The Money Multiplier in the Financial Crisis: a Quantitative Evaluation.*

Jagjit S. Chadha[†] Luisa Corrado[‡] Jack Meaning[§] Tobias Schuler[¶]

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Abstract

We consider the response of the Federal Reserve to the financial crisis, specifically the unprecedented expansion of central bank money (bank reserves) to sustain trend growth in the level of broad money. The impact of the negative credit supply shock in 2008 pushed the policy rate to the zero lower bound but the use of bank reserves allowed some stabilization policy to continue. We compare the impact in a model of money and banking from changes in central bank money to a change in the policy rate and show a broadly equivalent ability to stabilize the economy, albeit with a different transmission mechanism. Our model shows that it is possible to match the observed fall in the money multiplier consistent with that observed in the data in response to a composite shock replicating the 2007-2008 crisis. We also run a counterfactual to suggest if the Federal Reserve had not bank reserves to such a degree, broad money would have fallen and the economy may have experienced a deeper contraction in output and the recovery would also have been more protracted, taking perhaps twice as long to return to equilibrium.

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†Director NIESR. E-mail: J.Chadha@niesr.ac.uk. Professor of Economics University of Kent and Faculty of Economics, University of Cambridge.

‡Professor of Economics, Department of Economics and Finance, University of Rome, Tor Vergata. E-mail: luisa.corrado@uniroma2.it.

§Corresponding Author. School of Economics, Keynes College, University of Kent, Canterbury, UK, CT2 9LP. E-mail: jm583@kent.ac.uk.

¶ifo Institute, Munich. E-mail: Schuler@ifo.de. Center for Business Cycle Analysis.

1 Introduction

Modelling the demand for narrow and broad money was once an integral part of macroeconomic models and the judgement on disequilibrium holdings a key monetary policy judgement (see, for example, Brunner and Meltzer, 1966). The financial crisis of 2007/8 brought into sharp relief the observation that macroeconomic models had increasingly used money as a simplistic veil, which was always cut to match the optimized nominal expenditure plans of households and firms. And so when shocks actually originated in the monetary and financial sector and exhausted the standard policy interest rate channel (by driving policy rates to the zero lower bound), judgement about the correct policy response became problematic. The collapse of the money multiplier, which is the ratio of narrow to broad money, since 2008, and the failure of huge expansions of central bank money, in many advanced economies, to bring about a sustained growth lending forces us to think about the policy response to a credit event.[1] Accordingly in this paper, as well as maintaining optimization for households and firms, we impose a more formal optimization problem for commercial banks in the management of the asset side of their balance sheet. We also consider the role of the central bank in offering money in a demand-determined manner to offset shocks at the zero lower bound.

The majority of central banks conduct monetary policy through manipulation of their short-term nominal interest rate.[2] And many models employing a short-term nominal interest rate do still characterize monetary policy as controlling the quantity of central bank (narrow) money in order to achieve a desired interest rate i.e. by withdrawing supply through open market operations to raise rates and increasing supply if they are targeting a lower rate. Disyatat (2008) explains how this policy amounts to an exercise in reverse causality. What happens in practice is that the policy maker sets the lending rate at which it will conduct operations and then provides, through open market operations, as much narrow money as commercial banks demand at that rate. Narrow money is thus demand determined. Commercial banks then supply loans at the market interest rate, which determines broad money. A key insight here is that the evolution of monetary aggregates 'reflects prevailing interest rates rather than determines them' and we seek to capture this interaction between

[1] See Garfinkel and Thornton (1991) for a precursor to our argument that the multiplier cannot be thought to be exogenous and ought to be interpreted with reference to policy and underlying economic conditions, including financial spreads. In a paper focussed on the empirical evaluation of the relationship between central bank reserves and broader money and bank lending, Carpenter and Demiralp (2012), echoing Johannes and Rasche (1983), find little evidence supporting the standard money multiplier story, but suggest that a more complex relationship between monetary policy and the quantity of lending, one where demand for loans and reserves, which are dependent on interest rates, could play a role.

[2] The consensus rationale for this can be found in Poole (1970).

interest rate spreads and lending in our model.[3]

We suggest thinking about variations in the quantity of broad and narrow money as an optimal portfolio choice on the part of commercial banks that matches deposit demand from households with a choice about assets as reserves or loans.[4] The use of non-conventional monetary policies, which have increased the supply of narrow money to commercial banks allows us a background against which to judge our model. Accordingly, we build on the money and banking sector model of Goodfriend and McCallum (2007), in which the overall level of deposits is determined by narrow money from the central bank, and loans produced by commercial banks. However unlike their model, which has a fixed ratio between the two monetary aggregates, we derive a demand schedule for narrow money from banks' profit-maximizing condition and allow this to determine the level of narrow money, with the central bank meeting this demand perfectly elastically. The quantity of loans is then derived from the bank's optimizing condition and loan production function and so we can observe richer narrow and broad monetary dynamics the two aggregates evolve in response to macroeconomic and financial conditions. A further innovation is the inclusion of open market operations as a practical mechanism to effect these changes in reserves and so they might be supplied in a disequilibrium manner by the central bank or to meet demand by commercial banks. We model the central bank exchanging newly created reserves with the private sector for deposits, which are backed up with increased reserve holdings on commercial banks' balance sheets.

The rest of the paper is as follows. In Section 2, we briefly outline recent developments in the narrow and broad money and discuss what may have been driving trends with particular regard to policy at the Fed. We then provide an exposition of a model of money, banking and reserves. In Section 4 we discuss the implications of our model for the money multiplier, which is the inverse of the reserve-deposit ratio, and how this affects banks and the wider economy. We show that, by allowing the composition of money to vary as the relative returns/costs of narrow and broad money change, banks can optimally meet deposit demand. To illustrate these points more clearly in Section 6 we present the impulse responses of the models key variables to both real and financial shocks and compare the responses when narrow money or the interest rate is pegged. To strengthen this conceptual point, in Section 7 we carry out welfare analysis by deriving a welfare loss function for the representative household from a second order approximation to utility.

Finally, in Section 8 we apply the model to the recent financial crisis and find it does a passable job of matching the evolution of key variables in the US economy since 2008.

[3] See Chadha, Corrado and Holly (2014) for a thorough analysis of this issue.

[4] See Gale (2011) on this point.

We then investigate what the results of the model imply for the money multiplier and find that following a shock similar to that experienced by the US during the financial crisis, it is optimal for banks to demand much more narrow money and for credit money in the form of loans to contract. This leads to a significant fall in the money multiplier consistent with that observed in the data. We then perform a counterfactual exercise in which we subject the model to the same shock but hold the quantity of reserves fixed. The model implies that, had the Federal Reserve not massively expanded narrow money and maintained a fixed multiplier, broad money would have fallen by significantly more and the US economy may have experienced a contraction in output 1% greater, inflation would have fallen by an additional 2.5% and employment would have been 2% lower. The recovery would also have been more protracted, taking roughly twice as long to return to equilibrium.

2 Money: Broad and Narrow

The question of maintaining the level of broad money growth in response to a shock has been a key aspect of financial crisis management since, at least, Friedman and Schwartz's (1963) magisterial analysis of the Great Depression. Figure 1 shows that total bank deposits have continued to grow after the financial crisis shock as in the immediate period prior to it. Indeed the without an increase in bank reserves, the total quantity of bank deposits would have fallen, broadly-speaking in line with commercial bank credit. The contraction of new credit and lending by commercial banks to the wider economy in the period following the financial crisis followed heavy losses and heightened uncertainty, after which banks become more cautious in their new lending, sought to repair balance sheets and shrink loan books. Figure 2 illustrates the nature of the negative credit supply shock as it shows in late 2008 a sharp increase in the corporate bond credit spread and also spread of commercial paper over the Federal Funds rate, subsequently we can note year on year growth in loans at a nadir of nearly -10%. It is the consequences of this large credit shock that we seek to understand in this model.

The second factor, which is clear in Figure 1 that the Federal Reserve massively expanded the quantity of central bank money through the quantitative easing programmes. Figure 3 shows how the Federal Reserve's balance sheet has evolved with an unprecedented rise in the level of reserves, mostly effected through the Large Scale Asset Purchases (LSAPs) in which the Fed purchased mostly Government bonds and Mortgage-Backed Securities with newly created reserves. In this way, the LSAPs can be thought of as analogous to traditional open market operations, albeit differing in the quantity and type of assets purchased, and the duration for which the assets are held.

