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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 uniformly less effective at easing credit market conditions and stabilizing economic activity 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 balance channel" is at work in the economy. More segmented credit markets imply larger, but more local effects of particular asset purchases. With strongly segmented credit markets, large scale purchases of MBS are useful to stabilize the housing market but do little to mitigate the contractionary effect of the crisis on employment and output.

JEL classification codes: E32, E44, E52, E58.

Keywords: Financial frictions, mortgage-backed securities (MBS), corporate bonds, unconventional monetary policy, large scale asset purchases (LSAPs), portfolio balance channel, credit spreads.

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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 credit 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 among the general public 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 dynamic macroeconomic models with financial frictions (see in particular Chen *et al.* (2012), Cúrdia and Woodford (2010, 2011), Del Negro *et al.* (2011), Gertler and Karadi (2011, 2013), He and Krishnamurthy (2012), and Williamson (2012)).[1] In these papers, LSAPs consist either in central bank purchases of

[1] Other relevant frameworks includes Brunnermeier and Sannikov (forthcoming) and Christiano *et al.* (2013), even if these papers do not examine LSAPs.

corporate bonds[2], of long term Treasury bonds[3], or of both.[4]

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") – 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 September 2012 and implemented since then) also includes additional purchases of MBS at a pace of $40 billions per month. Thus, from a theoretical perspective, understanding whether, to what extent, and under which circumstances targeted purchases of MBS should be expected to have similar effects as equivalent purchases of corporate bonds 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.[5]

The aim of this paper is to provide insights to these questions. We introduce a housing sector 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 each bank is divided into two branches specialized in mortgage and corporate lending. 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, 2013), the moral

[2]See e.g. Curdia and Woodford (2011), Del Negro *et al.* (2011), Gerter and Karadi (2011) and Willamson (2012).

[3]See Chen *et al.* (2012).

[4]See Gertler and Karadi (2013).

[5]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 LSAPs work through a channel different than a mere "signaling effect" about the future path of the central bank's target rate.

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.[6] 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 the degree to which credit markets are *segmented*, and thus influences the extent to which a "portfolio balance 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, 2013), LSAPs can be seen as central bank intermediation aiming at supplementing private intermediation: in the model, purchasing securities (MBS or corporate bonds) is equivalent to 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 borrowers and entrepreneurs are forced to borrow from their relative bank's branch, so that there are two distinct borrowing rates in the corporate and the mortgage loans markets, but bankers can

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

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, the second configuration is meant to capture the situation of complete disarray in financial market functioning that, according to many authors, was prevalent during the 2007-2009 financial crisis (when QE1 was implemented). Considering these two polar cases enables us to shed light on the importance of the "portfolio balance channel" in the effectiveness of LSAP programs.

Our results show that LSAPs targeting the mortgage loan market are, in both configurations, less effective at mitigating the economic contraction generated by the financial crisis than LSAPs targeting the market for corporate bonds. Yet, the size of the stabilizing effects crucially depends on the extent to which credit markets are segmented. When credit market are partially segmented, large scale purchases of MBS have almost identical effects as equivalent size purchase of corporate bonds. The moderate difference between the two programs comes from the fact that 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 slightly more bank capital than equivalent purchases of mortgage securities. The portfolio balance channel then 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 useful to stabilize the housing market (decreasing the reallocation of houses units between patient and impatient workers following the crisis) but are now much less effective at stabilizing aggregate employment and output than equivalent purchases of corporate bonds. The reason is that, in the US, residential investment accounts for a significantly smaller share

of GDP than non-residential investment (2.5% and 10.7%, respectively), and the absence of any pass-through effect of the central bank's MBS purchases to other credit markets implies that the overall effect on economic activity is limited.[7]

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 bank's large scale asset purchases, assuming either partial or total credit markets segmentation. Finally, Section 5 provides concluding comments.

2 The model

Our model is based on the canonical New-Keynesian model of Christiano et al. (2005) and Smets and Wouters (2007), extended to incorporate imperfect financial intermediation activities in line with Gertler and Kiyotaki (2010) and Gertler and Karadi (2011). We introduce in this benchmark setup a housing sector, à la Iacoviello (2005), and two types of credit activities: mortgage and corporate loans. The economy is composed of three types of consumers: patient and impatient workers, who derive utility from consumption of the non-durable final good and from housing services, and entrepreneurs, who produce intermediate goods using capital and labor and derive utility only from non-durable consumption. Patient workers are net savers and save in the form of interest-bearing deposits. Impatient workers and entrepreneurs are net borrowers, and must borrow part of the funds they need using their housing stock and their capital stock, respectively, as collateral.

Banks act as intermediaries between savers and borrowers. They collect deposits from patient workers and distribute loans to impatient workers and entrepreneurs. Since loans are distributed on a collateral basis, which requires some expertise, banks are divided into two branches specialized in corporate and mortgage loan activities. As in Gertler and Kiyotaki (2010), a moral hazard problem between bankers and

[7] A by-product of this conclusion is that, from a theoretical perspective, analyzing the effects of LSAPs by abstracting from the mortgage market and assuming that the central bank purchases corporate bonds instead of MBS (as done in the previous literature) is a correct approximation when financial markets work normally. However, such modeling assumption may lead to substantially biased results if financial markets are in complete disarray, as many argue was the case in the 2007-2009 crisis.

loan branch managers will create a wedge between the interest rate on loans and the interest rate on deposits.

The model also includes three types of firms: capital producing firms, which repair the depreciated capital and build new one, retailers, which produce retail goods using intermediate goods as inputs (acting in a monopolistically competitive market with sticky prices), and final good producers. Firms are held by patient workers who receive any profit in the form of dividends.

Finally, there is a government, which collects taxes and makes public spending, and a central bank. The central bank conducts both conventional and unconventional monetary policy (LSAPs) when the functioning of credit markets is severely disrupted.

2.1 Patient workers

There is a continuum of identical patient workers of unit mass. Patient workers are owners 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 at the bank. Let C_t^s be the representative patient worker's consumption, h_t^s its housing stock and L_t^s the number of hours supplied. The program solved by the representative patient worker is:[8]

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

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

$$C_t^s + D_t + q_t^h (h_t^s - h_{t-1}^s) + T_t^s = W_t^s L_t^s + \frac{R_{t-1}}{\pi_t} D_{t-1} + \Pi_t^{nf} + \Pi_t^l, \tag{2}$$

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 period t bank deposits and bond holdings, W_t^s is the real wage for labor supplied by savers, q_t^h is the real housing price, $\pi_t = P_t/P_{t-1}$ the gross rate of inflation, Π_t^{nf} are nonfinancial firms' redistributed profits, Π_t^l are the payouts received from

[8] Without loss of generality, we follow Woodford (2003) and consider the limit case in which the transaction services provided by money are negligible, so that the economy becomes cashless.

ownership of banks, and T_t^s are lump-sum taxes paid by savers. 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 savers' maximization problem yields the following first-order conditions:

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

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

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

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

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, characterized by a discount factor β^b which is smaller than that of patient workers: $\beta^b < \beta^s < 1$. 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 and L_t^b the number of hours worked, the program solved by the representative impatient worker is:

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

with $j^b > 0$. Impatient workers' choices must obey the intertemporal budget constraint

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

where W_t^b is impatient workers' real wage and T_t^b are lump-sum taxes. In addition, impatient workers have access to mortgage loan contracts offered by banks.[9] These

[9] Of course, mortgage loan contracts offered to workers can be viewed as mortgage-related securities from the viewpoint of bankers. In particular, to each loan amount S_t^h granted to impatient workers is associated a quantity Q_t^h of *claims,* backed by the housing stock of impatient workers,

contracts stipulate that the loan amount S_t^h granted to borrowers 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 borrowers. Impatient workers thus maximize (7) subject to (8) and (9). The first-order conditions are:

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

$$q_t^h = \frac{j^b}{\lambda_t^b} \left(h_t^b \right)^{-\sigma} + \beta^b E_t \Lambda_{t,t+1}^b q_{t+1}^h + \left[1 - \beta^b E_t \left(\frac{\Lambda_{t,t+1}^b R_t^h}{\pi_{t+1}} \right) \right] \frac{S_t^h}{h_t^b}, \tag{11}$$

$$\lambda_t^b W_t^b = (L_t^b)^{\varphi}, \tag{12}$$

where λ_t^b is the Lagrange multiplier associated with impatient workers' budget constraints, and $\Lambda_{t,t+1}^b = \lambda_{1t+1}^b / \lambda_{1t}^b$. In addition, it is easy to verify that the restriction $\beta^b < \beta^s$ implies that inequality (9) 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:

$$\max E_t \sum_{i=0}^{\infty} (\beta^e)^i \ln(C_{t+i}^e - gC_{t+i-1}^e), \tag{13}$$

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

whose unit price is equal to the price of a unit of housing stock (so that $S_t^h = q_t^h Q_t^h$). In the remaining of the paper, we thus use the two terms of "mortgage loans" and "mortgage securities" interchangeably. Although modelling the complex process of securitization – pooling individual loans so as to convert them into liquid MBS – is beyond the scope of this paper, Hancock and Passmore (2011) show that the Fed's purchase of MBS during QE1 significantly lowered MBS yields *and* mortgage loan rates altogether.

