Does Easing Monetary Policy Increase Financial Instability?

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April 4, 2017

Abstract

This paper develops a model featuring both a macroeconomic and a financial friction that speaks to the interaction between monetary and macro-prudential policy and to the role of US monetary and regulatory policy in the run up to the Subprime mortgage crisis. There are two main results. First, interest rate rigidities in a monopolistic banking system increase the probability of a financial crisis (relative to the case of flexible interest rate) in response to contractionary shocks to the economy, while they act as automatic macro-prudential stabilizers in response to expansionary shocks. Second, when the interest rate is the only available instrument, monetary policy faces a trade-off between macroeconomic and financial stability. This trade off is both qualitative and quantitative in response to contractionary shocks, while it is only quantitative in response to positive shocks. We show that a second instrument, such as a Pigouvian tax on credit to households on the demand side of the market, is needed to restore efficiency in the economy when both frictions are at work.

Keywords: Macro-Prudential Policies, Monetary Policy, Financial Crises, Financial Regulation, Pecuniary Externality, Interest Rate Rigidities, Subprime mortgage crisis.

JEL codes: E44, E52, E61.

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1 Introduction

The notion that excessively loose monetary policy can sow the seeds of financial instability was famously put forward right after the bursting of the US "dot-com" bubble by Borio and White (2003) and Rajan (2005). The issue gained further prominence after the US Subprime mortgage crisis and the ensuing Great recession. Some macroeconomists pushed this argument as far as assigning to monetary policy a main role for causing the Subprime crisis (see, among others, Taylor (2007, 2010)). But others, like Svensson (2010) and Bernanke (2010), together with a sizable body of real estate literature (Keys et al., 2010, Coleman IV et al., 2008, Avery and Brevoort, 2015), argued forcefully against this idea blaming instead the crisis on an ineffective regulatory policy.

This paper speaks to this controversy by studying the interaction between a traditional macroeconomic stabilization role for monetary policy and a more novel financial stability objective. It develops a simple model of consumption and collateralized borrowing featuring both a macroeconomic and a financial friction —namely, an interest rate rigidity that gives rise to a traditional macroeconomic stabilization objective and a pecuniary externality that gives rise to a more novel financial stability objective— in which macro-prudential policies must complement monetary policy in responding to shocks.

The macroeconomic stabilization objective arises from the presence of monopolistic competition and interest rates rigidity in the banking sector.[1] Due to monopolistic power, banks apply a markup on their funding cost and curtail aggregate lending. When some banks cannot fully adjust their lending rates in response to shocks to their funding costs, the economy as a whole is distorted and reaches an equilibrium that is not efficient, in a manner similar to models with staggered price setting.

The financial stability objective stems from the fact that the model endogenously generates financial crises when a collateral or leverage constraint on borrowing occasionally binds. When this constraint binds, like for instance in the case of a binding loan-to-value limit in mortgage lending, a pecuniary externality arises. Individual borrowers do not internalize the effect of their decisions on the market price of collateral, and hence borrow and consume more than socially efficient. This increases the likelihood to hit the constraint and the intensity with which the constraint binds, which in this set up means increasing the frequency and the severity of financial crises (see, among many others, Lorenzoni, 2008, Mendoza, 2010, Bianchi, 2011, Benigno et al., 2013). We take a pecuniary externality perspective to introduce financial stability considerations because it defines clearly the scope for government intervention in public finance terms and also naturally leads to a model-consistent definition of financial crisis as the event in which borrowing is curtailed.

[1]It is a well established fact in the empirical banking literature that bank retail interest rates change only infrequently. See Hannan and Berger (1991) and Neumark and Sharpe (1992).

There are two main results. First, the paper finds that interest rate rigidities have a different impact on financial stability considerations depending on the sign of the shock hitting the economy. In response to expansionary shocks that increase the funding cost of banks (e.g., a positive shock to aggregate demand) the average bank lending rate rises too. However, because of interest rate stickiness, it increases less than in a flexible interest rate equilibrium. This affects next period net worth through two channels. On the one hand, relatively lower lending rates prompt consumers to borrow more than in the flexible-rate case, and thus lowers next period net worth; on the other hand, interest rate repayments are lower relative to the flexible case, thus increasing next period net worth. When the second effect dominates the first one, which happens in our model for a coefficient of relative risk aversion larger than 1, the probability of a crisis (our financial stability indicator in the model) is lower than in the flexible interest rate case. Thus, interest rate rigidity acts as a sort of automatic macro-prudential stabilizer in response to shocks that increase bank funding costs. In contrast, in the presence of a contractionary shock that lowers the funding cost of banks (e.g., a negative shock to aggregate demand), the average lending interest rate falls less than in the flexible-rate equilibrium. Because of the same mechanisms working in reverse, the interest rate rigidity leads to a higher probability of a financial crisis than in the flexible interest rate case. Thus, interest rate rigidity magnifies financial stability concerns (relative to the flexible-rate case) in response to shocks that push down bank funding costs such as a recession or the bursting of an asset price bubble. Note moreover that, while the implications of interest rate rigidity for the probability of a crisis are 'asymmetric' in the model with respect to the sign of the shock, the effects of a positive or a negative shock on the equilibrium allocations of the economy are perfectly symmetric.

Second, our analysis shows that, if the government has only one policy instrument (say the monetary policy interest rate) and faces both the financial and the macroeconomic friction, efficiency can never be achieved when a negative shocks hits the economy and may not be achieved in response to positive shocks. However, when the government has two instruments (such as for instance a tax on debt and the monetary policy interest rate), efficiency can be achieved in response to both negative and positive shocks. Intuitively, when both frictions are at work and there is only one instrument, a shock that lowers the funding cost of banks requires interventions of opposite direction on the same policy tool (in our case, the monetary policy interest rate). The same problem may arise with positive shocks if the increase in the interest rate needed to address the real rigidity is different than the level needed to address the pecuniary externality. In general, however, with positive shocks, the interest rate changes needed to address the two distortions go in the same direction. The model therefore entails a stark qualitative trade-off between macroeconomic and financial stability in response to negative shocks and a possibly quantitative one in the case of positive shocks that can be resolved only with a second policy instrument.

The paper also illustrates that not all macroprudential policy tools are alike. In particular, in our model, capital and reserve requirements act on the same bank funding cost margin as the monetary policy rate, an hence on the same supply side of the credit market. To eliminate the pecuniary externality that stems from the demand side of the credit market, the government intervention needs to act on the households' intertemporal margin. In our model, therefore, the only policy tool that can get the job done and complements the policy interest rate (or the other monetary instruments) is a Pigouvian tax on bank credit. As we shall see, alternative monetary policy instruments could all address the pecuniary externality or the interest rate rigidity in isolation. However, once the interest rate is committed to address macroeconomic stability, additional monetary policy instruments act on the same bank funding margin and do not help to restore efficiency. This illustrates the merit of introducing in our analysis an explicit macroeconomic friction that justifies monetary policy intervention, as opposed to modeling the macroeconomic environment with a reduced form representation like a Taylor rule for the policy interest rate.

Finally, we use the lenses of our model to discuss the US Subprime mortgage crisis and its possible causes. Within the logic of our model, there are two ways to interpret it. On the one hand, one can take into account that regulatory responsibilities in the United States are shared among a multiplicity of institutions and that these institutions had the levers to tighten the regulatory environment before the crisis in a prudential manner. In this case, and noting that regulation did not start to tighten until about 2006, we could conclude that the crisis stemmed primarily from a regulatory failure, consistent with views prevailing in the real estate literature. However, one could also note that in the face of regulatory inaction, the Fed should have taken into account that the monetary policy interest rate was effectively the only policy instrument available to address both macroeconomic and financial stability. From this perspective, our model implies that, indeed, the policy rate should have been set higher than the level needed to address only the macroeconomic friction, consistent with the some of the views in the macroeconomics literature.

The paper is related to three strands of literature. The first is a branch of the New Keynesian literature that considered financial frictions and Taylor-type interest rate rules (see, for example, Christiano et al., 2007, Kannan et al., 2012).[2] These papers consider either interest rate rules augmented with macro-prudential arguments —such as credit growth, asset prices, loan-to-value limits— or a combination of interest and macro-prudential rules in order to allow monetary policy to "lean against financial winds". However, in

[2]This literature is large and fast-growing. See also Angelini et al. (2014), Beau et al. (2012), Angeloni and Faia (2009), Paoli and Paustian (2013), Lambertini et al. (2013), and Clerc et al. (2015).

these papers, policy does not target a second, explicit and microfunded market failure in a public finance sense, like in the pecuniary externality literature. In this sense, they do not have a clearly identified financial stability objective and scope for government intervention to address it. In our model, there is a well defined pecuniary externality that justify government intervention for financial stability purposes.

The second is a growing literature on pecuniary externalities that interprets financial crises as episodes of financial amplification in environments where credit constraints are only occasionally binding (see, among others, Lorenzoni, 2008, Korinek, 2010, Bianchi, 2011, Jeanne and Korinek, 2010b, Benigno et al., 2013). In this class of models, the need for macro-prudential policies (like capital or reserve requirements) stems from a well-defined market failure: a pecuniary externality originating from the presence of the price of collateral in the aggregate borrowing constraint of households. However, in all these models, the financial friction is the only distortion in the economy. The question of how the pursuit of financial stability may affect and interact with the macroeconomic stability objective is therefore novel relative to this literature.

The third and last is a small but growing literature that has considered both macroeconomic and financial frictions at the same time, like this paper. Woodford (2012), sets up a New Keynesian model with credit frictions in which the probability of a financial crisis is endogenous (i.e., it is a regime-switching process that depends on the model variables). He then 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 explicitly model financial stability. This does not allow to study the relative effectiveness of alternative macro prudential tools as we do in this paper.

Kashyap and Stein (2012) use a modified version of the pecuniary externality framework of Stein (2012) where the central bank has both a macroeconomic and a financial stability objective. Similar to our findings, they find that a trade-off emerges between the two objectives when the policy interest rate is the only instrument and it is resolved when there is a second tool (such as an interest rate paid by the central bank on depository institutions' required reserve balances). However, they do not model the macroeconomic stability objective explicitly, and describe the macroeconomic environment by means of a Taylor rule for the nominal interest rate. As we shall see, introducing and explicit albeit simple microfoundation for macroeconomic stability gives rise to a more fundamental policy trade off and it also determines which policy instrument is most effective.

More recently, Korinek and Simsek (2016) and Farhi and Werning (2016) studied environments with pecuniary externality, nominal rigidities, and demand externalities. Demand externalities, in turn, originate from constraints on monetary policy such as the zero lower bound and or a fixed exchange rate regime. In this paper we purposefully abstract from constraints on monetary policy and focus on an unconstrained monetary policy to study the policy trade-off induced by monetary and financial stability considerations in normal times, before a financial crisis or another shock pushes the economy against the zero lower bound.

The rest of the paper is organized as follows. Section 2 describes the model economy. Sections 3 and 4 characterize the decentralized and the socially planned equilibrium of the economy, respectively. Section 5 looks discuss the US Subprime mortgage crisis and it possible causes through the lenses of our model. Section 6 concludes. An Online Appendix reports additional results referred to in the text and the numerical solution of the model.

2 The Model

We include monopolistic banking and interest rate rigidities in the pecuniary externality framework of Jeanne and Korinek (2010a). In their set-up, consumers borrow directly from international capital markets (or foreign banks) at the gross world interest rate R. In our model, instead, consumers borrow from a monopolistic banking sector that intermediates foreign saving. While this is a stark assumption, it is a simple way to introduce heterogeneity in a model that features another important source of complexity in the form of an occasionally binding collateral constraint. This implies that the lending rate faced by borrowers is affected by both domestic and external factors in the model, i.e., the behavior of banks and government policy as well as the supply of foreign saving.[3] Alternatively, borrowers could be interpreted as entrepreneurs/households in a closed economy enjoying a comparative advantage in owning the asset.

