Large Scale Asset Purchases with segmented mortgage and corporate loan markets

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Abstract

We introduce Large Scale Asset Purchases (LSAPs) in a New-Keynesian DSGE model that features distinct mortgage and corporate loan markets. We show that following a significant disruption of financial intermediation, central-bank purchases of mortgage-backed securities (MBS) are significantly less effective at easing credit market conditions than outright purchases of corporate bonds. Moreover, the size of the effects crucially depends on the extent to which credit markets are segmented, i.e. to which a " portfolio rebalance channel" is at work in the economy. More segmented credit markets imply stronger, but more local, effects of particular asset purchases.

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1 Introduction

The recent financial crisis started with the burst of the housing bubble and the collapse in the value of mortgage-related securities. Large financial institutions, which were holding significant amounts of those securities, experienced a severe deterioration of their balance sheet, leading them to fire-sell assets and to drastically reduce the amounts of loans distributed to households and firms. Both this deleveraging process and the erosion of confidence in the solidity of the banking system led to sharp increases in long-term interest rates and credit spreads. Central banks in many countries quickly faced the unprecedented situation of having their main policy instrument – the overnight interest rate – stuck at the zero lower bound while excess returns were still rising and the economic activity was contracting. As a result, major central banks around the world implemented a series of unconventional monetary policy measures designed to ease the functioning of credits markets and to reduce credit spreads. Large Scale Asset Purchases (LSAP) programs initiated by the Fed have probably been the most spectacular and most widely discussed of those policies, raising lengthy discussions at the public level and stimulating a vigorous debate among academic researchers.

As emphasized by Woodford (2012), for LSAP programs to work, it must either be the case that (i) securities with identical risk and return characteristics have additional features that make them imperfectly substitutable from the viewpoint of investors (such as liquidity providing services), or (ii) there are limits to the quantities of assets that some investors can buy at prevailing market prices, i.e. some investors are submitted to binding constraints.

Building on these considerations, a growing recent literature has started to develop suitable frameworks to analyze the qualitative and quantitative effects of LSAPs within New-Keynesian DSGE models with financial frictions (see in particular Chen *et al.* (2012), Cúrdia and Woodford (2010, 2011), Del Negro *et al.* (2011) and Gertler and Karadi, 2011, 2012). In these papers, LSAPs consist either in central bank purchases of corporate bonds[1], of long term Treasury bonds[2], or of both.[3]

Yet, as far as we know, no existing studies have considered the possibility for the central bank to buy mortgage-related securities. This is somewhat surprising since the primary focus of the first round of LSAPs (often referred to as "QE1")

[1]See e.g. Curdia and Woodford (2011), Del Negro et al. (2011) and Gerter and Karadi (2011).
[2]See Chen et al. (2011).
[3]See Gertler and Karadi (2012).

– by far the most important of all LSAP programs in terms of volume – has been the acquisition of Mortgage-Backed Securities (MBS): among the \$1.75 trillion of Fed's purchases of long-term assets involved in QE1, \$1.25 trillion involved MBS. Besides, the most recent Fed's operation (announced in 13 September 2012) also projects additional purchases of MBS at a pace of \$40 billion per month. For this reason, understanding why, to what extent, and through which mechanisms targeted purchases of MBS should be expected to ease credit markets functioning and stimulate economic activity is of crucial importance. Actually, a recent controversy has emerged in academic debates as to whether, and why, large scale purchases of MBS should be expected to have a significant impact on the economy beyond their mere impact on the mortgage loan market.[4]

The aim of this paper is to provide insights to these questions. We introduce a housing sector, à la Iacoviallo (2005), and differentiated corporate and mortgage credit markets into the New-Keynesian DSGE model with financial frictions proposed by Gertler and Karadi (2011). In our framework, impatient households must obtain loans to increase their housing stock, and entrepreneurs must borrow funds to finance their capital acquisition. Credit intermediation activities are provided by banks, which collect deposits from patient households and distribute loans to borrowing consumers and firms. Yet, credit markets are *segmented,* in the sense that mortgage and corporate credit intermediation have different risks associated with them, justifying that interest rates on loans (and credit spreads) may be different between branches. While bankers act in depositors' interest, branch managers seek to maximize their own branch's terminal net worth in a context of imperfect information and agency problems.

As in Gertler and Kiyotaki (2010) and Gertler and Karadi (2011, 2012), the moral hazard problem faced by bankers vis-à-vis their branch managers sets a limit on the ability of those branches to raise funds and creates a wedge between the interest rate on loans and the interest rate on deposits.[5] Since the degree of financial frictions is not necessarily the same in the two branches, the leverage ratios and loan returns may also differ. The extent to which bankers can reallocate equity capital between branches along the business cycle to attenuate these differences in spreads reflects

[4]For example, while Bernanke repeatedly argued that large purchases of MBS should be expected to have a significant impact on all long-term interest rates (see e.g. Bernanke, 2012), Woodford (2012) offers convincing arguments why this might not necessarily be the case. Woodford (2012) also challenges the view that LASPs work through a channel different than a mere "signaling effect" about the future path of the central-bank's target rate.

[5]See also Bernanke and Gertler (1989), Carlstrom and Fuerst (1997) and Bernanke *et al.* (1999) for ealier models relying on imperfect information problems in the credit market to generate a financial accelerator.

the degree to which credit markets are *segmented*, and thus influences the extent to which a "portfolio rebalance channel" is at work in the economy.

We calibrate our model to simulate a financial crisis by introducing a large exogenous "confidence shock" in the banking system. Our shock, materialized as an abrupt, unexpected increase in the intensity of agency problems affecting the relationship between bankers and managers, is meant to capture the distress in credit intermediation activities that followed the burst of the housing bubble and the collapse of major financial institutions such as Lehman Brothers. We show that this large defiance shock in the banking system triggers an abrupt decline in housing and capital asset prices, a decline in loans distributed to consumers and firms (as branches start to deleverage), a significant increase in credit spreads (despite the central bank cutting its target interest rate), and a sharp economic contraction (with output, consumption, investment and hours worked all dropping down).

We analyze in this context the effects of LSAPs provided by the central bank. As in Gertler and Karadi (2011, 2012), LSAPs can be seen as central bank intermediation aiming at supplementing private intermediation by providing additional loans to households and entrepreneurs at current market conditions (with the difference that the central bank is not balance-sheet constrained). We compare the effectiveness of two LSAPs programs of identical size: the first one consists in offering loans to entrepreneurs, and the second one consists in providing loans to borrowing consumers. Moreover, we conduct these experiments under two configurations regarding the degree of credit market segmentation. In the first configuration, credit markets are *partially segmented* (in the sense that impatient workers and entrepreneurs are forced to borrow to their relative bank's branch, so that there are two distinct borrowing rates in the corporate and the mortgage loans markets, but bankers can freely reallocate equity capital between branches). By contrast, in the second configuration, credit markets are *totally segmented* (equity capital reallocation between branches is no longer possible). As discussed later, considering these two polar cases enables us to shed light on the importance of the "portfolio rebalance channel" in the effectiveness of LSAP programs.

Our results show that under both configurations, LSAPs targeting the mortgage loan market are significantly less effective at mitigating the economic contraction generated by the financial crisis than LSAPs targeting the market for corporate bonds. In our simulations. Yet, the reasons for why central-bank purchases of MBS are less effective than equivalent purchases of corporate bonds differ between the two configurations. In the partial segmentation case, central-bank purchases of corporate bonds are more effective because corporate loan branches are, on average, less leveraged than mortgage loan branches (i.e., corporate loan branches are submitted to a greater moral hazard problem than mortgage loan branches at the steady state). Thus, compared to a situation without intervention, the central bank's purchases of corporate bonds free up more bank capital than equivalent purchases of mortgage securities. The portfolio rebalance channel also implies that part of this freed equity capital can be profitably reinjected into the mortgage credit branch since, for each dollar of equity capital, the higher leverage ratio implies that banks can expand loans by a greater amount in the mortgage loan branch.

In the complete segmentation case, the absence of equity capital transfers implies that the portfolio rebalance channel is not at work. Consequently, LSAPs targeting a particular credit market have more " local" effects: central-bank purchases of corporate bonds have a stronger effect on the corporate loan market but a weaker effect on the mortgage loan market (and conversely for central-bank purchases of MBS). In this configuration, large scale MBS purchases are again much less effective at stabilizing the economy than equivalent purchases of corporate bonds, but for a different reason than in the partial segmentation case: in the US, residential investment accounts for a significantly smaller share of GDP than non-residential investment (2.5% and 10.7%, respectively). Thus, although central-bank purchases of MBS are useful to stabilize the housing market, the absence of any pass-through effect to other credit markets implies that the overall effect on economic activity is limited.

The remainder of the paper is organized as follows. Section 2 introduces the model. Section 3 describes the calibration. Section 4 simulates the effects of a financial crisis by introducing a large confidence shock in the banking system. The model is then used to analyze the transmission mechanisms of the central banks' large scale asset purchases, assuming either partial or total credit markets segmentation. Finally, Section 5 provides concluding comments.