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 $Y_{m,t}$ of intermediate goods according to the production function

$$Y_{m,t} = A(U_t K_{t-1})^{\alpha}(L_t^s)^{(1-\alpha)\vartheta}(L_t^b)^{(1-\alpha)(1-\vartheta)}, \tag{14}$$

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 $P_{m,t}$ (relatively to output price) and buy a quantity I_t of new units of capital from capital producers at unit price q_t^c. The capital stock evolves according to

$$K_t = I_t + [1 - \delta(U_t)]\, K_{t-1}. \tag{15}$$

Entrepreneurs must finance part of their capital acquisition by obtaining funds from intermediaries. To do so, they issue one-period bonds in order to borrow 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:

$$P_{m,t}Y_{m,t} + S_t^c = C_t^e + T_t^e + W_t^b L_t^b + W_t^s L_t^s + q_t^c I_t + \frac{S_{t-1}^c R_{t-1}^c}{\pi_t}, \tag{16}$$

where T_t^e are lump-sum taxes raised by the government. 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)[10] 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.

Entrepreneurs thus solve (13) subject to (14)–(17). Denoting by λ_t^e the Lag-

[10] As with mortgage loans, we assume that to each loan amount S_t^c is associated a quantity Q_t^c of *corporate bonds,* backed by entrepreneurs' capital stock, whose unit price is equal to the price of a unit of capital (so that $S_t^c = q_t^c Q_t^c$).

range multiplier on the budget constraint (16), we obtain the following first-order conditions:

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

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

$$W_t^s = \vartheta (1 - \alpha) \frac{P_{m,t} Y_{m,t}}{L_t^s}, \tag{20}$$

$$W_t^b = (1 - \vartheta)(1 - \alpha) \frac{P_{m,t} Y_{m,t}}{L_t^b}, \tag{21}$$

$$\alpha \frac{P_{m,t} Y_{m,t}}{U_t} = \delta'(U_t) q_t^c K_{t-1}, \tag{22}$$

where $\Lambda_{t,t+1}^e = \lambda_{t+1}^e / \lambda_t^e$.

It can also be verified that the condition $\beta^e < \beta^s < 1$ 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 savers. While bankers aim to maximize the expected discounted flows of dividends distributed to savers, 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 entrepreneurs and borrowers can only borrow from their respective loan branch, 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 (2012), the degree of market segmentation is likely to influence significantly the effects of LSAPs. Our

model will thus allow to make 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 period t, the loan-branch manager l of bank j has a net worth $n^l_{j,t}$ accumulated from the past. He then collects deposits $d^l_{j,t}$ from savers 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 loans granted at t and pays to savers 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–of-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 man-

agement and transfer the collected funds $\lambda_t^l s_{j,t}^l$ to the household of which they are a member.[11] If this occurs, bankers can force the loan branch into bankruptcy and recover the remaining fraction of assets.

As seen below, this agency problem generates in each period a positive gap between the interest rate on loans R_t^l and the interest rate on deposit R_t, implying that loan branches make profits on each dollar of loan intermediated. 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 savers in the form of dividends. Denoting by $V_{j,t}^l$ the expected terminal wealth of branch l in bank j, we have:

$$V_{j,t}^l = \max E_t \sum_{k=0}^{n} (\beta^s)^{k+1}(1-\theta)(\theta)^k \Lambda_{t,t+1+k}^s m_{j,t+1+k}^l.$$

The prevention of misbehavior from branch managers requires that the following incentive constraint must hold:

$$V_{j,t}^l \geq \lambda_t^l s_{j,t}^l. \tag{27}$$

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

$$V_{j,t}^l = \nu_t^l \cdot s_{j,t}^l + \eta_t^l \cdot n_{j,t}^l$$

with

$$\nu_t^l = E_t \left\{ \beta^s \Lambda_{t,t+1}^s (1-\theta) \left(\frac{R_t^l - R_t}{\pi_{t+1}} \right) + \beta^s \Lambda_{t,t+1}^s \theta x_{t,t+1}^l \nu_{t+1}^l \right\},$$

$$\eta_t^l = E_t \left\{ (1-\theta) + \beta^s \Lambda_{t,t+1}^s \theta z_{t,t+1}^l \eta_{t+1}^l \right\},$$

where $x_{t,t+1}^l \equiv s_{t+1}^l / s_t^l$ and $z_{t+1}^l \equiv n_{t+1}^l / n_t^l$ are, respectively, the gross growth rate of asset holdings and the gross growth rate of net worth between t and $t+1$ in each loan branch.[12] The variable ν_t^l represents the expected discounted marginal gain for loan branches from an additional unit of assets $s_{j,t}^l$, holding $n_{j,t}^l$ constant. Likewise,

[11] Thus, λ_t^l is a natural measure of the "degree of confidence" that savers 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.

[12] As explained below, the ratio $\xi_{j,t+1}^l / n_t^l$ of transfers relatively to net worth can be assumed to be the same for any bank j, implying that ν_t^l and η_t^l do not depend on bank-specific factors.

η_t^l is the expected discounted marginal gain from adding a unit of equity capital $n_{j,t}^l$, holding $s_{j,t}^l$ constant.

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

$$\begin{aligned} s_{j,t}^l &= \frac{\eta_t^l}{\lambda_t^l - \nu_t^l} n_{j,t}^l \\ &= \phi_t^l n_{j,t}^l, \end{aligned} \tag{28}$$

where $\phi_t^l \equiv \eta_t^l/(\lambda_t^l - \nu_t^l)$, is an endogenously determined *leverage ratio* for loan branches. As (28) shows, the branch ability to expand loans is constrained by its net worth, as any loan amount greater than $s_{j,t}^l = \phi_t^l n_{j,t}^l$ would imply that the net gain from defaulting was larger than the cost, thus violating the incentive constraint.

Using (26), we can also express $x_{t,t+1}^l$ and z_{t+1}^l as

$$x_{t+1}^l = \frac{\phi_{t+1}^l}{\phi_t^l} z_{t+1}^l,$$

$$z_{t+1}^l = \frac{1 + \varrho_{t+1}^l}{\pi_{t+1}} \left[(R_t^l - R_t)\phi_t^l + R_t \right],$$

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

As emphasized earlier, we will consider two assumptions regarding equity capital transfers. When credit markets are "totally segmented", we assume $\varrho_t^l = 0$ 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). Bankers aim to maximize the total expected discounted flow of dividends distributed to shareholders. In the appendix accompanying this paper, we show that as long as $\phi_t^c(R_t^c - R_t) > \phi_t^h(R_t^h - R_t)$, it is optimal for bankers to transfer equity capital from their mortgage loan branch to their corporate loan branch. Yet, at the aggregate level, these capital inflows generate an increase in the supply of corporate loans and a decrease in the

supply of mortgage loans, leading in turn to a decrease in R_t^c and an increase in R_t^h.[13] Thus, equity capital transfers occur until the following non-arbitrage condition

$$\phi_t^c(R_t^c - R_t) = \phi_t^h(R_t^h - R_t) \tag{29}$$

is satisfied at any period in time. Since this condition only depends on the *aggregate* amount of equity capital transfer and not on individual amounts, we assume that each bank j makes the same transfer amount in proportion to its net worth, so that the ratio $\xi_{j,t+1}^l/n_t^l$ does not depend on j, conformably with our above analysis.

Condition (29) underlines how the "portfolio rebalance channel" is at work in this economy. When capital inflows are possible between branches, bankers make continuous arbitrage between profit opportunities offered by the two loans branches. For bankers, each dollar invested in loan branch l allows it to increase loans by ϕ_t^l dollars, and to receive $\phi_t^l(R_t^l - R_t)$ 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. As analyzed below, this mechanism implies that LSAPs targeting a particular loan market should spread out to the other credit market until condition (29) is satisfied.

