Large Scale Asset Purchases as a Tool of Monetary Policy

Mark Gertler and Peter Karadi

NYU, ECB

February 2012

PRELIMINARY AND INCOMPLETE,
PLEASE DO NOT CIRCULATE!

Abstract

We introduce long-term government bonds along with private credit instruments into a monetary DSGE model with financial intermediaries that face endogenously determined balance sheet constraints. We use it to compare the effects of large-scale purchases of private and government assets after a simulated crisis experiment. Financial intermediaries are the price-setting marginal buyers of both private and government assets, so a crisis that tightens their funding constraints results in a correlated movement in private and government asset yields. We introduce agency frictions that make it more difficult for financial intermediaries to obtain funding for private than for government assets. This implies lower bond premia for government assets, in line with evidence. As a result, purchase of government assets on a comparable scale has smaller effects on yields and the real economy than purchase of private assets. We also show that a binding zero-lower bound on the nominal interest rate substantially amplifies the effects of credit policies, as it limits the offsetting effects of the interest rate rule.

JEL codes: E44, E52

1 Introduction

[TO BE COMPLETED]

2 The Model: Key Ingredients

The framework is based on Gertler and Karadi (2011). It is a reasonably standard New Keynesian model modified to allow for banks that transfer funds from households to non-financial firms, as well as to the government. An agency problem constrains the ability of banks to obtain funds from households. It ultimately makes the balance sheet of the banking sector a critical determinant of the cost of credit that borrowers face. One difference from GK is that banks may intermediate the funding of long term government bonds as well the funding of non-financial firms.

In addition, there is a central bank that can conduct monetary policy either by adjusting the short term interest rate (so long as the zero lower bound is not binding) or by engaging in asset purchases. The central bank may purchase long term government bonds as well as private securities.

In this section we characterize the distinct elements of the model, which involve the behavior of households, banks and the central bank. We defer a description of the production sector and complete equilibrium to the next section. For didactic reasons, we start with the case where banks intermediate all the funding of non-financial firms and long-term government bonds. This simple setup allows us to starkly illustrate some of key results regarding the effects of central bank asset purchases. We then subsequently allow households to directly hold long term securities subject to transactions costs and then draw out the implications of this more general setting.

In the interest of parsimony, we abstract from a number of the features present in conventional quantitative DSGE models that are not central to understanding the effects of central bank asset purchases (e.g, variable capital utilization, wage rigidity, price and wage indexation, etc.). However we include two standard features, habit formation and flow investment adjustment, because they can be added at minimal cost of complexity and they substantially improve the model's quantitative performance.

2.1 Households

There is a continuum of identical households of measure unity. Each household consumes, saves and supplies labor. Households save by lending funds to competitive financial intermediaries and possibly also by lending funds to the central bank.

Within each household there are two types of members: workers and bankers. Workers supply labor and return the wages they earn to the household. Each banker manages a financial intermediary and similarly transfers any earnings back to the household. The household thus effectively owns the intermediaries that its bankers manage. It deposits funds, however, in intermediaries that is does not own. Finally, within the family there is perfect consumption insurance. As will become clear, this simple form of heterogeneity within the family allows us to introduce financial intermediation in a way that maintains much of the tractability of a representative agent framework.

At any moment in time the fraction $1-f$ of the household members are workers and the fraction f are bankers. Over time an individual can switch between the two occupations. In particular, a banker this period stays a banker next period with probability σ, which is independent of history (i.e., of how long the person has been a banker.) The average survival time for a banker in any given period is thus $\frac{1}{1-\sigma}$. We introduce a finite horizon for bankers to insure that over time they do not retain earnngs to the point where they can fund all investments from their own capital. Thus every period $(1-\sigma)f$ bankers exit and pay out there retained earnings as dividends to their respective household. The bankers who exit become workers and are replaced by a similar number of workers randomly become bankers, keeping the relative proportion of each type fixed. The household, though, provides its new bankers with a small amount of start up funds equal to $\frac{X}{(1-\sigma)f}$ per new banker.

Let C_t be consumption and L_t family labor supply. Then the households discounted utility u_t is given by

$$u_t = E_t \sum_{i=0}^{\infty} \beta^i \left[\ln(C_{t+i} - hC_{t+i-1}) - \frac{\chi}{1+\varphi} L_{t+i}^{1+\varphi} \right] \tag{1}$$

with $0 < \beta < 1$, $0 < h < 1$ and $\chi, \varphi > 0$. As in Woodford (2003), we consider the limit of the economy as it become cashless, and thus ignore the convenience yield to the household from real money balances.

Both intermediary deposits and government debt are one period real bonds that pay the gross real return R_t from $t-1$ to t. In the equilibrium we consider, the instruments are both riskless and are thus perfect substitutes. Thus, we impose this condition from the outset. Thus let D_{ht} be the total quantity of short term debt the household acquires, W_t, be the real wage, Π_t payouts to the household from ownership of both non-financial and financial firms and, T_t lump sum taxes. Then the household budget constraint is given by

$$C_t = W_t L_t + \Pi_t - X + T_t + R_t D_{ht-1} - D_{ht} \tag{2}$$

where X is the total transfer the household gives to its members that enter banking at t. Finally, as will be clear later, it will not matter in our model whether households hold government debt directly or do so indirectly via financial intermediaries (that in turn issue deposits to households.)

The household's objective is to choose C_t, L_t, and D_{ht} to maximize (1) subject to (2). Let $u_{C_t t}$ denote the marginal utility of consumption. Then the first order conditions for labor supply and consumption/saving are standard:

$$u_{C_t} W_t = \chi L_t^{\varphi} \tag{3}$$

$$E_t \Lambda_{t,t+1} R_{t+1} = 1 \tag{4}$$

with

$$\Lambda_{t,t+1} \equiv \beta \frac{u_{C_{t+1}}}{u_{C_t}}$$

2.2 Banks

Banks lend funds obtained from households to non-financial firms and to the government. In addition to acting as specialists that assist in channeling funds from savers to investors, they engage in maturity transformation. They hold long term assets and fund these assets with short term liabilities (beyond their own equity capital.)[1] In addition, financial intermediaries in this model are meant to capture the entire banking sector, i.e. investment banks as well as commercial banks.

[1] In Gertler and Kiyotaki (2010), we consider a generalization of this framework that has banks manage liquidity risks (stemming from idiosyncratic shocks to firm investment opportunities) via an interbank market. In this setup, financial frictions may also affect the functioning of the interbank market.

Intermediaries fund two type of activities: First, they make loans to non-financial firms to finance capital. Let Z_t be the net period income flow to the bank from a loan that is financing a unit of capital, Q_t, the market value of the security, δ the depreciation rate of a unit of capital and ψ_t a random disturbance. Then the rate of return to the bank on the loan, R_{kt+1}, is given by:

$$R_{kt+1} = \frac{Z_{t+1} + (1-\delta)Q_{t+1}}{Q_t}\psi_{t+1}$$

The variables Z_t, Q_t , and ψ_t are determined in the general equilibrium of the model, as we show later.

In addition, banks hold long term government bonds. Here we suppose that it is too costly for households to directly manage long term bonds in their portfolios. As we noted earlier, we relax this assumption by permitting household to directly hold long term securities subject to explicit transactions costs. For our benchmark model, however, banks intermediate all the funding of long term bonds. We assume each bond is a perpetuity that pays one dollar per period indefinitely. Let q_t be the price of the bond and P_t the price level. Then the rate of return on the bond R_{bt+1} is given by

$$R_{bt+1} = \frac{1/P_t + q_{t+1}}{q_t}$$

The general equilibrium also determines P_t and q_t

2.2.1 The Bank's Maximization Problem

Let n_t be the amount of equity capital - or net worth - that a banker/intermediary j has at the end of period t; d_t the deposits the intermediary obtains from households, s_t the quantity of financial claims on non-financial firms that the intermediary holds and b_t the quantity of long term government bonds. The intermediary balance sheet is then given by

$$Q_t s_t + q_t b_t = n_t + d_t \tag{5}$$

Net worth is accumulated through retained earnings. It is thus the difference between the gross return on assets and the cost of liabilities:

$$n_t = R_{kt} Q_{t-1} s_{t-1} + R_{bt} q_{t-1} b_{t-1} - R_t d_{t-1} \tag{6}$$

The banker's objective is to maximize the discounted stream of payouts back to the household, where the relevant discount rate is the household's intertemporal marginal rate of subsitution, $\Lambda_{t,t+i}$. Under frictionless capital markets the timing of the payouts is irrelevant. To the extent the intermediary faces financial market frictions, it is optimal for the banker to retaining earnings until exiting the industry. Accordingly, the banker's objective is to maximize expected terminal wealth, given by

$$V_t = E_t \sum_{i=1}^{\infty} (1-\sigma)\sigma^{i-1}\Lambda_{t,t+i} n_{t+i} \tag{7}$$

To motivate a limit on the bank's ability to obtain deposits, we introduce the following moral hazard/costly enforcement problem: At the beginning of the period the banker can choose to divert funds from the assets it holds and transfer the proceeds to the household of which he or she is a member.[2] The cost to the banker is that the depositors can force the intermediary into bankruptcy and recover the remaining fraction of assets. However, it is too costly for the depositors recover the funds that the banker diverted.