2 The model

Our model extends the Gertler and Karadi's (2011) New-Keynesian model with imperfect credit intermediation to incorporate a housing sector as in Iacoviello (2005) and segmented corporate and mortgage credit markets. We consider a discrete time, infinite horizon economy, populated by three classes of infinitely lived economic agents: savers, borrowers and entrepreneurs, each of which has a continuum of measure one of identical members. Savers have a discount rate smaller than that of borrowers and entrepreneurs. Both savers and borrowers consume, work, and hold housing stock. Entrepreneurs produce homogeneous intermediate goods in a competitive market. The final goods are assembled by differentiated retailers using the intermediate goods. The capital goods are produced by competitive capital producing firms, with a technology that uses final goods as inputs.

In financial markets, banks intermediate funds from savers to borrowers and entrepreneurs on a collateral basis. The presence of a moral hazard problem between savers and banks sets a limit on the ability of the latter to supply loans in the credit markets and creates a wedge between the interest rate on loans and the central bank policy rate. We assume that in normal times, the central bank policy follows a simple Taylor rule with substantial interest-rate smoothing. When the functioning of credit markets is severely disrupted, the central bank can also, in addition, replace private intermediaries to provide credits to borrowers and entrepreneurs by purchasing different loan assets (securities).

2.1 Patient workers

There is a continuum of identical patient workers of unit mass. Patient workers are shareholders of banks and nonfinancial firms (capital producing firms and retail firms). They consume, work, save and adjust their housing stock in order to maximize their lifetime utility function. Saving is done in the form of interest-bearing deposits to the bank. Let C_t^s be the representative patient worker's consumption , h_t^s its housing stock, L_t^s the number of hours supplied and M_t^s/P_t the real money balances, where M_t^s is money holding and P_t the aggregate price level at period t. The program solved by the representative patient worker is:

$$\max E_t \sum_{i=0}^{\infty} (\beta^s)^i \left[\ln(C_{t+i}^s - gC_{t+i-1}^s) + j^s \frac{(h_{t+i}^s)^{1-\sigma}}{1-\sigma} - \frac{\left(L_{t+i}^s\right)^{1+\varphi}}{1+\varphi} + \chi \ln \frac{M_{t+i}^s}{P_{t+i}} \right], \quad (1)$$

subject to the budget constraint for any date t (expressed in real terms):

$$C_t^s + D_t + q_t^h(h_t^s - h_{t-1}^s) + T_t^s = W_t^s L_t^s + \frac{R_{t-1}}{\pi_t} D_{t-1} + \frac{M_t^s - M_{t-1}^s}{P_t} + \Pi_t^f + \Pi_t^l. \quad (2)$$

where $0 < \beta^s < 1$, is the subjective discount factor, $0 < g < 1$ is a consumption habit parameter, and $j^s, \sigma, \varphi > 0$ are other preferences parameters. In (2), D_t denotes the bank deposits at the end of period t, W_t^s is the real wage for labor supplied by patient workers, q_t^h is the real housing price, $\pi_t = P_t/P_{t-1}$ the gross rate of inflation, Π_t^f are nonfinancial firms' redistributed profits, Π_t^l are the payouts received from ownership of banks, and T_t^s are lump-sum taxes paid by patient workers. We assume that bank deposits and the government debt are perfect substitutes, both paying the same gross nominal return R_t from t to $t+1$. Solving patient workers' maximization problem yields the following first-order conditions:

$$\lambda_t^s = \frac{1}{C_t^s - gC_{t-1}^s} - \beta^s g E_t \left(\frac{1}{C_{t+1}^s - gC_t^s} \right), \tag{3}$$

$$q_t^h = \frac{j}{\lambda_t^s}(h_t^s)^{-\sigma} + \beta^s E_t \Lambda_{t,t+1}^s q_{t+1}^h, \tag{4}$$

$$\lambda_t^s W_t^s = (L_t^s)^{\varphi}, \tag{5}$$

$$1 = \beta^s E_t \Lambda_{t,t+1}^s \frac{R_t}{\pi_{t+1}}, \tag{6}$$

where λ_t^s is the Lagrange multiplier associated with patient workers' budget constraint, and $\Lambda_{t,t+1}^s \equiv \lambda_{t+1}^s / \lambda_t^s$.

2.2 Impatient workers

There is also a continuum of identical "impatient" workers of unit mass, for whom the subjective discount factor β^b is greater than that of patient workers: $\beta^s < \beta^b < 1$. They consume, work and adjust their housing stock in order to maximize lifetime utility. Denoting by C_t^b the representative impatient worker's consumption , h_t^b its housing stock, L_t^b the number of hours worked and M_t^b money demand, the program solved by the representative impatient worker is:

$$\max E_t \sum_{i=0}^{\infty} (\beta^b)^i \left[\ln(C_{t+i}^b - gC_{t+i-1}^b) + j^b \frac{(h_{t+i}^b)^{1-\sigma}}{1-\sigma} - \frac{\left(L_{t+i}^b\right)^{1+\varphi}}{1+\varphi} + \chi \ln \frac{M_{t+i}^b}{P_{t+i}} \right], \tag{7}$$

Impatient workers' choices must obey the intertemporal budget constraint

$$C_t^b + q_t^h(h_t^b - h_{t-1}^b) + \frac{R_{t-1}^h S_{t-1}^h}{\pi_t} + T_t^b = W_t^b L_t^b + S_t^h + \frac{M_t^b - M_{t-1}^b}{P_t}, \tag{8}$$

where W_t^b is impatient workers' real wage, M_t^b is money demand, and T_t^b are lump-sum taxes. In addition, impatient workers have access to mortgage loan contracts offered by banks.[6] These contracts stipulate that the loan amount S_t^h granted to

[6] Of course, mortgage loan contracts offered to workers can be viewed as mortgage-backed securities from the viewpoint of bankers. We use the two terms interchangeably in the remaining of the paper.

impatient workers at the gross nominal interest rate R_t^h is constrained by the value of their collateral, defined as the expected value of their housing stock at $t+1$. The borrowing constraint is

$$R_t^h S_t^h \leq \mu^b E_t q_{t+1}^h h_t^b \pi_{t+1}, \tag{9}$$

where $0 < \mu^b < 1$ is the loan-to-value (LTV) ratio. As shown in Kiyotaki and Moore (1997), such type of borrowing constraint can be endogenously derived from a costly enforcement problem between bankers and impatient workers. Impatient workers thus maximize (7) subject to (8) and (9). The first-order conditions are:

$$\lambda_{1t}^b = \frac{1}{C_t^b - gC_{t-1}^b} - \beta^b g E_t \left(\frac{1}{C_{t+1}^b - gC_t^b} \right), \tag{10}$$

$$q_t^h = \frac{j^b}{\lambda_{1t}^b}(h_t^b)^{-\sigma} + (1-\mu^b)\beta^b E_t \Lambda_{t,t+1}^b q_{t+1}^h + \frac{S_t^h}{h_t^b}, \tag{11}$$

$$\lambda_{1t}^b = \lambda_{2t}^b R_t^h + \beta^b E_t \lambda_{1t+1}^b \frac{R_t^h}{\pi_{t+1}}, \tag{12}$$

$$\lambda_{1t}^b W_t^b = (L_t^b)^{\varphi}, \tag{13}$$

where λ_{1t}^b and λ_{2t}^b are the Lagrange multipliers associated with impatient workers' budget and borrowing constraints, respectively, and $\Lambda_{t,t+1}^b = \lambda_{1t+1}^b / \lambda_{1t}^b$. In addition, it is easy to verify that the restriction $\beta^s < \beta^b$ implies that inequality (8) binds at optimum.

2.3 Entrepreneurs

There is a continuum of identical entrepreneurs of unit mass. Entrepreneurs produce and sell intermediate goods and use collected earnings to consume, aiming to maximize their intertemporal utility function:

$$\max E_t \sum_{i=0}^{\infty} (\beta^e)^i \ln(C_{t+i}^e - gC_{t+i-1}^e), \tag{14}$$

where β^e, the subjective discount factor of entrepreneurs, satisfies $\beta^s < \beta^e < 1$.

In any period t, entrepreneurs start with an amount K_{t-1} of capital inherited from the preceding period. They then combine capital and labor from patient (L_t^s) and impatient (L_t^b) workers – adjusting the capital utilization rate U_t – to produce a quantity Y_t of intermediate goods according to the production function

$$Y_t = A(U_t K_{t-1})^{\alpha} (L_t^s)^{(1-\alpha)\vartheta} (L_t^b)^{(1-\alpha)(1-\vartheta)}, \tag{15}$$

with $0 < \alpha, \vartheta < 1$, where A is a total factor productivity level.