Banking sector aggregation. Let $S_t^{l,p}$ be the aggregate loan amount granted by loan branches l and N_t^l be their total equity capital. Given that the leverage ratio ϕ_t^l does not depend on bank-specific factors, summing (28) across individual loan branches yields:

$$S_t^{l,p} = \phi_t^l N_t^l. \tag{30}$$

As mentioned above, a constant fraction θ of branches close at the end of any period t. To keep the total number of loan branches fixed in each loan sector we also assume that, for each exiting branch, a new branch is established and receives from savers 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:

$$N_t^l = \theta N_{t-1}^l \left[\phi_{t-1}^l \left(\frac{R_{t-1}^l - R_{t-1}}{\pi_t}\right) + \frac{R_{t-1}}{\pi_t}\right] + \omega^l S_{t-1}^{l,p} + \Theta_t^l, \tag{31}$$

[13] Of course, the argument goes in reverse way if $\phi_t^c(R_t^c - R_t) < \phi_t^h(R_t^h - R_t)$.

where $\omega^l S_{t-1}^{l,p}$ 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.

2.5 Non-borrowing firms

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

Capital producing firms. In any period t, capital producing firms build new capital using the final good as input and sell it to entrepreneurs at the relative price q_t^c per unit. Denoting by I_t the amount of capital created at t, we assume that investment is subject to adjustment costs materialized by a quadratic function $f\left(I_t/I_{t-1}\right)$ satisfying $f\left(1\right) = f'\left(1\right) = 0$ and $f''\left(1\right) > 0$. The problem of capital producers is thus to maximize profits:

$$\max E_t \sum_{\tau=t}^{\infty} \left(\beta^s\right)^{\tau-t} \Lambda_{t,\tau}^s \left\{ q_t^c - \left[1 - f\left(\frac{I_\tau}{I_{\tau-1}} \right) \right] \right\} I_\tau.$$

Solving this problem delivers as first-order condition a dynamic equation for the real price of capital

$$q_t^c = 1 + f\left(\frac{I_\tau}{I_{\tau-1}} \right) + f'\left(\frac{I_\tau}{I_{\tau-1}} \right) \frac{I_\tau}{I_{\tau-1}} - \beta^s E_t \Lambda_{t,\tau+1}^s f'\left(\frac{I_{\tau+1}}{I_\tau} \right) \left(\frac{I_{\tau+1}}{I_\tau} \right)^2, \qquad (32)$$

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

Final good producing firms. There is a perfectly competitive final good market. Final output Y_t is produced through a CES composite made of a continuum of mass unity of retail goods, indexed by $f \in (0,1)$:

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

where $Y_{f,t}$ is the output of retailer f and $\varepsilon > 1$ is the elasticity of substitution between retail goods. Profit maximization by final good producers leads to the standard demand function:

$$Y_{f,t} = \left(\frac{P_{f,t}}{P_t}\right)^{-\varepsilon} Y_t, \tag{33}$$

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

$$P_t = \left[\int_0^1 P_{f,t}^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}. \tag{34}$$

Retail firms. 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 index them to the lagged inflation rate using an indexation coefficient $\gamma_p \in (0,1)$. The retailers' pricing problem is then to choose the optimal reset price P_t^* to solve

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

subject to (33). The first-order condition is:

$$E_t \sum_{i=0}^{\infty} (\gamma\beta^s)^i \Lambda_{t,t+i}^s \left[\frac{P_t^*}{P_{t+i}} \prod_{k=1}^{i} (\pi_{t+k-1})^{\gamma_p} - \mu P_{m,t+i}\right] = 0,$$

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

Given (34) 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:

$$P_t = \left[(1-\gamma)(P_t^*)^{1-\varepsilon} + \gamma(\Pi_{t-1}^{\gamma_p} P_{t-1})^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}. \tag{35}$$

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:

$$\log R_t = (1-\rho^R)\left[\log R + \kappa_\pi \log\left(\pi_t/\pi\right) + \kappa_y \log\left(Y_t/Y\right)\right] + \rho^R \log R_{t-1} + \varepsilon_t^R, \quad (36)$$

where R, π and Y are the steady state values of the short-term interest rate, inflation rate, and output level, respectively, 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_t^R is an exogenous monetary policy shock.

LSAPs To reduce excess returns on assets and to put downward pressures on loan interest rates, the central bank can decide to purchase corporate bonds or MBS at existing market conditions. In contrast with private financial institutions, central bank intermediation does not suffer from agency problems. However, the central bank does not have as much expertise as private banks in monitoring loans, so that central bank intermediation is subject to an efficiency cost assumed to be 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 can thus only improve financial conditions when private credit markets are severely disrupted and the excess returns are large.[14]

The central bank funds its securities purchases by issuing short term (one period) debt D_t^g at the gross nominal interest rate R_t. The raised funds allow it to purchase a total value $S_t^{c,g}$ of corporate bonds and $S_t^{h,g}$ of MBS in the hands of private banks, and it is assumed that any profits or losses made by the central bank through LSAPs, $\Phi_t = (R_{t-1}^i - R_{t-1} - \iota)S_{t-1}^{c,g} + (R_{t-1}^h - R_{t-1} - \iota)S_{t-1}^{h,g}$, are transferred to the Treasury. Let S_t^l, $l \in \{c, h\}$, be the total value of corporate and mortgage loans, respectively. We have

$$S_t^l = S_t^{l,p} + S_t^{l,g}. \quad (37)$$

[14]For example, ι can be calibrated so as to imply that no central bank intervention is desirable at the steady-state. In this case, the "Bills only" doctrine applies in normal times, and LSAPs are only justified to the extent that unusually large shocks generate an abrupt increase in credit spreads. See Curdia and Woodford (2010) for more discussion on this point.

The central bank decides on the amount of public credit intermediation $S_t^{l,g}$ it undertakes in any period t. We assume that $S_t^{l,g}$ follows a first-order stochastic process :

$$\log S_t^{l,g} = \rho^g \log S_{t-1}^{l,g} + (1-\rho^g) \log S^{l,g} + \Upsilon \epsilon_t, \tag{38}$$

where the autoregressive coefficient ρ^g is between 0 and 1, $\Upsilon > 0$ is a scale parameter, and ϵ_t is an exogenous shock described below.

Fiscal policy. Government expenditures G are exogenously fixed and are financed by fiscal revenues (lump-sum taxes raised on consumers) and by income transfers related to the central bank holdings of private securities. We also assume that the government runs a balanced budget, implying that

$$G = T_t^s + T_t^b + T_t^e + \Phi_t.$$

Thus, profits or losses made by the central bank are compensated by equivalent variations in taxes raised on consumers so as to keep the budget balanced.

2.7 Market clearing conditions

In equilibrium, 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 $f(I_t/I_{t-1})I_t$. The market clearing condition in the final goods market is:

$$Y_t = C_t^s + C_t^b + C_t^e + \left[1 + f\left(\frac{I_t}{I_{t-1}}\right)\right] I_t + G. \tag{39}$$

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

$$h_t^s + h_t^b = 1. \tag{40}$$

The corporate and mortgage loan market equilibrium conditions are respectively

$$\frac{\mu^e E_t \left[1 - \delta(U_{t+1})\right] q_{t+1}^c K_t \pi_{t+1}}{R_t^c} = S_t^c, \tag{41}$$

$$\frac{\mu^b E_t q^h_{t+1} h^b_t \pi_{t+1}}{R^h_t} = S^h_t. \tag{42}$$

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 Model analysis

We now turn to the quantitative analysis of the model. After describing our calibration procedure, we show that our model can reproduce reasonably well the characteristic features of the US economy following the trigger of the crisis, materialized here as a sudden increase in agency problems in financial markets. 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 in stimulating the real economy.

3.1 Calibration

To facilitate comparisons, most parameter values are set as in Gertler and Karadi (2011). The discount factor of savers is set to $\beta^s = 0.99$, implying an annual steady state real interest rate of 4%. The inverse of the Frisch labor supply elasticity is set to $\varphi = 0.276$. The habit parameter g is set to $g = 0.815$. The share of capital in the production function is set to $\alpha = 0.33$, the steady state value of the utilization rate to $U = 1$, and the steady-state depreciation rate to $\delta = 0.0025$. The elasticity of the marginal depreciation rate of capital with respect to the utilization rate is set to $\zeta = 7.2$. For the inverse elasticity of net investment to the price of capital, we find that setting $\eta_c = 0.5$ (a value somewhat smaller than the value of 1.72 considered by Gertler and Karadi, 2011) enables to obtain a larger decline in investment and output during the crisis without altering the other predictions of the model. The probability of keeping prices fixed is $\gamma = 0.779$, and the indexation parameter is $\gamma_p = 0.241$. The steady-state inflation factor is set to unity. The monetary policy rule parameters are calibrated as follows: 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 $\rho^R = 0.8$. The steady-state ratio of government spending to GDP is set to 20%. The survival probability of banks, $\theta = 0.972$, implies an expected

horizon of eight years for loan branches.

