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Financial Regulation in General Equilibrium*

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Abstract

This paper explores how different types of financial regulation could combat many of the phenomena that were observed in the financial crisis of 2007 to 2009. The primary contribution is the introduction of a model that includes both a banking system and a "shadow banking system" that each help households finance their expenditures. Households sometimes choose to default on their loans, and when they do this triggers forced selling by the shadow banks. Because the forced selling comes when net worth of potential buyers is low, the ensuing price dynamics can be described as a fire sale. The proposed framework can assess five different policy options that officials have advocated for combating defaults, credit crunches and fire sales, namely: limits on loan to value ratios, capital requirements for banks, liquidity coverage ratios for banks, dynamic loan loss provisioning for banks, and margin requirements on repurchase agreements used by shadow banks. The paper aims to develop some general intuition about the interactions between the tools and to determine whether they act as complements and substitutes.

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1. Introduction

This paper explores how different types of financial regulation could combat many of the phenomena that were observed in the financial crisis of 2007 to 2009. The primary contribution is the introduction of a model that includes both a banking system and a "shadow banking system" that each help households finance their expenditures. Households sometimes choose to default on their loans, and when they do this triggers forced selling by the shadow banks. Because the forced selling comes when net worth of potential buyers is low, the ensuing price dynamics can be described as a fire sale. The presence of the banking and shadow banking system, and the possibility that their interaction can create fire sales distinguishes our analysis from previous studies.

The model builds on past work by Tsomocos (2003) and Goodhart, Tsomocos and Vardoulakis (2010) and uses many of the same ingredients as their general equilibrium model. In particular, the model includes two periods and allows for heterogeneous agents who borrow and lend to each other through financial intermediaries. When the borrowers default, the intermediaries suffer losses and tighten lending standards to future borrowers. Thus, the model also includes a possible credit crunch.

While extremely stylized, the model is still rich enough to compare the efficacy of several regulatory tools that are otherwise difficult to assess. In particular, the proposed framework can contrast five different policy options that officials have advocated for combating defaults, credit crunches and fire sales, namely: limits on loan to value ratios, capital requirements for banks, liquidity coverage ratios for banks, dynamic loan loss provisioning for banks, and margin requirements on repurchase agreements used by shadow banks. The paper aims to develop some general intuition about the extent to which different regulatory tools act as complements and substitutes.

Perhaps the most compelling conclusion from the analysis is the importance of taking a stand on the economic function played by the shadow banks and the precise risks that their presence creates for the rest of the financial system. This manifestation of the model embeds one rationale for the shadow banks existence and pinpoints the problems that emerge because of the way that they contribute to producing fire sales.

While these assumptions generate many specifc predictions, the most general implication is that fire-sale risk can be controlled in three very different ways. One approach is to create incentives to make fewer mortgage loans initially, in which case a house prices crash generates fewer losses for lenders. A second approach is to push banks to be better capitalized in the event of a bust. This approach helps contain the follow-on effects of mortgage defaults. A third approach is to attempt to offset the spillovers between the bust and the boom. Most policies that mitigate the effects of house price decline have the unintended effect of exacerbating house price increases during a boom. Hence another policy option is to try to limit this spillover. In this model, the primary difference in the incidence and efficacy of different regulations turns on which of these channels that they operate through.

While this conclusion seems quite intuitive, this research program is just beginning and the modeling approach is very flexible. So this model is better thought of as a framework for comparing different potential financial externalities and for regulating them. Hence the longer term conclusions about regulatory design will depend on analyzing many variants of the model and determining which are robust to the many possible formalizations of the financial system. The findings here should be viewed as provisional first steps.

The remainder of the paper proceeds as follows. Section 2 introduces the broad features of the model, motivating agent heterogeneity, the restrictions on market structure that are imposed, and introducing the notation used to describe each agent's choices. The optimization problems for the consumers, banks and non-banks are introduced and the model's externalities are also described. Section 3 introduces the regulatory tools that can be used to control the externalities. Section 4 solves a calibrated version of the model that can be used to conduct regulatory experiments. Section 5 shows the effects of the various policies one at a time and an example of a combined regulatory intervention. No single tool can offset the many knock-on effects that follow from defaults. Section 6 concludes.

2. *Model Ingredients and Motivation*

Because the model has many moving parts it is helpful to start with a broad overview that explains why such complexity is necessary. Two features of the model are taken for granted. One is that these issues must be analyzed in a general equilibrium model with fully endogenous prices that embody all the effects of potential regulations. Secondly, the analysis must be dynamic because many potential regulations differ in their ex-ante and ex-post effects. Without multiple time periods these considerations cannot be studied and the model takes the minimal step in this direction by having two periods.

The job of the financial system in the model is to intermediate funds between borrowers and lenders.[1] The two types of consumers are introduced. They are assumed to differ not only in their wealth, but also in their goods endowments so that there is a natural reason for trade. One household (R) is very well endowed with "housing", which is a durable good. A second household (P) is less well endowed with "potatoes", a non-durable. The R household will be selling homes to finance its consumption of potatoes, while the P household will need to borrow to buy housing. In the initial period P and R also want to trade to correct for their different endowments.

To simplify, there is no uncertainty in the initial period. In the second period, house prices are stochastic and can rise or fall. By assumption when they fall, the drop is substantial enough to trigger a default by P on their housing loans. These defaults will have potential knock-on effects as described below.

The desire to study the shadow banking system and the potential effects of regulatory arbitrage requires the inclusion of two types of financial institutions. To simplify this interaction both institutions are assumed to be risk-averse so that there are limits to how much credit each will extend. The "non-bank" (N) is less risk-averse than the "bank" (B).[2] The bank takes deposits, makes loans, securitizes loans and is subject to capital requirements. The non-bank buys securitized assets and funds itself via repurchase agreements with the banks.

With this structure, the non-banks resemble, in two respects, the off-balance sheet entities that figured prominently in the crisis. First, the combination of their low risk aversion and lack of capital requirements means that they will be riskier than the banks. Second, if the assets that the non-banks hold lose value due to default, their ability to continue their repo financing will vanish and the bad assets that serve as collateral on the repos will flow back into the banking system.

In this case, the banks still have deposit contracts to honor so it is possible that they have to sell some of assets that they receive from the non-banks. With the previous non-banks wiped

[1] In the course of doing so, the bank engages in some maturity transformation since, as discussed later, the deposits it offers can be demanded before mortgage loans it makes mature.

[2] The bank has more assets in which it can invest to hedge its risks than the non-bank. Should the two institutions have the same risk aversion and face the same costs of defaulting, the bank would have higher leverage. Hence, a less risk averse non-bank sector facilitates credit extension and qualitatively provides another reason for lower lending margins.

out, there will be limited buyers so that selling causes the price of the collateral to fall further. This kind of fire sale nicely captures the Shleifer and Vishny (2011) definition of a fire sale in that prices are depressed by the combination of forced selling and a lack of natural buyers. This is one potential knock-on effect from the initial default.

There are two remaining actors in the model. During the second period a first-time home buyer (F) who is endowed only with potatoes comes on the scene. These agents serve two purposes. First, absent some first time buyers any defaults by P would be relatively innocuous because they would wind up back in their own houses. Second, the first time buyers still need to borrow to acquire their housing. The borrowing terms for F can be compared in situations when there is, or is not, a default by P. Across these scenarios, the value of F's endowment need not change, so F's creditworthiness is not affected directly by the default. If P's default worsens the credit terms for F, then F faces a credit crunch. This is a second potential knock-on effect from the default.

The final agent in the model is called the central bank (CB). The CB provides banks with short-term debt which is completely riskless, i.e. not subject to potential default. The potential reliance on CB lending is a shortcut that captures the observation that distressed borrowers lose access to longer-term funding and find that lenders shorten the maturity of loans to guarantee repayment. More generally, the central bank is standing in for the rest of the world financial system that is assumed to be a source of potential funding for this economy.

There are additional timing assumptions, not discussed so far, that relate to the sequence of when loans are made and repaid. The assumptions are standard ones that give rise to a transaction facilitating role for banks.

2.1 Agent P's optimization problem

Agent P derives utility from consuming potatoes and housing. He is endowed with potatoes in every period and every state (1, 2g, and 2b). Throughout, the labeling convention indentifies agents with superscripts, and goods, and periods/states with subscripts. Thus his endowment of potatoes is given by the $\bar{e}^P = (e^P_{1,p}, e^P_{2g,p}, e^P_{2b,p})$ in period 1, the good and the bad state in period 2, respectively.

Agent P is not endowed with any housing initially, so he enters the housing market in period 1 to purchase a home. He will reoptimize his housing consumption in period 2, recognizing that houses bought in period 1 will depreciate but can continue to provide housing services in the second period. P's housing choices are labeled $c_{1,h}^{P}$, $c_{2g,h}^{P}$ and $c_{2b,h}^{P}$. To fund his purchase he sells some of his endowment of potatoes, $(q_{1,p}^{P}, q_{2g,p}^{P}, q_{2b,p}^{P})$, and also enters into a mortgage agreement $MORT^{P}$, with interest rate r^{MORT}, pledging the house as collateral. The remaining potatoes that are consumed are denoted by $c_{1,p}^{P}$, $c_{2g,p}^{P}$, and $c_{2b,p}^{P}$.

If the bad state realizes, the value of the house falls and P must decide whether to continue paying the mortgage or to default. P will choose to default in equilibrium when the value of his collateral, $P_{2b,h}c_{1,h}^{P}$, is less than the the amount he has to repay, i.e. the principal, $MORT^{P}$ plus interest $MORT^{P} \cdot r^{MORT}$, where P_{2bh} is the equilibrium price of houses in the bad state.[3] In the case of default, P also suffers a non-pecuniary (reputational) penalty τ_{2b}^{P} per each dollar of default, i.e. τ_{2b}^{P} times the difference between the amount owed and the salvage value of the collateral.[4] After a default P must re-enter the housing market to get a new house, $c_{2b,h}^{P}$. In what follows the housing price decline is assumed to be sufficiently large so that default will be optimal.

His expected utility, $\overline{U}^{P}$, is then given by:

$$\overline{U}^{P} = U^{P}\left(c_{1,p}^{P}, c_{1,h}^{P}\right) + \xi \cdot \omega_{2g}\left[U^{P}\left(c_{2g,p}^{P}, (1-\delta)c_{1,h}^{P} + c_{2g,h}^{P}\right)\right] +$$

$$\xi \cdot \omega_{2b}\left[U^{P}\left(c_{2b,p}^{P}, c_{2b,h}^{P}\right) - \tau_{2b}^{P}\left[MORT^{P}(1+r^{MORT}) - P_{2b,h}c_{1,h}^{P}\right]\right] \qquad (1)$$

where $0 < \xi,$ and $\delta < 1$ are the time discount for future utility and the depreciation of houses, respectively. The probabilities of the good and the bad state occurring in period 2 are given by $0 < \omega_{2g}, \omega_{2b} < 1$ respectively, with $\omega_{2g} + \omega_{2b} = 1$. All agents are assumed to have the same beliefs about the probabilities of the states and the same discount and depreciation rates.

All contracts are denominated in money, thus giving banks a role in facilitating transactions. P takes a short-term loan LST_{1}^{P}, with interest rate r_{1}^{ST}, and combines it with his time

[3] The default condition is an extension of Geanakoplos (1997, 2003) and Geanakoplos and Zame (2002) to an economy with nominal contracts.

[4] Given market incompleteness, default increases the hedging opportunities of market participants and the penalties for default should be less than infinite to improve welfare, see Dubey, Geanakoplos, Shubik (2005). Diamond (1984) interprets default penalties as a reduced form way to approximate time spent in bankruptcy proceedings, the resources costs of "explaining" poor results, and loss of "reputation" in bankruptcy.

1 monetary endowment, $Money_1^P$, to purchase his house. He repays the loan at the end of period 1 with the proceeds of the potatoes sales, $P_{1,p}q_{1,p}^P$, where $P_{1,p}$ is the price of potatoes at t=1. Thus his budget constraint for housing purchase satisfies

$$P_{1,h}c_{1,h}^P \leq Money_1^P + MORT^P + LST_1^P$$

and the repayment of the short-term loan has to satisfy

$$LST_1^P(1 + r_1^{ST}) \leq P_{1,p}q_{1,p}^P$$

When the good state occurs, agent P repays his mortgage, and chooses whether to buy more housing, $c_{2g,h}^P$ at the price of $P_{2g,h}$. He funds this using his monetary endowment, $Money_{2g}^P$, and with a new short-term loan, LST_{2g}^P. The loan will be repaid by selling potatoes, $q_{2g,p}^P$, at a price of $P_{2g,p}$. Thus his constraints are given by:

$$MORT^P(1 + r^{MORT}) + P_{2g,h}c_{2g,h}^P \leq Money_{2g}^P + LST_{2g}^P$$

$$LST_{2g}^P(1 + r_{2g}^{ST}) \leq P_{2g,p}q_{2g,p}^P$$

The only difference in the bad state of the world is that agent P does not repay his mortgage, thus his constraints are given by:

$$P_{2b,h}c_{2b,h}^P \leq Money_{2b}^P + LST_{2b}^P$$

$$LST_{2b}^P(1 + r_{2b}^{ST}) \leq P_{2b,p}q_{2b,p}^P$$

2.2 Agent F's optimization problem

Agent F enters the economy in the second period and he is endowed with potatoes, $e_{2s,p}^F$ for $s \in \{g, b\}$. His optimization problem is identical in both states, i.e. he purchases houses, $c_{2s,h}^F$, which he funds with his monetary endowment, $Money_{2s}^F$, and short-term loans, LST_{2s}^F. His constraint in every state is, thus, given by

$$P_{2s,h}c_{2s,h}^F \leq Money_{2s}^F + LST_{2s}^F$$

The interest rate on the short-term loans is r_{2s}^{ST}, and they are repaid with the proceeds from the potatoes sales, which are $P_{2s,p}q_{2s,p}^F$. Thus,

$$LST_{2s}^F(1 + r_{2s}^{ST}) \leq P_{2s,p}q_{2s,p}^F$$

F's optimal choices depend only on the state of the world, $s\epsilon\{g,b\}$, that is realized. Thus, the utililty he optimizes, which is given by the consumption of houses he purchases and of the potatoes he has not sold, is

$$U^F\left(c^F_{2s,p}, c^F_{2s,h}\right)$$

Nevertheless, all the various regulations described later on are determined before the state of the world is realized. The effect of regulation on F's welfare can be summarized by his expected utility, $\overline{U}^F$, i.e.