We assume that it is easier for the bank to divert funds from its holdings of private loans than from its holding of government bonds: In particular, it can divert the fraction θ of its provate loan porfolio and the fraction $\alpha\theta$ with $0 \leq \alpha < 1$, from it government bond portfolio. Here we are attempting to capture is a simple way that the bank's private loan portfolio is likely an easier target for bank malfeasance than its government bond portfolio given that it is more difficult for depositors to monitor the performance of latter than the former.

Accordingly for depositors to be willing to supply funds to the banker, the following incentive constraint must be satisfied

$$V_t \geq \theta Q_t s_t + \alpha\theta q_t b_t. \tag{8}$$

The left side is what the banker would lose by diverting a fraction of assets. The right side is the gain from doing so.

The bankers maximization problem is to choose s_t, b_t and d_t to maximize (7) subject to (5), (6) (8).

[2]One way the banker may divert assets is to pay out large bonuses and dividends to the household.

2.2.2 Solution

Let λ_t be the Lagrange multiplier associated with the incentive constraint (8) and let $\widetilde{\Lambda}_{t,t+1}$ be the bank's "augmented" stochastic discount factor, equal to the product $\Lambda_{t,t+i}$ and the multplier Ω_{t+1}:

$$\widetilde{\Lambda}_{t,t+1} \equiv \Lambda_{t,t+1} \cdot \Omega_{t+1} \tag{9}$$

where the Ω_{t+1} reflects the shadow value of a unit of net worth to the bank at $t+1$, as we make clear shortly. Then we can characterize the solution as follows:

The expected excess returns on bank assets satisfy

$$E_t \widetilde{\Lambda}_{t,t+1}(R_{kt+1} - R_{t+1}) = \frac{\lambda_t}{1+\lambda_t}\theta \tag{10}$$

$$E_t \widetilde{\Lambda}_{t,t+1}(R_{bt+1} - R_{t+1}) = \alpha \cdot \frac{\lambda_t}{1+\lambda_t}\theta \tag{11}$$

When the incentive constraint is not binding the discounted excess returns are zero. With $\lambda_t = 0$, $\forall\ t$,financial markets are frictionless: Banks acquire assets to the point where the discounted return on each asset, equals the discounted cost.of deposits. Further, in this case Ω_{t+1} equals unity, so that for each asset the standard arbitrage condition under perfect markets arises: The expected product of the households' intertemporal marginal rate of substitution and the excess return equals zero.

When the incentive constraint is binding, however, limits to arbitrage emerge that lead to positive excess returns in equilibrium. The excess returns increase with how tightly the incentive constraint binds, as measured by the multiplier λ_t. Note that the excess return to capital implies that for a given riskless interest rate, the cost of capital is higher than would otherwise be. As consequence, investment and real activity will be lower than would be otherwise in general equilibrium. Indeed, a financial crisis in the model will involve a sharp increase in the excess return to capital.

Notice also that the excess return on government bonds is smaller than the excess return on loans by the multiple $\alpha < 1$. This occurs because the proportion of funds a bank can divert from its bond portolio is only the fraction α of the proportion it can divert from its loan portfolio. As a result the incentive friction that limits arbitrage is weaker for government bonds than for loans by the factor α.

The limits to arbitrage stem from the following restriction that the incentive constraint places on the size of a bank's portfolio relative to its net worth:

$$\begin{aligned} Q_t s_t + \alpha q_t b_t &= \phi_t n_t \text{ if } \lambda_t > 0; \\ &< \phi_t n_t \text{ if } \lambda_t = 0 \end{aligned} \tag{12}$$

with

$$\phi_t = \frac{E_t \widetilde{\Lambda}_{t,t+1} R_{t+1}}{\theta - E_t \widetilde{\Lambda}_{t,t+1}(R_{kt+1} - R_{t+1})} \tag{13}$$

The measure of assets that enters the bank's balance sheet constraint applies a weight of α to government bonds, reflecting the weaker constraint on arbitrage for this asset than for loans. As the bank expands this adjusted measure of assets by issuing deposits, its' incentive to divert funds increases. The constraint (**??**) limits the portfolio size to the point where the bank's incentive to cheat is exactly balanced by the cost of losing the franchise value. In this respect the agency problem leads to an endogenous capital constraint
.

Observe that ϕ_t is the maximum ratio of the adjusted measure of assets to net worth that the bank may hold without violating the incentive constraint. It depends inversely on θ; An increase in the bank's incentive to divert funds reduces the amount depositors are willing to lend. Conversely, an increase in the discounted excess return on assets, $E_t \widetilde{\Lambda}_{t,t+1}(R_{kt+1} - R_{t+1})$, or the discounted safe rate, $E_t \widetilde{\Lambda}_{t,t+1} R_{t+1}$,increases the franchise value of the bank, V_t reducing the bank's incentive to divert funds. Depositors thus become willing to lend more, raising ϕ_t.

Finally, the weight Ω_{t+1} that augments the bank's discount factor is the marginal value of net worth averaged across exiting and continuing states:

$$\Omega_{t+1} = 1 - \sigma + \sigma \frac{\partial V_{t+1}}{\partial n_{t+1}} \tag{14}$$

with

$$\frac{\partial V_t}{\partial n_t} = E_t \widetilde{\Lambda}_{t,t+1}[(R_{kt+1} - R_{t+1})\phi_t + R_{t+1}]$$

With probability $1 - \sigma$ the bank exits and has a marginal value of net worth of unity since it simply transfers its retained earnings to the household. With probability σ it continues and uses the net worth to expand its base asset base. So long as the excess returns on assets are positive, the marginal value $\frac{\partial V_t}{\partial n_t}$ exceeds unity.

2.2.3 Aggregation

Let S_{pt} be the total quantity of loans that banks intermeduate, B_{pt} the total number of government bonds they hold. and N_t their total net worth. Since all the components of the maximum adjusted leverage ratio ϕ_t do not depend on bank specific factors, we can simply sum across the portfolio restriction on each individual bank (12) to obtain

$$Q_t S_{pt} + \alpha q_t B_{pt} \leq \phi_t N_t \tag{15}$$

Equation (15) restricts the aggregate value of (adjusted) assets that the banking systen can hold to be less than or equal to the multiple ϕ_t of total bank capital. When the constraint is binding, variation in N_t, will induce fluctuations in overall asset demand by intermediaries. Indeed, in the general equilibrium of the model, a crisis will feature a sharp contraction in N_t.

Total net worth evolves as the sum of the retained earnings by the fraction σ of surviving bankers and the transfers that new bankers receive, X, as follows.

$$N_t = \sigma[(R_{kt} - R_t)\frac{Q_{t-1}S_{pt-1}}{N_{t-1}} + (R_{bt} - R_t)\frac{q_{t-1}B_{pt-1}}{N_{t-1}} + R_t]N_{t-1} + X \tag{16}$$

The main sources of variation in N_t are fluctuations in the ex post return on loans R_{kt} and the ex post return on bonds R_{bt}. Further, the percentage impact of this return variation on N_t in each case, is increasing in the bank's degree of leverage, reflected by the respective ratios of assets to net worth, $Q_{t-1}S_{pt-1}/N_{t-1}$ and $q_{t-1}B_{pt-1}/N_{t-1}$.

2.3 Central Bank Asset Purchases

As equations (10) and (11) suggest, if private intermediation is balance sheet constrained, excess returns on assets arise. If these constraints are particularly tight, as would be the case in a financial crisis, then excess returns will be unusually high, with negative consequences for the cost of capital and real activity. Within our model, large scale asset purchases provide a way for the central bank to reduce excess returns and thus mitigate the consequences of a disruption of private intermediation.

In particular, we now allow the central bank to purchase quantities private loans S_{gt} and loan term government bonds B_{gt} . For each each type of security it pays the respective market prices Q_t and q_t. Though when limits to arbitrage in the private market are operative, the central bank's acquisition of securities will have the effect of bidding up the prices on each of these instruments and down the excess returns. To finance these purchases, it issues riskless short term debt D_{gt} that pays the safe market interest rate R_{t+1}. In particular, the central bank's balance sheet is given by

$$Q_t S_{gt} + q_t B_{gt} = D_{gt} \tag{17}$$

where we assume that the central bank turns over any profits to the Treasury and receives transfers to cover any losses. For the time being we suppose that the central bank issues the short term debt to households. Later we discuss an equivalent scenario where D_{gt} is interpretable as interest bearing reserves (essentially overnight government debt) held by banks on account at the central bank.