Concerning the parameters specific to our model, we set the discount factor of borrowers and entrepreneurs to $\beta^b = \beta^e = 0.975$. We set the technology parameter ϑ to $\vartheta = 0.64$, implying a borrowers' income share in total wage income of around 36 percent, which is in line with evidence in Campbell and Mankiw (1989). The curvature parameter on housing in the utility function, σ, influences the response of the housing price and relative housing stocks to changes in the economic environment. We find that setting $\sigma = 3$ allows to imply a declining housing price after a negative shock affecting the financial system, while still generating substantial reallocation of housing units between savers and borrowers. We calibrate the LTV ratio for impatient workers at $\mu^b = 0.55$, as estimated by Iacoviello (2005). The value of the LTV ratio for entrepreneurs, μ^e, and the weights on housing in the households' utility function, j^b and j^s, are set so that the steady state corporate debt to output ratio S^c/Y equals to 0.72, the steady state mortgage debt to output ratio S^h/Y equals to 0.73 and the fraction of housing stock held by savers at the steady states is $h^s = 1/3$. The values of S^c/Y and S^h/Y are calibrated to match the ratio of total debt owed by the domestic nonfinancial corporate and non-corporate business sector to GDP and the ratio of outstanding mortgage debt to GDP in the U.S., respectively, at the onset of the crisis (first two quarters of 2007), as reported by the Board of Governors of the Federal Reserve System. For the savers' housing stock, we use data from the 2007 American Housing Survey which indicates that among the 75.6 millions of total occupied units, 24,9 millions were clear of mortgages (see Table 3.15 p. 162).

Concerning the banking sector, our strategy is to calibrate the spread between the interest rate on corporate loans and the policy rate, $R^c - R$, the spread between the interest rate on mortgage loans and the policy rate, $R^h - R$, the leverage ratio in the corporate loan sector ϕ^c and the size of transfers from the corporate loan to the mortgage loan branches Θ^c/N^c, and let the values for λ_c, λ_h, ω_c and ω_h be determined endogenously.[15] The spread $R^c - R$ is set to 169 basis points (annualized) at the steady-state, based on the pre-crisis level of excess return on Moody's Seasoned Baa corporate bond yield over the 10-year Treasury constant maturity rate (averaged over 2006). The spread $R^h - R$ is set to 127 basis points (annualized), based on the

[15] Details on how these relationship are derived at the steady-state are given in the accompanying appendix.

pre-crisis spreads between the 15-year fixed rate mortgage average and the 10-year Treasury constant maturity rate (averaged over 2006). We calibrate the leverage ratio for corporate lending to $\phi^c = 4$ and the steady-state net worth transfers to $\Theta^c/N^c = 0.001$.[16] The implied steady state leverage ratio of mortgage credit intermediation ϕ^c is around 5.26, reflecting the fact that large and complex commercial and investment banks which intensively invested in mortgage related securities were thinly capitalized and did not have a sufficient cushion to absorb the losses as they were hit by the subprime crisis.

3.2 Simulating the financial crisis: the moral hazard shock

As emphasized earlier, we interpret the financial crisis as stemming out from a major loss of confidence in the financial system, due to an exacerbation of agency problems in credit intermediation activities. Since, in our model, the degree of financial market imperfections is materialized by the fraction $\lambda_{l,t}$ of assets that loan branch managers can divert in any period t, we introduce a shock to this parameter. Specifically, we assume that $\lambda_{l,t}$ is a first-order autoregressive process with autoregressive coefficient 0.8. We favor this negative "confidence shock" affecting financial markets to a more traditional "capital quality" shock considered in Gertler and Karadi (2011, 2013) for pragmatic reasons, as in our model this shock does qualitatively a better job at accounting for the main features of the current crisis than the capital quality shock does.

Figure 1 displays the impulse response functions of the model following a positive 5% shock to $\lambda_{l,t}$ in both the corporate and mortgage loan sectors, assuming at this stage that there is no central bank intervention on credit markets. In the figure, solid lines are used to depict the responses in an economy with partially segmented credit markets, while dashed lines are used for an economy with total credit market segmentation.

In both economies, the exacerbation of agency problem in financial intermediation generates an instantaneous increase in borrowing rates, R_t^c and R_t^h (with a larger increase in corporate loan rates) and induces loan branches to deleverage (see Panel A – *Financial and credit market-related variables*). This induces a significant decrease in the amounts of loans S_t^c and S_t^h granted to entrepreneurs and borrowing

[16] Quantitatively, our results are not sensitive to the assumed value for Θ^c/N^c.

consumers. With loans becoming scarce and more expensive, the demand for capital and the demand for housing from impatient borrowers decrease. As a result, asset prices drop: in the partially segmented economy, the capital price q_t^c collapses by -7%, and the housing price q_t^h decreases by -0.3%. In the totally segmented economy, the corresponding declines are -7.7% and -0.3%, respectively.

The fact that the capital price declines less in an economy with partial credit market segmentation underlines the role of equity capital inflows in the propagation of the crisis. When credit market are partially segmented, Figure 1 (Panel A) shows that, in order to compensate from the disproportional increase in the corporate loan rate compared to the mortgage loan rate, bankers choose to reallocate equity capital by transferring funds from the mortgage loan branch to the corporate loan branch. At the aggregate level, these transfers occur until the "leverage adjusted excess returns", $\phi_t^l(R_t^l - R_t)$, are the same in each branch $l \in (c, h)$. Thus, compared to an economy in which credit markets are totally segmented, equity capital transfers tend to mitigate the reduction in loans granted to entrepreneurs.

Figure 1 (Panel B – *Real economy variables*) shows how the "real side" of the economy is in turn affected by the disruption in financial markets. The decline in corporate loans generates a collapse in aggregate investment, which drops by -10% in the partial segmentation case, and by -12% in the economy with total segmentation. As capital accumulation slows down, the marginal productivity of labor also falls for several quarters, and so do real wages. Labor supply decreases as a result of this decline in real wages, and aggregate consumption decreases as a joint result of the lower wage income and of the negative impact on households' wealth implied by sharply falling asset prices. With low investment and low consumption, aggregate demand falls, generating a decrease in output and a decrease in the price level.

Facing a simultaneous contraction in output and in the inflation rate, the central bank reacts by cutting its policy rate R_t.[17] Yet, as Figure 1 (Panel B) reveals, this reduction in the policy rate is not sufficient to counteract the negative effects of distressed financial markets conditions on long-term interest rates. With a decreasing

[17] For technical reasons – in particular, to avoid handling the computational difficulties associated with solving a large scale DSGE model with occasionally binding constraints – the size of the confidence shock has been limited so as to avoid that the central banks policy rate hits the zero lower bound. Papers in the literature that have explicitly handled this constraint (e.g. Del Negro *et al.* (2011), Chen *et al.* (2012) and Gertler and Karadi (2011, 2013)) have typically found that the effects of large shocks on financial markets are *qualitatively* the same, but are substantially *amplified* when the ZLB constraint is hit.

R_t and strongly increasing R_t^c and R_t^h, credit spreads jump by a significant amount. In accordance with the data, the credit spread increase in the corporate loan sector is larger than the one in the mortgage loan sector: in the economy with partial credit market segmentation, $R_t^c - R_t$ increases by 720 basis points, and $R_t^h - R_t$ increases by 550 bps. In the economy with total credit market segmentation, the corresponding increases are 680 bps and 440 bps, respectively.

Overall, although the model is too simple to match quantitatively all observed features following the crisis, we find that the inclusion of a mortgage sector and of segmented corporate and mortgage credit markets allows to account for a broader set of empirical facts associated with the burst of the financial crisis (declining housing prices, housing reallocation between savers and borrowers, differentiated credit spread evolutions on credit markets, etc.), without altering the accurate predictions of the Gertler and Karadi (2011) model on the behavior of other variables. Thus, we believe that the model is a useful benchmark to analyze the differentiated effects of LSAPs targeting different assets (MBS versus corporate loans).