The financial friction is given by the presence of collateralized borrowing. The real friction, strictly speaking, has two parts: the first is the presence of market power in the loan market exercised by monopolistically competitive banks; the second is infrequent adjustment of real lending rates by banks.[4]

The economy is populated by two sets of agents: a continuum of monopolistically competitive banks and a continuum of identical and atomistic consumers. Each set of agents has a unit mass. There are only three periods, denoted $t = 0, 1, 2$, representing the short, medium and long term respectively.

At the beginning of period 0 consumers own an asset in fixed, unit supply. In order to consume, they must either sell a fraction $(1 - \theta_{i,1})$ of the asset or borrow from banks

[3] We also note that it is now common in the literature to use a small open economy frameworks like ours even for countries like the United States (see for instance the work by Bianchi and Mendoza (2013), Jeanne and Korinek (2010b), Favilukis et al. (2010).

[4] Note that real and nominal interest rates coincide when expected inflation is zero. So here we are implicitly assuming that good prices are completely fixed in the short run.

$(b_{i,1})$. They have a well-defined loan demand that is decreasing in the lending interest rate (R_{L1}). Monopolistic banks collect deposits from foreign savers at the interest rate $(R_t = R)$ and —given loans demand— optimally set their lending rates. We assume that, when the cost of funds (R) changes because of shocks or policy interventions, only a fraction of banks (μ) can reset their lending rates, while the remaining banks $(1 - \mu)$ need to keep their lending rates fixed. The purpose of this key assumption is to introduce macroeconomic stabilization considerations in a relatively simple manner, but it can be justified by both theoretical and empirical grounds.[5]

At the beginning of period 0, the funding cost of banks is hit by a temporary shock $(R \pm \upsilon)$. While this is a reduced form shock in our model, a drop (increase) in the funding cost of banks can be triggered by a negative (positive) aggregate demand shock in a standard New-Keynesian framework. In our model, the source of such shock must be external, but in a more general (heterogeneous agents) set-up it could be domestic or external. In terms of a standard Taylor (interest rate) rule this shock can be interpreted as a change in the real, long-run value of the policy rate (the so-called natural interest rate). In the rest of the paper we label an increase (decrease) in R a positive (negative) shock and will assume that it is driven by an increase (decrease) in aggregate demand. The loan market clears after the realization of this shock, which all agents observe. Then households consume $(c_{i,0})$ at the end of period 0.

In period 1, consumers have a stochastic endowment (e), they repay their debt $(b_{i,1}R_{L1})$, borrow an additional amount from banks $(b_{i,2})$, realize bank profits $(\pi_{i,1})$, and consume $(c_{i,1})$. Borrowing in period 1 is subject to a collateral constraint, with $(b_{i,2})$ limited to a fraction of the market value of the consumers' assets. This assumption is realistic and its purpose is to introduce explicit financial stability considerations in the model. If hit by a shock in period 0, the bank funding cost returns to long term value value (R) in period 1.

In period 2, consumers receive a 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 $(c_{i,2})$.

We now discuss the consumers' and banks' problems in turn.

2.1 Consumers and Loan Demand

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

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

[5]Note here that nominal interest rate rigidity translates into real rate rigidity to an extent that depends on the degree of good price rigidity. As we noted, we implicitly assume that good prices are completely fixed in the short term. For examples of nominal interest rate rigidities see, among others, Hannan and Berger (1991) and Neumark and Sharpe (1992).

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:

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

Consumer enter period 0 endowed with a unit of the asset $\theta_{i,0} = 1$ with price p_0. In order to consume in period 0, they need to either sell a fraction of their assets $(1 - \theta_{i,1})$ or borrow from banks $(b_{i,1})$. And as they are identical, in a symmetric equilibrium, we will have $\theta_{i,0} = \theta_{i,1} = \theta_{i,2} = 1$.[6]

In period 1, consumers faces a collateral constraint of the form:

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

where $\theta_{i,1}$ is the share of the asset held at the beginning of period 1. Equation (4) can also be interpreted as a Loan-to-Value constraint (LTV). The LTV constraint implies that households can borrow up to a fraction (Θ) of the value of the collateral. Following Jeanne and Korinek (2010a), in our model Θ is set to 1 for simplicity. Note that the fraction Θ determines households' maximum leverage:

$$L^{\max} = \frac{1}{1-\Theta}. \tag{5}$$

where $L = L^{\max}$ when the LTV constraint is binding, and $L < L^{\max}$ otherwise (see the Online Appendix for details). According to equation (5), this implies an unbounded maximum leverage ratio. In equilibrium, however, leverage is pinned down by preferences, interest rates, the deterministic return on the asset and the shadow price of the constraint. As we discuss below (and show in Appendix A), therefore, in our model equilibrium leverage is well defined and bounded.[7]

As Mendoza (2010) discusses and illustrates at length, when the collateral or leverage

[6] As in Jeanne and Korinek (2010b), we assume that consumers derive some benefits from owning the asset. For instance, this asset can be interpreted as house.

[7] Alternatively, we can specify a Debt-To-Income (DTI) constraint, where total expected repayment (interest + principal) next period cannot be larger than a fraction of income. As we show in the Appendix A, the qualitative properties of our model are the same in the LTV economy and the DTI economy. The only difference is a quantitative one, stemming from the fact that the shadow price of the constraint will always be higher in the DTI economy than in the LTV economy.

constraint occasionally binds, it triggers a process of asset price deflation and deleveraging in which small business cycle shocks are amplified, like in a financial crisis. In this sense, collateralized borrowing brings into the analysis financial stability considerations. We therefore label states in which the collateral constraint is binding as "crisis states" and interpret the probability that the constraint will bind in period 1 (i.e., the crisis probability) as our measure of financial stability.[8]

Consumers maximize (1) subject to the budget constraint (3) and the collateral constraint (4). Dropping the subscript i, the utility maximization problem of the *representative consumer* can be written as:

$$\max_{b_1,b_2,\theta_2}\left\{\begin{array}{c} u\Big(b_1+(1-\theta_1)p_0\Big)+\mathbb{E}_0\Big[u\Big(e+b_2+(\theta_1-\theta_2)p_1+\pi_1- \\ -b_1R_{L1}\Big)+\theta_2 y+\pi_2-b_2R_{L2}-\lambda(b_2-\theta_1p_1)\Big]\end{array}\right\}. \tag{6}$$

Because of the occasionally binding constraint, the solution of this problem is non trivial. Solving the maximization problem backward, the first order conditions are:

$$\begin{array}{l} p_1=\frac{y}{u'(c_1)}, \\ u'(c_1)=R_{L2}+\lambda, \\ u'(c_0)=R_{L1}\mathbb{E}_0\big[u'(c_1)\big]. \end{array} \tag{7}$$

The first equation represents the asset pricing condition for the economy. The second and third equations are the Euler equation for consumption in period 1 and 0, respectively. The numerical solution of this problem is derived in the Online Appendix, where we also show that the problem has a well behaved closed-form solution when the constraint is not binding.

In order to allow for market power in the banking sector, we model the loan market a-la Dixit and Stiglitz (1977) following Gerali et al. (2010). Thus, we assume that loan contracts bought by consumers are a constant elasticity of substitution composite of differentiated financial products, each supplied by a bank j with an elasticity of substitution ζ. In particular, in order to obtain a loan of size $b_{i,t}$, the consumer i needs to take out a continuum of loans $b_{ij,t}$ from all existing banks j, such that:

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

Demand by consumer i seeking a loan of size $b_{i,t}$ can be derived by minimizing the total repayment due to the continuum of banks j over $b_{ij,t}$. Aggregating over symmetric

[8] While that is a somewhat crude definition, it is also an established one in the literature, used for example in Mendoza (2010) and Bianchi (2011).

consumers, yields the following downward-sloping loan demand curve:

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

with the aggregate lending interest rate given by:

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

2.2 Banks and Loan Supply

There is a continuum of monopolistically competitive domestic banks indexed by $j \in [0,1]$ and owned by households.[9] In particular, we assume that each bank j supplies a differentiated financial product, and no other bank produces the same variety. However, banks compete with each other since costumers perceive each variety as an imperfect substitute. Because of market power banks can set the lending rate to maximize profits, taking into account the elasticity of demand for their variety.

Each bank j collects deposits $d_{j,t}$ from foreign savers at the funding cost R, where R is exogenous. We further assume that foreign savers can supply an infinite amount of deposits, so that banks can satisfy any quantity demanded. Finally, banks use deposits to supply loans to consumers with the following constant return to scale production function:[10]

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

In each period, bank j maximizes its profits by choosing price and quantity for given funding cost:

$$\max_{R_{Lj,t}, b_{j,t}} b_{j,t} R_{Lj,t} - d_{j,t} R, \tag{12}$$

subject to the demand schedule in (9) and to the production function in (11). The first order condition for this problem implies that the optimal lending rate is a constant markup ($\mathcal{M}$) over the marginal cost of funds:

$$R_{Lt}(j) = \frac{\zeta}{\zeta - 1} R_t = \mathcal{M} R. \tag{13}$$

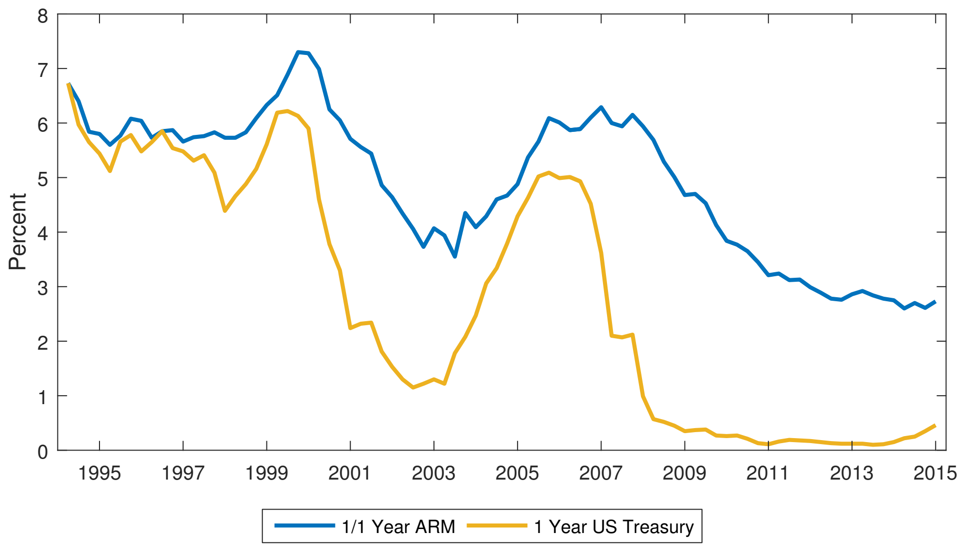
[9]Market power is a standard assumption in banking. It can be justified by the presence of switching costs that lead to long-term relationships between banks and their costumers (Diamond (1984) for example). Empirically, the presence of market power in banking and its determinants over the business cycle are well documented. See, for example, Berger et al. (2004) and Degryse and Ongena (2008).

[10]More realistic balance sheet assumptions with bank reserves and bank capital are discussed below when we specify government policy.

Together with consumers' optimality conditions, equation (13) determines the equilibrium of the economy: once the lending rate is set, households choose consumption and hence borrowing, and loan market clearing closes the model.

As we noted earlier, we also assume interest rate rigidity: banks cannot always adjust lending rates in response to changes in their funding costs, which in turn can be affected by various macroeconomic shocks. In particular, when the funding cost changes because of the shock (v) in period 0, we assume that only a fraction μ of the banks can reset the lending rate, whereas the remaining $1-\mu$ banks cannot. This entails that, following a shock to the deposit rate, the *aggregate* lending rate will be different from the one desired by banks. Given that consumers are price takers and that their loan demands depend on the *average* interest rate in the economy, this friction leads to a distortion in the competitive equilibrium of the economy that creates scope for policy intervention to restore efficiency. However, lending rates are again fully flexible in the long-run (i.e., in period 2).