$$\overline{U}^F = \omega_{2g}\left[U^F\left(c^F_{2g,p}, c^F_{2g,h}\right)\right] + \omega_{2b}\left[U^F\left(c^F_{2b,p}, c^F_{2b,h}\right)\right]$$

2.3 Agent R's optimization problem

Agent R is the mirror image of Agent P in that he is endowed only with houses and needs to sell them to obtain potatoes. His endowments are denoted e^R_{1h} in period 1 and $e^R_{2s,h}$ in state $s \in \{g,b\}$ of period 2. He buys $c^R_{1,p}$ potatoes in period 1 and $c^R_{2s,p}$ in state s of period 2, which he funds by combining short-term loans of LST^R_1 and LST^R_{2s}, with his monetary endowments $Money^R_1$ and $Money^R_{2s}$. In order to repay the short-term loans, he sells some of housing endowment, $q^R_{1,h}$ and $q^R_{2s,h}$, at the market prices $P_{1,h}$ and $P_{2s,h}$. He consumes the remainder of housing endowment. His expected utility, $\overline{U}^R$, is then:

$$\overline{U}^R = U^R\left(c^R_{1,p}, c^R_{1,h}\right) + \xi \cdot \omega_{2g}\left[U^R\left(c^R_{2g,p}, (1-\delta)c^R_{1,h} + c^R_{2g,h}\right)\right] +$$
$$\xi \cdot \omega_{2b}\left[U^R\left(c^R_{2b,p}, (1-\delta)c^R_{1,h} + c^R_{2b,h}\right)\right]$$

The cases considered below presume that the total endowment of potatoes in the economy is higher than the endowment of houses. Thus, the relative price of potatoes over houses is low and the proceeds from houses sales at t=1 are higher than the funds needed to purchase potatoes. Thus, agent R will want to save. He deposits D^R at a promised interest rate r^D in order to use them to purchase potatoes in period 2. His budget constraint in the beginning of period 1 is, thus,

$$P_{1,p}c^R_{1,p} + D^R \leq Money^R_1 + LST^R_1$$

The short-term loan repayment at the end of the period must satisfy

$$LST^R_1(1 + r^{ST}_1) \leq P_{1,h}q^R_{1,h}$$

In the second period, R therefore has three potential sources of funds, his monetary endowment, new short-term loans and his deposits, to purchase potatoes. Deposits, however, are not fully insured and in the event of a mortgage default, the bank may choose to default on its deposits. Letting $1 - V_{2s}^{D}$ be the proportion of deposits that are not repaid, R's potatoes purchases satisfy

$$P_{2s,p} c_{2s,p}^{R} \leq Money_{2s}^{R} + LST_{2s}^{R} + V_{2s}^{D} D^{R}(1 + r^{D})$$

While his short-term loan repayment requires

$$LST_{2s}^{R}(1 + r_{2s}^{ST}) \leq P_{2s,h} q_{2s,h}^{R}$$

One important implication of the potential deposit default is that it reduces R's willingness to save via the bank. The alternative to using the bank is to retain housing that will be sold in the second period. But skewing R's portfolio choice in the initial period will alter house price dynamics, most notably making the house price boom more pronounced than if deposit defaults are less costly.

2.4 Non-Financial Benchmark

Before introducing the financial institutions it is helpful to describe how the households would operate in the absence of a financial system. Both P and R are trying to equate the marginal utility of consumption of houses and potatoes within each period, and marginal utility of total consumption across periods and future states of the world. Because R is endowed with a durable good, he can essentially self-insure by holding onto houses to facilitate his intertemporal smoothing. He could also use money as a store of value to transfer wealth. Absent a financial system, P can only transfer wealth over time via money holdings (i.e., hoarding).

In the calibrated example studied below, P's endowments are much less valuable than R's and are sufficiently low that he does not have enough wealth to equate his marginal utility of first and second period consumption without borrowing. In particular, P would want to have a negative money balance from one period to another, i.e. borrow. Hence in a world without the bank and non-bank, P would exhaust all his money trying to buy enough housing in the initial period to equate the utility of housing and potatoes. In the second period, if times are good, then he consumes much more housing and potatoes, and if times are bad his consumption of both plunges.

In contrast, R's endowments are high enough that he can use a combination of carrying money and holding onto his housing to smooth his consumption both across the two goods in period one and over time in period 2. Hence R does not really need the financial system.[5]

Once the financial system exists (regardles of whether the non-banks are present), P can tap the financial system to improve his consumption smoothing. He will borrow against his second period endowment and that allows him to acquire more housing in the initial period and be subject to smaller fluctuations.

2.5 Commercial bank's B optimization problem

Bank B faces a rich portfolio problem. On the asset side, it extends short-term loans to fund transactions, makes mortgage loans to households and offers repo loans to the non-banks. Its funding comes via deposits, D^B, from agent R, central bank borrowing from the discount window ($DISC_1^B$, $DISC_{2g}^B$, or $DISC_{2b}^B$) and endowed equity E_1^B in period 1 and E_{2s}^B in state *s* in period 2.[6] Its objective is to maximize its discounted profits, π_1^B at the end of period 1 and π_{2s}^B at the end of period 2 in state s.

To simplify the analysis and avoid corner solutions regarding portfolio choices, the bank is assumed to be risk averse, so that it tries to maximize a concave profit function $Prof^B$ of the realized profits. A risk averse banking sector cares about the whole distribution of returns and forms its portfolio by allocating its funds according to the risk/return profile of assets. B's overall payoff also depends on the non-pecuniary penalty it suffers in case it defaults on its deposits, where the percentage of deposits defaulted is $(1 - v_{2s}^B)$ and the reputational penalty for default on one unit of deposits in state s is τ_{2s}^B. Hence, B maximizes the following expected payoff

$$\overline{Prof}^B = Prof^B(\pi_1^B) + \xi \sum_s \omega_{2s}[Prof^B(\pi_{2s}^B) - \tau_{2s}^B[1 - v_{2s}^B]D^B(1 + r^D)]$$

[5] If R is banned from using money as a store of value then he reverts to using only his housing to smooth consumption. In this case, there are (at least) two distinct equilibria. In one, R hoards housing and offers little to P in the first period making house prices high. These high prices are then confirmed in the second period by having R again offer little housing to P. But there is a second equilibrium where R sells much more housing in all periods and house prices are low. This second equilibrium disappears once money can be carried over time (or when there is a financial system that permits inter-temporal trade.)

[6] Equity markets are not considered in the current modeling framework, though they can be easily introduced as in Tsomocos (2003) and Goodhart, Sunirand and Tsomocos (2006). This does not bias our results.

The bank has a complicated asset allocation problem that differs in the two periods. In the first period it makes short-term loans, LST_1^B, and also extends mortgages loans which are partially securitized and partially retained on its books. The securitized loans, called mortgage backed securities (MBS) in what follows, will be sold to the non-bank. The non-bank will finance the purchase with an repo loan, $REPO^B$, from the bank (that will have the MBS as collateral).

The presence of the MBS complicates the notation needed to describe the bank's balance sheet. The total amount of mortgages that bank B extends is $MORT^B$. Amongst these it chooses to securitize MBS_1^B in period 1 at the price of $P_{1,MBS}$. Thus, the net contribution of the bank's own funds in the mortgage extension is $MORT^B - P_{1,MBS}MBS_1^B$, which in what follows is called commited cash (CC^B) because it represents the assets set aside to fund mortgages. CC^B is <u>not</u> the number of mortgages remaining on the bank's book after securitization, which is $MORT^B - MBS_1^B$, since the price of MBS in period 1 can be different from one.[7]

To account for these connections it is helpful to write the constraints that the bank faces in period 1 as two separate constraints. The first relates B's potential uses of funds (short-term loans, repo lending, and net mortgage funding) to its sources of funds (equity, central bank borrowing and deposits):

$$LST_1^B + REPO^B + CC^B \leq E_1^B + DISC_1^B + D^B$$

The second relates total mortgage funding to its components, i.e. own contribution and securitization:

$$MORT^B \leq CC^B + P_{1,MBS}MBS_1^B$$

This separation clarifies the fact that the funding decision of the bank is separate from the securitization choice, and embeds the restriction that the revenue from securitization is derived from mortgage extensions (and not other assets).

At the end of period 1, the bank receives the revenue for the short-term loan extension, settles its liabilities with the central bank and chooses how much cash to keep in its books, so as to be used in period 2, i.e.

$$DISC_1^B(1 + r_1^{CB}) + cash_1^B \leq LST_1^B(1 + r_1^{ST})$$

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[7] The price can differ both because the difference in timing of when the mortgage is paid off and when the MBS must be financed and because the risk aversion of the non-bank differs from the bank.

The cash at the end of period differs from the commited cash because it is not necessarily earmarked toward supporting mortgage funding.

In period 2, the bank has a further timing mismatch between its inflows and its outflows. One outflow is the redemptions of deposits (plus interest) that are due to R. A second outflow will be additional short-term loans that will facilitate trade between the households during period 2. These occur before its mortgage loans are repaid. Hence if the bank's cash and new equity, E_{2s}^{B}, are not sufficiently high, the bank may again need to borrow from the central bank, or it may choose to securitize some of its remaining mortgages to raise money quickly.

Given these timing conventions, a critical consideration is whether there are any defaults. If the good state obtains in period 2, house prices rise and there are no mortgage defaults. This means that repo loans and deposits are also repaid. The bank's main choice is whether to fund its short-term loans by borrowing from the central bank at rate r_{2g}^{CB} or by securitizing some of the mortgages remaining on its books, $MORT^{B} - MBS_{1}^{B}$, and sell them at the price of $P_{2g,MBS}$. Letting the percentage of securitization be denoted by $0 \leq \sigma_{2g}^{B} \leq 1$, B's constraint is:

$$LST_{2g}^{B} + v_{2g}^{B} D^{B}(1 + r^{D}) \leq cash_{1}^{B} + E_{2g}^{B} + DISC_{2g}^{B} + P_{2g,MBS}\, \sigma_{2g}^{B}(MORT^{B} - MBS_{1}^{B})$$

(where v_{2g}^{B} is the repayment rate on deposits, which in equilibrium will be 1 in the good state.)

At the end of the period both repo loans and mortgages mature. The bank receives $REPO^{B}(1 + r^{REPO})$ and $(1 - \sigma_{2g}^{B})(MORT^{B} - MBS_{1}^{B})(1 + r^{MORT})$, respectively, since the rest of the mortgages have been securitized either in period 1 or in the beginning of the good state. Finally, the bank receives the revenues for the short-term loans and repays the central bank loans it undertook. This leaves it with a profit π_{2g}^{B}, which is given by the following constraint:

$$\pi_{2g}^{B} \leq LST_{2g}^{B}\left(1 + r_{2g}^{ST}\right) + REPO^{B}(1 + r^{REPO}) + (1 - \sigma_{2g}^{B})(MORT^{B} - MBS_{1}^{B})(1 + r^{MORT}) - DISC_{2g}^{B}(1 + r_{2g}^{CB})$$

In the bad state, households default on their mortgages which triggers a different chain of events. The MBS that the bank has sold, MBS_{1}^{B}, are backed by mortgages, thus a mortgage default reduces their value. Depending on the size of the loss in value on the MBS, the non-banks may prefer to hand back the MBS to the bank rather than repay the full amount of the repo loan. Suppose the repo loan is defaulted upon. In this case, instead of receiving the repo loan repayment, $REPO^{B}(1 + r^{REPO})$, the bank may wind up owning the MBS it extended in period 1, which are now written on defaulted mortgages. However, it still has to repay its depositors and needs to seize the houses pledged as collateral against its mortgages – which can be resold to recover some value at the end of the period. Thus, the effective delivery on the total amount of mortgages, $MORT^B$, will be the value of the foreclosed collateral, $P_{2b,h}c_{1,h}^P$, instead of $MORT^B(1+r^{MORT})$. It is convenient to compute the ratio $\frac{P_{2b,h}c_{1,h}^P}{MORT^B(1+r^{MORT})}$, which is the effective percentage repayment on mortgages and denote it by V_{2b}^{MORT}.

The short-term liquidity, $DISC_{2b}^B$, that the bank can withdraw from the central bank to cover its deposit obligations must be fully repaid. So it cannot exceed the sum of the new equity capital, E_{2b}^B, accumulated reserves, $cash_1^B$, and the amount recovered from mortgage investments that will arrive at the end of the period. The bank faces the choice between holding the MBS it received from defaulted repo loans or putting them up for sale in the market. The bank equates the margins between the two choices and liquidates ϑ_{2b}^B of the defaulted MBS ($0 \le \vartheta_{2b}^B \le 1$) at the price of $P_{2b,MBS}$.

In principle, the bank could choose to sell all of its MBS ($\vartheta_{2b}^B = 1$). In that case, the bank may choose to go further and securitize some additional mortgages left in its balance sheet, i.e. of the $MORT^B - MBS_1^B$ that it holds, it could sell a fraction $0 \le \sigma_{2b}^B \le 1$. This would constitute an extreme fire sale, since the additional selling would further suppress MBS prices because only the undercapitalized non-banks would be buying them. In what follows, this possibility is allowed for, but in the numerical exercises presented later the bank will not choose to further securitize its existing assets.