At the end of period t, entrepreneurs sell their output to retailers at the competitive market price P_t^m (relatively to output price) and sell the depreciated capital $[1-\delta(U_t)]\, K_{t-1}$ to capital goods producers at the (relative) capital price q_t^c. They must also finance their capital acquisition by obtaining funds from intermediaries. To do so, they issue one-period bonds in an amount S_t^c just sufficient to cover their funding needs. Denoting by R_t^c the nominal gross interest rate on these bonds, entrepreneurs are subject to the following flow-of-funds constraint:

$$P_t^m Y_t + [1-\delta(U_t)]\, q_t^c K_{t-1} + S_t = C_t^e + W_t^b L_t^b + W_t^s L_t^s + q_t^c K_t + \frac{S_{t-1}^c R_{t-1}^c}{\pi_t}. \tag{16}$$

In addition, due to a costly enforcement problem, the loan amount entrepreneurs can obtain (or, equivalently, the amount of funds they can obtain by issuing corporate bonds) is limited by the following credit constraint:

$$R_t^c S_t^c \leq \mu^e E_t \left[1-\delta(U_{t+1})\right] q_{t+1}^c K_t \pi_{t+1}, \tag{17}$$

where $0 < \mu^e < 1$ is the LTV ratio for entrepreneurs. The borrowing constraint (17) implies that the expected value of the capital stock, used as collateral to secure loans, must be enough to ensure repayment of debt and interests.

Denoting by λ_t^e the Lagrange multiplier on the budget constraint (16), we obtain the following first-order conditions:

$$\lambda_t^e = \frac{1}{C_t^e - gC_{t-1}^e} - \beta^e g E_t \left(\frac{1}{C_{t+1}^e - gC_t^e} \right), \tag{18}$$

$$q_t^c = \beta^e E_t \left\{ \Lambda_{t,t+1}^e \left(\alpha \frac{Y_{t+1}}{X_{t+1} K_t} + q_{t+1}^c (1-\delta(U_{t+1})) \right) \right\} + \left(1 - \beta^e E_t \left\{ \frac{\Lambda_{t,t+1}^e R_t^c}{\pi_{t+1}} \right\} \right) \frac{S_t^c}{K_t}, \tag{19}$$

$$W_t^s = \vartheta(1-\alpha) \frac{Y_t}{X_t L_t^s}, \tag{20}$$

$$W_t^b = (1-\vartheta)(1-\alpha) \frac{Y_t}{X_t L_t^b}, \tag{21}$$

$$\alpha \frac{Y_t}{X_t U_t} = \delta^{'}(U_t) K_{t-1}, \tag{22}$$

where $\Lambda^e_{t,t+1} = \lambda^e_{t+1}/\lambda^e_t$.

It can also be verified that the condition $\beta^s < \beta^e < 1$ is sufficient to ensure that inequality (17) binds at optimum.

2.4 Banking sector

There is a continuum of competitive banks of measure unity, indexed by $j \in (0, 1)$, each of which is managed by a banker. Each bank j is composed of one corporate and one mortgage loan branch which specialize in corporate and mortgage lending, respectively, and finance themselves by collecting deposits from patient workers. While bankers aim to maximize the expected discounted flows of dividends distributed to patient workers, each loan branch is managed by a manager whose aim is to maximize the terminal wealth of its own branch. Credit markets are thus segmented, in the sense that mortgage and corporate credit intermediation have different risks associated with them, justifying that interest rates on loans (and credit spreads) may be different between branches. Yet, the degree of credit market segmentation also depends on the extent to which capital inflows are possible between branches, i.e. on the extent to which the banker can reallocate funds between its respective branches facing changes in the economic environment. If equity capital reallocation between branches is possible, we will speak of "partially segmented" credit markets. If equity capital reallocation is impossible, we will speak of "totally segmented" credit markets. Considering these two polar cases is important since, as argued by Woodford, the degree of market segmentation is likely to influence significantly the effects of LSAPs. Our model will thus allow making quantitative predictions on the effects of LSAPs in these two extreme cases.

Loan branches. Let $l \in \{c, h\}$ be an index representing corporate and mortgage loan branches respectively. At the beginning of period t, the loan-branch manager l of bank j starts with a net worth $n^l_{j,t}$ accumulated from the past. He then collects deposits $d^l_{j,t}$ from patient workers and provides one-period loans $s^l_{j,t}$. The balance sheet of the branch is:

$$s^l_{j,t} = d^l_{j,t} + n^l_{j,t}. \tag{23}$$

Let $\xi^l_{j,t}$ (which could be positive or negative) denote net-worth transfer between loan branches. A positive (negative) $\xi^c_{j,t}$ represents an amount of equity capital that the corporate loan branch receives from (transfers to) the mortgage branch, implying that $\xi^c_{j,t} = -\xi^h_{j,t}$. Thus, the net worth $n^l_{j,t}$ is the sum of retained earnings that a loan branch accumulates from intermediating credits, $m^l_{j,t}$, and net worth transfers $\xi^l_{j,t}$:

$$n^l_{j,t} = m^l_{j,t} + \xi^l_{j,t}. \tag{24}$$

At $t+1$, each loan branch receives the stochastic return R^l_t on securities purchased at t and pays to patient workers the non-contingent nominal gross interest rate R_t on deposits. The loan-branch net worth (prior to net worth transfers) is thus, in real terms :

$$\begin{aligned} m^l_{j,t+1} &= \frac{R^l_t}{\pi_{t+1}} s^l_{j,t} - \frac{R_t}{\pi_{t+1}} d^l_{j,t} \\ &= \frac{R^l_t - R_t}{\pi_{t+1}} s^l_{j,t} + \frac{R_t}{\pi_{t+1}} n^l_{j,t}, \end{aligned} \tag{25}$$

Accordingly, the end-period net worth of each loan branch is:

$$n^l_{j,t+1} = \frac{R^l_t - R_t}{\pi_{t+1}} s^l_{j,t} + \frac{R_t}{\pi_{t+1}} n^l_{j,t} + \xi^l_{j,t+1}. \tag{26}$$

Agency problems in credit intermediation. Following Gertler and Kiyotaki (2010) and Gertler and Karadi (2011), we assume that the relationship between bankers and branch managers is subject to a moral hazard/costly enforcement problem owing to the fact that , at the beginning of any period t, managers can choose to divert a (possibly stochastic) fraction λ^l_t of the assets they have under their management and transfer the collected funds $\lambda^l_t s^l_{j,t}$ to the household of which they are a member.[7] If this occurs, bankers can force the loan branch into bankruptcy and recover the remaining fraction of assets. Denoting by $V^l_{j,t}$ the expected terminal wealth of branch l in bank j,

$$V^l_{j,t} = \max E_t \sum_{k=0}^{n} (\beta^s)^{k+1} (1-\theta)(\theta)^k \Lambda^s_{t,t+1+k} m^l_{j,t+1+k}.$$

the prevention of misbehavior from branch managers requires that the following incentive constraint holds:

$$V^l_{j,t} \geq \lambda^l_t s^l_{j,t}, \tag{27}$$

[7] Thus, λ^l_t is a natural measure of the "degree of confidence" that patient workers have in the banking system, and we will interpret the recent crisis and the severe disruption in financial intermediation following the collapse of Lehman Brothers as a large brutal shock to this parameter.

Using (25) and after a few manipulations, $V^l_{j,t}$ can be expressed as follows:

$$V^l_{j,t} = \nu^l_t \cdot s^l_{j,t} + \eta^l_t \cdot n^l_{j,t}$$

with

$$\nu^l_t = E_t \left\{ \beta^s \Lambda^s_{t,t+1}(1-\theta) \left(\frac{R^l_t - R_t}{\pi_{t+1}} \right) + \beta^s \Lambda^s_{t,t+1} \theta x^l_{t,t+1} \nu^l_{t+1} \right\}$$

$$\eta^l_t = E_t \left\{ (1-\theta) \left(\frac{R_t}{\pi_{t+1}} \right) + \beta^s \Lambda^s_{t,t+1} \theta z^l_{t,t+1} \eta^l_{t+1} \right\}$$

where $x^l_{t,t+1} \equiv s^l_{t+1}/s^l_t$ and $z^l_{t+1} \equiv n^l_{t+1}/n^l_t$ are, respectively, the gross growth rate of asset holdings and the gross rate of net worth between t and $t+1$ in each loan branch.[8] The variable ν^l_t represents the expected discounted marginal gain for loan branches from an additional unit of assets $s^l_{j,t}$, holding $n^l_{j,t}$ constant. Likewise, η^l_t is the expected discounted marginal gain from adding a unit of equity capital $n^l_{j,t}$, holding $s^l_{j,t}$ constant. .