In November 2008 the Fed announced it would begin purchasing housing agency debt and mortgage-backed agency securities to the value of $600bn in response to the housing crisis and in order to promote the health of mortgage lending. In March 2009 this was increased to $1.25 trillion. These purchases were largely of maturities between 3 months and 5 years. As they reached maturity, the principal was reinvested to fund the purchase of Treasury securities and maintain the value of the agency debt and agency backed securities section of the LSAP. Accompanying this extension was the announcement that the Fed would buy $300bn of Treasury securities, over 60% of which were of between 3 and 10 year maturities. The purchase of Treasuries was designed to support falling asset prices by acting as a large buyer and through the portfolio balance channel this should spread to other assets in the economy.

These large scale asset purchases were predominantly funded by the creation of several trillion dollars of new reserves, making them the largest quantitative easing programme enacted since the crisis. In November 2010, in light of a continuing weakness in economic forecasts, the purchase of longer-term Treasuries was extended further by $600bn under a second round of quantitative easing (QE2) which took the total LSAP to over $2 trillion. In September 2011, the FOMC announced a maturity extension programme under which it bought an additional $400bn of longer-dated treasuries but simultaneously sterilized these by selling short-term Treasuries to the same value. The goal was to lower longer-term yields without increasing the size of the central bank's balance sheet by "twisting" the yield curve and increasing the average maturity of the Fed's Treasuries portfolio by 25 months. In September 2012 the Fed announced QE3. This heralded an important change in the setting of asset purchase programmes as, unlike the previous policies, QE3 was open-ended, with the Federal Reserve committing to buy $40bn of MBS a month until the outlook for the labour market "improves substantially....in a context of price stability". It was also a direct injection of liquid reserves into the economy aimed at improving confidence and conditions in impaired credit markets. The purchases were eventually halted in October 2014 after accumulating some $4.5Tn in assets. By explicitly tying the duration of the programme to conditions in the macroeconomy the Federal Reserve hoped to relieve uncertainty and return confidence to agents to make longer-term decisions about investment and spending.

Initially the Fed supplied reserves to banks through the TAF and other facilities but sterilized the effect of this lending on the base. After the collapse of Lehmans the monetary base exploded, but only because the Fed no longer had the resources to sterilize. This initial increase in the base was indeed largely demand determined. But the increase in the base associated with QE -post March 2009, however, may not have been demand determined, as the Fed may have supplied reserves that commercial banks may not have wanted to hold but that the banking system was forced to hold. We will try to tease out the impact of both types of reserves accumulations in our model.

Obviously, if there was a fixed money multiplier, this huge expansion in narrow money would be expected to lead to an equivalent boom in broad money. Similarly, the contraction in the credit supply and loan issuance of commercial banks would act to reduce broad money. As already observed though, the growth in the level of broad money has been reasonably constant, implying that the increase in narrow money has worked to almost exactly offset the contraction in credit money. Whilst these two effects pull in opposite directions on the broad monetary aggregate, they both act to move the money multiplier in the same way, down, as narrow money has formed an increasing fraction of the total money supply. We will go on to show how this fall in the multiplier may, in part, be explained by banks' optimizing behaviour causing them to rebalance their portfolio between narrow and credit money as the relative returns/costs of each vary and this may have acted to reduce the duration and severity of the economic downturn by offsetting an escalation in market-determined premia.[5]

2.1 The Central Bank Balance Sheet

Let us set out a simple framework for analyzing extraordinary central bank balance sheet monetary policies, which have expanded reserves.[6] For simplicity, we abstract from other forms of central bank money and concentrate on bank reserves alone in this exposition, so that high powered money is identical to reserves. More traditionally the central bank controls the stock of fiat money (outside money) and financial intermediaries creates other forms of inside money, which are intra-private sector claims. As financial intermediation allows deposits also to serve as money, they offer a close substitute to (outside) fiat money that means that the ability of the central bank to determine the overall nominal level of the broad money stock depends on the relationship between outside and inside money. In principle, the central bank has a powerful tool to regulate the balance sheet of financial intermediaries and to affect the quantity of money in circulation: reserves, which may be either or both of fractional and/or voluntary.

[5]See Walsh (2009) for a very interesting attempt to understand policy at the ZLB.

[6]See Chadha, Corrado and Meaning (2012) for more detail.

Private Sector			
Assets		Liabilities	
Deposits	D	Loans	$(D - r)$
Bonds	γB	Tax	$\sum_{i=0}^{\infty} \beta^i t_i$
Capital	$\gamma_k K$		

Government			
Assets		Liabilities	
Tax	$\sum_{i=0}^{\infty} \beta^i t_i$	Bonds	B

Commercial Banks			
Assets		Liabilities	
Reserves	r	Deposits	D
Loans	$(D - r)$		

Central Bank			
Assets		Liabilities	
Bonds	$(1 - \gamma)B$	Reserves	r
Capital	$(1 - \gamma_k)K$		

We first look at the private sector's balance sheet. The private sector has three forms of assets: deposits, D, held at banks and some fraction of bonds, γB, issued by the government and a fraction of total capital.[7] Their liabilities are loans, $D - r$, provided by banks and capital, K. Capital lies on the liability side of households' balance sheet because households own the firms and firms treat capital as a liability. The government sector has liabilities in the form of outstanding public debt, B, and assets given by the present discounted value of future taxation. The commercial banks' balance sheet liabilities are deposits, D. Some fraction of liabilities, r, is held as reserves and the rest, $D - r$, is available to be lent to the private sector. The central bank holds assets in the form of some fraction of government bonds, $(1 - \gamma)B$, and a fraction of capital, $(1 - \gamma_k)K$, with liabilities determined by central bank money, which are bank reserves.[8] The net assets of commercial banks and of the central bank are both zero. The private sector has net assets given by $D + \gamma B + \gamma_k K - \left(D - r + \sum_{i=0}^{\infty} \beta^i t_i\right)$ and so because $r = (1 - \gamma)B + \gamma_k K$ and $\sum_{i=0}^{\infty} \beta^i t_i = B$, we can note that the net private sector assets are also zero.

We can see from this flow of funds the mechanism by which extraordinary policies occur. The central bank can perform quantitative easing which involves the expansion of its balance sheet by the issuance of bank reserves that are backed by increased holdings of either bonds or capital. The bank reserves are lodged with commercial banks on whom the private sector, which has sold the bonds or capital to the central bank, have a deposit claim. Alternatively, credit easing is conducted through changing the composition of the

[7] In this example we assume that the private sector is represented by households, so firms are included here.

[8] If we operate in an open economy, central bank assets would also include foreign exchange reserves r^f.

balance sheet and increasing holding of 'risky' capital compared to 'less risky' bonds: in effect reducing the quantum of credit risk lodged within the private sector. With the overall quantity of liabilities unchanged, the central bank can buy capital from the private sector, increasing its own holdings. It funds these purchases by selling bonds back to the private sector, leaving the net effect on the size of both the central bank and private sector's assets at zero. Due to the differing properties of bonds and capital as collateral in loan production, this exchange has implications for levels of deposit demand which we will discuss later.

3 The Model of Banking and Money

We now outline the model, which is an extended version of that developed by Goodfriend and McCallum (2007) and extended by Chadha and Corrado (2012). Primarily it is a Calvo-Yun monopolistically competitive production economy with sticky prices and four main agents; households, who can work either in the goods producing sector for firms or for banks monitoring loan quality for banks, who meet consumers' deposit demand via reserves and a loans production function, and the monetary authority.[9]

3.1 Households

Households are faced with a utility function in real consumption, c, and leisure:

$$U = E_0 \sum_{t=0}^{\infty} \beta^t [\phi \log(c_t) + (1-\phi)\log(1 - n_t^s - m_t^s)]. \tag{1}$$

They can supply labour to the goods production sector, n^s, or to financial intermediaries in the form of monitoring work, m^s. They are also subject to the budget constraint:

$$\begin{aligned} & q_t(1-\delta)K_t + \frac{\gamma B_t}{P_t^A} + \frac{D_{t-1}}{P_t^A} + w_t(n_t^s + m_t^s) + c_t^A(\frac{P_t}{P_t^A})^{1-\theta} + \Pi_t \\ & -w_t(n_t + m_t) - \frac{D_t}{P_t^A} - tax_t - q_t K_{t+1} - \frac{\gamma B_{t+1}}{P_t^A(1+R_t^B)} - c_t = 0 \end{aligned} \tag{2}$$

where q_t is the price of capital, K_t is the quantity of capital, P_t is the price of household's produced good, P_t^A is the consumption good price index, n_t is the labour demanded by household as producer, m_t, is the labour demanded by household's banking operation, w_t

[9] There is also a fiscal authority which runs a balanced budget. We fix levels of government debt as constant unless exogenously shocked, thus the government's role within this set-up is benign. The annex outlines the model in more detail.

is the real wage, D_t is the nominal holding of broad money, tax_t is the real lump-sum tax payment, R_t^B is the nominal interest rate on government bonds purchased in $t+1$, B_{t+1}. We also assume that any profit from the banking sector, Π_t, goes to the households' sector. The Lagrange multiplier of this constraint is denoted as λ_t and θ is the elasticity of household demand.