Figure 1 US Short-term Mortgage and Treasury Bills Rates



Note. Nominal 1-year yields on US Adjustable Rate Mortgages (ARM) and Treasury Bills. Sample period: 1995:Q1–2015:Q4, in percent.

The fact that the adjustment of lending rates to changes in bank funding cost is only partial and heterogeneous (especially in the short run) is well-established in the empirical banking literature. It can be justified by the presence of adjustment costs and monopolistic power. For example, Hannan and Berger (1991) show that, in the presence of fixed adjustment costs, banks reset 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 Diebold and Sharpe, 1990, Neumark and Sharpe, 1992). Empirically, Kwapil and Scharler

(2010) find that the pass-through of changes in the policy rate to consumer loan rates in the United States can be as low as 0.3, implying that banks smooth lending rates significantly. Espinosa-Vega and Rebucci (2004) find similar evidence for small open economies. The recent work by Driscoll and Judson (2013) and Yankov (2014) extends the previous literature with more recent micro-panel data. Moreover, Garriga et al. (2016) show that interest rate rigidities can be quantitatively as important as rigidities in product markets.

Figure 1 provides some direct evidence in support of this key assumption. It plots the time series of the yield on a 1-year Adjustable Rate Mortgage (ARM), together with the yield on a 1-year Treasury Bill for the United States. It shows that the Treasury yield is more volatile than the mortgage rate and also that the gap between the two varies significantly over time, with the mortgage rate arguably following the treasury yield with some delay. Similar evidence emerges by comparing treasuries and mortgage rates over longer maturities (not reported).

Note here that all agents (banks, consumers, and the government) observe the shock to the deposit rate in period 0 before making their decisions. We consider three states: no shock ($\upsilon = 0$), a temporary increase in funding costs ($\upsilon > 0$), and a temporary reduction in funding costs ($\upsilon < 0$). As we noted earlier, these states can be interpreted as the result of temporary aggregate demand shocks, driven by changes in preferences or fiscal policy in a closed economy or as a foreign demand shock in a small open economy.

2.3 Government

The government has two instruments, a macroprudential tool and a monetary policy tool. It can use either of them or both of them at the same time. Revenues (or financing) associated with these tools are always rebated in lump-sum manner to households.[11]

Policy is "macroprudential" in a well defined sense in our model. Because of the occasionally binding collateral constraint, there is a pecuniary externality. This externality arises when the constraint binds or is expected to bind with positive probability. In our set up, therefore, a macro-prudential intervention is a policy action that is called for in a public finance sense before the constraint binds. These are interventions in period zero, anticipating the possibility that constraint might bind in period one. Their objective and effect is to eliminate the externality. In so doing, policy typically reduces the probability that the constraint will bind in the future and ameliorates the averse dynamics of deleveraging and adjustment when it does occasionally bind.

Prudential policy is conducted with a Pigouvian tax on domestic credit (bank loans) that affects directly the demand for loans. This tax operates on households, on the

[11] As we discuss below, the use of the two instruments gives rise to no coordination problem.

demand side of the credit market as opposed to banks on the supply side. So, this is not a tax on foreign borrowing (a capital control) like the case analyzed by Jeanne and Korinek (2010a) and Bianchi (2011). In that environment, the constraint is on foreign borrowing and there is no domestic financial intermediation. In our set up, the constraint is on domestic borrowing from banks, while foreign borrowing is frictionless —and, as we show below, the associated pecuniary externality requires an intervention on that margin if there are also interest rate rigidities.[12]

Following Kashyap and Stein (2012), monetary policy is conducted with an additive factor (ψ) on the bank funding cost (R). While this is a stylized and reduced form representation of monetary policy, because R is exogenous and the supply of foreign saving is perfectly elastic in the model, it is simple and intuitive. Indeed, when a central bank changes its interbank interest rate target, it is raising the banks' opportunity cost of meeting their daily liquidity needs. In the terminology of Stein (2012), this increases the scarcity value of bank reserves.

To see this, Kashyap and Stein (2012) show that the interbank rate, or bank funding cost (R) in our model, can be decomposed in the sum of the interest rate on reserves (IOR, if any is paid) and a scarcity value term (SV), where R is also exogenous but nominal rather than real in their model. If the IOR is zero (because there are no reserve requirements or they are not remunerated) then $R = SV$. So, under the assumption that prices are fully fixed, our additive factor (ψ) can be interpreted as a monetary policy intervention adding to a given SV.[13]

Note finally that, following the New-Keynesian tradition, the government also has the possibility to use a separate subsidy (η) to remove the distortion due to monopolistic competition. As we shall see, the main results of the analysis are not affected by this policy action.

2.4 Shocks and Parameter Values

Table 1 summarizes the assumptions we make on the parameters and the stochastic processes of the model. We choose a parametrization to study the solution of the model in the case in which there are financial stability considerations at play because of the pecuniary externality. This happens when the borrowing constraint does not bind today, but can bind tomorrow with positive probability.

[12] In our model, a tax on foreign debt (i.e., a capital controls) would be needed to guarantee monetary policy independence if the exchange rate were to be fixed. Note however that we do not model the exchange explicitly in the model. Nonetheless, in the Appendix, we show that a tax on foreign borrowing of banks could achieve the same allocation as a tax on domestic credit if the there are no interest rate rigidities.

[13] In the Appendix we show that, once we introduced a system of remunerated required reserves in our set set up, the effects of changing (ψ) are the same as increasing the coefficient of reserve requirements or lowering the rate of remuneration of those reserves.

Table 1 CALIBRATION OF MODEL'S PARAMETER AND SHOCKS

Variable	*Symbol*	*Value*	*Source/Target*
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	Borio and Fritz (1995)
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 US CPI; R_L is the 15-Year mortgage fixed rate deflated with US CPI. U.S. monthly data from 1985:M1 to 2007:M3.

We assume that endowment e is uniformly distributed over the $[\bar{e} - \varepsilon, \bar{e} + \varepsilon]$ interval. We then analyze the model's properties for different values of the maximum size of the endowment shock (ε), which controls the variance of the shock. We consider values for ε and the expected value $\bar{e}$ such that the economy is not constrained in the absence of disturbances, but it may be constrained for a sufficiently large negative realization of the shock with positive probability.

Following Jeanne and Korinek (2010a), we set the return of the asset (y) and the expected value of the endowment to $\bar{e} = 1.3$ and $y = 0.8$. Jeanne and Korinek (2010a) choose these two parameters jointly with the maximum size of the endowment shock (ε) to control when the borrowing constraint binds. We take these two parameters as given, and set the maximum value of the endowment shock following the same strategy.

We calibrate the remaining parameters using US data from 1985 to 2007, i.e., from the beginning of the Great Moderation to the subprime crisis. The gross rate on deposit, i.e., the cost of bank funds, is set to $R = 1.015$, matching the average real yield of the 3-Month Treasury Bill over the period 1985-2007 (deflated nominal yields with US CPI). The elasticity of substitution between financial products is set to $\zeta = 33.3$, implying a gross markup of $\mathcal{M} \simeq 1.03$. This markup generates a spread between deposit and lending rates of about 250 basis points, which matches the average spread in the data between the 15-year mortgage fixed rate and the the 3-Month Treasury Bill rate. The period utility is CES with relative risk aversion coefficient $\varrho = 2$, which is a conventional value.[14]

As we show in the Appendix, under these assumptions, the model economy is never constrained when $\varepsilon \leq \varepsilon^b = 0.095$, and the probability of observing a crisis in period 1 is zero. In this case, the model has a closed-form solution given by optimality conditions

[14]As discussed in more detail below, a coefficient of relative risk aversion (ϱ) larger than 1 is crucial for some of our results.

(7) together with $\lambda = 0$. In contrast, when $\varepsilon > 0.095$ the probability that the constraint will bind in period 1 positive. In this second case, the model must be solved numerically as shown in the Online Appendix).

The calibration of the degree of interest rate stickiness (μ) is more difficult. Although there is compelling evidence on the imperfect adjustment of retail interest rates rate to movements in policy rates, the precise degree of such rigidity varies across studies. We assume that only 50 percent of the banks can adjust their lending rates in response to a change in their funding costs, consistently with the smaller degree of stickiness in the empirical literature.[15] Note also that, as long as there is some interest rate stickiness (i.e., $\mu > 0$), the calibration of this parameter does not affect the qualitative behavior of our model. In the long-run, in contrast, pass-through is assumed to be complete.

Finally, we assume that the deposit rate shock υ in period 0 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 US 3-Month Treasury Bill over the 1985-2007 period.

3 Decentralized Equilibrium

We can now analyze the decentralized equilibrium of the economy without any government intervention. In order to build intuition, we consider first the effects of the financial friction, by comparing the allocation in our model economy with an economy in which the collateral constraint is never binding. Second, we will analyze the effect of the macroeconomic friction by comparing the allocation in our model economy with 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 Financial Friction

The financial friction affects the economy only when the collateral constraint is not binding today but can bind tomorrow with a positive probability. Figure 2 displays the equilibrium value of key endogenous variables for different values of the maximum size of the shock (ε, displayed on the horizontal axis), which parametrizes the volatility of the shock. As we discussed earlier, given the parameter values in Table 1, the threshold for ε that makes the collateral constraint bind in period one with positive probability is $\varepsilon^b \simeq 0.095$.

[15] For the United States, Kwapil and Scharler (2010) estimate a short-run pass-through of changes in the policy rate to consumer loans of 0.3; 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.

The upper-left panel of Figure 2 plots the equilibrium level of borrowing in period 0 (b_1). Conditional on b_1, it is possible to compute net worth ($e - b_1 R_{L1}$), consumption (c_1), and the probability of observing a crisis (π) in period 1, which are plotted in the other three panels.

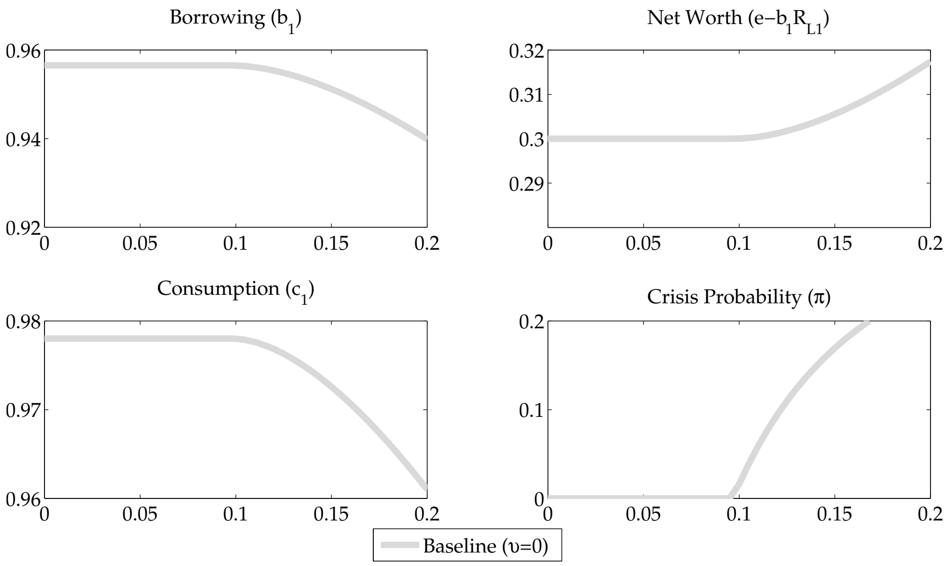


Figure 2 Model Equilibrium with Financial Friction. On the horizontal axis is the maximum size of the endowment shock (ϵ), which parametrizes its volatility.