Clearly, the incentive constraint (27) places a restriction on the amount of loans $s^l_{j,t}$ a branch can distribute relatively to its net worth. This limit to arbitrage possibilities creates a wedge $R^l_t - R_t > 0$ between the policy rate and the interest rates on loans. Indeed, when constraint (27) binds, which occurs when $0 < \nu^l_t < \lambda^l_t$, we obtain:

$$\begin{aligned} s^l_{j,t} &= \frac{\eta^l_t}{\lambda^l_t - \nu^l_t} n^l_{j,t} \\ &= \phi^l_t n^l_{j,t}, \end{aligned} \tag{28}$$

where $\phi^l_t \equiv \eta^l_t/(\lambda^l_t - \nu^l_t)$, is an endogenously determined *leverage ratio* for loans branches. As (28) shows, the branch ability to expand loans is constrained by its net worth, as any loan amount greater than $s^l_{j,t} = \phi^l_t n^l_{j,t}$ would imply that the net the gain from defaulting was larger than the cost, thus violating the incentive constraint.

Using (26), we can also express $x^l_{t,t+1}$ and z^l_{t+1} as

$$x^l_{t+1} = \frac{\phi^l_{t+1}}{\phi^l_t} z^l_{t+1},$$

$$z^l_{t+1} = \frac{1+\varrho^l_{t+1}}{\pi_{t+1}} \left[(R^l_t - R_t)\phi^l_t + R_t \right],$$

[8]Note that, in any period t, the optimal transfer $\xi^l_{j,t+1}/n^l_{j,t}$ relative to net worth is the same for any bank j, implying that ν^l_t and η^l_t do not depend on bank-specific factors.

where $\varrho_t^l = \xi_t^l/(n_t^l - \xi_t^l)$ is the transfer relative to net worth.

Banking sector aggregation. Let S_t^c be the aggregate corporate bond holdings and S_t^h be aggregate MBS holdings by private banks at t. Denote by N_t^l the total equity capital of loan branches of type l. Given that the leverage ratio ϕ_t^l does not depend on firm-specific factors, summing (28) across individual loan branches yields:

$$S_t^l = \phi_t^l N_t^l. \tag{29}$$

To ensure that the net worth of loan branches does not grow to infinity, it is assumed that at the end of any period t, a constant fraction θ of branches close for an exogenous reason and their net worth is transferred back to patient workers in the form of dividends. To keep the total number of loan branches of each type fixed we also assume that, for each exiting branch, a new branch is established and receives from patient workers a start-up funds equal to a fraction ω^l of loans intermediated in the preceding period as initial net worth. Summing (26) and (28) across banks, we obtain the equation describing how the aggregate net worth N_t^l in loan branch $l \in \{c, h\}$ evolves through time:

$$N_t^l = \theta N_{t-1}^l \left[\phi_{t-1}^l \left(\frac{R_{t-1}^l - R_{t-1}}{\pi_t} \right) + \frac{R_{t-1}}{\pi_t} \right] + \omega^l S_{t-1}^l + \Theta_t^l, \tag{30}$$

where $\omega^l S_{t-1}^l$ are total start-up funds received by new loan branches and Θ_t^l is the aggregate level of equity capital transfers between loan branches decided by bankers.

As emphasized earlier, we will consider two assumptions regarding equity capital transfers. When credit market are "totally segmented", we assume $\Theta_t^l = 0$ for any l and t. By contrast, when credit markets are "partially segmented", equity capital transfers are possible and are optimally determined by bankers. We now turn to this optimal capital transfer decision.

Banker's equity capital transfer (partial segmentation case). Let M_t^l be the dividend transfers to patient workers from exiting loan branches at the end of period t. We have:

$$M_{j,t+1}^l = (1-\theta) \left\{ \theta N_{t-1}^l \left[\phi_{t-1}^l \left(\frac{R_{t-1}^l - R_{t-1}}{\pi_t} \right) + \frac{R_{t-1}}{\pi_t} \right] + \omega^l S_{t-1}^l + \Theta_t^l \right\} \left[\frac{\phi_t^l}{\pi_{t+1}} (R_t^l - R_t) + R_t \right], \ l \in \{$$

The banker's problem is to choose Θ_t^c $(= -\Theta_t^h)$ so as to maximize the total expected discounted flow of dividends distributed to shareholders. It thus solves

$$\max E_t \sum_{k=0}^{n} (\beta^s)^k \Lambda^s_{t,t+k+1} (M^c_{t+k+1} + M^h_{t+k+1}), \tag{31}$$

subject to (**??**), (30) and $\Theta^c_t + \Theta^h_t = 0$.

The first-order condition is:

$$\phi^c_t (R^c_t - R_t) = \phi^h_t (R^h_t - R_t). \tag{32}$$

Condition (32) underlines how the "portfolio rebalance channel" is at work in this economy. For bankers, each dollar invested in loan branch l allows it to increase loans by ϕ^l_t dollars, and to receive $\phi^l_t (R^l_t - R_t)$ dollars of excess return. The condition then simply states that, at the optimum, equity capital transfers between branches are made until there is an equality between marginal returns in the two branches.

2.5 Non-borrowing firms

Besides entrepreneurs who need to raise funds on financial markets, the economy features two types of non-borrowing firms: capital producing firms and retail firms. For simplicity, we assume that both types of firms are held by patient workers, who are the recipients of any profit.

Capital producing firms. In any period t, competitive capital producing firms buy the depreciated capital $[1 - \delta(U_t)] K_{t-1}$ to entrepreneurs at a unit price, repair it, and build new capital. They then sell the new and refurbished capital K_t to entrepreneurs at price q^c_t per unit. Denoting by I_t the gross capital created at t, the total quantity of capital evolves according to

$$K_t = I_t + [1 - \delta(U_t)] K_{t-1}. \tag{33}$$

We assume that the investment function is subject to adjustment costs. The problem of capital producers is to maximize profits:

$$\max \sum_{\tau=t}^{\infty} (\beta^s)^{\tau - t} \Lambda^s_{t,\tau} \left\{ (q^c_t - 1) - f\left(\frac{I_\tau}{I_{\tau-1}}\right) \right\} I_\tau,$$

subject to (33), where $f(\cdot)$ is a quadratic adjustment cost function satisfying $f(1) = f'(1) = 0$ and $f''(1) > 0$. This profit maximization problem delivers as first-order condition a dynamic equation for the real price of capital

$$q_t^c = 1 + f\left(\frac{I_\tau}{I_{\tau-1}}\right) + f'\left(\frac{I_\tau}{I_{\tau-1}}\right)\frac{I_\tau}{I_{\tau-1}} - \beta^s E_t \Lambda^s_{t,\tau+1} f'\left(\frac{I_{\tau+1}}{I_\tau}\right)\left(\frac{I_{\tau+1}}{I_\tau}\right)^2, \qquad (34)$$

which is the usual Tobin's q, implying that the price of capital is related to the adjustment cost of investment.

Retail firms. There is a continuum of mass unity of retail firms, indexed by $f \in (0,1)$, each one producing in period t a quantity $Y_{i,t}$ of a differentiated good. Final output Y_t is produced through a CES composite of these individual retail goods,

$$Y_t = \left(\int_0^1 Y_{f,t}^{(\varepsilon-1)/\varepsilon} df\right)^{\varepsilon/(\varepsilon-1)},$$

where $\varepsilon > 1$ is the elasticity of substitution between retail goods. The final good market is perfectly competitive. Profit maximization by final good producers leads to the standard demand function:

$$Y_{f,t} = \left(\frac{P_{f,t}}{P_t}\right)^{-\varepsilon} Y_t, \qquad (35)$$

where P_t, the aggregate price index, is defined by:

$$P_t = \left[\int_0^1 P_{f,t}^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}. \qquad (36)$$

Retailers simply repackage intermediate goods. In period t, they buy intermediate goods from entrepreneurs at the relative price $P_{m,t}$ (determined in a perfectly competitive market), repackage it and sells the obtained retail good at price $P_{f,t}$ to final good producers (so that one unit of intermediate good produces one unit of retail output). Following Calvo (1983), we assume that in each period t, the probability of a retail firm being able to reset its price is $1-\gamma$. During periods for which they are unable to reset prices, they simply indexed them to the lagged rate of inflation. The retailers' pricing problem is then to choose the optimal reset price P_t^* to solve

$$\max E_t \sum_{i=0}^{\infty} \gamma^i \beta^i \Lambda^s_{t,t+i}\left[\frac{P_t^*}{P_{t+i}}\prod_{k=1}^{i}(\pi_{t+k-1})^{\gamma_P} - P_{m,t+i}\right] Y_{f,t+i},$$

subject to (35). The first-order condition is:

$$E_t \sum_{i=0}^{\infty} \gamma^i \beta^i \Lambda^s_{t,t+i} \left[\frac{P^*_t}{P_{t+i}} \prod_{k=1}^{i} (\pi_{t+k-1})^{\gamma_P} - \mu P_{m,t+i} \right] = 0,$$

where $\mu = \varepsilon/(\varepsilon - 1) > 1$ is the steady-state markup factor.