In addition, households have a 'deposit-in-advance' constraint which requires them to hold deposits with a financial intermediary in order to effect their consumption plans, where v_t is the velocity of broad money,

$$c_t = v_t D_t / P_t^A. \tag{3}$$

3.2 Firms

The production sector, characterized by monopolistic competition and Calvo pricing, employs a Cobb-Douglas function with capital, K_t, and labour, n_t, subject to productivity shocks. Firms decide the amount of production they wish to supply and the demand for labour by equalizing sales to net production:

$$K_t^{\eta}(A1_t n_t)^{1-\eta} - c_t^A (P_t/P_t^A)^{-\theta} = 0, \tag{4}$$

where η denotes the capital share in the firm production function, $A1_t$ is a productivity shock in the goods production sector whose mean increases over time at a rate ϱ and θ denotes the elasticity of aggregate demand, c_t^A. The Lagrange multiplier of this constraint is denoted as, ξ_t. By clearing the household and production sectors,[10] we can define the equilibrium in the labour market and in the goods market. Specifically, the demand for monitoring work:

$$m_t = \left(\frac{\phi}{\lambda_t c_t} - 1\right) \frac{1-\alpha}{w_t} c_t \tag{5}$$

depends negatively on wages, w_t, and positively on consumption, c_t, and where $1-\alpha$ is the share of monitoring in the loan production function. These two sectors also provide the standard relationship for the riskless interest rate and the bond rate.

3.3 Banks

The role of banks in our economy is to meet the deposit demand of liquidity constrained consumers confronted with the deposit-in-advance constraint. These deposits are created in two ways. They are either created by the central bank in the form of narrow money (reserves)

[10] For details on the model set-up, derivation and notation see the technical appendix, available on request.

which are lent to or lodged with commercial banks or commercial banks can create deposits themselves by producing loans which generate an equivalent deposit on the liabilities side of the bank's balance sheet. Thus

$$L_t + r_t = D_t \tag{6}$$

and broad money is determined in part by the central bank, but also mostly by the banking system. $\frac{D}{r}$ therefore represents the money multiplier and, as the only source of narrow money in our model is reserves, $\frac{1}{MM} = \frac{r}{D}$, which equals the reserve ratio.[11]

3.3.1 Reserves and Loans

We abstract from cash and assume that narrow money consists solely of reserves, which are supplied in normal times to commercial banks by the central bank perfectly elastically in response to their demand. In order to obtain any excess reserves commercial banks face a cost, which is the central bank's policy rate, paid via open market operations conducted at a discount window (see section 4.1).[12]

Alternatively, commercial banks can create deposits themselves by producing loans, which generate an equivalent deposit on the liabilities side of the bank's balance sheet but also incur a cost. Banks produce these loans by applying a production technology to collateral posted by households in the form of bonds, b, or capital, qK. This process is captured by a Cobb-Douglas production function for loans where collateral is combined with monitoring work, m:

$$L_t/P_t^A = F(\gamma b_{t+1} + A3_t k q_t K_{t+1})^{\alpha}(A2_t m_t)^{1-\alpha} \qquad 0 < \alpha < 1, \tag{7}$$

$A2_t$ denotes a shock to monitoring work, $A3_t$ is a shock on capital as collateral and $b_{t+1} = B_{t+1}/P_t^A(1 + R_{t+1}^B)$. The parameter k denotes the inferiority of capital as collateral in the banking production function[13], while α is the share of collateral in loan production. Increasing monitoring effort is achieved by increasing the number of people employed in the banking sector and therefore reducing the employment in the goods production sector.

The decision of commercial banks across these two assets is articulated in two stages. In the first stage, interest rates are determined and then, given the constellation of spreads,

[11] Under a 100% reserve system, the broad money supply, and thus consumption within our model would be restricted by the creation of narrow money by the central bank. In this variant $D_t = r_t$ and the subsequent problem of reserve demand simplifies to depend purely on demand for consumption at the given policy rate.

[12] See Freeman and Haslag (1996).

[13] Capital is considered inferior as there are increased costs to the bank of verifying its physical quality and condition as well as its market price. It is also less liquid should it need to be called upon in the case of default.

banks decide or choose a level of reserves and loans in order to maximize expected returns. This approach directly addresses the reverse causality criticism of Disyatat (2008). Following Baltensperger (1980), banks seek to maximize total returns within period subject to the returns from loans, L_t, which are lent out at the collateralized interest rate of R_t^L, the cost of obtaining reserves, $R_t r_t$, and the payment of deposit interest, R_t^D, to deposits:

$$\max_{r_t} \Pi_t = R_t^L L_t - R_t r_t - R_t^D D_t, \tag{8}$$

$$\text{s.t. } C_t = \frac{1}{2} R_t^T (\bar{r} - r_t)^2 + \tau_t (\bar{r} - r_t). \tag{9}$$

Commercial bank profits are also subject to a side constraint motivated by concerns over reserve management. We assume that banks have an exogenous target for the level of reserves, $\bar{r}$, perhaps set by custom and practice or by legislation.[14] We assume that any deviation from this target imposes two costs on the bank. The first is symmetric and derives from the bank's desire to smooth the path of reserves and avoid any sharp swings in its asset position as these may signal mismanagement and result in reputational loss. In the model the cost of such deviations from target is the uncollateralized interest rate, R_t^T. This is because if $r_t < \bar{r}$, the commercial bank will fund its shortfall at the penalty rate, and if $r_t > \bar{r}$ the commercial bank will have missed the opportunity to lend out those reserves at the same penalty rate and thus incurs the opportunity cost, R_t^T.

The second term relates to the need of commercial banks to hold a certain level of reserves to meet its desired reserve target in any given period. Whilst exogenous in our framework, this target is most likely driven by the level of required reserves set by the regulator (Basel III, 2010), although banks may set a target in excess of this minimum limit if they have heightened precautionary motives for holdings safe, liquid assets, such as central bank reserves. Therefore, the second term, τ_t, can be thought of as an exogenous shift in the ex-ante probability of a reserve shortfall or a change in the propensity to hold reserves, which might be policy induced. It represents shifts in the level of reserves necessary to meet the bank's target holdings, so an increase in τ_t corresponds to bank reserves expected to being below the target level $\bar{r}$.

Solving Equations (8) and (9) with respect to reserves, the optimal, profit-maximizing level of reserves gives us the commercial bank demand curve and can be written as:

$$\hat{r}_t = \frac{\hat{\tau}_t}{\hat{R}_t^T} - \left[\frac{\hat{R}_t + \hat{R}_t^L}{\hat{R}_t^T} \right] + \bar{r}. \tag{10}$$

[14] In practise, most major economies have a minimum level of required reserves relative to depositis.

It is a positive function of the probability of the commercial bank being short its obligated level of reserves, $\bar{r}$, and negative in $\hat{R}_t$, and, $\hat{R}_t^L$, which is the cost of reserves and the opportunity cost of reserves, the loan rate. We therefore emphasize that the relative cost and returns of the two mechanisms of meeting deposit demand change, so do the bank's optimal quantities of each.