When $\varepsilon \leq \varepsilon^b$ the economy is never constrained, and households' decisions are not affected by the endowment volatility in period 1. In this case, if faced with a negative endowment shock, households can borrow from banks to smooth consumption. In contrast, if there is high enough volatility that the constraint can bind in period 1 with positive probability, consumers insure against this possibility with precautionary saving. Thus, they reduce borrowing and consumption in period 0 as well as in period 1 itself. The mechanics of the comparative statics in Figure 2 are as follow. The Lagrangian multiplier (λ) in the Euler equation (7) represents the shadow value of the collateral constraint. When λ is expected to be positive, the marginal utility of consumption increases (because of precautionary savings), leading to a lower equilibrium level of consumption relative to the case in which λ is zero. In turn, this increases the equilibrium level of net worth in period 1. The probability of a crisis (π) is positive and increasing in the shock variance, but less than one-for-one as lower consumption and borrowing in period 0, all else equal, make the collateral constraint less likely to bind in period 1.

3.2 Macroeconomic Friction

Let us now analyze how the macroeconomic friction affects our model economy. First, monopolistic power lowers average output below the socially optimal level. In our model, monopolistic competition in the banking sector implies an inefficiently low level of consumption, because lending interest rates are, on average, higher than under perfect competition. Second, interest rate rigidities imply that banks' average markup will vary over time *in response to shocks*, violating efficiency conditions.

To see how this distortion works in our model, assume for the moment that interest rates can freely adjust and that lending rates at the beginning of period 0 are at the desired level, set as a markup over the funding cost ($R_{L1} = \mathcal{M}R$). If a positive shock $\upsilon > 0$ hits the economy, banks face a new, higher funding 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 at a higher lending rate. In response to the higher interest rate, consumption and borrowing in period 0 will be lower relative to the case in which $\upsilon = 0$.

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

$$R_{L1}^{\mu} = \mathcal{M}(R + \upsilon). \tag{14}$$

The remaining $1 - \mu$ banks will not be allowed to reset their lending rates, implying that:

$$R_{L1}^{1-\mu} = \mathcal{M}R < R_{L1}^{\mu}. \tag{15}$$

As a consequence, the aggregate lending rate in the economy would differ from its flexible-rate counterpart. In fact, according to equation (10), the aggregate lending rate in the sticky-rate economy becomes:

$$R_{L1} = \mathcal{M}(R + \mu\upsilon), \tag{16}$$

which is lower than the lending rate prevailing under flexible rates in the case of a positive bank funding shock. A similar gap of opposite sign emerges when the υ shock is negative.

In general, interest rates stickiness results in an average interest rate, R_{L1}, which differs from the one required to obtain the same allocation obtained under flexible interest rates (henceforth "flex-rates" allocation), thus also affecting the aggregate level of borrowing and consumption. With a positive shock, debt and consumption are higher than in the flex-rates economy, because interest rates increase by less than they would in a fully flexible world. But, with a negative shock, debt and consumption are lower than in the flex-rates economy, because interest rates decrease by less than they would in a flexible world. As we shall see, this property has crucial implications for the results of our analysis when the macroeconomic frictions interact with the financial friction.

3.3 The Interaction Between the Financial and Macroeconomic Friction

In this section we show that the impact of staggered interest rates setting on the crisis probability depends on the sign of the shock hitting the economy. In response to a positive shock, due for example to an aggregate demand expansion, the probability of a crisis in the sticky-rate economy is lower (increases less) than in the in the flex-rate economy. In contrast, in response to a negative shock to the deposit rate, due for example to an aggregate demand contraction, the crisis probability is higher (it falls less) than in the flex-rate economy.

We first analyze the effect of a positive shock to the risk-free interest rate (Figure 3). The benchmark is the economy with both frictions and no shock (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 has hit, under flexible and sticky interest rates respectively. As we showed before, under the assumption of sticky rates, the aggregate lending rate in the economy does not increase as much as the bank funding cost following a positive shock. On the one hand, lower lending rates —relative to the flex-rates case— prompt consumers to borrow more ($b_{\mathbf{1}}$) in period 0 and to consume more (c_1) in period 1, as shown by the difference between the circles line and the asterisks line. All else equal, this implies higher expected next-period refinancing needs (b_2) and, therefore, a higher expected probability that the constraint will be binding in period 1. On the other hand, and despite the higher level of borrowing in period 0, expected 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. As the effect of the lower interest rates on net worth dominates the effect on borrowing and consumption, the probability that the constraint will bind in period 1 increases by less than in the flex-rates case in equilibrium —as we can see from the bottom right-hand panel of Figure 3.[16]

Consider now a negative shock. As we can see from Figure 4, in the case of a negative shock, sticky interest rates exacerbate the effects of the financial friction rather than dampening it. Under interest rate stickiness (circles line), the average lending rate now falls by less than the risk-free interest rate. In the sticky rate economy, consumption and

[16]The effect of the lower interest rates on net worth dominates the effect on borrowing and consumption as long as the coefficient of relative risk aversion (ϱ) is larger than 1. With log-utility the two effects cancel out.

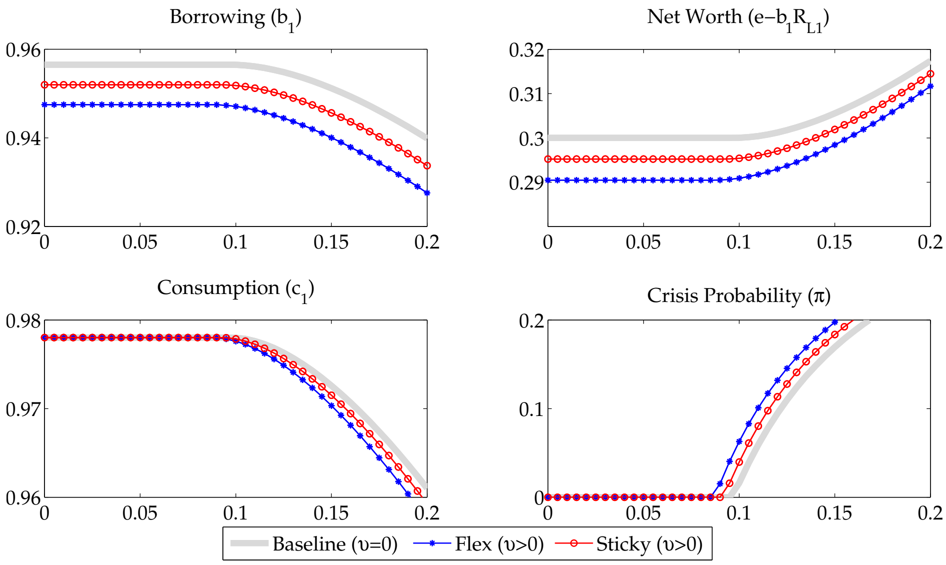


Figure 3 Model Equilibrium with Both Frictions: Positive Shock to the Deposit Rate. On the horizontal axis is the maximum size of the endowment shock (ϵ). The thick solid line displays the equilibriums in the absence of shocks; the thin line with asterisk markers and the thin line with circle markers display the equilibrium after a positive shock under flex-rates and sticky-rates, respectively.

borrowing are lower (or increase less) than in the flex-rate economy (asterisks line) in response to the shock, but next period interest payments are higher. As a result next-period net worth in the sticky rates economy is lower than in the flex-rate economy, and the crisis probability is higher (or it falls less).

In conclusion, when both the macroeconomic and the financial friction are present in the model, interest rate stickiness reduces the crisis probability relative to the flex-rate equilibrium in response to an increase in bank funding costs (such as when aggregate demand is expanding). However, it increases the probability of a crisis relative to the flex-rate equilibrium in response to a fall of bank funding costs (such as when aggregate demand is contracting).

Thus, in our model, sticky rates act as automatic macro-prudential stabilizer in response to positive shocks, while they exacerbate financial stability concerns in response to a negative shock. In this sense, the interaction of the two frictions has an asymmetric impact on financial stability in the model, although the allocation is perfectly symmetric in response to positive and negative shocks.

These results are robust to assuming different values for all parameters of the model, including 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

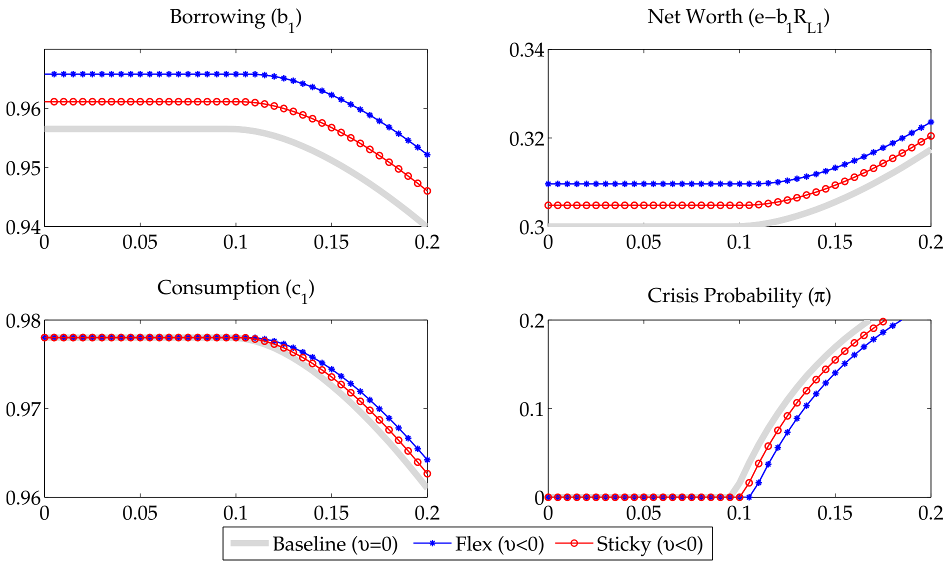


Figure 4 Model Equilibrium with Both Frictions: Negative Shock to the Deposit Rate. On the horizontal axis is the maximum size of the endowment shock (ϵ). The thick solid line displays the equilibriums in the absence of shocks; the thin line with asterisk markers and the thin line with circle markers display the equilibrium after a negative shock under flex-rates and sticky-rates, respectively.

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 Pursuing Macroeconomic and Financial Stability and the Policy Trade-off

In this section we discuss how government intervention, and in particular monetary and macro-prudential policies, can address the market failures of our model economy. To build intuition, we first analyze the cases in which there is only the financial friction or the macroeconomic friction. We then consider the case in which the government faces both frictions with either one or two policy instruments.

A key result of the analysis is that a policy-maker with the interest rate as the only policy instrument faces a trade-off between macroeconomic and financial stability when a negative bank funding cost shock hits the economy. In contrast, when the policy-maker has two instruments (e.g., a macro-prudential tool, such as a tax on bank credit, and a monetary policy instrument, like for instance the policy interest rate), she/he can address both distortions.

