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Reconnecting Money to Inflation: the Role of the External Finance Premium*

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Abstract

We re-connect money to inflation using Goodfriend and McCallum's (2007) model where banks supply loans to cash-in-advance constrained consumers on the basis of the value of collateral provided and the monitoring skills of banks. We show that when shocks to monitoring and collateral dominate those to goods productivity and the velocity of money demand, money and the external finance premium become closely linked. This is because increases in asset prices allow banks to raise the supply of loans leading to an expansion in aggregate demand, via a compression of financial interest rates spreads, which in turn tends to be inflationary. Thus money and financial spreads are negatively correlated when banking sector shocks dominate. We suggest a simple augmented stabilising monetary policy rule that exploits the joint information from money and the external finance premium.

JEL Classification: E31; E40; E51.

Keywords: money, DSGE, policy rules, external finance premium.

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1 Introduction

On the surface the quantity of money plays little or no active role in modern macroeconomic models, with money pinned down endogenously by demand, production and inflation outcomes rather than exerting any independent source of macroeconomic fluctuations. Typically, it is the short term policy rate that regulates aggregate demand and is used as the instrument of monetary policy, with money supplied elastically to meet any idiosyncratic money market shocks. In such models the policy interest rate is sufficient to understand the constellation of market determined interest rates, and money (or liquidity) exerts no independent effect on the economy and so becomes less worthy of study (Goodhart, 2007). Accordingly, current monetary policy practice is somewhat ambivalent about the role of monetary aggregates and focuses on the ultimate objectives of policy, inflation and employment.

Although there is widespread agreement that in the long run there is, more or less, a one-to-one relationship between money growth and inflation and no relationship between money growth and real quantities (see Lucas, 1996), there is little consensus on what role monetary aggregates should play in the conduct of monetary policy over the short run when money might give a varying degree of guidance to short run movements in output and inflation. In this respect the European Central Bank follows a two-pillar approach. The first of these gives a prominent role to money (Stark, 2008). The second pillar relies on a ‘broadly based assessment of the outlook for future price developments’. By contrast the Federal Reserve explicitly eschews any role for money in the conduct of monetary policy. The Bank of England also places a less prominent weight on money, not least because financial liberalisation and changing payment technologies have masked the inflationary signal from growth in observed money aggregates.¹

At the same time the role of banks, other financial institutions and the financial system - that provide liquidity and the markets in which asset prices are set - are given particular prominence in discussions of the transmission mechanism of monetary policy.²

“..the cost and availability of nondeposit funds for any given bank will depend on the perceived creditworthiness of

¹See Meyer (2001), Woodford (2007a) and (2007b) and King (2002).

²See Bernanke *et al* (1999) for a clear exposition.

the institution. Thus, the concerns of holders of uninsured bank liabilities about bank credit quality generate an external finance premium for banks that is similar to that faced by other borrowers. The external finance premium paid by banks is presumably reflected in turn in the cost and availability of funds to bank-dependent borrowers. Importantly, this way of casting the bank-lending channel unifies the financial accelerator and credit channel concepts, as the central mechanism of both is seen to be the external finance premium and its relationship to borrowers' balance sheets. The only difference is that the financial accelerator focuses on the ultimate borrowers – firms and households – whereas financial intermediaries are the relevant borrowers in the theory of the credit channel.” Bernanke, 2007.

So 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.³ 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 or liquidity, can play independently of the policy rate. One avenue we explore in this paper, is motivated by the role of money as a supply of payment services to liquidity constrained consumers. The premium price of such loans reflects the marginal costs to banks of their supply and so it responds to increases in supply efficiency relative to demand for liquidity. 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 loans (monitoring) or the value of posted collateral.

Although it is widely agreed that the external finance premium - the difference between the opportunity cost of internally generated finance and the cost of issuing equity or bonds - represents a significant financial friction or wedge, there is no clear economy-wide proxy.⁴ In Figure 1 we therefore

³See Christiano, Motto and Rostagno (2007) for a discussion of these issues.

⁴Levin, Natalucci, and Zakrajšek (2004) use a combination of bond market and balance

illustrate with one measure of the external finance premium (EFP) for the US. This is the difference between Moody's Aaa and Baa rated long maturity corporate bond rate. We also include a plot of the growth of real (M2) money balances. For much of the period the external finance premium and the growth in real money balances are positively related suggesting that the demand for real money balances tends to be associated with increases in the EFP - reflecting positive demand shifts in the demand for money. However, from the mid-1990s the relationship breaks down as increases in real money balances seem to lead to a compression of the EFP, which suggests that positive supply shifts to the supply of broad monetary balances were dominant in the money market(s).

In this paper we examine the conditions under which monitoring money might add usable information about the current and prospective state of the economy. The key insight is whether observed money aggregates reflect a dominance of supply or demand shocks in the money market and thus whether observed interest rate spreads reflect aggregate demand driven need for higher levels of money balances or whether the supply of funds exogenously creates more money (or liquidity) and drives down interest rate spreads. We show how financial conditions, as represented by the external finance premium, feed back into aggregate demand and require the attention of monetary policy makers over and above that suggested by a simple interest rate rule that focuses on inflation alone.⁵

The paper is structured as follows. In section 2 we consider the role of money in a standard macro model and show that it is endogenous to the equilibrium for output and inflation and consider with a simple example what happens to the stabilising policy rule when market interest rates, which clear the money and spending markets, are disconnected from the policy rate. In Section 3, we re-examine the role of money for policy in the context of Goodfriend and McCallum's (2007) model which incorporates a banking sector into a DSGE model and reconnects the money market and financial

sheet information to calculate the EFP at the level of firms. De Graeve (2007) estimates the EFP from a DSGE model. See also Chadha *et al* (2008).

⁵Even inflation targeting policymakers do concern themselves with output fluctuations and this is even more explicit under the Federal Reserve's dual mandate (see, for example, Mishkin, 2007). As the two-sector economy we study involves the supply of banking services as an intermediate good, we concentrate on the implications of strict inflation targeting as a proxy for a central bank that does not pay attention to monetary aggregates as an intermediate target.

spreads back to equilibrium output and inflation. From impulse responses generated from a calibration of the model dynamics around steady-state paths, 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 goods sector productivity. Section 4 explores the conditions under which money provides a reliable signal about inflation and output and suggests a simple augmented rule to capture the signal. That is we observe that when supply shocks dominate in the money market, spreads and money will move in opposite directions and so a rule that employs information about the difference in money and spreads, may be better. We show that this rule is better able to stabilise the economy compared to a simple inflation targeting rule when there are shocks to financial markets. Section 5 concludes and offers some directions for future work.

2 Endogenous Money?

The debate on the use of money in macroeconomic models can be considered at a number of levels. First, whether it is sufficient simply to append a money demand function to a standard New Keynesian framework to deal with the question of the money market. We show the consequences of such an approach in this section. Then we may wish to consider whether perturbations to money markets, which broadly-speaking price and allocate broad money, can feed into the determination of output and inflation such that these need to be considered as a separate channel when setting monetary policy (Meier and Müller, 2005). In the first instance we can consider a simple model of money demand (for which supply is implicitly perfectly elastic) appended to a standard New Keynesian framework (see McCallum (2001) and King (2002)), which uses a monopolistically competitive supply side with Calvo price setting. In this section we examine in this simple setting what role money plays in determining equilibrium and show that money is essentially decoupled and plays no significant role in the determination of output and inflation. We also consider the equilibrium conditions when money and output are influenced by market interest rates, which may be decoupled from policy rates. In the next section we explore in more detail the implications of this possibility in a model that re-establishes a key role for money in determining equilibrium by endogenising the supply of money

via the banking sector.

We set up a simple New Keynesian model where 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. This intertemporal equation also operates as the basic asset pricing equation in a New-Keynesian model. 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.⁶ In equation (3) real balances, $\check{m}_t - p_t$, 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, $\check{\eta}$. 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, \check{y}_t , which we interpret as the flex-price level of output is given by (5). Finally, the forward-looking Phillips curve, (2), determines the split between current and expected inflation as a function of the current output gap but we can use the current inflation rate to back out the price level: 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 (see Yun, 1996) thus inflation is simply the ratio of firms that re-price at the new price level, p_t , relative to those that cannot re-price, (6).

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.

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

$$\pi_t = \beta E_t \pi_{t+1} + \kappa (y_t - \check{y}_t) + \epsilon_{B,t} \quad (2)$$

⁶The 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: $p_t = E_t p_{t+1} + (1 - \tau\beta) (y_t - \hat{y}_t) + \frac{\tau}{1-\tau} \epsilon_{A,t}$. Under either formulation inflation or the price level is less responsive to the output gap as $\tau \rightarrow 1$.

$$\check{m}_t - p_t = y_t - \check{\eta}R_t + \epsilon_{C,t} \quad (3)$$

$$R_t = \phi_\pi \pi_t + \epsilon_{D,t} \quad (4)$$

$$\tilde{y}_t = \epsilon_{E,t} \quad (5)$$

$$\pi_t = \frac{1 - \tau}{\tau} p_t. \quad (6)$$

We can substitute (4) into (1), (5) into (2) and solve (6) for p_t and substitute into (3) to give us a system of three difference equations that can be written in vector form, if we suppress the stochastic errors, as:

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

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

$$\mathbf{x}'_t \equiv [y_t \quad \pi_t \quad \check{m}_t],$$

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, ϵ_t ,⁷ will depend upon matching the number of eigenvalues of the matrix $\mathbf{\Lambda}$ within the unit circle with the number of predetermined state variables (see, for example, Blanchard and Kahn, 1980). And typically the coefficients of the policy rule, (4), are set to ensure local determinacy.⁸

What concerns us here is the role, if any, that money, \check{m}_t , plays in this economy. We note that the matrix, $\mathbf{\Lambda}$, can be written in block form, where each block is a 2 x 2 matrix:

$$\begin{aligned} \mathbf{\Lambda} &= \begin{bmatrix} \kappa \frac{\sigma}{\beta} + 1 & \sigma \phi_\pi - \frac{\sigma}{\beta} & 0 \\ -\frac{\kappa}{\beta} & \frac{1}{\beta} & 0 \\ 1 - \frac{\kappa}{\beta - \tau \beta} (\tau + (\tau - 1)(\sigma + \eta \phi_\pi)) & \sigma \phi_\pi + \frac{1}{\beta - \tau \beta} (\tau + (\tau - 1)(\sigma + \eta \phi_\pi)) & 0 \end{bmatrix} \\ &= \begin{bmatrix} \mathbf{A} & \mathbf{0} \\ \mathbf{C} & \mathbf{D} \end{bmatrix}. \end{aligned}$$

The block triangularity of $\mathbf{\Lambda}$ means that its eigenvalues are simply given by the eigenvalues of \mathbf{A} , referring to $[\pi_t \quad y_t]$ and \mathbf{D} , referring to $[\check{m}_t]$. Also the determinacy of $\mathbf{\Lambda}$ follows from the determinacy of \mathbf{A} given \mathbf{D} is a null matrix.

