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by Livio Stracca[2]

In 2007 all ECB publications feature a motif taken from the €20 banknote.

1 The views expressed in this paper are of the author and are not necessarily shared by the European Central Bank. I thank participants in a seminar at the University of Binghamton, USA, and in particular Barry Jones and Chris Hanes for useful comments. I thank also Edward Nelson, David Laidler, Federico Ravenna and an anonymous referee for useful suggestions.

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CONTENTS

Abstract

This paper presents a dynamic general equilibrium model with sticky prices, in which "inside" money, made out of commercial banks' liabilities, plays an active, structural role role. It is shown that, in such a model, an inside money shock has a well-defined meaning. A calibrated version of the model is shown to generate small, but non-negligible effects of inside money shocks on output and inflation. I also simulate the effect of a banking crisis in the model. Moreover, I find that it is optimal for monetary policy to react to such shocks, although reacting to inflation alone does not result in a significant welfare loss.

Keywords: Endogenous money, inside money, monetary policy, dynamic general equilibrium models, deposit in advance constraint.

JEL: E43.

Non-technical summary

The importance of inside money (i.e. money produced by the private sector and not by the government or the central bank) is rather undisputed empirically, but it is uncertain whether it may hinge on a structural role for this variable in the transmission of monetary policy, in addition to its impact on current and future real short-term interest rates, or on the fact that money contains forward-looking information on variables such as asset yields that are unobservable. In the former case, inside money can play an active role in the business cycle and contain independent information not only empirically, but also conceptually. In the latter case, inside money is causally passive and may be of interest for economists and policy-makers only from an empirical standpoint.

Mainstream monetary economics has by and large endorsed the passive view, and often argued that monetary aggregates lack not only conceptual, but also empirical interest. On the other hand, some economists such as Laidler (1999, 2006) have emphasised the possibility of an active role for inside money. Laidler (1999) distinguishes several cases, and identifies the existence (absence) of non-monetary liabilities in the liabilities side of the balance sheet of commercial banks as a key element for inside money to play a passive (active) role in the economy. In the absence of non-monetary liabilities, broad money determines the supply of loans to the private sector, and if loans are a special form of financing, inside money demand shocks may have significant aggregate implications on output, consumption and investment. The problem with this argument, however, is that in modern financial systems banks do have a significant amount of non-monetary liabilities in their balance sheet.

The objective of the present paper is to shed some light on the active versus passive views of inside money by building a dynamic stochastic general equilibrium model in which the existence of inside money is explained in structural terms and where shocks to inside money demand and supply have a definite meaning. The structural, active role of inside money in the general equilibrium model of this paper does not stem from the absence of bank non-monetary liabilities, but from the special role that bank deposits play in alleviating asymmetric information between sellers and buyers, as emphasised by Kiyotaki and Moore (2002). This special role is substantiated by the assumption of a deposit in advance constraint, which requires part of consumption expenditure to be financed out of bank deposits. This appears to be a realistic assumption, even in highly developed financial systems such as in the United States. Since bank deposits provide a liquidity service to bank customers which is costly to supply, bank deposits are remunerated at below-market rates, a feature that is also very realistic.

In this context, inside money demand and supply shocks can be given a precise connotation. A money demand shock is defined as an unexpected change in the tightness of the deposit in advance constraint, for example reflecting changes in the payments technology and in particular in banks' ability to mobilise non-monetary assets or changes in tastes by consumers. A money supply shock is an unexpected change in the conditions at which banks provide monetary services to the customers and is reflected in a change in the spread between the interest paid on bank deposits and the prevailing market interest rate. While the money supply shock originates exclusively in the banking sector, the money demand shock may also (and arguably mainly) originate in the household sector.

The main results of the analysis are as follows:

- Generally, the paper shows that based on realistic modelling assumptions and conservative calibration it is possible to give a non-negligible, albeit relatively small, structural role to inside money;
- More specifically, inside money supply shocks are found to have a small expansionary impact on output, inflation and interest rates;
- Second, money demand shocks are found to have a more significant, but contractionary impact;
- Third, the presence of inside money in the model leads to an attenuation of technology and monetary policy shocks on key variables such as output and inflation;
- Fourth, simulating a banking crisis as a simultaneous increase in the cost of bank lending to firms and of producing deposits leads to an unambiguous contraction of economic activity and inflation and to a fall in interest rates.
- Finally, the inside money shocks enter in an optimal simple linear monetary policy rule, but their contribution to the overall central bank loss is found to be minimal. In other words, it appears that reacting to inflation is sufficient for stabilization purposes.

Central banks generally see broad money as passive, responding to the economic weather, not making it. *The Economist, 9 June 2007.*

Monetary developments can reflect two different causes: changes in the demand for money and changes in the supply of money. They have very different implications for inflation. Movements in the demand for broad money, relative to spending in the economy, reflecting changes in the way different assets and liabilities are used in transactions or shifts in portfolio preferences, have no implications for spending in the economy or the path of inflation. (...) Changes in the supply of broad money, however, will lead to an imbalance in the relationship between money and prices. Either spending and the price level will adjust or the central bank will have to alter its policy to eliminate the change in the supply of money. (...) What can generate such shocks to the supply of money? Modern models of monetary policy tend to be silent on this point. *M. King (2007), pp. 16-17.*

1 Introduction

One of the most common thought exercises by monetary economists over the past decades has been the evaluation of the impact of an exogenous injections of government created (or "outside") money on economic activity, goods and asset prices. The seminal work of Tobin (1969) has been subsequently developed into full-blown stochastic dynamic general equilibrium models where agents optimize and markets clear, subject to suitably specified frictions. An important finding of this literature is that, in their impact period, monetary injections have a liquidity effect which is substantiated in a fall of the nominal and real interest rate, a temporary rise in output and a more persistent increase in the price level.

From a conceptual standpoint, a clear distinction has to be made between *inside* money that is, in a modern financial system, not under the direct control of the central bank or any other government authority, and *outside* money that is a net asset for the private sector. Inside money is essentially a form of private credit that circulates as medium of exchange and is therefore in zero net supply in the private sector (Lagos 2006). Inside money is created mainly, although not exclusively, by commercial banks and cannot be produced in excess of the preferences of the public, as expounded clearly in Dalziel (2000) and Goodhart (2002). Government-produced money, by contrast, may create spending power in excess of the desires of the public (forced net saving).

Clearly, the identification of a liquidity effect requires money to be exogenous. If money is driven by a combination of demand and supply shocks, the identification of the shock may be lost.[1] This difficulty is reflected in the typical finding of empirical papers when analysing the impact of shocks to relatively broad, and therefore mainly inside, definitions of money on aggregate demand. While most studies identify a clearly expansionary effect of inside money (shocks) on aggregate demand, consistent with the liquidity effect, they also encounter a "liquidity puzzle", whereby nominal and real interest rates go up, not down, in the aftermath of the shock (Leeper, Sims and Zha 1996). This has led researchers to concentrate on narrower definitions of money which are supposedly under the direct control of the monetary authority and have therefore a higher degree of exogeneity. More recently, several papers have found significant evidence of an independent explanatory role of *broad* monetary aggregates in empirical aggregate demand (IS curve) relationships; latest in the series is, for example, Hafer, Haslag and Jones (2006).[2]

Nonetheless, the question of what type of phenomenon is captured by shocks to inside money, as identified in the empirical literature, remains essentially unexplained in the profession. As emphasised by Smets (2003), the importance of inside money, which is rather undisputed empirically, may hinge either on a structural role for this variable in the transmission of monetary policy in addition to its impact on current and future real short-term interest rates, or on the fact that money contains forward-looking information on variables such as asset yields that are unobservable.[3] In the former case, inside money can play an active role in the business cycle and contain independent information not only empirically, but also conceptually. In the latter case, inside money is causally passive and may be of interest for economists and policy-makers only from an empirical standpoint.