3.3 Large scale asset purchases with partial credit market segmentation

We now analyze the effects of LSAPs in the crisis experiment undertaken above, assuming for the moment that credit markets are partially segmented. To do so, we assume that in response to the large confidence shock on the financial system, the central bank directly purchases private securities at current market conditions. As explained in Gertler and Karadi (2011), LSAPs can thus be viewed as central bank intermediation, with the difference that this intermediation is not subject to agency problems.[18] To facilitate comparisons, we distinguish between two kinds of LSAPs: the first one consists in purchasing corporate bonds only, and the second one consists in purchasing mortgage securities (MBS) only. In each case, we assume that the amount of credit intermediation $S_t^{l,g}$ provided by the central bank follows the same first-order autoregressive process (38) with autoregressive factor $\rho^g = .9$, where ϵ_t is the 5% confidence shock introduced above. The scale parameter Υ is set so that the total amount of assets purchased by the central bank represents 2%

[18] This transmission channel of LSAPs, where central bank purchases of securities help to mitigate credit market imperfections, is sometimes referred to as the "credit easing" channel of LSAPs.

of steady-state GDP at impact.[19] Results from these experiments are displayed in Figure 2 (Panels A and B).

Consider first the responses of the economy following LSAPs of corporate bonds only (long dashed line). As in Gertler and Karadi (2011, 2013), the central bank intervention allows to mitigate the increase in the corporate loan rate and excess return. As a result, the total loan amount distributed to firms decreases less compared to baseline (and so do the price of capital), which tends to attenuate the contractionary effects of the crisis on investment and on entrepreneurs' consumption (and, ultimately, on aggregate output). Yet, the additional interesting feature of our model is that it enables to analyze how such policy affects credit markets other than those targeted by the program (in particular, the mortgage loan market) and, more generally, to analyze how such policy influences macroeconomic variables less directly related to firms' environment. As Figure 2 shows, when credit markets are partially segmented, large scale purchases of corporate bonds also generate a significant decrease in the mortgage loan rate, and thus attenuate the fall in mortgage loans granted to borrowing households. This contributes to stabilize the housing market, with housing prices and borrowers' housing stock (and consumption) decreasing less compared to baseline.

The reasons for these favorable effects of LSAPs – going beyond the mere stabilization of the corporate loan market – are obviously to be found in the *portfolio balance channel* emphasized by Bernanke (2012) and the preferred-habitat literature (see Andrés *et al.* (2004) and Vayanos and Vila (2009) for modern formulations of this theory). Others things equal, large scale purchases of corporate bonds reduce the aggregate supply to the private sector of such bonds. This tends to increase their price and to decrease their return compared to mortgage-related securities. Yet, when equity capital transfers between loan branches are possible, bankers arbitrage away this difference in marginal returns by transferring equity capital from the corporate to the mortgage loan branch until the "leverage-adjusted" excess returns are the same in both sectors (see equation (29)). This explains why LSAPs of corporate bonds spread out to other credit markets and have a broader economic effect than a mere easing of credit market conditions for entrepreneurs.

Consider now the responses of the economy following a LSAP program involving

[19] Our policy simulation is only meant to be suggestive, as we do not attempt to perfectly reproduce the timing of shocks and policy interventions involved in the recent crisis.

MBS purchases by an equivalent amount (dotted lines). As Figure 2 shows, this alternative policy has, qualitatively, very similar effects on aggregate variables. This results again from the portfolio balance channel, which generates pass-through effects from one credit market to another. Yet, Figure 2 also shows that these effects are *quantitatively* slightly weaker than those obtained from an equivalent size purchases of corporate bonds. The reason for this difference is that mortgage loan branches are, on average, more leveraged than corporate 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 purchases of MBS relax banks' balance sheet constraint proportionately less than equivalent purchases of corporate bonds. This effect is similar to the one obtained by Gertler and Karadi (2013) when comparing the relative efficacy of LSAPs targeting private securities versus Treasury bonds. However, our results show that to the extent that frictions in the mortgage and the corporate loan markets are not too different from each other (as reflected by the small difference in steady-state credit spreads in each sector), this quantitative difference should remain small. The implication of such finding is straightforward: to the extent that excess returns on two classes of similar-maturity assets are roughly the same *and* that portfolio adjustments by investors can be done at small cost, it doesn't matter much which asset the central bank purchases since the portfolio balance channel implies that both policies will have quantitatively similar effects on credit markets. The corollary of this proposition of course also holds: if two similar-maturity assets have large differential returns (reflecting significantly different degrees of financial frictions), the efficacy of LSAPs is greater if the central bank purchases the asset with the largest return.[20]

3.4 Large scale asset purchases with totally segmented credit markets

The extent to which the portfolio balance channel has been at work in recent experiences of unconventional monetary policies is the subject of considerable debate in the recent literature. Empirical studies usually tend to confirm that LSAPs of particu-

[20] Thus, in Gertler and Karadi (2013), LSAPs of corporate bonds are about twice as effective as equivalent-size purchases of long-term government bonds because the excess return on the former are about twice as large as the excess return on the latter.

lar assets (whether MBS or long-term Treasury bonds) helped to ease other credit market conditions by reducing yields on other assets (see in particular Gagnon *et al.* (2011), Krishnamurthy and Vissing-Jorgensen (2011), Swanson (2011), D'amico and King (2012), Hamilton and Wu (2012) and Li and Wei (2013)).[21] Yet, Woodford (2012) stresses that the period over which LSAP1 took place (December 2008 - March 2010) was a period of significant disruption of the markets involved in mortgage securitization, leading to a much stronger degree of credit market segmentation than usual. According to Woodford (2012), credit market segmentation is a credible reason for why targeted central bank purchases of a particular asset (here, MBS) should affect its yield and price. Yet, it also reduces the extent to which such effects are expected to be passed on to other credit markets. In other words, LSAPs are expected to have much more "local" effects when the functioning of financial markets is so disrupted that credit market segmentation is strong.[22]

To explore the implications of this line of arguments within our model, we now analyze the effects of the two types of LSAPs considered above within an environment in which equity capital transfers between loan branches are no longer possible (which can be seen as an extreme form of credit market segmentation). Results from these experiments are displayed in Figure 3. Again, dashed lines are used for a LSAP program involving corporate bonds, and dotted lines are used for LSAPs targeting MBS.

Overall, the results clearly confirm Woodford's assertions. As shown in Figure 3, central bank purchases of corporate bonds reduce the borrowing rate of entrepreneurs by a much larger extent than in the former case of partial market segmentation. Yet, they also leave the mortgage loan rate almost unaffected. The opposite result of course holds when considering large scale purchases of MBS: they lower the mortgage loan rate by a greater amount than in the partial segmentation case, but have no visible effect on the yield on corporate bonds. Thus, different LSAP programs clearly have much more "local" effects when credit markets are totally segmented. This set of theoretical results is well supported by empirical evidence in Gagnon

[21] See also Joyce *et al.* (2011) for an analysis in the UK. A thorough analysis of the effects of LSAP1 on MBS yields and mortgage rates is also provided by Hancock and Passmore (2011), although these authors do not consider the pass-through effects of MBS purchases to other credit markets.

[22] Del Negro *et al.* (2011) also interpret the 2008-2009 financial crisis as a major freezing of secondary markets for private securities, materialized as a decrease in the "resaleability" of these assets.

et al. (2011) and Krishnamurthy and Vissing-Jorgensen (2011), who find that the impact of LSAP programs on MBS rates is large when such programs involve MBS purchases, but not when they involve other asset purchases (in particular, Treasury bonds).[23]

The model then also makes predictions concerning the macroeconomic effects of LASPs that are not often discussed in the academic literature (whether theoretical or empirical). Figure 3 shows that while central bank purchases of corporate bonds significantly moderate the negative effects of the financial crisis on economic activity as a whole (as measured, e.g., by aggregate output and employment), equivalent-size purchases of MBS have very little effects on macroeconomic variables other than those related to the housing market. For example, in the model, the decline in output following the large negative confidence shock is -1.66 percent when there is no central bank intervention, -0.82 percent in the case of central bank purchases of corporate bonds, and -1.61 percent in the case of central bank purchases of MBS. Clearly, under this extreme form of credit market segmentation, large scale purchases of MBS do very little to attenuate the recession. Again, this sharply contrasts with the case of partial credit market segmentation in which both types of programs were quite effective to attenuate the macroeconomic effects of the crisis.