⁷Which is an analogous 3 x 1 vector for the shocks.

⁸See Woodford (2003) for a comprehensive treatment of this problem.

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 real rates must increase (decrease) by more than any positive (negative) inflation shock. The 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 simply no role in this economy for the money stock to destabilise the economy independently. To break this result we need a separate supply function for money which will create some disequilibria in the money market and thus some disturbance to nominal expenditures or some cause for disconnect across interest rates, so that the interest rate entering the policy rule is not necessarily the same as the return from bonds or other risky investments.⁹ To illustrate the mechanism, which we will explore in the subsequent section, let us posit a simple mechanism for an external finance premium, which determines equilibrium in the broad money market and also impacts on aggregate demand, such that the premium is countercyclical. If the quality of collateral is procyclical we can write a simple expression for the EFP as:¹⁰

$$efp_t = -\lambda y_t, \tag{9}$$

so that the market interest rate, R_t^m , becomes:

$$R_t^m = R_t + efp_t$$

and equation (1) and (3) is then solved with the market interest rate, R_t^m , rather than the policy rate, that is the market interest rate clears the output and money markets:

$$y_t = E_t y_{t+1} - \sigma (\phi_\pi \pi_t - \lambda y_t - E_t \pi_{t+1}) \tag{1'}$$

⁹We outline the various financial spreads resulting from this model in Section 3.

¹⁰There is a large literature on the countercyclicity of risk premia and we develop a micro-foundation for this possibility in the subsequent section. For a recent empirical motivation for this point see Cochrane and Piazzesi (2005).

$$\begin{aligned}
m_t - \frac{\tau}{1-\tau}\pi_t &= y_t - \eta\phi_\pi\pi_t + \lambda y_t \\
&= (1+\lambda)y_t - \eta\phi_\pi\pi_t.
\end{aligned} \tag{3'}$$

In this case the recursion result still obtains because the $\mathbf{\Lambda}'$ matrix takes the following form, so that money does not matter provided the system remains determinate:

$$\mathbf{\Lambda}' = \begin{bmatrix} \kappa\frac{\sigma}{\beta} - \sigma\lambda + 1 & \sigma\phi_\pi - \frac{\sigma}{\beta} & 0 \\ -\frac{\kappa}{\beta} & \frac{1}{\beta} & 0 \\ \Theta_1 & \Theta_2 & 0 \end{bmatrix},$$

where $\Theta_1 = -(\lambda+1)(\sigma\lambda-1) - \frac{\kappa}{\beta-\tau\beta}(\tau+(\tau-1)(\sigma+\sigma\lambda+\eta\phi_\pi))$ and $\Theta_2 = \frac{1}{\beta-\tau\beta}(\tau+(\tau-1)(\sigma+\sigma\lambda+\eta\phi_\pi)) + \sigma\phi_\pi(\lambda+1)$. The determinacy conditions for the $\mathbf{\Lambda}'$ matrix are now found to depend crucially on the way in which market interest rates move with the cycle:

$$\phi_\pi > \frac{\lambda(1-\beta)}{\kappa} + 1. \tag{10}$$

The altered conditions tell us that if money is provided at an interest rate that differs from the policy rate, R_t , which itself varies with the level of demand in the economy, λ , the monetary policymaker has to offset the spread as well as ensuring the policy rate increases or decreases the real rate in response to change in the level of demand. 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 ensuring that the money supply feeds back to perturb both aggregate demand and policy makers.

3 A General Equilibrium Monetary Model with Banking

As pointed out by Goodhart (2007) and by Kiyotaki and Moore (2001) money (aggregates) should be reconnected to general equilibrium models as they affect consumption decisions of liquidity constrained households and the spreads across several financial instruments and assets. And as Woodford (2007a) states ‘money matters’ in such circumstances as it may be the root of disequilibrium and instability in the economy originating from the financial

sector. So we consider a model that will allow us to fill in elements of the Λ matrix.

A convenient way to incorporate money and financial spreads (asset prices) into a general equilibrium setting is to study the banking sector proposed by Goodfriend and McCallum (2007).¹¹ 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 labour 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, adopts a standard Cobb-Douglas production function with capital and labour 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. That is with the standard equations (1), (2) and (4), from Section 2, dropping out.

We now turn to the analysis of how the banking sector affects the economy. The key assumption is that the banking sector matches deposit demands from liquidity constrained consumers from a loan producing technology. Specifically, banks substitute monitoring work for collateral in supplying loans. Increasing monitoring effort is achieved by increasing the amount of people employed in the banking sector and therefore reducing the employment in the goods production sector. At the same time households' consumption is affected by the availability of loanable funds. We assume a fractional reserve requirement with a fixed reserve-deposit ratio.¹² Given this technology banks decide the amount of loans they can supply and the demand for monitoring work.¹³ We can write a relationship for consumers in

¹¹See also Gilchrist's comment (2008) on Goodfriend and McCallum's model (2007).

¹²In a separate paper, we analyse the implications of an endogenous choice of bank reserve holdings. We find that this has serious implications for the question of whether central banks should pay interest rates on bank reserves. See Chadha and Corrado (2008).

¹³For details on the model set-up, derivation and notation see the technical appendix. We follow McCallum and Goodfriend's terminology as closely as possible in this section. The bank balance sheet and loan production function is key and outlined in the appendix.

the GM framework around an equilibrium steady state c as

$$c_t = v_t c + (1 - \alpha)(m_t + a2_t) + \alpha \left[\frac{b}{b + k_1}(b_t + c_t) + \frac{k_1}{b + k_1}(q_t + a3_t) \right]. \quad (11)$$

With the presence of a cash in advance constraint, a shock to velocity, v_t , will increase consumption. Consumption is also positively affected by the amount of monitoring work, m_t , where $(1 - \alpha)$ represents the share of monitoring costs in the loan production function; by the amount of collateral represented by bonds, b_t , and capital whose value is given by q_t . A positive shock to monitoring work, $a2_t$, by increasing the efficiency of banking effort in producing loans will increase 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.¹⁴The demand for monitoring work is given by:

$$m_t = -w_t - \frac{(1 - \alpha)c}{mw} \left(c_t + \frac{\phi}{\lambda} \lambda_t \right). \quad (12)$$

A higher wage, w_t , will reduce monitoring work. Similarly it will be affected by the gap between the marginal utility of consumption and the marginal value of households' funds, λ_t .¹⁵ 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 reconnect money and asset prices back to output and inflation, as consumption, which accounts for most of output fluctuations 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 and the level of economic activity and have also important implications for asset prices.

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

¹⁴The 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 . Details of the derivation are reported in the Technical Annex pages 7-8, equation (A.3).

¹⁵Goodfriend and McCallum (2007) assume log utility.

$$\Omega_t = \frac{k_2}{b + k_2} (c_t - q_t - a_3 z_t) - \frac{b}{b + k_2} b_t, \quad (13)$$

which depends on the value of the collateral, q_t and b_t , on a collateral shock, $a_3 z_t$, and on consumption. Higher levels of consumption increase the marginal value of capital and hence the collateral value, q . 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 .¹⁶

The marginal value of collateralised lending also feeds back into the capital asset price equation:

$$q_t = (\delta_1 + \gamma_1) (E_t \lambda_{t+1} - \lambda_t) + \delta_1 E_t q_{t+1} - \frac{k \Omega_t \phi}{c \lambda} (c_t + \lambda_t) + \quad (14)$$

$$k \Omega_t \left(\frac{\phi}{c \lambda} - 1 \right) (\Omega_t + a_3 z_t) + \gamma_1 E_t [m c_{t+1} + (1 - \eta) (n_{t+1} + a_1 l_{t+1})].$$

In (14) the marginal value of collateralised lending, Ω_t , can potentially amplify asset price volatility and enrich the response of the economy to both real and financial shocks. Both real, a_1 , and financial shocks, $a_3 z$, directly feed back into asset prices alongside the expected marginal productivity of capital $[m c_{t+1} + (1 - \eta) (n_{t+1} + a_1 l_{t+1})]$ where $m c_{t+1}$ denotes the marginal costs in period $t + 1$ 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.¹⁷

¹⁶The parameter $k_2 = \frac{kK}{c}$ is a function of k_1 , of steady-state capital, K , and of the steady-state ratio of consumption to output, c . Details of the derivation are reported in the Technical Annex pages 8, equation (A.11).

¹⁷The 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 $\gamma_1 = \frac{\beta \eta m c}{1+\gamma} \left(\frac{n}{K} \right)^{1-\eta}$ is function of steady-state employment in goods sector, n , of steady-state marginal costs, $m c$, 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, see equation (A.12).

