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Jagjit S. Chadha, Luisa Corrado and Sean Holly

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Jagjit S. Chadha† Luisa Corrado‡ and Sean Holly§

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Abstract

Prior to the financial crisis mainstream monetary policy practice had become disconnected from money. We outline the basic rationale for this development using a simple model of money and credit in which we explore the conditions under which money matters directly for the conduct of policy. Then, drawing on Goodfriend and McCallum's (2007) DSGE model, we examine the circumstances under which money becomes more closely linked to inflation. We find that money matters when the variance of the supply of lending dominates productivity and the velocity of money demand. This is because amplifying the role of loans supply leads to an expansion in aggregate demand, via a compression of the external finance premium, which is inflationary. We consider a number of alternative monetary policy rules, and find that a rule which exploits the joint information from money and the external finance premium performs best.

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†Professor of Economics, Chair in Banking and Finance, Department of Economics, University of Kent. E-mail: jsc@kent.ac.uk.

‡Associate Professor of Economics, University of Rome, Tor Vergata and Fellows CIMF and CReMic, Faculty of Economics University of Cambridge. E-mail: lc242@cam.ac.uk

§Faculty of Economics, Sidgwick Avenue, University of Cambridge and Fitzwiliam College Cambridge. E-mail: Sean.Holly@econ.cam.ac.uk

1 Introduction

The standard, mainstream macroeconomic model (Woodford, 2003, Galí, 2008) has little, if any, independent role for the money supply. Money is endogenous and adjusts with movements in the demand for money. The use of the nominal short term interest rate as the instrument of policy insulates the real economy from shocks to the money market. This insight goes back to Poole (1970) who showed that the use of the interest rate as the instrument of policy insulates the economy from shocks to the demand for money. More recently, Ireland (2000) has shown that Poole's result carries over to the New Keynesian model. This dichotomy would suggest that there will be little short term relationship between changes in the stock of money and credit and output and inflation, even though in the long run the price level will rise in proportion with the stock of money. This paper contributes to this discussion by considering why and in what circumstances the monetary authorities should pay attention to the monetary aggregates.

Despite the clarity of this result in the mainstream theoretical model, there is conflicting empirical evidence on the role of money and credit in business cycles. For example, Reynard (2007) provides evidence to suggest there is a systematic empirical relationship between movements in money and subsequent prices and output. Using data for the US, the Euro area and Switzerland he finds that monetary developments provide information about subsequent inflation. Nelson (2002) also finds empirical evidence of a direct effect of base money on output. He argues that money may be acting as a proxy for various yields that affect aggregate demand. By contrast, Ireland (2004) provides a model in which empirical measures of real money balances must first be adjusted for shifts in money demand in order to isolate the effects of money on output and inflation. Even when taking this into consideration, he finds that money plays a minor role in explaining the business cycle.[1]

Andres *et al* (2006) examine the role of money using an estimated model of the Eurozone built on a dynamic equilibrium framework. They find that, first, consumption is not affected by money balances. Secondly, shocks to money demand can forecast real balances, but it requires real shocks to explain the bulk of fluctuations in prices, output and interest rates. Favara and Giordani (2009) offer a direct evaluation of the contribution that money can make to explaining movements in inflation and output. Using a VAR, they find that shocks to monetary aggregates appear to have substantial and persistent effects on inflation, output and interest rates.

Benk *et al* (2005) take a different approach and construct a measure of credit shocks and find the credit shocks have a role in explaining GDP. The credit shocks it is argued are the product of legislative changes in the regulation of banks in the US. The mainstream view that narrow definitions of money (M0 and M1) do not appear to have significant real effects draws on the early

[1] A modified version of the standard New Keynesian model with non-separability in preferences (Aurouba and Schorfheide, 2011) also allows a non-negligible role for money in the determination of output and inflation and thus, in the conduct of monetary policy. However, quantitative analysis documents the irrelevance of this channel.

work of Chari *et al* (1995) who found that monetary aggregates covary mainly positively with output because money demand is primarily driven by aggregate shocks to the private economy. Christiano *et al* (1999) find that shocks to money demand measured by narrow measures of money (M0 and M1) do not have significant real effects while shocks to M2, which involve a measure of credit, has some significant real effects.

At first blush the different empirical results in the literature are difficult to reconcile. One obvious possibility is that over the sample periods being used monetary policy was not always conducted strictly along the lines of the new Keynesian framework. There, as we have already noted, the role of the short term interest rate is central. It is certainly true for example in the United Kingdom, there were significant periods during which monetary aggregates were targeted or else the exchange rate. A policy of an explicit reliance upon the short-term nominal interest rate started only in 1992 with the formal adoption of inflation targeting. It may be that these alternative regimes impart a sufficient departure from the canonical new Keynesian model for effects of money to show up in the data. Moreover, the European Central Bank has always followed a two-pillar approach. The first of these gives a prominent role to a 'broadly based assessment of the outlook for future price developments' and the second pillar relies on a monetary analysis of trends (Stark, 2008).

But we are interested in explaining the results with reference to the prominence of shifts in the supply of bank credit.[2] The role of banks, other financial institutions and the financial system - that provide loans and help determine asset prices - are often given particular prominence in discussions on the transmission mechanism of monetary policy.[3] And so a significant corpus of economists have not given up entirely on the idea that the monetary aggregates can sometimes contain information about the future state of the economy, as well as about the transmission mechanism of monetary policy.[4] To borrow an analogy from Kiyotaki and Moore (2001) 'the flow of money and private securities through the economy is analogous to the flow of blood...money is the blood that dispatches resources in response to those (price) signals (p. 5)'. More recently, and especially in the light of recent turbulence in world financial markets, economists have been re-examining the role that money, and more generally credit, can play independently of the policy rate. One avenue we explore in this paper, is motivated by the role of money as a suppler of payment services to credit constrained consumers. The price, as a premium above the policy rate, of such loans reflects the marginal costs to banks of their supply and so it responds to increases in the efficiency of supply relative to the demand for loans. This relative price can move out of line with the policy rate set by the central bank when there are independent sources of fluctuations in the ability of banks to supply liquidity, for example, as a result of their efficiency in screening

[2] Recently, Chadha et al (2010) have found a significant role for supply shocks in explaining broad money movements prior to and subsequent to the financial crisis.

[3] See Bernanke *et al* (1999) for a clear exposition.

[4] See Christiano, Motto and Rostagno (2007) for a discussion of these issues.

loans (monitoring) or the value of posted collateral.

The paper is structured as follows. In section 2 we consider the role of money in a highly stylised macro model and show that, in accordance with with the mainstream literature, that shocks to money demand do not affect output and inflation. We then go on to consider a version of this model with credit following Bernanke and Blinder (1988). There is an external finance premium (EFP) so that there is not always a one to one correspondence between the interest rate set by policymakers and that which lenders pay. In this case the monetary authorities cannot completely insulate the real economy from shocks in financial markets, compared to the situation in which only money demand shocks matter. This leads to a modification of the standard Taylor principle for the stability of the model under an interest rate rule. In particular factors that determine the supply of loans can alter the appropriate policy response to inflation. To help to flesh out this insight with a more fully specified and micro-founded model, in Section 3, we re-examine the role of money for policy in the context of Goodfriend and McCallum's (2007) model which adds a banking sector to a DSGE model.[5] This means that shocks in the financial sector that affect the external finance premium can now alter output and inflation. In Section 4, using an impulse response analysis we show that under an inflation targeting policy, money and financial spreads become negatively correlated when shocks to the supply of bank loans dominate those to money demand or to productivity in the real economy. Section 5 explores the conditions under which money provides a reliable signal about inflation and output and considers a number of simple augmented rules to capture the signal. We observe that when supply shocks dominate in the money market, spreads and money move in opposite directions and so one rule that has attractive properties is one that employs information about the difference in money and spreads. We show that such a rule is better able to stabilise the economy compared to a simple inflation targeting rule when there are shocks to financial markets. Section 6 concludes and offers some directions for future work.

2 Money, Credit and Interest Rate Rules

In the first part of this section we take a stylised version of the New Keynesian model and show the standard result that as long as the policy rule satisfies the Taylor principle, output and inflation can be insulated from money demand shocks. In the second part we go on to re-examine this result in a NK version of Bernanke and Blinder's (1988) credit model, in which financial spreads also matter for the level of output. We now find that monetary policy also needs to be responsive to conditions in credit markets which we capture by the external finance premium (Meier and Müller, 2005) in order to stabilise output and inflation. First, consider a simple model of money demand (for which supply is implicitly perfectly elastic) appended to a standard New Keynesian

[5] See Curdia and Woodford (2010) for an alternative take on the importance of the EFP.

framework (see King, 2002), which uses a monopolistically competitive supply side with Calvo price setting. And examine, in this simple setting, that the stock of money plays is essentially decoupled and plays no role in the determination of output and inflation.