4.1 Addressing the Pecuniary Externality

As it is well known, the occasionally binding constraint that is in our model generates a pecuniary externality. This pecuniary externality drives a wedge between private and socially optimal allocations because private agents do not internalize the effect of their decisions on the asset price that enters the specification of the borrowing constraint. Unlike private agents in a decentralized economy, a social planner internalizes that consumption decisions affect the asset price —as shown by the asset price equation in (7)— which, in turn, affects the aggregate collateral constraint in (4).[17]

To see this, we write the planner problem for this economy as follows:

$$\max_{b_1,b_2} \left\{ \begin{array}{c} u(b_1) + \mathbb{E}_0 \Big[u\big(e + b_2 + \pi_1 - b_1 R_{L1}\big) + y - b_2 R_{L2} \\ -\lambda^{sp} \left(b_2 - p_1(e + b_2 - b_1 R_{L1}) \right) \Big] \end{array} \right\},$$

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

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

The asset price, $p_1(c_1)$, therefore, depends on aggregate consumption in the planner problem. The corresponding optimality conditions are:

$$\begin{aligned} u'(c_0) &= R_{L1}\mathbb{E}_0\big[u'(c_1) + \lambda^{sp} p'(c_1)\big], \\ u'(c_1) &= R_{L2} + \lambda^{sp}(1 - p'(c_1)). \end{aligned} \tag{17}$$

By comparing (7) and (17) and noting that $p'(c_1) > 0$, it is clear that there is a wedge between the decentralized and the planned allocation: the social planner saves more than private agents in period zero whenever the borrowing constraint is expected to bind in period 1 with positive probability. She/he internalizes the endogeneity of next period's asset price to this period's aggregate saving. Consumption and borrowing in period 0 are also excessive relative to the planned allocation and the crisis probability will be higher. Instead, when the constraint is not expected to bind, the two allocations coincide.

Pigouvian tax on credit. The social planner and the decentralized allocations can be equalized by setting a state-contingent Pigouvian tax on credit in period 0, namely $b_1(1 - \tau))$, rebating the proceeds with lump-sum transfers. The expression for this tax rate is:

$$\tau = \frac{\mathbb{E}_0\left[\lambda^{sp} p'(c_1)\right]}{\mathbb{E}_0\left[u'(c_1)\right]}. \tag{18}$$

[17]See Bianchi (2011), Jeanne and Korinek (2010a,b), Benigno et al. (2013) for a more detailed discussion.

This is derived by equating (7) with (17), after introducing the credit tax in the budget constraint (3). Equation (18) states that when the constraint is expected to bind in period 1 with positive probability, the policy-maker imposes a tax on credit in period 0. The tax induces private agents to consume and borrow less in period 0, relative to the equilibrium without government intervention.

Alternative macro-prudential tools. In practice, this tax may be difficult to implement. However, the pecuniary externality can be addressed also with other instruments. An alternative way to decentralize the social planner allocation is to act on the supply side of the credit market as opposed to the demand side and increase the banks' funding cost. For instance, the policy-maker can increase the bank funding cost by an additive factor ψ at the beginning of period 0, affecting banks' marginal costs, and hence the lending rate offered to consumers.

In the Appendix, we show that–if rebated in a lump-sum manner–this policy action has the same effect of the Pigouvian tax on credit. Specifically, we prove that the value of ψ that equates the two margins is given by:

$$\psi = \frac{\mathbb{E}_0\left[\lambda^{sp} p'(c_1)\right]}{\mathbb{E}_0\left[u'(c_1)\right]} R. \tag{19}$$

This equation says 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 component to interest rate policy. This, in turn, implies that when the constraint is expected to bind with positive probability, the central bank would raise interest rates so that households consume and borrow less in period 0, reducing the probability of hitting the constraint in period 1. This intervention can be interpreted as a "leaning against the wind" policy, namely an increase in the domestic interest rate over and above what is needed for macroeconomic stabilization purposes justified by financial stability considerations.

As Korinek and Simsek (2016) pointed out, interest rate policy may fail to address the pecuniary externality if monetary policy faces additional constraints giving also rise to demand externalities. However, in the Appendix, we show that the same allocation could also be achieved by increasing reserve requirements or by decreasing the interest rate on remunerated reserves, as well as taxing foreign borrowing of banks. This is because these instruments all act on the same wedge as the additive factor ψ (i.e., on the supply side of the loans market).

In summary, when the borrowing constraint is the only friction in the economy, the pecuniary externality can be addressed either on the demand or the supply side of the credit market by using a menu of alternative policy instruments that substitute each other. The specific instruments that we considered are the Pigouvian tax on credit, interest rate policy, changes in the coefficient of reserve requirements or changes in the interest rate on remunerated reserves, or a tax on bank foreign borrowing.

4.2 Addressing Monopolistic Competition and Interest Rate Rigidity

Recall that, in the banking sector, our model features two distortions. The first is the presence of market power. The second is staggered adjustment of lending rates. In this section we want to study policies that address staggered interest rate setting in isolation from the distortions induced by market power. Therefore, following the New-Keynesian tradition, we remove the effects of market power introducing a subsidy (η) to interest rate repayments so as to remove the markup, i.e. $\mathcal{M}(1-\eta_t) = 1$, without affecting our results.

Staggered interest rate setting implies an inefficient level of credit and consumption because the economy's aggregate lending rate generally differs from the one prevailing under flexible rates. A first way to address interest rate stickiness is *via* the supply side of the market through a direct intervention on banks' funding costs. Assume like before that the central bank can intervene directly on R by an additive factor ψ. Conditional on a shock the bank funding cost, the deposit rate faced by banks becomes $R + \upsilon + \psi$. If the the central bank set ψ such that:

$$\mathcal{M}(R+\upsilon) = \mu\mathcal{M}(R+\upsilon+\psi) + (1-\mu)\mathcal{M}R,$$

the average lending rate in the economy (R_{L1}) equals its flexible counterpart. Solving this expression for ψ yields:

$$\psi = \frac{1-\mu}{\mu}\upsilon. \tag{20}$$

Hence, in response to a positive shock ($\upsilon > 0$), the central bank would raise interest rates by the factor $\psi > 0$; while in response to a negative shock it would lower it by $\psi < 0$.

Like in the case of the pecuniary externality, this allocation could be also achieved with other policy instruments, such as reserve or capital requirements. In the rest of the paper we shall focus on interest rate policy as this is how central banks usually target macroeconomic stability.

4.3 Addressing Both Frictions with Two Instruments

We now analyze the interaction between the two frictions. We consider a policy-maker who maximizes the expected utility of consumers (6), subject to their budget constraints

(3), the borrowing constraint (4), and interest rate staggering.[18]

The two instruments that we consider are the additive interest rate wedge (ψ) and the tax on credit (τ). The credit tax targets the pecuniary externality. The interest rate wedge targets interest rate staggering.

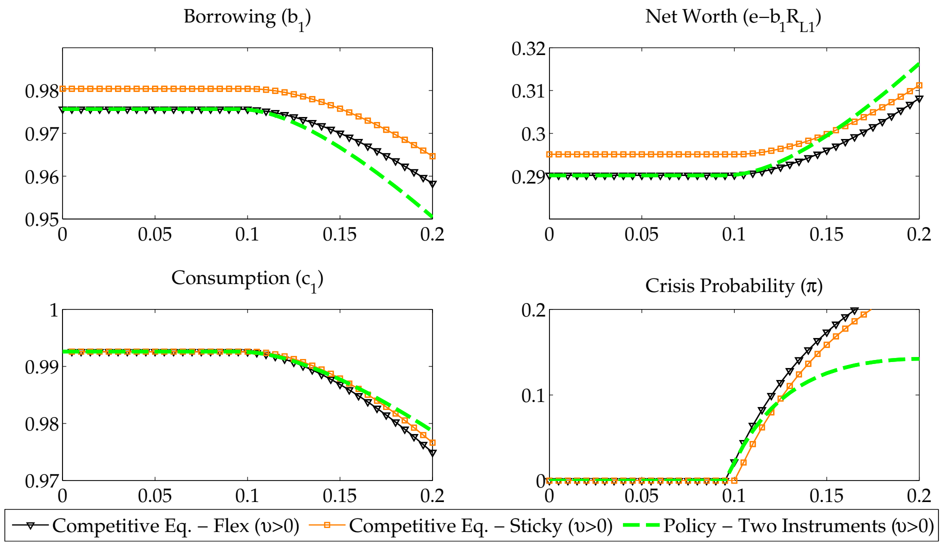


Figure 5 Efficient Allocation with Both Frictions: Positive Shock. On the horizontal axis is the maximum size of the endowment shock (ϵ). The thin lines with triangle and square markers display the equilibrium after a positive bank funding cost shock under flexible and sticky interest rates, respectively. In both of these two allocations, the pecuniary externality is at work. The dashed line displays the efficient allocation. The subsidy η is in place to remove the effects of market power.

A positive bank funding cost shock. Figure 5 summarizes the results in the case of a positive bank funding cost shock. The dashed line displays the equilibrium with two instruments. For comparison, we also report two additional allocations where there is no policy in place: the line with triangles plots the competitive equilibrium allocation in which interest rates are flexible; the line with squares plots the competitive equilibrium in which interest rates are sticky.[19]

With two instruments, the policy-maker can address the macroeconomic and financial friction separately.[20] The policy-maker can first increase the banks' funding cost by a

[18] Again, remember that we remove the effects of the market power distortion introducing a subsidy (η) to interest rate repayments such that $\mathcal{M}(1-\eta_t) = 1$. Our results in Figure 5 would be the same if we were not to do this.

[19] As we are removing the effects of the markup with the subsidy (η), borrowing under flexible interest rates in Figure 5 (triangles line) is now slightly larger than borrowing in Figure 3 (asterisks line).

[20] 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.

factor ψ, as in equation (20), restoring the aggregate lending rate that would prevail under flex rates. This moves the economy from the sticky-rates equilibrium (squares line) to the flex-rates competitive equilibrium (triangles line) with pecuniary externality. The policy-maker can then impose a tax on credit τ, as in equation (18), to address the pecuniary externality, that moves the economy to the dashed line.

Note here that, when $\varepsilon \leq \varepsilon^b$ there is no pecuniary externality because the constraint never binds. In this case, the flexible price allocation (line with triangles) and the efficient allocation (dashed line) coincide. When $\varepsilon > \varepsilon^b$, the level of borrowing in the efficient allocation in period 0 is lower than in the flexible rates equilibrium (upper-left panel of Figure 5), while consumption in period 1 is higher (lower-left panel of Figure 5). This is because whenever the collateral constraint is expected to bind with a positive probability, the tax on credit forces private agents to borrow less in period 0. This increases their net worth and consumption in period 1, thereby also reducing the probability of a financial crisis (upper and lower-right panels of Figure 5, respectively).

Figure 5 also shows the "automatic" macro-prudential role of interest rate stickiness in response to positive shocks. When the pecuniary externality is present but not large (because the uncertainty on the endowment shock is relatively small) a less than full adjustment in interest rates results in higher net worth than under flexible rates, and a crisis probability that is even lower than the case in which the credit tax addresses it, but rates are flexible. When the externality is larger, the crisis probability is higher than the case in which the externality is removed and rates are flexible. The tax on credit curtails borrowing without increasing debt service costs. As a result, in the efficient allocation, the crisis probability is always lower than the flex-rate equilibrium, and can fall below the sticky-rate when the endowment volatility is high enough.

A negative bank funding cost shock. Figure 6 summarizes the results in the case of a negative bank funding cost shock. To address interest rate rigidities, when a negative shock hits the economy, the policy-maker can always lower interest rates by a factor ψ. As we discussed earlier, borrowing will be higher but servicing this higher debt will be easier. As a result net worth will be higher and the crisis probability will be lower after this intervention.

To address the pecuniary externality, the policy-maker can also impose the tax on credit whenever there is a positive probability that the constraint will bind in period 1, regardless of the sign of the funding cost shock. So, when the policy-maker also uses the tax on credit, the probability of a crisis is even lower than in the flexible-rate case, and it is always below the sticky-rate level regardless of the level of endowment volatility.