3.1 Interest Rate Spreads

The last building block in the Goodfriend and McCallum's (2007) model is the determination of interest rate spreads. Table 1 describes the set of interest rate spreads delivered by the model. 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:

$$R_t^T = E_t(\lambda_t - \lambda_{t+1}) + E_t\pi_{t+1}. \quad (15)$$

The difference between R^T and the so-called interbank rate R^{IB} is equal to the marginal product of loans (L), per unit of labour, $(1 - \alpha)\frac{L_t}{m_t}$, and to their marginal cost, $\frac{w_t}{P_t}$.¹⁸ The interbank rate R^{IB} is less than R^T by the extent of the uncollateralised external finance premium, which is the premium paid by the private sector for loans:

$$R_t^{IB} = R_t^T - \underbrace{[v_t + w_t + m_t - c_t]}_{EFP_t}. \quad (16)$$

The uncollateralised 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 , the share of collateral cost in loan costs (α), reserve requirements (rr),¹⁹ and decreasing in consumption, c_t .²⁰

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

$$R_t^B = R_t^T - \left[\frac{\phi\Omega}{c\lambda} (c_t + \lambda_t) - \left(\frac{\phi}{c\lambda} - 1 \right) \Omega\Omega_t \right], \quad (17)$$

where $(c_t + \lambda_t)$ measures the household marginal utility relative to households shadow value of funds while Ω is the marginal value of the

¹⁸Note that with a fractional reserve system the following relationship holds $L_t = D_t(1 - rr) = \frac{c_t P_t}{V_t}(1 - rr)$ where L is the amount of loans, D are deposits and rr is the fractional reserves/deposit ratio.

¹⁹As these two parameters are both constant in this paper they do not appear in the log-linearisation, we relax this assumption in other work.

²⁰The collateralised external finance premium is simply the uncollateralised external finance premium multiplied by $(1 - \alpha)$, i.e. the share of monitoring costs in loan costs, and it is less than the uncollateralised external finance premium. As the shares α and $(1 - \alpha)$ are constant both the collateralised and uncollateralised versions of the EFP coincide when loglinearised.

collateral. It is, in fact, these key margins - the real marginal cost of loan management versus the liquidity service yield - that determine the behaviour of spreads in this model.

Finally the monetary authorities, who set the interbank lending rate, are assumed to follow an inflation targeting rule, as equation (4) in Section 2, using the interbank interest rate as an instrument:

$$R_t^{IB} = \phi_\pi \pi_t + \epsilon_t. \quad (18)$$

In this section we have outlined, briefly the key elements of the McCallum and Goodfriend 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 following section we shall analyse 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.

3.2 Impulse Responses

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. 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 for key variables. As well as the impulses and the asymptotic moments shown for Figures 2-9, for Figure 10, we pick the central 100 observations of the large-sample simulation and obtain the HP filtered series. Table 2 reports the size, in standard errors selected for the shocks. The full set of parameter settings is described in the technical annex.

The dynamics of the model suggest that a key role is played by the external finance premium 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.

Figure 2 describes the effects of a shock, $a1$, to goods productivity.²¹ Under the inflation targeting rule inflation is stabilised. Hence hours worked

²¹The benchmark model has 20 endogenous variables $\{c, n, m, w, q, P, \pi, mc, H,$

in the goods production sector, n , and the benchmark rate R^T are almost invariant to the shock.²² However c , w , q , m are all higher. 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 reflects 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 EFP. But as we have pointed out 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.

Figure 3 describes the effects of a shock to banking productivity, $a2$. Again under inflation targeting the rule is stabilising and therefore so is the benchmark interest rate R^T . 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 is to decrease the EFP and so here money might indicate some loosening of financial conditions.

Figure 4 reports the effects of a negative shock to collateral, $a3$. Under inflation targeting inflation is stable and so is the benchmark interest rate R^T . There are implied small changes in c and w . As we have a negative shock on collateral there will be a rise in monitoring hours m . The joint effect is to increase the EFP, alongside a fall in the quantity of money.

Figure 5 reports the effect of a positive shock to velocity v with an inflation targeting rule. There is an increase in c , w , n and inflation. Because the capital/labour ratio is lower, the price of capital q rises while hours of monitoring, m , decrease. The joint effect is a decrease in the EFP and a fall in the money supply. Note that in each case the liquidity service yield moves in the same direction as the external finance premium and so we concentrate on understanding the responses of the EFP to shocks.²³ We find that money

$b, \Omega, EFP, R^T, R^B, R^{IB}, R^L, R^D, \lambda, \xi, T$, 5 lagged variables $\{P_{-1}, H_{-1}, c_{-1}, b_{-1}, R_{-1}^B\}$ and 6 exogenous shocks $\{a1, a2, a3, \varepsilon, \epsilon, v\}$. The full derivation of the model with a detailed description of the calibrated values for the parameters and the Matlab file using the King-Watson algorithm for the impulse response are available on request. See Chadha and Nolan (2007) for exposition of these techniques in more detail.

²²For 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.

²³The 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.

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 liquidity becomes abundant (scarce).

4 A Policy Rule with Money

The previous section has shown that financial conditions might matter when setting monetary policy. The model properties are summarised in Table 3. Shocks to productivity and to velocity have symmetric effects on money and the external finance premium. A positive shock to productivity raises both the demand for money and the external finance premium. A negative shock to velocity has a similar effect. However, 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 an opposite effect on money to the effect on the external finance premium. Even though we do not observe the shock to monitoring and to collateral directly we can infer it indirectly from a change in the spread between money and the external finance premium. So a positive shock to either monitoring or collateral will increase the spread while a negative shock will reduce it. This suggests that the spread can 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.

We can illustrate the extent that there may be joint information from money and the external finance premium in terms of the volatility of inflation and output.²⁴ The ratio of the standard deviation of financial and real and velocity shocks is::

$$\Phi_m : \frac{\sigma_{mon} + \sigma_{col}}{\sigma_{prod} + \sigma_{vel}}.$$

Figure 6 traces out the effect of a steadily rising ratio of financial to productivity and velocity shocks (with Φ_m on the x-axis) in the model

²⁴Given the primitive utility function, we could trace out the direct welfare consequences for the representative household but as these are typically found to be proportional to the variance of inflation and output, we trace these paths for simplicity. See Woodford, 2003.

outlined in Section 3 with an inflation targeting central bank. The right hand-side vertical axis measures the correlation between the external finance premium and money. In the simulations as the standard deviation of shocks to collateral and monitoring rises, the correlation falls and eventually becomes *negative*. The standard deviation of inflation rises with the relative standard deviation of financial shocks: clearly suggesting that an inflation targeting central bank will be failing to exploit the joint information from money and the external finance premium.

Let us now assume that the monetary authority augments its inflation targeting rule with a term in the spread:

$$R_t^{IB} = \phi_\pi \pi_t + \phi_m (H_t - EFP_t) + \epsilon_t,$$

where H is money and EFP is the external finance premium.²⁵ In Figure 7 we vary the loading ϕ_m on the spread, holding the relative standard deviation of the shocks fixed with $\Phi_m = 30$. We note that 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 for $\phi_m = 1$ but clearly the optimal weight will depend on Φ_m .²⁶ This calibration result mimics the analytical result in Section 2, equation (10), which showed that the policy rule needs to offset the EFP. 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 in this model.

The impulse responses when this augmented rule ($\phi_m = 1$) is used are shown in Figures 8 and 9. The results for both the augmented (solid) and benchmark (dotted) rule are plotted. We confine ourselves to depicting the effects of a negative shock to collateral and a positive shock to velocity.²⁷ Figure 8 shows that with a negative collateral shock and the benchmark rule there is a fall in the loans made by banks along with a fall in consumption, inflation and employment in the goods sector. With the augmented rule the effect on inflation is largely ameliorated. The effect on assets prices

²⁵Given the bank balance sheet $H_t + L_t = D_t$ and $D_t = L_t/(1 - rr)$ it follows that $H_t = rrD_t$. So in a log-linearised version of the model high-powered money, H_t , is equal to the level of deposits, D_t , and therefore loans, L_t .

²⁶How the central bank should measure money and the EFP in reality, given the preponderance of possible measures, and then ‘learn’ about the appropriate weight on ϕ_m constructing priors and updating posteriors, we leave to future work.

²⁷The results for shocks to productivity and monitoring are available on request.

is reversed and the decline in bank lending is very slight and temporary. 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 velocity, Figure 9, again the effect is to better stabilise this economy, with goods sector employment, real wages, consumption and inflation each becoming less volatile. The policy rate itself also has to move by less in this case and loans supply returns back to its initial level with no overshoot, which is found in the case of the benchmark rule.

As a final illustration of the model's properties with and without the augmented rule, we simulate the model stochastically by repeatedly shocking productivity, velocity, collateral and monitoring. Figure 10 shows, mirroring Figure 1, the paths for real money growth (dotted line) and the external finance premium (solid line) over 100 time periods in four simple scenarios. The first charts shows the real money stock deviation from steady state and the EFP over a simulated 25 year period and we can observe a similar cyclical standard deviation and positive covariance. The chart below simulates the same time series with the augmented policy rule and suggests no substantial change in the behaviour of the simulated time series. The chart in the upper right of the panel corresponds to the case of the benchmark rule with a dominant role for banking sector shocks and suggests both an sharp increase in the standard deviation of observed real money balances and the EFP and a negative correlation. If on the other hand, we adopt the augmented rule, there is a clear reduction in the standard deviation of real money balances. Here we can see that the augmented rule is able to reduce the variability substantially compared to the benchmark rule, suggesting some substantial gain from the employment of the augmented rule in the presence of dominant shocks emanating from the financial sector. The observation that money has been missed in this cycle *may* follow.