In the simple New Keynesian model all variables are expressed as log deviations from steady-state. Equation (1) gives aggregate demand, y_t, as a function of this period's expectation, E_t, of demand next period, y_{t+1}, and of the expected real interest, where R_t is the policy rate, $E_t\pi_{t+1}$ is the next period expectation of inflation and σ is the intertemporal rate of substitution in output.[6] Equation (2) is the forward-looking New Keynesian Phillips curve that relates current inflation, π_t, to discounted expected next period inflation, where β is the subjective discount factor, and is proportional to the deviation of aggregate demand from supply, where κ is the slope of the Phillips curve.[7] In equation (3) real balances, $h_t - p_t$, are held in proportion to demand, y_t, and inversely with the opportunity cost of holding non-interest paying money, R_t, with a semi-elasticity, θ. Equation (4) is a simple interest rate-based rule that is used to stabilise inflation about its steady state value with the weight on inflation given by ϕ_π. The supply side of the economy, $\tilde{y}_t$, which we interpret as the flex-price level of output is given by (5). Finally, τ is the fraction of firms that hold prices fixed and so $(1-\tau)$ is the fraction which are given a signal to re-price as a mark-up over marginal costs thus inflation in equation (6) is simply the ratio of firms that re-price at the new price level, p_t, relative to those that cannot re-price.

The system is subject to stochastic shocks, $\epsilon_{A,t}$, $\epsilon_{B,t}$, $\epsilon_{C,t}$, $\epsilon_{D,t}$, $\epsilon_{E,t}$ which are respectively to demand, mark-up, money markets, monetary policy and to aggregate supply.

$$y_t = E_t y_{t+1} - \sigma\left(R_t - E_t\pi_{t+1}\right) + \epsilon_{A,t} \tag{1}$$

$$\pi_t = \beta E_t\pi_{t+1} + \kappa\left(y_t - \tilde{y}_t\right) + \epsilon_{B,t} \tag{2}$$

$$h_t - p_t = y_t - \theta R_t + \epsilon_{C,t} \tag{3}$$

$$R_t = \phi_\pi \pi_t + \epsilon_{D,t} \tag{4}$$

$$\tilde{y}_t = \epsilon_{E,t} \tag{5}$$

$$\pi_t = \frac{1-\tau}{\tau} p_t. \tag{6}$$

We can substitute (4) into (1), (5) into (2) and solve (6) for p_t and substitute into (3) to give

[6] This intertemporal equation also operates as the basic asset pricing equation in a New-Keynesian model.

[7] The term κ is related to two deep parameters in the underlying Calvo-Yun model (see Yun, 1996): the probability of firms maintaining a fixed price in the next period, τ, and the subjective discount factor, β. In inflation space κ can be shown to be equal to $\frac{(1-\tau)(1-\tau\beta)}{\tau}$ and thus in price space, with the deviation in the price level proportional to inflation (see equation 6), the Phillips curve becomes: $p_t = E_t p_{t+1} + (1-\tau\beta)\left(y_t - \hat{y}_t\right) + \frac{\tau}{1-\tau}\epsilon_{A,t}$. Under either formulation inflation or the price level is less responsive to the output gap as $\tau \rightarrow 1$.

us a system of three difference equations that can be written in vector form, if we suppress the stochastic errors, as:

$$E_t \mathbf{x}_{t+1} = \mathbf{\Lambda} \mathbf{x}_t, \tag{7}$$

where the transpose of the vector of state variables $\mathbf{x}_t$ is:

$$\mathbf{x}_t^{'} \equiv \left[\begin{array}{ccc} y_t & \pi_t & h_t \end{array} \right],$$

where $\mathbf{\Lambda}$ is a 3 x 3 matrix. The existence or not of a unique solution for $\mathbf{x}_t$, as is well understood, given the forcing processes, $\boldsymbol{\epsilon}_t$,[8] will depend upon matching the number of eigenvalues of the matrix $\mathbf{\Lambda}$ within the unit circle with the number of predetermined state variables. And typically the coefficients of the policy rule, (4), are set to ensure local determinacy.[9]

What concerns us here is the role, if any, that money, h_t, plays in this economy. We note that the matrix, $\mathbf{\Lambda}$, can be written in block form:

$$\begin{aligned} \mathbf{\Lambda} &= \left[\begin{array}{ccc} \kappa\frac{\sigma}{\beta}+1 & \sigma\phi_\pi - \frac{\sigma}{\beta} & 0 \\ -\frac{\kappa}{\beta} & \frac{1}{\beta} & 0 \\ 1-\frac{\kappa}{\beta-\tau\beta}\left(\tau+(\tau-1)\left(\sigma+\theta\phi_\pi\right)\right) & \sigma\phi_\pi+\frac{1}{\beta-\tau\beta}\left(\tau+(\tau-1)\left(\sigma+\theta\phi_\pi\right)\right) & 0 \end{array} \right] \\ &= \left[\begin{array}{cc} \mathbf{A} & \mathbf{0} \\ \mathbf{C} & \mathbf{D} \end{array} \right]. \end{aligned}$$

Where A is 2×2, C is 1×2, D is a 1×1 null matrix and 0 is a 2×1 null column vector. The block triangularity of $\mathbf{\Lambda}$ means that its eigenvalues are simply given by the eigenvalues of $\mathbf{A}$, referring to $\left[\begin{array}{cc} \pi_t & y_t \end{array} \right]$ and $\mathbf{D}$, referring to $[h_t]$. Also the determinacy of $\mathbf{\Lambda}$ follows from the determinacy of $\mathbf{A}$ given $\mathbf{D}$ is a null matrix. In this case, with both inflation and output non-predetermined, determinacy will require A to have two eigenvalues outside the unit circle and for the trace $Tr(A)$ to be positive. This requires the $Det(A) - Tr(A) > -1$, for which a necessary and sufficient condition is that:

$$\phi_\pi > 1. \tag{8}$$

Which is the familiar condition that for stability real rates must increase (decrease) by more than any positive (negative) inflation shock. This solution is recursive in that as long as inflation and output are pinned down to a unique solution path then the money stock (and the price level) is (are) also determined in each period. In other words there is no role here for the money stock to destabilise the economy independently. This is essentially the New Keynesian generalisation of the Poole assignment. Using the short term interest rate as the instrument of policy the real sector can be insulated from shocks to the demand for money. Moreover, shocks to aggregate demand can also be offset completely (Galí, 2008).

[8] Which is an analagous 3 x 1 vector for the shocks.
[9] See Woodford (2003) for a comprehensive treatment of this problem.

2.1 Credit in a NK Model

We now consider how a primitive banking sector can be introduced into the NK model using the approach of Bernanke and Blinder (1988). Aggregate demand in equation (1'), now depends on the interest rate on loans in the credit market, R_t^m, rather than directly on the policy rate, R_t, for which we will now solve:

$$y_t = E_t y_{t+1} - \sigma \left(R_t^m - E_t \pi_{t+1} \right) + \epsilon_{A,t}. \tag{1'}$$

The Phillips curve is (2) as above. So the interest rate on loans is determined by market clearing, for which we will now solve. The real supply of loans by banks, $l_t^s - p_t$, depends positively on the external finance premium $(R_t^m - R_t)$ and on (real) bank deposits, $(d_t - p_t)$ where γ_c can be interpreted as a measure of the extent of leverage of loans over deposits, while the costs of monitoring or the availability of collateral would be reflected in α_c.

$$l_t^s - p_t = \alpha_c (R_t^m - R_t) + \gamma_c (d_t - p_t) + \epsilon_{ms,t}. \tag{9}$$

We now turn to the real demand for loans, $l_t^d - p_t$, which depends negatively on the external finance premium,

$$l_t^d - p_t = -\theta_c (R_t^m - R_t) + \epsilon_{md,t}. \tag{10}$$

Bank deposits, replacing money demand in (3), are held to finance output,

$$(d_t - p_t) = y_t. \tag{3'}$$

Equating $l_t^s = l_t^d$ and suppressing stochastic terms, we can solve for the market interest rate in terms of the policy rate, which is set by (4), and the parameters of loan supply:

$$R_t^m = R_t - \frac{\gamma_c}{\alpha_c + \theta_c} y_t = R_t - \lambda_c y_t \tag{11}$$

Solving for the equilibrium in the market for loans, and using the policy rule in (4) we can reduce the model to the two equation system

$$E_t y_{t+1} + \sigma E_t \pi_{t+1} = y_t \left(1 - \sigma \lambda_c\right) + \sigma \phi_\pi \pi_t \tag{12}$$

$$\beta E_t \pi_{t+1} = -\kappa \left(y_t - \widetilde{y}_t \right) + \pi_t, \tag{13}$$

where $\lambda_c = \frac{\gamma_c}{\alpha_c + \theta_c}$. The necessary and sufficient condition for the stability of this model is now:

$$\phi_\pi > 1 + \lambda_c \frac{(1-\beta)}{\kappa}. \tag{14}$$

In contrast to the standard New Keynesian model the policymaker needs to be more responsive to inflation in order to offset the effect of developments in credit markets and more so when banks increase their loans supply relative to their deposit base. Hence the new condition (14) tells us that if money (or credit) is provided at an interest rate that differs from the policy rate, R_t, which itself varies with the costs of monitoring and the availability of collateral (or with the extent of leverage in the banking sector) the policymaker has to offset that spread as well as ensuring the policy rate increases or decreases the real rate. In other words the price at which money is supplied by the banking system might matter. The model examined in the following section gives us a micro-founded route to the result here and starts to fill in the missing arguments of a typical NK model by suggesting that the money/credit affects both aggregate demand and policy.

