (Loans)	ζ	33.3	250 b.p. spread of R_L on R^*
Risk Aversion Coefficient	ϱ	2	Standard value
Interest rate stickiness	μ	0.5	Kwapil and Scharler (2010)
Shocks			
Shock to the endowment	$\tilde{\epsilon}$	$[-\epsilon, +\epsilon]$	
Shock to the interest rate	υ	$[-0.02, +0.02]$	St. Deviation 3M US T-Bill

Note. 3M US T-Bill is the the average 3-Month Treasury Bill deflated with consumer prices; R_L is the 15-Year mortgage fixed rate deflated with consumer prices. U.S. monthly data from 1985 to 2007 3M.

Before describing the assumptions on the parameter values, we define the process driving the stochastic endowment received by household. We assume that the endowment e has expected value $\bar{e}$ and that it is subject to the following shock:

$$e = \bar{e} + \tilde{\varepsilon}, \tag{13}$$

where $\tilde{\varepsilon}$ is uniformly distributed over the $[-\varepsilon, +\varepsilon]$ interval (alternatively, this implies that the endowment e is uniformly distributed over the $[\bar{e} - \varepsilon, \bar{e} + \varepsilon]$ interval).

We will analyze the model's properties for different values of the maximum size of the shock to the endowment (ε): in particular, we will consider parameter values such that the economy may be constrained for sufficiently large negative shocks but would not be constrained in the absence of uncertainty. As shown in Appendix A, under these assumptions the model can be solved largely in closed form.

While it is possible to make reasonable assumptions for the majority of parameters, two degrees of freedom are left for the solution of the model: the return of the asset (y) and the expected value of the endowment ($\bar{e}$). Following Jeanne and Korinek (2010a), we assume $\bar{e} = 1.3$ and $y = 0.8$.

We calibrate the remaining parameters using U.S. data from 1985 to 2007, i.e. from the beginning of the Great Moderation to the global financial crisis. The gross risk free real interest rate is set to $R^* = 1.015$ in order to match the average yield of the 3-Month Treasury Bill (deflated with consumer prices) over the period 1985-2007. We set the elasticity of substitution between financial products to $\zeta = 33.3$, which implies a gross markup of $\mathcal{M} \simeq 1.03$. This markup yields approximately a spread of 250 basis points over the risk free interest rate, which is consistent with the average spread of the 15-

Year mortgage fixed rate over the 3-Month Treasury Bill rate.[7] Household preferences are given by a constant elasticity of substitution utility function, with a relative risk aversion coefficient $\varrho = 2$, which is a conventional value.

Under these assumptions, the model economy is never constrained when $\varepsilon \leq \varepsilon^b = 0.095$. That is, below the threshold ε^b, the constraint never binds, the probability of observing a crisis in period 1 is zero, and the model has a closed-form solution given by optimality conditions (6) together with $\lambda = 0$. In contrast, when $\varepsilon > 0.095$ there exists a positive probability that the constraint will bind in period 1: in this case the model does not have a closed-form solution and, therefore, the level of debt and consumption have to be solved numerically (as shown in Appendix A).

The calibration of the degree of interest rate stickiness (μ) is not trivial. Even if there is compelling evidence on the imperfect adjustment of retail interest rates rate to movements in the risk free rate, the degree of such rigidity is not consistently quantified. For the U.S., estimate a short-run pass through of 0.3 for consumer loans and of and 0.7 for mortgage loans.[8] Based on this evidence we assume that, in the short run, only 50 percent of the banks that can adjust their lending rates conditional to a movement in the interest rate. In the long-run, in contrast, pass through is assumed to be complete. Notice that, even if the value of μ is slightly larger than the empirical estimates in the literature, the calibration of this parameter does not affect the qualitative behavior of our model.

Finally, we assume that risk free interest rate is affected by a shock in period 0, such that:

$$R_1 = R^* + \upsilon, \tag{14}$$

where υ can take three values, namely $\upsilon = \{0, +0.02, -0.02\}$. The size of the shock matches the standard deviation of the yield on the U.S. 3-Month Treasury Bill over the 1985-2007 period.

3 Decentralized equilibrium

We can now analyze the decentralized equilibrium of the economy. In order to build intuition, we will consider first the effects of the financial friction —which manifests itself conditional on shocks to the endowment— by comparing the optimal allocations in our model economy with the allocations in an economy where the collateral constraint is

[7] Notice here that Gerali et al. (2010) set the elasticity of loan contracts to about 2.5, to match an average spread of 170 basis points of deposit rates on the policy rate. Our number differs from theirs because we assume that the markup is applied to gross interest rate (i.e., $\mathcal{M}R$) instead of the net interest rate (i.e., $1 + \mathcal{M}r$).

[8] These estimates are in line with older studies on interest rate pass-through in the U.S.. For example, Cottarelli and Kourelis (1994) estimate a short run pass through of 0.32 and a long run pass through of 1; Moazzami (1999) and Borio and Fritz (1995) report a short run coefficient of 0.4 and 0.34, respectively.

never binding. Second, we will analyze the effect of the macro friction —which manifests itself conditional on shocks to the risk free interest rate— by comparing the optimal allocations in our model economy with the allocations in an economy with fully flexible interest rates. Third, and finally, we will analyze the full model, when both frictions are at work simultaneously.

3.1 The financial friction

The financial friction affects the economy only when the collateral constraint is active with a positive probability. In particular, a shock ($\tilde{\varepsilon}$) to the endowment received by households, if large enough to make the collateral constraint binding, will lead to a downward spiral of declining consumption, falling asset prices, and tighter borrowing constraints typical of the financial accelerator models (as, for example, in Bernanke et al., 1996, Kiyotaki and Moore, 1997). We define the states in which the collateral constraint is binding as "crisis states" and the probability that the constraint will bind in period 1 (i.e., the crisis probability) as our measure of financial stability.[9]

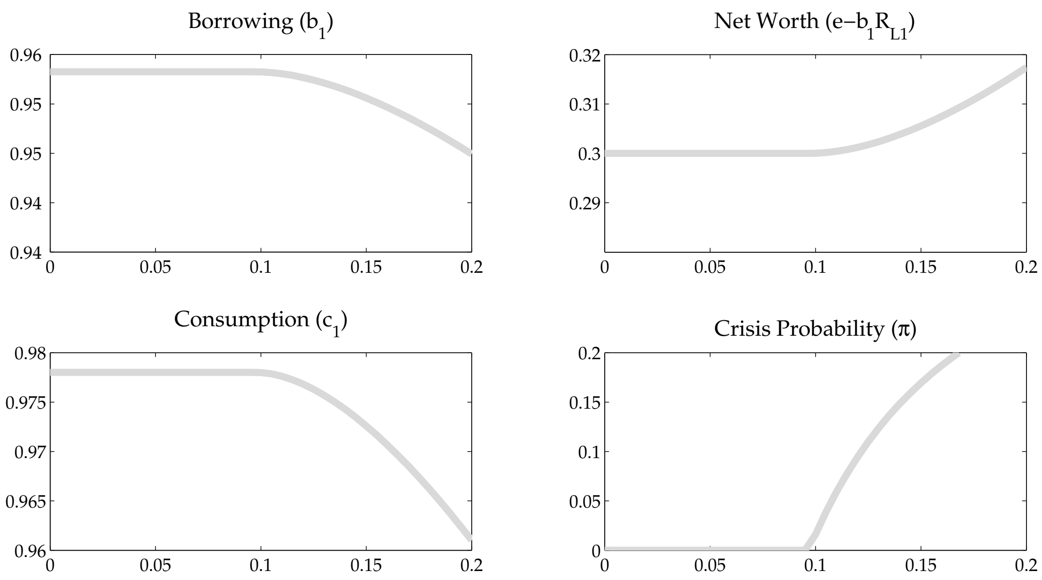
We consider different values of the maximum size of the shock (ε) so that i) the collateral constraint never binds (i.e., the shock $\tilde{\varepsilon}$ is not large enough to push the economy in the constrained region); and ii) the collateral constraint is occasionally binding (i.e., for large enough realizations of the shock $\tilde{\varepsilon}$ the economy may enter the constrained region and experience a financial crisis). As we discussed earlier, the threshold level of ε above which the collateral constraint may be binding with positive probability is $\varepsilon^b \simeq 0.095$.

Figure 2 displays the equilibrium allocation of some variables in our model for different values of the maximum size of the shock (ε), which is displayed on the horizontal axis. Specifically, the four panels of Figure 2 display equilibrium borrowing (b_1) in period 0, net worth ($e - b_1 R_{L1}$) and consumption (c_1) in period 1, and the probability of observing a crisis (π) in period 1.

When $\varepsilon \leq \varepsilon^b$ the economy is never constrained, otherwise it is constrained with positive probability. In particular, when the constraint is never binding, households' decisions are not affected by the size of the shock ε: if hit by a negative endowment shock, households can borrow from banks to keep their current and future consumption at their optimal level. In contrast, when the maximum size of the shock is above its threshold (ε^b), households take into account that there is a positive probability that the constraint will bind in period 1 and insure through two different mechanisms. First, they reduce their borrowing in period 0, so that their net worth next period will be higher; second, they reduce their consumption in period 1, so that their refinancing needs next period will be lower. Notice, however, that this does not imply that the

[9]Note that both Woodford (2012) and Benigno et al. (2012) define financial stability in these terms.

Figure 2 Model equilibrium with financial friction



Note. On the horizontal axis is the maximum size of the endowment shock (ϵ).

constraint will never be binding. In fact, the probability of a crisis (π) is positive and increases in a non-linear way with the maximum size of the shock to the endowment.