Any consumption above the level equivalent to the quantity of reserves requires households to borrow from the commercial banks, and thus receive a deposit which can be used to effect transactions.[15] Loan demand can thus be pinned down to the difference between deposit demand and the quantity of reserves demanded by the commercial bank. By combining equations (6), (7) and (10) we can write the quantity of credit money the banking sector should extend in the form of loans as

$$L_t = D_t - \frac{\hat{\tau}_t}{\hat{R}_t^T} + \frac{\hat{R}_t + \hat{R}_t^L}{\hat{R}_t^T} - \bar{r}.$$

We can then show how total deposits depend on both money created by the central bank in response to commercial bank demands or reflecting reserves imposed on commercial banks through policy and that created by the banking sector through loans:

$$D_t = \frac{\hat{\tau}_t}{\hat{R}_t^T} - \left[\frac{\hat{R}_t + \hat{R}_t^L}{\hat{R}_t^T}\right] + \bar{r} + F(\gamma b_{t+1} + A3_t k q_t K_{t+1})^{\alpha}(A2_t m_t)^{1-\alpha}.$$

Finally, we can put this back in to the deposit-in-advance constraint which allows us to show the interconnectivity between the real economy, the financial sector and the bank's decision between monetary aggregates:

$$c_t = \upsilon_t \frac{F(\gamma b_{t+1} + A3_t k q_t K_{t+1})^{\alpha}(A2_t m_t)^{1-\alpha}}{P_t^A(1 - rr_t)}. \tag{11}$$

And this can be re-written as:

$$c_t = \upsilon_t \left[\underbrace{\frac{\hat{\tau}_t - \hat{R}_t - \hat{R}_t^L}{\hat{R}_t^T P_t^A} + \bar{r}}_{base} + \underbrace{\frac{F(\gamma b_{t+1} + A3_t k q_t K_{t+1})^{\alpha}(A2_t m_t)^{1-\alpha}}{P_t^A}}_{credit}\right].$$

The first two terms inside the square bracket represent narrow money, comprising

[15] In this way our model differs from others where loans are used to fund investment and have a direct productive purpose. However, by creating broad money and funding consumption they are acting, through the sales equal net production constraint, to achieve a similar effect.

portfolio demand and an exogenous term, whilst the third is money created by the banking sector. If it becomes optimal for commercial banks to create less credit money through loans, then the only way to support a given level of broad money, and thus activity, is to increase the quantity of narrow money equivalently. As the central bank is the only agent who can create narrow money, they must increase the supply of reserves, and in our benchmark framework this is exactly what they do, meeting the increased demand for reserves elastically and injecting reserves to meet policy objectives. This allows commercial banks to achieve a given asset mix.

3.4 Interest Rates and Spreads

The inclusion of this banking sector gives rise to a number of interest rates and financial spreads. The benchmark theoretical interest rate R^T is the standard intertemporal nominal pricing kernel, priced from expected real consumption growth and inflation. Basically it boils down to a one-period Fisher equation:

$$R_t^T = E_t(\lambda_t - \lambda_{t+1}) + E_t\pi_{t+1}. \tag{12}$$

The central bank policy rate is the market clearing rate for reserves and is set by a feedback rule responding to inflation, π_t, and output, y_t, with parameters, ϕ_π and ϕ_y, respectively. Policy rates are smoothed so that $1 > \rho > 0$:

$$R_t = \rho R_{t-1} + (1-\rho)(\phi_\pi \pi_t + \phi_y y_t). \tag{13}$$

To find the excess of the loan rate R^L over funding costs, R, as the real marginal cost of loan production, we divide the factor price, $\frac{w_t}{P_t^A}$, by the marginal product of labour which equates the marginal product of loans per unit of labour $(1-\alpha)\frac{L_t}{m_t}$ where loans are defined by the following relationship $L_t = D_t(1-rr_t) = \frac{c_t P_t^A}{v_t}(1-rr_t)$:

$$EFP_t = \frac{w_t v_t m_t}{(1-\alpha)(1-rr_t)c_t}.$$

Therefore in log-linear form the interest rate on loans, R_t^L, is greater than the policy rate by the extent of the external finance premium.

$$R_t^L - R_t = \underbrace{[v_t + w_t + m_t + rr_t - c_t]}_{EFP_t}. \tag{14}$$

The external finance premium, EFP_t, is the real marginal cost of loan management, and it is increasing in velocity, v_t, real wages, w_t, monitoring work in the banking sector, m_t, and the reserve ratio, rr_t, and decreasing in consumption, c_t. Recall that $rr_t = \frac{1}{MM_t}$ the EFP is also decreasing in the money multiplier, meaning that in this model banks switch to narrow money taking more of the burden of meeting deposit demand, when the external finance premium is higher.

The yield on government bonds is derived by maximizing households' utility with respect to bond holdings, $R_t^T - R_t^B = \left[\frac{\phi}{c_t \lambda_t} - 1\right] \Omega_t$. In its log-linear form it is the riskless rate, R_t^T, minus the liquidity service on bonds, which can be interpreted as a liquidity premium (LP):

$$R^B R_t^B = R^T R_t^T - \underbrace{\left[\left(\frac{\phi}{c\lambda} - 1\right) \Omega \Omega_t - \frac{\phi \Omega}{c\lambda} (c_t + \lambda_t)\right]}_{LP_t}, \tag{15}$$

where $(c_t + \lambda_t)$ measures the household marginal utility relative to households shadow value of funds while Ω_t is the marginal value of the collateral. It is in fact these key margins - the real marginal cost of loan management versus the liquidity service yield - that determine the behavior of spreads. In the above expression, ϕ denotes the consumption weight in the utility function whereas λ_t is the shadow value of consumption, c_t. The interest rate on deposits is the policy rate, R_t, minus a term in the reserve deposit ratio:

$$R_t^D = R_t - \frac{rr}{1 - rr} rr_t. \tag{16}$$

As these spreads influence the portfolio decisions of banks they will also impact on the resulting path of consumption. When we come to the analysis of the model we will discuss these premia as a way of understanding our key results.

4 Monetary Policy

This model framework allows us to capture a number of interesting elements of monetary policy. First in our benchmark model the direct instrument of monetary policy is the short-term nominal interest rate, which we have seen is set in response to a standard active interest rate rule. By varying this rate, the policy maker is changing the cost to commercial banks of obtaining reserves. The endogenously determined external finance premium also changes the return on loans. The liquidity premium impacts on the value of collateral available to households and the deposit rate, a cost of funding, is a negative (positive) function of the reserve-deposit ratio (money multiplier). These effects will change the opportunity cost of meeting deposit demand with narrow money from the central bank rather than extending loans and cause the bank to reset its portfolio mix between narrow money and loans. The central bank can also decide not to change the interest rate and allow the demand for reserves to stabilize the economy. We will show in Section 6 the implications of these alternatives for the wider economy.

4.1 Open Market Operations: A Mechanism to Control Reserves

Under non-conventional and conventional monetary policies, the central bank varies the size of its balance sheet, increasing or decreasing the quantity of reserves in the economy to meet the demand of commercial banks at its target policy rate.[16] Previous models have lacked a mechanism by which the quantity of reserves in the economy can be controlled by the central bank. We aim to provide a more accurate approximation of the practicalities of reserve management by modelling open market operations whereby an asset, primarily bonds, is bought from the private sector in exchange for newly created money. The central bank now holds more bonds on its balance sheet. The private agent from whom the bonds have been purchased receives a newly created deposit in their commercial bank account, whilst their commercial bank's own account with the central bank is credited with an equal increase of freshly created reserves.[17]

To incorporate this mechanism into our model we assume the central bank must match its only liability, reserves, by holding just one class of assets, government bonds, the total supply of which is held fixed unless exogenously shocked.[18] When the central bank buys bonds through an open market operation it increases the fraction of the total bond supply which it holds, and decrease that held by the private sector. We can therefore define total bond holdings as the sum of private sector and central bank bond holdings,

$$b_t = b_t^{CB} + b_t^{P}, \tag{17}$$

As central bank bond holdings must equal reserves, we can substitute and re-arrange to give the log linear relationship

$$b_t^p \hat{b}_t^p = b_t \hat{b}_t - r_t \hat{r}_t \tag{18}$$

[16] See Berrospide (2012) for an analysis of the demand for liquidity.

[17] We abstract from the possibility of banks themselves holding bonds and acting as the central bank's counterparty in an open market operation. Whilst this would be closer to how traditional open market operations have been carried out, it is not consistent with recent large scale asset purchases carried out by central banks which avoided buying assets directly from banks. In the context of our model, the distinction between the two frameworks holds little importance.

[18] Variants of the model in which the central bank can swap reserves for capital, or even capital for bonds can be explored in future work.

It is this newly defined variable b^p which determines the amount of collateral households have available and thus b^p which features in our equations for loan supply and the marginal value of collateralized lending as well as the consolidated government budget constraint.[19]

The mechanism outlined here abstracts from sterilized open market operations in which the purchases of assets are funded not by the creation of new reserves, but rather by the sale of other assets on the central bank's balance sheet and act through 'credit easing' channels as defined by Bernanke (2009):

'In a pure QE regime, the focus of policy is the quantity of bank reserves, which are liabilities of the central bank; the composition of loans and securities on the asset side of the central bank's balance sheet is incidental....In contrast, the Federal Reserve's credit easing approach focuses on the mix of loans and securities that it holds and on how this composition of assets affects credit conditions for households and businesses.'