3 A General Equilibrium Monetary Model with Banking and Credit

As pointed out by Goodhart (2007) and by Kiyotaki and Moore (2001) money (aggregates) should be be made to mattter in general equilibrium models as they affect consumption decisions of liquidity constrained households and the spreads across several financial instruments and assets. And as Woodford (2007) states 'money matters' in such circumstances as it may be the root of disequilibrium and instability in the economy originating from the financial sector. A way to incorporate money and financial spreads into a general equilibrium setting is to study the banking sector proposed by Goodfriend and McCallum (2007).[10] The main feature of the model is the inclusion of a banking sector alongside households, production and the monetary authority. The model by GM complements the traditional accelerator effect (Bernanke *et al.*, 1999) with an attenuator effect, which is present in the model because monitoring effort is drawn into the banking sector in response to the expansion of consumption, which is accompanied by an expansion of bank lending that raises the marginal cost of loans and the external finance premium.

The main feature of this model is the underpinning of household, production and the monetary authority with a banking sector. Households, who are liquidity constrained, decide the amount of consumption and the amount of labor they wish to supply to the goods production sector and to the banking sector. They also demand deposits, money (liquidity), as a function of the amount of consumption they wish to finance. The production sector is standard (Yun, 1996), characterised by monopolistic competition and Calvo pricing, with a Cobb-Douglas production function, subject to productivity shocks. Profit maximising firms decide the amount of production they wish to supply and the demand for labour. By clearing the household and production sectors we can define the equilibrium in the labour market and in the goods market. These two sectors also provide the standard relationship for the riskless interest rate and the bond rate.

[10] See also Gilchrist's comment (2008) on Goodfriend and McCallum's model (2007).

Finally, the banking sector matches deposit demand from liquidity constrained consumers with a loan producing technology. Specifically, banks substitute monitoring work for collateral in supplying loans. More monitoring is achieved by increasing the number of people employed in the banking sector and therefore reducing employment in the goods production sector. A fractional reserve requirement with a fixed reserve-deposit ratio is assumed. Given this technology banks decide on the amount of loans they can supply and the amount of monitoring required. At the same time households' consumption is affected by the availability of loanable funds. The Appendix lists all the model equations.

3.1 Consumption and Collateral

But we can summarize the relationship for consumers in the GM framework around an equilibrium steady state c in the reduced form (subscript t denotes deviations from steady state and variables with no subscript are steady-state parameters):[11]

$$c_t = \left\{ v_t c + (1-\alpha)(m_t + a2_t) + \alpha \left[\frac{b}{b+k_1} b_t + \frac{k_1}{b+k_1}(q_t + a3_t) \right] \right\} \left(\frac{b+k_1}{b(1-\alpha)+k_1} \right). \tag{15}$$

With the presence of a cash in advance constraint, a shock to velocity, v_t, will increase consumption. Consumption, c_t, is also positively affected by the amount of monitoring work, m_t, where α is the share of collateral in the loans production function and $(1-\alpha)$ represents the share of monitoring costs. It is also affected by the amount of collateral represented by bonds, b_t, and capital whose value is given by q_t. A positive shock to monitoring, $a2_t$, by increasing the efficiency with which banks produce loans, increases the supply of loans and therefore consumption. Similarly a negative shock to collateral, $a3_t$, by reducing the price of capital, q_t, will negatively affect consumption. The parameters c, b and k_1 represent the steady-state fraction of consumption in output, the holding of bonds and a composite parameter reflecting the inferiority of capital compared to bonds as liquidity.[12] The demand for monitoring work is given by:

$$m_t = -w_t - \frac{(1-\alpha)c}{mw}(c_t + \frac{\phi}{\lambda}\lambda_t). \tag{16}$$

A higher wage, w_t, will reduce the resources devoted to monitoring. Similarly monitoring will be affected by the marginal utility of consumption and the marginal value of households' funds, λ_t. The steady state parameters, m, w, and $\frac{\phi}{\lambda}$ represent the steady-state proportions of employment in the banking sector, the level of the real wage, and the ratio of the weight of consumption in the utility function relative to the steady-state shadow value of consumption.

With a banking sector of this type in the model, we can link money and asset prices directly

[11] The model is fully derived in the extended technical appendix available from the authors' website.

[12] The parameter $k_1 = \frac{(1+\gamma)kK}{c}$ is a function of the ratio of consumption to output, c, of the parameter reflecting the inferiority of capital as collateral, k, of steady-state capital, K, and of the trend growth rate, γ.

to output and inflation, as consumption, which accounts for most of the fluctuations in output in this model, is closely dependent on money market perturbations, the development of banking technology and asset prices outcomes. Now money and lending affect consumption, the level of economic activity and will also have implications for asset prices.

A key term here is the marginal value of collateralized lending, Ω_t, which increases as consumption rises and falls as collateral becomes more widely available:

$$\Omega_t = \frac{k_2}{b+k_2}\left(c_t - q_t - a3_t\right) - \frac{b}{b+k_2} b_t. \tag{17}$$

Ω_t depends on the value of the collateral, q_t and b_t, on a collateral shock, $a3_t$, and on consumption, c_t. Higher levels of consumption increase the marginal value of capital and hence the collateral value, q_t. The increase in collateral value leads to more borrowing and more consumption. The parameter k_2 is again a composite coefficient similar to k_1.[13]

The marginal value of collateralized lending also feeds back into the capital asset price equation, q_t:

$$\begin{aligned} q_t \quad = \quad & \left(\delta_1 + \gamma_1\right)\left(E_t \lambda_{t+1} - \lambda_t\right) + \delta_1 E_t q_{t+1} - \frac{k\Omega\phi}{c\lambda}\left(c_t + \lambda_t\right) + \\ & k\Omega\left(\frac{\phi}{c\lambda} - 1\right)\left(\Omega_t + a3_t\right) + \gamma_1 E_t\left[mc_{t+1} + (1-\eta)\left(n_{t+1} + a1_{t+1}\right)\right]. \end{aligned} \tag{18}$$

In (18) the marginal value of collateralized lending, Ω_t, potentially can amplify asset price volatility and magnify the response of the economy to both real and financial shocks. Both real, $a1$, and financial shocks, $a3$, directly feed back into asset prices alongside the expected marginal productivity of capital $[mc_{t+1} + (1-\eta)(n_{t+1} + a1_{t+1})]$ where mc_{t+1} denotes marginal cost in period $t+1$, η is the share of capital in the goods production function and n is employment in the goods production sector. Similarly expected asset prices, $E_t q_{t+1}$, the change in the shadow value of households' funds $(E_t \lambda_{t+1} - \lambda_t)$ alongside the wedge between the marginal utility of consumption and the shadow value of funds also affect the value of capital, q_t. The parameter δ_1 is a composite function of the depreciation rate of capital while the parameter γ_1 is a composite function of steady-state marginal costs, of steady-state employment in the goods sector and of the capital share in the production of goods.[14]

[13] The parameter $k_2 = \frac{kK}{c}$ is a function of k, of steady-state capital, K, and of the steady-state ratio of consumption, c.

[14] The parameter $\delta_1 = \frac{\beta(1-\delta)}{1+\gamma}$ is a function of the discount factor, β, of the depreciation rate of capital, δ, and of the trend growth rate, γ. The parameter $\gamma_1 = \frac{\beta\eta mc}{1+\gamma}(\frac{n}{K})^{1-\eta}$ is function of steady-state employment in goods sector, n, of steady-state marginal costs, mc, of steady-state capital, K, and of the parameter reflecting the capital share in the production function of the goods sector, η. Details of the derivation are reported in the technical appendix.

3.2 Interest Rate Spreads

The last building block involves the determination of interest rate spreads. The benchmark theoretical interest rate R^T is simply a standard intertemporal nominal pricing kernel, priced off real consumption and inflation. It can be written as one-period Fisher equation:

$$R_t^T = E_t(\lambda_t - \lambda_{t+1}) + E_t\pi_{t+1}. \tag{19}$$

The difference between the interbank rate R and R^T is the external finance premium, which is the premium paid by the private sector for loans:

$$R_t^T - R_t = \underbrace{[v_t + w_t + m_t - c_t]}_{EFP_t}. \tag{20}$$

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 decreasing in consumption, c_t.[15] The external finance premium is also dependent on the share of collateral costs in loan costs (α), and reserve requirements (rr), but as these two parameters are both constant in this model they do not appear in the log-linearization.

The yield on government bonds is the benchmark rate, R^T, minus the liquidity service on bonds:

$$R_t^B = R_t^T - \left[\frac{\phi\Omega}{c\lambda}(c_t + \lambda_t) - \left(\frac{\phi}{c\lambda} - 1\right)\Omega\Omega_t\right], \tag{21}$$

where $(c_t + \lambda_t)$ measures the household's marginal utility relative to the household's shadow value of funds while Ω is the marginal value of the collateral. In the model these key margins - the real marginal cost of loan management versus the liquidity service yield - determine the behavior of spreads.