As we discussed earllier, these kinds of asset purchases essentially involve substituting central bank intermediation for private intermediation. What gives the central bank an advantage in this situation is that, unlike private intermediaries it is able to obtain funds elastically by issuing short term liabilities. It is able to do so because within our framework the government can always commit to credibly honoring its debt. Accordingly, there is no agency conflict than inhibits the central bank from obtaining funds from the private sector. Put differently, in contrast to private financial intermediation, central bank intermediation is not balance sheet constrained.[3]

At the same time, we allow for the central bank being less efficient than the private sector at making loans. In particular, we assume the central bank pays an efficiency cost of τ_s per unit of private loans intermediated and τ_b per unit of government bonds. Accordingly, for asset purchases to produce welfare gains, the central bank's advantage in obtaing funds cannot be offset

[3]As Wallace (1981) originally noted, for government financial policy to matter it is important to identify what is special about government intermediation. Sargent and Wallace (1981) provide an early example of how credit policy could matter, based on a setting of limited participation in credit markets.

by its disdvantage in making loans. It's advantage in obtaining funds is greatest when excess returns are large (i.e when limits to private arbitrage are tight), as will be the case in a financial crises. As for its disadvantage in making loans: It is reasonable to suppose τ_b is small. For τ_s, it depends on the type of credit instrument. The types of "private loans" for which one might expect τ_s to be small include highly rated securitized assets such as agency mortgage backed securities as opposed to commercial and industrial loans that involve extensive monitoring. Accordingly, it is the former type of instrument we have in mind in charactering central bank purchases of private securities as opposed to the latter.

The way asset purchases affect the real economy is ultimately by affecting the price Q_t and (hence the) excess return on capital $E_t\widetilde{\Lambda}_{t,t+1}(R_{kt+1} - R_{t+1})$. Accordingly, let S_t and B_t be the total supplies of private loans and long term government bonds, respectively. Then by definition:

$$\begin{aligned} S_t &= S_{pt} + S_{gt} \\ B_t &= B_{pt} + B_{gt} \end{aligned} \tag{18}$$

where as before S_{pt} and B_{pt} are the total amounts that are privately intermediated. We combine these identities with the balance constraint on the banks to obtain the following relation for total the total value of private securities intermediated, Q_tS_t :

$$Q_tS_t \leq \phi_tN_t + Q_tS_{gt} + \alpha(q_tB_{gt} - q_tB_t) \tag{19}$$

When the aggregate balance sheet constraint is not binding, asset price and returns are determined by frictionless arbitrage. Asset purchases by the central bank of either private loans or long term bonds are neutral. They simply lead to central bank intermediation displacing some private intermediation, without any effect on asser prices. To the extent central bank intermediation involves efficiency costs, further, asset purchases are clearly welfare reducing in this kind of environment.

This neutrality result disappears, however, if the constraint is binding.. Given the total quantity of bank equity, an increase in the central bank's holding of either private securities or long term governments raises the total demand for private securities. Intutitively, with limits to arbitrage present on private credit flows, central bank intermediation expands overall asset demand and does not simply displace bank intermediation one for one. Further, given that asset supplies are relatively inelastic in the short run, the enhanced asset demand pushes up Q_t and down the excess return on capital.

Equation (19) also reveals that it matters which asset the central bank acquires. In particular, purchases of government bonds will have a weaker effect on the demand for private assets than would the the direct purchase of this asset by the factor $\alpha < 1$. Intuitively, the central bank acquiring government bonds frees up less bank capital than does the does the acquisition of a similar amount of private loans. It is effectively by freeing up intermediary capital that asset purchases are able to expand the overall demand for private assets. In the limiting case of frictionless arbitrage in the government bond market (i.e., $\alpha = 0$), bond purchases have no effect.

Purchases of either asset affect the excess returns of both due to the arbitrage relation implied by equations (10) and (11):

$$E_t\widetilde{\Lambda}_{t,t+1}(R_{bt+1} - R_{t+1}) = \alpha E_t\widetilde{\Lambda}_{t,t+1}(R_{kt+1} - R_{t+1}) \tag{20}$$

As we noted earlier, though, because limits to arbitrage are weaker for government bonds than for private securities, the excess return on the former is only the fraction α of the excess return on the latter. Thus, everything else equal, in the wake of an asset purchase, government bond yields should move by less than the yield on private securities. This should hold regardless of which asset the central bank purchases.

Finally, up to this point we have assumed that the central bank funds assets purchases by issuing short term debt directly to households. An equivalent formulation has the central bank issue the debt directly banks which in turn fund this activity by issuing deposits to households. The short term government debt that banks absorb, further, can take the form of interest bearing reserves held on account at the central bank, as was the case in practice for the most part.. Assuming that the agency friction does not apply to intermediating reserves, the bank will not be constrained in its funding of this asset. Thus, as in the baseline scenario, the central bank is able to elastically issue short term liabilities to fund its asset purchases. It is straightforward to show that the equilibrium conditions in the scenario are identical to those in the baseline case. The identical balance sheet constraint on bank asset holdings applies.

2.4 Allowing for Direct Household Securities Holdings

We now permits households to directly private securities and long term government bonds. However, we introduce limitis on household participation by assuming transaction costs. Absent, these costs households would engage in frictionless arbitrage of asset returns.

We suppose that for private securities a household faces a holding cost equal to the percentage $\frac{1}{2}\kappa_s(S_{ht}-\overline{S}_h)^2/S_{ht}$ of the value of the securities in its respective portfolio, $S_{ht} \geq \overline{S}_h$. Similarly, for government bonds there is a holding cost equal to the percentage $\frac{1}{2}\kappa_s(B_{ht}-\overline{B}_h)^2/B_{ht}$ of the total value of government bonds held for $B_{ht} \geq \overline{B}_h$. Accordingly, there is a certain amount of each asset that the household can hold costlessly. Going above these levels involves transactions costs which are increasing at the margin. We motivate this cost structure as capturing in a simply way limited participation is asset markets by households that leads to incomplete arbitrage.

Accordingly, the household budget constraint becomes

$$\begin{aligned} & C_t + D_{ht} + Q_t[S_{ht} + \frac{1}{2}\kappa_s(S_{ht}-\overline{S}_h)^2] + q_t[B_{ht} + \frac{1}{2}\kappa_s(B_{ht}-\overline{B}_h)^2] \\ = \; & W_t L_t + \Pi_t + T_t + R_t D_{ht-1} + R_{kt} S_{ht-1} + R_{bt} B_{ht-1} \end{aligned} \tag{21}$$

Resolving the household's optimization yields the same first order conditions for labor supply and deposits as before. The choices for private securities and long term government bonds are given by

$$\begin{aligned} S_{ht} &= \overline{S}_h + \frac{E_t \Lambda_{t,t+1}(R_{kt+1} - R_{t+1})}{\kappa_s} \\ B_{ht} &= \overline{B}_h + \frac{E_t \Lambda_{t,t+1}(R_{bt+1} - R_{t+1})}{\kappa_b} \end{aligned} \tag{22}$$

Demand for each asset above its frictionless capacity level is increasing in the excess return relative to the respective curvature parameter that governs the marginal transaction cost. Note that as marginal transactions cost go to zero, excess returns disappear: Households are able to engage is frictionless arbitrage of security returns. Conversely, as marginal transactions costs go to infinity, households asset demands go to their respective frictionless capacity values, $\overline{S}_h$ and $\overline{B}_h$.

Overall, one can view the household asset demand structure as a parsimonious way to capture two important forms of heterogeneity that are absent from the model. First, in reality, a sizeable fraction of non-financial firms are able to obtain funds by issuing securities directly to households on the open market and do not have to borrow directly from banks. These firms are typically large well established entities, in contrast to younger and smaller non-financial borrwers that typically require the kind evaluation and monitoring services that banks offer. Second, households differ in their ability to manage a sophisticated portfolio:A limited supply of "sophisticated" households accordingly prevents frictionless arbitrage of security returns by the household sector. In practice both forms of heterogenity help explain why both private and government securities holdings are divided between households and banks. Our model provides a very simple way to account for this pattern of asset holdings.that is meant to be a stand-in for a more explicit treatment.

With households directly participating in securities markets, the equilibrium conditions in the markets for private loans and government bonds now require:

$$\begin{aligned} S_t &= S_{pt} + S_{ht} + S_{gt} \\ B_t &= B_{pt} + B_{ht} + B_{gt} \end{aligned} \tag{23}$$

To understand the implications for central bank asset purchases, note that with direct household participation in securturies markets we can rewrite the aggregate bank portfolio constraint (19) as

$$Q_t(S_t - S_{ht}) \leq \phi_t N_t + Q_t S_{gt} + \alpha q_t[B_{gt} - (B_t - B_{ht})] \tag{24}$$

with S_{ht} and B_{ht} given by (22). The portfolio constraint is now a restricton on the total demand for securities net the quantity held be households.