The correlations between inflation, money and EFP are tabulated for the different cases in Table 4. Along the diagonals we show the standard deviation of money, inflation and the EFP for the benchmark simulation, banking shocks dominant simulation and one with the standard policy rule and for the augmented policy rule. It is the numerical equivalent of Figure 10. In this case the standard deviation of money and the 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. The correlations between money, inflation and the external finance premium are similar when

we adopt either the benchmark or the augmented rule.

On the right hand side of the panel we report the correlations when banking shocks dominate. The correlation between money and inflation which is positive with the benchmark rule becomes negative with the augmented rule. Similarly the correlation between money and the EFP, which is negative with the benchmark rule, is reduced further once the augmented rule is in place - as the rule exploits the joint information from money and the EFP. Under the augmented rule, with a predominance of banking shocks, the volatility of money and particularly inflation are reduced.

We treat the results as an indication of the extent to which an augmented rule, which uses the joint information from money and financial spreads, may help to 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 money 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 Conclusions

In a monetary economy, it seems very unlikely that developments in money markets do not matter. Disruptions to money markets since August 2007 have led to financial market spreads widening and some contraction in the availability of liquidity for the private sector. To some extent this is the mirror of the situation in recent years when financial spreads have narrowed when liquidity has been ample. The role of money to both originate as well as reflect or amplify shocks seems important. When setting monetary policy, central bankers purport to 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. In this paper we 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).²⁸ We establish the pivotal role of 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

²⁸In some sense we follow the second conjecture of Christiano *et al* (2007).

not quite so true when there are shocks to the supply of credit coming through collateral and the costs of monitoring a loan portfolio.²⁹ In these circumstances if the Central Bank responds in some measure to movements in the spread between money and the external finance premium, a much greater degree of control of inflation can be achieved.

Technical Appendix

A Model Set Up

This is a modified version of the Goodfriend and McCallum's model (2007) incorporating a government (including central bank) budget constraint and a cash-in-advance constraint with stochastic velocity of money demand.

Utility function:

$$U = E_0 \sum_{t=0}^{\infty} \beta^t [\phi \log(c_t) + (1 - \phi) \log(1 - n_t^s - m_t^s)] \quad (19)$$

c_t denotes real consumption, n_t^s is supply of labour in goods sector and m_t^s is the supply of monitoring work in the banking sector.

- Budget constraint:

$$q_t(1 - \delta)K_t + \frac{B_t}{P_t^A} + \frac{H_{t-1}}{P_t^A} + w_t(n_t^s + m_t^s) + c_t^A \left(\frac{P_t}{P_t^A}\right)^{1-\theta} \quad (20)$$

$$- w_t(n_t + m_t) - \frac{H_t}{P_t^A} - tax_t - q_t K_{t+1} - \frac{B_{t+1}}{P_t^A(1 + R_t^B)} - c_t = 0$$

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 is the real wage, H_t is the nominal holding of high powered money, tax_t is the real lump-sum tax payment, R_t^B is the nominal interest rate on government bonds purchased in t and mature in $t + 1$, B_{t+1} . The Lagrangian multiplier of this constraint is denoted as, λ_t .

²⁹Lown and Morgan, 2006, report that the loan officer surveys do have significant exogenous information for business cycle.

- Sales equal net production constraint:

$$K_t^\eta (A1_t n_t)^{1-\eta} - c_t^A (P_t/P_t^A)^{-\theta} = 0 \quad (21)$$

$A1_t$ is a productivity shock in the goods production sector whose mean increases over time at a rate γ . In (18) and (19) the superscript A indicates that the variable is an aggregate taken as given from each household. The Lagrangian multiplier of this constraint is denoted as, ξ_t .

- Government (including central bank budget constraint):

$$T_t = g_t - tax_t = \frac{H_t}{P_t^A} - \frac{H_{t-1}}{P_t^A} + \frac{B_{t+1}}{P_t^A(1+R_t^B)} - \frac{B_t}{P_t^A} \quad (22)$$

g_t is real government expenditure and T_t is real government lump-sum transfer.

- Deposit/money constraint:

$$c_t = v_t D_t / P_t^A \quad (23)$$

V_t denotes velocity and D_t are deposits.

- Bank balance sheet:

$$\begin{aligned} H_t + L_t &= D_t \\ D_t &= L_t / (1 - rr) \end{aligned} \quad (24)$$

H_t is high-powered money, L_t is the amount of loans and rr is the fractional reserve/deposit ratio which is assumed to be constant.

- Production function pertaining to management of loans:

$$L_t / P_t^A = F(b_{t+1} + A3_t k q_t K_{t+1})^\alpha (A2_t m_t)^{1-\alpha} \quad 0 < \alpha < 1 \quad (25)$$

with

$$b_t = B_{t+1} / P_t^A (1 + R_t^B) \quad (26)$$

From (23):

$$c_t = v_t \frac{F(b_{t+1} + A3_t k q_t K_{t+1})^\alpha (A2_t m_t)^{1-\alpha}}{P_t^A (1 - rr)} \quad (27)$$

$A2_t$ denotes a shock to monitoring work, $A3_t$ is a shock on capital as collateral. The parameter k denotes the inferiority of capital as collateral in the banking production function, while α is the share of collateral in the loan production function. For a complete list of all variables and parameters in the model see Tables A.1 and A.2.

A.1 First Order Conditions

- Derivative with respect to m_t^s and n_t^s of (19) and (20)

$$-\frac{(1-\phi)}{1-n_t^s-m_t^s} + w_t\lambda_t = 0 \quad (28)$$

- Derivative with respect to m_t .

$$\begin{aligned} \frac{\phi}{c_t} \frac{\partial c_t}{\partial m_t} - \lambda_t w_t - \lambda_t \frac{\partial c_t}{\partial m_t} &= 0 \\ w_t &= \left(\frac{\phi}{\lambda_t c_t} - 1\right) \frac{\partial c_t}{\partial m_t} \end{aligned} \quad (29)$$

Given:

$$c_t = \frac{v_t D_t}{P_t^A} = \frac{v_t L_t}{P_t^A(1-rr)} = \frac{v_t F(b_{t+1} + A3_t k q_t K_{t+1})^\alpha (A2_t m_t)^{1-\alpha}}{(1-rr)} \quad (30)$$

then

$$\frac{\partial c_t}{\partial m_t} = \frac{1-\alpha}{m_t} c_t$$

So (29) becomes:

$$w_t = \left(\frac{\phi}{\lambda_t c_t} - 1\right) \frac{1-\alpha}{m_t} c_t \quad (31)$$

- Derivative with respect to n_t

$$\begin{aligned} \lambda_t w_t &= \xi_t A1_t (1-\eta) \left(\frac{K}{n_t A1_t}\right)^\eta \\ w_t &= \frac{\xi_t}{\lambda_t} A1_t (1-\eta) \left(\frac{K}{n_t A1_t}\right)^\eta \end{aligned} \quad (32)$$

- Derivative with respect to K_{t+1}

$$\frac{\phi}{c_t} \frac{\partial c_t}{\partial K_{t+1}} + E_t \lambda_{t+1} q_{t+1} (1-\delta) \beta - q_t \lambda_t - \lambda_t \frac{\partial c_t}{\partial K_{t+1}} + E_t \xi_{t+1} \beta \eta K_t^{\eta-1} (A_1 n_t)^{1-\eta} \quad (33)$$

Given

$$\begin{aligned} \frac{\partial c_t}{\partial K_{t+1}} &= \frac{c_t \alpha A_3 k q_t}{b_{t+1} + A_3 k q_t K_{t+1}} \\ &= \Omega A_3 k q_t \end{aligned} \quad (34)$$

where

$$\Omega = \frac{c_t \alpha}{b_{t+1} + A_3 k q_t K_{t+1}} \quad (35)$$

then (33) can be rewritten:

$$\left(\frac{\phi}{c_t \lambda_t} - 1 \right) \Omega A_3 k q_t + E_t \frac{\lambda_{t+1}}{\lambda_t} q_{t+1} (1-\delta) \beta - q_t + E_t \beta \eta \left[\frac{\lambda_{t+1}}{\lambda_t} \frac{\xi_{t+1}}{\lambda_{t+1}} \left(\frac{A_1 n_t}{K_t} \right)^{1-\eta} \right] \quad (36)$$

- Derivative with respect to P_t :

$$\begin{aligned} 0 &= \lambda_t (1-\theta) c_t^A (P_t)^{-\theta} (P_t^A)^{-(1-\theta)} + \theta \xi_t c_t^A (P_t)^{-\theta-1} (P_t^A)^\theta \\ \frac{\xi_t}{\lambda_t} &= \frac{\theta-1}{\theta} \frac{P_t}{P_t^A} \end{aligned} \quad (37)$$

- Derivative with respect to B_{t+1}

$$\frac{\phi}{c_t} \frac{\partial c_t}{\partial B_{t+1}} - \lambda_t \frac{\partial c_t}{\partial B_{t+1}} + E_t \beta \frac{\lambda_{t+1}}{P_{t+1}^A} - \frac{\lambda_t}{P_t^A (1+R_t^B)} = 0$$

Given

$$\frac{\partial c_t}{\partial B_{t+1}} = \frac{\Omega}{P_t^A (1+R_t^B)}$$

then

$$\begin{aligned} &= \left[\frac{\phi}{\lambda_t c_t} - 1 \right] \frac{\Omega}{P_t^A (1+R_t^B)} + \beta E_t \frac{\lambda_{t+1}}{P_{t+1}^A} - \frac{\lambda_t}{P_t^A (1+R_t^B)} \\ &= \left[\frac{\phi}{\lambda_t c_t} - 1 \right] \Omega - 1 + \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \frac{P_t^A}{P_{t+1}^A} (1+R_t^B) \right]. \end{aligned} \quad (38)$$

A.2 Interest Rates

FOC with respect to c_t gives

$$\left(\frac{U_{t,C}}{\lambda_t} - 1 \right) = 0 \quad (39)$$

where $U_C = \frac{\phi}{c_t}$. Substituting in (38) gives riskless rate R^T :

$$1 + R_t^T = E_t \frac{\lambda_t P_{t+1}^A}{\lambda_{t+1} P_{t+1}} \quad (40)$$

The interest rate on bonds, R^B , is derived from (38):

$$R_t^T - R_t^B = \left[\frac{U_C}{\lambda_t} - 1 \right] \Omega_t = \left[\frac{\phi}{c_t \lambda_t} - 1 \right] \Omega_t \quad (41)$$

So $\frac{U_C}{\lambda_t}$ measures the household marginal utility relative to households shadow value of funds while Ω is the marginal value of collateral.