Finally the monetary authorities, who set the interbank lending rate, are assumed to follow a simple inflation targeting rule in the first instance:

$$R_t = \phi_\pi \pi_t + \epsilon_t. \tag{22}$$

In this section we have outlined, briefly the key elements of the GM model and explained how it links explicitly output to developments in the monetary sector and how the interaction between those sectors determine financial spreads. In the following section we shall analyze the key responses of the model to a series of shocks and try to infer from this what is the relationship between money and inflation, and what role financial spreads play.

[15] The collateralized external finance premium is simply the uncollateralized external finance premium multiplied by $(1-\alpha)$, i.e. the share of monitoring costs in loan costs, and it is less than the uncollateralized external finance premium. As the shares α and $(1-\alpha)$ are constant both the collateralized and uncollateralized versions of the EFP coincide when log linearized.

4 Model Results

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 variables to different shocks, to obtain asymptotic variance and covariances and to simulate the data. The simulation is carried out by running a random number generator in Matlab. Following a fixed random seed, we generate a set of normal distributed exogenous shocks of length $K = 10,000$. These random shocks are fed into the recursive law of motion of key variables for which see the Technical Annex. For the impulse response analysis and simulation exercise we examine the effects of real and financial shocks described in Table A3. We also report the choice of moments for the forcing variables. These are standard parameters in the literature.

4.1 Calibration

Following Goodfriend and McCallum (2007) we choose the consumption weight in utility, ϕ, to give 1/3 of available time in either goods or banking services production.[16] 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 the canonical quarterly value while the mark-up coefficient in the Phillips curve, κ, is set to 0.05. The depreciation rate, δ, is set to be equal to 0.025 while the trend growth rate, γ, is set to 0.005 which corresponds to 2% per year. The steady-state value of the ratio of bond holdings to GDP, b, is set to 0.56 as of the third quarter of 2005.

The parameters linked to money and banking are defined as follows. Velocity at its steady state level is defined as the ratio of US GDP to M3 as of the fourth quarter of 2005, yielding 0.31. The fractional reserve requirement, rr , is set at 0.005, measured as the ratio of US bank reserves to M3 as at the fourth quarter 2005. The fraction of collateral, α, in loan production is set to 0.65, the coefficient reflecting the inferiority of capital as collateral, k, is set to 0.2 while the production coefficient of loan, F, is set to 9. The low value of capital productivity reflects the fact that usually banks use a higher fraction of monitoring services and rely less on capital as collateral. Turning to the parameters in the various policy rules,[17] we set the coefficient on inflation with inflation targeting, ϕ_π^T, to be equal to 50 as in GM in order to reflect a strong response to inflation and a smoothing parameter, ρ, equal to 0.8; the coefficient on inflation with a Taylor rule, ϕ_π, is set to 1.5 while the coefficient on output, ϕ_y, is set to 0.5 as in GM. For the rule which responds to asset prices we assume a coefficient on asset price growth, ϕ_q, equal to 0.5.

[16] Tables A1 and A2 of the appendix report the values for the parameters and steady-state values of relevant variables.

[17] The policy rules are described in more detail in Section 5.

4.2 Implied Steady-States

With these parameters 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, not far from the 1.6%, share of total US employment in depository credit intermediation as of August 2005. 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 policy rate, R, is 0.84% per annum which is close to the 1% per year average short-term real rate (see Campbell, 1999). The government bond rate, R^B, is 2.1% per annum. Finally the collateralised external finance premium, $R^L - R$, is around 2% per annum which is in line with the average spread of the prime rate over the federal funds rate in the US.[18]

4.3 Examining the Role of Money in this Economy

In this section we describe, briefly, the effects of a series of shocks to productivity, velocity and to two types of shocks to the financial sector.[19] As is implied by Section 2, the dynamics of the model suggests that a key role is played by the loan rate, the external finance premium and policy rate, as a regulator of demand. For example, any shock that raises collateral value will increase the supply of loans. At the same time the collateral shock will increase the demand for deposits and therefore the amount of monitoring work that needs to be carried out by banks. So the increase in the amount of employment in monitoring work will increase the real marginal cost of the management of loans and so the positive effect of higher collateral will be attenuated. What we try to do here is simply assess the impact of some key driving forces both on the quantity of money in this model and also the external finance premium at which that money is supplied.

4.3.1 Goods productivity

A shock, $a1$, to goods productivity,[20] under the inflation targeting rule, can be stabilised. Hence hours worked in the goods production sector, n, and the benchmark rate R^T are almost invariant to the shock.[21] However c, w, q, m are all higher. In fact with hours worked in goods production relatively stable, increased productivity shows up as higher consumption c and higher real wages w. Also increases in q reflect a higher marginal product of capital. The increase in monitoring hours m reflects the increased demand for and supply of deposits. The combined effect is to increase the

[18] The equations for the steady-states are listed the extended technical appendix available on request. The solution for the steady-states uses a nonlinear routine in Maple and the file is also available on request.

[19] The diagrams of the impulse responses to mark-up, money and government shocks are available on request. Those discussed here are available in the technical appendix.

[20] The benchmark model has 20 endogenous variables $\{c, n, m, w, q, P, \pi, mc, H, b, \Omega, EFP, \; R^T, R^B, R, R^L, R^D, \lambda, \xi, T\}$, 5 lagged variables $\{P_{-1}, H_{-1}, c_{-1}, b_{-1}, R^B_{-1}\}$ and 7 exogenous shocks $\{a1, a2, a3, \varepsilon, \epsilon, \upsilon, u\}$. We report only the results of the four shocks $a1, a2, a3, \upsilon$.

[21] For R^T_t this happens as $R^T_t = \lambda_t + E_t\pi_{t+1} - E_t\lambda_{t+1}$ where the inflation rate π and changes in λ are almost zero.

EFP. But the movement of money (deposits/loans) in the same direction as the external finance premium implies that money would be a poor indicator of financial conditions, as the increase in money does not imply that there has been an inflationary monetary expansion.

4.3.2 Banking productivity

Again under an inflation targeting rule, a shock to banking productivity, $a2$ is stabilised and therefore so is the benchmark interest rate. Because of higher banking productivity, monitoring hours, m, decline while there is little effect on the value of collateral q, on consumption c and on real wages w. The combined effect, by reducing the marginal costs of loan supply is to decrease the EFP. In this case therefore money might indicate some loosening of financial conditions.

4.3.3 Collateral prices

Under inflation targeting, a positive shock to collateral, $a3$, leads to stable inflation and benchmark interest rate, R^T. There are small increases in c and w. As we have a positive shock to collateral there is a fall in monitoring hours m, which dominates the costs of loans supply. The overall effect in general equilibrium is to reduce the EFP, alongside an increase in the quantity of money. In these circumstances, the increase in money is associated with some loosening of financial conditions.

4.3.4 Money velocity

With an inflation targeting rule, a positive shock to velocity v increases c, w, n and inflation. Because the capital/labour ratio is lower, the price of capital q rises while hours of monitoring, m, decrease as the existing stock of money works harder. The joint effect is a decrease in the EFP and a fall in the money supply.[22] In this case, as with the productivity shock, money does not turn out to be a good indicator of inflationary pressure.

4.3.5 The information content of money

Overall we find that money plays a crucial role in driving the EFP when the banking sector itself is the source of the shock (i.e. monitoring efficiency and/or collateral shocks) with banks becoming more or less able to supply a given quantity of loans. It is this independent source of supply shocks to the loanable funds market which drives the EFP in the opposite direction to that of the quantity of loans and so can act to compress (unwind) yields when there liquidity becomes abundant (scarce).

[22] The liquidity service yield is sensitive to inflation dynamics and as these are relatively stable here the yield varies little, we explore this spread in other work. But note that in each case the direction of the liquidity service yield (not shown) is well explained by the direction of the external finance premium and so we concentrate on understanding the responses of the EFP to shocks.

We can examine the information content of money more formally in the GM model by examining some properties of the simulated data. We can simulate the model under the benchmark case and for illustrative purposes we can also raise the standard deviation of $a2$ and $a3$ shocks from 1 to 5% to examine what happens when such shocks are dominant. Table 1 - for the benchmark shocks and banking dominant shocks - shows, on the left hand side of the table the lead, contemporaneous and lagged correlation between money and inflation and output from HP filtered simulations. The main difference in the two cases is that when banking shocks dominate, money has positive rather than negative lead information for inflation. Following King (2002), the final two columns show the sum of contemporaneous money and 4 lags of money in a regression of inflation and of output on lags of inflation, output and money. We can see that money has significant information for inflation in both cases but when banking shocks are dominant, money has positive information, in the sense that positive money growth leads to higher inflation. It would therefore seem appropriate for central banks to place emphasis on monetary aggregates when banking sector or loans supply shocks dominate.

5 Reconsidering Simple Policy Rules

The previous section has shown that monetary and financial conditions might well matter when setting monetary policy, over and above the policy rate. We concentrate on comparing shocks to the supply of banks loans involving collateral or monitoring costs. Note that a negative shock to the financial system originating in a rise in the cost of monitoring loans or a reduction in the collateral of borrowers has a opposite-signed impact on money and on the external finance premium - in this case money will contract and the spread widen. This suggests that the information on the spread and money might be used to inform monetary policy, that is to say as well as reacting to inflation directly the central bank can also respond to the spread.