In this general case, the effects of asset purchases on prices and excess returns depend on the responsive of household as well as bank portfolios to arbitrage opportunities. Consider first the case where the the marginal transaction costs facing the household are infinity (i.e. $\kappa_s = \infty$). In this instance, a household holds the respective frictionless capacity value of each asset, $\overline{S}_h$ and $\overline{B}_h$ and is completely unresponsive to arbitrage opportunities. Here the analysis is very similar to the simple case of no direct household participaton analyzed in section xx. If the portfolio constraint is not binding, then as before banks adjust their asset holding to drive excess returns to zero. Even though households cannot absorb additional securities, they are willing to absorb deposits which do not involve transactions.costs. Given that banks are free to arbitrage returns central bank asset purchases are neutral. An increase in either S_{gt} or B_{gt} simply leads to a one for one reduction in private bank intermediation of the respective security without any impact on prices or returns.

If the portfolio constraint binds then, as in the simple case of section xx, asset purchases increase the net demand for private securities. The presence of inelastic household security demands, further, strengthens of a given size purchase of either security. It does so by reducing the participation of the active traders in the market.(in this case the banks). Because everything else equal the purchases are larger relative to bank holdings of the respective asset, they will have a larger impact on prices and returns. These results are consistent with the that asset prices depend and asset supplies if household demand is relative inelastice (e.g for "preferred habitat" reasons.) We stress, however, that it is also key that arbitrage by the active traders in the market in the limited. Absent the balance sheet constraint on banks, asset purchases would be neutral despite inelastic asset demands by households.

As household security demands become increasing elastic (κ_s and κ_b move toward zero), the effects of central bank asset purchases weaken. As before, assuming total supplies of each asset are inelastic in the short run, central bank purchases of either security will place downward pressure on excess returns. A decline in excess returns, however, reduces households' security holdings, dampening the overall effect of the purchases on asset demands. Put differently, household asset demands move in a way that offsets the effect of central bank asset purchases. This offsetting effect becomes stronger as transactions cost become smaller. In the limiting case of zero transactions cost, of course, households are able to perfectly arbitrage and central bank asset purchases are neutral.

In sum, for central bank asset purchase to affect asset prices and returns, limites to arbitrage must be present for both households and banks.

3 The Production Sector, Government, and Equilibrium

We now close the model by describing the non-financial production sector, government policy, and the general equilibrium.

3.1 Non-financial Firms

There are five three types of non-financial firms in the model: intermediate goods producers, capital producers, and monopolistically competitive retailers. The latter are in the model only to introduce nominal price rigidities. We describe each in turn.

3.1.1 Intermediate Goods Producers

Intermediate goods producers make output that the sell to retlailers. They are competitive and earn zero profits in equilibrium. Each operates a constant returns to scale technology with capital and labor inputs. Let Y_t be output, A_t total factor productivity, L_t labor, K_t capital, Then:

$$Y_t = A_t(K_t)^{\alpha} L_t^{1-\alpha} \tag{25}$$

Let P_{mt} be the relative price of intermediate goods. Then the firm's demand for labor is given by

$$W_t = P_{mt}(1-\alpha)\frac{Y_t}{L_t} \tag{26}$$

It follows that we may express gross profits per unit of capital Z_t as follows:

$$Z_t = P_{mt}\alpha\frac{Y_t}{K_t}. \tag{27}$$

The acquisition of capital works as follows. At the end of any period t, the intermediate goods producer is left with a capital stock of $(1-\delta)K_t$. It then buys I_t units of new capital from capital producers. Its capital stock for $t+1$ is then given by

$$K_{t+1} = \psi_{t+1}[I_t + (1-\delta K_t] \tag{28}$$

where ψ_t is a random disturbance that we refer to as a "capital quality" shock. Following the finance literature (e.g., Merton (1973)), we introduce the capital quality shock as a simple way to introduce an exogenous source of variation in the return to capital[4]. It is best thought of as capturing some

[4]Other recent papers that make use of this kind of disturbance include, Gertler and Karadi (2009), Brunnermeier and Sannikov (2009) and Gourio (2009).

form of economic obsolescence, as opposed to physical depreciation.[5]

To finance the new capital, the firm must obtain funding from a bank. For each new unit of capital it acquires it issues a state-contingent claim to the future stream of earnings from the unit: $\psi_{t+1}Z_{t+1}, (1-\delta)\psi_{t+1}\psi_{t+2}Z_{t+2}, (1-\delta)^2\psi_{t+1}\psi_{t+2}\psi_{t+3}Z_{t+3},$ .etc. As we discussed, earlier, banks are able to perfectly monitor firms and enforce contracts. As a result, through competition, the security the firm issues is perfectly state-contingent.with producers earning zero profits state=by-state. In addition, the value of the security Q_t is equal to the market price of the capital underlying security. Finally, the perod $t+1$ payoff is $(Z_{t+1} + (1-\delta)Q_{t+1})\psi_{t+1}$: the sum gross profits and the value of the leftover capital multipled by the capital quality shock, which corresponds to the definition of the rate of return in equation x.

Before proceeding, It is worth emphasizing that the financial frictions that banks face in obtaining funds from depositors affect the cost of capital to non-financial firms. As we saw in the section xx, the capital constraints on banks limit the supply of funds they can intermediate, which raises loan rates. As we illustrate later, a financial crisis sharply sharply tightens these capital constraints.

3.1.2 Capital Goods Producers

Capital producers make new capital using input of final output and subject to adjustment costs. They sell the new capital to firms at the price Q_t. Given that households own capital producers, the objective of a capital producer is to choose I_t to solve:

$$\max E_t \sum_{\tau=t}^{\infty} \Lambda_{t,\tau} \left\{ Q_\tau^i I_\tau - \left[1 + f\left(\frac{I_\tau}{I_{\tau-1}}\right)\right] I_\tau \right\} \tag{29}$$

[5]One way to motivate this disturbance is to assume that final output is a C.E.S. composite of a continuum of intermediate goods that are in turn produced by employing capital and labor in a Cobb-Douglas production technology. Suppose that, once capital is installed, capital is good-specific and that each period a random fraction of goods become obsolete and are replaced by new goods. The capital used to produced the obsolete goods is now worthless and the capital for the new goods is not fully on line. The aggregate capital stock will then evolve according to equation. (**??**).

From profit maximization, the price of capital goods is equal to the marginal cost of investment goods production as follows,

$$Q_t = 1 + f\left(\frac{I_t}{I_{t-1}}\right) + \frac{I_t}{I_{t-1}} f'(\frac{I_t}{I_{t-1}}) - E_t \Lambda_{t,t+1} (\frac{I_{t+1}}{I_t})^2 f'(\frac{I_{t+1}}{I_t}) \tag{30}$$

Profits (which arise only outside of steady state), are redistributed lump sum to households.

3.1.3 Retail Firms

Final output Y_t is a CES composite of a continuum of mass unity of differentiated retail firms, that use intermediate output as the sole input. The final output composite is given by

$$Y_t = \left[\int_0^1 Y_{ft}{}^{\frac{\varepsilon-1}{\varepsilon}} df\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{31}$$

where Y_{ft} is output by retailer f.

Retailers simply re-package intermediate output. It takes one unit of intermediate output to make a unit of retail output. The marginal cost is thus the relative intermediate output price P_{mt}. We introduce nominal rigidities following Calvo. In particular, each period a firm is able to freely adjust its price with probability $1 - \gamma$. Accordingly, each firms chooses the reset price P_t^* to mazimize expected discounted profits subject to the restriction on the adjustment frequency. Following standard arguments, the first order necessary condition for this problem is given by:

$$\sum_{i=0}^{\infty} \gamma^i \beta^i \Lambda_{t,t+i} \left[\frac{P_t^*}{P_{t+i}} - \mu P_{mt+i}\right] Y_{ft+i} = 0 \tag{32}$$

with $\mu = \frac{1}{1-1/\varepsilon}$. From the law of large numbers, the following relation for the evolution of the price level emerges.

$$P_t = \left[(1-\gamma)(P_t^*)^{1-\varepsilon} + \gamma(P_{t-1})^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}} \tag{33}$$

3.2 Government Policy

Government expenditures consumption of: government consumption, which we hold fixed at G, and the net interest payments from an exogenously fixed stock of long term government debt, which we fix at $\overline{B}$. Revenues consist of of lump sum taxes and the earnings from central bank intermediation net transaction costs. As discussed in section x, central bank asset purchases are financed by short term government debt. Given the central bank balance sheet (17), we can express the consolidated government budget constraint as:

$$G+(R_{bt}-1)\overline{B}=T_t+(R_{kt}-R_t-\tau_s)Q_{t-1}S_{gt-1}+(R_{kt}-R_t-\tau_g)q_{t-1}B_{gt-1} \quad (34)$$

where government bonds, B_{gt-1}, finance total government intermediated assets, $Q_t\psi_{t-1}S_{t-1}$.