5 Calibration

Table 2 reports the values for the parameters and Table 3 the steady-state values of relevant variables.[20] Following Goodfriend and McCallum (2007) we choose the consumption weight in utility, ϕ, to yield 1/3 of available time in either goods or banking services production. We also set the relative share of capital and labour in goods production η to be 0.36. We choose the elasticity of substitution of differentiated goods, θ, to be equal to 11. The discount factor, β, is set to 0.99 which is close to the canonical quarterly value while the mark-up coefficient in the Phillips curve, κ, is set to 0.1. The depreciation rate, δ, is set to be equal to 0.025 while the trend growth rate, ϱ, is set to 0.005 which corresponds to 2% per year. The steady-state value of bond holding level relative to GDP, b, is set to 0.56 as of the third quarter of 2005. The steady state of private sector bond holdings relative to GDP is set at 0.50, consistent with holdings of U.S. Treasury securities as of end of year 2006.[21]

The deep parameters linked to money and banking are defined as follows. Velocity at its steady state level is set at 0.276 which is close to the ratio between US GDP and M3 at fourth quarter 2005, yielding 0.31. The fractional reserve requirement, rr, is set at 0.1. This is consistent with the reserve ratio set by the Federal Reserve on all liabilities above the low reserve tranche and approximately equal to the average tier one capital ratio in the US since the mid 2000s.

[19] As we deal with a consolidated government budget constraint, the net effect of interest payments on bonds held by the central bank is zero.

[20] The equations for the steady-state equations are listed in the technical appendix, available on request.

[21] The steady state of the transfer level, the Lagrangian of the production constraint and base money depend on the above parameters. The steady state of the marginal cost is $mc = \frac{\theta-1}{\theta}$.

This leaves us three key deep parameters to manipulate which may influence the rest of the steady state variables. Interestingly these are three financial variables and so are of particular interest to our debate on policies. α is the Cobb-Douglas weight of collateral in loan production. This is the degree to which banks base their lending on collateral as opposed to monitoring work or information based lending. The benchmark calibration in Goodfriend and McCallum (2007) of 0.65 is within a range throughout the literature of 0.6 to 0.89, Zhang (2011), so we follow this. k, is the degree to which capital is less efficient as collateral than bonds as it entails higher costs to the bank in order to check its physical condition and market price. It is also less liquid should default occur and the collateral be called upon to repay the value of the loan. We set this parameter to 0.2 which not only follows Goodfriend and McCallum (2007), but is validated by data on the Term Security Lending Facility which found less liquid assets were swapped for bonds in a ratio of 0.21. F, can be thought of as total factor productivity in loan production, or a measure of the efficiency with which banks use the factors of production to produce loans[22]. As in Goodfriend and McCallum (2007) we set this to ensure the rest of our steady state values meet three criteria as closely as possible:

- a 1% per year average short-term real “riskless rate” that is the benchmark in the finance literature,
- a 2% average collateralized external finance premium that is in line with the average spread of the prime rate over the federal funds rate in the postwar United States,
- a share of total U.S. employment in depository credit intermediation as of August 2005 of 1.6% as reported by the Bureau of Labor Statistics.

The value this yields is $F = 9.14$. With these parameter values we see that the steady state of labour input, n, is 0.31 which is close to 1/3 as required. The ratio of time working in the banking service sector, $\frac{m}{m+n}$, is 1.9% under the benchmark calibration, is not far from the 1.6% share required. As the steady-states are computed at zero inflation we can interpret all the rates as real rates. The riskless rate, R^T, is 6% per annum. The interbank rate, R, is 0.84% per annum which is close to the 1% per year average short-term real rate. The government bond rate, R^B, is 2.1% per annum. Finally the collateralized external finance premium is 2% per annum which is in line with the average spread of the prime rate over the federal funds rate in the US. The model is solved using the solution methods of King and Watson (1998) who also provide routines to derive the impulse responses of the endogenous

[22]Some authors have also described it as a measure of credit conditions within the economy. The rationale for this seems plausible as when credit conditions are tight, banks will require more collateral and will employ more monitoring work to provide the same amount of loans to the economy.

variables to different shocks, to obtain asymptotic variance and covariances of the variables and to simulate the data. For the impulse response analysis and simulation exercise we consider the real and financial shocks described in Table 4, which reports the volatility and persistence parameters. These are standard parameters in the literature.

6 Why Money Matters

Having outlined a model which incorporates both narrow and broad money, we can begin to think more profoundly about how the balance between the two may affect banks and the wider economy. Banks, with two sources for meeting deposit demand, make their choice between obtaining narrow money from the central bank or creating their own deposits by issuing loans. As the policy rate falls, narrow money becomes a relatively cheaper way of meeting deposit demand.[23] Similarly, if the return on loans were to fall, or the cost of producing them to rise, then it becomes less profitable for banks to originate deposits in this way. The optimal quantity of narrow money has now increased, whilst the amount of loans has fallen, meaning that the optimizing money multiplier is now lower. By providing more narrow money as a cheaper means of meeting deposit demand when loan production becomes more costly the central banks can effectively subsidize deposit creation. If the central bank were to increase the cost of narrow money by raising the policy rate, or the costs of producing loans were to fall (their returns to rise) then the converse would be true and it would be optimal for the money multiplier to rise.

Using our model we are able to trace this story through to the wider economy by analyzing the response of the model to various shocks. First, Figure 4 shows the impulse responses of the model's key variables to a negative shock to the value of collateral, the asset prices, that households have available to provide in return for loans. It can be thought of as akin to the shock, see Figure 2, which hit the US following the collapse in Lehman Brothers. We first analyze the response of our artificial economy when the policy rate moves to offset the shock and then when the policy rate is held at the steady state and reserves are demanded by the commercial banks instead. When the shock hits, asset prices fall, eroding the value

[23] An interesting point of note here is that, although it is not the purpose of our paper, this framework allows for the possibility of paying interest on reserves. Without a zero lower bound imposed on the policy rate charged at the discount window can go negative. In such a setting, charging a negative rate to borrow reserves is equivalent to paying banks to take reserves. This turns the cost implied by $R_t r_t$ in equation (8) into an income stream, paid by the central bank. This is a useful way of thinking about the expansion of reserves under recent quantitative easing programmes and the need for interest on reserves. With rates charged at discount windows cut to zero, and central banks seeking to expand reserve supply either further, interest on reserves (or a negative cost of holding reserves in our framework) was essential to maintain demand for the increased supply.

of collateral available for loan production. To produce the same quantity of loans, banks now need to employ more monitoring work relative to the quantity of loans, as they cannot rely on collateral. Not only does this push up the cost of loan production, but it also draws resources out of the production sector, causing a fall in production and employment in the real economy. The higher cost of loan production leads to a fall in loan supply, whilst the lower production reduces deposit demand both of which lower the level of broad money in the economy. If on the other hand, the policy rate is held constant, even though the impact on output and inflation is broadly similar, the increase in reserves allows monitoring work to fall in line with loans and so limit the increase in the external finance premium. The loan rate though, which is the sum of the policy rate and the external finance premium shows somewhat more volatility and hence output and inflation fall slightly more in this alternate policy world. In the next section, we shall show the results of the model with all shocks and measure the welfare of the household with under a policy regime of active interest rate rules and reserves on demand.

Figure 5 shows the impact on our economy of an exogenous increase in reserves as outline in section 4.1. The exogenous increase in reserves draws away work in monitoring at banks, reduces the external finance premium and leads to some switch into goods employment. Asset prices and loans are bolstered, so that overall nominal deposits increase. Output and inflation raise and so the reserves injection acts somewhat like a positive demand shock, or subsidy to banking intermediation. In this sense, following a negative shock to intermediation if loans become a relatively more expensive way of creating deposits the central bank can step in to increase the supply of relatively cheaper narrow money, which it injects through open market operations. As mentioned, this supports deposit creation. With fewer resources being drawn away from the production sector into monitoring work and broad money being supported both by increased narrow money and a smaller reduction in loan creation, output and inflation might fare better, falling by less and returning to equilibrium more quickly. In this instance, if associated with a cut in the central bank policy rate, it will act to make reserves an even cheaper way for banks to meet deposit demand and further increases their demand. When met by the central bank with increased supply this adds to the shock-attenuating effect of reserve provision.

We have therefore have two strands to consider. The correct response of the central bank to a negative credit, or collateral, shock in terms of the policy rate or the supply of narrow money (reserves). And the role of exogenous increases in reserves, which might be thought of as policy-induced changes in the asset mix held by commercial banks. All of these are stabilizing according to our impulse responses but in order to choose, we need to examine the response of the whole model and also conduct some welfare analysis.