Before considering this point in detail, we assess the effectiveness of the various policy rules proposed by Gilchrist and Saito (2006). We use the following rules for comparison.

Targeting Rule

$$R_t = \phi_\pi^T \pi_t + \epsilon_t. \tag{23}$$

The policy rate is set by a feedback rule responding to inflation, π_t, with parameters, ϕ_π^T, where we assume that the policymaker targets zero percent inflation.

Money Rule. We also consider an alternative rule where the central bank controls the growth of high powered money:

$$\Delta h_t = \rho^H \Delta h_{t-1} + \epsilon_t \tag{24}$$

where $h_t = \log(H_t)$ and Δh_t denotes the growth rate of H_t. In (24) we assume that $0 <| \rho^H |< 1$

while ϵ_t is the random component of policy behaviour.

Taylor Rule with Inflation and Output. We assume, as also in GM, an alternative rule where policy-makers respond to output, y_t, and inflation, π_t, while also smoothing interest rates:

$$R_t = \rho R_{t-1} + (1-\rho)(\phi_\pi \pi_t + \phi_y y_t) + \epsilon_t \tag{25}$$

with $0 < \rho < 1$. In contrast to the inflation targeting rule (23) where the policymaker targets zero inflation, the weight on inflation, ϕ_π, is lower at 1.5.

Policy Rule with Asset Price Growth. We also consider, as in Gilchrist and Saito (2006), an alternative formulation of (25) where the policy-maker responds to the growth rate of observed asset prices, Δq_t:

$$R_t = \rho R_{t-1} + (1-\rho)(\phi_\pi \pi_t + \phi_q \Delta q_t) + \epsilon_t \tag{26}$$

Augmented Rule. As an illustration of how policymakers might seek to respond directly to supply side shocks to the supply of loans - as suggested by equation (14) - we now assume that the monetary authority augments its inflation targeting rule with a term in the difference between the external finance premium and money to capture the impact of the supply of money:

$$R_t = \phi_\pi^T \pi_t + \phi_m(h_t - EFP_t) + \epsilon_t, \tag{27}$$

where h is money and EFP is the external finance premium. In this case when there is a demand shock, h_t and EFP_t will move in the same direction and the augmented rule will have the same effect as an inflation targeting rule. But when the shock is to the supply of loans, money and the external finance premium will move in opposite directions, thereby altering the interest rate set by the monetary authority.

In the next section we assess the policy outcomes both in terms of the volatility of output and inflation and a welfare approximation of the representative household from the implementation of a rule that targets zero inflation versus alternative rules that respond to aggregate demand, money, asset prices and the augmented rule. The welfare analysis will allow us to better understand how the policy maker should respond when banking shocks dominate.

5.1 Welfare Analysis

We first consider a welfare criterion often used to assess policy alternatives that depends only on the variance of output and inflation (e.g. Galí (2008)) and employs a standard loss function:

$$L_t^s = \frac{1}{2}\sigma_\pi^2 + \frac{1}{2}\sigma_y^2. \tag{28}$$

Given the primitive utility function of GM model, we also trace out the direct welfare consequences for the representative household. 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. 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.[23] 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.[24]

$$\begin{aligned} U_t - U &= -\frac{1}{2} E_0 \sum_{t=0}^{\infty} \beta^t L_t + \mathcal{O}^3 \\ \text{with } L_t &= \frac{1}{2} \left[\begin{array}{c} \sigma_c^2 + \frac{\theta}{\chi(1-\eta)} \left(\frac{n}{c} - \frac{w}{c} \right) \sigma_\pi^2 - \\ \frac{w}{c} \sigma_w^2 - \frac{n}{c} \sigma_n^2 + \frac{mc}{c} \sigma_{mc}^2 \end{array} \right] \end{aligned} \tag{29}$$

where $\chi = \frac{(1-\theta)(1-\beta\theta)}{\theta} \frac{1-\eta}{1+\eta(\theta-1)}$.

In the next section we will evaluate each policy rule under standard loss function (28) and the welfare approximation (29) when the standard deviation of the financial shocks rise.

5.2 Policy Experiment

Using both the welfare criteria, we can calculate the loss under each policy rule when we increase the standard deviation of banking shocks and then rank them using the metric laid out by Gilchrist and Saito (2006).

$$Gain(x) = \frac{L(\text{Less Stabilising Policy}) - L(\text{Rule } x)}{L(\text{Less Stabilising Policy}) - L(\text{Most Stabilising Policy})} \tag{30}$$

The gain is defined as the difference between the loss, L, obtained from pursuing the policy rule x versus the less stabilising rule (the asset rule), divided by the difference between outcomes obtained from pursuing the most stabilising rule (the augmented rule), versus the asset rule. Doing so enables us to summarise the result of our policy comparison: if the relative gain is above (below) one, the policy in question is better (worse) than the augmented rule. If it is negative than the given policy actually performs worse than the benchmark. In Table 2 we can see that as we increase the size of banking shocks the asset-price rule performs worst relative to the augmented rule because it does not distinguish between demand or supply shock driven changes in asset price.

[23] 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.

[24] The welfare approximation is reported the Technical Appendix and draws on Chadha, Corrado and Meaning (2012).

By contrast the gain from a money rule rises, and while it is inferior to the augmented rule over the range we report, it is approaching the augmented rule when shocks to the supply side of the banking sector are particularly large relative to productivity and velocity shocks.[25]

Focussing on the augmented rule, we now trace out the effect on the policy losses of a steadily rising ratio of financial (monitoring, σ_{mon}, and collateral, σ_{col}) to real and monetary shocks in the model outlined in Section 3. The exercise here is to vary the ratio of the standard deviation of financial to real and monetary shocks, Φ_m, defined as:

$$\Phi_m : \ \frac{\sigma_{mon} + \sigma_{\text{col}}}{\sigma_{prod} + \sigma_{vel} + \sigma_{mrk} + \sigma_{mp} + \sigma_{gov}}. \tag{31}$$

In Figure 1 we vary on the x-axis the loading ϕ_m on the spread in the augmented rule, holding the relative standard deviation of the shocks fixed[26] and report the loss given by the welfare approximation (29). We note that the loss, L, is initially declining in ϕ_m. And so it seems clear that over some range when financial shocks are dominant inflation can be better stabilised. For this illustrative calculation the standard deviation is minimised at around $\phi_m = 1$.[27] This simulation echoes the analytical result in Section 2, equation (14), which shows how the policy rule needs to offset those factors that might increase the external finance premium. In this simulation at least, the Central Bank best achieves the stabilisation of inflation by exactly offsetting any narrowing or widening of the spread between the external finance premium and money.

5.3 Money under alternative rules

The correlations between inflation, money and the EFP are tabulated for the two different policy rules in Table 3. Along the diagonals we show the standard deviation of money, inflation and the EFP for the benchmark simulation and for the 'banking shocks dominant' simulation. In the benchmark case the standard deviations of money and EFP are not altered greatly by the augmented rule, suggesting that the augmented rule does not help stabilise the economy over and above a simple rule. However, when banking shocks dominate, the correlation between money and inflation becomes positive and the correlation between the external finance premium and money becomes negative. But when with bank dominant shocks the augmented rule is adopted, the correlation between money and inflation is once more negative and the correlation between money

[25] In terms of the Poole (1970) optimal choice of monetary policy instrument, it is clear that for sufficently large shocks to the supply side of the financial system, the standard assignment may be reversed.

[26] We set the standard deviation of the banking shocks to 0.05 and fix the standard deviations of the real and monetary shocks to their benchmark values as in Table 3. This gives a minimum of Φ_m equal to 0.54 when the the standard deviation of the two banking shocks is set to 0.01 and a maximum of Φ_m equal to 2.73 when the the standard deviation of the two banking shocks is set to 0.05.

[27] How the central bank should measure money and the EFP in reality, given the preponderance of possible measures, and then 'learn' by about the appropriate weight on ϕ_m constructing priors and updating posteriors we leave to future work.

and the EFP very small, as interest rates respond to money growth and to the EFP. Under the augmented rule, with a predominance of banking shocks, the volatility of money and particularly inflation are reduced compared to the inflation only rule.

We treat the evidence here as illustrative of the extent to which an augmented rule of this type, which accounts for the joint information from money and financial spreads, may help stabilise a monetary economy. The identification of this information involves the simple insight that money growth and financial spreads will move in opposite directions under supply shocks to financial markets and, provided a suitable measure of money (or liquidity) and a constellation of financial spreads can be located, some weight might be given to a rule of this form for monetary policy analysis.