The intuition for the comparative statics in Figure 2 is the following. The Lagrangian multiplier λ in the Euler equation (6) represents the shadow value of the collateral constraint. When the shock to the endowment is not large enough to push the economy in the constrained region, $\lambda = 0$ and the economy achieves its first-best allocation. In contrast, when the shock is large enough, λ may be positive and increasing in the maximum size of the shock: therefore, the larger the maximum size of the shock, the larger is the value of λ and the level of precautionary savings undertaken by consumers.

3.2 The macroeconomic friction

Let's now analyze how the macroeconomic friction affects our model economy. As is well known from the standard New Keynesian literature, there are two potential distortions typical of models with monopolistic competition and staggered price setting. First, monopolistic power forces average output below the socially optimal level. Second, staggered price setting implies that both the economy's average markup and the relative price of different goods will vary over time *in response to shocks*, violating efficiency conditions.[10] As we shall see in the next section, our model displays both distortions.

[10] Not here that, if no shock pushes the economy away from its equilibrium, the average markup would be equal to the constant frictionless markup and the price of all goods in the economy would be the same, implying that no efficiency condition would be violated.

Let's assume for the moment that interest rates can freely adjust and that lending rates at the beginning of period 0 are set to the desired optimal level, namely a markup over the marginal cost ($R_{L1} = \mathcal{M}R^*$). If a positive shock $\upsilon > 0$ hits the economy, banks face a new, higher marginal cost and update their lending interest rates such that $R_{L1} = \mathcal{M}(R^* + \upsilon)$. Households update their loans demand accordingly and the loans market clears: in response to the higher interest rate, consumption and borrowing in period 0 fall relative to the case in which $\upsilon = 0$. This allocation (henceforth "flex-rates" allocation) is efficient conditional on the shock.

In a sticky-rates environment, in contrast, not all banks can reset their lending rate so as to be consistent with the new marginal cost. The fraction μ of banks that can reset lending rates will clearly set:

$$R^{\mu}_{L1} = \mathcal{M}(R^* + \upsilon),$$

In contrast, the remaining $1 - \mu$ banks will not be allowed to reset their lending rates even though their marginal cost has changed, implying that they are forced to apply a non optimal markup:

$$R^{1-\mu}_{L1} = R_{L1} = \widetilde{\mathcal{M}}(R^* + \upsilon) < R^{\mu}_{L1},$$

with $\widetilde{\mathcal{M}} < \mathcal{M}$.[11] As a consequence, the average lending rate in the economy can be computed as:

$$\bar{R}_{L1} = \mathcal{M}(R^* + \mu\upsilon),$$

which is, in the case of positive shocks to the interest rate, larger than the lending interest rate prevailing under the flex-rates regime.

The model properties analyzed in this section can be summarized as follows. In general, interest rates stickiness results in an average interest rate ($\bar{R}_{L1}$) which is different from the one required to obtain the flex-rates allocation, therefore affecting the aggregate level of borrowing and consumption. More specifically, the effect of interest rate stickiness on the equilibrium allocations of our decentralized economy is asymmetric and depends on the sign of the shock to the interest rate.

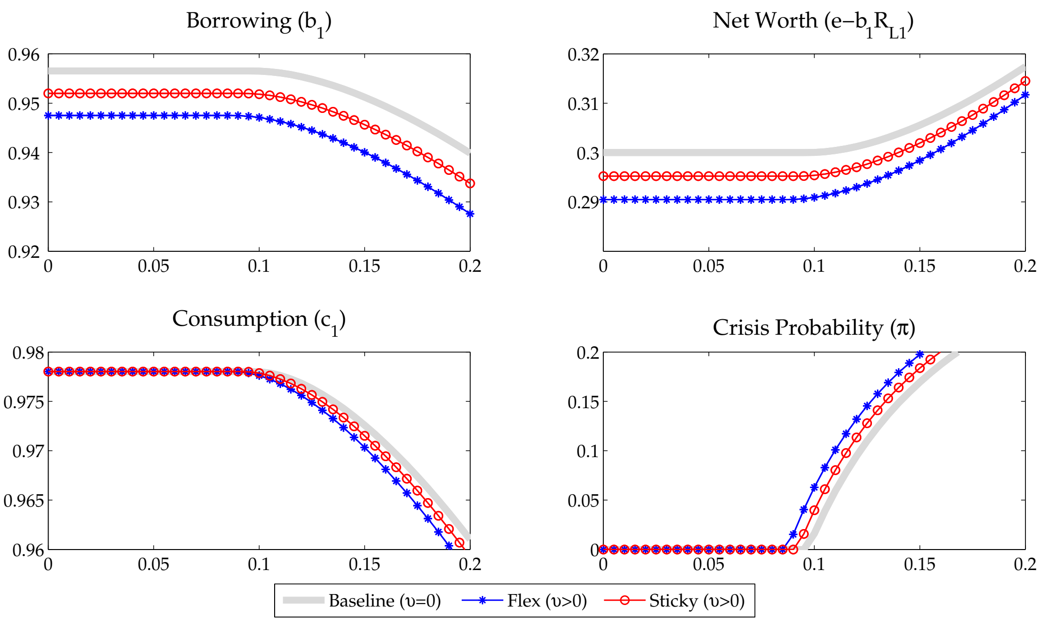
When a positive shock hits the interest rate, debt and consumption are higher than in the flex-rates economy, because interest rates increase by less than they would do in a fully flexible world. On the contrary, when a negative shock hits the economy, debt and consumption are lower than in the flex-rates economy, because interest rates decrease by less than they would do in a fully flexible world. As we shall see, this property has crucial implications for the results of our analysis when the macroeconomic friction interacts with the financial friction.

[11] Notice that the fraction of banks which cannot adjust their rates will keep them at the original level, i.e. $\mathcal{M}R^*$.

3.3 The interaction between the financial friction and the macroeconomic friction

Given that the model's behavior is asymmetric, let's analyze first the effect of a positive shock to the risk free interest rate (Figure 3). The benchmark is the economy with both frictions but no interest rate shocks (solid line, i.e. the same allocation as in Figure 2). The thin line with asterisk markers and the thin line with circle markers display the equilibrium after the shock under flexible and sticky interest rates, respectively.

Figure 3 Model equilibrium with both frictions - Positive Shock to the interest rate

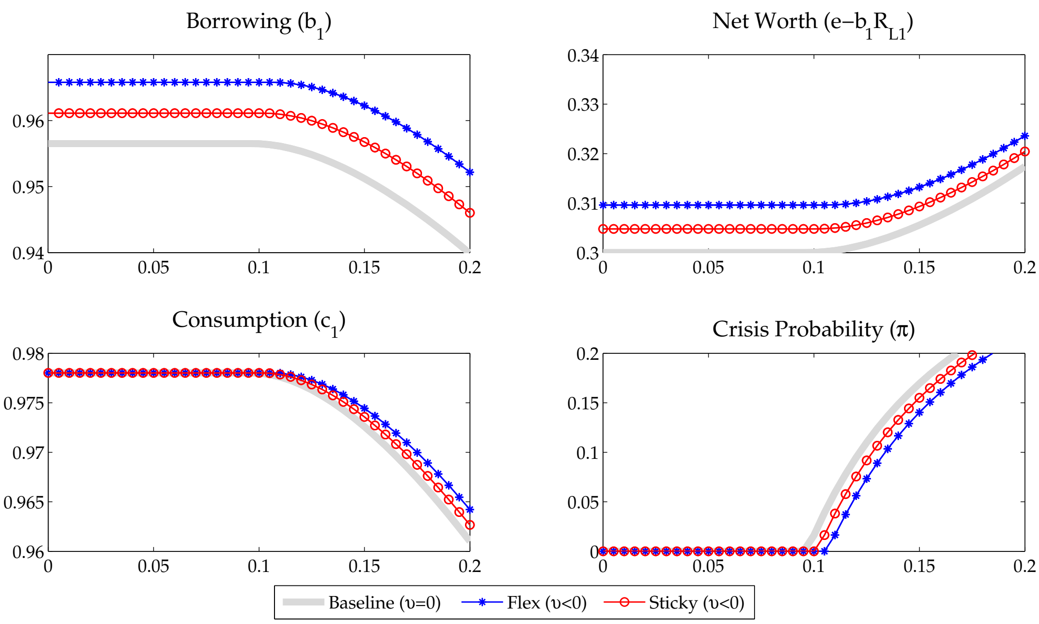


Note. On the horizontal axis is the maximum size of the endowment shock (ϵ). The thick solid line displays the equilibriums when no shock hits the risk free interest rate; the thin line with asterisk markers and the thin line with circle markers display the equilibrium after a positive shock hits the risk free rate under flex-rates and sticky-rates, respectively.

As we showed above, under the assumption of sticky interest rates, the average lending rate in the economy does not increase as much as the risk free rate following a positive shock. What are the implications for financial stability? On the one hand, lower lending rates —relative to the flex-rates case— prompt consumers to borrow more (b_1) in period 0 and to consume more (c_1) in period 1 relative to the efficient level, as showed by the difference between the circles line and the asterisks line. All else equal, this implies higher next period refinancing needs (b_2) and, therefore, higher probability that the constraint will be binding in period 1. On the other hand, and despite the higher level of borrowing in period 0, net worth ($e - b_1 R_{L1}$) in period 1 is larger under sticky-rates than under flex-rates, because of lower interest rate repayments. All else equal, this implies a relaxation of the borrowing constraint in period 1. The net effect is displayed in the bottom right-hand panel of Figure 3: when a positive shock hits the economy, with sticky interest rates the probability that the constraint will bind in period 1 increases by less than in the flex-rates case. This is because the effect of the interest rate shock on net worth dominates the effect on borrowing and consumption.