7 Welfare Analysis

Having discussed in the previous section why variance in the money multiplier can improve welfare over the cycle we seek to strengthen this result by quantifying its impact on the representative household. To do this we carry out some more stringent welfare analysis by deriving a welfare loss function from a second order approximation to utility.

7.1 Deriving The Welfare Loss Function

The welfare approximation derived from the canonical New Keynesian model finds that welfare of the representative household only depends on the variance of output and inflation (Galí, 2008). We wish to investigate whether this result continues to hold when applied to our richer class of model. The use of the approximation allows us to quantify precisely the welfare rankings arising from each of our policy rules, possibly allowing some normative statements. Thus, we derive a quadratic loss function using a second-order Taylor approximation to utility by using the labour demand function, marginal cost function and sales-production constraint to substitute for household consumption.[24] Once re-ordered and simplified we are left with a loss function with relevant terms in the variances of consumption, inflation, wages, employment in the goods sector and the marginal cost.

$$\begin{aligned} U_t - U &= -\frac{1}{2} E_0 \sum_{t=0}^{\infty} \beta^t L_t + O3 \qquad (19) \\ \text{with } L_t &= \frac{1}{2} \left[\begin{array}{c} \sigma_c^2 + \frac{\theta}{\chi} \left[\frac{\frac{n}{c} - \frac{w}{c}}{1-\eta} \right] \sigma_\pi^2 - \\ \frac{w}{c} \sigma_w^2 - \frac{n}{c} \sigma_n^2 + \frac{mc}{c} \sigma_{mc}^2 \end{array} \right] \end{aligned}$$

where $\chi = \frac{(1-\theta)(1-\beta\theta)}{\theta} \frac{1-\eta}{1+\eta(\theta-1)}$. Given that $\frac{w}{c} > 0$ *and* $\frac{n}{c} > 0$, more flexible wages and employment improves welfare, whilst $\frac{mc}{c} > 0$ *and* $\frac{\theta}{\chi} \left[\frac{\frac{n}{c} - \frac{w}{c}}{1-\eta} \right] > 0$, so more stable marginal cost, consumption and inflation improves welfare.[25]

Remark The welfare of the representative household in this model, as in the original New Keynesian framework, is approximated by standard variables on the supply side rather

[24] The additive nature of our household's utility function allows us to take a Taylor expansion of each term and substitute it back into the original function. The labour demand function is then rearranged for monitoring work, a second order expansion taken and substitution made. This process is then repeated for the marginal cost equation. Following Galí (2008) we substitute the resulting linear term in goods sector employment for a second order term in inflation using the sales equal net production constraint.

[25] Whilst it is likely to derive a different loss function through a different sequence of substitutions, ours seems both plausible and parsimonious.

than those specifically attributable to financial factors. This means that changes in financial conditions only impact on utility in so far as they impact on the variance of consumption, inflation, wages, labour supply hours and marginal costs.

Table 5 shows the asymptotic standard deviations and the contemporaneous cross-correlations with consumption from a simulation of each model. Broadly the results are similar with the correlations between real and financial variables unchanged across policy regimes. The key difference is that the interest rate spreads become more countercyclical as does monitoring employment, which tends to drive up slightly the overall variance of output and inflation when reserves are used rather than interest rates to stabilize the economy. We use these values to calculate the welfare loss in Table 6 from each model. We can see that the welfare loss under a regime where the central bank uses an active interest rate is smaller than one in which reserves are used. In part this is because a reserves policy cannot offset exogenous increases in reserves but an interest rate rule can for Poole-type reasons. But it also it tells us that if the interest rate cannot be used, for example, at the zero lower bound reserves may be able to undertake a role in substituting.

8 Capturing the Crisis

We now look at the ability of the model to help us understand the response of the economy and the financial sector to the initial shock of the financial crisis and examine what it may tell us about the behaviour of the multiplier in this period. The obvious problem is how to replicate the shock(s) that afflicted the US economy, culminating in the recession of 2008. This particular crisis had a number of characteristics which are compatible with our model. House prices fell, reducing the value of collateral the private sector had to post against loans from the financial sector. Banks also tightened credit conditions and, due to increased precautionary motives and economic uncertainty, increased their preference for liquidity. Whilst the exact sizes and interconnected nature of each of these factors may for practical purposes be intractable, it seems plausible that some combination of shocks along these lines is an appropriate, though rudimentary way to think of the origins of the crisis, and one that it is within the capabilities of our model to capture. We therefore subject the model to collateral shock. We run two simulations. One where there are no reserve injections but where the policy rate falls and one where the policy rate is held constant but there is a reserves injections.

Whilst, as with any model of this ilk, there remains a degree of oversimplification, the model we have outlined manages to capture well the general evolution of the US economy in the second half of 2008. Figure 6 plots the impulse responses of variables following the collateral shock. What we see is that, following a collateral/credit shock implying around 0.7% off nominal lending, reserves increase by around 1% of GDP for a fall in output of around 0.2% and the equivalent policy rate response is some 25bp. A 10% fall in loans would therefore imply just under an increase in reserves of some 14% of GDP or a cut in interest rate of some 3.5%. The narrative from our model is that as the external finance premium rose and loans would became more expensive to verify and produce, banks maximizing behaviour would drive them to reduce loan production and shrink the supply of broad money. However, this effect was attenuated by the increased supply of narrow money, demanded by banks and supplied by the Fed through large scale asset purchase programmes and the massive expansion of its balance sheet, which was akin to a negative interest rate.

The implication is that if the Federal Reserve had been able to choose negative interest rate, this might also have offset the broad money contraction and limited the increase in financial spreads. The model suggests that the policies used might be associated with limiting the contraction in output by some 1% or more, preventing a fall in inflation of an additional 2.5% and unemployment increasing by some 2%. In the absence of such policies, the recovery would also have been more protracted, taking roughly twice as long to return to equilibrium.

9 Conclusion

In a prophetic final note Milton Friedman (2006) argued that the Fed had offset the impact of the collapse of the dot-com bubble by maintaining the level of broad money growth, arguing: 'that monetary policy deserves much credit for the mildness of the recession that followed the collapse of the U.S. boom in late 2000.' Subsequently, it seems that rumours of the death of the money, as a useful concept may, as the saying goes, have been greatly exaggerated. Following the financial crises of 2007-8, the Fed seems to have used these ideas again by stabilizing the growth in broad money. Accordingly, this paper provides a way of framing the components of broad money for the post-crisis world: there is an optimal choice for commercial banks as to how they collectively meet deposit demand with reserves or loans.[26] But the Fed has also generated off-equilibrium holdings of reserves via QE. And yet, the post-crisis variation in the quantity of reserves may have acted to stabilize broad money and may have been welfare enhancing compared to a no-policy alternative. Of course, some of the stabilizing properties of broad money growth in terms of generating confidence may be important but are not modelled here.

[26] See Kashap and Stein (2012) for separate analysis using interest on reserves. That is not necessary for our result.

We have also go some way to addressing the common criticisms levelled at modelling money and its role in monetary policy. By modelling reserves as demand determined, conditioned on the prevalent interest rates in the economy and allowing the central bank to set the interest rate and then provide this narrow money perfectly elastically through open market operations to meet the demand of commercial banks we provide a framework which is hopefully more recognizable to monetary policy practitioners. As far as non-conventional monetary policies are concerned, we do not think they necessarily depart from standard open market operations, other than in their size or duration. In our model, we find that the supply of central bank money, or reserves, whilst not preventing an extended downturn may have played a substantive role in preventing the downturn turning into a sustained depression.