In conclusion, if complemented by the tax on credit, monetary policy can always address both the financial and the macroeconomic friction, independently of the sign

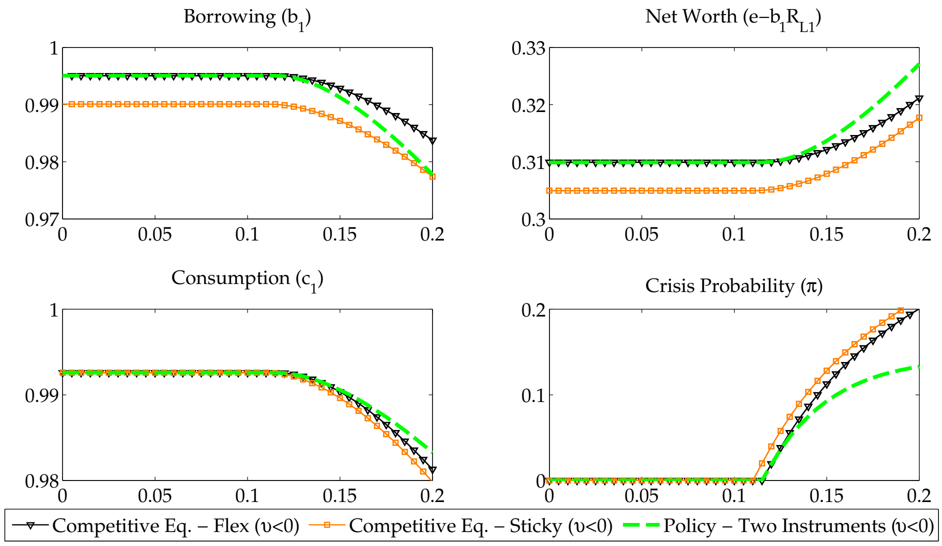


Figure 6 Efficient Allocation with Both Frictions: Positive Shock. On the horizontal axis is the maximum size of the endowment shock (ϵ). The thin lines with triangle and square markers display the equilibrium after a positive bank funding cost shock under flexible and sticky interest rates, respectively. In both of these two allocations, the pecuniary externality is at work. The dashed line displays the efficient allocation. The subsidy η is in place to remove the effects of market power.

of the shock hitting the economy. Note, however, that not all pairs of instruments we discussed earlier can be used to achieve the same outcome. Intervening with the interest rate acts on the supply side of the credit market via bank funding costs (i.e., on the banks' marginal cost of funds) and hence R_L. Our credit tax is an instrument on the demand side of the market, i.e., a household instrument. As we saw earlier, the other monetary instruments that we discussed (ϕ and R^f) would also act the same supply side of the market by affecting R_L. They would therefore not provide a second independent lever to affect the consumption and borrowing. In this sense, the tax on credit complements monetary instruments discussed in the paper in restoring efficiency, while the coefficient or reserve requirements, the rate of remuneration of those reserves, or a capital control are substitutes for the interest rate in our model.

4.4 Addressing Two Frictions with One Instrument: The Monetary Policy Trade-off

We saw earlier that, to restore efficiency, we need an instrument that affects the supply side of the credit market (like all the monetary tools we considered) and one that affects the demand, like the tax on credit. In this section we study what happens when there is no tax on credit to complement monetary policy in addressing both the macroeconomic and the financial friction of our economy.

Specifically, let us consider the case in which both frictions are present in the model but the policy-maker has only the interest rate. In this case, there is a policy trade-off in response to negative shocks. The trade-off emerges because, when the economy is hit by negative shocks, addressing both frictions requires interventions of opposite sign on the same policy instrument.

As we showed earlier, in the case of a positive shock, 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 (20). To address the financial friction, she/he must set the interest rates by the factor $\psi = \mathbb{E}_0\left[R(\lambda^{sp} p'(c_1))/u'(c_1)\right] > 0$, as implied by equation (19). Therefore, when a positive shock hits the economy, a single instrument may restore efficiency. As Kashyap and Stein (2012) noted, in this case, a second instrument might be necessary only if the level of the interest needed to address the pecuniary externality is different than the level needed to address the interest rate stickiness. In general, nonetheless, the two frictions require movements of the interest rate in the same direction.

In contrast, when a negative shock hits the economy, the macroeconomic friction and the financial friction require opposite actions on the interest rate. The macroeconomic friction requires a decrease in interest rates: given that lending interest rates fall less than in the flexible rate case, monetary policy wants to push them down to their flexible levels by setting $\psi < 0$. In contrast, the pecuniary externality requires a positive ψ independently of the sign of the shock. Hence, if the interest rate is the only instrument, the policy maker would try to lower interest rates to address the macroeconomic friction and, at the same time, to raise the interest rate to address the financial friction. As a result the optimal level of the policy interest rate, and hence of the aggregate lending rate prevailing in the economy, is always higher than in the case in which there are two instruments.

The intuition for the result is the same as before. 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.

This trade-off therefore is different than the one faced in response to positive shocks and highlighted by Kashyap and Stein (2012). As we discussed earlier, in the case analyzed by Kashyap and Stein (2012) $R = SV + IOR$, where R is pinned down by a Taylor rule that summarizes the macroeconomic objectives of the central bank, and SV is used for financial stability purposes. So, in that simpler framework, for any given levels of R and SV, IOR can always be adjusted to reconcile the two policy objectives. In our model, however, when both frictions are at work, they require movements in the policy rate (R) in opposite directions in response to negative shocks. As a result, introducing required reserves is not sufficient to resolve this trade-off.

Thus, in our model, the trade-off monetary policy faces in response to negative shocks is not only quantitative, like in the case of positive shocks, but also more fundamentally qualitative. And this shows the value added of introducing an explicit, albeit simple, macroeconomic friction in the analysis alongside a financial friction.

5 US Monetary and Regulatory Policies in The Run-up to the Subprime Mortgage Crisis

In this section we look at the US Subprime mortgage crisis through the lenses of the model and discuss its possible causes. As the model is stylized, we do not attempt a quantitative assessment of alternative causes or a counterfactual exercise of what would have happened under alternative policy scenarios.[21] As we shall see, the stark policy trade-off in response to negative demand shocks identified in our model is useful to interpret the ongoing controversy on the possible causes of the Subprime crisis.

Under former Chairman Alan Greenspan, the Federal Reserve lowered its benchmark policy interest rate from 6.5 percent to about 2 percent in 2000-01 as a response to the bursting of the dot-com bubble and the associated drop in aggregate demand. It then further lowered interest rates to 1 percent in 2002-03, close to but still well above the zero lower bound to address a Japan-style deflationary scare. It finally started a sequence of tightening actions in June 2004, bringing the Fed funds rate back to 5 percent only by 2006.

In the United States, institutional responsibility for financial stability is shared among a multiplicity of agencies, including but not limited to the Federal Reserve. For instance, since the Glass-Steagall Act of 1932, US depository institutions (e.g., banks, thrifts, credit unions, savings and loans, etc.) have been regulated by multiple federal agencies: the Office of the Comptroller of the Currency being in charge of nationally chartered banks and their subsidiaries; the Federal Reserve covering affiliates of nationally chartered banks; the Office of Thrift Supervision overseeing savings institutions; the Federal Deposit Insurance Corporation insuring deposits and having supervisory authority over

[21]For such an assessment see, for example, Duca et al. (2016). In that study, however, there is no normative benchmark like in this paper.

state-chartered and nationally-chartered banks. Outside the banking system, the Security and Exchange Commission (SEC) is responsible for capital markets regulation, the Commodities and Futures Trading Commission (CFTC) oversees derivative markets, while yet other agencies cover other specialized intermediaries and markets.

It is therefore safe to assume that a "second" policy instrument, a broadly defined regulatory policy making function, was available to address financial stability in the run up to the Subprime crisis. The open question is whether monetary policy was kept too loose for too long, or whether the regulatory lever was used ineffectively. As we mentioned earlier, one strongly held view is that monetary policy must bear the bulk of the responsibility for the crisis, while several contributions in the real estate literature found that ineffective regulation before the crisis contributed significantly to the build up of financial excesses and the Subprime debacle.

Figure 7 provides a picture of the evolution of the Fed funds rate (the benchmark US policy interest rate) and the US mortgage market over the 2000-07 period. The figure also reports the last important deregulation measure and the first tightening regulatory measures we can clearly identify (vertical bars).

The first vertical bar (labelled *SEC*) corresponds to the SEC's proposal in July 2004 of a system of voluntary regulation under the Consolidated Supervised Entities program, allowing investment banks to hold less capital in reserve and increase leverage. The second vertical bar (labelled *FDIC1*) corresponds to the issuance by federal regulators of the "Interagency Guidance on Nontraditional Mortgage Product Risks" in October 2006, a response to growing concerns about delinquencies and defaults of nontraditional mortgage products. While the Guidance does not prohibit specific practices, it does discuss which practices are likely to generate the greatest problems. The third vertical bar (labelled *FDIC2*) correspond to the issuance of the "Statement on Subprime Mortgage Lending" in July 2007, a complement to the Guidance with a focus on safety and soundness related to subprime mortgage lending practices (particularly those relating to adjustable rate mortgages).[22]

Broadly speaking, Figure 7 shows that as the Fed started to tighten its monetary policy stance, the prime segment of the mortgage market turned around as one would expect. In contrast, the Subprime segment of the market continued to boom, with increased perceived risk of loans portfolios and declining lending standards. Despite this, the first restrictive regulatory action we can identify was undertaken only in late 2006 (vertical bar labelled *FDIC1* in Figure 7), after almost two years of steady increases in the federal funds rate.

[22]For more details, see the following references:
https://www.sec.gov/rules/final/34-49830.pdf
https://www.fdic.gov/news/news/financial/2006/fil06089.pdf
https://www.fdic.gov/news/news/financial/2007/fil07062.pdf.

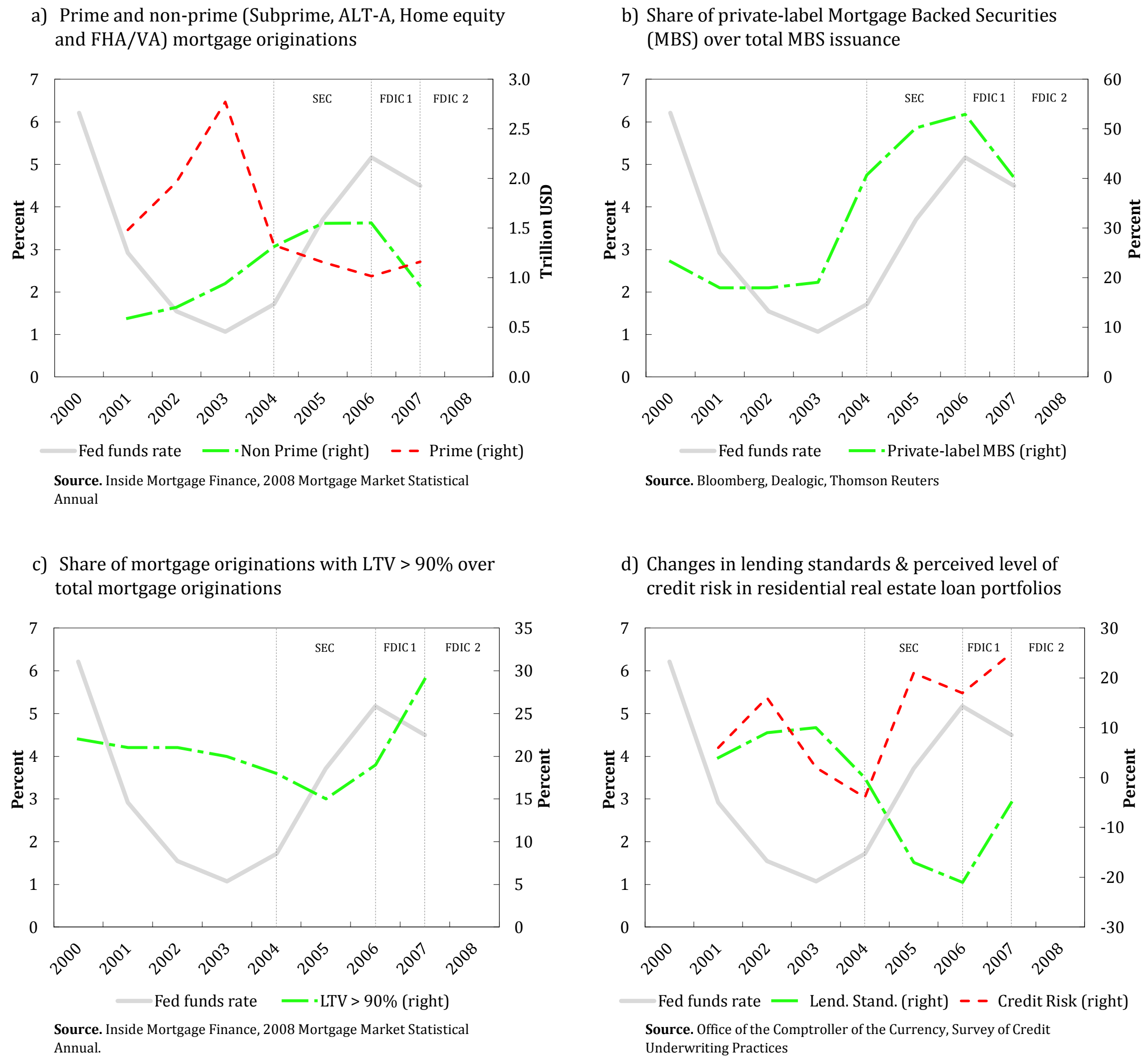


Figure 7 U.S. Mortgage Markets, the Federal Funds Rate, and Selected Regulatory Measures. The figure reports the Fed funds rate together with prime and sub-prime mortgage market indicators from 2000 to 2008. The figures also reports (vertical bars) the last important deregulatory measure and the first measures that tighten regulation that we can clearly identify (see text for more details).