Even without an extreme fire sale, the bank will not be able to avoid defaulting on its depositors and will repay a portion $0 \le v_{2b}^B < 1$ of its total obligations. As mentioned earlier, the bank suffers a non-pecuniary penalty, τ_{2b}^B, for every unit of deposit obligations it defaults upon.[8] Thus, its constraint in the beginning of the bad state is given by:

$$LST_{2b}^B + v_{2b}^B D^B(1+r^D)$$
$$\le cash_1^B + E_{2b}^B + DISC_{2b}^B + P_{2b,MBS}[\vartheta_{2b}^B \ MBS_1^B + \ \sigma_{2b}^B(MORT^B - MBS_1^B)]$$

At the end of the period, short-term loans and short-term borrowing from the central bank are settled, and the bank receives the proceeds from liquidated mortgages still on its balance sheet, which are equal to the initial mortgages, L_{MORT}^B, minus the MBS the bank liquidated in the

[8] In deciding whether to default the bank will therefore weigh the marginal benefit of defaulting, i.e. the marginal payoff of keeping one additional unit to lend, versus τ_{2b}^B.

beginning of the period, $\vartheta_{2b}^{B} MBS_1^B + \sigma_{2b}^{B}(MORT^B - MBS_1^B)$. What is left is the bank's profit, π_{2b}^{B}, which should be interpreted as the private benefit the bank extracts given that it has (partially) defaulted on its depositors:

$$\pi_{2b}^{B} \leq LST_{2b}^{B}(1 + r_{2b}^{ST}) + V_{2b}^{MORT}\left(MORT^B - \vartheta_{2b}^{B} MBS_1^B - \sigma_{2b}^{B}(MORT^B - MBS_1^B)\right)(1 + r^{MORT}) \\ - DISC_{2b}^{B}(1 + r_{2b}^{CB})$$

Once the bank optimizes it will turn out that the private benefit is pinned down by the marginal default penalty, τ_{2b}^{B}, the central bank interest rate, r_{2b}^{CB}, the bank's risk-aversion, and potentially by liquidity regulation. The rest of the bank's income will accrue to depositors.

2.6 Non-bank financial institution's (N) optimization problem

The non-bank financial institution is endowed with its own capital in period 1, E_1^N, and receives further capital in the good and bad states. It enters into an loan agreement with bank B in period 1, $REPO^N$, which is offered at an interest rate r^{REPO}. It uses the total funds to buy mortgage backed securities, MBS_1^N, at a price of $P_{1,MBS}$. The repo loan is backed by the MBS that N buys. Thus, in the event of repo default, the non-bank financial institution pays nothing on its loan obligation, $REPO^N(1 + r^{REPO})$, but instead forfeits its MBS to the bank. Their value is equal to the delivery on the mortgages that back them, i.e. $V_{2b}^{MORT}(1 + r^{MORT})$ per MBS. Given that both its liabilities and assets are long-term, N cares only about its period 2 profits, π_{2g}^{N} or π_{2b}^{N}. In particular, given its risk aversion, it optimizes over the expected value of a concave function $Prof^N$ of future profits. Finally, in the event of default, N suffers a reputational loss proportional to the amount it defaults less any salvage value of the collateral it turns over to the bank. The per unit reputational penalty is τ_{2b}^{N}. Thus, N tries to maximize

$$\overline{Prof^N} = \xi \cdot \omega_{2g} Prof^N(\pi_{2g}^{N}) + \xi \\ \cdot \omega_{2b}\left[Prof^N(\pi_{2b}^{N}) - \tau_{2b}^{N}[REPO^N(1 + r^{REPO}) - V_{2b}^{MORT} MBS_1^N(1 + r^{MORT})]\right]$$

As mentioned, N uses its period 1 balance sheet to invest in MBS. Its constraint is

$$P_{1,MBS} MBS_1^N \leq E_1^N + REPO^N$$

Both N's assets, MBS_1^N, and liabilities, $REPO^N$, mature at the end of period 2. N is endowed with new additional capital in the beginning of period 2, E_{2g}^N and E_{2b}^N, respectively. It uses its capital to purchase mortgage backed securities, MBS_{2s}^N, at a price $P_{2s,MBS}$ in state s:

$$P_{2s,MBS} MBS_{2s}^N \leq E_{2s}^N$$

The equation above reflects the cash-in-market pricing of MBS in period 2 a la Allen and Gale (2005). This assumption creates the possibility of a fire sale because total expenditure for MBS is equal to the money that N has at hand.

When the good state realizes, all the MBS that it owns are valuable (and worth $\left(MBS_1^N + MBS_{2g}^N\right)(1 + r^{MORT})$) so N repays the repo loan and pockets the difference as its profit π_{2g}^N,

$$\pi_{2g}^N \leq \left(MBS_1^N + MBS_{2g}^N\right)(1 + r^{MORT}) - REPO^N(1 + r^{REPO})$$

On the contrary, when the bad state realizes, N defaults on its repo loan and loses the MBS_1^N mortgage backed securities it had put as collateral. Its profit, π_{2b}^N, is the payoff of the MBS bought during the fire sale event, MBS_{2b}^N, which are backed by defaulted mortgages, hence

$$\pi_{2b}^N \leq V_{2b}^{MORT} MBS_{2b}^N (1 + r^{MORT})$$

2.7 Markets and Equilibrium

The rational expectations equilibrium that is computed simply equates supply and demand in the relevant markets. The potatoes market clears when the potatoes sold by agent P (and agent F) in period 1 (and each state in period 2) are equal to the potatoes purchased and consumed by agent R. Hence, $q_{1,p}^P = c_{1,p}^R$ and $q_{2s,p}^P + q_{2s,p}^F = c_{2s,p}^R$ for each state s. Similarly, the houses bought by agents P and F are equal to the total supply by agent R plus the foreclosed houses put into the market by bank B due to mortgage defaults in the event that the bad state materializes in period 2. The market clearing conditions are thus given by $q_{1,h}^R = c_{1,h}^P$, $q_{2g,h}^R = c_{2g,h}^P + c_{2g,h}^F$, and $q_{2b,h}^R + c_{1,h}^P = c_{2b,h}^P + c_{2b,h}^F$.

The loan market equilibria are as follows. The mortgage market clears when $MORT^P = MORT^B$, while the repo market equilibrium requires $REPO^B = REPO^N$. Likewise, the short-term loan market clears in period 1 when $LST_1^B = LST_1^P + LST_1^R$, and in period 2 when $LST_{2s}^B = LST_{2s}^P + LST_{2s}^R + LST_{2s}^F$ (for both states).

The deposit market clears when $D^B = D^R$, while borrowing in the money market requires $DISC_1^B = M_1^{CB}$ in period 1 and $DISC_{2s}^B = M_{2s}^{CB}$ for each state s. The interest rates for the money market are assumed to be set by the Central Bank at r_1^{CB} and r_{2s}^{CB}, with quantities (M_1^{CB} and M_{2s}^{CB}) adjusting to reflect demand at those prices.

In addition, the non-bank's portfolio must reflect the full set of prices in the economy. The prices of MBS, $P_{1,MBS}$ and $P_{2s,MBS}$, are determined in equilibrium when the supply of securitized products is equal to the demand for them. This implies $MBS_1^B = MBS_1^N$ in period 1, $\sigma_{2g}^B(MORT^B - MBS_1^B) = MBS_{2g}^N$ in the good state, and $\vartheta_{2b}^B \ MBS_1^B + \ \sigma_{2b}^B(MORT^B - MBS_1^B) = MBS_{2b}^N$ in the bad one. Finally, realized percentage default on deposits, V_{2s}^D, is equal to the amount the bank chooses to repay, v_{2s}^B.

2.8 Fire Sales and Amplification

Before turning to the full model solution and simulation, it is helpful to highlight the potential fire sale mechanism that differentiates this model from others aimed at studying regulation. As mentioned above, when endowments are low in the bad state (which can be loosely thought of as an adverse productivity shock) house prices will collapse. This collapse is unavoidable and hence is optimal from an individual's point of view.

However, there are several channels through which the financial system may amplify the initial impulse that will lead to other inefficiencies. Regulations may be useful if they can limit this amplification. One important property of the model is that there are no magic bullets. In particular, any regulations that dampen the effects of defaults create other distortions.

The first channel of financial amplification comes because of the assumed cash-in-the-market pricing that governs sales of mortgage backed securities. This comes directly from N's budget constraint in the bad state, which says:

$$P_{2b,MBS}MBS_{2b}^N = E_{2b}^N$$

where $P_{2b,MBS}$ is the price of MBS in the bad state, MBS_{2b}^N, is the quantity of MBS that N is forced to absorb, and E_{2b}^N is N's monetary endowment in the bad state. Thus, the more of the MBS that the bank returns to the market, the lower the price of MBS. This simple formulation is intended to capture the Shleifer and Vishny (2011) characterization of a fire sale whereby prices for assets are depressed because the natural buyers of the assets are impaired at the time of the sale. Obviously any regulation that limits the size of the initial repo default can potentially influence the size of the fire sale.

But the presence of the fire sale also creates three follow on effects. The first comes because banks must make an active portfolio choice between holding onto its mortgage backed securities and extending new loans. The bank is assumed to be unable to issue equity (in the immediate aftermath of the bad shock), so its balance sheet capacity is limited. Thus, the bank must trade off using its capital to hold a mortgage backed security or to initiate new loans. So the losses on the MBS sales from the cash-in-the-market pricing tighten this capital constraint and potentially create a "credit crunch" for new borrowers (in that the bank's capital problem reduces the supply of loans that are available.)

The second potential inefficiency comes because the repo default also raises the incentive for the bank to default on its deposit contracts. The losses to the depositor (R) reduces his wealth, causing him to sell additional housing to finance his purchases of goods. The additional housing sales will lead to lower housing prices.

The default risk on the deposits also distorts R's willingness to save using the banking system. R can shelter his wealth from default risk by retaining more of his endowment and selling more of it in the second period. This behavior changes the relative price of housing in the second period even absent default. For F, any regulations that lead to a higher supply of housing during the boom leaves him better off (and vice versa).[9]

Finally, there is a third channel that arises from the interaction of the cash-in-the-market fire sale and the other two follow-on effects. The bank always considers the arbitrage relation between MBS prices and the price of houses. When the bank receives the MBS that are issued against defaulted mortgages (from N), either it can hold the MBS to maturity and then seize the house, or it can sell the MBS right away. This can be seen by noting that $P_{2b,MBS}$, the price of MBS in the bad state, is given by

$$P_{2b,MBS} = \frac{V_{2b}^{MORT}(1 + r^{MORT})}{1 + r_{2b}^{CB}}$$

where V_{2b}^{MORT} is the percentage of mortgages that are repaid $\left(\frac{P_{2b,h}c_{1,h}^{P}}{MORT^{B}(1+r^{MORT})}\right)$, r^{MORT} is the mortgage rate, and r_{2b}^{CB} is the central bank interest rate on short term borrowing in the bad state. Substituting further reveals the exact linkage between MBS prices and house prices to be:

[9] For P, the effects are more complicated because most policies influence housing prices in both the first and second period, so his welfare depends on what happens in both periods.

$$P_{2b,MBS} = \frac{P_{2b,h} c_{1,h}^P}{MORT^B} \frac{1}{1 + r_{2b}^{CB}} \Leftrightarrow P_{2b,h} = P_{2b,MBS} \frac{MORT^B}{c_{1,h}^P} (1 + r_{2b}^{CB})$$

This implies that given the amount of collateral, $c_{1,h}^P$, and the mortgages extended in period 1, $MORT^B$, a bigger fire sale in the bad state, which results in lower $P_{2b,MBS}$, will necessarily surpress the price of houses, $P_{2b,h}$. Therefore, the model also embodies the kind of downward spiral emphasized by Brunnermeier and Pedersen (2009). Specifically, the initial house price decline lowers the value of the MBS that serve as collateral on the repo loan, the sale of that collateral reduces house prices, which then further reduces the MBS price.

The simplest way to avoid the knock-on effects from the fire-sales would be to eliminate the non-banks from the economy. But this would entail two costs. First, the risk-sharing provided by N would vanish. Second, the non-banks support the market for mortgage backed securities. Without the MBS the hedging opportunities for the banks are reduced, which the banks crave because of the incomplete asset markets.

The immediate effect of this modification to the model would be to reduce the risk-bearing capacity of the financial system because the total equity in the financial system would be lower. To make an exercise of this type informative it therefore makes sense to increase the banking system's capital by the amount that had been endowded to the non-banks.

The effects from this thought experiment are intuitive. In the initial period, mortgage extensions would decrease and the cost of mortgages would rise. So P would be able to buy less housing and is less able to smooth his housing across periods. The banks, however, would fare better in event of a house price collapse. The gains are possible for two reasons. First, having made fewer mortgages their exposure to mortgage default would be reduced. Second, being better capitalized reduces the need to default. *A priori* one cannot tell whether P's overall utitlity would be higher or lower because limiting his access to mortgages in the intial period limits his default losses in the second period.[10] The message from this thought experiment is that both financial innovation (as represented by the existence of the non-banks and the MBS) and higher bank capitalization can potentially improve the functioning of the financial system.

The remainder of the paper explores less draconian interventions to deal with fire-sales. But given both the spillovers from defaults and the attempts to avoid the costs of default, no

[10] In the numerical example considered in section 4, the ambiguous effects on P's welfare disappear when the bank does not get the capital that was endowed to the non-bank. In that case, the reduction in housing finance in the initial period is so large that it dominates the welfare effects and P is definitely worse off.

single regulatory tool will be sufficient to correct the externalities in this model. Rather a combination of tools will be needed to control for the inefficiencies that obtain in equilibrium. Accordingly the next section shows the balance sheets of the financial institutions at the various stages when decisions are made and introduces the potential regulatory tools that could be deployed to manage the externalities.

3. Financial regulation

There are five regulatory tools for mitigating the effects of house price collapses. In addition to defining these tools, this section presents intuition about how they operate and describes the costs and benefits of deploying each tool.

3.1 Loan to Value Regulations

The most direct tool is a loan to value restriction for households. By limiting the amount of borrowing that the household can undertake, the losses in the financial system in the event of default will be reduced. The loan to value ratio is given by

$$LTV^{\boldsymbol{P}} = \frac{MORT^{B}}{P_{1,h}c_{1,h}^{P}}$$

But restricting P's ability to borrow will not only leave these households with less housing than they desire, but also can also make R worse off because limiting demand reduces house prices and hence the value of his endowment. However, loan to value regulations can result in lower deposit defaults, thus the effect on R's overall utility is ambiguous.

In this framework, there are no second period mortgages, so there is no analog to the loan to value ratio that can be imposed after the uncertainty is revealed. With a more complete dynamic model, such regulations could be useful. One interesting observation is that in a boom existing borrowers will have reaped a capital gain on their land, and their creditworthiness will be high. So imposing a limit on borrowing that would be strict enough to constrain the existing home owners would seriously limit the ability of new borrowers to obtain credit.