5.4 The Augmented Rule and the Economy

The impulse responses when this augmented rule ($\phi_m = 1$) is used are shown in Figures 2 and 3. The results for both the augmented (solid) and benchmark (dotted) rule are plotted. We confine ourselves to depicting the effects of a shock to collateral and to monitoring.[28] Figure 2 shows that with a positive collateral shock and the benchmark rule there is an increase in consumption, goods sector employment and a fall in monitoring employment. With the augmented rule the effect on inflation is largely ameliorated. The effect on asset prices is reversed, as there is a smaller increase in goods employment and capital does not become as scarce. The effect on the EFP is the same in both cases but the augmented rule helps to short circuit the effects of the supply shock on inflation, asset prices and bank lending. For the shock to monitoring, shown in Figure 3, the effect is to better stabilise the economy with smaller consumption, real wage and inflation deviations. Again the smaller increase in good sector employment means that capital does not become quite so scarce in the case of the augmented rule and there is a very small fall rather than an increase in the asset price.

6 Conclusions

Disruptions to financial markets since August 2007 have led to the widening of spreads and a significant contraction in the availability of money and credit to the private sector. To some extent this is the mirror of the situation in previous years when financial spreads narrowed as money and credit became more ample. The role of money to both originate as well as reflect or amplify shocks seem especially important when there are shocks to the supply of loans. When setting monetary policy, central bankers monitor monetary developments (to varying degrees) but there seems to be little clear guidance as to how this information is to be used, if at all.

[28] The results for shocks to productivity and velocity are available on request.

In this paper we have analysed how a standard inflation targeting rule is altered in the presence of a credit channel and we find that when credit is supplied procyclically simple inflation targeting may not be sufficient to stabilise the economy. We then examined the role of money in a DSGE model with an integrated banking sector that supplies loans and accepts deposits along the lines of Goodfriend and McCallum (2007)[29] and established the pivotal role of money and the external finance premium. While in normal circumstances money may convey little extra information to a Central Bank about the state of the economy over and above that in inflation, this is not true when there are dominant shocks to the supply of credit arising from changes in the value of collateral or the costs of monitoring a loan portfolio.[30] In these circumstances, if the Central Bank responds in some measure to opposing movements in money and the external finance premium, a much greater degree of control of inflation can be achieved and so money can clearly matter.[31]

We have not necessarily captured all of the features of the present crisis or the boom that preceded it, since the external finance premium in this paper is confined to the relationship between banks and the private sector. Nevertheless, it is clear that an important role has also been played in recent monetary policy developments by supply of money or credit at a finance premium internal to the financial system.[32] A model that captures other financial premia and other constituents of broad money or more generally liquidity would still lead to similar results to those in this paper, that is, the Central Bank ought to respond to shocks to the supply of money and credit when setting monetary policy.

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[29] In some sense we follow the second conjecture of Christiano et al (2007). We also produce a stronger result that Stracca (2013) about the importance of money.

[30] Chadha, Corrado and Sun (2010) decompose money in demand and supply and assess the contribution of supply to money and EFP. They find that supply shocks have played a significant role in the time series in each of the USA, UK and Eurozone in the short to medium term.

[31] For a similar result from a search theoretic perspective see Chiu and Meh (2011).

[32] Banks before the crisis hardly felt the need to monitor or question the collateral of other banks. The current crisis has seen a freezing of the interbank market as banks began to closely monitor counterparty risk.

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Model Appendix

A The Linearised Model

The model[33] is composed of the following linearised equations.[34]

Supply of Labour:

$$\frac{n}{(1-n-m)}\widehat{n}_t + \frac{m}{(1-n-m)}\widehat{m}_t - \widehat{\lambda}_t - \widehat{w}_t = 0 \tag{A1}$$

Demand for Labour:

$$\widehat{m}_t + \widehat{w}_t + \frac{(1-\alpha)c}{mw}\left(\widehat{c}_t + \frac{\phi}{\lambda}\widehat{\lambda}_t\right) = 0 \tag{A2}$$

Supply of Banking Services:[35]

$$\begin{aligned} \widehat{c}_t \quad = \quad & \widehat{v}_t c + (1-\alpha)(a2_t + \widehat{m}_t) + \\ & \alpha\left[\frac{bc}{bc+(1+\gamma)kK}(\widehat{c}_t + \widehat{b}_t) + \frac{kK(1+\gamma)}{bc+(1+\gamma)kK}(a3_t + \widehat{q}_t)\right] \end{aligned} \tag{A3}$$

reported in the main text as:

$$\widehat{c}_t = \left\{ \begin{array}{c} \hat{v}_t c + (1-\alpha)(\hat{m}_t + a2_t) + \\ \alpha\left[\frac{b}{b+k_1}\hat{b}_t + \frac{k_1}{b+k_1}(\hat{q}_t + a3_t)\right] \end{array} \right\} \left(\frac{b+k_1}{b(1-\alpha)+k_1}\right) \tag{32}$$

where $k_1 = \frac{(1+\gamma)kK}{c}$

CIA constraint:

$$\widehat{c}_t + \widehat{P}_t = \widehat{H}_t + \widehat{v}_t \tag{A4}$$

Aggregate Supply:

$$\widehat{c}_t = (1-\eta)(1+\frac{\delta K}{c})(a1_t + \widehat{n}_t) - \frac{\delta K}{c}\hat{q}_t \tag{A6}$$

[33] The full derivation of the first-order conditions and their log-linear formulation are described in section A of the Technical Appendix, available from our webpages.

[34] The model is defined in the Matlab file gmvsys.m. Standard deviation and persistence structure of the stochastic variables are defined in the driver file gmvdrv.m.

[35] The relationship is derived by setting $b = \frac{B}{P(1+R^B)c}$.

Marginal cost:

$$\widehat{mc}_t = \widehat{n}_t + \widehat{w}_t - \widehat{c}_t \tag{A7}$$

Mark-up:

$$\widehat{mc}_t = \widehat{\xi}_t - \widehat{\lambda}_t \tag{A8}$$

Inflation:

$$\widehat{\pi}_t = \widehat{p}_t - \widehat{p}_{t-1} \tag{A9}$$

Calvo pricing:

$$\widehat{\pi}_t = \kappa\widehat{mc}_t + \beta E_t\widehat{\pi}_{t+1} + u_t \tag{A10}$$

Marginal Value of Collateralised Lending:

$$\widehat{\Omega}_t = \frac{kK}{bc + kK}\left(\widehat{c}_t - \widehat{q}_t - a3_t\right) - \frac{bc}{bc + kK}\widehat{b}_t \tag{A11}$$

reported in the main text as:

$$\widehat{\Omega}_t = \frac{k_2}{b + k_2}\left(\widehat{c}_t - \widehat{q}_t - a3_t\right) - \frac{b}{b + k_2}\widehat{b}_t$$

where $k_2 = \frac{kK}{c}$.

Asset Pricing:[36]

$$\begin{aligned}\widehat{q}_t\left[1 - k\Omega(\frac{\phi}{c\lambda} - 1)\right] \quad = \quad & [\frac{\beta(1-\delta)}{1+\gamma} + \frac{\beta\eta mc}{1+\gamma}(\frac{n}{K})^{1-\eta}]\left(E_t\widehat{\lambda}_{t+1} - \widehat{\lambda}_t\right) + \frac{\beta(1-\delta)}{1+\gamma}E_t\widehat{q}_{t+1} + \\ & \frac{k\Omega\phi}{c\lambda}\left(-\widehat{c}_t - \widehat{\lambda}_t\right) + k\Omega(\frac{\phi}{c\lambda} - 1)\left(\widehat{\Omega}_t + a3_t\right) + \\ & \left(\frac{\beta\eta mc}{1+\gamma}(\frac{n}{K})^{1-\eta}\right)E_t\left[\widehat{mc}_{t+1} + (1-\eta)\left(\widehat{n}_{t+1} + a1_{t+1}\right)\right]\end{aligned} \tag{A12}$$

reported in the main text as:

$$\begin{aligned}\widehat{q}_t \quad = \quad & (\delta_1 + \gamma_1)\left(E_t\widehat{\lambda}_{t+1} - \widehat{\lambda}_t\right) + \delta_1 E_t\widehat{q}_{t+1} - \frac{k\Omega\phi}{c\lambda}\left(\widehat{c}_t + \widehat{\lambda}_t\right) + \\ & k\Omega(\frac{\phi}{c\lambda} - 1)\left(\widehat{\Omega}_t + a3_t\right) + \gamma_1 E_t\left[\widehat{mc}_{t+1} + (1-\eta)\left(\widehat{n}_{t+1} + a1_{t+1}\right)\right]\end{aligned}$$

where $\delta_1 = \frac{\beta(1-\delta)}{1+\gamma}$ and $\gamma_1 = \frac{\beta\eta mc}{1+\gamma}(\frac{n}{K})^{1-\eta}$.

Government Budget Constraint:[37]

$$T\widehat{T}_t = H\left(\widehat{H}_t - \widehat{H}_{t-1}\right) + cb\widehat{b}_t - cb\left(1 + R^B\right)\left(\widehat{b}_{t-1} - \widehat{\pi}_t + \widehat{R}^B_{t-1}\right) \tag{A13}$$

---

[36] Note that in steady-state $\frac{\xi}{\lambda} = mc$ and $\frac{\lambda_{t+1}}{\lambda_t} = \frac{1}{1+\gamma}$.