Mainstream monetary economics has by and large endorsed the passive view, and often argued that monetary aggregates lack not only conceptual, but also empirical interest. On the other hand, some economists such as Laidler (1999, 2006) have emphasised the possibility of an active role for inside money. Laidler (1999) distinguishes several cases, and identifies the existence (absence) of non-monetary liabilities in the liabilities side of the balance sheet of commercial banks as a key element for inside money to play a passive (active) role in the economy. In the absence of non-monetary liabilities, broad money determines the supply of loans to the private sector, and if loans are a special form of financing, inside money demand shocks may have significant aggregate implications on output, consumption and investment. This argument is developed in more detail in Hartley and Walsh (1991) and Hartley (1998), and is used more recently in Christiano, Motto and Rostagno (2003) and Goodfriend and McCallum (2007). The problem with this argument, however, is that in modern financial systems banks *do* have a significant amount of non-monetary liabilities in their balance sheet.

The objective of the present paper is to shed some light on the active versus

[1] This is a point raised by several authors; see for example Leeper and Roush (2003).
[2] Nelson (2002) reaches similar conclusions for the monetary base.
[3] See Nelson (2003) for a forceful support of the latter view.

passive views of inside money by building a dynamic stochastic general equilibrium model in which the existence of inside money is explained in structural terms and where shocks to inside money demand and supply have a definite meaning. It should be noted that giving a structural interpretation to inside money supply shocks has proven to be remarkably difficult in the literature and is a matter that is still unsettled for academics but in demand by policy-makers, as shown in the above quotation of Mervyn King (see also Goodhart 2007). Economists in the Post Keynesian tradition have typically taken the view that there is no such thing as an exogenous shock to nominal money supply in a modern credit-money system, which is often labelled as the *radical endogeneity* theory of money (Kaldor 1982; Palley 1991; Howells 1995). These authors see inside money as demand-determined (i.e. with demand automatically creating its own supply), and therefore essentially uninteresting if not on its own right. As noted by Dalziel (2000), this is also very much the view of modern mainstream economics.

The structural, active role of inside money in the general equilibrium model of this paper does not stem from the absence of bank non-monetary liabilities, but from the special role that bank deposits play in alleviating asymmetric information between sellers and buyers, as emphasised by Kiyotaki and Moore (2002). This special role is substantiated by the assumption of a deposit in advance constraint, which requires part of consumption expenditure to be financed out of bank deposits. This appears to be a realistic assumption, even in highly developed financial systems such as in the United States. Since bank deposits provide a liquidity service to bank customers (in the meaning of Barnett 1980) which is costly to supply, bank deposits are remunerated at below-market rates, a feature that is also very realistic.

In this context, inside money demand and supply shocks can be given a precise connotation. A money demand shock is defined as an unexpected change in the tightness of the deposit in advance constraint, for example reflecting changes in the payments technology and in particular in banks' ability to mobilise non-monetary assets or changes in tastes by consumers. A money supply shock is an unexpected change in the conditions at which banks provide monetary services to the customers and is reflected in a change in the spread between the interest paid on bank deposits and the prevailing market interest rate. While the money supply shock originates exclusively in the banking sector, the money demand shock may also (and arguably mainly) originate in the household sector.

Overall, the main aim of this paper is to build a workhorse general equilibrium model giving a structural role to inside money. The existence of such a model could provide the basis for further work on the role of inside money, as advocated by Laidler (2006). It is also the precondition for being able to distinguish between the active and passive views of inside money, from both a quantitative and a qualitative perspective. The *main result* of this paper is that it is possible to build a dynamic general equilibrium model based on reasonable assumptions and calibrated using conservative values that is able to deliver a non-negligible, albeit small, structural role of inside money shocks in explaining key variables such as output and inflation.

It is also useful to compare this paper with Goodfriend and McCallum (2007). The two papers are very much in the same spirit as they aim at giving a structural role to banking in a New Keynesian model used for monetary policy analysis and, crucially, at evaluating the plausible quantitative importance of banking frictions for this type of models. At the same time, there are three important differences. First and foremost, the focus of the present paper is on the liabilities side of the balance sheet of banks, while Goodfriend and McCallum focus on the asset side. Second, as noted I allow for the existence of bank non-monetary liabilities, while Goodfriend and McCallum do not. Finally, in Goodfriend and McCallum there is no investment, while in the present paper investment is fully endogenous.

The paper is organised as follows. In Section 2 we present the model, and in Section 3 the calibration. Impulse responses, the analysis of the results and a sensitivity analysis is in Section 4. Section 5 concludes.

2 The model

There are five types of agents in the model: a representative household, a representative final good producer, a continuum of intermediate goods producers, a financial intermediary, and the monetary authority. The government is assumed to play a completely passive role and just balance its books. The focus and main innovative element of the paper is the modelling of the financial intermediary and in particular the determination and function of inside money in the liabilities side of its balance sheet.

Investment is endogenous in the model as for example in Casares and McCallum (2000) and Ellison and Scott (2000). Although capital accumulation in itself does not play a pivotal role in the model, we follow King and Rebelo (2000) in emphasising that including capital in the model is an essential prerequisite for any realistic representation of the supply side of the model.

The main actions and the timing in the model can be described succinctly as follows. At the beginning of each period t, the representative household lends deposits and bank bonds to the financial intermediary, who subsequently makes loans to intermediate goods producing firms. Banks can also conduct open market operations with the central bank, at a price (interest rate) decided by the latter, in which they exchange bonds with high-powered money.[4] Non-financial firms produce goods and pay out a wage and dividends to households as, respectively, a remuneration for their work effort and a compensation as firm shareholders. During this time interval, the household sector consumes and provides work effort. At the beginning of the subsequent period $t+1$, firms pay back the loan to the financial intermediary, the financial

[4] Given that in the model only banks hold high-powered money, we will also refer to bank reserves interchangeably.

intermediary pays back deposits and bank bonds to the household sector, and the whole cycle starts again.

2.1 Households

A representative household derives utility from consumption. Consumption, c_t, is financed out of labour income and previously accumulated financial wealth. The balance sheet of the household can be written as follows:

$$P_t c_t + D_t + B_t + \frac{\phi_d}{2} P_t (\frac{D_t - D_{t-1}}{P_t})^2 = W_t n_t + D_{t-1} R^D_{t-1} + B_{t-1} R_{t-1} + G_t \qquad (1)$$

where P_t is the price level, D_t is one-period deposits (inside money), W_t is the nominal wage, n_t is hours worked, B_t is one-period bonds (issued by the financial intermediary[5]), R_t is the (risk-free) gross rate of return on bonds, R^d_t is the corresponding concept for deposits, G_t represents dividends paid by intermediate goods producing firms. Note that we introduce a quadratic adjustment cost paid by the household, i.e. the term

$$\frac{\phi_d}{2} P_t (\frac{D_t - D_{t-1}}{P_t})^2 \qquad (2)$$

which captures the observed sluggish adjustment of deposits as typically estimated in empirical money demand models; see Cooley and Quadrini (1999) for more discussion.

Writing the budget constraint (1) in real terms leads to:

$$c_t + b_t + d_t + \frac{\phi_d}{2} (d_t - \frac{d_{t-1}}{\pi_t})^2 = w_t n_t + \frac{d_{t-1} R^d_{t-1}}{\pi_t} + \frac{b_{t-1} R_{t-1}}{\pi_t} + g_t \qquad (3)$$

where π_t is the gross inflation rate and variables in lowercase letters are real rather than nominal.

In addition, the household faces a *second* constraint on this current consumption expenditure, i.e. a *deposit in advance constraint*:

$$\alpha_t P_t c_t \leq D_t, \qquad (4)$$

or, in real terms

$$\alpha_t c_t \leq d_t, \qquad (5)$$

where $\alpha_t = \rho_\alpha \alpha_{t-1} + (1 - \rho_\alpha)\alpha + q_t$, with $0 < \alpha \leq 1$, $0 \leq \rho_\alpha < 1$ and q_t is an i.i.d. money demand shock with standard deviation σ_q.