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Table 1: List of Variables

Variable	Description
c	Real Consumption
n	Labour Input
m	Labour Input for Loan Monitoring, or 'Banking Employment'
w	Real wage
q	Price of Capital Goods
P	Price Level
π	Inflation
mc	Marginal Cost
r	Reserves
rr	Reserves/Deposit Ratio
D	Deposits
L	Loans
P^A	Aggregate Prices
b	Real Bond Holding
b^p	Real Private Sector Bond Holdings
Ω	Marginal Value of Collateral
EFP	Uncollateralized External Finance Premium (R^T - R^{IB})
LSY^B	Liquidity Service on Bonds
LSY^{KB}	Liquidity Service on Capital ($kLSY^B$)
R^T	Benchmark Risk Free Rate
R^B	Interest Rate for Bond
R	Policy Rate
R^L	Loan Rate
R^D	Deposit Rate
λ	Lagrangian for Budget Constraint (shadow value of consumption)
ξ	Lagrangian for Production Constraint
T	Real transfer (%)

Table 2: Parameterization

Parameter	Description	Value
β	Discount factor	0.99
κ	Coefficient in Phillips curve	0.1
α	Collateral share of loan production	0.65
ϕ	Consumption weight in utility	0.4
η	Capital share of firm production	0.36
δ	Depreciation rate of capital	0.025
ϱ	Trend growth rate of shocks	0.015
ρ	Interest rate smoothing	0.8
ϕ_π	Coefficient on Inflation in Policy	1.5
ϕ_y	Coefficient on Output in Policy	0.5
F	Production coefficient of loan	9.14
k	Inferiority coefficient of capital as collateral	0.2
θ	Elasticity of substitution of differentiated goods	11

Table 3: Steady State Parameters

Steady State	Description	Value
m	Banking Employment	0.0063
n	Labour Input	0.3195
R^T	Risk Free Rate	0.015
R^{IB}	Interbank Rate	0.0021
R^L	Loan Rate	0.0066
R^B	Bond Rate	0.0052
b/c	Bond to Consumption Ratio	0.56
b^p/c	Private Sector Bond Holdings to Consumption Ratio	0.50
γ (b^p/b)	Fraction of Bonds Held By Private Sector	0.893
c	Consumption	0.8409
T/c	Transfers Over Consumption	0.126
w	Real Wage	1.9494
λ	Shadow Value of Consumption	0.457
ν	Velocity	0.31
Ω	Marginal Value of Collateral	0.237
K	Capital	9.19
K^P	Private Sector Capital Holdings	9.19
rr	Reserve ratio	0.1
r/c	Reserves to Consumption	0.36

Table 4: Properties of Exogenous Shocks

Shock Name	Standard Deviation	Persistence
Productivity	0.35%	0.95
Monitoring	1.00%	0.95
Collateral	0.35%	0.9
Monetary Policy	0.82%	0.3
Mark Up	0.11%	0.74
Bond Holdings	1.00%	0.9
Velocity	1.00%	0.33
Reserves	1.00%	0.33

Table 5: Impact on the Economy of Flexible or Constant Interest Rates

Policy	Flexible Interest Rates		Constant Interest Rates	
	St.Dv	Corr	St.Dv	Corr
Real Consumption/Output	1.05	1	1.17	1
Inflation	0.40	0.62	0.42	0.69
Employment in Monitoring	3.55	-0.74	3.28	-0.83
Employment in Goods Sector	1.60	0.96	1.81	0.97
Real Wage	1.69	0.99	1.91	0.99
Private Sector Bond Holdings	1.79	-0.34	1.85	-0.40
Asset Prices	1.02	0.98	1.14	0.99
Loans	1.10	0.29	1.15	0.40
Reserves	1.62	0.73	1.83	0.77
Policy Rate	1.05	-0.08	0.80	-0.36
Loan Rate	0.68	-0.83	0.70	-0.88
Bond Rate	3.99	0.49	3.24	0.50
Deposit Rate	1.04	-0.16	0.85	-0.45
External Finance Premium	1.37	-0.35	0.82	-0.46
Liquidity Premium	4.52	-0.56	3.68	-0.62

Note: The first two columns of results correspond to the model with an active interest reaction function and in the final two columns the policy rate is held constant. All shocks are included in these results as given by Table 4.

Table 6: Relative Welfare Analysis

Fixed or Flexible Interest Rates	Welfare Loss
Constant interest rates	4.293
Flexible interest rates	3.908

Note: Loss determined by a quadratic loss function derived using a second-order Taylor approximation to utility. See Section 7.1