But the effect of staggered interest rates setting on the model equilibrium is not symmetric. In fact, in the case of a negative shock, sticky interest rates exacerbate the effects of the financial friction rather than dampening it. To see that, Figure 4 displays how the model equilibrium and the crisis probability vary in response to a negative shock to the risk free interest rate. Under interest rate stickiness, the average lending rate now falls by less than the risk free interest rate. As a consequence, the crisis probability under sticky-rates (circles line) is now larger than in the flex-rates case (asterisks line).

Figure 4 Model equilibrium with both frictions - Negative shock to the interest rate



Note. On the horizontal axis is the maximum size of the endowment shock (ϵ). The thick solid line displays the equilibriums when no shock hits the risk free interest rate; the thin line with asterisk markers and the thin line with circle markers display the equilibrium after a negative shock hits the risk free rate under flex-rates and sticky-rates, respectively.

Thus, the analysis of this section can be summarized by the following —positive— result:

Result 1 *When both the macroeconomic and the financial friction are present, sticky interest rates interact in an asymmetric fashion with the distortionary effects of the financial friction, depending on the sign of the shock hitting the economy. Interest rate stickiness exacerbates the distortion induced by the financial friction conditional* *on positive shocks to the interest rate, while it dampens the distortionary effects of the financial friction conditional on negative shocks to the interest rate.*

Note here that our qualitative results are robust to a different calibration of some key parameters —namely, the size of the shock to the interest rate (υ) and the degree of interest rate stickiness (μ). Changing these parameters does not affect the mechanisms driving the result, but only the magnitude of the effects. In other words, for every possible value of υ and μ the allocation under sticky-rates (circles line) is bounded between the allocation under flex-rates (asterisks line) and the allocation where no shock hits the economy (solid line).

4 Restoring efficiency

In this section we consider the allocation of a social planner who faces the same constraints of atomistic agents but addresses the market failures of our model economy (i.e., constrained efficient allocation). Then, we will show how a policy maker with a macro-prudential instrument (a tax on borrowing) and a monetary policy instrument (the policy interest rate) can address both distortions induced by the credit friction and the macroeconomic friction in the decentralized economy. In contrast, if the policy rate is the only available instrument, the policy maker faces a trade off between macroeconomic and financial stability when the economy is hit by negative shocks.

To build understanding and intuition for the main results, we first analyze the case in which there is only the financial friction or the macroeconomic friction. Then, we consider the case in which the policy authority faces both frictions with either one or two policy instruments.

4.1 Addressing the pecuniary externality

The pecuniary externality drives a wedge between private and socially optimal outcomes because atomistic agents do not internalize the effect of their individual decisions on a key market price entering the specification of the financial friction, regardless the sign of the shock. A social planner, unlike atomistic agents, can internalize that consumption decisions affect the asset price —as showed by the asset price equation in (6)— which, in turn, affects the aggregate collateral constraint in (4).[12]

Following Jeanne and Korinek (2010a), the planner's problem of this economy can

[12] See Benigno et al. (2012), Bianchi (2011), Bianchi and Mendoza (2011), Jeanne and Korinek (2010b) for a more detailed discussion.

be written as:

$$\max_{b_1,b_2} \mathcal{V} = u(b_1) + \mathbb{E}\Big[u\big(e + b_2 + \pi_1 - b_1 R_{L1}\big) + y - b_2 R_{L2}\Big] - \\ -\lambda^{sp}\left(b_2 - p_1(\underbrace{e + b_2 - b_1 R_{L1}}_{c_1})\right),$$

where the maximization is subject to the budget constraint (3), the aggregate borrowing constraint (4), and to the pricing rule of the competitive equilibrium allocation:

$$p_1(c_1) = \frac{y}{u'(c_1)},$$

where the asset price, $p_1(c_1)$, is now a function of aggregate consumption.

The corresponding first order conditions are:

$$\begin{aligned} u'(c_0) &= R_{L1}\mathbb{E}\big[u'(c_1) + \lambda^{sp} p'(c_1)\big], \\ u'(c_1) &= R_{L2} + \lambda^{sp}(1 - p'(c_1)). \end{aligned} \tag{15}$$

By comparing (6) and (15) and noting that $p'(c_1) > 0$, it is clear that there is a wedge between the decentralized and the social planner allocation: the social planner saves more than the competitive agents whenever the borrowing constraint is expected to bind in period 1 with positive probability (i.e., whenever $\mathbb{E}[\lambda^{sp}] > 0$). This reflects the fact that the social planner internalizes the endogeneity of next period's asset price to this period's aggregate saving. As a consequence, when the constraint never binds, the allocation of resources in the economy is efficient (ignoring the other frictions in the model). However, when there is a positive probability that the constraint binds in period 1, the allocation is not efficient. Consumption and borrowing in the decentralized equilibrium are excessive relative to the allocation chosen by the social planner (i.e., there is overborrowing in the parlance of the literature). As a result, the crisis probability is also higher in the decentralized equilibrium relative to the social planner equilibrium.

In this set up, Jeanne and Korinek (2010a) showed that an efficient allocation can be restored in the decentralized economy by imposing a Pigouvian tax on borrowing in period 0, namely $b_1(1-\tau)$, which is rebated with transfers (TR) in a lump-sum fashion. The optimal tax is given by:

$$\tau = \mathbb{E}\left[\frac{\lambda^{sp} p'(c_1)}{u'(c_1)}\right], \tag{16}$$

This equation states that whenever the borrowing constraint binds in period 1 with positive probability, the policy maker imposes a positive tax on borrowing in period 0, prompting atomistic agents to issue less debt in period 0 than under decentralized equilibrium. This is because both the shadow value of the collateral constraint (λ^{sp}) and the derivative $p'_1(c_1)$ are positive.

4.1.1 Addressing the pecuniary externality with the interest rate

A Pigouvian tax on borrowing may be difficult to implement. But the constrained efficient allocation can also be decentralized with the interest rate. The policy maker can equally reduce households' borrowing by increasing lending interest rates. For instance the policy maker (e.g., a central bank in this specific case) can increase the interest rate at the beginning of period 0, affecting banks marginal cost and, therefore, consumers' borrowing and consumption decisions.

This increase in interest rates —if rebated with lump sum transfers (TR)— has the same effect of the Pigouvian tax analyzed above. To see this, assume for simplicity that the central bank can affect the interest rate by an additive factor ψ, so that the marginal cost for banks would be given by $R^* + \psi$. The consumers' maximization problem becomes:

$$\begin{aligned}\max_{b_1,b_2,\theta_1,\theta_2} \mathcal{V} &= u(b_1) + \mathbb{E}\Big[u\big(e + b_2 + \pi_1 - b_1\mathcal{M}(R^* + \psi) + TR\big) + \\ &\quad + y - b_2 R_{L2}\Big] - \lambda^{sp}(b_2 - p_1).\end{aligned}$$

By equalizing the first order condition with respect to b_1 of the decentralized equilibrium and the social planner equilibrium, we can derive the level of ψ which closes the wedge:

$$\begin{cases} u'(c_0) = R_{L1}\mathbb{E}\big[u'(c_1) + \lambda^{sp} p'(c_1)\big], \\ u'(c_0) = \mathcal{M}(R^* + \psi)u'(c_1), \end{cases}$$

Solving for ψ yields:

$$\psi = \mathbb{E}\left[\frac{\lambda^{sp} p'(c_1)}{u'(c_1)}\right] R^*. \tag{17}$$

Notice that as long as the shadow value of the collateral constraint (λ^{sp}) is different from zero, ψ is positive and can be interpreted as a prudential "markup" factor on the risk free interest rate. This, in turn, implies that whenever the constraint is binding with positive probability, the central bank would raise interest rates so that households consume less and issue less debt in period 0, reducing the probability of hitting the constraint in case of an adverse shock in period 1. The following remark summarizes the result.

Remark 1 *When the credit constraint is the only friction in the economy and the policy rate is the only instrument, a social planner can achieve constrained efficiency by increasing interest rates in period* 0*. This allocation is isomorphic to the one obtained with the Pigouvian tax on debt analyzed in the previous section.*

Thus, it may seem that monetary policy can address financial stability and achieve constrained efficiency. As we shall see below, however, this is not always the case: when both frictions are present it will depend on the sign of the shock hitting the economy.

4.2 Addressing monopolistic competition & interest rate stickiness

Our simple model is characterized by two macroeconomic distortions, whose implications are usually analyzed separately. The first distortion is the presence of market power in the loan markets, exercised by monopolistically competitive banks. The second distortion results from our assumption of infrequent adjustment of lending rate by banks. In this section we discuss why these distortions imply a deviation from the efficient allocation that would be chosen by a social planner, and we show which policies can be enacted to restore efficiency.

Monopolistic competition in the banking sector implies a inefficiently low level of consumption, because lending interest rates are, on average, higher than under perfect competition. As it is standard in the New Keynesian literature, this inefficiency could be eliminated in the decentralized economy through the suitable choice of a subsidy to interest rate repayments such that:

$$R_{Lt} = \underbrace{\mathcal{M}(1-\eta_t)}_{1} R_t.$$

Hence, the optimal allocation can be attained if $\mathcal{M}(1-\eta_t) = 1$ or, equivalently, by setting $\eta = \zeta$. By construction, in this case, the equilibrium is efficient. However, given that addressing this friction does not change the main properties of the model, in what follows, we solve the model without removing monopolistic competition.[13]

Staggered interest rate setting constitutes a source of inefficiency on two different grounds. Specifically, in response to shocks, interest rate stickiness implies that (i) the economy's average markup will generally differ from the constant frictionless markup; and (ii) the interest rate charged on different loans in the economy will not be the same. This violates efficiency conditions because the varying markup and the interest rate dispersion in the economy will lead to different borrowed and consumed amounts in the decentralized economy.