The constraint in (4) represents an innovative element of this analysis and it is opportune to spend a few words about its rationale.[6] The basis for this assumption is the observation that most purchases can be done indifferently using cash and bank

[5] We assume for simplicity that government bonds are in zero net supply.

[6] The deposit in advance constraint is obviously not a complete innovation of this paper; see for example Einarsson and Marquis (2001) and more recently Goodfriend and McCallum (2007).

deposits, and that it is now very easy to covert bank deposit holdings into cash. In practice, D_t can be thought as an aggregate including both bank deposits and cash. On the other hand, if you try to purchase any non-durable good, as well as many durable goods, in the United States using a non-monetary financial asset such as a Treasury bill you may be sorely disappointed (not to speak of the situation in Europe). Another way of explaining this point is the assumption that portfolio adjustment costs are *minimal* between cash and deposits, while they are *substantial* between deposits and other assets.[7] Thus, the parameter α can be interpreted as a measure of these costs.

From a theoretical perspective, the role of bank deposits in this economy may be characterised in the context of the analytical framework of Kiyotaki and Moore (2002), where agents face limits to their commitment to repay debt obligations, especially in a multilateral setting where the creditor does not know the credit history of the borrower.[8] Hence, financial or real assets have to be pledged to back up the commitment, which entails significant costs if portability is limited. For example, imagine the situation in a furniture shop in which the client (borrower) could, theoretically, choose to pay a certain piece of furniture by issuing a credit towards the seller (lender). If the seller has doubts on the willingness or ability to repay by the client, he might want to ask him to pledge a financial asset, say a bond. If producing the bond at short notice entails a fixed cost for the client, it could be impossible to close the deal, which implies that the trade does not take place even if both agents could gain from it. This type of problem may explain the existence of special institutions, banks, which are most efficient in producing portable assets, i.e. deposits. In essence, banks are able to produce a commitment technology which allows them to issue "saleable paper" against "non-saleable" paper in the assets side, using the language of Kiyotaki and Moore. This is what these authors refer to as inside money, denoted by D_t in this paper.

The household acts so as to maximise a discounted sum of expected utilities,

$$E_t \sum_{j=0}^{\infty} \beta^j U_{t+j} \tag{6}$$

where $0 < \beta < 1$ is the discount factor and U_t is the instantaneous utility function, and E_t is the expectation operator based on a full knowledge of all variables dated t. The utility function is defined in a log-linear form as:

$$U_t = \ln c_t - \phi n_t \tag{7}$$

where ϕ measures the relative importance of leisure. The representative household

[7] For example, the banking industry has now completely automated the distribution of cash, but the liquidation of financial assets still often requires clients to physically go to the bank (or at least undertake complex transactions on the internet).

[8] See also Kocherlakota (1998).

determines the level of $\{c_t, n_t, b_t, d_t\}$ by maximising the lifetime utility function (6) subject to the two constraints in (3) and (5).

The first order conditions for this problem identify the choice variables $\{c_t, n_t, b_t, d_t\}$ and the two constraints (3) and (5) the two respective Lagrange multipliers, λ_t and ξ_t, taking other variables as given:

$$\frac{1}{c_t} + \lambda_t + \xi_t \alpha_t = 0 \tag{8}$$

$$\lambda_t = -\frac{\phi}{w_t} \tag{9}$$

$$-\lambda_t + \beta R_t E_t \frac{\lambda_{t+1}}{\pi_{t+1}} = 0 \tag{10}$$

$$\beta E_t \frac{\lambda_{t+1}(R_t - R_t^d)}{\pi_{t+1}} + \phi_d \lambda_t (d_t - \frac{d_{t-1}}{\pi_t}) = \beta \phi_d E_t \frac{\lambda_{t+1}}{\pi_{t+1}} (d_{t+1} - \frac{d_t}{\pi_{t+1}}) + \xi_t \tag{11}$$

Moreover, the usual transversality conditions are assumed to hold.

It is useful to spend a few words on equation (11) since this is closely related to inside money. The left hand side of the equation shows the marginal costs of choosing one additional unit of real deposits in terms of the utility derived from the alternative investment in bonds: these include the forgone interest rate income (which is related to the interest rate spread between the two instruments, $R_t - R_t^d$) and the marginal adjustment cost, which is assumed to exist for deposits but not for bonds. The marginal benefits are included in the right hand side: lower future adjustment costs and the Lagrange multiplier of the deposit in advance constraint, i.e. the marginal benefit of relaxing the constraint.

It is also worth noting that rearranging terms in (11) we obtain

$$(d_t - \frac{d_{t-1}}{\pi_t}) = \beta E_t \frac{\lambda_{t+1}}{\lambda_t \pi_{t+1}} (d_{t+1} - \frac{d_t}{\pi_{t+1}}) + \frac{1}{\phi_d} [\frac{\xi_t}{\lambda_t} - \beta E_t \frac{\lambda_{t+1}(R_t - R_t^d)}{\lambda_t \pi_{t+1}}] \tag{12}$$

The last term of the right hand side of the equation,

$$\frac{\xi_t}{\lambda_t} - \beta E_t \frac{\lambda_{t+1}(R_t - R_t^d)}{\lambda_t \pi_{t+1}} \tag{13}$$

is a theoretical inside money demand function which equates the relative tightness of the deposit in advance constraint vis-a-vis the budget constraint to the present value of the forgone interest rate income. The rest of the equation is specified in a partial adjustment format in which the real change in bank deposits (inside money), $(D_t - D_{t-1})/P_t$, depends on its future values and on the deviation of the equilibrium condition in (13) from zero.

2.2 Firms

Generally, this part of the model is relatively standard; the only element which is worth noting is the assumption that firms have to borrow from the financial intermediary in order to obtain resources for paying the wage bill and invest. We assume, for simplicity, that firms do not retain any own funds and pay out all their profits in dividends.

2.2.1 Final goods producer

The representative final goods producer is defined in the standard way as a perfectly competitive firm, purchasing $y_t(z)$ units of each intermediate good z at a price $P_t(z)$. The final good is aggregated in the customary way as:

$$y_t = (\int_0^1 y_t(z)^{\frac{\mu-1}{\mu}} dz)^{\frac{\mu}{\mu-1}} \tag{14}$$

where μ is the demand elasticity for each intermediate good. The demand equation for each intermediate good which maximises the final goods producer's profits is:

$$y_t(z) = (\frac{P_t(z)}{P_t})^{\mu} y_t \tag{15}$$

and the aggregate price index is defined as:

$$P_t = (\int_0^1 P_t(z)^{1-\mu} dz)^{-\frac{1}{1-\mu}} \tag{16}$$

2.2.2 Intermediate goods producers

There is a continuum of monopolistically competitive producers of differentiated goods, indexed by z, each of which hiring (homogeneous) labour $(n_t(z))$ from households. Since workers must be paid in advance of production, firms need to borrow the wage bill from the financial intermediary. Moreover, firms also need to borrow in order to invest in buying new capital goods. Since the interest payments are assumed to be linked to the nominal interest rate, this model features a cost channel of monetary policy as for example in Ravenna and Walsh (2006).[9]

Nominal loans for firm z are denoted by $L_t(z) = W_t n_t(z) + P_t i_t(z)$, where $i_t(z)$ is investment. It should be noted that there is no default from debt obligations in equilibrium, but this does not mean that all borrowers are necessarily trustworthy. We assume that some "would-be" firms who would default on their obligations are excluded ex ante from receiving credit, after some screening and monitoring activity by the financial intermediary for which the latter has to expend some costs (more on

[9] See Gaiotti and Secchi (2006) for empirical support for the existence of the cost channel.

this later). As a result, only the successful applicants are given credit, and exist as firms in this economy.