Consider now each panel of Figure 7 in more detail. Panel (a) reports the mortgage origination by category over the period 2001-2007. While prime mortgage origination started to fall in 2003, non-prime originations continued to increase in 2004 and 2005.[23] The share of non-prime 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 Fed was already tightening its monetary policy stance. A similar pattern emerges by looking at the issuance of mortgage backed securities (MBS).[24] In fact, Panel (b) of

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

[24]MBS which can be issued or guaranteed by a government sponsored enterprise (GSE) such as Fannie Mae or Freddie Mac (usually referred to as "'agency MBS')" or they can be issued by private institutions, such as subsidiaries of investment banks, commercial banks, financial institutions, non-bank mortgage

Figure 7 shows that the share of private label MBS increased sharply in the 2003-06 period. Panel (c) of Figure 7 reports the share of mortgage origination with a Loan-to-Value (LTV) ratio greater than 90 percent, which typically reflects regulatory LTV limits. Here we can see that the share of high-LTV mortgages spiked in 2005, two years after the beginning of the monetary policy tightening. Finally, Panel (d) of Figure 7 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.[25] The figure shows that, while the level of perceived risk was sharply increasing starting from 2004, banks started easing their lending standards in 2003 and the process accelerated in 2004-05. This is additional evidence that while loan quality was relatively stable or improving from 2000 to 2003, it deteriorated sharply from 2004 to 2007.

Despite this evidence, US regulatory agencies, including the regulatory arm of the Fed, did not take action, while monetary policy was being tightened. On the contrary, some agencies provided additional deregulatory momentum while monetary policy was being tightened. For instance, the SEC proposed a system of voluntary regulation under the Consolidated Supervised Entities Program in 2004 that allowed investment banks to hold even less capital (vertical line in our charts labeled *SEC*). Regulators did not decide to act until October 2006 when new guidelines tightened "non-traditional" mortgage lending practices (vertical line labeled *FDIC1*). However, these new underwriting criteria did not apply to subprime loans, whose standards were modified in a subsequent action introduced only in July 2007 (vertical line labeled *FDIC2* in Figure 7). By that time, more than 30 subprime lenders had gone bankrupt and many more had to follow.

The variables plotted in Figure 7 are equilibrium outcomes. Nonetheless, they show that policy measures aimed at tightening the subprime sector of the US mortgage market kicked in much later than the tightening of monetary policy enacted by the Federal Reserve. This is consistent with the findings of Duca et al. (2016), who show that the easing of US mortgage capital requirements–rather than the loose monetary conditions–fueled the subprime boom and the jump in house prices relative to rents in the United States.[26]

Within the logic of our model, there are two alternative ways to interpret this evidence. On the one hand, one can take into account that regulatory responsibilities in the United

lenders and home builders (usually called "private label" MBS).

[25]The Office of the Comptroller of the Currency publishes an annual underwriting survey of lending standards and credit risk for the most common types of commercial and retail credit offered by national banks. Using data from the 2009 survey, which covered 52 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. Net percentage calculated by subtracting the percent of banks tightening from the percent of banks easing. Negative values, therefore, indicate easing.

[26]See also Duca et al. (2011), Keys et al. (2010), Coleman IV et al. (2008), and Avery and Brevoort (2015).

States are shared among a multiplicity of institutions, and that these institutions had the levers to tighten the regulatory environment in the run up to the crisis. In this case, noticing that regulation did not start to tighten until about 2006, we could conclude that the crisis stemmed primarily from a regulatory failure consistent with the view prevailing in the real estate literature. However, one could also notice that in the face of regulatory inaction, the Fed should have taken into account that the monetary policy interest rate was effectively the only policy instrument available to address both macroeconomic and financial stability. From this perspective, our model implies that, indeed, the policy rate could have been set higher than the level needed to address only macroeconomic stability and the associated deflationary concerns, consistent with the view perhaps prevailing in the macroeconomics literature. Common to both interpretations is the recognition that the government was facing a trade-off between financial stability and the desire to reflate the economy after the bursting of the dot-com bubble, consistent with the predictions of our model in response to contractionary shocks.

6 Conclusions

In this paper, we develop a model with bank lending interest rate rigidities and an occasionally binding collateral constraint. The first friction gives rise to a macroeconomic stabilization objective akin to the traditional objective of monetary policy, while the second gives rise to a pecuniary externality and a novel financial stability objective. The model speaks to the interaction between macroeconomic and financial stability and embeds a trade-off that can be addressed only by complementing traditional monetary policy interventions with a second, macro-prudential policy instrument.

There are two main results. First, we find that interest rate rigidities have a different impact on financial stability (defined as the probability that the collateral constraint binds) depending on the sign of the shock hitting the economy. In response to expansionary shocks that raise the funding cost of banks (such as an expansionary aggregate demand shock), interest rate rigidity acts as a sort of automatic macro-prudential stabilizer. This is because higher debt today, induced by lower interest rates (relative to the flexible interest rate equilibrium), is offset by lower interest repayments tomorrow, resulting in higher net worth and lower probability of a crisis in the future. In contrast, when the economy is contracting and bank funding costs decline (for instance, in response to a contractionary shock), real interest rate rigidity leads to a relatively higher crisis probability through the same mechanisms working in reverse: borrowing and consumption are relatively lower today, but they are offset by relatively higher debt service tomorrow, resulting in lower future net-worth and higher crisis probability. While the allocations in response to positive and negative shocks are fully symmetric, the implications for financial stability are asymmetric.

Second, we find that, when the interest rate is the only policy instrument to address both the macroeconomic and the financial friction that are in the model, and a negative shock hits the economy, a policy trade-off emerges. This is because the two frictions require interventions of opposite direction on the same instrument. Other instruments, however, may be at the policy-maker's disposal to pursue financial stability. Our model shows that when a second instrument that can operate on the household's margin on the demand side of the credit market is available, such as for instance a tax on bank credit, this trade-off disappears and efficiency can be restored. Moreover, we also show that alternative monetary instruments, like the coefficient of reserve requirement or the rate of remuneration of these reserves or capital controls substitute the interest rate and cannot complement it because they act on the same bank's margin, on the supply side of the credit market in our model.

The model is useful to interpret the controversy on the origins of the US Subprime mortgage crisis. It implies that if the Fed was cognizant that financial regulation was being ineffective, it should have adopted a tighter monetary policy stance than the it actually did, consistent with some of the views in the macroeconomic literature that monetary policy was too loose for too long during the 2000-2004 period. But the model also suggests that the Subprime mortgage boom could not have been prevented with monetary policy alone without additional costs in terms of macroeconomic stability. Indeed, through the lenses of the model, and , consistent with the view prevailing in the real estate literature, regulation should have complemented monetary policy's stabilization efforts during 2000-2004 with a tightening well before the beginning of the crisis in 2006. A quantitative exploration of the trade-off identified in the model in the context of a more conventional New Keynesian model with price rigidities and pecuniary externalities is an interesting avenue for future research.

7 Acknowledgements

This paper was previously circulated under the title "Coordinating Monetary and Macro-Prudential Policies." We would like to thank the editor, Iftekhar Hasan, and a referee for their useful comments. For useful discussions and helpful comments we also thank Andy Blake, Giancarlo Corsetti, Bora Durdu, Jihad Dagher, John V. Duca, Zheng Liu, Gabor Pinter, Jeremy Stein and seminar participants at the 2016 Chinese Real Estate Congress (E-House China Best Paper Award), the 2016 AREUEA National Conference, the 2016 IFABS/ASSA Annual Meeting, 2013 Macro Banking and Finance Workshop, the 2013 MMF Conference, the Cattolica University, the Bank of Italy, the EPFL, the Bank of Portugal, the Banque de France, the Bank of England, the IADB, 2012 LACEA Annual

Meetings, and 2012 EEA Annual Meetings. The information and opinions presented in this paper are entirely those of the authors, and not necessarily those of the Bank of England or the NBER.

A Additional Results

Leverage. Consider a loan-to-value (LTV) constraint where one can borrow up to a fraction (Θ) of the value of the collateral, say a house:

$$b \leq \Theta p. \tag{A.1}$$

The LTV constraint implies the following leverage ratio:

$$L^{\max} = \frac{p}{p - \Theta p} = \frac{1}{1 - \Theta}. \tag{A.2}$$

Here, leverage L is well defined only if $\Theta < 1$ (i.e., for positive levels of "equity"), and $L = L^{\max}$ when the LTV constraint is binding and $L < L^{\max}$ otherwise.

How does leverage behave in our simple model? In our model $\Theta = 1$. So equation (A.2) implies a unbounded maximum leverage ratio. In equilibrium, however, leverage is pinned down by preferences, interest rates, the deterministic return on the asset and the shadow price of the constraint and is lower than ∞.

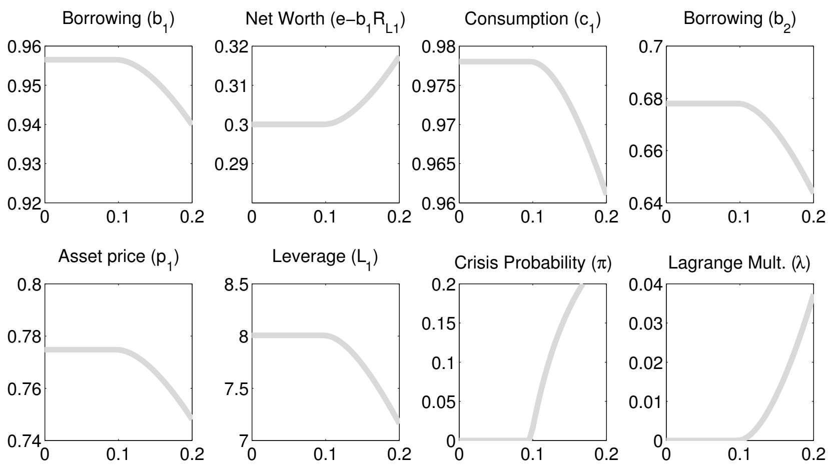


Figure A.1 Model Equilibrium with Financial Friction. On the horizontal axis is the maximum size of the endowment shock (ϵ).