While

$$R_t^L - R_t^B = \left[\frac{U_{t,C}}{\lambda_t} - 1 \right] k \Omega_t \quad (42)$$

where k determines to which capital is collateralisable.

To find the interbank rate R^{IB} we must equate marginal product of loans per unit of labour $m_t (1 - \alpha) \frac{L_t}{m_t}$ to their marginal cost $\frac{w_t}{P_t^A}$ where loans are defined as $L_t = D_t(1 - rr) = \frac{c_t P_t^A}{v_t}(1 - rr)$. So the difference between rates is equal to real marginal cost of loan management:

$$R_t^T - R_t^{IB} = \left[\frac{v_t m_t w_t}{(1 - \alpha)(1 - rr)c_t} \right] \quad (43)$$

Since $(1 - \alpha)$ is the factor share of monitoring, the marginal cost of loan production is multiplied by $(1 - \alpha)$ and the relevant relationship becomes:

$$R_t^L - R_t^{IB} = \left[\frac{v_t m_t w_t}{(1 - rr)c_t} \right] \quad (44)$$

B Steady-State

For the productivity and monitoring shocks we assume a trend growth rate equal to $A2_t = A1_t = (1 + \gamma)^t$. In steady state $q = 1$, $A2 = A1 = (1 + \gamma)$, λ shrinks at rate γ so $\frac{\lambda_{t+1}}{\lambda_t} = \frac{1}{(1+\gamma)}$ and there is no inflation so $P = P^A = 1$ while K is constant.

From (35):

$$\Omega = \frac{\alpha}{\left(\frac{b}{c} + \frac{kqK}{c}\right)} \quad (45)$$

From (28)

$$\frac{1 - \phi}{1 - n - m} = w\lambda \quad (46)$$

From (31):

$$w = \left(\frac{\phi}{c\lambda} - 1\right) \frac{(1 - \alpha)c}{m} \quad (47)$$

From (37) $\frac{\xi}{\lambda} = \frac{\theta - 1}{\theta}$. Replacing in (32):

$$w = \frac{\theta - 1}{\theta} (1 - \eta) \left(\frac{K}{n}\right)^\eta \quad (48)$$

From (36):

$$\begin{aligned} \left(\frac{\phi}{c\lambda} - 1\right)\Omega kq + \frac{1}{1 + \gamma}q(1 - \delta)\beta - q + E_t\beta\eta \left[\frac{1}{1 + \gamma} \frac{\xi}{\lambda} \left(\frac{n}{K}\right)^{1-\eta}\right] &= 0 \quad (49) \\ \left(\frac{\phi}{c\lambda} - 1\right)\Omega kq - 1 + \frac{\beta}{1 + \gamma} \left[(1 - \delta) + \eta \frac{\theta - 1}{\theta} \left(\frac{n}{K}\right)^{1-\eta}\right] &= 0 \end{aligned}$$

From (20), (21):

$$1 = \left(\frac{K}{c}\right)^\eta \left(\frac{n}{c}\right)^{1-\eta} - \frac{\delta K}{c} \quad (50)$$

From (22)

$$T = -R^B b \quad (51)$$

where $b = \tilde{b}c$, \tilde{b} is steady state debt-to-output ratio in calibration.

C The Linearised Model

The model is composed by the following linearised equations.³⁰

Supply Labour (from (28)):

$$\frac{n}{(1-n-m)}\hat{n}_t + \frac{m}{(1-n-m)}\hat{m}_t - \hat{\lambda}_t - \hat{w}_t = 0 \quad (\text{A1})$$

Demand for Labour (from (31)):

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

Supply of Banking Services (combining (24) and (25))³¹:

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

reported in the main text as:

$$c_t = \hat{v}_t c + (1-\alpha)(a2_t + \hat{m}_t) + \alpha \left[\frac{b}{b+k_1} (\hat{c}_t + \hat{b}_t) + \frac{k_1}{b+k_1} (a3_t + \hat{q}_t) \right].$$

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

CIA constraint (from (23)):

$$\hat{c}_t + \hat{P}_t = \hat{H}_t + \hat{v}_t \quad (\text{A4})$$

Aggregate Supply (combining (32) and (50)):

$$\hat{c}_t = (1-\eta) \left(1 + \frac{\delta K}{c} \right) (a1_t + \hat{n}_t) \quad (\text{A6})$$

Marginal cost:

$$\widehat{mc}_t = \hat{n}_t + \hat{w}_t - \hat{c}_t \quad (\text{A7})$$

³⁰The model is defined in the Matlab file gmvsys.m. Standard deviation and persistence structure of the stochastic variables are defined in the driver file gmvdv.m.

³¹The relationship is derived by setting $b = \frac{B}{P(1+R^B)\gamma c}$ and $b_{t+1} = b_t c_t$ where b_{t+1} is defined in (26).

Mark-up (from (37)):

$$\widehat{m}c_t = \widehat{\xi}_t - \widehat{\lambda}_t \quad (\text{A8})$$

Inflation:

$$\widehat{\pi}_t = \widehat{p}_t - \widehat{p}_{t-1} \quad (\text{A9})$$

Calvo pricing:

$$\widehat{\pi}_t = \kappa \widehat{m}c_t + \beta E_t \widehat{\pi}_{t+1} + u_t \quad (\text{A10})$$

Marginal Value of Collateralised Lending (from (35)):

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

reported in the main text as:

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

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

Asset Pricing (from (38))³²:

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

reported in the main text as:

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

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

³²Note that in steady-state $\frac{\xi}{\lambda} = mc$ and $\frac{\lambda_{t+1}}{\lambda_t} = \frac{1}{1+\gamma}$.

Government Budget Constraint³³:

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

Bond Holding:

$$\widehat{b}_t = \varepsilon_t \quad (\text{A14})$$

Riskless Interest Rate (from (40)):

$$\widehat{R}_t^T = \widehat{\lambda}_t + E_t\widehat{\pi}_{t+1} - E_t\widehat{\lambda}_{t+1} \quad (\text{A15})$$

Liquidity Service of Bonds (from (38))³⁴:

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

External Finance Premium (from (43)):

$$\widehat{EFP}_t = \widehat{v}_t + \widehat{w}_t + \widehat{m}_t - \widehat{c}_t \quad (\text{A17})$$

Other Interest Rates:

$$\widehat{R}_t^{IB} = \widehat{R}_t^T - \widehat{EFP}_t \quad (\text{A18})$$

$$\widehat{R}_t^L = \widehat{R}_t^{IB} + \widehat{EFP}_t \quad (\text{A19})$$

$$\widehat{R}_t^D = \widehat{R}_t^{IB} \quad (\text{A20})$$

Policy Feedback Rule:

$$\widehat{R}_t^{IB} = \phi_\pi\widehat{\pi}_t + \epsilon_t \quad (\text{A21})$$

Velocity:

$$\widehat{v}_t = \nu_t \quad (\text{A22})$$

For notational convenience the relevant log-linearised equations with variables denoting deviation from steady-state are reported in the main text without $\widehat{\cdot}$.

³³We 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: $\widehat{r}_t = r_t - r = \ln(x_t/y_t) - \ln(x/y) = \widehat{x}_t - \widehat{y}_t$.

³⁴Log-linearisation of interest rate is defined as difference from steady state: $R_t = R + \widehat{R}_t$.

D Simulation

We consider contemporaneous shocks to $a1, a2, a3, v$. The benchmark model has 20 endogenous variables $\{c, n, m, w, q, P, \pi, mc, H, b, \Omega, EFP, R^T, R^B, R^{IB}, R^L, R^D, \lambda, \xi, T\}$, 5 lagged variables $\{P_{-1}, H_{-1}, c_{-1}, b_{-1}, R_{-1}^B\}$ and 7 exogenous shocks $\{a1, a2, a3, \varepsilon, \epsilon, v, u\}$. The equations (A1) through (A22), 5 lagged identities construct the model to be solved by King and Watson (1998) algorithm. To obtain the simulated series we have produced 10,000 draws for the shocks from a normal distribution and plotted the middle 100 time units. Table A.1 provides a complete list of the endogenous and exogenous variables of the model and their meaning:

Table A.1 The Variables

| | |
|-------------|--|
| 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 |
| H : | Base money |
| b : | Real bond holding |
| Ω : | Marginal value of collateral |
| EFP : | Uncollateralised 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^{IB} : | Interbank 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 |

D.1 Calibration

Table A.2 reports the values for the parameters and steady-state values of relevant variables. 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 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 bond holding level relative to GDP, \tilde{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 between US GDP and M3 at fourth quarter 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 facts that usually banks use higher fraction of monitoring services and rely less on capital as collateral.

With this 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 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 interbank rate, R^{IB} , 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 is 2% per annum which is in line with the average spread of the prime rate over the federal funds rate in the US.

| Table A.2 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 | Production coefficient of loan | 9 |
| k | Relative Inferiority of capital as collateral | 0.2 |
| θ | Elasticity of substitution of differentiated goods | 11 |
| 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^{IB} | Steady state of interbank rate | 0.0021 |
| R^L | Steady state of loan rate | 0.0066 |
| R^B | Steady state of bond rate | 0.0052 |
| \tilde{b} | Steady state of bond holding level | 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 |

Parametrisation can be changed in gmsys.m. Steady state of transfer level, Lagrangian of production constraint and base money depend on above parameters. Steady state marginal cost is $mc = \frac{\theta-1}{\theta}$.³⁵

³⁵The Matlab files using the King-Watson (1998) algorithm to solve the system and to obtain the impulse responses and all the simulated series and simulation code are naturally available on request.