Each firm has an identical Cobb-Douglas production function defined as follows:

$$y_t(z) = A_t k_t^{\gamma}(z) n_t^{1-\gamma}(z), \tag{17}$$

where A_t is an economy-wide productivity shifter and $0 < \gamma < 1$. The law of motion of A_t is given by:

$$A_t = \exp(\chi t + \theta_t) \tag{18}$$

where $\chi > 0$ is the rate of technical progress and θ_t is a technology shock:

$$\theta_t = \rho_\theta \theta_{t-1} + \varepsilon_{\theta t} \tag{19}$$

with $\varepsilon_{\theta t}$ being a white noise shock with standard deviation σ_θ. In the following we will denote by y_t^k, y_t^n the marginal productivities respectively of capital and labour. Real profits are given by[10]

$$g_t(z) = \frac{P_t(z)}{P_t} y_t(z) - \frac{R_{t-1}^l (W_{t-1} n_{t-1}(z) + P_{t-1} i_{t-1}(z))}{P_t} - C_p(P_t(z)) - C_k(i_t(z)) \tag{20}$$

where δ is the rate of capital depreciation, so that $k_{t+1}(z) = i_t(z) + (1-\delta)k_t(z)$ and R_t^l is the per-period gross rate of return required by the financial intermediary. Hence, profits depend on the difference between sales and total costs, lagged one period, as well as on the last two terms which denote, respectively, adjustment costs on nominal prices and on capital and which are specified as:

$$C_p(P_t(z)) = \frac{\phi_p}{2}\left(\frac{P_t(z)}{P_{t-1}(z)} - 1\right)^2 \tag{21}$$

$$C_k(k_t(z)) = \frac{\phi_k}{2}(k_t(z) - k_{t-1}(z))^2 \tag{22}$$

We follow the same quadratic specification of price adjustment costs as in Rotemberg (1982), assuming a zero steady state inflation rate. We also assume quadratic adjustment costs for capital.[11] Note that factor prices, i.e. wages and the price of capital goods, are economy-wide costs. Also note that wage and investment costs have to be repaid one period later, given that loans by the financial intermediary have a one period maturity.

Excluding price adjustment costs, each firm's real marginal costs, $rmc_t(z)$, have the following expression (assuming that the firm discounts the future at the same

[10] Note that loans taken from the financial intermediary at time t are entirely passed to wage earners and used to pay investment projects; therefore, they do not appear altogether in the profit equation of time t.

[11] Cesares and McCallum (2000), among others, have argued that capital adjustment costs are likely not to be quadratic. We stick to the quadratic specification only for reasons of simplicity, in the belief that it will not matter much for the objectives of the present analysis.

rate as the representative household and taking into account that the repayment of current-period loans takes place one period later):

$$rmc_t(z) = E_t \frac{\beta w_t R_t^l}{y_t^n(z)\pi_{t+1}} + E_t \frac{\beta R_t^l}{y_t^k(z)\pi_{t+1}} + \frac{\phi_k}{y_t^k} E_t(\Delta k_t(z) - \beta \pi_{t+1} \Delta k_{t+1}(z)) \tag{23}$$

where the last term is related to the presence of capital adjustment costs in the profit equation (20), with $\Delta k_t(z) = k_t(z) - k_{t-1}(z)$.

Intermediate firms are owned by households and their managers are assumed to transfer all dividends to households at the end of each period. For simplicity, there is no accumulation of own funds and therefore no explicit modelling of the optimal choice of net worth. Each manager is risk neutral and acts so as to maximise the discounted sum of real dividends defined as in (18), i.e. $E_t \sum_{j=0}^{\infty} \beta^j g_{t+j}(z)$, using the same time discount rate as the representative household. This leads to the following equilibrium conditions for labour demanded, capital, and prices charged:[12]

$$w_t = E_t \frac{\beta y_t^n(z)}{R_t^l \pi_{t+1}} \tag{24}$$

$$\frac{\beta R_t^l}{\pi_{t+1}} + \phi_k \Delta k_t(z) = \frac{P_t(z)}{P_t} y_t^k(z) + \beta(1-\delta) E_t \pi_{t+1} + \beta \phi_k E_t \pi_{t+1} \Delta k_{t+1}(z) \tag{25}$$

$$p_t(z) - p_{t-1}(z) = \beta E_t(p_{t+1}(z) - p_t(z)) - \frac{1}{\phi_p}(p_t(z) - p_t^*(z)) \tag{26}$$

where p and p^* are respectively the log of $P_t(z)$ and of the price that each firm would charge in the absence of price adjustment costs ($P_t^*(z)$), which is a mark-up over real marginal costs (excluding adjustment costs):

$$P_t^*(z) = \frac{\mu}{\mu - 1} rmc_t(z) \tag{27}$$

Note that equation (25) describes the optimal accumulation of capital by firms, whereby the marginal cost of a unit of capital, given by its price P_t and by the adjustment cost term $\phi_k \Delta k_t(z)$ is equated to the marginal revenue given by the expected resale price of the capital good in the following period (adjusted for depreciation) and the additional income stemming from the increase in productivity made possible by capital accumulation. As regards the labour demand equation in (24), note that this adjusts marginal labour productivity in the current period by the expected gross real interest rate to be paid in period $t+1$.

Finally, since firms are identical and standard assumptions apply, it is possible to derive the aggregate behaviour from the conditions derived for each individual firm.

[12] See for example Roberts (1995) for the derivation of equation (26).

2.3 The financial intermediary

A representative financial intermediary (bank) has the following budget constraint at time t:

$$L_t + M_t = B_t + D_t \tag{28}$$

where L_t is total loans and M_t represents the stock of bank reserves. In this model, lending to firms is *not* constrained by deposits and high-powered money on the liabilities side, since the financial intermediary can also issue bank bonds, B_t. It should be emphasised that the presence of these non-monetary liabilities distinguishes this model from Hartley (1998), Hartley and Walsh (1991), Christiano, Motto and Rostagno (2003) and Goodfriend and McCallum (2007), where deposits *constrain* the supply of loans to firms on the asset side of the balance sheet.[13]

The *real* profits of the financial intermediary, g_t^f, are expressed as follows:

$$g_t^f = d_t + b_t + \widetilde{b}_t + \frac{m_{t-1}}{\pi_t} + l_{t-1}\frac{R_{t-1}^l}{\pi_t} - \frac{d_{t-1}R_{t-1}^d}{\pi_t} - \frac{b_{t-1}R_{t-1}}{\pi_t} - \frac{\widetilde{b}_{t-1}R_{t-1}}{\pi_t} - (1+\sigma)l_t - m_t - \frac{\omega_t d_t}{m_t} \tag{29}$$

where lowercase letters denote real variables, as usual, $\widetilde{b}_t = \widetilde{B}_t / P_t$ represents (real) bonds lent to the central bank as a result of an open market operation (described in more detail in the next section), $\sigma > 0$ is a scalar, and

$$\omega_t = (1 - \rho_\omega)\omega + \rho_\omega \omega_{t-1} + j_t \tag{30}$$

where $\omega > 0$ is a scalar, j_t is an i.i.d. shock with standard deviation σ_j. The shock j plays an important role in this paper since it represents an "inside money shock", a concept which the earlier literature has had some trouble in pinning down in a logically consistent way, as argued in the Introduction. Since the banking sector is assumed to be competitive, bank profits will be zero in equilibrium. The banker is a risk neutral manager with the same discount factor as the representative household, and aims at maximising the present value of profits.[14]

The bank's profits depend on the difference between the remuneration of the assets side of the balance sheet and the interest paid on its liabilities side. There are, however, also two additional terms which model the *cost of financial intermediation*. The bank intermediation costs in real terms, f_t, are given by:

$$f_t = \sigma l_t + \frac{\omega_t d_t}{m_t} \tag{31}$$

[13] See Laidler (1999, 2006) for an extensive treatment of this issue.