3.2 Margin Requirements for Repurchase Agreements

A slightly less direct tool imposes a "margin requirement" on repurchase agreements. This requirement limits N's ability to take on leverage in buying MBS. Hence, it is akin to imposing loan to value restriction on N because it forces N to put in more of his own capital to fund the MBS purchases. By forcing N to have more capital behind his MBS purchases, margin requirements limit the consequences of the repo default by forcing his capital to absorb more of his losses. The margin requirement is calculated as:

$$MR^N = \frac{E_1^N}{P_{1,MBS} MBS_1^N}$$

Because N has lower risk aversion than B, and a lower default penalty, it is efficient to leave N exposed to more housing risk than B. Thus, margin restrictions partially impede risk sharing and will raise the cost of mortgage borrowing. Recall that in the second period, N is assumed to use only its incremental capital to fund all of its additional purchases, so there is no scope for a second period margin requirement.

3.3 Liquidity and Capital Requirements

While banks contribute to all three of the knock-on effects from the house price declines, regulating them, while not restricting leverage of households or non-banks, is a relatively indirect way of moderating the effects of house price declines. Because the banks are collecting payments and making loans at various points in time, the bank regulations have a time dimension that adds further complexity to studying them. To see how they might operate it is helpful to record the balance sheets at the four critical points where bank regulation could be applied.

At the beginning of period one, the bank extends short-term loans to households, makes repo loans to N, and also keeps some "committed cash" that it will use to extend mortgages (CC^B) when the mortgage market opens in the middle of period one. These assets are funded using the bank's equity, as well as taking deposits from households, and borrowing from the central bank. Accordingly B's balance sheet is

Assets	Liabilities
LST_1^B	E_1^B
$REPO^B$	D^B
CC^B	$DISC_1^B$

It is possible to define a capital ratio and a liquidity coverage ratio for the bank, although neither is very interesting at this point in time. The capital ratio characterizes B's loss absorbing liabilities relative to its assets. In keeping with currently international banking regulations, the so-called Basel rules, the assets are weighted to reflect their risk. Under the Basel rules both cash and the short-term loan are riskless and get a risk weight of 0, so they drop out from the calculation of risk weighted assets that appears in the denominator of the capital ratio. Thus, the capital ratio is given by

$$CR^B_{begin\ 1} = \frac{E^B_1}{rw^{REPO}_1 \cdot REPO^B}$$

where rw^{REPO}_1 is the risk weight associated with the repo loan.

The liquidity coverage ratio (LCR^B) seeks to measure the fraction of assets that are liquid in the sense of being potentially sold without moving prices meaningfully. In the context of the model, riskless assets will be considered liquid and all other assets are deemed illiquid. The LCR^B gauges the extent to which B can avoid contributing to a fire sale by having other assets to liquidate in order to pay depositors.

$$LCR^B_{begin\ 1} = \frac{LST^B_1 + CC^B}{LST^B_1 + REPO^B + CC^B}$$

If either of these ratios were at the regulatory limit, then the bank could not convert the committed cash into mortgage loans once the mortgage market opened (assuming the same regulatory limits applied after the mortgage lending occurred). Hence in what follows neither of these tools are considered. But if either were deployed in a way that changed allocations, the effect would be to constrain mortgage credit, leaving the P households with less housing than is desired while restricting R's ability to smooth consumption over time by limiting his housing sales in period 1.

Once the mortgage market opens in the middle of period 1, the bank has two important changes to its balance sheet position. First, it uses the committed cash to extend mortgage loans to the household thereby taking on mortgage risk. Second, it partially hedges the mortgage risk by securitizing some of the mortgages and retaining $MORT^B - MBS^B_1$.

Importantly, the securitization yields immediate revenue whereas a mortgage does not get repaid until period 2. This difference in the timing of cash flows associated with the two ways of owning mortgage risk, along with the difference in the willingness of N and B to bear mortgage risk, will mean that MBS prices need not match the value of a mortgage. Consequently there will be some profit (or loss) that will occur with the securitization, denoted $(P_{1,MBS} - 1)MBS^B_1$.

Because the profit (or loss) will ultimately accrue to equity, it is recorded as an additional liability. The income coming from the interest payment on short-term loans, $r_1^{ST} LST_1^B$,and the expense due to central bank loans, $r_1^{CB} DISC_1^B$, should be recorded as accrued income and expense respectively. Although the payments will occur in the future, the bank can realize them on its income statement now. Consequently, the bank can report profits of $\pi_1^B = r_1^{ST} LST_1^B - r_1^{CB} DISC_1^B + (P_{1,MBS} - 1) MBS_1^B$. Thus, the balance sheet for B at the middle of period one is:

Middle of Period 1

Assets	Liabilities
LST_1^B	E_1^β
$REPO^B$	π_1^B
$MORT^B - MBS_1^B$	D^B
$r_1^{ST} LST_1^B$	$DISC_1^B$
	$r_1^{CB} DISC_1^B$

This implies that the capital ratio will be:

$$CR_{mid1}^B = \frac{E_1^B + \pi_1^B}{rw_1^{MORT} \cdot (MORT^B - MBS_1^B) + rw_1^{REPO} \cdot REPO^B}$$

where rw_1^{MORT} is the risk weight associated with mortgages (and all the riskless assets continue to have a risk weight of 0).

Were the regulators to set the capital ratio high enough so that it was a binding constraint, then B could respond by initiating fewer mortgages. Alternatively, assuming the risk weights on mortgages and secured repo lending differed, the bank could also respond by securtizing more of the mortgages that it did initiate. So bank regulation in this model has the potential of pushing intermediation outside of the banking system, rather than simply reducing intermediation.

The implications for the households will depend on which choice the bank makes. If it chooses to securitize more, then the direct effect on household mortgage credit will be much less than if it chooses to simply reduce the amount of mortgage credit. If mortgage lending is reduced then P will be unable to consume as much housing as he would prefer and R will have to retain more housing than he would prefer and is therefore less able to smooth his consumption.

The liquidity coverage ratio is given by

$$LCR^B_{mid1} = \frac{LST^B_1}{LST^B_1 + REPO^B + MORT^B - MBS^B_1}$$

If the regulator forces B to hold more liquid assets, then it necessarily forces a reduction in the quantity of mortgages that are granted. This must occur because any attempt to securitize more mortgages will require additional repo lending, and hence would not succeed in raising LCR^B. So regulation via liquidity coverage ratios and capital ratios will have different effects on banks or households.

At the end of period 1, B repays its central bank loans and is paid back on its short-term loans. As a result, it credits and debits accrued income and expense accounts respectively, and records the associated receipts as $cash^B_1$. The balance sheet at the end of the period is

End of Period 1

Assets	Liabilities
$REPO^B$	E^B_1
$MORT^B - MBS^B_1$	π^B_1
$cash^B_1$	D^B

Because the cash is riskless, the capital adequacy ratio at the end of period 1 is

$$CR^B_{end1} = \frac{E^B_1 + \pi^B_1}{rw^{MORT}_1 \cdot (MORT^B - MBS^B_1) + rw^{REPO}_1 \cdot REPO^B}$$

Notice that the conversion of the accruals into cash has no effect on the capital ratio, so it is unchanged from the middle of the period. However, the liquidity ratio will differ between the middle and the end of period 1.

The liquidity coverage ratio at the end of the period will be:

$$LCR^B_{end1} = \frac{cash^B_1}{cash^B_1 + REPO^B + MORT^B - MBS^B_1}$$

The LCR at the end of period 1 could be higher or lower than at the middle of the period. The cash holdings will depend on the size of the interest spread that B makes on its short-term loans and on the profits from securitization, and there is no general way to determine if the resulting amount of cash will be higher or lower than the liquid assets that were on the balance sheet in the middle of the period. Thus, it is possible that the LCR at the end of period 1 binds when it did not bind in the middle of the period. In this case, B would have to restrict mortgage lending to circumvent the constraint.

The spirit of liquidity regulation is to force banks to have sufficient short-term assets to cover short-term liabilities. This perspective suggests that the middle of the period LCR better captures the purpose of the regulation than the end of period LCR, hence in the calibrations that follow, the middle of the period LCR will be analyzed.

At the conclusion of period 1, the uncertainty about housing prices is revealed and then the bank gets its second injection of equity. The new equity augments the cash that was carried over from period 1. Therefore, the balance sheet for B will be

Beginning of Period 2

Assets	Liabilities
$REPO^B$	$E_1^B + E_{2s}^B + \pi_1^B$
$MORT^B - MBS_1^B$	D^B
$cash_{2s}^B$	

The liquidity coverage ratios and capital ratios both increase by the size of the capital increment. The resolution of uncertainty will not tighten the LCR, but it can tighten the capital ratio because the risk weights on the assets will change in view of the impending default.

In the middle of period 2, the bank makes its last set of active decisions. Because there is no default in the good state, it is easier to start with this possibility. In this case, the bank securitizes a fraction σ_{2g}^B of the mortgages remaining on its balance sheet, repays depositors (an amount $D^B(1 + r^D)$), extends new short-term loans and borrows further from the central bank.

Because it is known that mortgages will repay fully, there is a capital gain on existing MBS. The only difference between the price on MBS at this point and the final value of a mortgage is the fact that the MBS bring payments immediately and hence do not require any financing, so they are worth more than the mortgages (by the time value of money).

The mid period profits are therefore $P\_L^B_{mid2g} = \left(P_{2g,MBS} - 1\right) \sigma^B_{2g}(MORT^B - MBS^B_1) - D^B r^D$ and the balance sheet for B becomes

Middle of Period 2 in the good state

Assets	Liabilities
LST^B_{2g}	$E^B_1 + E^B_{2g} + \pi^B_1$
$REPO^B$	$P\_L^B_{mid2g}$
$\left(1 - \sigma^B_{2g}\right)(MORT^B - MBS^B_1)$	$DISC^B_{2g}$

The capital ratio in the good state is uninteresting because all the assets are riskless and will pay off fully. This is an extreme outcome because in the model it makes sense to allow the banks to book the gains from the high asset prices. But in reality this seems to have also partially occurred. Banks globally in early 2007 appeared to be very well capitalized, even though two years later most were found to be seriously undercapitalized. Hence the model prediction that capital ratios during good times are unlikely to be effective at constraining risk taking seems realistic.

The liquidity coverage ratio is

$$LCR^B_{mid2g} = \frac{LST^B_{2g}}{LST^B_{2g} + REPO^B + \left(1 - \sigma^B_{2g}\right)(MORT^B - MBS^B_1)}$$

Imposing a liquidity requirement in the boom would force the bank to reduce its mortgage exposure. This could have the effect of reducing the house price appreciation in the boom. So unlike the capital regulation, liquidity regulation can be used to lean against the boom. As will be clear shortly, if this ratio were binding in the good state when asset values are high it would be much more binding in the bad state with low assets.

The bank's choices after house prices collapse are more complicated because it has to take back the MBS tied to defaulted morgages and decide how much to default on its deposit obligations. The rising risk weights on assets will reduce the bank's capital ratio. Regulators at this point have the right to demand that the bank take corrective actions such as writing-off repo loans and disposing some of the tainted MBS. The receipt of the MBS rather than the repo loan repayment triggers a loss (of $P\_L^B_{mid2b} = REPO^B - (1 - \vartheta^B_{2b})MBS^B_1 - P_{2b,MBS}\vartheta^B_{2b}MBS^B_1$), where the last term reflects the fact some of the recovered MBS are resold at cash-in-the-market prices. The balance sheet after these corrective actions and before the bank extends short-term loans and decides how much to repay depositors will be

Middle of Period 2 in the Bad State before deposit repayment

Assets	Liabilities
$MORT^B - \vartheta_{2b}^B MBS_1^B$	$E_1^B + E_{2b}^B + \pi_1^B$
$cash_{2s}^{B\,\prime}$	$P\_L_{mid2b}^B$
	D^B

Technically, a bank's health improves if it defaults on its deposits because the default delivers an accounting windfall (of $D^B - v_{2b}^B D^B(1 + r^D)$). Therefore, the mid period profit, after deposits are repaid, will be $P\_L_{mid'2b}^B = (1 - v_{2b}^B)D^B - v_{2b}^B D^B r^D$- $(REPO^B - MBS_1^B) - (1 - P_{2b,MBS})\vartheta_{2b}^B MBS_1^B$. This implies that B's balance sheet will be

Assets	Liabilities
LST_{2b}^B	$E_1^B + E_{2b}^B + \pi_1^B$
$MORT^B - \vartheta_{2b}^B MBS_1^B$	$P\_L_{mid'2b}^B$
	$DISC_{2b}^B$

Bank regulators will not reward banks for defaulting on deposits. So it is logical to consider the capital ratio prior to the deposit repayment decision. Hence, the relevant regulatory ratio is

$$CR_{mid2b}^B = \frac{E_1^B + E_{2b}^B + \pi_1^B + P\_L_{mid2b}^B}{rw_{2b}^{MORT} \cdot (MORT^B - \vartheta_{2b}^B MBS_1^B)}$$

where rw_{2b}^{MORT} is the risk weight on the defaulted mortgages. If the capital ratio is now binding it will force the bank to securtize more mortgages, which due to the cash-in-the-market pricing will exacerbate the fire sale and potentially trigger the type of spiral described earlier. Thus, if the bank was not sufficiently well capitalized prior to the house price collapse to absorb the losses, capital regulation will be pro-cyclical. Admittedly, this follows because the bank is not able to immediately raise new equity, but this restriction seems realistic.

The bank's liquidity coverage ratio will be

$$LCR_{mid2b}^{B} = \frac{LST_{2b}^{B}}{LST_{2b}^{B} + MORT^{B} - \vartheta_{2b}^{B} MBS_{1}^{B}}$$

If the LCR does become binding then bank would also have to adjust to this constraint by securitizing more mortgages and adding to the fire sale. A crucial difference from CR_{mid2b}^{B} is that the loss in profits from the fire sale does not enter the calculation of LCR_{mid2b}^{B}. Thus, liquidity regulation will be even more pro-cyclical than capital regulation.