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Table 1. **Interest Rate Spreads**

| Interest Rate | Description | Equation |
|--------------------|----------------------------------|--|
| R_t^T | Benchmark rate | $E_t(\lambda_t - \lambda_{t+1}) + E_t\pi_{t+1}$ |
| R_t^{IB} | Interbank (and policy) rate | $R_t^T - [v_t + w_t + m_t - c_t]$ |
| R_t^B | Yield on government bonds | $R_t^T - \left[\frac{\phi\Omega}{c\lambda} (c_t + \lambda_t) - \left(\frac{\phi}{c\lambda} - 1 \right) \Omega\Omega_t \right]$ |
| R_t^L | Interest rates on loans | $R_t^{IB} + [v_t + w_t + m_t - c_t]$ |
| R_t^D | Deposit rate | R_t^{IB} |
| $R_t^L - R_t^{IB}$ | External finance premium | $[v_t + w_t + m_t - c_t]$ |
| $R_t^T - R_t^B$ | Liquidity Service Yield on Bonds | $\left[\frac{\phi\Omega}{c\lambda} (c_t + \lambda_t) - \left(\frac{\phi}{c\lambda} - 1 \right) \Omega\Omega_t \right]$ |
| $R_t^L - R_t^D$ | Loan-Deposit spread | $[v_t + w_t + m_t - c_t]$ |

Note: Variables with no time denotation are steady-state parameters (see technical appendix for more details) all other terms with a subscript t are expressed as deviations from steady state.

| Table 2. Calibration of exogenous shocks | | |
|---|-------|--------------------------|
| Description | Value | Source |
| Persistence | | |
| ρ_{a1} productivity shocks | 0.95 | King (2002) |
| ρ_{a2} banking productivity shocks | 0.95 | |
| ρ_{a3} collateral shocks | 0.9 | |
| 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 | |
| ρ_v velocity shocks | 0.33 | King (2002) |
| Volatility | | |
| σ_{a1} productivity shocks | 0.72% | King (2002) |
| σ_{a2} banking productivity shocks | 1.00% | |
| σ_{a3} collateral shocks | 1.00% | |
| 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% | |
| σ_v velocity shocks | 1.00% | King (2002) |

Table 3. **The Information Content of Money**

| Shock | Sign Shock | Money | EFP | Info |
|--------------|------------|-------|-----|------|
| Productivity | + | + | + | × |
| Monitoring | + | + | - | ✓ |
| Collateral | - | - | + | ✓ |
| Velocity | - | + | + | × |

Note: The direction of response is denoted here in qualitative terms from the impulse response analysis shown in Figures 2-5.

Table 4. **Correlation between Money, Inflation and the EFP**

| Simple inflation-targeting policy rule | | | | | | |
|---|----------|---------|-------------------------|----------|---------|---------|
| Benchmark Shocks | | | Banking Shocks Dominant | | | |
| | M_{2t} | π_t | EFP_t | M_{2t} | π_t | EFP_t |
| M_{2t} | 1.34% | -0.59 | 0.59 | 5.85% | 0.60 | -0.60 |
| π_t | | 0.06% | -0.97 | | 1.31% | -1.00 |
| EFP_t | | | 2.98% | | | 64.21% |

| Augmented policy rule | | | | | | |
|------------------------------|----------|---------|-------------------------|----------|---------|---------|
| Benchmark Shocks | | | Banking Shocks Dominant | | | |
| | M_{2t} | π_t | EFP_t | M_{2t} | π_t | EFP_t |
| M_{2t} | 1.37% | -0.89 | 0.64 | 2.41% | -0.95 | -0.80 |
| π_t | | 0.03% | -0.56 | | 0.05% | 0.73 |
| EFP_t | | | 3.05% | | | 64.79% |

Note: The table shows second moments of the key variables in calibrated models. Note we consider a broad money similar to Figure 1. In the stylized model of Goodfriend and McCallum, fluctuations of monetary base H_t , loan or deposits L_t , D_t and broad money M_{2t} are identical. Variables are taken as deviations from steady states using HP filter. In each of the triangular panel we calculate asymptotic contemporaneous correlations in off-diagonal cells. Along the diagonal we calculate standard deviation.

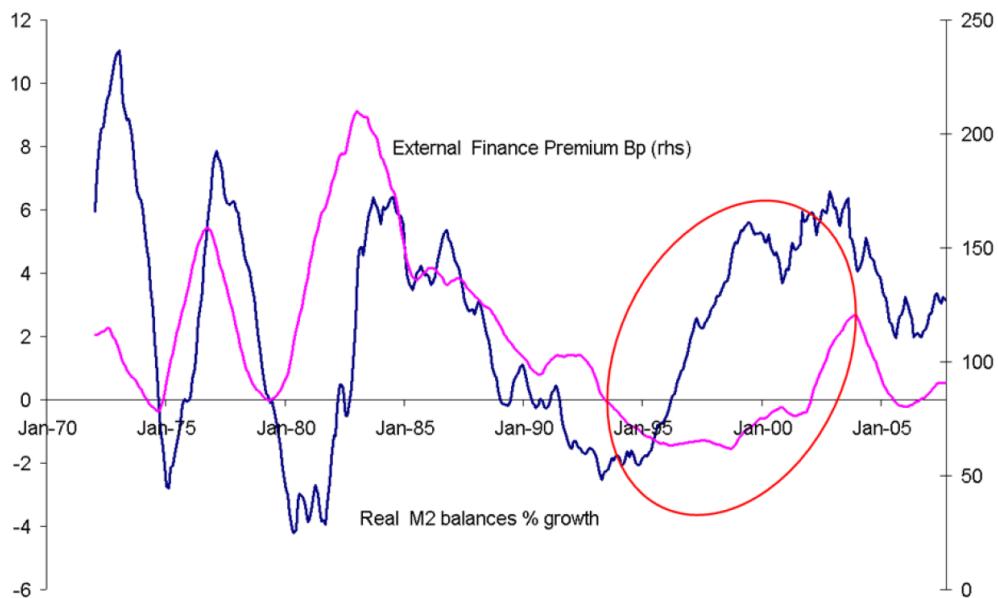


Figure 1: US Real Money Growth and the External Finance Premium

Note: We plot average growth rate of real money versus the external finance premium averaged for last two years respectively. The real money growth is calculated as nominal M2 adjusted by core CPI, both seasonal adjusted and taken from OECD Main Economic Indicators. EFP is the difference of annual yield in Moody's Baa- and Aaa- rated long term corporate bonds.

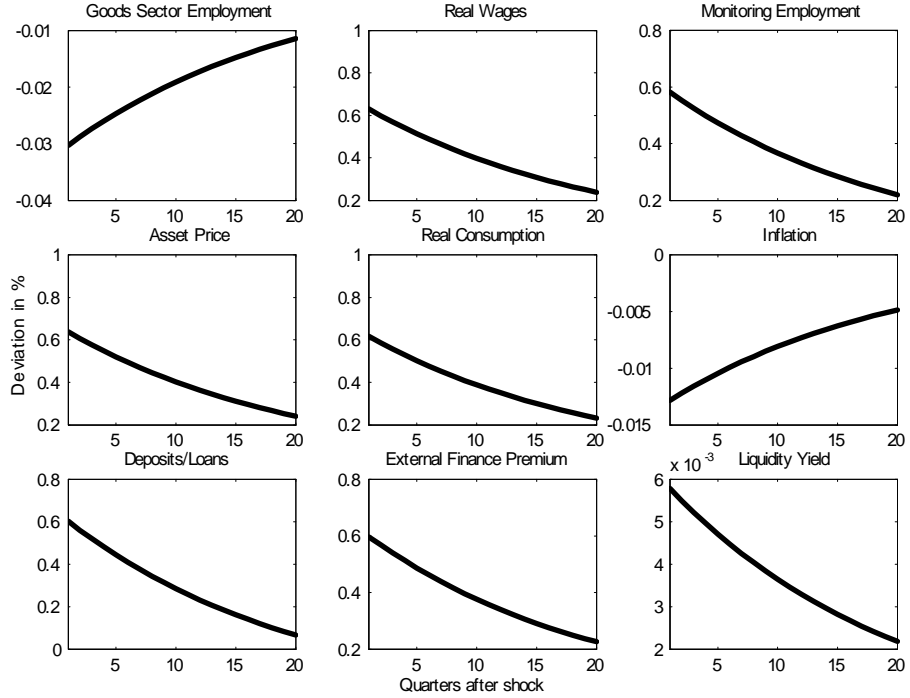


Figure 2: Impulse Responses to Productivity Shock under Inflation Targeting

Note: In Figure 2-5 we report impulse responses of key variables under a benchmark calibration of exogenous shocks and policy rate set by simple inflation-targeting central bank. Please refer to Technical Appendix for calibration values. The impulse responses show percentage deviation from steady state from period 1 when there is a 1% shock of magnitude to specific source of fluctuation.