[37] We define the percentage deviation from steady state of flow and stock variables by $\ln x_t - \ln x$, while for interest rates and ratio variables they are $R_t = R + \widehat{R}_t$ (rates) and $r_t = r + \widehat{r}_t$ (ratio, assuming $r_t = x_t/y_t$), respectively. It can be shown the approximation comes from first-order Taylor expansion: $e^x \approx 1 + x$, while for rate variable: $\widehat{R}_t \approx \ln(1 + R_t) - \ln(1 + R)$ and for ratio: $\widehat{r}_t = r_t - r = \ln(x_t/y_t) - \ln(x/y) = \widehat{x}_t - \widehat{y}_t$.

Bond Holding:

$$\widehat{b}_t = \varepsilon_t \tag{A14}$$

Riskless Interest Rate:

$$\widehat{R}^T_t = \widehat{\lambda}_t + E_t\widehat{\pi}_{t+1} - E_t\widehat{\lambda}_{t+1} \tag{A15}$$

Liquidity Service of Bonds:[38]

$$\frac{1+R^B}{1+R^T}\left(\widehat{R}^B_t - \widehat{R}^T_t\right) = \frac{\phi\Omega}{c\lambda}\left(\widehat{c}_t + \widehat{\lambda}_t\right) - \left(\frac{\phi}{c\lambda} - 1\right)\Omega\widehat{\Omega}_t \tag{A16}$$

External Finance Premium:

$$\widehat{EFP}_t = \widehat{\upsilon}_t + \widehat{w}_t + \widehat{m}_t - \widehat{c}_t \tag{A17}$$

Other Interest Rates:

$$\begin{aligned}
\widehat{R}_t &= \widehat{R}^T_t - \widehat{EFP}_t && \text{(A18)}\\
\widehat{R}^L_t &= \widehat{R}_t + \widehat{EFP}_t && \text{(A19)}\\
\widehat{R}^D_t &= \widehat{R}_t && \text{(A20)}
\end{aligned}$$

Policy Feedback Rule:

$$\widehat{R}_t = \phi_\pi\widehat{\pi}_t + \epsilon_t \tag{A21}$$

Velocity:

$$\widehat{\upsilon}_t = \upsilon_t \tag{A22}$$

For notational convenience the relevant log-linearised equations with variables denoting deviation from steady-state are reported in the main text without $\widehat{\ }$. We consider contemporaneous shocks to $a1, a2, a3, v$. The benchmark model has 20 endogenous variables $\{c, n, m, w, q, P, \pi, mc, H, b, \Omega, EFP, R^T, R^B, R, R^L, R^D, \lambda, \xi, T\}$, 5 lagged variables $\{P_{-1}, H_{-1}, c_{-1}, b_{-1}, R^B_{-1}\}$ and 7 exogenous shocks $\{a1, a2, a3, \varepsilon, \epsilon, \upsilon, u\}$. The equations (A1) through (A22), 5 lagged identities construct the model to be solved by King and Watson (1998) algorithm. Tables A1 to A3 provide a complete list of the endogenous and exogenous variables of the model and their meaning. Steady state of transfer level, Lagrangian of production constraint and base money depend on above parameters.

[38] Log-linearisation of interest rate is defined as difference from steady state: $R_t = R + \widehat{R}_t$.

Table A1. The Variables in Goodfriend and McCallum (2007)	
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
P^A:	Aggregate price level
π :	Inflation
mc :	Marginal cost
H :	Base money
b :	Real bond holding
Ω :	Marginal value of collateral
EFP :	External Finance Premium (R^T - R)
LP^B	Liquidity Premium on Bonds
LP^K	Liquidity Premium on Capital (kLP^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 lump-sum transfer

Table A2. Calibration

Parameter	Description	Value
β	Discount factor	0.99
κ	Slope of Phillips curve	0.05
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
γ	Trend growth rate	0.005
rr	Reserve ratio	0.005
F	Scaling coefficient in the production of loans	9
k	Relative Inferiority of capital as collateral	0.2
θ	Elasticity of substitution of differentiated goods	11
ϕ_π^T	Response to inflation with inflation targeting	50
ϕ_π	Response to inflation	1.5
ϕ_y	Response to output	0.5
ϕ_q	Response to asset price growth	0.5
ρ	Smoothing parameter in the feedback rule	0.8
Steady-States	Description	
R^T	Steady state of benchmark risk free rate	0.015
n	Steady state of labour input	0.3195
m	Steady state of banking employment	0.0063
R	Steady state of policy rate	0.0021
R^L	Steady state of loan rate	0.0066
R^B	Steady state of bond rate	0.0052
$\widetilde{b}$	Steady state level of bond holding	0.56
c	Steady state of consumption	0.8409
w	Steady state of real wage	1.9494
λ	Steady state of shadow value of consumption	0.457
v	Steady state level of velocity	0.31
Ω	Steady state of marginal value of collateral	0.237
K	Steady state of Capital	9.19

Table A3. Calibration of exogenous shocks

	Description	Value	Source
	Persistence		
ρ_{a1}	productivity shocks	0.95	King (2002)
ρ_{a2}	banking productivity shocks	0.95	Goodfriend and McCallum (2007)
ρ_{a3}	collateral shocks	0.9	Goodfriend and McCallum (2007)
ρ_ϵ	monetary policy shocks	0.3	King (2002)
ρ_u	mark-up shocks	0.74	Smets and Wouters (2007)
ρ_ε	government debt shocks	0.9	Chadha and Nolan (2007)
ρ_v	velocity shocks	0.33	King (2002)
	Volatility		
σ_{a1}	productivity shocks	0.72%	King (2002)
σ_{a2}	banking productivity shocks	1.00%	Goodfriend and McCallum (2007)
σ_{a3}	collateral shocks	1.00%	Goodfriend and McCallum (2007)
σ_ϵ	monetary policy shocks	0.82%	King (2002)
σ_u	mark-up shocks	0.11%	Smets and Wouters (2007)
σ_ε	government debt shocks	1.00%	Chadha and Nolan (2007)
σ_v	velocity shocks	1.00%	King (2002)

Table 1. The Information Content of Money for Output and Inflation:
Robust Regressions on Simulated Data

	$t-4$	$t-3$	$t-2$	$t-1$	$t=0$	$t+1$	$t+2$	$t+3$	$t+4$	$\sum$	F
Inflation											
Benchmark	-0.03	-0.08	-0.16	-0.31	-0.60	-0.23	-0.05	0.06	0.11	-0.03	25.3^{**}
Banks dominant	-0.22	-0.16	-0.06	0.06	0.20	0.29	0.32	0.32	0.30	0.05	3.7^{*}
Output											
Benchmark	0.03	0.15	0.30	0.49	0.69	0.45	0.25	0.09	-0.03	1.23	93.1^{**}
Banks dominant	-0.06	0.06	0.21	0.42	0.66	0.49	0.32	0.19	0.09	1.19	116.6^{**}

Note: the first two rows show the lagged, contemporaneous and lead correlations between money and inflation for the benchmark shocks and for the 'banking shocks dominate' case. Rows three and four report the same for output. An HP filter with $\lambda = 1,600$ is used. The final two columns sum the coefficients on money from a regression of inflation on lags of itself, and current and lagged terms in money and output as in King (2002) and the F-test tests for joint significance of the coefficients using White heteroscedastic consistent standard errors from 500 random draws from the initial simulation of 10,000.

Table 2. Relative Gains

S.D. of banking shocks	1%	2%	3%	4%	5%
			Welfare Approximation		
Augmented	1	1	1	1	1
Taylor	0.987	0.985	0.983	0.982	0.982
Money	0.822	0.903	0.934	0.950	0.960
Targeting	0.459	0.477	0.481	0.482	0.483
Asset	0	0	0	0	0
			Standard Loss Function		
Augmented	1	1	1	1	1
Taylor	0.995	0.990	0.989	0.989	0.988
Money	0.862	0.934	0.957	0.970	0.976
Targeting	0.508	0.471	0.456	0.447	0.442
Asset	0	0	0	0	0

The relative gain $Gain(x) = \frac{L(\text{Asset Rule}) - L(\text{Rule } x)}{L(\text{Asset Rule}) - L(\text{Augmented Rule})}$ is defined as the loss from the welfare approximation, L, obtained from pursuing the policy rule x versus the less stabilising rule (the asset rule), divided by the difference between outcomes obtained from pursuing the most stabilising rule (the augmented rule) versus the less stabilising rule (the asset rule).

Table 3. Correlation between Money, Inflation and the EFP

	Simple inflation-targeting policy rule							
	Benchmark Shocks				Banking Shocks Dominant			
	D_t	π_t	c_t	EFP_t	D_t	π_t	c_t	EFP_t
D_t	1.34%	−0.59	0.69	0.59	1.63%	0.20	0.66	−0.21
π_t		0.06%	−0.35	−0.97		0.22%	0.27	−1.00
c_t			1.14%	0.30			1.2%	−0.29
EFP_t				2.98%				10.89%
	Augmented policy rule							
	Benchmark Shocks				Banking Shocks Dominant			
	D_t	π_t	c_t	EFP_t	D_t	π_t	c_t	EFP_t
D_t	1.37%	−0.88	0.71	0.64	1.41%	−0.89	0.72	−0.046
π_t		0.03%	−0.69	−0.56		0.03%	−0.70	0.023
c_t			1.13%	0.34			1.18%	−0.17
EFP_t				3.05%				11%

Note: The table reports standard deviations along the diagonals and correlations in the upper off diagonal cells. D_t denotes deposits, π_t is inflation, c_t is consumption and EFP_t is the external finance premium. Variables are taken as deviations from steady states using a HP filter.