One way to unwind the consequences of interest rate stickiness is to implement a policy that affects interest rate in the loans market. Assume, for simplicity, that the central bank is in charge of this policy and that it can affect the interest rate by an additive factor ψ. Thus, the marginal cost for banks —conditional to a shock to the risk free interest rate— would be given by $R^* + \upsilon + \psi$. Then, the central bank would

[13]Notice that in a model without monopolistic competition but with interest rate rigidities, any increase in marginal cost would lower the ex-post markup below one. Therefore, without monopolistic competition, interest rate stickiness would be inconsistent with the rational behavior of firms. With monopolistic competition, as long as the shocks are not too large, firms' ex-post markups will always remain above one.

set:

$$\psi : \bar{R}_{L1} = \mathcal{M}(R^* + \upsilon),$$

which is the efficient level of the lending interest rate in the undistorted economy. Solving this equality yields:

$$\psi = \frac{1-\mu}{\mu}\upsilon. \tag{18}$$

Hence, in response to a positive shock to the risk free rate ($\upsilon > 0$), the central bank would raise interest rates above the competitive equilibrium level by the factor $\psi > 0$; in contrast, in response to a negative shock to the risk free rate ($\upsilon > 0$), the central bank would lower interest rates below the competitive equilibrium level by the factor ψ < 0.

To see why this would be a decentralized equilibrium, note the following: in response to such policy intervention, banks that can adjust their interest rates would do so and take an optimal decision; in contrast, banks that are not allowed to change their interest rates would not be optimizing anyway. But consumers would face the same aggregate interest rate prevailing without sticky-rates (that is, as in the undistorted economy) and hence make optimal decisions.

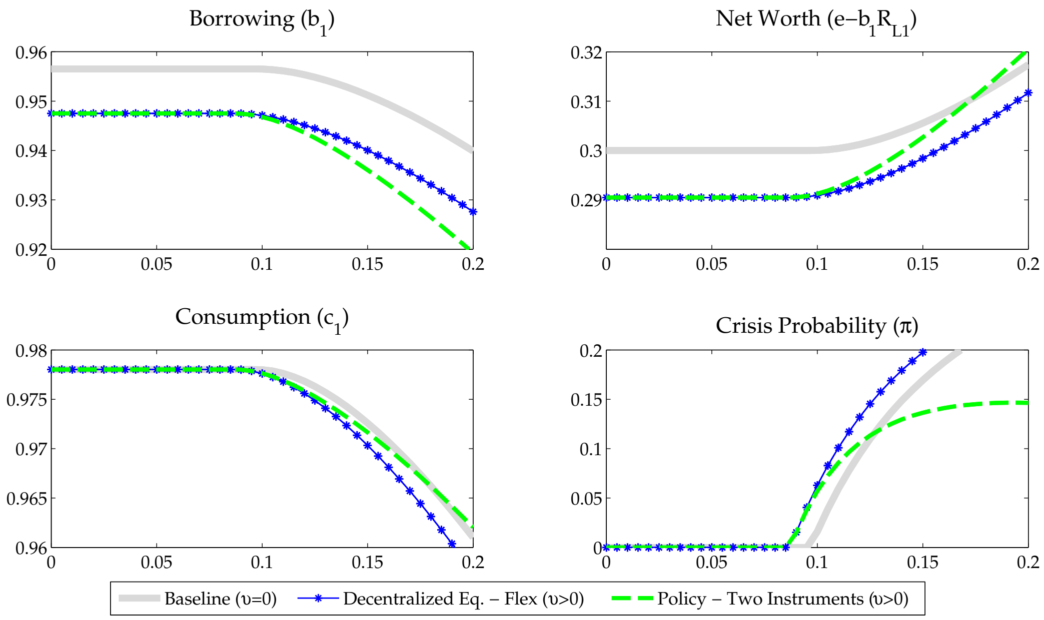
4.3 Addressing both frictions with two instruments

We now analyze how to implement the constrained efficient allocation in the decentralized economy when both frictions are present and two instruments are at the policy maker's disposal. Specifically, we consider a policy maker that maximizes the expected utility of consumers (5), subject to their budget constraints (3) and borrowing constraints (4). We assume that the policy maker has two instruments to address the two frictions in the economy: the wedge on the interest rate (ψ) to address the macroeconomic friction and a prudential tax on debt (τ) to address the financial friction.

It is important to note here that, when two instruments are available, the policy maker can address the macroeconomic and financial stabilization problems separately. This is regardless of whether a single policy authority is in charge of both monetary and financial-stability policy (e.g., a central bank) or whether one authority is in charge of monetary policy and the other is in charge of macroprudential policy. In other words, in our set up, there are no incentives for a central bank and a financial stability authority to deviate from a coordinated equilibrium.

With these considerations in mind, consider first a positive shock to the risk free interest rate. The dashed line of Figure 5 displays the model equilibrium and the crisis probability when the policy maker restores efficiency. Figure 5 also displays two allocations that were already analyzed in the previous sections: the competitive equilibrium where no shock hits the economy and interest rates are flexible (thick solid line) and

Figure 5 Model efficient allocation with both frictions - Positive shock to the interest rate



Note. On the horizontal axis is the maximum size of the endowment shock (ϵ). The thick solid line displays the equilibriums when no shock hits the risk free interest rate; the thin line with asterisk markers displays the equilibrium after a positive shock hits the risk free rate under flex-rates; the dashed line displays the efficient allocation with two policy instruments.

the competitive equilibrium where a positive shock hits the economy and interest rates are flexible (asterisks line).

The policy maker restores efficiency by undertaking two independent policy actions, one for each distortion in the economy. Consider first the macroeconomic friction and then the financial friction.[14] Hence, the policy maker first raises interest rates by a factor $\psi > 0$ to restore the average lending rate that would prevail under flex-rates, moving the economy to the flex-rates competitive equilibrium (asterisk line). Then, the policy maker imposes a distortionary tax on debt (τ) to restore the efficient level of borrowing, moving the economy to the constrained efficient equilibrium (dashed line).

Note here that, as shown in equation 16, the optimal level of τ is zero when the constraint never binds and positive when the constraint is expected to bind with positive probability in period 1. Figure 5 shows that when $\varepsilon \leq \varepsilon^b$ the asterisks line and dashed line coincide. However, when $\varepsilon > \varepsilon^b$ the tax on borrowing is positive, borrowing in period 0 is lower than in the flex-rates competitive equilibrium (upper-right panel of Figure 5), while consumption in period 1 is is larger (lower-right panel of Figure 5). That is, whenever the collateral constraint is expected to bind with a positive probability, the policy maker forces atomistic agents to borrow less in period 0 —therefore increasing

[14]Note here that changing the order of the policy actions would not alter the results.

their net worth next period— and to consume more in period 1, thereby reducing the probability of a financial crisis.

Another way to see this is by looking at the bottom right-hand panel of Figure 5, which illustrates the extent to which the social planner insures the economy against adverse shocks in terms of crisis probability. Whenever the constraint is binding with positive probability, the probability of a crisis under a policy maker addressing both frictions (dashed line) is always lower relative to the competitive equilibrium with flexible rates (asterisks line).

Consider now a negative shock to the risk free interest rate (Figure 6). Again, the two frictions are addressed separately. To address the financial friction —and independently of the sign of the shock— the policy maker imposes a positive tax on debt whenever there is a positive probability that the constraint will bind in period 1. However, and differently from the case of a positive shock, when a negative shock hits the economy, the policy maker lowers interest rates ($\psi < 0$) to address the macroeconomic friction and achieve constrained efficiency.

The following statement summarizes these results:

Remark 2 *With two instruments, for example a macro-prudential tax on borrowing and the policy interest rate, a policy maker can address both the financial and the macroeconomic friction and achieve constrained efficiency in the decentralized economy, independently of the sign of the shock hitting the economy.*

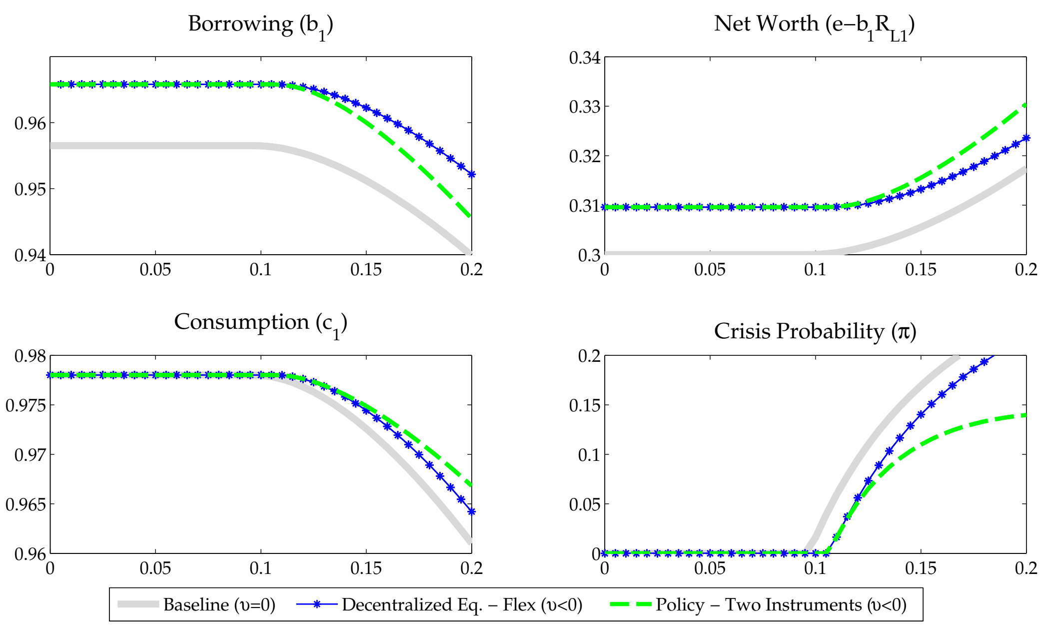
4.4 The trade off: addressing both frictions with one instrument

Let's now consider the case in which both frictions are present but the interest rate is the only instrument at the policy maker's disposal.