[14] Note that we include no adjustment costs on deposit and lending rates, for the sake of simplicity, although this would have been consistent with the introduction of price stickiness for non-financial firms. In other words, the intermediation services provided by banks are no different from other (retail) good and services in the economy, and there is no particular reason to suppose that their prices are less sticky. Likewise, it would not be unreasonable to introduce monopolistic competition in the banking sector.

The first term captures the notion that lending activity is costly because the financial intermediary has to undertake a screening (ex ante) and monitoring (ex post) activity of the recipients of the credit and given that lending is not collateralised. As noted earlier, this screening activity ensures that there is no default in equilibrium, i.e. credit is "as if" it were collateralised in the same manner of Goodfriend and McCallum (2007). Note that we assume a simple linear specification for the intermediation costs stemming from lending activity, which implies that the marginal intermediation cost is a scalar. For intermediation costs on deposits, instead, we propose a non-linear formulation, $\omega_t d_t / m_t$, whereby intermediation costs tend to go to zero if $m_t \rightarrow \infty$, while they go to infinity when $m_t \rightarrow 0$. The existence of costs for the financial intermediary to manage deposits on the liabilities side of its balance sheet can be related to the obligation to provide liquidity services to customers.[15] One important consequence of the proposed specification is that it establishes a *link between inside and outside money*, by making the marginal cost for the bank of issuing deposits dependent on the amount of outside money (bank reserves) available in its balance sheet. This appears to be a realistic characterization of modern financial systems, in which (despite technical and institutional progress) only outside money retains *ultimate* finality. Therefore, deposits may be seen as portable financial assets guaranteeing a riskless conversion into outside money. For banks to be able to provide this conversion service to customers efficiently, it is reasonable to assume that it matters significantly if they have enough outside money in their balance sheet. In fact, in many countries a reserve requirement is still imposed, which obliges banks to hold a certain fraction of their deposit liabilities in the form of bank reserves, i.e. outside money.

The financial intermediary chooses R_t^l, R_t^d and $M_t = P_t m_t$ taking other variables in equation (29) as given. The nominal interest rate R_t, in particular, is assumed to be set by the central bank. The resulting first order conditions respectively for lending, deposits and bank reserves, which can be derived from simple algebra, are:

$$\beta E_t \frac{R_t^l - R_t}{\pi_{t+1}} = \sigma \tag{32}$$

$$\beta E_t \frac{R_t - R_t^D}{\pi_{t+1}} = \frac{\omega_t}{m_t} \tag{33}$$

$$m_t = E_t \left(\frac{\omega_t d_t \pi_{t+1}}{\beta (R_t - 1)}\right)^{\frac{1}{2}} \tag{34}$$

Equation (32) describes the *external finance premium* for non-financial firms, $R_t^l - R_t$, in this economy, which as noted is a scalar when deflated with expected inflation.

[15] This assumption is, of course, related to the special role played by bank deposits in eliminating information asymmetries in retail trade, as argued in Section 2.1. A deposit insurance scheme paid by the banking industry could also be a way to rationalise these costs. See Belongia and Ireland (2004) for similar considerations, and Chari, Christiano and Eichenbaum (1995) for a qualitatively similar formulation of the cost of producing bank deposits.

By contrast, equation (33) identifies an *inside money premium*, $R_t - R_t^d$, which is inversely related to the amount of high-powered money in circulation. Together with equation (34), which describes the demand for bank reserves, this creates and *inside money channel* of the transmission of monetary policy. This can be seen most clearly by merging equations (33) and (11), which after neglecting terms related to adjustment costs for simplicity of exposition, becomes

$$\frac{\omega_t}{m_t} = E_t \frac{\xi_t}{\lambda_{t+1}} \tag{35}$$

The right hand side of the equation is the relative tightness of the deposit in advance constraint as compared with the (future expected) budget constraint. Two observations are noteworthy. First, from equation (35) it is evident that, in the absence of portfolio adjustment costs, a shock to the relative tightness of the deposit in advance constraint, which can be interpreted as a money demand shock, has the same impact as an inside money supply shock, i.e. to ω_t, in the left hand side. Deposits adjustment costs introduce a wedge between money demand and money supply shocks, as will be clearer later on. Second, and related to the transmission of monetary policy, a (say) reduction in outside money following a monetary contraction (namely an increase in R_t) leads to an expansion of the term in the left hand side of the equation (and to an *increase* in the inside money premium, see equation (33)). Other things being equal, this leads to a rise in the right hand side, i.e. in an increase in the relative tightness of the deposit in advance constraint compared with the budget constraint. In other words, purchasing liquidity services from banks becomes more expensive and this leads our representative household to economise on them. In a later section of the paper, I will show how a monetary policy shock affects the key variables in the system (such as output and inflation) depending on the existence of the inside money channel. The inside money channel can be switched off, at least in the limit, by imposing $\omega_t \to 0$.[16]

A straightforward extension of this model would be to endogenise the lending costs and link them to firms' net worth in a financial accelerator framework. This avenue is not pursued further for two reasons. First, introducing this type of dynamics goes beyond the scope of this paper which instead focuses on the action in the *liabilities* side of banks' balance sheet.[17] Therefore, this paper has to be seen as complementary to that of Goodfriend and McCallum (2007), where the action is on the asset side of the bank balance sheet. Second, it is also notable that there appears to be much stronger empirical evidence linking what this paper defines as the inside money premium, i.e. a spread between an interest rate tightly related to monetary policy and the rate of

[16]Note that ω cannot be exactly zero since the transmission of monetary policy depends on its being strictly positive, even if arbitrarily small. If $\omega = 0$, then monetary policy is ineffective since bonds and bank reserves are perfect substitutes.

[17]Likewise, we do not consider the role of bank capital and the possible discountinuties in bank behaviour related to the existence of minimum capital requirements. See von Peter (2004) for an analysis which goes in this direction.

remuneration of broad money, with the stance of monetary policy than for simple empirical *bank-based* measures of the external finance premium. To show this, **Table 1** reports some correlations between the federal funds rate on the one hand (in levels and detrended) and the two spreads on the other on US data since 1977. For the inside money premium, we take the spread between the federal funds rate and the own rate on M2 (i.e. a proxy for $R_t - R_t^d$). To compute the external finance premium, we take the prime loan rate as well as a banking lending rate to corporations with maturity up to one year, from the Federal Reserve's Quarterly Terms of Bank Lending to Business (QTBL). These data are available quarterly from the first quarter of 1977, and the correlations shown in the table thus refer to the sample period between 1977 and end-2006. It is noteworthy that the correlation is strong and positive for the spread with the own rate on M2, while it is smaller (and negatively signed[18]) for both the prime loan rate and the QTBL rate. Hence, there is *prima facie* evidence that the link between the inside money premium and the stance of monetary policy is significantly stronger than with the external finance premium, which appears to justify the modelling choice of this paper.

In order to cross check this evidence in a slightly more sophisticated manner, I estimate a five-variable VAR model on US data including, in this order, real GDP, the GDP deflator, a commodity price index, the federal funds rate and the spread between the federal funds rate and the own rate on M2. The model is identified using a standard Choleski decomposition as in Christiano, Eichenbaum and Evans (1999) and also includes a constant and a linear trend.[19] The choice of the identification is important because there is obviously a strong correlation between the federal funds rate and the spread, as shown in Table 1. We select this particular identification order because it delivers an impulse response profile to a shock to the federal funds rate which is in keeping with the standard expected impact of a contractionary monetary policy shock.[20] **Figure 1** reports the impulse response to a one standard deviation shock in the federal funds rate. As can be seen, output falls temporarily and the price level falls permanently, in line with the conventional wisdom. What is also interesting is that the contractionary monetary policy shock has a clear *upward* impact on the spread, i.e. determines a large and statistically significant *increase* in the inside money premium. We also repeat the exercise by including another measure of the spread as the last variable in the VAR: the difference between the loan prime rate and the federal funds rate. This maintains the identification of a shock to the federal funds rate as a monetary policy shock. As can be seen in **Figure 2**, this time the effect of the shock on the spread has an uncertain sign, it is smaller in magnitude and less

[18]Namely pointing to an attenuation, rather than accelerationist role; while this can be rationalised, as in fact Goodfriend and McCallum (2007) do, it is nevertheless against the common perception of the role of the external finance premium in the transmission of monetary policy.