Given (36) and the probability γ of having the price unchanged, we can deduce by the law of large numbers the evolution of the aggregate price level:

$$P_t = \left[(1-\gamma)(P^*_t)^{1-\varepsilon} + \gamma(\Pi^{\gamma_P}_{t-1} P_{t-1})^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}. \tag{37}$$

2.6 Government and central bank policy

Conventional monetary policy. The central bank sets its policy rate R_t according to the following Taylor rule:

$$\log R_t = (1-\rho^R)\left[\log R + \kappa_\pi \log \pi_t + \kappa_y \log Y_t\right] + \rho^R \log R_{t-1} + \varepsilon^R_t, \tag{38}$$

where R is steady state short-term interest rate, ρ^R is the parameter capturing the degree of interest rate smoothing, the coefficients κ_π and κ_y are the relative weights assigned to the inflation rate and the output gap, respectively, and ε^R_t is an exogenous monetary policy shock.

LSAPs To reduce excess return on assets and to put downward pressures on loan interest rates, the central bank can decide to purchase corporate bonds or MBS. Differently from private financial institutions, there is no moral hazard problem that inhibits central bank intermediation. However, central bank's intermediation is also subject to an efficiency cost equal to ι percent of units of loans intermediated. The fact that the central bank is less efficient than the private sector in providing credit intermediation services implies that it cannot entirely substitute private banks in this activity. LSAPs thus only improve financial conditions when private credit markets are severely disrupted and the excess returns are large.

The central bank funds its securities purchases by issuing the short term debt D^g_t at the gross nominal rate of interest R_t. The raised funds allow it to purchase a total value $S^{c,g}_t$ of corporate bonds and $S^{h,g}_t$ of MBS in the hands of private banks.

Let $S^{T,l}_t$, $l \in \{c, h\}$, be the total value of corporate and mortgage loans respectively. We have

$$S^{T,l}_t = S^l_t + S^{l,g}_t. \tag{39}$$

Denote by Ψ_t^l be the fraction of securities of type l that the central bank chooses to buy at t. Following Gertler and Karadi (2011), we assume that the central bank responds to disruptions in financial intermediation by following the simple feedback rule:

$$\Psi_t^l = \Psi^l + \varpi^l E_t \left[(\log R_{t+1}^l - \log R_{t+1}) - (\log R^l - \log R) \right], \tag{40}$$

where Ψ^l is the steady state fraction of corporate or mortgage loans intermediated via the central bank's credit facilities, and ϖ^l is a feedback parameter associated with the deviation of credit spreads from their steady-state level. This implies that total (private + central bank) value of corporate and mortgage loans to entrepreneurs and impatient workers can be expressed as follows:

$$S_t^{T,l} = \phi_t^l N_t^l + \Psi_t^l S_t^{T,l},\ l \in \{c, h\}. \tag{41}$$

Finally, it is assumed that the Treasury receives any profits (covers any losses) made by the central bank through LSAPs.

Fiscal policy. Government expenditures G are exogenously fixed and are financed by fiscal revenues (lump-sum taxes raised on consumers) and by income transfers from the central bank related to its holding of private securities:

$$G = T_t^s + T_t^b + (R_{t-1}^i - R_{t-1} - \iota) S_{t-1}^{c,g} + (R_{t-1}^h - R_{t-1} - \iota) S_{t-1}^{h,g}.$$

2.7 Market clearing conditions

In equilibrium, the final output is equal to the sum of aggregate consumption $C_t = C_t^s + C_t^b + C_t^e$, investment I_t, government expenditures G, and the cost associated with the production of new capital $f(I_t/I_{t-1})I_t$ and the efficiency costs induced by the central bank's purchase of private securities $\iota(\Psi_t^c S_t^{T,c} + \Psi_t^h S_t^{T,h})$. The market clearing condition in the final goods market is:

$$Y_t = C_t^s + C_t^b + C_t^e + I_t + f\left(\frac{I_t}{I_{t-1}}\right) I_t + G + \iota(\Psi_t^c S_t^{T,c} + \Psi_t^h S_t^{T,h}). \tag{42}$$

The housing market equilibrium, assuming a fixed housing stock normalized to unity, is:

$$h_t^s + h_t^b = 1. \tag{43}$$

The corporate and mortgage loan market equilibrium conditions are respectively

$$\frac{\mu^e E_t \left[1-\delta(U_{t+1})\right] q^c_{t+1} K_t \pi_{t+1}}{R^c_t} = S^{T,c}_t, \tag{44}$$

$$\frac{\mu^b E_t q^h_{t+1} h^b_t \pi_{t+1}}{R^h_t} = S^{T,h}_t. \tag{45}$$

Finally, real wages W^s_t and W^b_t adjust to ensure the equality between supply and demand on each type of labor market.

3 Calibration

Table 1 summarizes parameter values of the model. The values of conventional parameters which are set within the range considered in the standard DSGE literature. The discount factor of savers is set to $\beta^s = 0.99$, implying an annual steady state real interest rate of 4%. The discount factor of borrowers and entrepreneurs is set at $\beta^b = \beta^e = 0.975$. The weight of money is $\chi = 3.409$, and inverse of Frisch labor supply elasticity is $\varphi = 0.276$. As for the intermediate goods producing sector, we calibrate the share of capital in the production function at $\alpha = 0.33$, which implies a steady state share of labor income in total output of about 60% and a steady-state capital-output ratio of about 5.1. The parameter controlling the saver's labor income share, ϑ, is set to 0.64, implying borrowers' income share is around 36 percent which is in line with evidence in Campbell and Mankiw (1989). We calibrate the steady state value of the utilization rate at $U = 1$ and the depreciation rate at $\delta = 0.0025$. The monetary policy rule is specified to match the conventional Taylor rule parameterization such that the coefficient on inflation is $\kappa_\pi = 1.5$, the coefficient on the output gap is $\kappa_y = 0.125$, and the interest rate smoothing parameter is $\rho^R = 0.8$.

We calibrate the LTV ratio for borrowers at $\mu^b = 0.55$. The value of the LTV ratio for entrepreneurs μ^e, and the weight on housing in the households' utility function j are set to have the steady state corporate debt to output ratio S/Y equal to 0.72, and steady state mortgage debt to output ratio B/Y equal to 0.64. The values of S/Y and B/Y are calibrated to the average ratio of total debt of nonfinancial sectors and of total home mortgage debt to GDP in the U.S. between 2000-2012, respectively. We choose a survival probability $\theta = 0.972$ that implies an expected horizon of eight years for loan branches.

We let the values for parameters λ_i, λ_h, ϕ^h, ω_i and ω_h be determined endoge-

Table 1: Parameters

Parameter		Value
β^s	Savers' discount rate	0.99
$\beta^{b,e}$	Borrower and entrepreneurs' discount rate	0.975
g	Habit parameter	0.815
j	Weight on housing in the households' utility function	0.1
χ	Weight on money in the households' utility function	3.049
σ^h	Intertemporal elasticity of housing service	1
φ	Inverse of Frisch labor supply elasticity	0.276
α	Capital share in production	0.33
ϑ	Saver's labor income share	0.64
U	Steady state capital utilization rate	1
$\delta(U)$	Steady state depreciation rate	0.025
ζ	Elasticity of marginal depreciation with respect to utilization	7.2
ε	Elasticity of substitution between final goods	4.167
η_i	Inverse elasticity of net investment to the price of capital	1.728
γ	Probability of fixed price	0.779
γ_p	Parameter of price indexation	0.241
ρ^R	Measure of interest rate smoothing	0.5
κ_π	Inflation coefficient of the Taylor rule	1.5
κ_y	Output-gap coefficient of the Taylor rule	0.125
S/Y	Corporate debt to output ratio	0.72
B/Y	Mortgage debt to output ratio	0.64
μ^b	LTV ratio on loans to borrowers	0.55
μ^e	LTV ratio on loans to entrepreneurs	0.146
θ^l	Survival probability of loan branches	0.972
Θ_t^c/N_t^c	Net worth transfers / total new worth of corporate loan branches	0.001
Θ_t^h/N_t^h	Net worth transfers / total new worth of mortgage loan branches	-0.0045
λ^c	Fraction of corporate loan branch asset that can be diverted	0.5798
λ^h	Fraction of mortgage loan branch asset that can be diverted	0.2246
ω^i	Proportional funds transfer to new corporate loan branches	0.0018
ω^h	Proportional funds transfer to new mortgage loan branches	0.00043

nously such that we have: the steady state spread between the interest rate on corporate loans and the policy rate of 217 basis points (annualized) and that between the rate on mortgage loans and the policy rate of 89 basis points (annualized)[9]; the leverage ratio for corporate lending ϕ^c of 4; and the steady state net worth transfers representing 0.1% of the total corporate-loan-branch net worth, i.e., $\Theta^i/N^i = 0.001$ which implies that $\Theta/N^h = 0.0045$.[10] The implied steady state leverage ratio of mortgage credit intermediation ϕ^c is 12, reflecting the fact that large and complex commercial and investment banks which intensively invest in mortgage related securities are thinly capitalized and do not have a sufficient cushion to absorb the losses as they were during the current financial crisis. As for the credit interventions, we adjust the size of the feedback coefficient ϖ^i and ϖ^h in the unconventional policy rule to hit a targeted size of purchases of approximately 3 percent of steady state GDP.