Before proceeding it is useful to recall that, in our model, the financial friction results in more borrowing than socially desirable in period 0 when the collateral constraint has a positive probability to bind in period 1, regardless of the sign of the shock. In contrast, the macroeconomic friction generates either more or less borrowing than socially desirable depending on whether the economy is hit by a positive or a negative shock. It is thus evident that, if the policy maker has only one instrument, she/he may face a trade off in the face of negative shocks when the economy requires interventions in opposite direction.

Consider a positive shock to the risk free interest rate. As we showed before, both the macroeconomic and the financial friction result in higher borrowing in period 0 relative to the socially efficient allocation. To address the macroeconomic friction, the policy maker can raise interest rates by the factor $\psi = (1 - \mu)\, \upsilon / \mu > 0$, as implied by equation

Figure 6 Model efficient allocation with both frictions - Negative shock to the interest rate



Note. On the horizontal axis is the maximum size of the endowment shock (ϵ). The thick solid line displays the equilibriums when no shock hits the risk free interest rate; the thin line with asterisk markers displays the equilibrium after a negative shock hits the risk free rate under flex-rates; the dashed line displays the efficient allocation with two policy instruments.

(18); and, to address the financial friction, she/he can further raise interest rates by the factor $\psi = \mathbb{E}\left[(R^{*}\lambda^{sp}p'(c_1))/u'(c_1)\right] > 0$, as implied by equation (17). Therefore, when a positive shock hits the economy, a single instrument can attain constrained efficiency.

However, when a negative shock hits the economy, the macroeconomic friction and the financial friction require opposite action on the interest rate. The macroeconomic friction requires a decrease in interest rates: given that interest rates fall by less than in the flexible rate case, the social planner intervenes to lower interest rates by the factor $\psi = -(1-\mu)\,\upsilon/\mu < 0$. In contrast, the financial friction requires an increase in interest rates independently of the sign of the shock. Hence, if the interest rate is the only instrument, the social planner would try to lower interest rates to address the macroeconomic friction and, at the same time, to raise interest rate to address the financial friction: not only he will not achieve the efficient allocation, but he will also face a trade off between financial and macroeconomic stability in this case.

Summarizing, the above analysis brings forth the second main result of the paper:

Result 2 *When both the macroeconomic and the financial frictions are present, if the policy interest rate is the only available instrument, a social planner that aims to achieve both macroeconomic and financial stability faces a policy trade off. In particular, the* *trade off emerges when the economy is hit by negative interest rate shocks, because addressing both distortions requires interventions of opposite sign on the interest rate.*

This result is consistent with the findings of Kashyap and Stein (2012), who raise the issue of the potential conflicts between price stability and financial stability when the policy rate is the only policy instrument. Formally, they show that the introduction of a second instrument (interest payments on reserves, in their model) can resolve such trade off. Our result above not only corroborates their result in a different setting, but also stresses the possibly asymmetric nature of the trade off between macroeconomic and financial stability.

5 Implications for monetary policy and financial stability

The results in the previous section have interesting implications for the debate on the role of U.S. monetary policy in the run up to the global financial crisis. Under former Chairman Alan Greenspan, the Federal Reserve lowered its benchmark rate from 6.5 percent to about 2 percent in 2000-01, as a response to the burst of the dot-com bubble; it further lowered interest rates to 1 percent in 2002-03; and finally started a long sequence of monetary policy tightening actions that, during the 2004-06 period, brought the federal fund rate back to 5 percent (Figure 1).

Against this background, Taylor (2007) put forth the idea that the Federal Reserve helped inflate U.S. housing prices by keeping rates too low for too long as from 2002. His main argument started from the observation that the policy rate was well below what implied by a standard Taylor rule, a good approximation to the conduct of monetary policy in the previous several years (Figure 1). As a consequence, "*those low interest rates were not only unusually low but they logically were a factor in the housing boom and therefore ultimately the bust*".[15] Therefore, according to this view, higher interest rates would have reduced both the probability and the severity of the bust that led to the great recession.

In this section we evaluate this claim against the qualitative predictions of our model. In particular, we will show that Taylor's argument can be rationalized within the logic of our model only if we make the following auxiliary assumptions: the policy authority is responsible for financial stability —besides the traditional objective of price stability— and it has only one instrument at its disposal. However, the argument is no longer valid within the logic of our model if the policy authority has two instruments to address the macroeconomic and the financial friction or, as we showed in the previous section, when there are two different policy authorities for macroeconomic and financial stability with

[15] John Taylor, interviewed by Bloomberg at the American Economic Association's annual meeting, Atlanta, January 5, 2010, available at:
http://www.bloomberg.com/apps/news?pid=newsarchive&sid=a44P5KTDjWWY

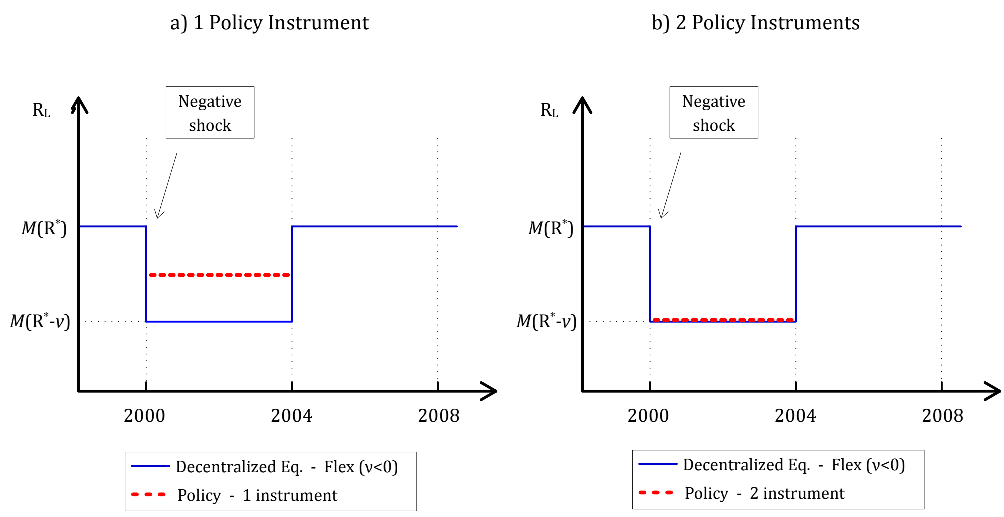
one instrument each. In the latter case, which is the institutional set up prevailing in the U.S., in response to a negative aggregate demand shock, the "optimal" response of the central bank is to slash interest rates, without concerns for financial stability that is addressed with the second instrument (or by the other authority). As we discuss below, the evidence suggests that the U.S. regulators were at best ineffective in curbing the continued expansion of subprime mortgage lending well past the point at which prime lending had started to decline. We conclude from this analysis that Taylor's claim that U.S. monetary policy is to blame for the great recession is not justified within the logic of our model, given the regulatory regime prevailing in the U.S. and the evidence we report on its inability to curb subprime while monetary policy was tightening during the period 2004-06.

To assess Taylor's contention through the lenses of the model, consider a negative shock hitting the economy, as the one realized in March 2000 when the dot-com bubble burst. Set the beginning of period 0 as the year 2000 and assume that the economy comes back to its pre-shock level of activity after four years, namely at the beginning of 2004 —consistent with the fact that the policy rate was raised for the first time in July 2004. Therefore, each time period in our model corresponds to about 4 years in the data.

Figure 7 reports the qualitative behavior of the lending interest rate —as implied by our model— when a negative shock hits the economy. We consider two policy regimes. First, the policy maker has just one instrument to address both frictions (Panel a). Second, the policy maker has two separate instruments to address the macroeconomic and the financial friction (Panel b). Notice that each panel of Figure 7 reports the behavior of two interest rates. The solid line is the lending rate that would prevail when there is no interest rate stickiness and no policy action is undertaken (i.e., in the decentralized economy when interest rates are fully flexible) and will serve as a benchmark. The dashed line is the lending interest rate that would prevail when interest rate stickiness is present and under the two policy regimes analyzed.

As summarized by Result 2 in the previous section, if the policy rate is the only instrument, there is a trade off between macroeconomic and financial stability conditional on a negative shock to our model economy. To achieve the efficient allocation, the policy maker ought to move interest rates in opposite directions. On the one hand, she would have to lower interest rates to restore the average lending rate that would prevail in the absence of interest rate stickiness. On the other hand, she would have to raise them to contain the overborrowing generated by the pecuniary externality. As a result interest rates in this environment would be set higher than the level predicated by focusing only on macroeconomic stability, as it is illustrated by the left-hand panel of Figure 7: assuming that the weight attached to macroeconomic and financial stability is the same, average lending interest rates would fall by less than in the flex-rates case. Therefore, under this regime, our model is consistent with Taylor's argument in

Figure 7 Alternative path of the lending interest rate under different assumptions about the number of instruments at policy maker's disposal



Note. *Decentralized Eq. - Flex* ($\nu < 0$) displays the lending interest rate in the decentralized economy under fully flexible interest rates; *Policy* displays the lending interest rate that would prevail with a policy maker addressing both the macroeconomic and the financial frictions with one or two instrument, respectively.

the sense that it suggests to keep interest rates higher than the flex-price case to avoid excessive borrowing, large asset price increases, and to reduce the probability of a crisis if the economy is hit by a negative shock in the future.