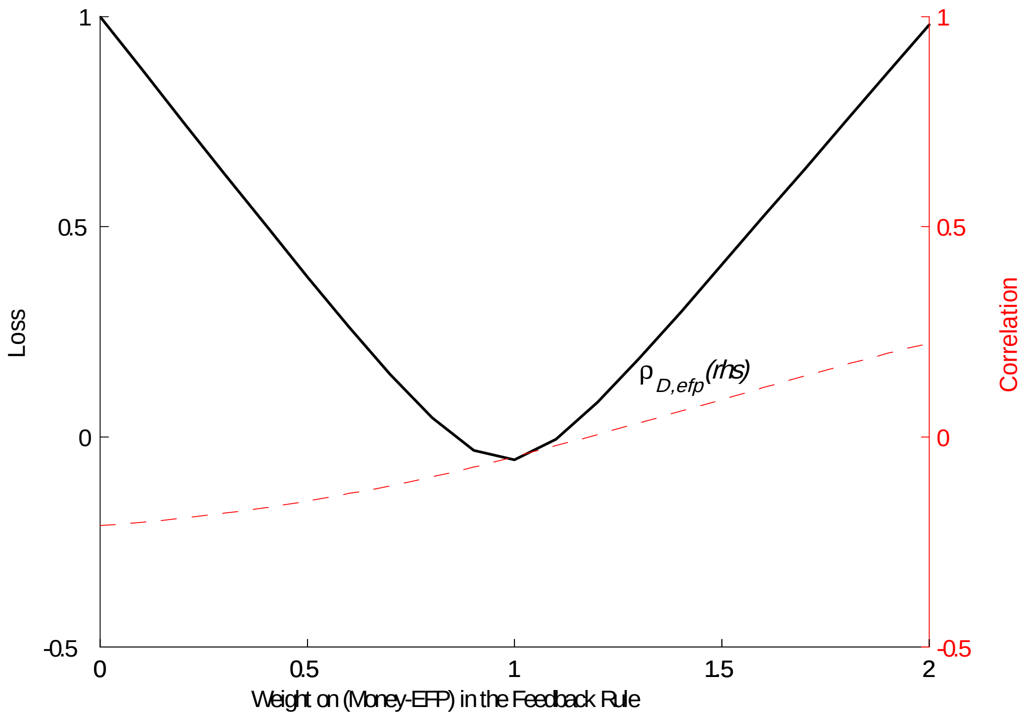

Figure 1: Optimal Weight on Money and EFP in Augmented Policy Rule. Note: On the x-axis we vary the weight on the augmented term in the feedback rule, money minus the external finance premium, when banking shocks are dominant i.e. by setting the standard deviation of the banking shocks to 0.05 and fixing the standard deviations of the real and monetary shocks to their benchmark values as in Table 3. On the y-axis we report the welfare approximation $L_t = \frac{1}{2}\left[\sigma_c^2 + \frac{\theta}{\chi(1-\eta)}\left(\frac{n}{c} - \frac{w}{c}\right)\sigma_\pi^2 - \frac{w}{c}\sigma_w^2 - \frac{n}{c}\sigma_n^2 + \frac{mc}{c}\sigma_{mc}^2\right]$ which is computed as a relative loss to the inflation targeting case (zero weight on Money-EFP). This result is similar to the standard loss in inflation and output $L_t^s = 0.5\sigma_\pi^2 + 0.5\sigma_y^2$ also computed as a relative loss to the inflation targeting case (zero weight on Money-EFP).

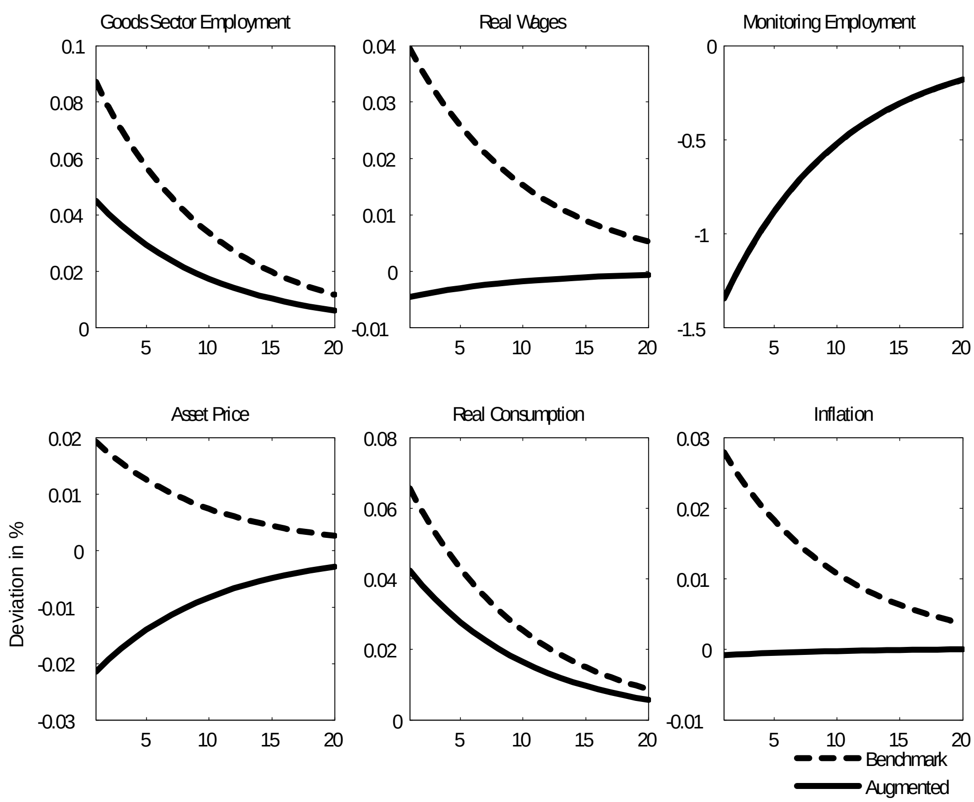

Figure 2: Key Responses to Positive Collateral Shock under Benchmark and Augmented Rule

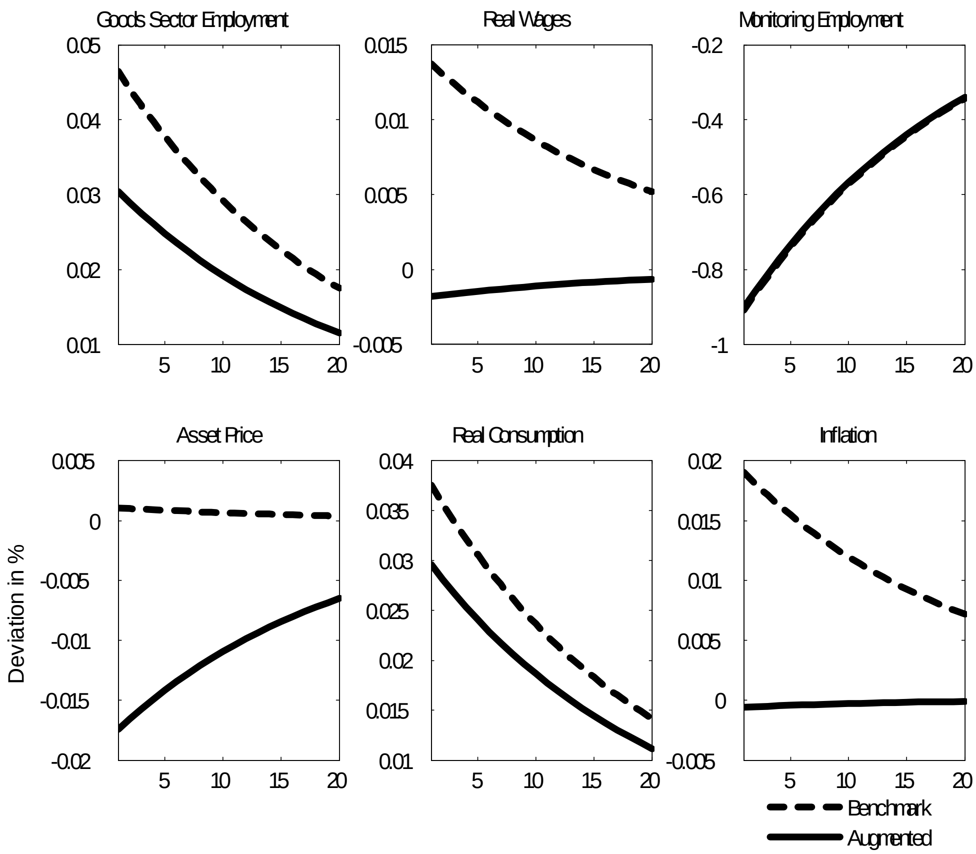

Figure 3: Key Responses to Positive Monitoring Shock under Benchmark and Augmented Rule