How can such differential effects be explained? When credit markets are strongly segmented, central bank purchases of corporate bonds stimulate loans to entrepreneurs, granted to finance investment in physical capital. As a result, aggregate investment decreases considerably less compared to the economy without intervention. Because nonresidential investment is a significant component of GDP (10.7% in the US economy), this policy stimulates aggregate demand and mitigates the crisis effects on aggregate output and employment. By contrast, if the central bank purchases MBS, the reduction in mortgage loan rates attenuates the fall in mortgage loans to

[23]Both Gagnon *et al.* (2011) and Krishnamurthy and Vissing-Jorgensen (2011) find stronger effects of LSAP1 on MBS rates than on Baa corporate bond yields. Note that our model predicts that corporate bond yields decrease *more* than mortgage rates following central bank purchases of MBS when credit market segmentation is *partial*, while it predicts the opposite when credit market segmentation is *total* (in this latter case, the corporate loan rate is virtually unaffected while the mortgage loan rate strongly decreases). Combining these two sources of evidence suggests that credit market segmentation was indeed strong during the period over which LSAP1 took place, even though not as strong as to imply, as in the extreme case of our model, the absence of any pass-through effect on other credit rates. An alternative explanation for the decline in corporate bond yields is that LSAPs also influenced the economy through a *signalling channel,* changing agents' expectations about the future path of the policy rate (Eggertson and Woodford (2003)).

impatient workers, thereby contributing to stabilizing the housing market. However, since the aggregate stock of houses is fixed in our model, this has no significant effect on employment and output (the policy mostly mitigates the redistributive effects of the crisis on housing holdings between patient and impatient workers).[24] Although the assumption of a fixed housing stock was made for simplicity and does not exactly match the situation of the US economy, residential investment is actually a very small fraction of GDP in the US (2.5%). Explicitly incorporating a construction sector in the model is thus unlikely to change significantly this conclusion.

4 Concluding remarks

We have introduced a housing sector and differentiated mortgage and corporate loan markets into a New-Keynesian model with financial frictions à la Gertler and Kiyotaki (2010) and Gertler and Karadi (2011). This framework enabled us to analyze and compare the effect of LSAP programs involving corporate bond or MBS purchases.

Our results show that LSAP effects depend crucially on the degree of credit market segmentation, as materialized by the possibility to make equity capital transfers between loan branches in the face of differing marginal returns. When credit markets are partially segmented, central bank purchases of a particular asset reduce the borrowing rate and expand loans on the corresponding credit market, but the portfolio balance channel implies that this effect spreads out to the other credit markets. In this case, the effectiveness of LSAP programs is the strongest when the central bank targets the credit market with the largest degree of financial frictions at the steady-state (i.e., the corporate loan market in our model). Nonetheless, to the extent that excess returns do not differ too much between the two sectors at the steady state, the quantitative differences in terms of policy responses between the two purchase programs are small. A corollary of this proposition, from a theoretical perspective, is that formal models which analyze LSAP effects by abstracting from modeling the housing market and assuming that the central bank purchases corporate bonds instead of MBS can still describe quite accurately the economy's

[24] Note however that this redistributive effect is not completely neutral, as it generates an aggregate "housing wealth effect" owing to the fact that impatient households have a larger propensity to consume wealth than patient households. Our simulation results show that this wealth effect is quantitatively small.

response to LSAPs if financial markets work normally (so that the portfolio balance channel is at work) and the degrees of markets frictions in the two credit markets are roughly the same.

When credit market are totally segmented, however, results are significantly different. In this case, LSAPs have much more local effects: central bank purchases of corporate bonds help to stabilize the corporate loan market (decreasing firms' borrowing rate and increasing loans to entrepreneurs) but do little on the mortgage loan market, and vice versa. Thus, which type of asset the central bank purchases now matters a lot, and the choice crucially depends on which credit market the central bank aims to stabilize (as well as which overall effect it expects from implementing its purchase policy). For example, stabilizing the housing market may have been desirable during the 2007-2009 financial crisis when the burst of the housing bubble was generating a significant increase in adjustable mortgage rates, which was forcing many borrowing households into foreclosure. Our model shows that central bank purchases of MBS indeed attenuates the sharp redistribution of housing units from impatient to patient workers. At the same time, it suggests that such policy should not be expected to have very strong effects on aggregate output and employment, if credit market segmentation is strong, since residential investment accounts for only a small share of GDP in the US economy. If the aim of LSAPs is to sustain economic activity as a whole, economic policies aiming more directly at expanding loans to businesses should rather be implemented. In this respect, it is interesting to observe that the Bank of England, through its recently implemented Funding for Lending Scheme (FLS), and the ECB in its recent discussions – two economic areas for which credit market segmentation remains strong due to sovereign debt concerns – are seeking more direct ways to stimulate loans to Small and Medium-sized Enterprises than current LSAP programs do.

References

[1] Bernanke, Ben S., 2012, "Monetary Policy since the Onset of the Crisis," *Speech* at the Federal Reserve Bank of Kansas City Economic Symposium, Jackson Hole, Wyoming August 31.

[2] Bernanke, Ben S. & Gertler, Mark, 1989, "Agency Costs, Net Worth, and Business Fluctuations," *American Economic Review*, vol. 79(1), p. 14-31.

[3] Bernanke, Ben S. & Gertler, Mark & Gilchrist, Simon, 1999, "The Financial Accelerator in a Quantitative Business Cycle Framework," in J. B. Taylor & M. Woodford (eds.), *Handbook of Macroeconomics*, edition 1, volume 1, chapter 21, p. 1341-93, Elsevier.

[4] Brunnermeier, Markus & Sannikov, Yuliy, forthcoming, "A Macroeconomic Model with a Financial Sector", *American Economic Review*, forthcoming.

[5] Calvo, Guillermo A., 1983, "Staggered prices in a utility-maximizing framework," *Journal of Monetary Economics*, Elsevier, vol. 12(3), p. 383-398.

[6] Campbell, John Y. & Mankiw, N. Gregory, 1989, "International evidence on the persistence of economic fluctuations," *Journal of Monetary Economics*, Elsevier, vol. 23(2), p. 319-333, March.

[7] Carlstrom, Charles T. & Fuerst, Timothy S., 1997, "Agency Costs, Net Worth, and Business Fluctuations: A Computable General Equilibrium Analysis," *American Economic Review*, vol. 87(5), p. 893-910.

[8] Chen, Han & Curdia, Vasco & Ferrero, Andrea, 2012, "The Macroeconomic Effects of Large Scale Asset Purchases," *Economic Journal*, vol. 122, Issue 564, p. 289-315.

[9] Christiano, Lawrence J. & Eichenbaum, Martin & Evans, Charles L., 2005, "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy," *Journal of Political Economy*, vol. 113(1), p. 1-45.

[10] Christiano,Lawrence & Motto, Roberto & Rostagno, Massimo, 2013, "Risk shocks", NBER Working Paper No. 18682.

[11] Cúrdia,Vasco & Michael Woodford, 2010, "Conventional and unconventional monetary policy," *Federal Reserve Bank of St. Louis Review*, issue May, p. 229-264.

[12] Cúrdia, Vasco & Woodford, Michael, 2011, "The Central-bank Balance Sheet as an Instrument of Monetary Policy," *Journal of Monetary Economics*, vol. 58(1), p. 54-79.

[13] D'Amico, Stefania & King, Thomas B., forthcoming, "Flow and Stock Effects of Large-Scale Treasury Purchases: Evidence on the Importance of Local Supply," *Journal of Financial Economics*, forthcoming.

[14] Del Negro, Marco & Eggertsson, Gauti & Ferrero, Andrea & Kiyotaki, Nobuhiro, 2011, "The Great Escape? A Quantitative Evaluation of the Fed's Liquidity Facilities," *Staff Reports* 520, Federal Reserve Bank of New York.

[15] Eggertsson, Gauti & Woodford, Michael, 2003, "The Zero Bound on Interest Rates and Optimal Monetary Policy," *Brookings Papers on Economic Activity*, vol. 34(1), p. 139-235.

[16] Gagnon, Joseph & Raskin, Matthew & Remache, Julie & Sack, Brian, 2011, "The Financial Market Effects of the Federal Reserve's Large-Scale Asset Purchases," *International Journal of Central Banking*, vol. 7(1), p. 3-43, March.

[17] Gertler, Mark & Karadi, Peter, 2011, "A model of unconventional monetary policy," *Journal of Monetary Economics*, vol. 58(1), pages 17-34.