4 Impulse response analysis

In this section, we first consider the responses of the baseline economy to an adverse confidence shock. Model simulations driven by this shock tolerably reproduce some stylized facts of the U.S. economy after the brust of the current financial crisis. Using the adverse confidence shock as the initiating shock for the crisis, we then analyze the transmission channels involved in the purchases of corporate bonds and MBS, and compare their relative efficacy in easing credit conditions and thus in stimulating the real economy.

4.1 Simulating the financial crisis: the adverse confidence shock

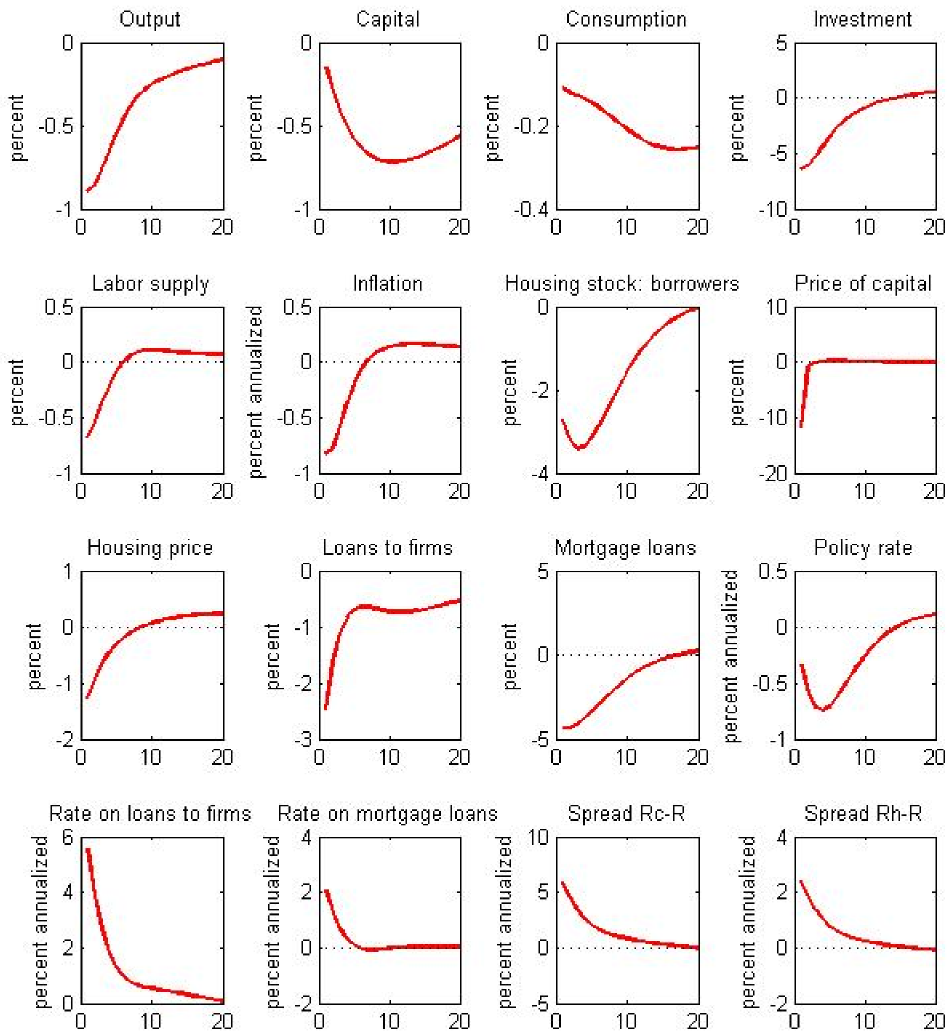
To simulate the financial crisis, we consider a symmetric and persistent adverse confidence to the banking sector which seem to capture one of the main features of the current financial crisis, i.e. a generalized defiance vis-à-vis banks and financial institutions. Our approach departs from other monetary DSGE models where the disrupted financial intermediation generally results from a deterioration of banks' loan portfolios following adverse shocks to bank assets or equity capital (Meh and

[9]The spread, $R_t^i - R_t$, is the averaged excess return on Moody's Seasoned Baa corporate bond over the average 10-year Treasury yield, and for $R_t^h - R_t$, we use information on the averaged spreads between the Freddie Mac and Fannie Mae current-coupon 30-year agency MBS yields and the average 10-year Treasury yield between 1996Q1 and 2007Q1.

[10]Qualitatively, our results will not hinge on the assumed value for Θ/N^i.

Moran 2010, Cúrdia and Woodford 2011), or shocks to capital quality (Gertler and Karadi 2011 and 2012). Our model simulations driven by confidence shocks tolerably reproduce some important stylized facts of the U.S. economy during the current financial crisis: Notably, rising market interest rates and credit spreads, and falling asset prices were accompanied by the severe contraction of available funds in the credit markets; these financial disruptions have significant effects on consumption and investment, resulting in a substantial fall in output and inflation rate.

Figure 1: Responses to Adverse Confidence Shock



The adverse confidence shock corresponds to an initial increase of 10% in both λ_t^c and λ_t^h with AR coefficient $\rho^\lambda = 0.8$. This shock might be interpreted as an erosion of market confidence or fall in risk appetite, possibly caused by a generalized uncertainty about banks' creditworthiness following a watershed event which has significant effects on the whole financial markets. The bankruptcy of Lehman on September 15, 2008, has been widely considered as such an event that triggered the general fears of bank insolvency. Figure 1 shows that the total loans to entrepreneurs and borrowers fall by 2.4% and 4.8%, respectively. The decline in housing price induces borrowers to sell their housing stock to savers. The investment decreases by 6% which is substantially larger than that of the aggregate consumption which drops by around 0.25 %. The greater fall in investment relative to the consumption is consistent with the broad empirical results. Consequently, the fall in both investment and consumption results in a drop in rate of inflation, a sharp contraction of economic activity and a low level of employment.

The central bank responds to the deflation by lowering its policy rate R_t, which initially falls by 41 annualized basis points and then decreases by 0.75% from its steady state value in three quarters. However, as revealed by the simulation, the reduction in the policy rate can no longer effectively affect the loan interest rates and both R_t^c and R_t^h increase, producing sharp increases in credit spreads. This counter-cyclical behavior of credit spreads that the model predicts is of broadly similar magnitude to the one we have recently experienced in the wake of the Lehman collapse in September 2008. Over that period, risk premiums in the credit markets quickly shifted upward in response to the extremely high investor's perceptions of the creditworthiness of the banking sector, indicating that banks and financial institutions faced systemic risk. The resulting substantially more tight funding constraint in turn required banks to deleverage and rebuild their balance sheets by increasing credit spreads. Nevertheless, the profitability of banks is considerably deteriorated due to the fact that the positive effect of larger spread is outweighed by the effect of a reduction in the supply of intermediation. If the size of the shock is sufficiently large, severely disrupting flows of funds to the private sector, the central bank should not only credibly commit to a forward path of short-term interest rates pinned at a low level, but also take policy measures with the goal of lowering the interest rate on loans and hence increasing the availability of credit, both of which are relevant for the spending of households and firms.

4.2 Large scale asset purchases under partial credit market segmentation

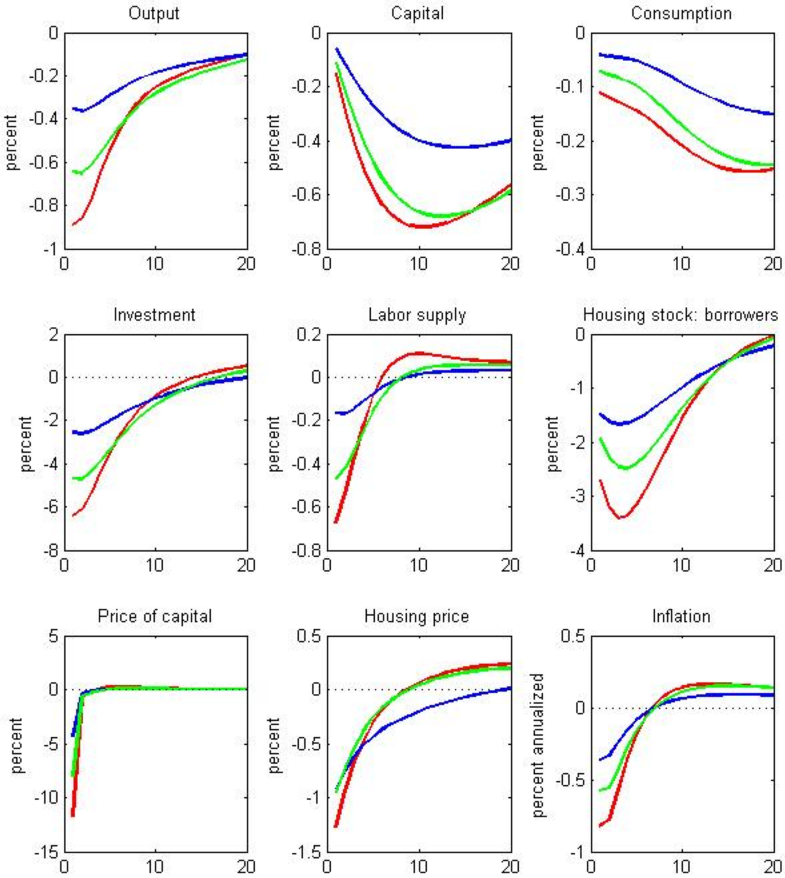
We consider now how LSAPs affect the financial market condition and real economic activity. We assume that the central bank, as the private bank's loan branches, can raise funds from savers and directly provide mortgage or corporate loans to the credit markets, while impatient workers are assumed to believe that the central bank will perfectly honor its liabilities. In the absence of the confidence problem, the central bank is not balance sheet contraint and can elastically supply a particluar type of asset to the private sector. By assuming the steady state central-bank holdings of corporate and mortgage loans represent 1% of GDP, and caliberating a peak effect of LSAP of 4% of steady state GDP, we will also compare the effectiveness of the purchase of mortgage and corporate loans at easing finacial market conditions and simulating economic activity.