The results are different when the policy maker has two separate instruments to address the financial and the macroeconomic friction. As noted above, this is equivalent to the case in which there are two separate and independent policy authorities, such as for example a central bank with the objective of price stability and a financial regulator with the objective of financial stability. As stated in Remark 2, in this case, the policy maker can achieve efficiency with two independent policy actions, regardless of the sign of the shock. Therefore, once the overborrowing generated by the financial friction is addressed with a macro-prudential tool, it is optimal for the central bank to lower interest rates in order to address interest rate stickiness and restore the flex-rates allocation. As a matter of fact, the right-hand panel of Figure 7 displays how the average lending rate under this regime (dashed line) is effectively equal to the one prevailing under the flexible interest rates (solid line).

In the U.S., institutional responsibility for financial stability is shared among a multiplicity of agencies. Therefore, for Taylor's contention to be justified within our model, we would have to observe an effective regulatory clampdown on mortgage lending during the period in which monetary policy was unusually lax by the Taylor's rule standard. As we shall see below, the regulatory effort to contain mortgage lending during the period 2003-06 was at best ineffective, if not absent altogether. The evidence we report, therefore, provides support to the idea that regulation (or, more exactly, the lack of thereof) was a key factor in determining the magnitude of the boom-bust cycle experienced by the U.S. housing market rather than monetary policy *per se*.

Since the Glass-Steagall Act of 1932, U.S. depository institutions (e.g., banks, thrifts, credit unions, savings and loans, etc.) have been regulated rather tightly by different federal agencies.[16] In contrast, non-depository mortgage originators, emerged in the early 1980s as a consequence the federal financial deregulation, have enjoyed much more lax regulation even when they were subsidiaries of bank holding companies (see Engel and McCoy, 2011, Demyanyk and Loutskina, 2012). Moreover, as it is well known, the rise of securitization was accompanied by a shift in the structure of the mortgage industry from an originate-and-hold model to an originate-and-distribute model. Note here that, well before the crisis, financial intermediation theory pointed out the risks associated with this shift, with securitization potentially leading to a reduction of financial intermediaries' incentives to carefully screen borrowers (see Diamond and Rajan, 2001, Petersen and Rajan, 2002). Given the picture emerging from these considerations, regulators should have been already on the alert.

Figure 8 provides a picture of the evolution of the U.S. mortgage market and monetary policy over the 2000-07 period. Broadly speaking, the picture shows that, after the Federal Reserve started to tighten its monetary policy stance and the prime segment of the mortgage marketed turned around, the subprime segment of the market continued to boom, with increased perceived risk of loans portfolios and declining lending standards. Despite this evidence, the first regulatory action was undertaken in late 2006, after almost two years of steady increases of the federal funds rate.

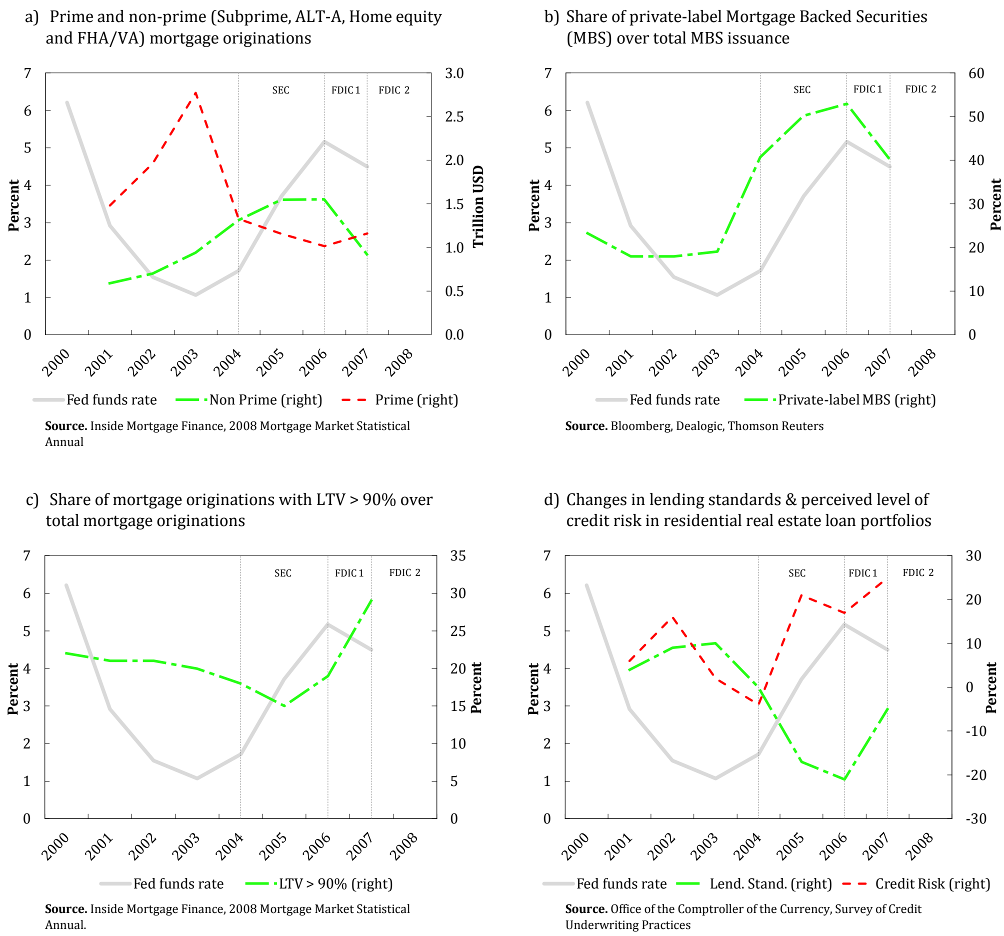
The upper-left panel of Figure 8 (Panel a) reports the evolution of the federal funds rate (annual average) together with mortgage originations by category over the period 2001-2007. While prime mortgage originations started to fall in 2003, non-prime mortgage originations continued to increase in 2004 and 2005.[17] As a matter of fact, the share of non-prime mortgage over total mortgage originations went from about 20 percent in 2001 to more than 50 percent in 2006, experiencing the largest increase in 2004, while the Federal Reserve was already tightening its monetary policy stance. A similar pattern emerges by looking at the issuance of mortgage backed securities (MBS).[18] The

[16]For instance, The Office of the Comptroller of the Currency is in charge of nationally chartered banks and their subsidiaries. The Federal Reserve covers affiliates of nationally chartered banks. The Office of Thrift Supervision oversees savings institutions. The Federal Deposit Insurance Corporation insures deposits of both state-chartered and nationally chartered banks.

[17]By prime loans we refer to loans that conform to Government Sponsored Enterprises (GSE) guidelines; by non-prime loans we refer to Alt-A, Home Equity, FHA/VA, and subprime mortgages.

[18]MBS which are issued or guaranteed by a government sponsored enterprise (GSE) such as Fannie Mae or Freddie Mac are referred to as "agency MBS". Some private institutions, such as subsidiaries

Figure 8 Monetary policy and the U.S. housing sector



upper-right panel of Figure 8 (Panel b) in fact displays how the share of private label MBS sharply increased in the 2003-06 period.

The lower-left panel of Figure 8 (Panel c) reports the federal funds rate together with the share of mortgage originations with a Loan-to-Value (LTV) ratio greater than 90 percent. Note here that, while the use of counter-cyclical LTV ratios has been suggested —and in some emerging market economies has already been adopted— as a macro-prudential policy tool, the share of high LTV ratio mortgages in the U.S. spiked in 2005, two years after the beginning of the monetary policy tightening.

Finally, the lower-right panel of Figure 8 (Panel d) reports additional evidence on the fact that, while loan quality was relatively stable or improving from 2000 to 2003, it deteriorated sharply from 2004 to 2007. The Office of the Comptroller of the Currency publishes an annual underwriting survey to identify trends in lending standards

of investment banks, banks, financial institutions, non-bank mortgage lenders and home builders, also issue mortgage securities, the so-called "private label" MBS.

and credit risk for the most common types of commercial and retail credit offered by national banks. Using data from the 2009 survey, conducted on fifty-two banks engaged in residential real estate lending, Panel (d) reports the evolution of changes in underwriting standards (dash-dotted line) and the perceived level of credit risk (dashed line) in residential real estate loan portfolios.[19] The figure shows that, while the level of perceived risk was sharply increasing starting from 2004, banks started easing their lending standards from 2003 and did even more so in the 2004-05 period.

Despite this evidence, U.S. regulators did not take action while monetary policy was being tightened. On the contrary, for instance, the SEC proposed in 2004 a system of voluntary regulation under the Consolidated Supervised Entities program, allowing investment banks to hold less capital in reserve and increase leverage that might have contributed to fueling the demand for mortgage backed securities (vertical line in our charts under label SEC).

When regulators finally decided to act, it was too late. It was not until September 2006 that regulators agreed on new guidelines (vertical line under label FDIC 1) aimed at tightening "non-traditional" mortgage lending practices. Note however that, even if it served as a signal to the mortgage market of changing direction of regulatory policy, the new underwriting criteria did not apply to subprime loans, whose standards were discussed in a subsequent regulatory action which was introduced in June 2007 (vertical line under label FDIC 2). By that time, more than 30 subprime lenders had gone bankrupt and many more followed suit.