3.4 Dynamic Provisioning

Although the aforementioned tools differ in several important respects, they all share one common feature: each is designed to make the fire sale less extreme. Whether they aim to twist allocations in the first period, or operate directly in the bad state, their motivation is to prop up house prices in the bust. To the extent they succeed this guarantees that agent F is worse off because he will face higher house prices and the value of his endowment will be lower.

In several cases, the tools also create incentives to have more houses sold in the first period. In these scenarios house prices will be lower than otherwise in the first period, which reduces the welfare of R, since his endowment is purely housing.

Likewise, the resource losses from defaults lead R to save partially by retaining housing rather than using deposits. This consideration means that any policies which reduce deposit defaults will lead to more savings being channeled through the bank and less self-insurance. But the reduction in self-insurance reduces the housing for sale in the good state, which means that house price appreciation in the boom is higher than otherwise – this again works to reduce F's purchasing power.

Thus, it should not be surprising that a regualtory tool which changes behavior in the good state could also be valuable. One such tool that was implemented in Spain is dynamic loan loss provisioning (see Fernández de Lis et al. (2010) for details). Within the framework of this paper, dynamic provisioning could be formalized as a requirement for the bank to keep cash on its balance sheet throughout the good state of the world when the growth of real estate related credit, g%, exceeds a certain threshold x%.[11] Letting the per unit requirement be denoted by κ, such regulation would imply that the gross dynamic provisioning is $(g\% - x\%)\kappa$.

The budget constraints of the bank is the good state would then become

$$LST^B_{2g,p} + LST^B_{2g,h} + v^B_{2g} D^B(1 + r^D) + (g\% - x\%)\kappa$$
$$\leq\ cash^B_1 + E^B_{2g} + DISC^B_{2g} + P_{2g,MBS}\, \sigma^B_{2g}(MORT^B - MBS^B_1)$$

and

$$\pi^B_{2g} \leq (g\% - x\%)\kappa + LST^B_{2g,p}\left(1 + r^{ST}_{2g,p}\right) + LST^B_{2g,h}\left(1 + r^{ST}_{2g,h}\right) + REPO^B(1 + r^{REPO})$$
$$+\ (1 - \sigma^B_{2g})(MORT^B - MBS^B_1)(1 + r^{MORT}) - DISC^B_{2g}(1 + r^{CB}_{2g}).$$

Where growth rate in real estate related credit is

$$g\% = \left(\frac{LST^P_{2g} + LST^F_{2g}}{MORT^B + LST^P_1} - 1\right)\%$$

(This same requirements can be imposed in the bad state but because lending growth is negative the constraint will never bind.)

One implication of this kind of regulation is that when it is binds, short-term loans for renting housing in the second period cost the bank more to make than short-term loans for potato purchases (because no cash has to be set aside against the potato loans). This will lead the bank to charge different interests on these two loans, and the potato loans will be cheaper. These markets clear when $LST^B_{2g,p} = LST^R_{2g}$ and $LST^B_{2g,h} = LST^P_{2g} + LST^F_{2g}$.

In the good state when credit growth exceeds x%, the regulation incentivizes the bank to reduce its real estate related credit extension and will charge a higher interest rate on LST^P_{2g} and LST^F_{2g} to internalize the shadow cost of the requirement. The welfare ramifications of regulation are subtle. On the one hand, the higher cost of credit makes both P and F worse off. On the other hand, their reduced housing demand reduces the relative price of housing and makes their endowments more valuable. Whether F's welfare rises or falls because of the regulation depends on which effect dominates: if the relative prices move sufficiently then extra wealth can allow F to secure more housing even though the borrowing cost he faces is higher.

[11] This formalization of the provisioning requirement deviates from what was actually implemented in Spain, where the rules took the form of requiring the banks to build up incremental capital. As discussed above, the capital ratio in the good state is already infinite.

3.5 Summary of Regulatory Tools

There are three major conclusions from the foregoing analysis. First, the endogenous responses to the different regulatory tools will differ. The tools affect different parts of the financial system and control fire sale risk through different channels, either reducing mortgage availability in the first period, making the bank better able to withstand a default when it occurs, or limiting real estate credit during the boom. With this set up, using regulations to alter allocations during the bust is easier than during the boom (when loan to value ratios and capital ratios naturally improve.) Second, the use of capital requirements creates strong incentives for regulatory arbitrage, whereby intermediation is pushed out of the banking system into the shadow banking system. Finally, the degree to which regulations act as complements or substitutes will depend on which of the channels through which they operate. The calibration in the next section makes it possible to explore these interactions.

4. Calibrated Example

The calibrated exercises that follow are based on parameter choices that trigger defaults in the bad state of the world.[12] For some of the endowments and parameters it is difficult to assess their plausibility independently, but the model can be judged by whether it implies reasonable levels for prices, as well as plausible values of leverage for households and financial institutions. Comprehensive values for all exogenous and endogenous variables can be found in tables 1 and 2 in appendix 1. This section shows the baseline equilibrium where there are no binding regulatory constraints. The following section explores deviations from the baseline where regulations that change allocations are introduced.

4.1 Endowments, Utility Functions and Profit Functions

Households are assumed to have constant relative risk aversion utility functions which are separable over time and across goods. For example, P's first period utility is $U^P\left(c_{1,p}^P, c_{1,h}^P\right) =$

[12] The presence of positive liquid wealth, in the form of private monetary endowments to households and financial intermediaries, guarantees nominal determinacy of the equilibrium solution (see Dubey and Geanakoplos (2006), Tsomocos (2008)). The equilibrium presented is locally unique, which makes it possible to perform comparative statics exercises.

$\frac{1}{1-\gamma^P}\left(c_{1,p}^P\right)^{1-\gamma^P} + \frac{1}{1-\gamma^P}\left(c_{1,h}^P\right)^{1-\gamma^P}$. The risk aversion coefficients are, $\gamma^P = 2.1$, $\gamma^F = 2.1$ and $\gamma^R = 2.4$, for agents P, F and R respectively.[13]

The financial institutions are also to be risk averse regarding their profits. For simplicity their payoffs are also assumed to be of the constant relative risk aversion form. The bank has a risk aversion coefficient of $\gamma^B = 1.4$ (and recall makes profits in both periods), while the more risk-loving non-bank realizes profits only in the second period and is assumed to have risk-aversion of γ^N =0.7.

Agent P's endowments are given by $\bar{e}^P = (10\,, 32\,, 5.8)$, implying that his endowment falls substantially in the bad state of nature. Agent F faces no volatility in his endowments, $\bar{e}^F = (11\,, 11)$. Agent R's endowment of houses is given by $\bar{e}^R = (1\,, 0\,, 0)$. The assumption about no new houses entering the economy in the second period simplifies some calculations but makes no qualitative difference and can be easily relaxed.

Monetary endowments for the agents and capital endowments for the financial institutions are chosen to make the possibility of default and its consequences interesting. One way to do this is to also endow agent R with a disproportionate amount of money in period 1 that must be deposited and to also make the bank's initial capital low compared to the overall liquid wealth in the economy, so that it needs to attract depositors. The endowments chosen for R and B are given by $\overline{Money}^R = (6.5\,, 0\,, 0)$ and $\bar{E}^B = (0.5\,, 0.5\,, 0)$. The fact that the bank does not receive new capital in the bad state of the world is a stand-in for the idea that raising new equity capital during crisis times is difficult.

To insure that house prices fall in the bad state of the world, households P and F are also presumed to have lower wealth in that case. Their monetary endowment are $\overline{Money}^P = (4.1\,, 4.1\,, 0.1)$ and $\overline{Money}^F = (4.1\ \,, 0.1)$, respectively. Likewise, the non-bank is endowed with lower capital in period 1 as well as in the bad state of the world, i.e. $\bar{E}^N = (1\,, 2\,, 1)$.

4.2 Interest Rates

The time periods in the model should be considered to be five years. The probability of the bad state, ω_{2b}, is to 10%, corresponding to a roughly 2% per year chance of a collapse, or alternatively to the assumption that there is a crisis every 50 years. Given this timing convention,

[13] By making R slightly more risk averse than the other two households he will be eager to sell houses not only to consume goods, but also to hedge the risks stemming from house price volatility.

the time discount rate ξ is $(0.9680)^5 = 0.85$ and the house price depreciation rate δ is 0.032 per year so that houses lose 15 percent of their value during a period.

The central bank interest rates are exogenously set to 2.29 % per year for period 1 and the good state (so that the five year value is 12 percent), and 3.07% per year in the bad state (for a cumulative rate of 20%). The higher rate during the collapse is intended to stand in for the requirement that the cost of funding for the financial system as a whole rises during a crisis.

The equilibrium interest rates reflect the default risk of the different contracts. In particular, the annual mortgage rate, repo lending rate and deposit rates in the equilibrium are 11.82%, 11.66% and 7.23% respectively.

4.3 Prices, Defaults and Fire Sales

Relative prices of houses, potatoes and MBS are very different in the good and bad states of nature. The specific values are shown in the table below. In the good state, potatoes are relatively cheap and the high housing prices make it unattractive to default on mortgage debt. With no mortgage defaults, repo loans are repaid and the bank fully pays depositors.

When the bad state occurs potatoes are dear relative to houses. More importantly, the absolute drop in price of houses means that the house value is sufficiently below the amount owed on the mortgage loan that it is optimal to default. This triggers a default on the repo loan as well because of the intimate connection between MBS prices and house prices.

	Period 1	Period 2, State g	Period 2, State b
Potatoes Prices	1.08	1.39	1.48
Housing Prices	676.96	1,111.41	362.73
MBS Prices	0.97	1.56	0.68
Relative price of potatoes to housing	0.0016	0.0013	0.0041

The magnitude of the defaults depends critically on the reputational penalties that the various actors incur in the event of default. These penalties are chosen to make the losses given a default to be plausible. The resulting equilibrium recovery rates given these penalties are 46.93%, 50.52%, and 55.94% for mortgage, repo and deposit obligations respectively. The recovery rates for mortgage related securities are higher than were observed in the wake of subprime mortgage crisis in the U.S. As expected, the recovery rate on the repos is higher than on the direct mortgages because of the additional capital that non-banks pledge.

The bank sells 6.80% of the MBS that it receives from the repo default in the bad state of the world. Assessing the magnitude of this selling is perhaps better done by comparing the relative quantities offered in the good and bad states. The bank securitizes 1.28 new MBS in the good state, while it sells 1.46 of them in the bad state despite the fact that the non-bank is much less well-capitalized in the bad state compared to the good one. This disparity suggests that the selling in the bad state can be dubbed a "fire-sale".

4.4 Regulatory Ratios

While regulation is non-binding in the initial equilibrium it is still useful to record the values of the key ratios that could be used to contain the spillovers from the defaults. The table below shows the relevant figures for capital and liquidity requirements for the banking sector, loan-to-value requirements for households, and margin requirements for the non-bank.

	Period 1	Beginning of bad state	Mid of bad state
Capital adequacy ratio	9.91%	3.46%	8.24%
Liquidity ratio	64.94%	-	46.36%
Margin on repos	4.78%	-	-
Loan-to-value ratio	65.32%	-	-

In the calculation of the capital adequacy ratio, the risk weights used are $rw_1^{MORT} = 0.50$, $rw_1^{REPO} = 0.30$, and $rw_{2b}^{MORT} = rw_{2b}^{REPO} = 1$. These are in line with the Basel III proposed weights (see Basel Committee on Bank Supervision, 2001). In particular, mortgages carry a higher risk weight than repo loans in period 1, both because the MBS are offered as collateral on the repos and because the non-bank has capital which can be seized in the event of default. The resulting bank capital ratio of nearly 10 percent in the first period implies that the bank would be well-capitalized under current Basel guidelines.

The non-bank also puts up capital of 4.78% on the repo loan. So using the repo market the non-bank is able to operate with leverage of just over 20. Prior to 2007 many of the large global investment banks were operating with leverage in excess of 20.

The loan to value ratio in equilibrium is lower than the norms that prevailed recently in the United States, where loans in excess of 95% of the value of the underlying real estate had become common. To find an equilibrium in which the banks are willing to lend that much requires the probability of the bad state to be very low, otherwise the bank's risk aversion stops it from making loans with very low down payment amounts. In equilibria where the bad state is very unlikely, both the banks and the non-banks take substantial mortgage risk so that prices are very different in good and bad state. So the equilibrium that is presented was chosen because the price volatility seems more realistic.

Finally, the liquidity ratio is relatively high in period 1. This occurs because of the large amount of short-term lending to households that regulators consider to be liquid. But for the qualitative properties of the model, the level is not too important. On the margin, if the LCR is increased then the bank still has to shift the composition of its portfolio to reduce other lending, so that the regulation will have the intended effect.

5. Regulatory comparative statics

Once any of the regulatory tools is deployed, all the endogenous variables in the model adjust. To keep the descriptions tractable, the discussion will focus on four types of variables that summarize the main linkages in the model. The first set includes the interest rates and recovery rates (in the event of default) on mortgages, repo loans, and deposits. The second group relates to level of mortgage-related securities, specifically the total quantity of mortgages extended, along with the breakdown of mortgages held by banks and the quantity securitized and the amount of MBS that are sold in a fire sale. The third collection covers the size of the bank's balance sheet and the allocation between long-term and short-term assets. Finally, the relative price changes are also recorded because they play a critical role in determining the welfare effects for the households. Complete results are shown in Tables 3 to 9 of appendix 2.

5.1 Loan to value regulation

Increasing the required downpayment on mortgages, reduces both mortgage extensions and MBS issuance and leads to a higher repayment rate on mortgages in the case of a house price bust. The combination of having fewer mortgages in default which are paying back more of what is owed, as well as a smaller repo default, means that the bank is better insulated against a default. This allows the bank to payback more on its deposits and to fire sale fewer MBS.