Figures 2 and 3 show the impact of MBS (in green lines) and corporate bonds (in blue lines) purchases on the dynamics of the baseline economy to the symmetric confidence shock. In the case of either MBS or corporate bonds purchases, by taking part of private banks' credit intermediation, the central bank can generally reduce the limits to arbitrage and therefore lower all yields on assets and raise their prices, effectively increase the availability of credit to borrowers and entrepreneurs. This general improvement in financial conditions in turn helps to moderate the adverse effects of the confidence shock on the real economy.

Note that asset purchases work, as documented in many empirical works, principally through reducing excess return on those assets, rather than via affecting the expected future path of the short-term interest rate.[11] The relevance of these purchases does not depend, in fact, on the household heterogeneity featuring the model, but the presence of limits to arbitrage and the binding incentive constraints that private banks face. Under these limits, private banks are unable to acquire arbitrary quantities of corporate bonds or MBS. When the central bank, not balance-sheet constrained, intervenes to support credit supply more directly by purchasing a particular type of assets in the hands of private banks, it reduces the limits to arbitrage. In other words, asset purchases by the central bank increase the degree of leverage in the whole credit market.

[11] This result is also found in empirical work by Gagnon et al. (2011) and D'Amico et al. (2012).

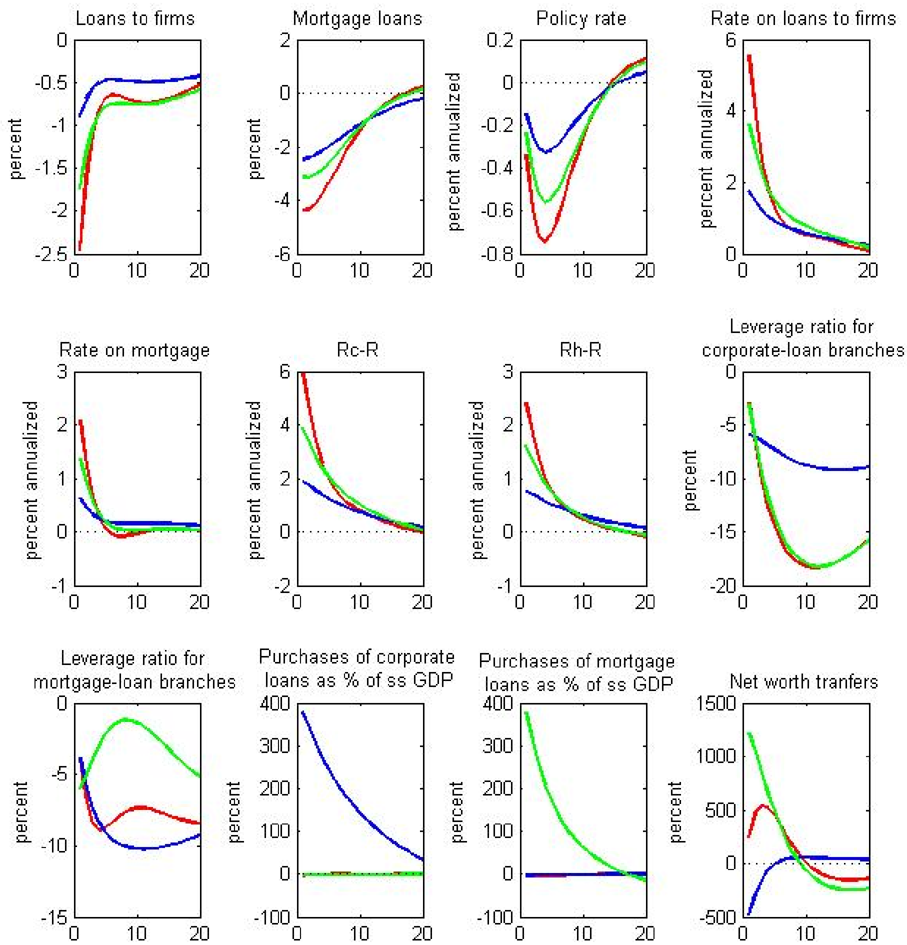
Figure 2: The Effects of Corproate Bond and Mortgage Loan Purchases-1



The free capital mobility between two credit markets allows the portfolio balance channel to play an important role in the transmission of the impact of LSAPs across asset markets. As the arbitrage relation (32) indicates, the excess return on mortgage loans, $R_t^c - R_t$, is only a fraction $\phi_t^c/\phi_t^h < 1$ of the excess return on corporate loans $R_t^c - R_t$. This implies that as long as the limits to arbitrage in mortgage credit intermediation are less restrictive relative to corporate credit intermediation, the decline in interest rate on mortgage loans in the wake of the asset purchases should be smaller than that in corporate loans. This is true whatever the credit market the central bank targets. Moreover, our simulations show that corporate bond purchases have greater effects than the equivalent size purchases of MBS on financial conditions and the economic activity, suggesting that the central bank should target corporate bonds in the context of a generalized loss of confidence in the banking sector.

As shown in Figure 3, the drop in yield on MBS in the case of MBS and corporate bonds purchases are respectively, 0.6% and 1.4% (annualized), and that on corporate bonds are respectively, 2% and 4% (annualized). Corporate bonds purchases lead to falls in the supply of mortgage and corporate loans (2.4% and 0.8%, respectively) are smaller than MBS purchases (3% and 1.7%, respectively). The declined cost of funding finally stimulates both consumption and investment. With purchases of corporate bonds, output and inflation falls by only 0.38% and 0.4 %, respectively, compared to 0.65% and 0.6% in the case of MBS purchases.

Figure 3: The Effects of Corproate Bond and Mortgage Loan Purchases-2



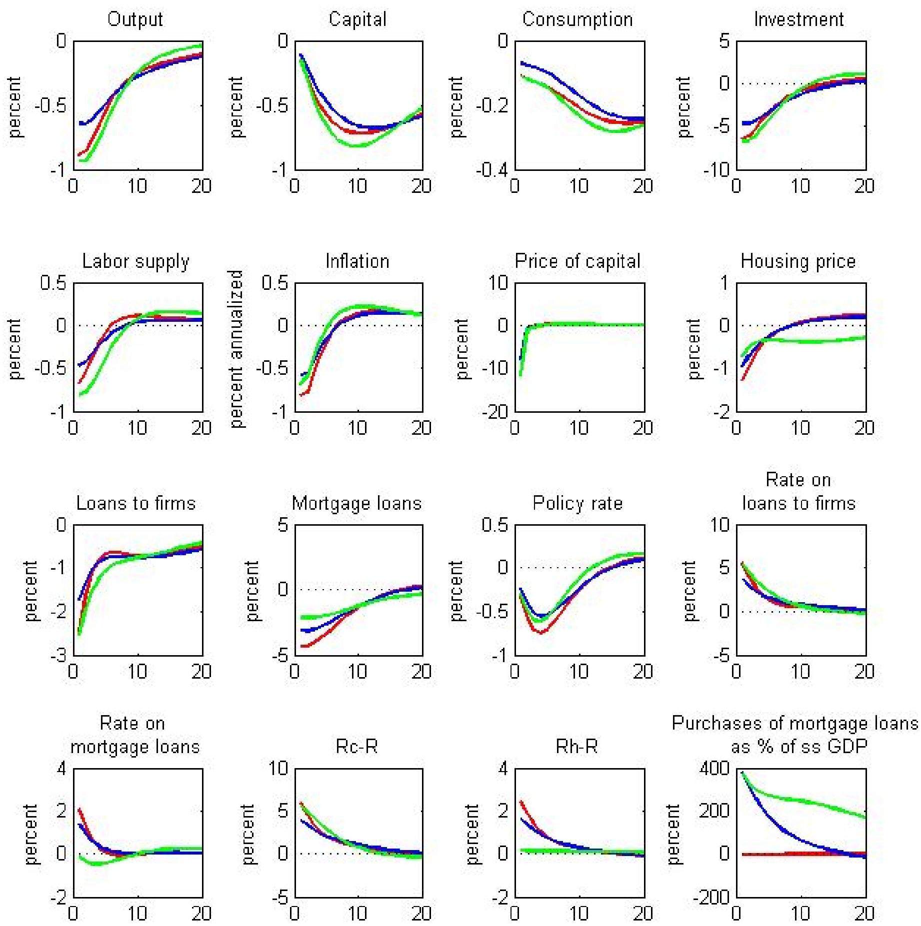
4.3 Large scale asset purchases with totally segmented credit markets