In summary, the evidence above suggests that Taylor's contention that excessively lax monetary policy might have contributed to the occurrence and the severity of the great recession does not appear justified within the logic of our model. Indeed, in the context of a framework in which the regulatory and monetary policy functions are assigned to different agencies that can rely on different instruments, the evidence above suggests that monetary policy was appropriately targeting macroeconomic stability. The regulatory function of the system, instead, was at best ineffective in addressing the financial imbalance that continued to growth in the subprime mortgage market while monetary policy was tightened in 2004-05. With the drop in interest rates after the burst of the dot-com bubble and with house prices at bubble-inflated prices, the mortgage industry found creative ways to expand lending and make large profits. Government regulators maintained a hands-off approach for too long: even though the variables plotted are equilibrium outcomes, Figure 8 shows that policy measures aimed at tightening a largely unregulated sector of the U.S. mortgage market kicked in much later than the tightening enacted by the Federal Reserve.

[19] Net percentage calculated by subtracting the percent of banks tightening from the percent of banks easing. Negative values, therefore, indicate easing.

6 Conclusions

We develop a simple model featuring both a macroeconomic and a financial stability objective that speaks to the interaction between monetary and macro-prudential policies. There are two main points.

First, the analysis of our decentralized economy shows that real interest rate rigidities interact in an asymmetric fashion with the distortionary effects of the financial friction, depending on the sign of the shock hitting the economy. In response to positive shocks to the risk free interest rate, the real rigidity acts as an automatic macro-prudential stabilizer. In contrast, when the risk free interest rate is hit by a negative shock, the same real rigidity fosters financial instability.

Second, if the interest rate is the only available policy instrument, achieving the monetary policy objectives and maintaining financial stability entails a trade off that should be taken into account by the policy authority. Specifically, the use of the policy interest rate as the only instrument to address both macroeconomic and financial frictions might lead to policy conflicts. Normally, however, other instruments are at policy makers' disposal in order to achieve and maintain financial stability. Our model shows that, when two instruments are available, the trade off disappears.

This second result has important implications concerning the debate on the role played by U.S. monetary policy for the stability of the financial system in the run up to the global crisis. In a series of papers Taylor (2007, 2010) suggests that higher interest rates in the 2002-2006 period would have reduced both the probability and the severity of the crisis. Our findings support this argument only if we make the auxiliary assumption that the policy authority —addressing all distortions present in our model— has just one instrument at its disposal, namely the policy rate. In contrast, when the policy authority has two different instruments, interest rates can be lowered as much as needed without concerns for financial stability, supporting the view of Bernanke (2010) that additional policy tools were needed to prevent the global financial crisis.

Hence, our simple model suggests that the monetary function of the Federal Reserve system cannot be blamed for the crisis without strong auxiliary assumptions. Indeed, our model suggests that it was the absence of an effective regulatory function that could have lead to the excesses that preceded the global financial crisis.

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A Appendix. Numerical Solution

Preliminaries. The first order conditions of the competitive equilibrium (CE) are:

$$\begin{cases} FOC(b_1): & u'(c_0) = R_{L1}\mathbb{E}\left[u'(c_1)\right], \\ FOC(b_2): & u'(c_1) = R_{L2} + \lambda, \\ FOC(\theta_2): & p_1 = y/u'(c_1). \end{cases}$$

The presence of the Lagrange multiplier shows that consumers are aware of the financial friction. In fact, they know that, in case of an adverse shock to the endowment, the might not be able to borrow as much as they would like. Therefore, whenever the collateral constraint is expected to bind at time 1 (i.e., whenever $\mathbb{E}\left[\lambda\right] > 0$), they reduce their optimal amount of consumption at time 0 and 1.

When the economy is not constrained ($\lambda = 0$) the model has the following close form solution:

$$\begin{cases} u'(c_1) = R_{L2} \\ u'(c_0) = \mathbb{E}\left[R_{L2}R_{L1}\right], \\ p_1 = \frac{y}{R_{L2}}. \end{cases} \implies \begin{cases} c_1^* = (R_{L2})^{-\frac{1}{\varrho}} \\ c_0^* = b_1^* = (R_{L2}R_{L1})^{-\frac{1}{\varrho}}, \\ p_1^* = \frac{y}{R_{L2}}. \end{cases}$$

Moreover, by definition, the collateral constraint must hold when the economy is not constrained[20]:

$$\underbrace{b_2^*}_{c_1^*+b_1^*R_{L1}-e} \leq \underbrace{p_1^*}_{\frac{y}{R_{L2}}},$$

which we can rewrite as:

$$e \geq e^b \quad = c_1^* + b_1^* R_{L1} - \tfrac{y}{R_{L2}}$$

That is, whenever the endowment is above a certain threshold ($e \geq e^b$) the economy is not constrained. On the other hand, when the economy is constrained ($e < e^b$) the collateral constraint is binding and consumers would like to borrow $b_2 > p_1$. Given that this is not possible, consumers will borrow as much as they can, trying to maximize their consumption in period 1. In this case, the collateral constraint will bind with equality $b_2 = p_1$, so that:

$$c_1 + b_1 R_{L1} - e = \frac{y}{u'(c_1)},$$

and using the fact that the utility function is in CES form:

$$c_1 + b_1 R_{L1} - e = y c_1^{\varrho}. \tag{A.1}$$

Therefore, depending wether the constraint is binding or not, we can express borrowing in period 0 as:

$$b_1 = \begin{cases} (R_{L2}R_{L1})^{-\frac{1}{\varrho}} & e \geq e^b \\ \frac{y c_1^{\varrho} - c_1 + e}{R_{L1}} & e < e^b \end{cases} \tag{A.2}$$

Finally, we assume that the endowment is stochastic and follows a uniform distribution $e \sim U(\bar{e} - \varepsilon, \bar{e} + \varepsilon)$.

[20] Note here that we are assuming that profits are realized at the end of the period so that they have no effect on the borrowing constraint.

Assumption on parameter values. To be able to solve the model we need to make assumptions on the value of two parameters: y and $\bar{e}$. In particular, we will consider values such that 1) the economy may be constrained for sufficiently large negative shocks but 2) would not be constrained in the absence of uncertainty.

First, we want a condition that is necessary and sufficient for the economy to be constrained with some probability, when $e \sim U(\bar{e}-\varepsilon, \bar{e}+\varepsilon)$. Let's reason the other way round: we already showed that the economy is indeed unconstrained in period 1 if and only if:

$$e \geq e^b = c_1^* + b_1^* R_{L1} - \frac{y}{R_{L2}}.$$

When e is stochastic, for the economy to be unconstrained, the above inequality must hold for all possible realizations of e (in particular the adverse realizations). In other words it must be the case that:

$$\begin{aligned} e - \varepsilon &\geq c_1^* + b_1^* R_{L1} - \frac{y}{R_{L2}}, \\ \bar{e} &\geq c_1^* + b_1^* R_{L1} - \frac{y}{R_{L2}} + \varepsilon. \end{aligned}$$

Therefore, when $\bar{e} < c_1^* + b_1^* R_{L1} - \frac{y}{R_{L2}} + \varepsilon$ there exists a non-zero probability that the constraint binds.

Second, we want a condition that is necessary and sufficient for the economy to be unconstrained when there is no uncertainty around the realizations of e (i.e., $\varepsilon = 0$ and $\bar{e} = e$). When $\varepsilon = 0$, the constraint is not binding in period 1 if and only if $e = \bar{e} \geq e^b$, that is:

$$\bar{e} \geq c_1^* + b_1^* R_{L1} - \frac{y}{R_{L2}}.$$

Therefore, with no uncertainty, when $\bar{e} \geq c_1^* + b_1^* R_{L1} - \frac{y}{R_{L2}}$ the constraint never binds.

Summarizing we choose an $\bar{e}$ such that would not be constrained in the absence of uncertainty but it economy may be constrained for sufficiently large negative shocks:

$$(R_{L2})^{-\frac{1}{\varrho}} + (R_{L2}R_{L1})^{-\frac{1}{\varrho}} R_{L1} - \frac{y}{R_{L2}} \leq \bar{e} < (R_{L2})^{-\frac{1}{\varrho}} + (R_{L2}R_{L1})^{-\frac{1}{\varrho}} R_{L1} - \frac{y}{R_{L2}} + \varepsilon.$$

This implies that there will be a threshold for the size of the shock (ε^b) above which the collateral constraint will start to be binding with positive probability. Specifically, the collateral constraint would be binding for realizations of e in the interval $[\bar{e}-\varepsilon, \bar{e}-\varepsilon^b]$. The level of ε^b can be easily computed as:

$$\varepsilon^b = \bar{e} - e^b = \bar{e} - c_1^* - b_1^* R_{L1} + \frac{y}{R_{L2}}.$$

Competitive equilibrium. We will find numerical values for consumption at time 1 (c_1) by using is the Euler equation $FOC(b_1)$, which gives us an optimal relation between consumption in period 0 and consumption in period 1.[21] In order to be able to solve this equation we need 1) to find an expression for borrowing as a function of consumption for both constrained and unconstrained states, as we already did in equation (A.2); and 2) to weight those states for their probability.

[21] Rember that $c_0 = b_1$ from the budget constraint.