	% change
Mortgage repayment rate	0.51%
Deposit repayment rate	0.94%
Mortgage rate	535 bps
Total mortgages	-4.74%
MBS in period 1	-7.34%
% Mortgages securitized	-2.72%
Bank's balance sheet size	-0.82%
Defaulted MBS sold	-3.46%
Relative price of potatoes to housing in the bad state	-0.92%

The lower fire sales result in a higher relative price of housing to potatoes in the bad state. The bank repays more of its deposits and agent R sells fewer houses to fund his purchases, which mitigates the second round of knock-on effects and restrains the marginal spiral. Agent R is better off, while agent F suffers from higher prices. Agent P's default penalty is lower but his overall utility falls for three reasons. One is that his housing purchases are rationed in period 1. A second is that the reduction in MBS leads to a higher mortgage rate. Finally, in the cases when he does default in period 2, his cost of renting a home is higher because of the higher relative prices of houses.

5.2 Haircuts regulation

Higher haircuts result in fewer repo loans extended to the non-bank and less securitization. In turn, this raises mortgage rates and reduces the total amount of mortgages extended (although the amount of mortgages on the bank's balance sheet rises). Agent P purchases fewer houses and which leaves him worse off in period 1 and in the good state, but will default less in the bad state, so the overall effect on his welfare is ambiguous.

With P's reduction in housing demand, R receives less income and is inclined to make fewer deposits. The bank raises the deposit rates it offers to attract enough deposits to support its balance sheet. R's choices in the second period depend on his overall wealth. If is it higher he will choose to sell some additional housing to buy more potatoes. In this case, higher house prices marginally raise his wealth but the lower total value of deposits goes in the opposite direction, so his total wealth is not much affected and his housing sales hardly change. Consequently with the parameters in this calibration R's overall welfare is barely changed.

	% change
Mortgage repayment rate	0.46%
Deposit repayment rate	0.52%
Mortgage rate	112 bps
Total mortgages	-0.94%
MBS in period 1	-3.68%
% Mortgages securitized	-2.76%
Bank's balance sheet size	-0.47%
Defaulted MBS sold	-1.10%
Relative price of potatoes to housing in the bad state	-0.06%

When a default occurs the bank takes back fewer MBS and has to fire sale less of them. This allows the bank to honor its deposits more fully and puts less pressure on house prices, so that house prices are higher. Although it is easier for F to borrow in the default state, he faces higher housing prices and he is worse off.

5.3 Capital regulation

An increase in capital requirements has competing effects for the bank because it both adds capital that can serve as a buffer against losses, and changes the incentives to securitize loans. Depending on whether the requirements bind in the middle of period 1 or just after uncertainty is revealed in period 2 leads to very different outcomes.

Consider first an increase in the capital requirement in the middle of period 1. As explained earlier, this incentivizes the bank to hold fewer mortgages on its balance sheet. It accomplishes this by both extending fewer mortgages and securitizing more of those loans that are originated. Hence, although the bank's balance sheet shrinks, the on-balance sheet reduction in mortgage exposure is partially offset by the increased repo exposure to mortgage risk. The higher cost of funding for the bank leads to a higher mortgage rate for borrowers.

When a default occurs there are, thus, two competing effects: the bank's own loss absorbing capital is higher, but the proportion of mortgage credit that is funded by the non-bank is higher, so in relative terms the repo default is bigger. The first, direct effect leads to a lower deposit default rate. In other equilibria where the probability of a bad state is much lower, it is possible that the repo default is sufficient large that the deposit default rate can rise.

The reduction in mortgage lending allows P to buy less housing and makes him worse-off. Agent F's utility goes down as well due to higher housing prices in period 2. The various changes have nearly off-setting effects for R. On the one hand he is able to sell fewer houses in the initial period, but his deposits are better protected in the event of default. On net his housing sales in the bad state are essentially unchanged. Bank profits in the good state of the world decline, while the non-bank realizes higher profits, as it is able to borrow at a better rate due to the bank's incentive to securitize more.

The possibility of a binding capital requirement in the middle of the bad state leaves the bank with few options, since the only immediate way to improve the ratio is to shrink assets by securitizing mortgages. Because of cash-in-the market pricing, selling at that point is unattractive. Anticipating this scenario the bank cuts back on mortgage lending and MBS origination in the first period, so that the quantity of MBS sold in the bad state falls (although the fraction of mortgages that are securitized winds up being higher.)

This caution regarding MBS origination leaves the bank better capitalized to withstand losses, and thus it extends more short-term loans in the bad state. These loans help prop up housing prices which help prevent further the losses on mortgages. The mortgage rates rises, and that along with the reduced quantity of mortgage lending leaves P worse off. Although it is easier for F to borrow in the bad state of the world, his utility goes down as well due to higher housing prices. R winds up marginally better-off as the higher deposit repayment rate in the bad state more than offsets the reduced amount of housing that can be sold in the first period.

	% change: CR period 1	% change: CR bad state
Mortgage repayment rate	0.30%	1.01%
Deposit repayment rate	0.36%	1.03%
Mortgage rate	32 bps	252 bps
Total mortgages	-0.49%	-1.43%
MBS in period 1	2.67%	-5.52%
% Mortgages securitized	3.17%	-4.15%
Bank's balance sheet size	-0.17%	0.10%
Defaulted MBS sold	-0.48%	-2.84%
Relative price of potatoes to housing in the bad state	-0.12%	-0.46%

5.4 Liquidity regulation

Liquidity regulation aims at insuring that the bank can raise money by having assets which can be sold without creating a fire sale. This type of regulation has different effects than capital requirements. For instance, whereas stricter capital requirements in period 1 result in higher securitization, the introduction of a higher LCR in period 1 reduces the origination of MBS. This occurs because the repo loans that support securitization are themselves illiquid, so securitization cannot be used to sidestep liquidity rules. Instead, a higher LCR leads the bank to switch its portfolio towards short-term loans and reduce both its mortgage extensions and repo loans. As a result, the losses from a housing bust and the resulting fire sales of MBS are lower, which in turn lowers defaults on both mortgages and deposits.

Although P is forced to cut back on mortgage borrowing, he can still get short-term loans which the bank counts as a liquid asset. This additional credit availability, alongside the reduced default costs associated with the lower mortgage borrowing leaves him better off. R again loses from the reduced ability to sell his endowment in period 1, but gains when the default rate on deposits declines. On net he is also better off.

The bank shifts its portfolio towards short-term assets and shrinks its overall balance sheet. Although it holds more liquid assets in period 2 as well, the net amount of short-term loans extended is lower, which reduces F's utility.

Raising the LCR in the bad state of the world has peverse effects. At that point, the only way to comply with the regulation is to sell MBS in a fire sale, which significantly reduces MBS prices. This results in a larger deposit default. Although housing prices increase due to higher liquidity, the lower repayment on deposits exacerbates the second knock-on effect and agent R sells more houses. The bank will anticipate this possibility so total mortgage extensions decline and this makes the house price collapse when it does occur slightly less extreme. Liquidity regulation within the bad state benefits agent P who is endowed with liquid good and,while it makes agent R slightly worse off. F suffers from the higher house prices.

	% change: LCR period 1	% change: LCR bad state
Mortgage repayment rate	5.30%	6.35%
Deposit repayment rate	6.80%	-8.05%
Mortgage rate	170 bps	-11 bps
Total mortgages	-7.88%	-3.77%
MBS in period 1	-9.35%	-0.05%
% Mortgages securitized	-1.60%	3.87%
Bank's balance sheet size	-1.78%	0.88%
Defaulted MBS sold	-5.95%	15.05%
Relative price of potatoes to housing in the bad state	-1.07%	-13.17%

5.5 Dynamic provisioning regulation

The baseline calibration implies that real estate related credit grows by 56 percent in the good state. The dynamic provisioning threshold is chosen to be 20 percent. The volume of period 1 real estate credit ($MORT^{P} + LST_{1}^{P}$) is about 33, so this constraint allows the bank to loan up to 36.3 in the second period without setting aside any cash. Once the lending crosses that threshold, κ governs the incremental amount of cash that is required. In the results shown below κ is set to 3.31, which implies that on the margin the bank holds 10 cents against every extra dollar of lending.

For the κ= 3.31 case, interest rates on real estate credit rise by 1.18 percentage points and the price of housing drops substantially (relative to potatoes).[14] The relative price drop leads to a large increase in the effective endowment of F, so even with the higher cost of borrowing, F is able to rent more housing and has higher utlity.

One interesting side effect of this type of regulation is that the bank can also loosen the provisioning constraint by doing more mortgage lending in the first period (by making the base level of real estate credit higher). The bank responds to this incentive so P is also able to borrow more during the first period and P's utlity is much higher.

The banks are one of the losers from this type of policy because its profits are much lower in the boom. The other party that is disadvantaged is R. The value of his endowment is reduced and his welfare drops. Thus, the dynamic provisioning regulation has the potential to distribute the burden of regulation very differently than the other tools.

	Incremental cash held per each dollar of new lending: 0.100
Rate on real estate related credit in the good state	118 bps
Level of real estate related credit in the good state	1.11%
Growth rate in real estate related credit	-43 bps
Relative price of potatoes to housing in the good state	2.08%
Utility of agent F	0.82%
Utility of agent P	1.36%

[14] As earlier, it is theoretically possible that interest rate increase is large enough in comparison to the relative price change so that F would not borrow more. But in the calibration this only happens for very tiny values of κ.

5.6 Multiple regulations

The one at time regulatory interventions provide several general lessons. First, all the regulations except liquidity rules result in reductions in mortgage availability that reduce the welfare of P. Second, R's utility is mostly unaffected by the various interventions because any factor reduces mortgage lending in the first period usually raises the repayment rates on deposits in the bad state of the world. These two forces move in opposite directions so R's welfare is relatively insensitive to the regulations. Third, F suffers if a policy helps to support house prices in the bad state, so such regulations always reduce his welfare. Fourth, the liquidity rules are very different than the capital, loan to value and margin rules, because they make more credit available to P and can raise his welfare. Finally, dynamic provisioning rules stand out by directly operating on allocations in the boom, rather the focusing on the bust. The provisioning rules reduce the value of land so much that F becomes rich enough to buy more housing and has higher welfare.

There are many, many ways to combine the regulations. As an indicative exercise consider imposing margin requirements on repos, along with dynamic provisioning rules, and capital requirements for banks (that bind only in the bad state of the world). This bundle is interesting because it includes a tool that operates in each state, and also works on each of the possible channels for managing the externalities associated with fire-sales: the loan to value rules limit mortgage extension in period 1 which make any potential fire-sale smaller; the capital regulation makes the banks better able to absorb losses and thereby reduces subsequent deposit defaults; the provisioning rules damp mortgage credit in the boom which damps the house price increase.

The regulatory combination introduces competing effects on the form and timing of real-estate related lending. Since the restriction on securitization makes long term real-estate related borrowing harder, P funds his higher housing purchases via short-term loans. Dynamic provisioning creates incentives for the bank to smooth its real-estate related lending, while capital regulations reduce the incentives to take mortgage risk.

The table below shows the effects for several key variables. The net effect of the rules results in the banks reducing mortgage lending, but funding more of the loans that are made itself.

The table presents the change in key variable for a 0.2% dynamic provisioning per incremental credit, 0.2% increase in haircuts and 1% increase in capital requirements.

% change	Dynamic provisioning, haircut and capital regulation
Mortgage extension	-0.076%
Period 1 real-estate short-term credit extension	0.143%
Bank's contribution to mortgage extension	0.186%
Fire-sales	-0.390%
Repayment rate on deposits	0.051%
P's welfare	0.005%
R's welfare	0.003%

P is forced to reduce housing consumption in period 1, but he consumes more in the boom and is is less prone to default in the bust. Taken together this makes P better off. R gains because his deposits are better-protected (due to the smaller fire sale and more strongly capitalized bank.) These regulations reduce the relative price of potatoes to houses in the second period and consequently F is worse off.

These package of regulations was not optimized in the sense of searching overall possible combinations. A topic for future research is a more throrough comparison of the interactions across tools. Because of the many off-setting effects of the various policies their interactions are rich and complex.

6. Conclusions

Despite the many simplifying assumptions in the model, it produces several sharp results that appear to be generic. Most importantly it highlights the substantial payoff to having a formal general equilibrium model that takes a clear stand on the purpose and risks associated with having the financial system rely on shadow banks to deliver funding to the economy. The shadow banks exist here because they are less risk averse (and face lower default costs) than the conventional banks. This leads them to operate with higher leverage (and more concentrated portfolios) than traditional banks. When borrowers default the shadow banks pass losses back to the rest of the financial system and kick off a cascade of other problems: deposit defaults, credit crunches and fire sales that can create margin spirals. Each of these possibilities is intuitive but sorting through them and their potential interactions absent the discipline of the model would be impossible. One important next step will be to allow for other rationales for shadow banks to operate and to explore the resulting ramifications.

Second, the model implies that the market incompleteness along with the deadweight costs of default distort the housing market. The wealthy agents endowed with houses make their savings decisions accounting for the possibility that deposits will not be fully repaid. When default penalties for banks are low, then the households internalize that risk putting less wealth into the banking system and hold more in the form of housing. This choice increases the supply of housing that is available in boom, which lowers house prices and raises welfare for the agents entering the housing market at that time.

Interestingly, trying to lean against the wind to reduce the credit expansion and house prices in the boom via regulation is not easy. The challenge comes because the boom brings large increases in asset prices. The high prices deliver capital gains to all the existing owners of the assets. The gains to current mortgage holders improve their equity and lower the loan to value ratio on their mortgages. High home prices improve bank capital ratios higher both because the mortgages are less risky and because the home price gains raise bank equity. Non-banks see their equity values rise because of higher MBS prices, which means their leverage falls. These three effects mean that during a boom it is difficult to impose higher loan to value requirements, to raise capital standards, or to lift margin requirements on repo loans enough to slow down credit expansion (and house price appreciation).

Third, the two regulatory tools that can effectively "lean against the wind" and potentially tame a boom are dynamic provisioning rules and liquidity requirements. The provisioning rules can be implemented directly to slow mortgage credit growth. Importantly, this kind of rule might bind only during a boom and creates the possibility of lowering the relative price of house prices which has very different welfare implications than other tools.

In contrast, using liquidity restrictions to slow a boom entails also changing bank lending during busts. Banks naturally have more liquid assets during booms than during busts (when liquidity optimally would be depleted to help cover deposit repayments). Therefore, if a liquidity ratio is binding during a boom it will be even more restrictive during a bust, making this kind of rule potentially very pro-cyclical: in this model, imposing a single across the board liquidity requirement creates a massive fire sale during the bust.