[18] Gertler, Mark & Karadi, Peter, 2013, "QE 1 vs. 2 vs. 3...: A Framework for Analyzing Large-Scale Asset Purchases as a Monetary Policy Tool," *International Journal of Central Banking*, vol. 9(1), p. 5-53.

[19] Gertler, Mark & Kiyotaki, Nobuhiro, 2010, "Financial intermediation and credit policy in business cycle analysis." In: Friedman, B.M., Woodford, M. (Eds.), *Handbook of Monetary Economics*, vol. 3. Elsevier, Amsterdam.

[20] Hamilton, James D. & Wu, Jing Cynthia, 2012, "The Effectiveness of Alternative Monetary Policy Tools in a Zero Lower Bound Environment," *Journal of Money, Credit and Banking*, vol. 44, Issue s1, p. 3-46.

[21] Hancock, Diana & Passmore, Wayne, 2011, "Did the Federal Reserve's MBS Purchase Program Lower Mortgage Rates?," *Journal of Monetary Economics*, vol. 58(5), p. 498-514.

[22] He, Zhiguo & Krishnamurthy, Arvind, 2012, "Intermediary Asset Pricing," *American Economic Review,* forthcoming.

[23] Iacoviello, Matteo, 2005, "House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle," *American Economic Review*, vol. 95(3), p. 739-764.

[24] Joyce, Michael & Lasaosa, Ana & Stevens, Ibrahim & Tong, Matthew, 2011, "The Financial Market Impact of Quantitative Easing in the United Kingdom," *International Journal of Central Banking,* 7(3), p. 113–161.

[25] Kiyotaki, Nobuhiro & Moore, John, 1997, "Credit Cycles," *Journal of Political Economy*, vol. 105(2), p. 211-248.

[26] Krishnamurthy, Arvind & Vissing-Jørgensen, Annette, 2011, "The Effects of Quantitative Easing on Interest Rates: Channels and Implications for Policy," *Brookings Papers on Economic Activity*, vol. 43(2), p. 215-287.

[27] Li, Canlin & Wei, Min, 2013, "Term Structure Modelling with Supply Factors and the Federal Reserve's Large Scale Asset Purchase Programs," *International Journal of Central Banking*, vol 9(1), p. 3-39.

[28] Smets, Frank & Wouters, Rafael, 2007, "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach," *American Economic Review*, vol. 97(3), p. 586-606.

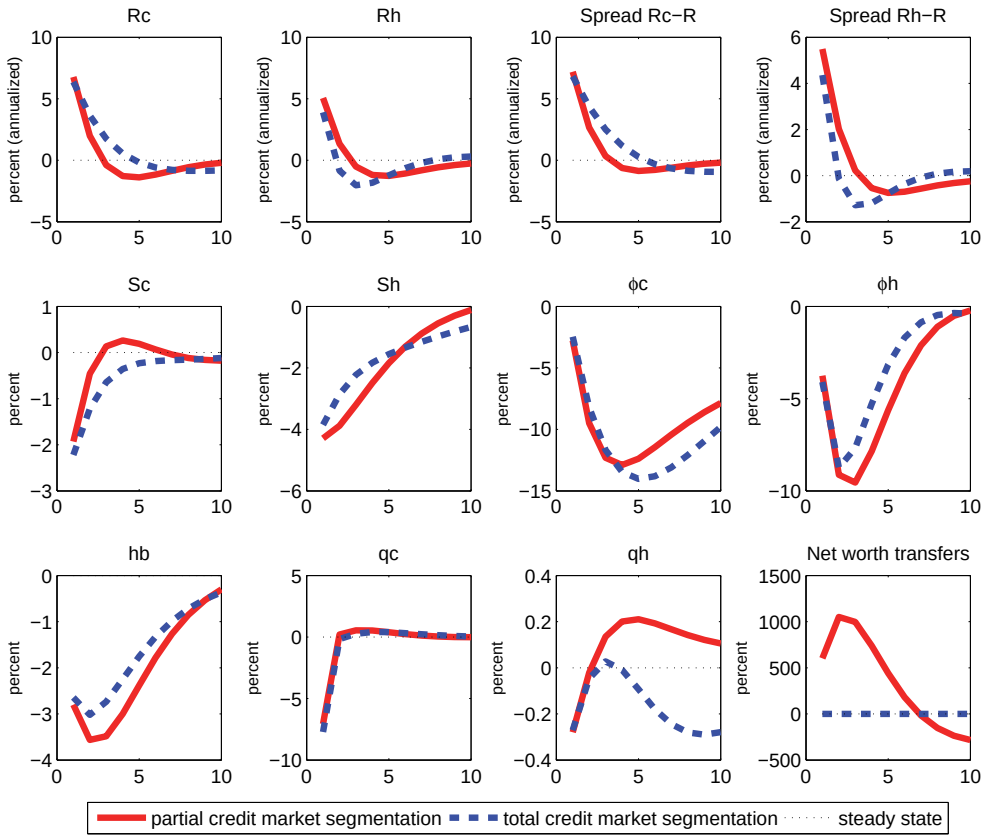
[29] Swanson, Eric, 2011, "Let's Twist Again: A High-Frequency Event-Study Analysis of Operation Twist and Its Implications for QE2", Federal Reserve Bank of San Francisco Working Paper 2011-08.

[30] Vayanos, Dimitri & Vila, Jean-Luc, 2009, "A Preferred Habitat Model of the Term Structure of Interest Rates," LSE, mimeo.

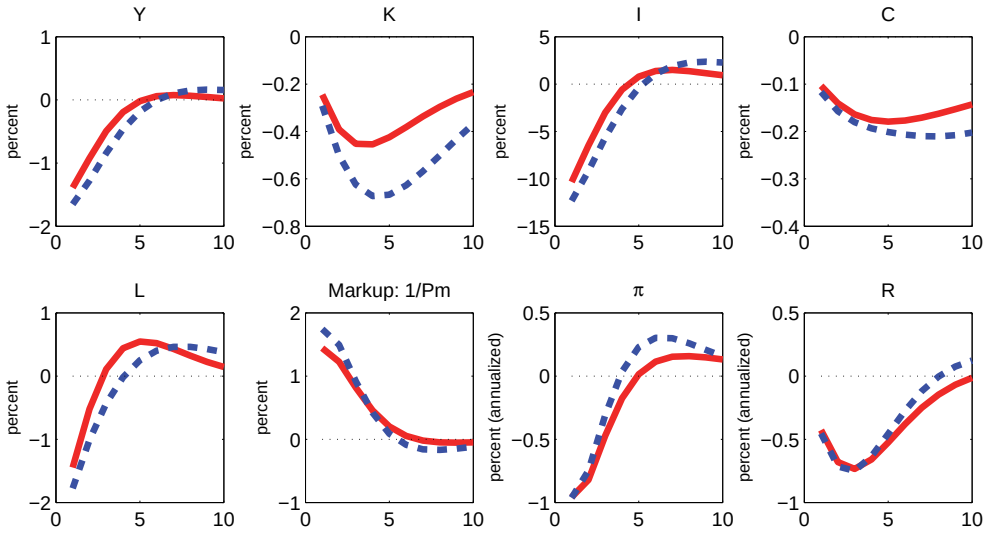
[31] Williamson, Stephen D., 2012, "Liquidity, Monetary Policy, and the Financial Crisis: A New Monetarist Approach", *American Economic Review*, Vol. 102(6), p. 2570–2605.

[32] Woodford, Michael, 2003, *Interest and Prices: Foundations of a Theory of Monetary Policy*, Princeton University Press.

[33] Woodford, Michael, 2012, "Methods of Policy Accommodation at the Interest-Rate Lower Bound," presented at the Federal Reserve Bank of Kansas City Economic Policy Symposium, Jackson Hole, WY, August 31, 2012.