[19]The model is estimated on the sample period between 1970 and 2006.

[20]Putting the spread before the fed funds rate, for example, weakens the identification of the monetary policy shock.

statistically significant.[21] Overall, both the simple correlation and the VAR evidence point to the fact that monetary policy shocks appear to affect bank intermediation costs more on the liabilities than on the asset side of the bank balance sheet. Of course, this evidence should not be seen as conclusive but does suggest that the modelling choice taken here may not be unreasonable.[22]

Table: Correlations with the federal funds rate

	FF	FF, detrended
FF-RM2	0.84	0.83
LPR-FF	-0.51	-0.51
QTBL-FF	-0.41	-0.25

Source: FRED and Federal Reserve of San Francisco databases. Sample period 1977:Q1 to 2006:Q4. FF stays for federal funds rate, PR for loan prime rate and QTBL for the QTBL rate. In the last column the FF is detrended using a HP1600 filter.

2.4 Monetary policy

The balance sheet of the central bank reads

$$\widetilde{B}_t = M_t \tag{36}$$

i.e. including high-powered money in the liabilities side and bonds in the assets side. Open market operations are conducted on the *money market* with the representative bank by exchanging M_t with $\widetilde{B}_t$. Taking into account the demand for bank reserves in (34), open market operations are conducted with the objective of ensuring the desired level of the risk-free (gross) interest rate, R_t, which is given by the following Taylor-type rule with interest rate smoothing:

$$R_t = (1-\rho)(\frac{1}{\beta} + \varphi_\pi(\pi_t - 1)) + \rho R_{t-1} + \varepsilon_t^R, \tag{37}$$

where $\frac{1}{\beta}$ is the steady state level of this interest rate, $0 < \rho < 1$, $\varphi_\pi > 1$, and ε_t^R is a monetary policy shock.

The central bank makes a profit (seignorage) when exchanging bank reserves with bonds; we assume that the profit is passed to the Treasury, which then uses it in order to balance its books.[23]

[21] Results using the QTBL lending rate, available from 1977 are qualitatively similar and are not reported for brevity.

[22] Note that we are referring to the external finance premium computed from bank lending rates, not from corporate bond spreads. Even there, however, the evidence on the effect of a monetary poilcy shock is inconclusive; see Bean et al. (2003).

[23] See Buiter (2007) for further discussion.

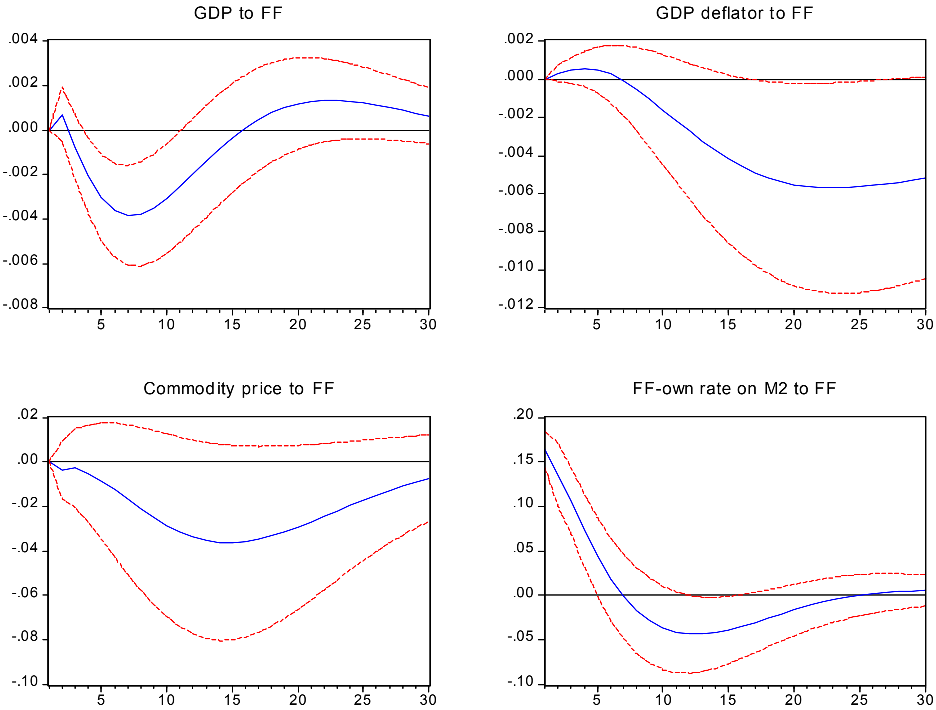

Figure 1: Impulse responses to a one standard deviation shock in the federal funds rate (FF). Sample period 1970:1 to 2006:4, quarterly data. See text for further explanations.

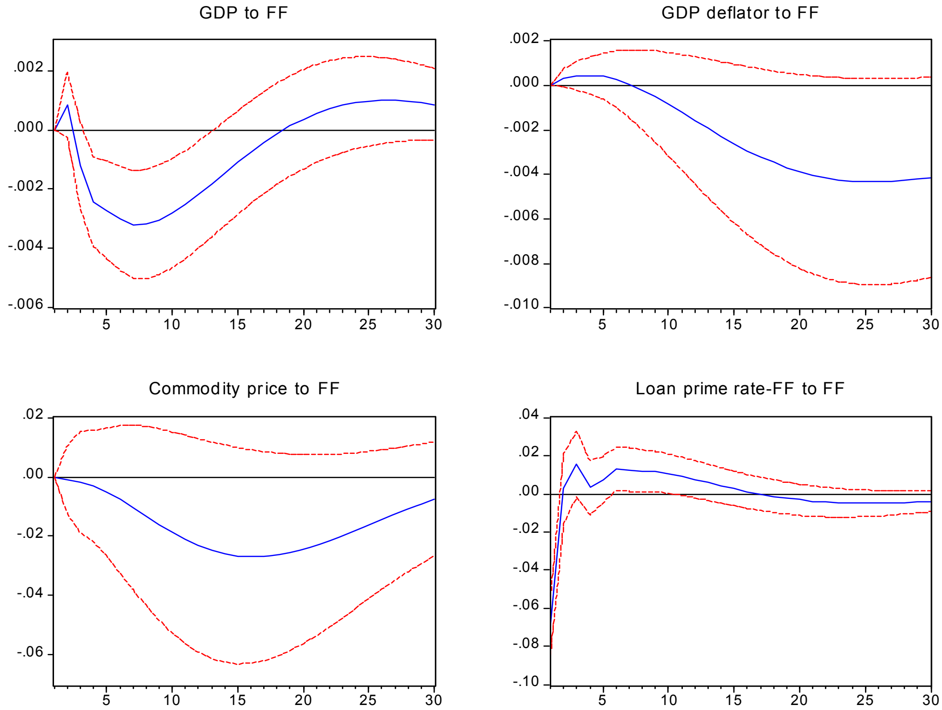

Figure 2: Impulse responses to a one standard deviation shock in the federal funds rate (FF). Sample period 1970:1 to 2006:4, quarterly data. See text for further explanations.