Fourth, given many complex interactions between the various agents in the model, no single regulatory tool is going to be sufficient to offset the many distortions arising from a default. The exact combination of tools that works best is no doubt specific to some of the details of the model, but the proposition that the multiple sources of inefficiency require multiple tools is general (Kashyap, Berner and Goodhart (2011)). The official sector has thus far has made substantial changes to capital rules, and much more limited progress on revising other regulations such as liquidity, margin requirements or time varying provisioning rules. This model suggests that capital alone is unlikely to be sufficient to contain the problems arising during a crisis.

Finally, this model should be viewed as a first step for analyzing these issues. The calibrated example analyzed in this paper highlights well the properties of a specific variant of this type of model. But the model is better viewed as a flexible framework that can be altered in a variety of ways to analyze different regulatory options.

For instance, one important omission from this model is the absence of the risk of a bank run. Depositors in the model face the risk that the bank may not fully repay them, but have no capacity to withdraw their deposits to head off the losses.[15] This could be easily remedied by switching to a true overlapping generations framework so that recent depositors could run against the bank well before their long-term deposits were supposed to be repaid. In addition to adding a certain amount of realism, adding this additional risk would make it possible to study other potential regulatory tools, such as the net stable funding ratio, which have no role in the current model. But this is only one of many potential extensions that should be explored.

[15] See Diamond and Rajan (2000) for a model that emphasizes how this possibility can interact with other financial stability considerations.

Appendix 1: Exogenous and endogenous variables in the initial equilibrium

Table 1: Exogenous variables

Endowments of goods	Households' wealth	F.I. capital	CB rates	Default penalties	Risk aversion	Other parameters
$e_{1,p}^{P} = 10$	$Money_{1}^{P} = 4.1$	$E_{1}^{B} = 0.5$	$r_{1}^{CB} = 0.12$	$\tau_{2b}^{P} = 4$	$\gamma^{P} = 2.1$	$\omega_{2b} = 0.1$
$e_{2g,p}^{P} = 32$	$Money_{2g}^{P} = 4.1$	$E_{2g}^{B} = 0.5$	$r_{2g}^{CB} = 0.12$	$\tau_{2g}^{B} = 1.2$	$\gamma^{F} = 2.1$	$\xi = 0.85$
$e_{2b,p}^{P} = 5.8$	$Money_{2b}^{P} = 0.1$	$E_{2b}^{B} = 0$	$r_{2b}^{CB} = 0.20$	$\tau_{2b}^{\beta} = 1.2$	$\gamma^{R} = 2.4$	$\delta = 0.15$
$e_{2g,p}^{F} = 11$	$Money_{2g}^{F} = 4.1$	$E_{1}^{N} = 1$		$\tau_{2b}^{N} = 0.2$	$\gamma^{B} = 1.4$	
$e_{2b,p}^{F} = 11$	$Money_{2b}^{F} = 0.1$	$E_{2g}^{N} = 2$			$\gamma^{N} = 0.7$	
$e_{1,h}^{R} = 1$	$Money_{1}^{R} = 6.5$	$E_{2b}^{N} = 1$				
$e_{2g,h}^{R} = 0$	$Money_{2g}^{R} = 0$					
$e_{2b,h}^{R} = 0$	$Money_{2b}^{R} = 0$					

Table 2: Initial Equilibrium variables

Prices	Interest rates/Money supply	Aggregate Consumption		Loans		Securitization	Delivery rates	F.I. profits
$P_{1,p} = 1.08$	$r_{1}^{ST} = 0.12$	$c_{1,p}^{P} = 0.859$	$c_{1,p}^{R} = 9.141$	$LST_{1}^{P} = 8.81$	$LST_{1}^{B} = 42.06$	$MBS_{1}^{B} = 21.52$	$V_{2g}^{MORT} = 1$	$\pi_{1}^{B} = 0.73$
$P_{2g,p} = 1.39$	$r_{2g}^{ST} = 0.12$	$c_{2g,p}^{P} = 1.126$	$c_{2g,p}^{R} = 41.478$	$LST_{2g}^{P} = 38.41$	$LST_{2g}^{B} = 67.05$	$\sigma_{2g}^{B} = 0.456$	$V_{2b}^{MORT} = 0.47$	$\pi_{2g}^{B} = 1.42$
$P_{2b,p} = 1.48$	$r_{2b}^{ST} = 0.20$	$c_{2b,p}^{P} = 0.285$	$c_{2b,p}^{R} = 15.997$	$LST_{2b}^{P} = 6.82$	$LST_{2b}^{B} = 19.76$	$\sigma^{B}_{2b} = 0$	$V_{2g}^{D} = 1$	$\pi_{2b}^{B} = 1.00$
$P_{1,h} = 676.96$	$r^{D} = 0.42$	$c_{1,h}^{P} = 0.055$	$c_{1,h}^{R} = 0.945$	$MORT^{P} = 24.32$	$DISC_{1}^{B} = 35.00$	$\vartheta_{2b}^{B} = 0.068$	$V_{2b}^{D} = 0.56$	$CC^{B} = 3.42$
$P_{2g,h} = 1{,}111.41$	$r^{MORT} = 0.75$	$c_{2g,h}^{P} = 0.047$	$c_{2g,h}^{R} = 0.788$	$LST_{2g}^{F} = 13.20$	$DISC_{2g}^{B} = 99.00$	$MBS_{2g}^{N} = 1.28$		$cash_{1}^{B} = 7.90$
$P_{2b,h} = 362.73$	$r^{REPO} = 0.74$	$c_{2b,h}^{P} = 0.019$	$c_{2b,h}^{R} = 0.803$	$LST_{2b}^{F} = 12.94$	$DISC_{2b}^{B} = 34.55$	$MBS_{2b}^{N} = 1.46$		$\pi_{2g}^{N} = 5.31$
$P_{1,MBS} = 0.97$	$M_{1}^{CB} = 35.00$	$c_{2g,p}^{F} = 0.396$		$LST_{1}^{R} = 33.25$	$REPO^{B} = 19.90$			$\pi_{2b}^{N} = 1.20$
$P_{2g,MBS} = 1.56$	$M_{2g}^{CB} = 99.00$	$c_{2b,p}^{F} = 0.538$		$LST_{2g}^{R} = 15.44$				
$P_{2b,MBS} = 0.68$	$M_{2b}^{CB} = 34.55$	$c_{2g,h}^{F} = 0.016$		$LST_{2b}^{R} = 0.004$				
		$c_{2b,h}^{F} = 0.036$		$D^{R} = 29.88$				

Appendix 2: Regulatory comparative statics

Table 3: Loan to Value Regulation

Prices	Interest rates/Money supply	Aggregate Consumption/ Utility		Loans		Securitization	Delivery rates	F.I. profits/ payoffs
$P_{1,p}$ 9.55%	r_1^{ST} 0 bps	$c_{1,p}^P$ -2.80%	$c_{1,p}^R$ 0.26%	LST_1^P 9.83%	LST_1^B 1.45%	MBS_1^B -7.34%	V_{2g}^{MORT} 0.00%	π_1^B 0.48%
$P_{2g,p}$ -2.02%	r_{2g}^{ST} 0 bps	$c_{2g,p}^P$ 0.09%	$c_{2g,p}^R$ 0.00%	LST_{2g}^P -2.02%	LST_{2g}^B -1.90%	σ_{2g}^B -15.75%	V_{2b}^{MORT} 0.51%	π_{2g}^B 8.95%
$P_{2b,p}$ -1.30%	r_{2b}^{ST} 0 bps	$c_{2b,p}^P$ -0.44%	$c_{2b,p}^R$ 0.02%	LST_{2b}^P -1.28%	LST_{2b}^B -1.28%	σ_{2b}^B 0.00%	V_{2g}^D 0.00%	π_{2b}^B 0.00%
$P_{1,h}$ 0.11%	r^D 282 bps	$c_{1,h}^P$ -0.88%	$c_{1,h}^R$ 0.05%	$MORT^P$ -4.74%	$DISC_1^B$ 1.95%	ϑ_{2b}^B 4.18%	V_{2b}^D 0.94%	CC^B 12.07%
$P_{2g,h}$ 0.00%	r^{MORT} 535 bps	$c_{2g,h}^P$ -0.88%	$c_{2g,h}^R$ 0.08%	LST_{2g}^F -2.00%	$DISC_{2g}^B$ -2.14%	MBS_{2g}^N -2.98%		$cash_1^B$ -1.04%
$P_{2b,h}$ -0.39%	r^{REPO} 534 bps	$c_{2b,h}^P$ -0.88%	$c_{2b,h}^R$ 0.05%	LST_{2b}^F -1.28%	$DISC_{2b}^B$ -1.37%	MBS_{2b}^N -3.46%		π_{2g}^N 0.87%
$P_{1,MBS}$ -0.17%	M_1^{CB} 1.95%	$c_{2g,p}^F$ -0.56%	$\bar{U}^P$ -0.57%	LST_1^R -0.77%	$REPO^B$ -7.87%			π_{2b}^N 0.00%
$P_{2g,MBS}$ 3.07%	M_{2g}^{CB} -2.14%	$c_{2b,p}^F$ -0.45%	$\bar{U}^F$ -1.64%	LST_{2g}^R -1.52%				$\overline{Prof}^B$ 1.90%
$P_{2b,MBS}$ 3.58%	M_{2b}^{CB} -1.37%	$c_{2g,h}^F$ -1.52%	$\bar{U}^R$ 0.10%	LST_{2b}^R -1.47%				$\overline{Prof}^N$ 0.68%
		$c_{2b,h}^F$ -0.88%		D^R -4.11%				

Table 4: Haircuts Regulation

Prices	Interest rates/Money supply	Aggregate Consumption/ Utility		Loans		Securitization	Delivery rates	F.I. profits/ payoffs
$P_{1,p}$ 0.68%	r_1^{ST} 0 bps	$c_{1,p}^P$ -0.57%	$c_{1,p}^R$ 0.05%	LST_1^P 0.74%	LST_1^B -0.19%	MBS_1^B -3.68%	V_{2g}^{MORT} 0.00%	π_1^B 0.90%
$P_{2g,p}$ -0.33%	r_{2g}^{ST} 0 bps	$c_{2g,p}^P$ 0.26%	$c_{2g,p}^R$ 0.00%	LST_{2g}^P -0.34%	LST_{2g}^B -0.31%	σ_{2g}^B -17.22%	V_{2b}^{MORT} 0.46%	π_{2g}^B 2.61%
$P_{2b,p}$ 0.15%	r_{2b}^{ST} 0 bps	$c_{2b,p}^P$ -0.03%	$c_{2b,p}^R$ 0.00%	LST_{2b}^P 0.15%	LST_{2b}^B 0.15%	σ_{2b}^B 0.00%	V_{2g}^D 0.00%	π_{2b}^B 0.00%
$P_{1,h}$ -0.39%	r^D 53 bps	c_{1h}^P -0.0,5%	$c_{1,h}^R$ 0.00%	$MORT^P$ -0.94%	$DISC_1^B$ -0.26%	ϑ_{2b}^B 2.68%	V_{2b}^D 0.52%	CC^B 16.27%
$P_{2g,h}$ 0.33%	r^{MORT} 112 bps	$c_{2g,h}^P$ -0.05%	$c_{2g,h}^R$ 0.01%	LST_{2g}^F -0.32%	$DISC_{2g}^B$ -0.38%	MBS_{2g}^N -0.64%		$cash_1^B$ 0.14%
$P_{2b,h}$ 0.21%	r^{REPO} 102 bps	$c_{2b,h}^P$ -0.06%	$c_{2b,h}^R$ 0.00%	LST_{2b}^F 0.15%	$DISC_{2b}^B$ 0.16%	MBS_{2b}^N -1.10%		π_{2g}^N 0.36%
$P_{1,MBS}$ -0.09%	M_1^{CB} -0.26%	$c_{2g,p}^F$ -0.26%	$\bar{U}^P$ 0.04%	LST_1^R -0.44%	$REPO^B$ -3.95%			π_{2b}^N 0.00%
$P_{2g,MBS}$ 0.64%	M_{2g}^{CB} -0.38%	$c_{2b,p}^F$ -0.03%	$\bar{U}^F$ -0.60%	LST_{2g}^R -0.24%				$\overline{Prof}^B$ 0.71%
$P_{2b,MBS}$ 1.11%	M_{2b}^{CB} 0.16%	$c_{2g,h}^F$ -0.57%	$\bar{U}^R$ 0.01%	LST_{2b}^R -26.13%				$\overline{Prof}^N$ 0.39%
		$c_{2b,h}^F$ -0.06%		D^R -0.74%				