We suppose monetary policy is characterized by a simple Taylor rule. Let i_t be the net nominal interest rate, i the steady state nominal rate, and Y_t^* the natural (flexible price equilibrium) level of output. Then:

$$i_t = i + \kappa_\pi \pi_t + \kappa_y(\log Y_t^* - \log Y_t) + \epsilon_t \quad (35)$$

and where ϵ_t is an exogenous shock to monetary policy, and where the link between nominal and real interest rates is given by the following Fisher relation

$$1 + i_t = R_{t+1}\frac{P_{t+1}}{P_t} \quad (36)$$

We suppose that the interest rate rule is sufficient to characterize monetary policy in normal times. In a crisis, however, we allow for large scale asset purchases. In particular, we suppose that at the onset of a crisis, which for we define loosely to mean a period where excess returns rise sharply, the central bank purchases the fraction φ_{st} of the outstanding stock of private securities and the fraction φ_{st} of the outstanding stock of long term government bonds:

$$\begin{aligned} S_{gt} &= \varphi_{st}S_t \\ B_{gt} &= \varphi_{st}B_t \end{aligned}$$

where both φ_{st} and φ_{bt} obey frist prder stationary stochastic processes. In the next section we claridy how the central bank intervenes in a crisis with asset purchases.

3.3 Resource Constraint and Equilibrium

Output is divided between consumption, investment, government consumption, and expenditures on central bank intermediation.Φ_t The economy-wide resource constraint is thus given by

$$Y_t = C_t + [1 + f\left(\frac{I_t}{I_{t-1}}\right)]I_t + G + \Phi_t \tag{37}$$

with $\Phi_t = \tau_s Q_{t-1} S_{gt-1} + \tau_g q_{t-1} B_{gt-1}$.

Finally, to close the model market clearing in market for private securities, long term government bonds and labor. The supply of private securities at the end of period t is given by the sum of newly acquire capital I_t and leftover capital $(1-\delta)\,K_t$:

$$S_t = I_t + (1-\delta)\,K_t \tag{38}$$

The supply of long term government bonds is fixed by the government

$$B_t = \overline{B} \tag{39}$$

Finally, the condition that labor demand equals labor supply requires that

$$(1-\alpha)\frac{Y_t}{L_t} \cdot E_t u_{Ct} = \frac{1}{P_{mt}} \chi L_t^{\varphi} \tag{40}$$

where the inverse of the price of intermediate goods $\frac{1}{P_{mt}}$ is effectivelt the retail goods price market. As we show, this markup can rise in a crisis, enhancing the contraction in employment.

We note that because of Walras' Law, once the market for goods, labor, securities, and interbank loans is cleared, the market for riskless debt will be cleared automatically. As we discussed, the short term government debt may either be directly held by households or instead by banks who in turn issue deposits to households. In the latter case, one can interpret the debt as interest bearing reserves..This completes the description of the model.

Absent credit market frictions, the model reduces to a simple monetary DSGE framework modified with habit formation and flow investment adjustment costs. With the credit market frictions, however, balance sheet constraints on banks ability to obtain funds affecting aggregate real activity. As we will show, a crisis is possible where weakening of bank balance sheets significantly disrupts credit flows, depressing real activity. In this situation further, central bank asset purchases may play a useful role.

4 Model Analysis

4.1 Calibration

Table 1 lists the choice of parameter values for our baseline model. Overall there are seventeen parameters. Twelve are conventional. Six $(\sigma, \theta, \alpha, \omega, \overline{K}^b, \overline{B}^b)$ are specific to our model.

We begin with the conventional parameters. For the discount factor β, the depreciation rate δ, the capital share α, the elasticity of substitution between goods, ε, and the government expenditure share, we choose conventional values. We use estimates from Primiceri, Schaumburg and Tambalotti (2006) to obtain values for most of the other conventional parameters, which include: the habit parameter h, ζ, the inverse elasticity of net investment to the price of capital η_i, the relative utility weight on labor χ, the Frisch elasticity of labor supply φ^{-1}, the price rigidity parameter, γ. Since the policy rule the authors estimate is somewhat non-standard, we instead use the conventional Taylor rule parameters of 1.5 for the feedback coefficient on inflation, κ_π, and 0.5 for the output gap coefficient, κ_y. For simplicity, we use minus the price markup as a proxy for the output gap.

Our choice of the financial sector parameters - the fraction of capital that can be diverted θ, the proportional transfer to entering bankers ω, the survival probability σ, the proportional advantage in seizure rate of government debt over private capital (α), the steady state proportion of direct private (Ψ) and government Ω asset holdings of households - is meant to be suggestive. We pick these parameters to hit the following four targets: a steady state interest rate spread for private assets of one hundred basis points; a steady state interest rate spread on government assets of fifty basis points; a steady state leverage ratio of financial intermediaries of six; and an average horizon of bankers of a decade. We set the direct private asset holdings of households to 50% that is the proportion of mortgage-backed securities held by leveraged financial institutions; and direct government asset holdings to 75%, which is their share of long term Treasuries and Agency debt. We base the steady state target for the spread on the pre-2007 spreads between mortgage rates and government bonds and between BAA corporate vs. government bonds. The steady state leverage ratio is trickier to calibrate. For investment banks and commercial banks, which were at the center of the crisis, leverage ratios (assets to equity) were extraordinarily high: typically in the range of twenty-five to thirty for the former and fifteen to twenty for the latter. Much of this leverage reflected housing finance. For the corporate and non-corporate business sectors this ratio is closer to two in the aggregate. Ideally one would like to extend the model to a multi-sector setting which accounts for the differences in leverage ratios. In the interest of tractability, however, we stick with our one sector setting and choose a leverage ratio of six for financial intermediaries, which roughly captures the aggregate data.[6]

Ten year yields are calculated implicitly according to the following equations:

$$P_t q_t = \sum_{s=1}^{40} \frac{1}{(1+i_{bt})^s} + \frac{\Phi_{bt}}{(1+i_{bt})^{40}}$$

$$P_t Q_t = E_t \sum_{s=1}^{40} \frac{(Z_{t+s} - \delta_{t+s}) P_{t+s}}{(1+i_{kt})^s} + \frac{\Phi_{kt}}{(1+i_{kt})^{40}}$$

4.2 Experiments

We begin with several experiments designed to illustrate how the model behaves. We then consider a "crisis" experiment that mimics some of the basic features of the current downturn. We then consider the role of central bank credit policy in moderating the crisis. Finally, we explore the implications of the zero lower bound on nominal interest rates.

Figure 1-2 shows the response of the model economy to two standard disturbances: a technology shock and a monetary shock. In each case, the direction of the shock is set to produce a downturn. The figure then shows the responses of key variables: output, inflation, nominal and real interest rates, resale price of capital (Q), corporate and government premia and the net worth of financial intermediaries. In each case the solid line shows the response of the baseline model. The dotted line gives the response of the same model, but with the financial frictions removed.

The technology shock is a negative one percent innovation in TFP, with a quarterly autoregressive factor of 0.95. The intermediary balance sheet mechanism produces a modest amplification of the decline in output in the baseline model relative to the conventional DSGE model. The amplification

[6] Note that the calibration implies that the fraction of assets the banker can divert is high, more than thirty percent. This is because the target steady state leverage ratio that helps pin down this parameter is relatively low. With modest elaborations of the model it is possible to make this value much lower. The key is to have the leverage ratio high in sectors that are investing (see Gertler and Kiyotaki, 2010).

is mainly the product of a substantially enhanced decline in investment: on the order of fifty percent relative to the frictionless model. The enhanced response of investment in the baseline model is a product of the rise in the premium, plotted in the last panel on the right. The unanticipated decline in investment reduces asset prices, which produces a deterioration in intermediary balance sheets, pushing up the premium. The increase in the cost of capital, further reduces capital demand by non-financial firms, which enhances the downturn in investment and asset prices. In the conventional model without financial frictions, of course, the premium is fixed at zero.

The monetary shock is an unanticipated twenty-five basis point increase in the short term interest rate. The effect on the short term interest rate persists due to interest rate smoothing by the central bank. Financial frictions lead to greater amplification relative to the case of the technology shock. This enhanced amplification is due to the fact that, everything else equal, the monetary policy shock has a relatively large effect on investment and asset prices. The latter triggers the financial accelerator mechanism.

4.2.1 Crisis Experiment

We now turn to the crisis experiment. The initiating disturbance is a decline in capital quality. What we are trying to capture is a shock to the quality of intermediary assets that produces an enhanced decline in the value of assets held by these institutions, due to their high degree of leverage. In this rough way, we capture the broad dynamics of the sub-prime crises. Note that there will be both an exogenous and endogenous component to the decline in asset values that the shock generates. The initial decline in capital reduces asset values by reducing the effective quantity of capital. There is, however, also a second round effect: due to the leverage ratio constraint, the weakening of intermediary balance sheets induces a drop in asset demand, reducing the asset price Q_t (the price per effective unit of capital) and investment. The endogenous fall in Q_t further shrinks intermediary balance sheets. The overall contraction is magnified by the degree of leverage.

It's best to think of this shock as a rare event. Conditional on occurring, however, it obeys an AR(1) process. We fix the size of the shock so that the downturn is of broadly similar magnitude to the one we have recently experienced. The initiating shock is a five percent decline in capital quality, with a quarterly autoregressive factor of 0.66. Absent any changes in investment, the shock produces a roughly ten percent decline in the effective capital stock over a two year period. The loss in value of the housing stock relative to the total capital stock was in this neighborhood.