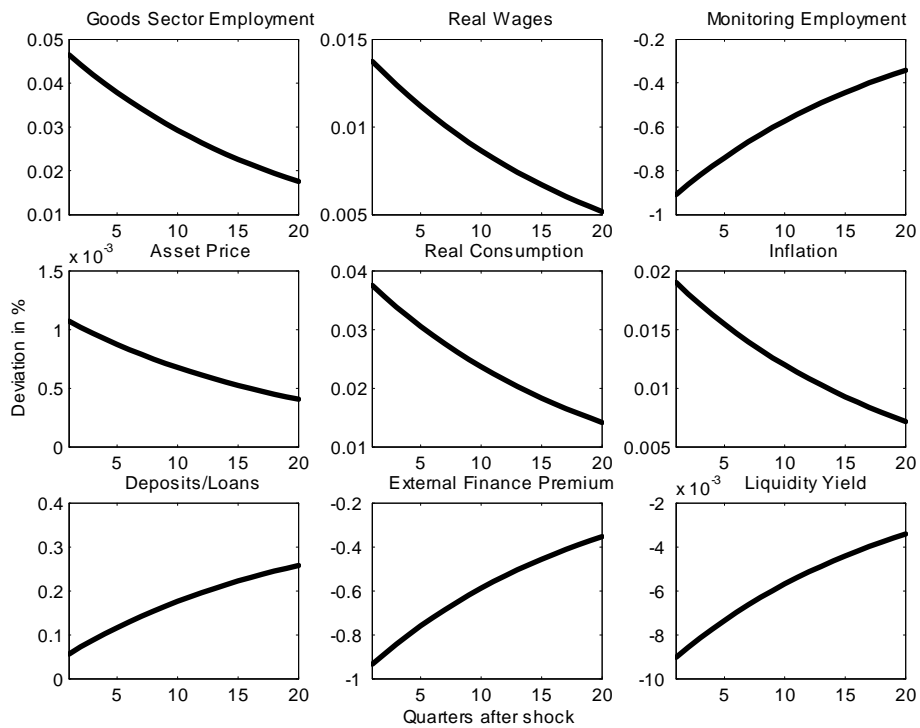


Figure 3: Impulse Responses to Monitoring Shock under Inflation Targeting

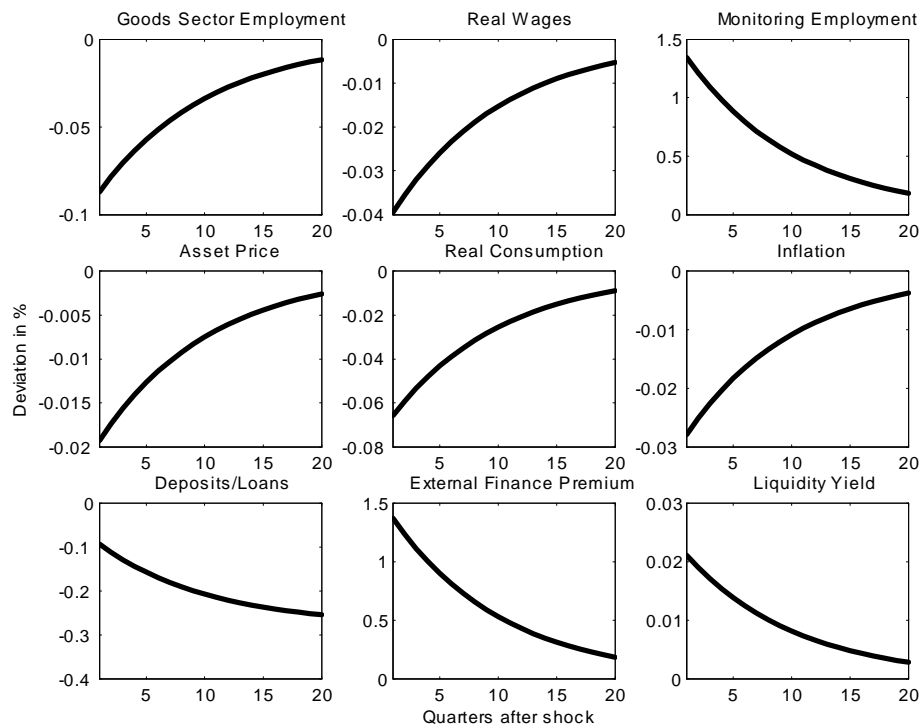


Figure 4: Impulse Responses to Negative Collateral Shock under Inflation Targeting

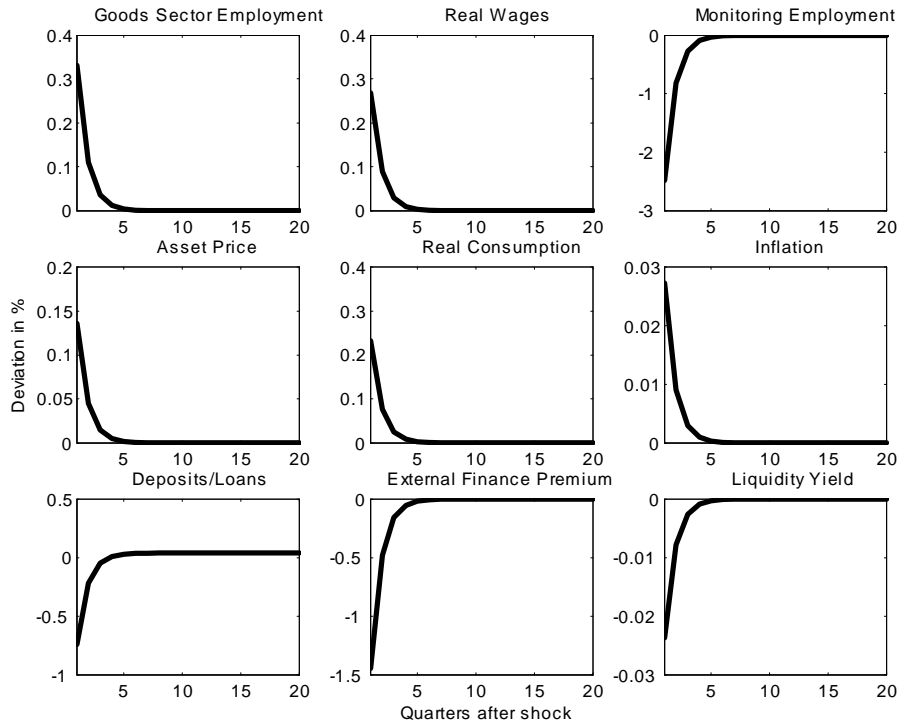


Figure 5: Impulse Responses to Velocity Shock under Inflation Targeting

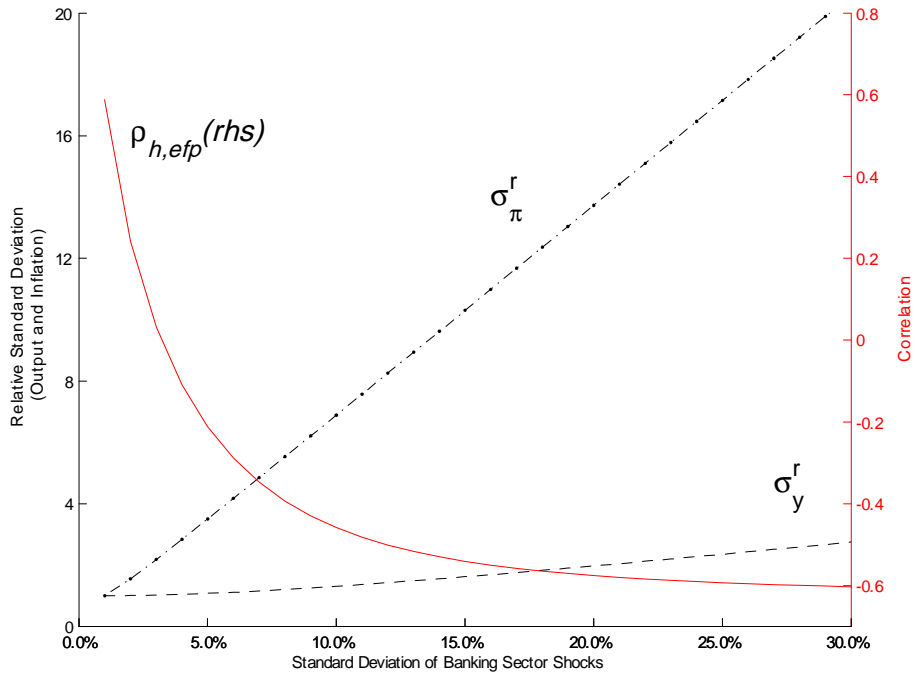


Figure 6: Inflation and Output Variances as a Function of Banking Sector Shocks

Note: On x-axis we allow various calibration of banking sector shocks, the monitoring productivity shock or collateral shock. $\sigma_i^r, i = y, \pi$ denotes relative standard deviation of output or inflation to the initial case (banking shocks are not dominant).

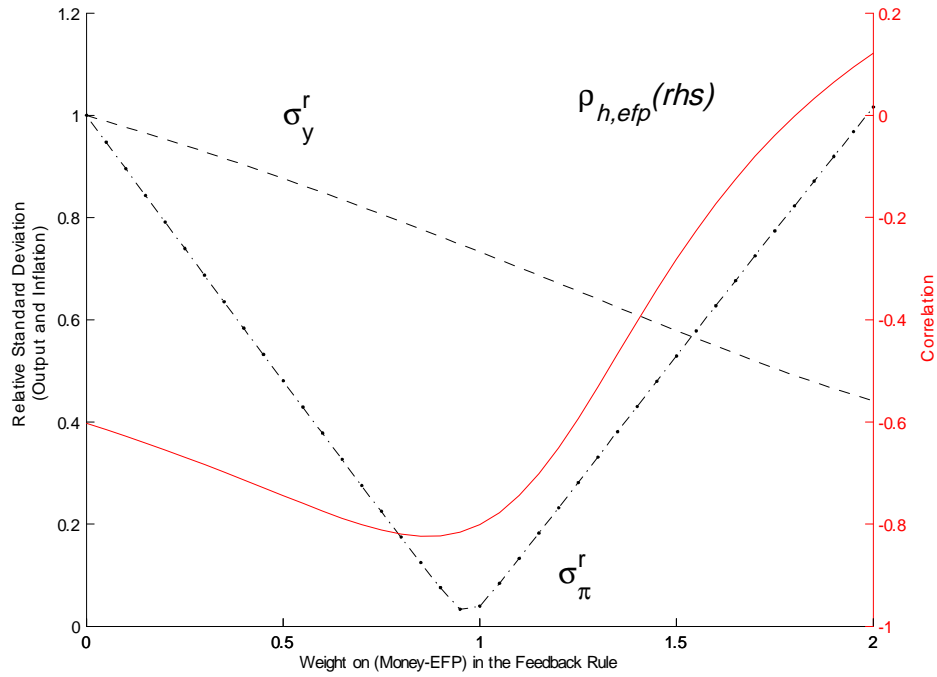


Figure 7: Optimal Weight on Money and EFP in Augmented Policy Rule

Note: On x-axis we allow various calibration for coefficient of augmented feedback term, Money minus External Finance Premium. $\sigma_i^r, i = y, \pi$ denotes relative standard deviation of output or inflation to the initial case (zero weight on Money-EFP).