In the previous section, we have examined the transmission channels of the Fed's LSAPs in an economy where credit markets are only partially segmented in the sense that loan branches are specialized in lending to entrepreneurs and borrowers, each of them has only access to one type of loan branch, while the equity capital can flow freely from one credit market to another. Given the limits to arbitrage due to the fact that loan branches are balance-sheet constrained, there is a role for the portfolio balance channel as we have discussed above. As emphasized by Woodford (2012), the existence of market segmentation makes it possible for central-bank purchases to affect the price of an asset, but at the same time limits the generality of the effects of a change in that particular asset price on the rest of the economy. In this section, our main goal is to investigate how the presence of totally segmented credit markets affects the efficacy of the central bank's purchases targeting MBS and corporate bonds, respectively. The market segmentation of this kind captures to some extent what momently happens in the wake of the Lehmen collapse, i.e., a situation characterized by a 'flight to quality', where there was little movement of capital between different risky credit markets and the capital withdrawn from these markets went to the safe assets-Treasury bonds.

To show how the effectiveness of LSAPs could be affected by the existence of complete market segmentation relative to that in the case of partially segmented credit markets. We assume that in every period there is no equity capital transfer between corporate and mortgage loan branches, implying that $\xi_t^l = \Theta_t^l = 0$ and $n_{j,t}^l = m_{j,t}^l$ and the no-arbitrage condition (32), which ensures the 'pass-through' effect of the central bank's MBS or corporate bonds purchases, is no longer applied.

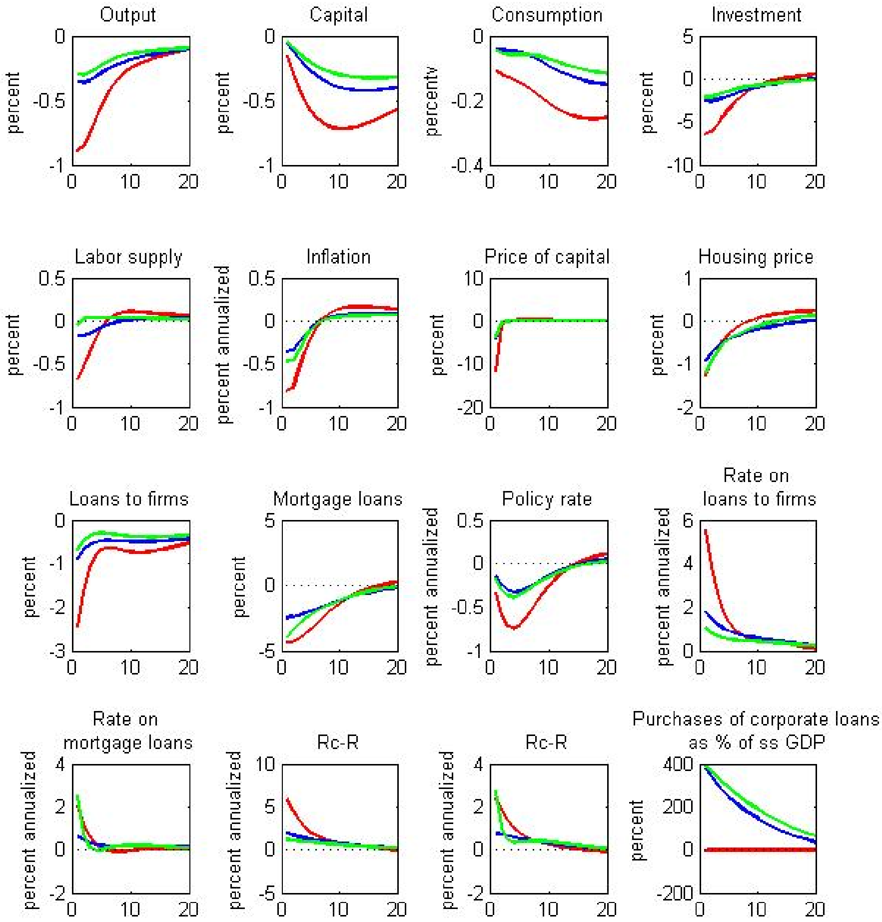
Figure 4 shows the differential effects of buying the same quantity of MBS in the baseline model with partially segmented markets (in blue line) and the model with totally segmented markets (in green line). The confidence shock introduced is the same as in the previous section. We see that with the existence of totally segmented markets, the purchases concentrating on MBS become ineffective in moderating the real activity and even cause a slightly deeper recession. Since there is no free mobility of net worth, purchases of one type of asset will not produce the general effects on both corporate and mortgage credit markets through the "portfolio balance channel", implying that the effects of MBS purchases on financial conditions are local. As shown in the figure, by taking part of mortgage credit intermediation from private banks, the central bank effectively reduces the constraint that restricts the mortgage-loan branches. The decline in aggregate supply of mortgage loans is only 2%, which is roughly half of that in the case without asset purchases. Instead of increasing by about 2%, the interest rate on mortgage loans falls to even negative, mainly through the reduction in excess return.

Figure 4: Mortgage Loan Purchases in an Economy with Partially and Totally Segmented Credit Markets



Turn now from LSAPs targeting MBS to those involving corporate bonds. Figure 5 shows that the response of output, inflation, investment and consumption to the confidence shock are similar when markets are partially and totally segmented. This implies that, in contrast to the case of MBS purchases, even in the absence of the portfolio balance channel, the central bank can still effectively stimulate the economic activity. As shown in the figure, the substantial impact of this intervention concentrates on the targeted asset markets, so that corporate bonds purchases effectively reduce the interest rate on corporate loans and stimulate entrepreneurs' demand for credits and hence the investment. Since the capital and labor are complementary factors of production, higher capital stock raises the marginal product of labor, inducing borrowers to increase their labor supply.

Figure 5: Corporate loan Purchases in an Economy with Partially and Totally Segmented Credit Markets



5 Conclusion

This paper contributes to the literature of DSGE New Keynesian framework with financial frictions by investigating the transmission mechanisms of the Fed's long-term asset purchases in a multi-sector setting where the adverse confidence problems affect corporate and mortgage credit markets. LSAPs can be effective in our framework because there are limits to arbitrage in private intermediation due to the existence of a moral hazard problem as in Gertler and Karadi (2011). We depart from Gertler and Karadi (2011, 2012) as well as other theoretical studies on LSAPs by explicitly incorporating distinct corporate and mortgage credit markets in our model to study the macroeconomic effects of the Fed's LSAP 1 and LSAP 4 which focus on the acquisition of MBS.

As in Gertler and Karadi (2011, 2012), LSAPs could be seen as central bank intermediation. In effect, the central bank is assumed to be able to elastically raise funds from the short-term bond markets while private banks are balance-sheet constrained. Under the assumption that entrepreneurs and households (borrowers) can only obtain funds from specialized loan branches and that corporate lending involves greater moral hazard problem than mortgage lending, our model allows not only studying the effects of the Fed's purchases of mortgage backed securities but also comparing the effectiveness of this policy with that of an alternative policy consisting to purchase corporate bonds. In our model, LSAPs targeting one credit market could be relevant by lowering the limits to arbitrage in both credit markets under the condition that bank equity capital can freely flow from one credit market to another, which gives the portfolio balance channel a significant role to play in the policy transmission. It is shown that, given that the limits to arbitrage in corporate credit market are more important than in mortgage credit market, whatever the primary goals of the central bank, stabilizing the housing market or the real economy during a financial crisis, a LSAP targeting the corporate loan market can always be more effective than purchases of residential mortgage related securities.

The structure of our model allows us to separate the effects due to the portfolio balance channel from these caused by central bank intermediation by assuming the absence of capital mobility between credit markets, i.e. credit markets are totally segmented. The segmentation of this kind makes it possible for central bank purchases to affect the price of an asset with stronger local effects while limiting the possibility for the effects of such a policy to be transmitted to the rest of the economy. In particular, a central bank intervention that absorbs MBS (corporate bonds) would be expected to lower more strongly the yields on MBS (corporate bonds) than when the markets are partially segmented with free capital mobility. Under the total segmentation, asset purchases targeting MBS will hardly exerts an influence on the economic activity while these targeting corporate bonds will be more effective than when the credit markets are partially segmented. However, if we allow the housing stock to vary in our model, a decrease in mortgage interest spread induced by LSAPS targeting MBS could increase the housing production and hence the total production.

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