Table 5: Capital Regulation in period 1

Prices	Interest rates/Money supply	Aggregate Consumption/ Utility		Loans		Securitization	Delivery rates	F.I. profits/ payoffs
$P_{1,p}$ 0.56%	r_1^{ST} 0 bps	$c_{1,p}^P$ -0.40%	$c_{1,p}^R$ 0.04%	LST_1^P 0.60%	LST_1^B -0.01%	MBS_1^B 2.67%	V_{2g}^{MORT} 0.00%	π_1^B 1.65%
$P_{2g,p}$ -0.33%	r_{2g}^{ST} 0 bps	$c_{2g,p}^P$ 0.05%	$c_{2g,p}^R$ 0.00%	LST_{2g}^P -0.34%	LST_{2g}^B -0.32%	σ_{2g}^B 32.60%	V_{2b}^{MORT} 0.30%	π_{2g}^B -3.93%
$P_{2b,p}$ 0.00%	r_{2b}^{ST} 0 bps	$c_{2b,p}^P$ -0.06%	$c_{2b,p}^R$ 0.00%	LST_{2b}^P 0.00%	LST_{2b}^B 0.00%	$\sigma^B_{\ 2b}$ 0.00%	V_{2g}^D 0.00%	$\pi_{2b}^{\beta B}$ 0.00%
$P_{1,h}$ -0.06%	r^D 5 bps	$c_{1,h}^P$ -0.12%	$c_{1,h}^R$ 0.01%	$MORT^P$ -0.49%	$DISC_1^B$ -0.02%	ϑ_{2b}^B -3.07%	V_{2b}^D 0.36%	CC^B -20.62%
$P_{2g,h}$ 0.02%	r^{MORT} 32 bps	$c_{2g,h}^P$ -0.12%	$c_{2g,h}^R$ 0.01%	LST_{2g}^F -0.33%	$DISC_{2g}^B$ -0.37%	MBS_{2g}^N -0.18%		$cash_1^B$ 0.01%
$P_{2b,h}$ 0.12%	r^{REPO} -21 bps	$c_{2b,h}^P$ -0.12%	$c_{2b,h}^R$ 0.01%	LST_{2b}^F 0.00%	$DISC_{2b}^B$ 0.00%	MBS_{2b}^N -0.48%		π_{2g}^N 1.87%
$P_{1,MBS}$ 0.13%	M_1^{CB} -0.02%	$c_{2g,p}^F$ -0.10%	$\bar{U}^P$ -0.04%	LST_1^R -0.18%	$REPO^B$ 2.95%			π_{2b}^N 0.00%
$P_{2g,MBS}$ 0.18%	M_{2g}^{CB} -0.37%	$c_{2b,p}^F$ -0.06%	$\bar{U}^F$ -0.29%	LST_{2g}^R -0.26%				$\overline{Prof}^B$ 0.11%
$P_{2b,MBS}$ 0.49%	M_{2b}^{CB} 0.00%	$c_{2g,h}^F$ -0.27%	$\bar{U}^R$ 0.01%	LST_{2b}^R 0.68%				$\overline{Prof}^N$ 0.39%
		$c_{2b,h}^F$ -0.12%		D^R -0.39%				

Table 6: Capital Regulation in the bad state

Prices	Interest rates/Money supply	Aggregate Consumption/ Utility		Loans		Securitization	Delivery rates	F.I. profits/ payoffs
$P_{1,p}$ -1.31%	r_1^{ST} 0 bps	$c_{1,p}^P$ -0.23%	$c_{1,p}^R$ 0.02%	LST_1^P -1.29%	LST_1^B -1.25%	MBS_1^B -5.52%	V_{2g}^{MORT} 0.00%	π_1^B 0.60%
$P_{2g,p}$ -0.02%	r_{2g}^{ST} 0 bps	$c_{2g,p}^P$ -0.32%	$c_{2g,p}^R$ 0.01%	LST_{2g}^P 0.00%	LST_{2g}^B -0.01%	σ_{2g}^B -24.14%	V_{2b}^{MORT} 1.01%	π_{2g}^B 4.59%
$P_{2b,p}$ 1.01%	r_{2b}^{ST} 0 bps	$c_{2b,p}^P$ -0.24%	$c_{2b,p}^R$ 0.01%	LST_{2b}^P 1.03%	LST_{2b}^B 1.03%	$\sigma^B_{\ 2b}$ 0.00%	V_{2g}^D 0.00%	π_{2b}^B 0.00%
$P_{1,h}$ -0.78%	r^D 136 bps	$c_{1,h}^P$ -0.46%	$c_{1,h}^R$ 0.03%	$MORT^P$ -1.43%	$DISC_1^B$ -1.68%	ϑ_{2b}^B 2.83%	V_{2b}^D 1.03%	CC^B 24.64%
$P_{2g,h}$ 0.28%	r^{MORT} 252 bps	$c_{2g,h}^P$ -0.46%	$c_{2g,h}^R$ 0.03%	LST_{2g}^F -0.01%	$DISC_{2g}^B$ -0.08%	MBS_{2g}^N -1.42%		$cash_1^B$ 0.89%
$P_{2b,h}$ 1.48%	r^{MORt} 262 bps	$c_{2b,h}^P$ -0.46%	$c_{2b,h}^R$ 0.03%	LST_{2b}^F 1.03%	$DISC$ 1.09%	MBS_{2b}^N -2.84%		π_{2g}^N 0.26%
$P_{1,MBS}$ -0.19%	M_1^{CB} -1.68%	$c_{2g,p}^F$ -0.15%	$\bar{U}^P$ -0.31%	LST_1^R -1.24%	$REPO^B$ -5.98%			π_{2b}^N -0.44%
$P_{2g,MBS}$ 1.44%	M_{2g}^{CB} -0.08%	$c_{2b,p}^F$ -0.24%	$\bar{U}^F$ -0.32%	LST_{2g}^R -0.01%				$\overline{Prof}^B$ 0.93%
$P_{2b,MBS}$ 2.93%	M_{2b}^{CB} 1.09%	$c_{2g,h}^F$ -0.29%	$\bar{U}^R$ 0.04%	LST_{2b}^R 11.57%				$\overline{Prof}^N$ 0.48%
		$c_{2b,h}^F$ -0.45%		D^R -0.95%				

Table 7: Liquidity Regulation in period 1

Prices	Interest rates/Money supply	Aggregate Consumption/ Utility		Loans		Securitization	Delivery rates	F.I. profits/ payoffs
$P_{1,p}$ 17.31%	r_1^{ST} 89 bps	$c_{1,p}^P$ -7.76%	$c_{1,p}^R$ 0.73%	LST_1^P 17.24%	LST_1^B 2.15%	MBS_1^B -9.35%	V_{2g}^{MORT} 0.00%	π_1^B 24.86%
$P_{2g,p}$ -7.63%	r_{2g}^{ST} 0 bps	$c_{2g,p}^P$ 2.95%	$c_{2g,p}^R$ -0.06%	LST_{2g}^P -7.73%	LST_{2g}^B -7.25%	σ_{2g}^B -4.23%	V_{2b}^{MORT} 5.30%	π_{2g}^B 27.25%
$P_{2b,p}$ -2.17%	r_{2b}^{ST} 0 bps	$c_{2b,p}^P$ -0.50%	$c_{2b,p}^R$ 0.03%	LST_{2b}^P -2.15%	LST_{2b}^B -2.15%	σ_{2b}^B 0.00%	V_{2g}^D 0.00%	π_{2b}^B 0.00%
$P_{1,h}$ -0.06%	r^D -49 bps	$c_{1,h}^P$ -1.01%	$c_{1,h}^R$ 0.06%	$MORT^P$ -7.88%	$DISC_1^B$ 3.99%	ϑ_{2b}^B 3.76%	V_{2b}^D 6.80%	CC^B 6.89%
$P_{2g,h}$ 0.30%	r^{MORT} 170 bps	$c_{2g,h}^P$ -1.01%	$c_{2g,h}^R$ 0.18%	LST_{2g}^F -7.55%	$DISC_{2g}^B$ -8.32%	MBS_{2g}^N -0.96%		$cash_1^B$ -2.13%
$P_{2b,h}$ -1.12%	r^{REPO} 69 bps	$c_{2b,h}^P$ -1.01%	$c_{2b,h}^R$ 0.06%	LST_{2b}^F -2.15%	$DISC_{2b}^B$ 2.22%	MBS_{2b}^N -5.95%		π_{2g}^N 8.03%
$P_{1,MBS}$ -1.04%	M_1^{CB} 3.99%	$c_{2g,p}^F$ -2.28%	$\bar{U}^P$ 0.42%	LST_1^R -1.85%	$REPO^B$ -10.81%			π_{2b}^N 0.00%
$P_{2g,MBS}$ 0.97%	M_{2g}^{CB} -8.32%	$c_{2b,p}^F$ -0.52%	$\bar{U}^F$ -6.72%	LST_{2g}^R -5.80%				$\overline{Prof}^B$ 0.93%
$P_{2b,MBS}$ 6.32%	M_{2b}^{CB} -2.22%	$c_{2g,h}^F$ -6.04%	$\bar{U}^R$ 0.18%	LST_{2b}^R -22.11%				$\overline{Prof}^N$ 0.48%
		$c_{2b,h}^F$ -1.02%		D^R -8.06%				

Table 8: Liquidity Regulation in the bad state

Prices	Interest rates/Money supply	Aggregate Consumption/ Utility		Loans		Securitization	Delivery rates	F.I. profits/ payoffs
$P_{1,p}$ 12.98%	r_1^{ST} 0 bps	$c_{1,p}^P$ -4.96%	$c_{1,p}^R$ 0.47%	LST_1^P 13.51%	LST_1^B 3.41%	MBS_1^B -0.05%	V_{2g}^{MORT} 0.00%	π_1^B 4.25%
$P_{2g,p}$ -4.13%	r_{2g}^{ST} 0 bps	$c_{2g,p}^P$ 3.20%	$c_{2g,p}^R$ -0.08%	LST_{2g}^P -4.24%	LST_{2g}^B -3.95%	σ_{2g}^B 47.78%	V_{2b}^{MORT} 6.35%	π_{2g}^B 0.79%
$P_{2b,p}$ -12.21%	r_{2b}^{ST} -1,705 bps	$c_{2b,p}^P$ 0.57%	$c_{2b,p}^R$ -0.03%	LST_{2b}^P 2.30%	LST_{2b}^B 2.35%	σ_{2b}^B 0.00%	V_{2g}^D 0.00%	π_{2b}^B 0.00%
$P_{1,h}$ -0.38%	r^D -140 bps	$c_{1,h}^P$ 1.12%	$c_{1,h}^R$ -0.07%	$MORT^P$ -3.77%	$DISC_1^B$ 4.59%	ϑ_{2b}^B 15.11%	V_{2b}^D -8.05%	CC^B -28.02%
$P_{2g,h}$ 0.05%	r^{MORT} -11 bps	$c_{2g,h}^P$ 1.12%	$c_{2g,h}^R$ 0.00%	LST_{2g}^F -4.09%	$DISC_{2g}^B$ -4.45%	MBS_{2g}^N 0.00%		$cash_1^B$ -2.43%
$P_{2b,h}$ 1.10%	r^{REPO} -221 bps	$c_{2b,h}^P$ 1.16%	$c_{2b,h}^R$ -0.07%	LST_{2b}^F 2.30%	$DISC_{2b}^B$ -6.52%	MBS_{2b}^N 15.05%		π_{2g}^N 6.14%
$P_{1,MBS}$ 0.25%	M_1^{CB} 4.59%	$c_{2g,p}^F$ -1.18%	$\bar{U}^P$ 2.17%	LST_1^R 0.73%	$REPO^B$ 0.21%			π_{2b}^N 22.28%
$P_{2g,MBS}$ 0.00%	M_{2g}^{CB} -4.45%	$c_{2b,p}^F$ 0.59%	$\bar{U}^F$ -3.34%	LST_{2g}^R -3.12%				$\overline{Prof}^B$ -0.70%
$P_{2b,MBS}$ -13.08%	M_{2b}^{CB} -6.52%	$c_{2g,h}^F$ -3.17%	$\bar{U}^R$ -0.04%	LST_{2b}^R 257.18%				$\overline{Prof}^N$ 2.83%
		$c_{2b,h}^F$ 1.17%		D^R -3.64%				

Table 9: Dynamic Provisioning Regulation (κ=3.31)

Prices	Interest rates/Money supply	Aggregate Consumption/ Utility		Loans		Securitization	Delivery rates	F.I. profits/ payoffs
$P_{1,p}$ 1.18%	r^{ST}_{1p} 0 bps	$c^P_{1,p}$ 1.08%	$c^R_{1,p}$ -0.09%	LST^P_1 1.52%	$LST^B_{1,p}$ 1.94%	MBS^B_1 7.60%	V^{MORT}_{2g} 0.00%	π^B_1 -15.02%
$P_{2g,p}$ 2.49%	r^{ST}_{1h} -50 bps	$c^P_{2g,p}$ 1.34%	$c^R_{2g,p}$ -0.03%	LST^P_{2g} 0.85%	$LST^B_{1,h}$ 1.52%	σ^B_{2g} 59.91%	V^{MORT}_{2b} 4.86%	π^B_{2g} -12.45%
$P_{2b,p}$ 3.43%	r^{ST}_{2gp} 0 bps	$c^P_{2b,p}$ 1.18%	$c^R_{2b,p}$ -0.06%	LST^P_{2b} 3.37%	$LST^B_{2g,p}$ -0.12%	σ^B_{2b} 0.00%	V^D_{2g} 0.00%	π^B_{2b} 0.00%
$P_{1,h}$ -0.43%	r^{ST}_{2gh} 175 bps	$c^P_{1,h}$ 2.46%	$c^R_{1,h}$ -0.14%	$MORT^P$ 2.54%	$LST^B_{2g,h}$ 0.86%	ϑ^B_{2b} -9.90%	V^D_{2b} 2.92%	CC^B -28.11%
$P_{2g,h}$ 0.14%	r^{ST}_{2b} 0 bps	$c^P_{2g,h}$ 2.46%	$c^R_{2g,h}$ -0.14%	LST^F_{2g} 0.89%	LST^B_{2b} 3.36%	MBS^N_{2g} 1.76%		$cash^B_1$ -1.74%
$P_{2b,h}$ 0.92%	r^D 221 bps	$c^P_{2b,h}$ 2.37%	$c^R_{2b,h}$ -0.14%	LST^F_{2b} 3.37%	$DISC$ 2.46%	MBS^N_{2b} -3.06%		π^N_{2g} -10.60%
$P_{1,MBS}$ -0.04%	r^{MORT} -302 bps	$c^F_{2g,p}$ 0.17%	$\overline{U}^P$ 1.36%	LST^R_1 1.94%	$DISC^B_{2g}$ 3.71%			π^N_{2b} 0.00%
$P_{2g,MBS}$ -1.73%	r^{REPO} -10 bps	$c^F_{2b,p}$ 1.21%	$\overline{U}^F$ 0.82%	LST^R_{2g} -0.12%	$DISC$ 4.64%			$\overline{Prof}^B$ -5.23%
$P_{2b,MBS}$ 3.16%	M^{CB}_1 2.46%	$c^F_{2g,h}$ 0.54%	$\overline{U}^R$ -0.14%	LST^R_{2b} -8.46%	$REPO^B$ 7.92%			$\overline{Prof}^N$ -3.62%
	M^{CB}_{2g} 3.71%	$c^F_{2b,h}$ 2.40%		D^R 1.80%				
	M^{CB}_{2b} 4.64%							

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