2.5 Equilibrium

A competitive equilibrium is an infinite sequence $\{P_t, c_t, D_t, B_t, n_t, W_t, k_t, R_t^d, R_t^l, R_t, \widetilde{B}_t, M_t\}$ in which all agents optimize, the central bank follows the policy rule in (37), and markets clear. The economy-wide resource constraint reads as follows:

$$y_t = c_t + i_t + \frac{\phi_k}{2}\Delta k_t^2 + \frac{\phi_p}{2}(\frac{P_t}{P_{t-1}} - 1)^2 + \frac{\phi_d}{2}(d_t - \frac{d_{t-1}}{\pi_t})^2 + \frac{\omega d_t}{m_t} + \sigma l_t \qquad (38)$$

i.e. including the (capital, price and deposit) adjustment costs for intermediate goods producers and the cost of financial intermediation.

3 Calibration of the baseline model

The baseline calibration of the model is conducted by choosing as much as possible values for the parameters that are standard in the literature and is largely based on producing key moments of the endogenous variables that are empirically realistic. **Table 2** reports an overview of the calibration values.

As regards time preference, since the period in the model represents a quarter, the discount factor β is set at 0.995 so as to obtain an annual real interest rate of 2 per cent. The parameter on the utility of leisure, ϕ, is parametrised so as to obtain a value of n at about $\frac{1}{3}$ in the steady state. The parameter α, which captures the severity of the deposit in advance constraint, is set at a 0.70. The ratio between $M2$ and private consumption in the United States has declined almost continuously in the past four decades, from approximately 1 to around 0.7. I choose a level that is closer to the value at the end of the sample period, as it should be more representative of the current situation. The depreciation rate is set at the standard value of 0.025 per quarter.

The parameter governing the spread between the bank lending rate and the interest rate on bonds, σ, is set so as to obtain a steady state spread $R^l - R$ in line with the historical average of the spread between the QTBL rate and the fed funds rate, similar to Goodfriend and McCallum (2007). The same reasoning is followed for selecting the parameter ω, based on the historical average spread between the fed funds rate and the own rate on M2. The parameter ruling adjustment costs in deposits, ϕ_d is set at 10, in line with empirical (broad) money demand models which typically find an adjustment to equilibrium of below 1/10 in a single quarter. The price adjustment parameter, ϕ_p is set at 4 which implies that prices are fully adjusted in about one year. The parameter driving capital adjustment costs, ϕ_k, is derived so as to obtain a response of investment which is about three times stronger than that of consumption to a monetary policy shock, which is in line with the literature. The parameters of the monetary policy rule are standard; the autocorrelation coefficient is 0.75, and the reaction to inflation in line with Taylor's original suggestion of 1.5. The steady state mark-up is set to 6/5, which implies a profit share of about 1/6.

The standard deviation of the technology shock is set at 0.008, a typical value in the Real Business Cycle literature.

Finally, the standard deviations of the shocks to inside money supply (σ_j) and to the monetary policy rule (σ_R) are recovered from the (first) VAR model estimated in the previous Section. The persistence of the the money supply shock (ρ_ω) is derived from the VAR equation relative to the spread between the fed funds rate and the own rate on M2. The autocorrelation of the technology shock is set at the standard value of 0.95. The standard deviation of the money demand shock, σ_q, and the persistence ρ_α are obtained by de-trending the ratio between M2 and private consumption and estimating a simple autoregressive time series model on the detrended series.

Table 2 - Calibration values

Parameter	Value	Parameter	Value
β	0.995	ϕ_p	4
ϕ	3	ϕ_k	4.5
γ	0.35	ρ	0.75
δ	0.025	ρ_π	1.5
σ	0.0075	σ_R	0.0025
ω	0.0037	σ_θ	0.008
α	0.7	σ_j	0.0018
ϕ_d	10	σ_q	0.006
ρ_α	0.88	ρ_ω	0.9

The model is simulated in DYNARE on Matlab. After identifying the zero-inflation, non-stochastic steady state of the model, a first order approximation is computed and impulse responses to the four structural shocks in the model (technology, policy, inside money demand, inside money supply) can be reported, to which I turn in the next Section.

4 Results

I present the results of the analysis in three steps. In Section 4.1, I first review the effect of the structural shocks in the baseline model, as well as of an additional structural shock in a close variant of the model. In Section 4.2, I conduct a sensitivity analysis in order to shed some light on role of some key parameters – notably related to the role of inside money – in the properties of the model. Finally, in Section 4.3 I conduct an optimal monetary policy analysis, in order to clarify whether a central bank should be responding to inside money shocks.

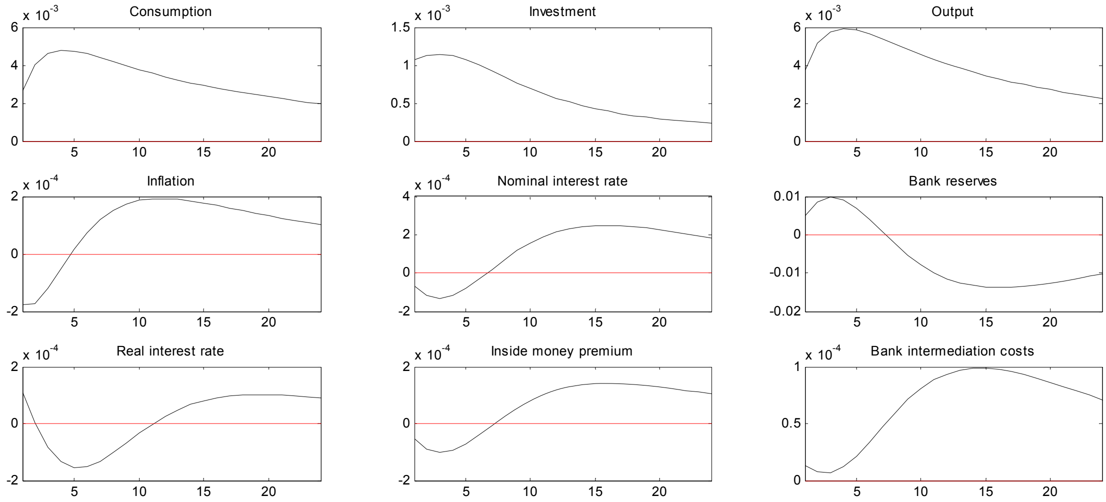

Figure 3: Impact of a one standard deviation technology shock on selected variables.

4.1 Responses to shocks in the baseline model

It is useful to start from the impact of technology and monetary policy shocks, since this can already give an idea whether the model is reasonable and consistent with conventional views on the effect of such shocks. **Figure 3** shows the effect of a one standard deviation positive technology shock on nine endogenous variables, namely consumption, investment, output, the inflation rate, the nominal interest rate, bank reserves, the real interest rate, defined as $R_t - E_t\pi_{t+1}$, the inside money premium $R_t - R_t^d$, and bank intermediation costs f_t. As standard in the literature, the technology shock raises consumption, investment and output, and leads to a fall of inflation on impact and to a fall in the real interest rate. Note, however, that due to the presence of various adjustment costs and inertia in the monetary policy rule the adjustment of the inflation rate to equilibrium contains some overshooting, which appears somewhat counterfactual.

Figure 4 reports the impact, on the same nine variables, of a one standard deviation increase in the nominal interest rate R_t. The impact of this shock is completely standard. The real interest rate also increases, while bank reserves fall. This leads to a contraction of consumption, investment, overall output and to a fall in inflation, with some delay (note that this holds despite the presence of a cost channel of monetary policy). Of some interest is, however, the positive impact on the inside money premium and on bank intermediation costs.