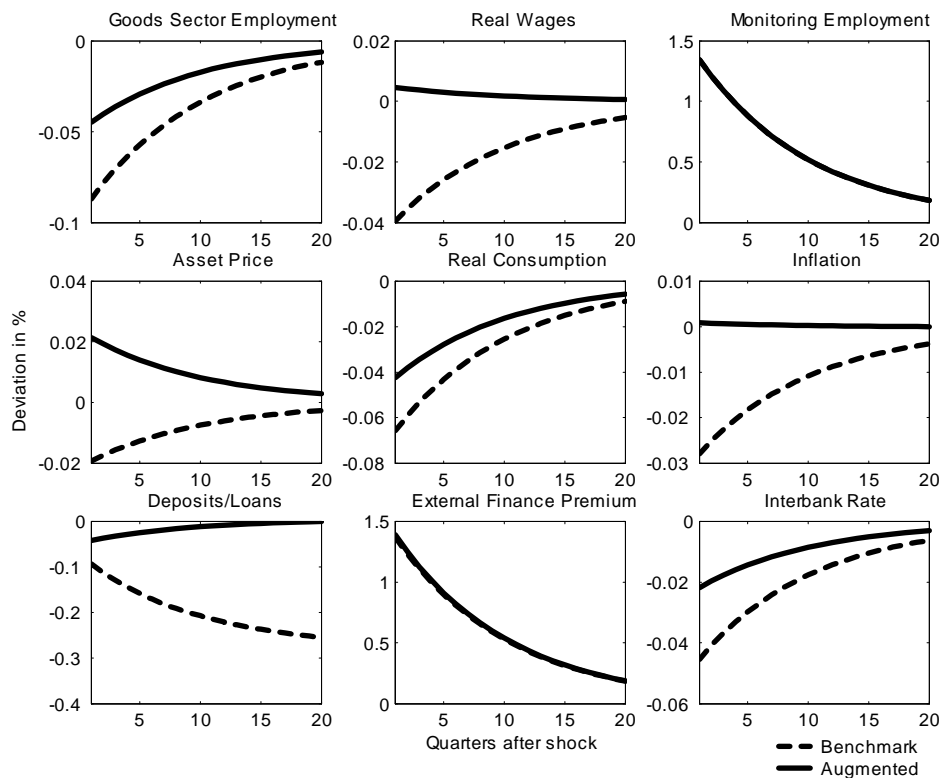


Figure 8: Key Responses to Negative Collateral Shock under Benchmark and Augmented Rule

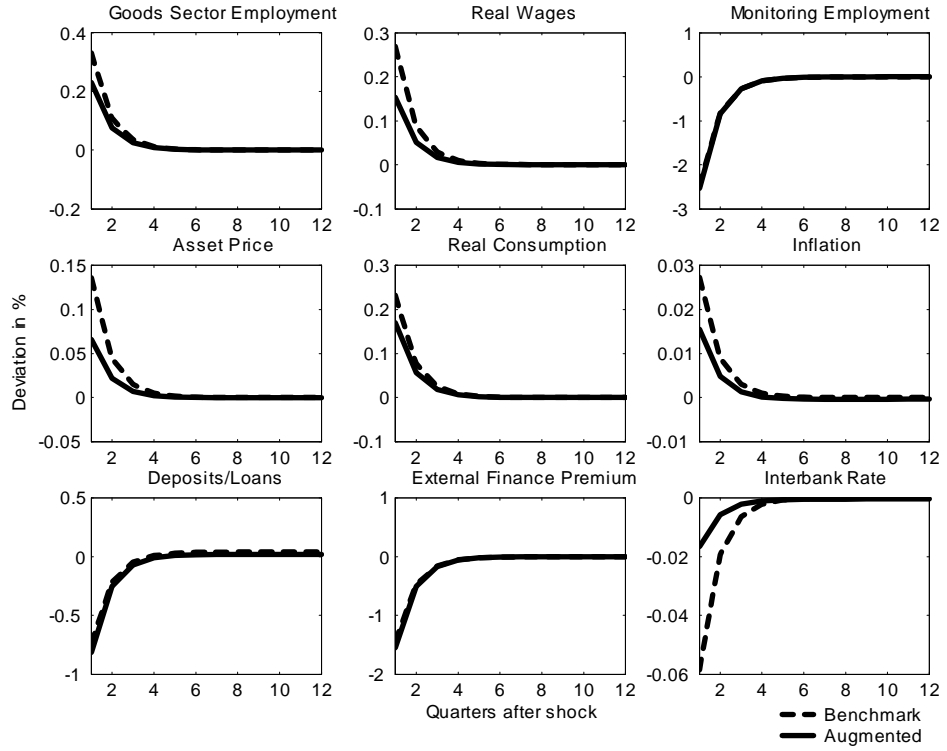


Figure 9: Key Responses to Velocity Shock under Benchmark and Augmented Rule

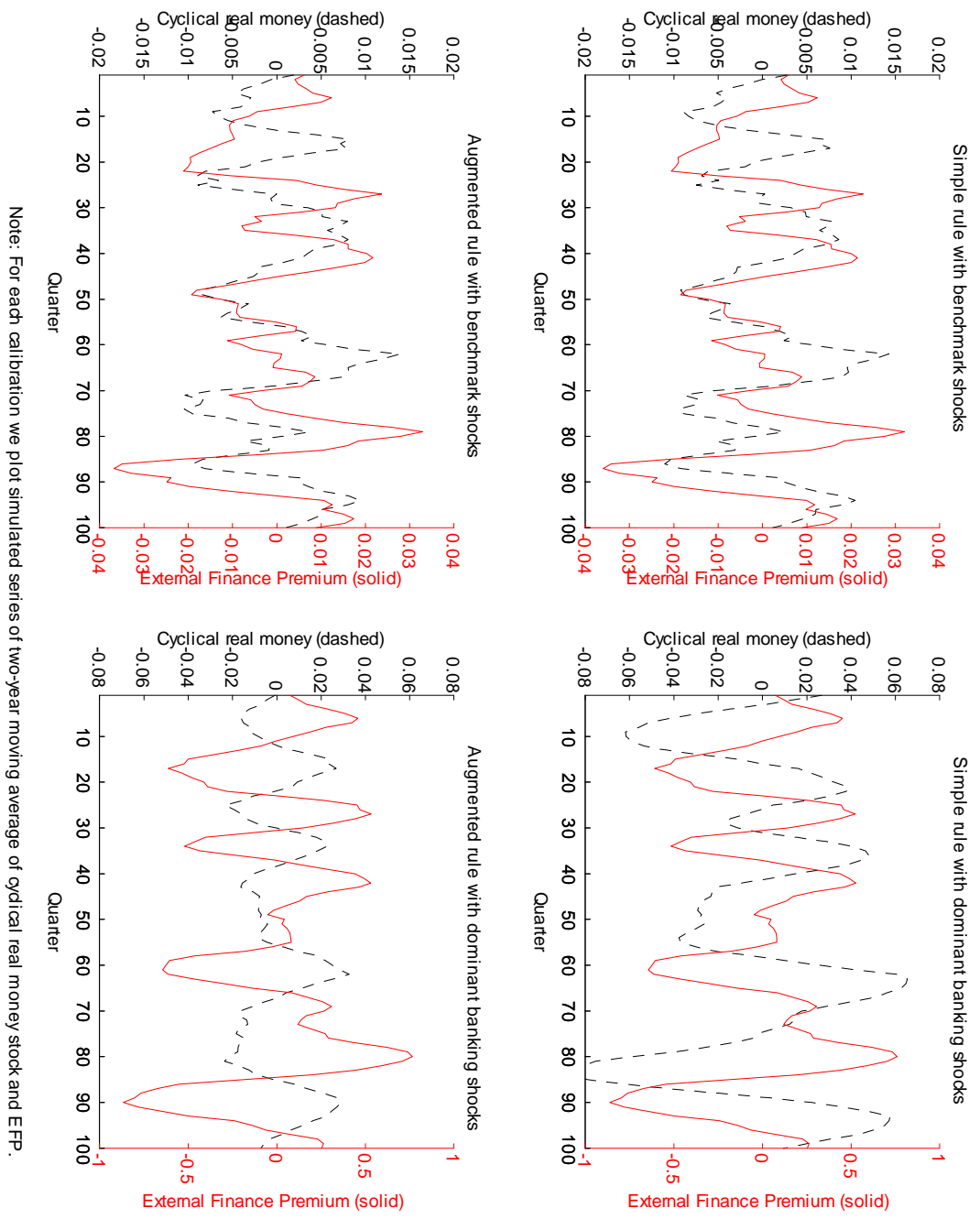


Figure 10: Simulation of Artificial Time Series from Models