We first consider the disturbance to the economy without credit policy and then illustrate the effects of credit policy. For the time being, we ignore the constraint imposed by the zero lower bound on the nominal interest, but then turn to this consideration.

As Figure 3 illustrates, in the model without financial frictions, the shock produces only a modest decline in output. Output falls a bit initially due to the reduced effective capital stock. Because capital is below its steady state, however, investment picks up. Individuals consume less and eventually work more.

By contrast, in the model with frictions in the intermediation process, there is a sharp recession. The deterioration in intermediary asset quality induces a firesale of assets to meet balance sheet constraints. The market price of capital declines as result. Overall, on impact intermediary capital drops more than fifty percent, which is more than ten times the initial drop in capital quality. As we noted earlier, the enhanced decline is due to the combination of the endogenous decline in Q_t and the high degree of intermediary leverage. Associated with the drop in intermediary capital, is a sharp increase in the spread between the expected return on capital and the riskless rate. Both investment and output drop as a result. Output initially falls about three percent relative to trend and then decreases to about six percent relative to trend. Though the model does not capture the details of the recession, it does produce an output decline of similar magnitude. Recovery of output to trend does not occur until roughly five years after the shock. This slow recovery is also in line with current projections. Contributing to the slow recovery is the delayed movement of intermediary capital back to trend. It is mirrored in persistently above trend movement in the spread. Note that over this period the intermediary sector is effectively deleveraging: it is building up equity relative to assets. Thus the model captures formally the informal notion of how the need for financial institutions to deleverage can slow the recovery of the economy.

4.2.2 Credit Policy Response

We now consider credit interventions by the central bank. Figure 4 presents a baseline capital quality shock with the zero lower bound of the nominal interest rate binding; and contrasts it with outcomes with (i) private asset purchases of the order of magnitude of 13% of GDP (QE1), and (*ii*) government bond purchases of 4% of GDP (QE2).

In each instance, the credit policy significantly moderates the contraction. The prime reason is that central intermediation dampens the rise in the spread, which in turn dampens the investment and the asset price decline.

Figure 5 directly compares the effects of the two policies. Yield responses are in line with event study evidence, and real effects are within the range of empirical estimates.

To compare policy effects with a similar magnitude (4% of GDP), Figure 6 plots policy effects of a purchase of private (e_{ψ}) and government (e_{Γ}) assets with the zero lower bound binding for 4 periods. Purchasing private assets has twice the effects of government asset purchases. The main reason is that by directly intermediating private assets, the central bank is eliminating larger distortions from the economy.

[TO BE COMPLETED]

5 Concluding Remarks

[TO BE COMPLETED]

References

[1] Andres, Javier, David Lopez-Salido, and Edward Nelson, 2004, "Tobin's Imperfect Asset Substitution in Optimizing General Equilibrium," *Journal of Money Credi and Banking,* Vol. 36, No. 4, pp. 665-690.

[2] Baumeister, C. and Luca. Benati, 2010, "Unconventional Monetary Policy and the Great Recession," European Working Paper 1258.

[3] Bernanke, Ben and Mark Gertler, 1989, "Agency Costs, Net Worth and Business Fluctuations," *American Economic Review,* March

[4] Bernanke, Ben, Mark Gertler, and Simon Gilchrist, 1999, "The Financial Accelerator in a Quantitative Business Cycle Framework," *Handbook of Macroeconomics,* John Taylor and Michael Woodford editors.

[5] Bonfim, Antonio.N., and Lawrence .H. Meyer, 2010, "Quantifying the Effects of Fed Asset Purchases on Treasury Yields," *Monetary Policy Insight, Fixed Income Focus.*

[6] Brunnermeier, Markus, 2010, "A Macroeconomic Model with a Financial Sector," mimeo.

[7] Carlstrom, Charles and Timothy Fuerst, 1997, "Agency Costs, Net Worth and Business Fluctuations: A Computable General Equilibrium Analysis," *American Economic Review*

[8] Christiano, Lawrence, Martin Eichenbaum and Charles Evans, 2005, "Nominal Rigidities and the Dynamics Effects of a Shock to Monetary Policy," *Journal of Political Economy*

[9] Chen, Han, Vasco Curdia and Andrea Ferrero, 2011, "The Macroeconomic Effects of Large Scale Asset Purchases," Federal Reserve Bank of New York, mimeo

[10] Christiano, Lawrence, Roberto Motto and Massimo Rostagno, 2005, "The Great Depression and the Friedman Schwartz Hypothesis," *Journal of Money Credit and Banking*

[11] Curdia, Vasco and Michael Woodford, 2011, "The Central Bank Balance Sheet As An Instrument of Monetary Policy," *Journal of Monetary Economics,* 58, pp. 54-79.

[12] D'Amico, S. and Thomas King, 2010, "Flow and Stock Effects of Large-Scale Treasury Purchases," *Finance and Economics Discussion Paper Series* 2010-52, September

[13] Doh, T. , 2010, "The Efficacy if Large-Scale Asset Purchases at the Zero Lower Bound." *FRB Kansas City* Q2, pp.5-34.

[14] Eggertsson, Gauti and Michael Woodford, 2003, "The Zero Lower Bound on Interest Rates and Optimal Monetary Policy," *Brookings Papers on Economic Activity.*

[15] Gagnon, Joseph, M. Raskin, J. Remache, and Brian Sack, 2011, "Large Scale Asset Purchases by the Federal Reserve: Did They Work? *FRB New York Staff Reports* 441 (March).

[16] Gertler, Mark and Nobuhiro Kiyotaki, 2010, "Financial Intermediaion and Credit Policy in Business Cycle Analysis," mimeo.

[17] Gilchrist, Simon, Vladmir Tankov and Egon Zakrajsek, 2009, "Credit Market Shocks and Economic Fluctuations: Evidence from Corporate Bond and Stock Markets."

[18] Hamilton, James and J. Wu, 2010, "The Effectiveness of Alternative Monetary Policy Tools in a Zero Lower Bound Environment," UCSD, mimeo.

[19] Holmstrom, Bengt and Jean Tirole, 1997, "Financial Intermediation, Loanable Funds and the Real Sector," *Quarterly Journal of Economics.*

[20] Holmstrom, Bengt and Jean Tirole, 1998, "Private and Public Supply of Liquidity," *Journal of Political Economy.*

[21] Iacoviello, Matteo, 2005, "House Prices, Borrowing Constraints and Monetary Policy in the Business Cycle," *American Economic Review*

[22] Jermann, Urban and Vincenzo Quadrini, 2008, "Financial Innovations and Macroeconomic Volatility," mimeo.

[23] Kiyotaki, Nobuhiro and John Moore, 2007, "Credit Cycles," *Journal of Political Economy*

[24] Kiyotaki, Nobuhiro and John Moore, 2008, "Liquidity, Business Cycles and Monetary Policy," mimeo.

[25] Kozicki, Sharon, E. Santor and L. Suchanek, 2010, "Central Bank Balance Sheets and the Long Term Forward Rate," Bank of Canada, mimeo.

[26] Krishnamurthy, Arvind and Annette Vissing-Jorgensen, 2011, *Brookings Papers on Economic Activity.*

[27] Merton, Robert C., 1973, "An Intertemporal Capital Asset Pricing Model, " *Econometrica*

[28] Primiceri, Giorgio, Ernst Schaumburg and Andrea Tambalotti, 2006, "Intertemporal Disturbances," NBER WP 12243.

[29] Reis, Ricardo, 2009, "Where Should Liquidity be Injected During a Financial Crisis?" mimeo.

[30] Sargent, Thomas J. and Neil Wallace, "The Real Bills Doctrine versus the Quantity Theory of Money," *Journal of Political Economy*

[31] Smets, Frank and Raf Wouters, 2007, "Shocks and Frictions in U.S. Business Cycles: A Bayesian DSGE Approach," *American Economic Review*

[32] Vayanos, Dimitri and Jean-Luc Vila, 2009, "A Preferred Habitat Modelof the Term Structure of Interest Rates," LSE, mimeo.