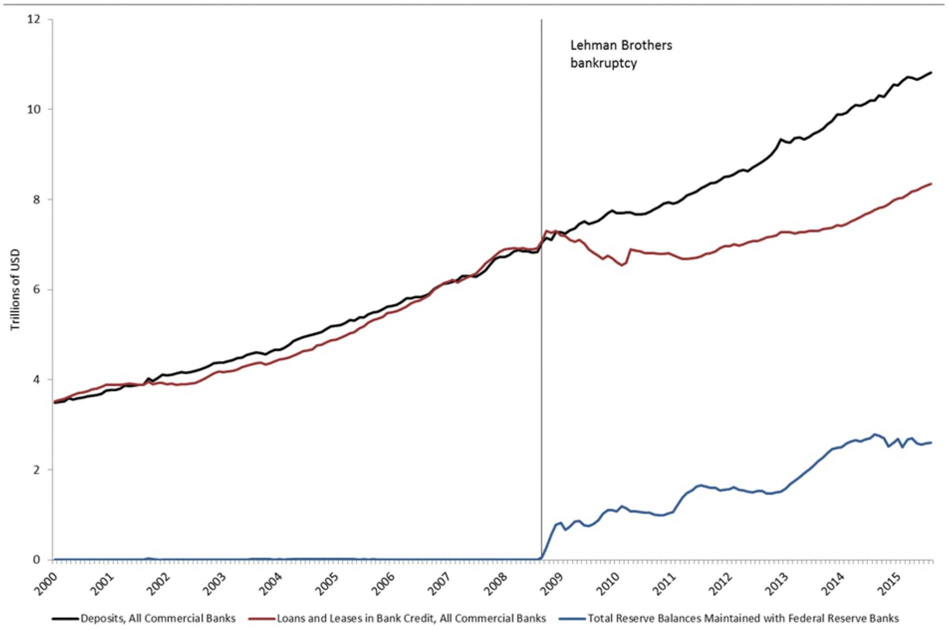

Figure 1: US Money Aggregates and Bank Credit

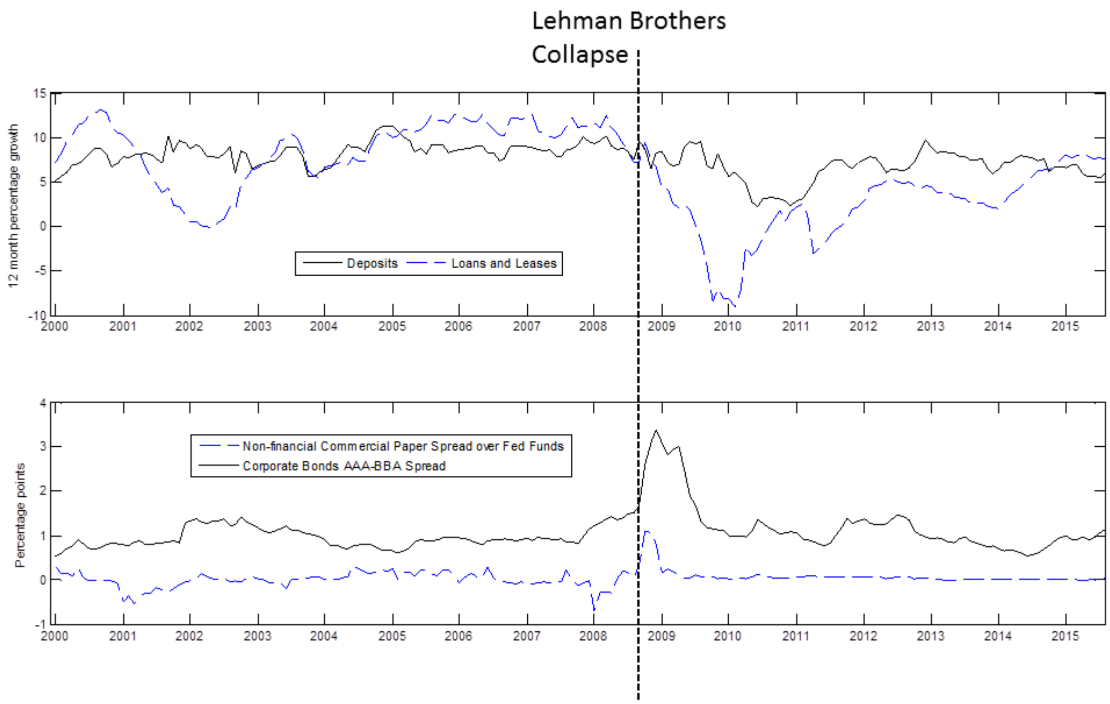

Figure 2: Deposit and Lending Growth and Financial Spreads

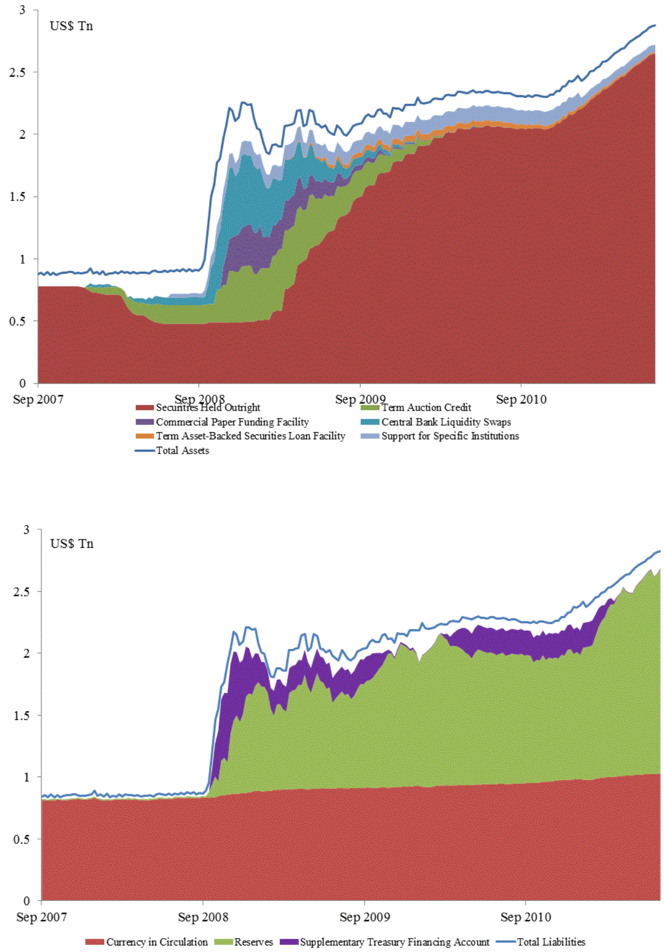

Figure 3: Federal Reserve Assets (top) and Liabilities (bottom)

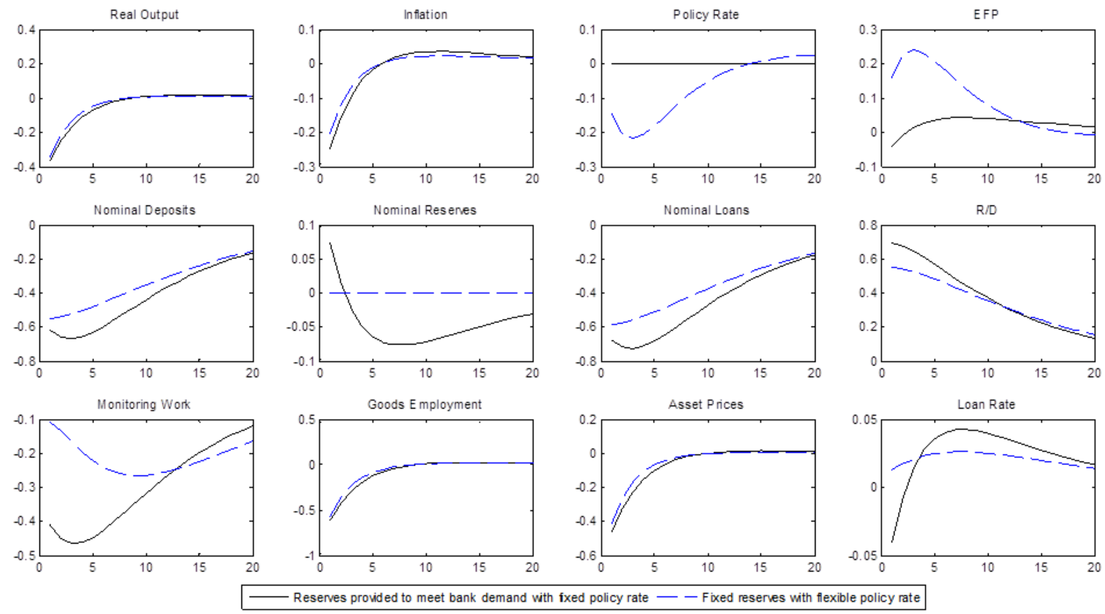

Figure 4: Negative Shock to Collateral

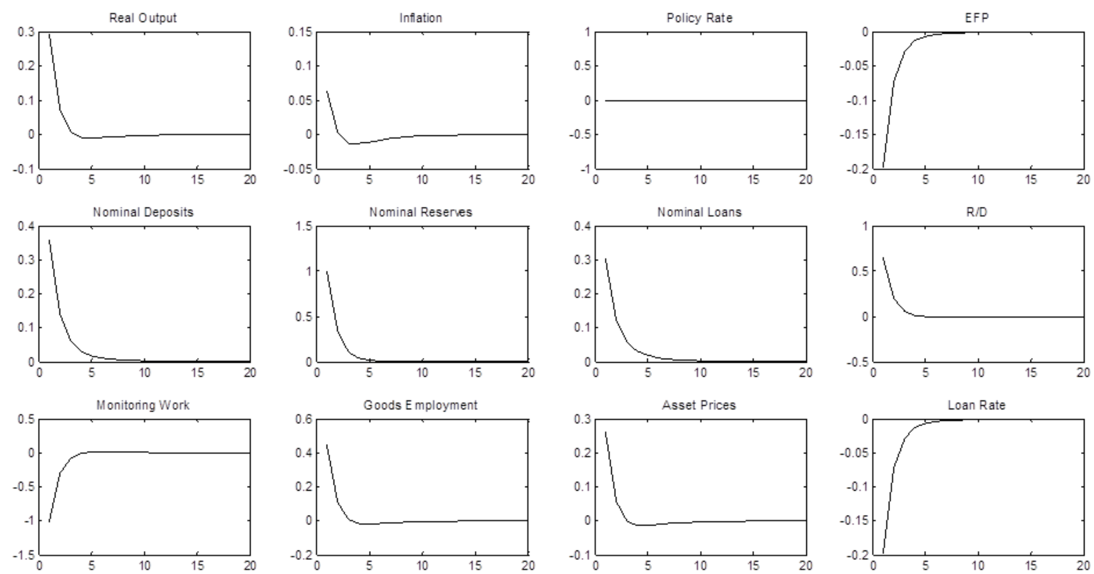

Figure 5: Exogenous shock to Reserves (Table 4)

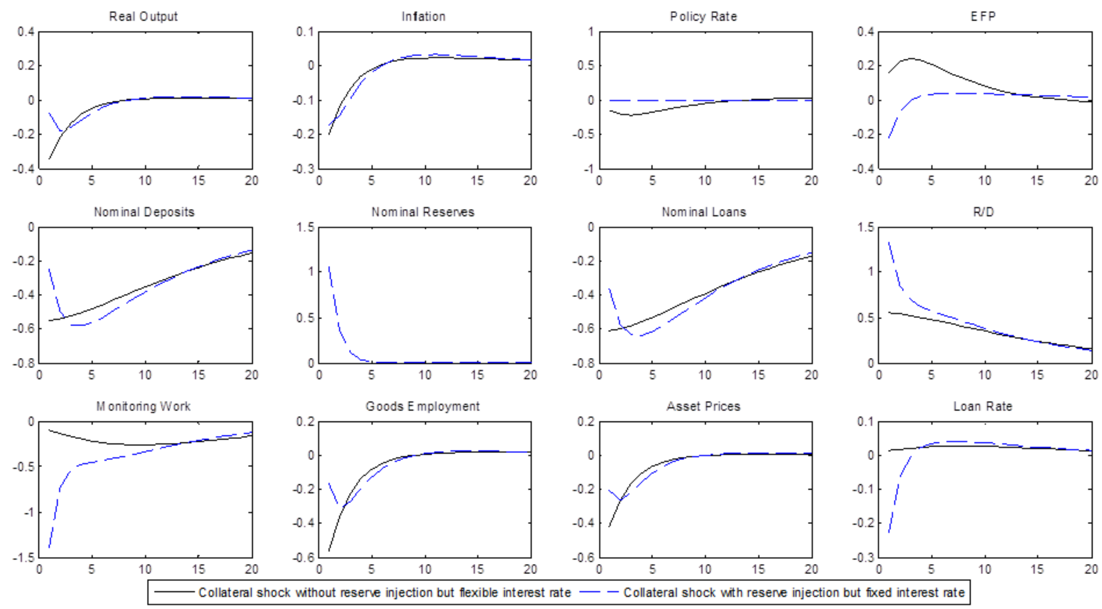

Figure 6: Crisis Shock with and without reserve injection