Figure A.1 reports the equilibrium leverage in our baseline model. Consider leverage in period 1 (the period in which there is the constraint) before the shock to the endowment realizes. Consistent with the above definition and the notation in the text, we have:

$$L_1 = \frac{p_1}{p_1 - b_2}. \tag{A.3}$$

When the collateral constraint is never binding, equilibrium leverage in our baseline model is equal to 8, even if for simplicity we set $\Theta = 1$. When the collateral constraint is binding with positive probability, leverage is lower and decreases with the maximum value of the shock.

Why does leverage (L_1) is lower with more volatile endowment shocks? When the collateral constraint is binding with positive probability (i.e., when $\pi > 0$) the Lagrange multiplier (λ) becomes positive. As a result, households optimally reduce their desired consumption and borrowing in both periods (b_1 and b_2). Lower borrowing in period 1 (b_2) implies lower leverage. Lower consumption implies a lower asset price (p_1), and a lower asset price (p_1) implies higher leverage as we can see from the partial derivative of L_1 with respect to p_1. The former effect dominates in our model.

Debt-To-Income constraint. Consider a debt-to-income constraint rather than a LTV constraint:

$$R_{L2}b_2 \leq \chi e, \tag{A.4}$$

where total expected repayment period 2—interest plus principal, $R_{L2}b_2$—cannot be larger than a fraction (χ) of expected income.

The problem for the representative household therefore is:

$$\mathcal{V}_1 = \max_{b_2,\theta_2} \left\{ u\Big(e + b_2 + (\theta_1 - \theta_2)p_1 + \pi_1 - b_1 R_{L1} \Big) + \theta_2 y + \pi_2 - b_2 R_{L2} - \lambda(R_{L2}b_2 - \chi e) \right\}, \tag{A.5}$$

The first order conditions for the competitive equilibrium (CE) therefore are:

$$\begin{cases} FOC(b_1): & u'(c_0) = R_{L1}\mathbb{E}_0\big[u'(c_1)\big], \\ FOC(b_2): & u'(c_1) = R_{L2} + \lambda R_{L2}, \\ FOC(\theta_2): & p_1 = y/\mathbb{E}_0\left[u'(c_1)\right]. \end{cases} \tag{A.6}$$

The only difference relative to the LTV economy is that R_{L2} now multiplies the Lagrange multiplier in $FOC(b_2)$. The shadow price of the constraint will always be higher in the DTI economy than in the LTV economy.

This implies that the qualitative properties of the model are the same as in the LTV economy. The allocations in the competitive equilibrium will be different, as well as the maximum value of the endowment for which the constraint binds with positive probability, but the behavior of the model is unchanged.

B Alternative Policy Instruments

B.1 Characterizing Monetary Policy

For simplicity, in the model, we represent monetary policy by assuming that the central bank can affect bank funding costs with an additive factor ψ, so that the marginal cost of funds for banks becomes $R + \psi$. In this appendix, we show that the effects of adding (subtracting) ψ are the same as those of increasing (decreasing) the coefficient of reserve requirements or lowering (increasing) the rate of remuneration of those reserves in a system of remunerated required reserves.

Suppose that banks must hold a fraction ϕ of their deposits in the form of *unremunerated* reserves:

$$f(j) \geq \phi d(j). \tag{B.1}$$

Bank j's balance sheet will be:

Assets	Liabilities
Loans $b(j)$ Reserves $f(j)$	Deposits $d(j)$

(B.2)

In each period, bank j maximizes its profits:

$$\max_{R_{Lt}(j),b_t(j),f_t(j),d_t(j)} b_t(j)R_{Lt}(j) + f_t(j) - d_t(j)R, \tag{B.3}$$

subject to the demand schedule in (9), the balance sheet constraint $b_t(j) + f_t(j) = d_t(j)$, and the regulatory constraint $f_t(j) \geq \phi d_t(j)$. Solving banks' maximization problems yields the following optimal level of the lending rate:

$$R_{Lt}(j) = \frac{\zeta}{\zeta - 1}\frac{R - \phi}{1 - \phi}. \tag{B.4}$$

This shows that the lending rate charged by banks is increasing in the coefficient of reserve requirement (i.e., the reserve requirement is a tax on banks). Increasing (decreasing) reserve requirements, therefore, has the same effect as adding (subtracting) ψ to R.

Suppose now that banks are required to hold a fraction ϕ of deposits in the form of *remunerated* reserves:

$$f(j) \geq \phi d(j), \tag{B.5}$$

where R^f is the interest rate at which required reserves are remunerated (i.e., r_{IOR} in the notation of Kashyap and Stein (2012)).

Bank j's balance sheet continues is unchanged. But bank $j's$ maximization problem becomes:

$$\max_{R_{Lt}(j),b_t(j),f_t(j),d_t(j)} b_t(j)R_{Lt}(j) + f_t(j)R^f - d_t(j)R, \tag{B.6}$$

subject to the demand schedule in (9), the balance sheet constraint $b_t(j) + f_t(j) = d_t(j)$, and the regulatory constraint $f_t(j) \geq \phi d_t(j)$.

Solving banks' maximization problems yields the following optimal level of the lending rate:

$$R_{Lt}(j) = \frac{\zeta}{\zeta - 1}\frac{R - \phi R^f}{1 - \phi}. \tag{B.7}$$

We can now see expression (B.7) that the lending rate, for given coefficient of reserve requirement ϕ, is decreasing in the rate of remuneration of these reserves, R^f. So remunerating these reserves can partially or completely offset the implicit "reserve requirement tax". Indeed, in the limiting case in which $R^f = R_t$, the lending rate coincides to the case in which there are no reserve requirements.

B.2 A Tax on Bank Foreign Borrowing

Assume that banks are required to pay a tax (Ξ) on their foreign borrowing. Bank maximize profits, which are now defined by:

$$\max_{R_{Lt}(j),b_t(j),d_t(j)} b_t(j)R_{Lt}(j) - d_t(j)R_t - d_t(j)\Xi. \tag{B.8}$$

subject to the demand schedule in (9) and the balance sheet constraint $b_t(j) = d_t(j)$.

Solving banks' maximization problems yields the following optimal level of the lending rate:

$$R_{Lt}(j) = \frac{\zeta}{\zeta - 1}\left(R_t + \Xi\right) = \mathcal{M}\left(R_t + \Xi\right). \tag{B.9}$$

We can see from the expression in (B.9) that the lending rate is higher relative to the case of no tax on foreign borrowing ($\Xi > 0$) and is increasing in the tax on borrowing. Moreover, equation (B.9) also shows that increasing (decreasing) the tax on foreign borrowing has the same effect as adding (subtracting) ψ to R.

B.3 Equivalence Results

If there is only one friction in the economy, either the pecuniary externality or interest rate rigidity, all the monetary policy instruments discussed above can be used to address them individually, including the tax on foreign borrowing. Therefore, they are substitute in the sense that we can use one or the other to achieve the same allocation.

It is evident that, when interest rates setting is staggered, the instruments ϕ and R_f can always restore the flexible average lending rate in the economy (R_{L1}), by affecting banks' funding costs directly. Consider now the pecuniary externality. It easy to see that leaning against the wind *via* the additive factor ψ can address it like the tax on credit. In this case the consumer maximization problem becomes:

$$\max_{b_1,b_2}\left\{\begin{array}{c} u(b_1) + \mathbb{E}_0\Big[u\big(e + b_2 + \pi_1 - b_1\mathcal{M}(R+\psi) + TR\big) + \\ +y - b_2 R_{L2} - \lambda(b_2 - p_1)\Big] \end{array}\right\}. \tag{B.10}$$

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:

$$\begin{cases} u'(c_0) = R_{L1}\mathbb{E}_0\big[u'(c_1) + \lambda^{sp}p'(c_1)\big], \\ u'(c_0) = \mathcal{M}(R+\psi)\mathbb{E}_0\left[u'(c_1)\right], \end{cases} \tag{B.11}$$

Solving for ψ yields:

$$\psi = \frac{\mathbb{E}_0\left[\lambda^{sp}p'(c_1)\right]}{\mathbb{E}_0\left[u'(c_1)\right]}R. \tag{B.12}$$

The same allocation can be achieved with the coefficient of reserve requirement or its rate of remuneration. With reserve requirements, the consumers' maximization problem becomes:

$$\max_{b_1,b_2}\left\{\begin{array}{c} u(b_1) + \mathbb{E}_0\Big[u\big(e + b_2 + \pi_1 - b_1\mathcal{M}\left(\frac{R_t-\phi}{1-\phi}\right) + TR\big) + \\ +y - b_2 R_{L2} - \lambda(b_2 - p_1)\Big] \end{array}\right\}. \tag{B.13}$$

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 ϕ which closes the wedge:

$$\begin{cases} u'(c_0) = R_{L1}\mathbb{E}_0\big[u'(c_1) + \lambda^{sp} p'(c_1)\big], \\ u'(c_0) = \mathcal{M}\left(\frac{R_t - \phi}{1-\phi}\right)\mathbb{E}_0\left[u'(c_1)\right], \end{cases} \tag{B.14}$$

Solving for ϕ yields:

$$\phi = \frac{\mathbb{E}_0\big[\lambda^{sp} p'(c_1)\big]}{\mathbb{E}_0\big[u'(c_1) + \lambda^{sp} p'(c_1)\big] - \frac{\mathbb{E}_0[u'(c_1)]}{R_t}}. \tag{B.15}$$

Similarly, in a system of remunerated reserve requirements, the consumers' maximization problem becomes:

$$\max_{b_1, b_2} \left\{ \begin{array}{c} u(b_1) + \mathbb{E}_0\Big[u\big(e + b_2 + \pi_1 - b_1\mathcal{M}\left(\frac{R_t - \phi R^f}{1-\phi}\right) + TR\big) + \\ +y - b_2 R_{L2} - \lambda(b_2 - p_1)\Big] \end{array} \right\}. \tag{B.16}$$

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

$$\begin{cases} u'(c_0) = R_{L1}\mathbb{E}_0\big[u'(c_1) + \lambda^{sp} p'(c_1)\big], \\ u'(c_0) = \mathcal{M}\left(\frac{R_t - \phi R^f}{1-\phi}\right)\mathbb{E}_0\left[u'(c_1)\right], \end{cases} \tag{B.17}$$

Solving for R^f yields:

$$R^f = R_t - (1-\phi)R_t\mathbb{E}_0\left[\lambda^{sp} p'(c_1)\right]. \tag{B.18}$$

The same allocation can also be achieved with the tax on foreign borrowing. With the tax on foreign borrowing, the consumers' maximization problem becomes:

$$\max_{b_1, b_2} \left\{ \begin{array}{c} u(b_1) + \mathbb{E}_0\Big[u\big(e + b_2 + \pi_1 - b_1\mathcal{M}\left(R_t + \Xi\right) + TR\big) + \\ +y - b_2 R_{L2} - \lambda(b_2 - p_1)\Big] \end{array} \right\}. \tag{B.19}$$

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 Ξ which closes the wedge:

$$\begin{cases} u'(c_0) = R_{L1}\mathbb{E}_0\big[u'(c_1) + \lambda^{sp} p'(c_1)\big], \\ u'(c_0) = \mathcal{M}\left(R_t + \Xi\right)\mathbb{E}_0\left[u'(c_1)\right], \end{cases} \tag{B.20}$$

Solving for Ξ yields:

$$\Xi = \frac{\mathbb{E}_0\left[\lambda^{sp} p'(c_1)\right]}{\mathbb{E}_0\left[u'(c_1)\right]} R. \tag{B.21}$$

The tax on foreign borrowing acts on banks' marginal cost of raising funds, therefore affecting the lending rate R_{Lt}. As such, it is a substitute for monetary policy, the coefficient of reserve requirements (ϕ), or the rate of remuneration of those reserves (R^f).

Finally, it is also easy to see that the tax on credit can also be used to address interest rate stickiness in the absence of the pecuniary externality.

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