[33] Wallace, Neil, "A Miller-Modigliani Theorem for Open Market Operations", *American Economic Review*

[34] Woodford, Michael, 2003, *Interest and Prices,* Princeton University Press

Table 1: Parameter values

Households		
β	0.995	Discount rate
h	0.815	Habit parameter
χ	3.482	Relative utility weight of labor
φ	0.276	Inverse Frisch elasticity of labor supply
Ψ	0.500	Proportion of direct capital holdings of HHs in ss
Σ	0.750	Proportion of long term Treasury holdings of HHs in ss
κ_s, κ_b	0.276	Portfolio adjustment cost parameters for HH
Financial Intermediaries		
θ	0.344872	Fraction of capital that can be diverted
α	0.500	Proportional advantage in seizure rate of gov. debt
ω	0.000749	Proportional transfer to the entering bankers
σ	0.972	Survival rate of the bankers
Intermediate good firms		
α	0.330	Capital share
δ	0.025	Depreciation rate
Capital Producing Firms		
η_i	1.728	Inverse elasticity of net investment to the price of capital
Retail Firms		
ϵ	4.167	Elasticity of substitution
γ	0.779	Probability of keeping the price constant
Government		
$\frac{G}{Y}$	0.200	Steady state proportion of government expenditures
ρ_i	0.000	Interest rate smoothing parameter
κ_π	1.500	Inflation coefficient in the Taylor rule
κ_X	-0.125	Markup coefficient in the Taylor rule

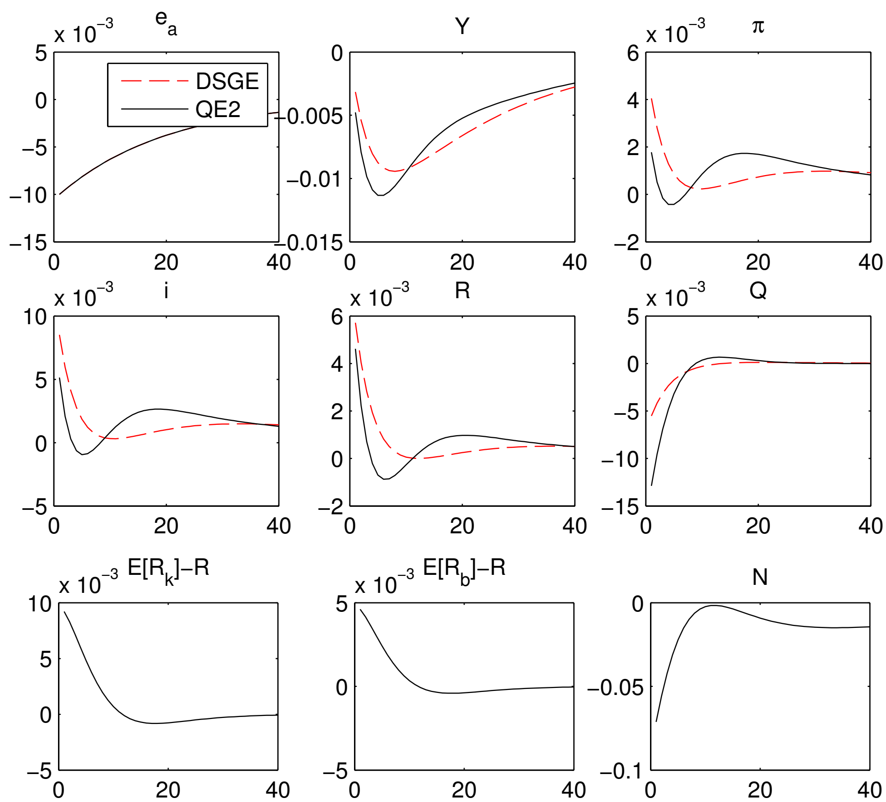

Figure 1: Impulse responses to a technology shock relative to a DSGE model without financial frictions

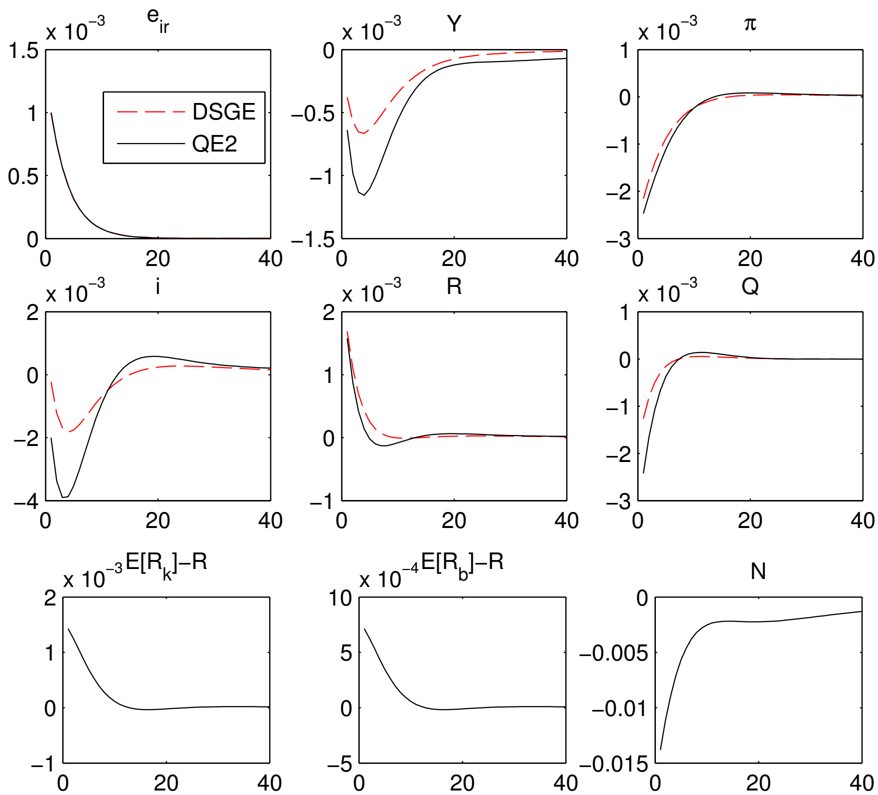

Figure 2: Impulse responses to a monetary policy shock relative to a DSGE model without financial frictions

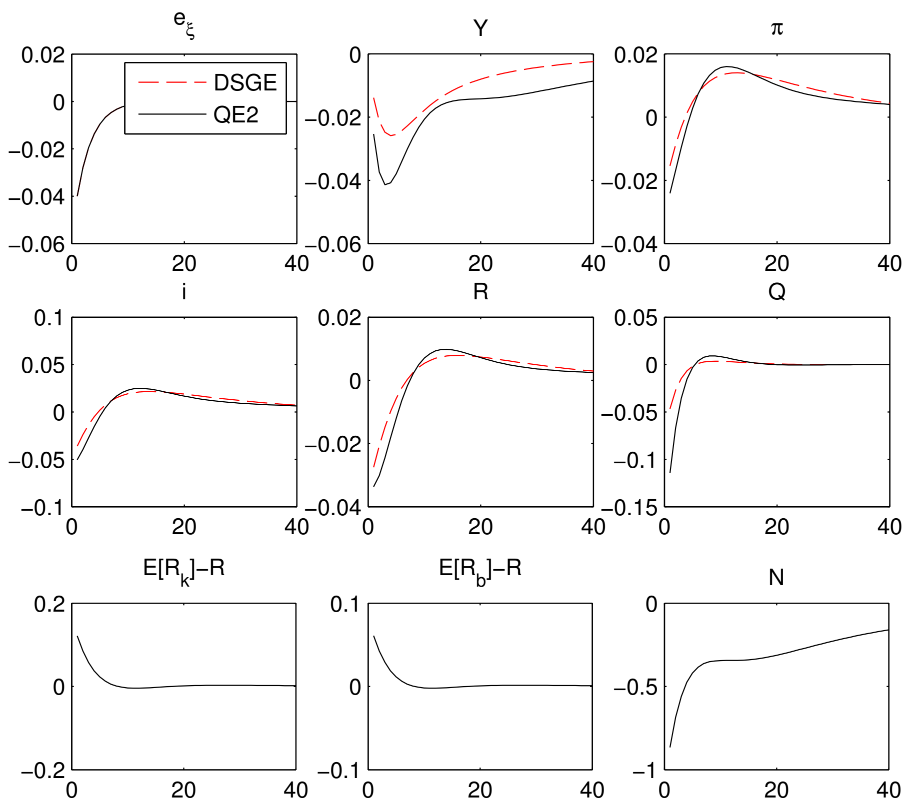

Figure 3: Impulse responses to a capital quality shocks relative to a DSGE model without financial frictions