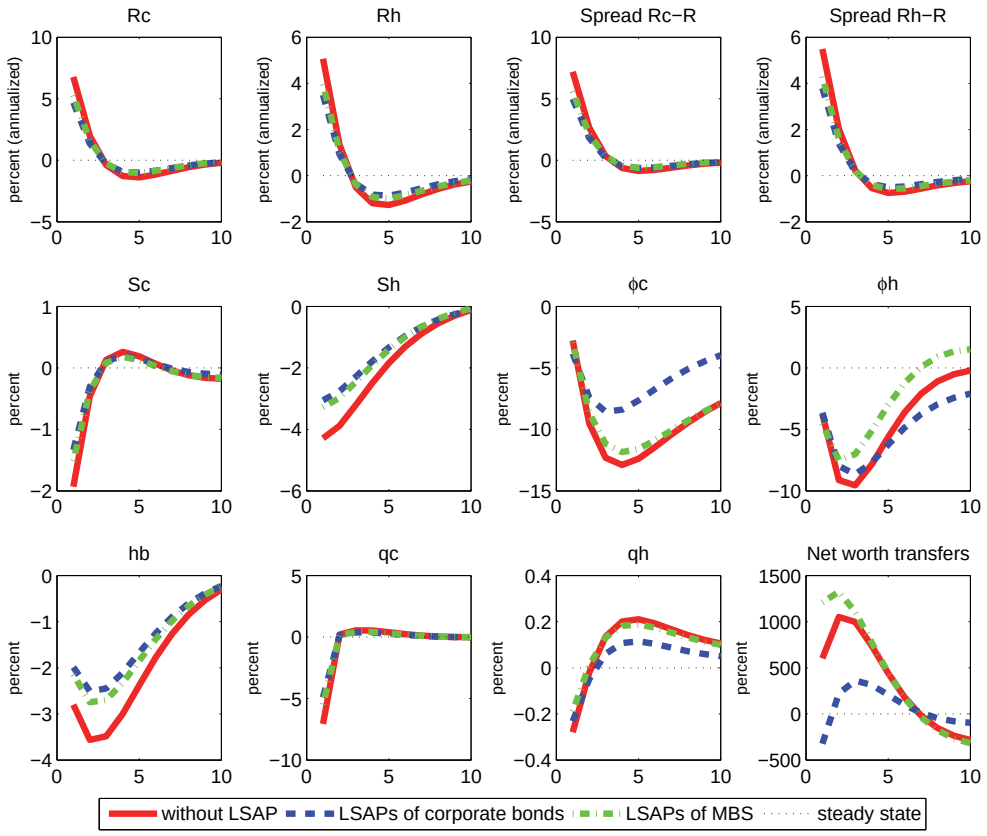


Panel A – Financial and credit market related variables

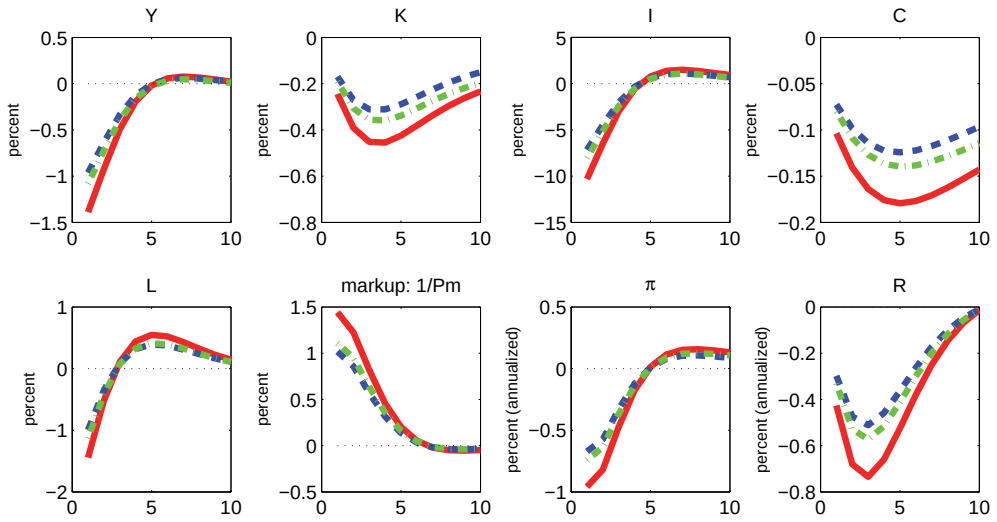


Panel B – "Real economy" variables

Figure 1: Impulse responses to a 5% moral hazard shock

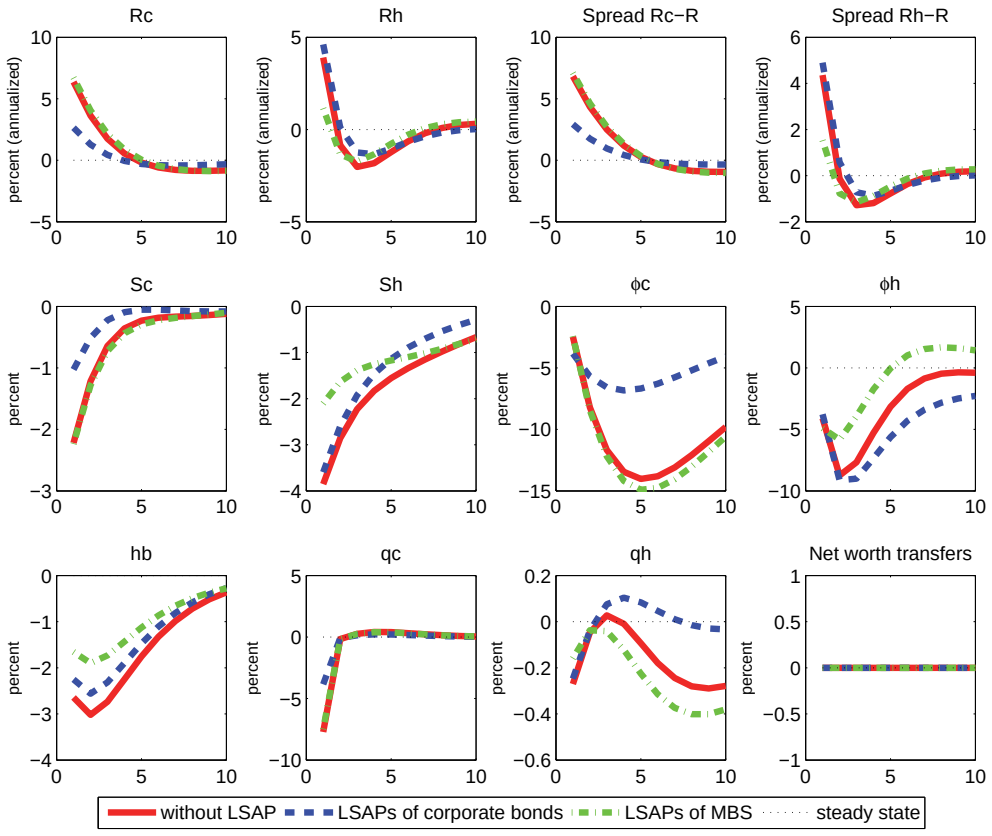


Panel A – Financial and credit market related variables

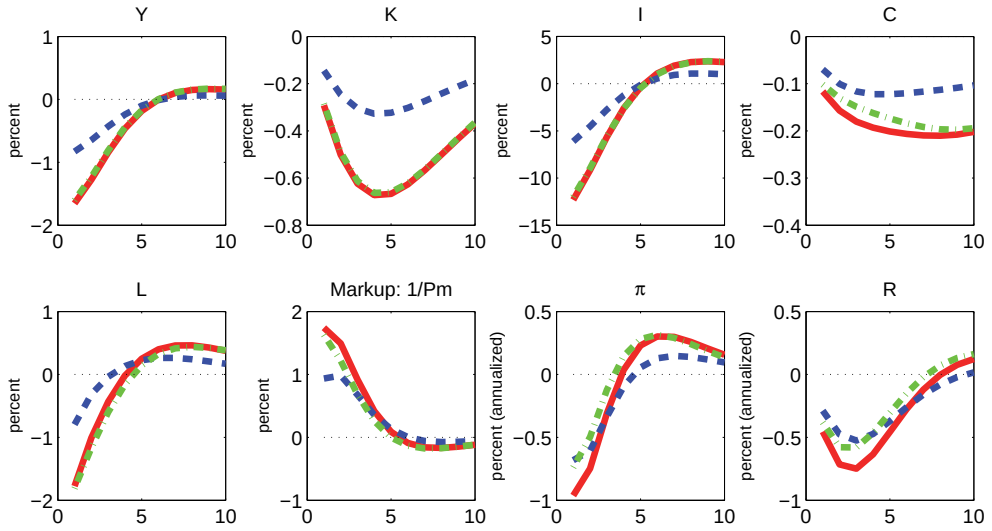


Panel B – "Real economy" variables

Figure 2: LSAPs – partial credit market segmentation



Panel A – Financial and credit market related variables



Panel B – "Real economy" variables

Figure 3: LSAPs – total credit market segmentation