First, combining $FOC(b_1)$, the budget constraint, and the expression for b_1 derived earlier in equation (A.2) we get:

$$\begin{cases} \mathbb{E}\left[b_1^{-\varrho}\right] = R_{L1}\mathbb{E}\left[c_1^{-\varrho}\right], \\ b_1 = \begin{cases} (R_{L2}R_{L1})^{-\frac{1}{\varrho}} & e \geq e^b, \\ \frac{yc_1^{\varrho} - c_1 + e}{R_{L1}} & e < e^b. \end{cases} \end{cases}$$

Second, given the assumed distribution for the endowment, the level of consumption in period 1 will be given by:

$$\Pr(e < e^b) \cdot \left[b_1^{-\varrho}\right]^{\text{binding}} + \Pr(e \geq e^b) \cdot \left[b_1^{-\varrho}\right]^{\text{non-binding}} = R_{L1}c_1^{-\varrho}.$$

The LHS of the previous equation can be expressed as follows[22]:

$$\begin{aligned} \mathbb{E}\left[b_1^{-\varrho}\right] &= \frac{1}{2\varepsilon}\int_{\bar{e}-\varepsilon}^{\bar{e}-\varepsilon^b}\left(\frac{yc_1^{\varrho} - c_1 + e}{R_{L1}}\right)^{-\varrho} de + \frac{1}{2\varepsilon}\int_{\bar{e}-\varepsilon^b}^{\bar{e}+\varepsilon} R_{L2}R_{L1} de = \\ &= \frac{1}{2\varepsilon}\int_{\bar{e}-\varepsilon}^{\bar{e}-\varepsilon^b}\left(\frac{yc_1^{\varrho} - c_1}{R_{L1}} + \frac{e}{R_{L1}}\right)^{-\varrho} de + \frac{R_{L2}R_{L1}}{2\varepsilon}\Big[e\Big]_{\bar{e}-\varepsilon^b}^{\bar{e}+\varepsilon} = \\ &= \frac{1}{2\varepsilon}\left[R_{L1}\frac{\left(\frac{yc_1^{\varrho}-c_1}{R_{L1}} + \frac{e}{R_{L1}}\right)^{-\varrho+1}}{-\varrho+1}\right]_{\bar{e}-\varepsilon}^{\bar{e}-\varepsilon^b} + \frac{R_{L2}R_{L1}}{2\varepsilon}\left[\varepsilon + \varepsilon^b\right] \\ &= \frac{R_{L1}^{\varrho}}{2\varepsilon(1-\varrho)}\left[\left(yc_1^{\varrho} - c_1 + e\right)^{-\varrho+1}\right]_{\bar{e}-\varepsilon}^{\bar{e}-\varepsilon^b} + \frac{R_{L2}R_{L1}}{2\varepsilon}\left[\varepsilon + \varepsilon^b\right]. \end{aligned}$$

The following equation can be solved numerically to obtain the competitive equilibrium level of consumption at time 1:

$$\begin{aligned} \text{LHS} &= \text{RHS} \\ \text{LHS} &= \frac{R_{L1}^{\varrho}}{2\varepsilon(1-\varrho)}\left[\left(yc_1^{\varrho} - c_1 + \bar{e} - \varepsilon^b\right)^{-\varrho+1} - \left(yc_1^{\varrho} - c_1 + \bar{e} - \varepsilon\right)^{-\varrho+1}\right] + \frac{R_{L2}R_{L1}}{2\varepsilon}\left[\varepsilon + \varepsilon^b\right] \\ \text{RHS} &= R_{L1}c_1^{-\varrho}. \end{aligned}$$

Finally, one can also derive the level of optimal debt at time 0, by using again $FOC(b_1)$:

$$\mathbb{E}\left[b_1\right] = \mathbb{E}\left[\left(R_{L1}c_1^{-\varrho}\right)^{-\frac{1}{\varrho}}\right].$$

Social planner. The social planner problem is solved with the same strategy. The first order conditions are:

$$\begin{cases} FOC(b_1): & u'(c_0) = R_{L1}\mathbb{E}[u'(c_1) + \lambda p'(c_1)], \\ FOC(b_2): & u'(c_1) = R_{L2} + \lambda(1 - p'(c_1)), \\ FOC(\theta_2): & p_1 = \frac{y}{u'(c_1)}. \end{cases}$$

[22] Suppose that X has the $U(a,b)$ distribution. Then the nth moment of X is given by $\mathbb{E}\left[X^n\right] = \frac{1}{b-a}\int_a^b x^n dx$

First we have to find an expression for $p'(c_1)$. From $FOC(\theta_2)$ we get:

$$p(c_1) = \frac{y}{u'(c_1)} = yc_1^{\varrho},$$

and computing the derivative:

$$p'(c_1) = \frac{\partial\left(yc_1\right)}{\partial c_1} = \varrho y c_1^{\varrho-1}.$$

Notice that the $p'(c_1)$ is positive and decreasing. Notice also that, by definition, the Lagrange multiplier (λ) is positive only when the constraint is binding. By looking at $FOC(b_1)$ of the social planner problem, we can state that the planner limits over-borrowing. In fact, $u'(c_1)^{SP} > u'(c_1)^{CE}$ which implies that consumption and, therefore, borrowing at time 1 are lower relative to the competitive equilibrium. On the other hand, the planner increases consumption in period 1: given that $p'(c_1) > 0$ from $FOC(b_2)$ we see that $u'(c_1)^{SP} < u'(c_1)^{CE}$.

We also need a value of λ. Notice that the Lagrange multiplier of the social planner is numerically different from the one of the competitive equilibrium problem. In fact, from $FOC(b_2)$ we get

$$\lambda = \frac{c_1^{-\varrho} - R_{L2}}{1+y}.$$

Combining these two results we can compute:

$$\lambda p'(c_1) = \begin{cases} 0 & e \geq e^b, \\ \frac{\varrho y}{1+y}\left(c_1^{-1} - R_{L2}c_1^{\varrho-1}\right) & e < e^b. \end{cases}$$

We can now solve for the level of c_1. The $FOC(b_1)$ can be written:

$$\mathbb{E}\left[b_1^{-\varrho}\right] = R_{L1}\mathbb{E}\left[c_1^{-\varrho} + \lambda p'(c_1)\right].$$

The LHS has already been computed before. The RHS is:

$$\begin{array}{l} \frac{R_{L1}}{2\varepsilon}\int\limits_{\bar{e}-\varepsilon}^{\bar{e}-\varepsilon^b}\left(c_1^{-\varrho} + \frac{\varrho y}{1+y}\left(c_1^{-1} - R_{L2}c_1^{\varrho-1}\right)\right)de + \frac{R_{L1}}{2\varepsilon}\int\limits_{\bar{e}-\varepsilon^b}^{\bar{e}+\varepsilon} c_1^{-\varrho}de, \\ \frac{R_{L1}}{2\varepsilon}\left[\left(c_1^{-\varrho} + \frac{\varrho y}{1+y}\left(c_1^{-1} - R_{L2}c_1^{\varrho-1}\right)\right)\left(\varepsilon - \varepsilon^b\right) + c_1^{-\varrho}\left(\varepsilon + \varepsilon^b\right)\right], \\ \frac{R_{L1}}{2\varepsilon}\left[\left(\frac{\varrho y}{1+y}\left(c_1^{-1} - R_{L2}c_1^{\varrho-1}\right)\right)\left(\varepsilon - \varepsilon^b\right) + 2c_1^{-\varrho}\varepsilon\right] \end{array}$$

Therefore, the following equation can be solved numerically to find the optimal consumption at time 1:

$$\begin{aligned} \text{LHS} &= \text{RHS} \\ \text{LHS} &= \frac{R_{L1}^{\varrho}}{2\varepsilon\left(1-\varrho\right)}\left[\left(yc_1^{\varrho} - c_1 + \bar{e} - \varepsilon^b\right)^{-\varrho+1} - \left(yc_1^{\varrho} - c_1 + \bar{e} - \varepsilon\right)^{-\varrho+1}\right] + \frac{R_{L2}R_{L1}}{2\varepsilon}\left[\varepsilon + \varepsilon^b\right] \\ \text{RHS} &= \frac{R_{L1}}{2\varepsilon}\left[\left(\frac{\varrho y}{1+y}\left(c_1^{-1} - R_{L2}c_1^{\varrho-1}\right)\right)\left(\varepsilon - \varepsilon^b\right) + 2c_1^{-\varrho}\varepsilon\right]. \end{aligned}$$

Finally, one can derive the optimal expression for borrowing at time 1 from the social planner $FOC(b_1)$:

$$b_1 = \left(R_{L1}\mathbb{E}\left[c_1^{-\varrho} + \lambda p'(c_1)\right]\right)^{-\frac{1}{\varrho}}.$$

Crisis Probability. The crisis probability is defined as the probability of the constraint to be binding:

$$\begin{aligned}\Pr\left[b_2 \right. &> \left. p_1\right] \\ &= \frac{1}{2\varepsilon}\int_{\bar{e}-\varepsilon}^{\bar{e}-\varepsilon^b} de = \frac{1}{2\varepsilon}\left(\varepsilon - \varepsilon^b\right).\end{aligned}$$

which, using the optimality conditions and the budget constraint, can be written as

$$\Pr\left[(c_1 - (e - b_1 R_{L1}) > \frac{y}{u'(c_1)}\right].$$

Now, knowing that $e = \bar{e} + \tilde{\varepsilon}$ and that $\tilde{\varepsilon} \sim \mathcal{U}(-\varepsilon, \varepsilon)$, we can write

$$\Pr\left[\tilde{\varepsilon} < \underbrace{c_1 - \bar{e} + b_1 R_{L1} - \frac{y}{u'(c_1)}}_{x}\right].$$

In particular, the probability of the constraint to be binding is given by:

$$\Pr\left[-\varepsilon \leq \tilde{\varepsilon} < x\right] = \frac{x - (-\varepsilon)}{2\varepsilon} = \frac{c_1 - \bar{e} + b_1 R_{L1} - y/u'(c_1) + \varepsilon}{2\varepsilon}.$$