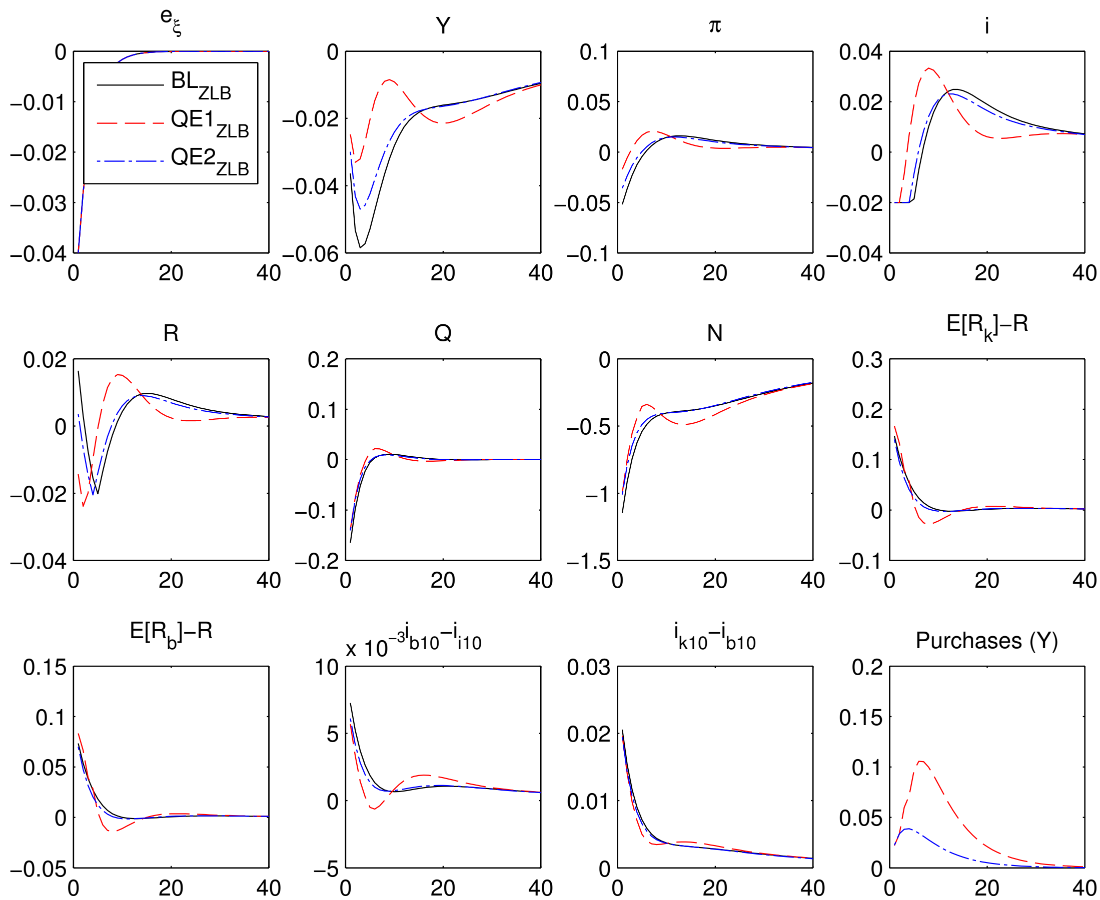

Figure 4: Crisis experiment. Impulse responses to capital quality shocks with exogenous credit policy and bond policy with the zero-lower bound with household holdings.

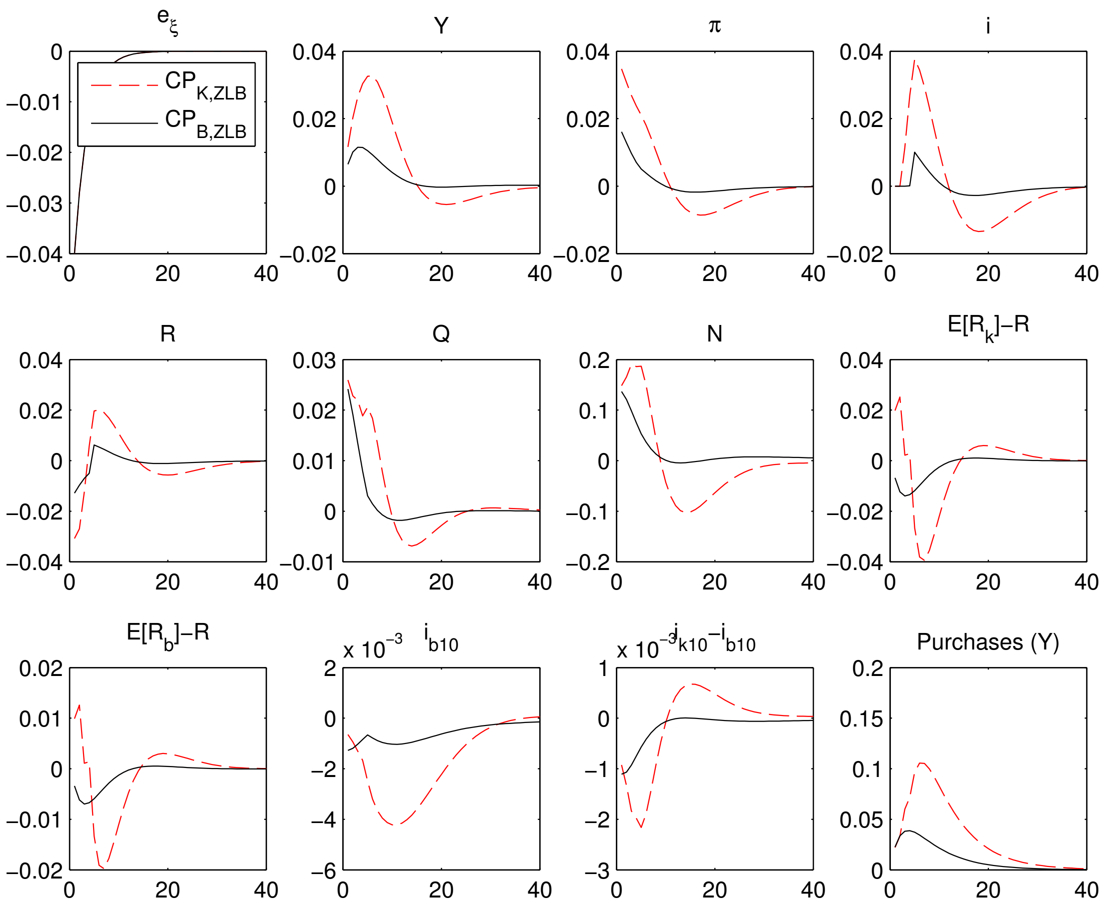

Figure 5: Effects of the policies following the crisis experiment.

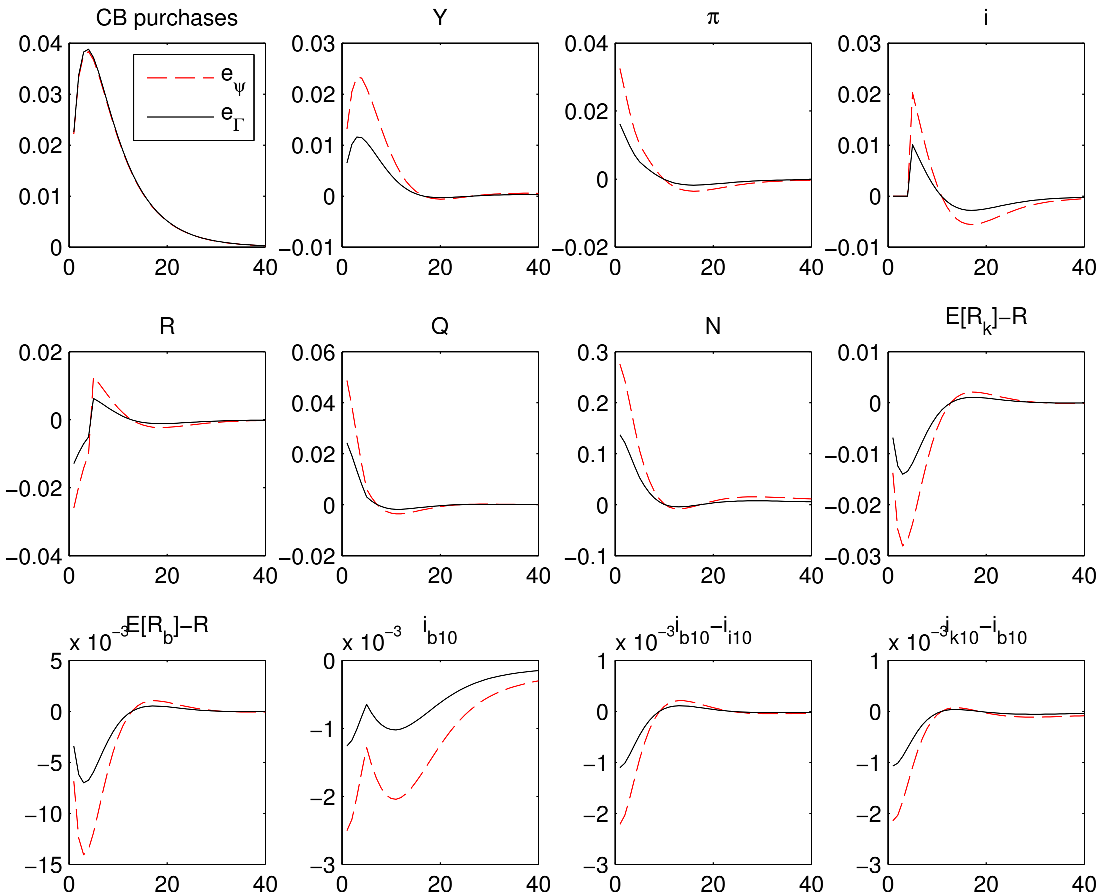

Figure 6: Impulse responses to similar size credit policy shock (ψ) and bond policy shock (Γ) with the ZLB for 4 periods.