Turning to an inside money supply shock, j_t, in **Figure 5**, an increase in the inside money premium amounts to a *tax on consumption*, which can be decomposed into two channels, namely (i) the need of increasing expenditure in liquidity services

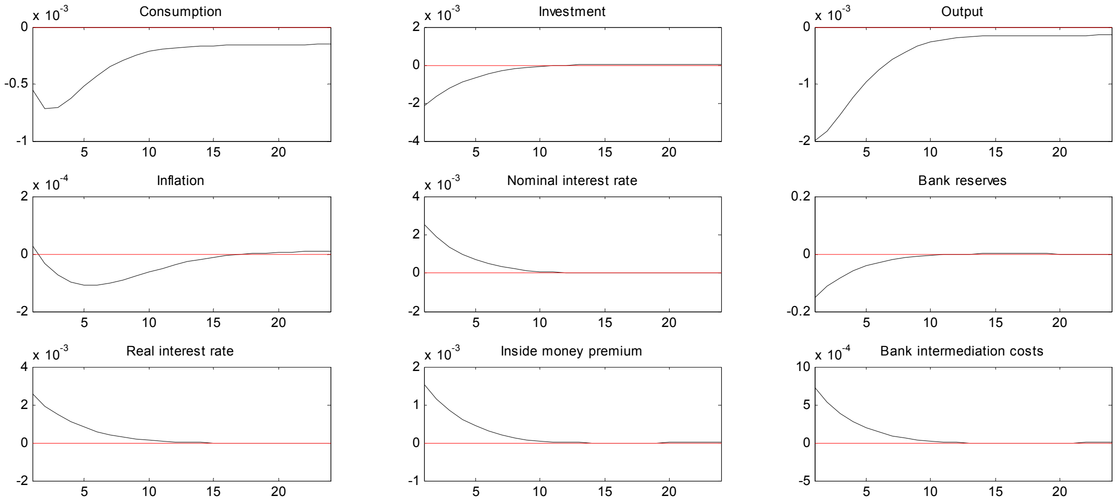

Figure 4: Impact of a one standard deviation contractionary monetary policy shock on selected variables.

for unchanged consumption, and (ii) the need to incur adjustment costs in bringing consumption to the new equilibrium. Simulations show that in the dynamics the latter channel is far more important quantitatively. At the same time, there is a counter-veiling effect because of the rise in bank intermediation costs, which leads to a rise in overall output and investment and, with some delay, to a rise in inflation. Thus, the overall impact is *expansionary* and this is reflected, via the Taylor rule, in an increase in the nominal interest rate. Note, however, that the financial intermediary demands more reserves despite the increase in the nominal interest rate, due to the shock to ω_t.

The impact of an inside money demand shock, q_t, reported in **Figure 6**, is the same in relation to its being, in substance, a tax on consumption. This explains the fall in consumption. Again, the lion's share of this effect is related to the presence of deposit adjustment costs, i.e. tied to the parameter ϕ_d. Unlike the case of the inside money supply shock, however, there is no increase in banking intermediation costs and therefore no overall increase in output and investment. As a result, the impact of the money demand shock is *contractionary.* Due to the consequent decrease of the nominal interest rate, the inside money premium falls, and the financial intermediary demands more reserves.

Table 3 below reports the variance decomposition of selected variables in the model. It is evident that, apart from the variables that are closely related to the process of financial intermediation (bank reserves, inside money premium and bank intermediation costs) the quantitative importance of the inside money supply shock is

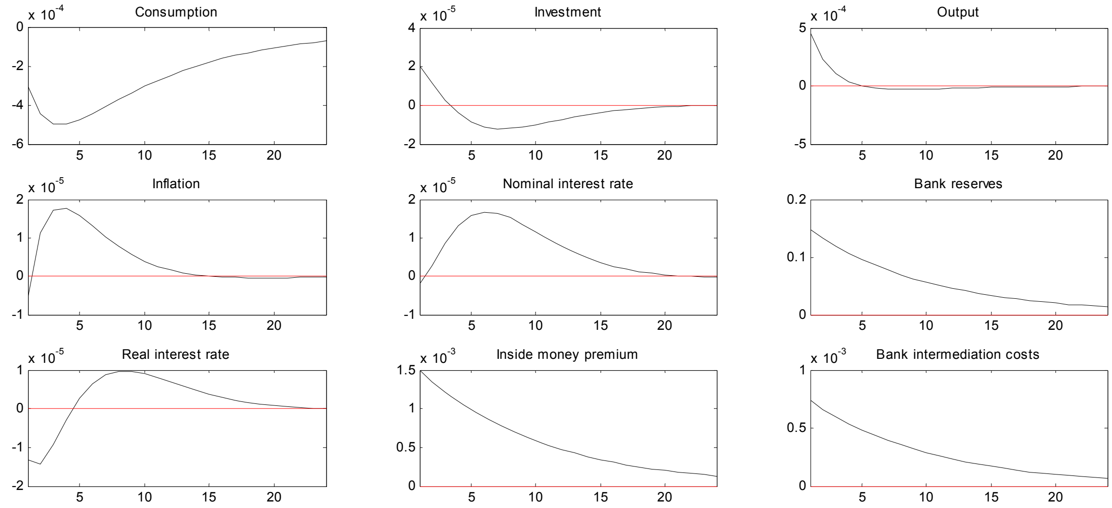

Figure 5: Impact of a one standard deviation inside money supply shock (j_t) on selected variables.

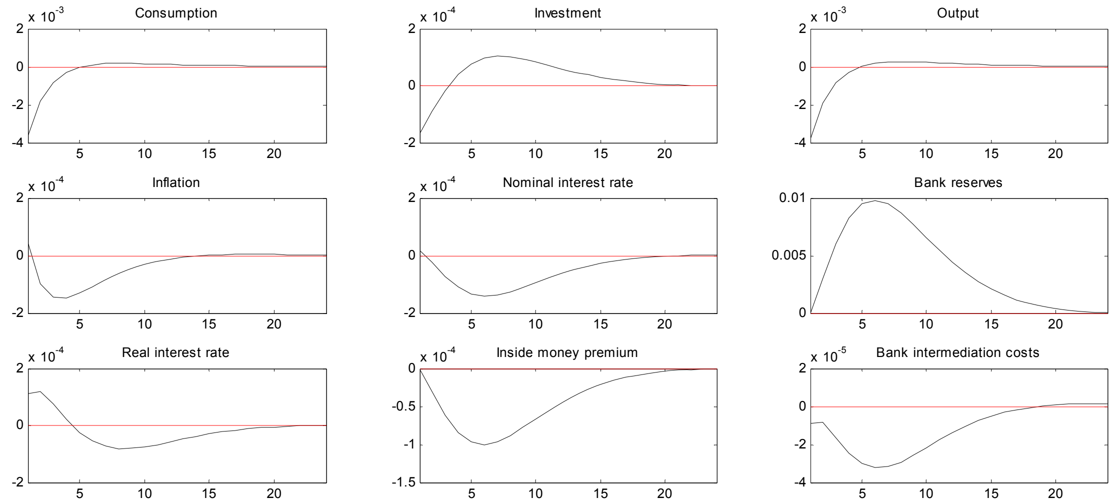

Figure 6: Impact of a one standard deviation inside money demand shock (q_t) on selected variables.

minimal. This can be explained rather straightforwardly since this shock affects the household's expenditure on liquidity services, i.e. $d_t(R_t - R_t^d)$, which in the model, as in reality, is a very small part of overall consumption and economic activity. The money demand shock, by contrast, has a far more important effect as it explains 5 per cent of consumption variability, 4 per cent of output variability and almost 13 per cent of inflation variability (significantly in excess of the contribution of monetary policy shocks).[24] Part of this effect goes through the expenditure on liquidity services, similar to the money supply shock, as evident in equation (35). The bulk of the effect, however, goes through overall consumption expenditure. Due to the existence of deposit adjustment costs, a rise in α_t results in an adjustment of *overall* consumption, at least temporarily, and not only in the consumption of a particular good represented by liquidity services.

In conclusions, two results appear noteworthy: (i) the impact of an inside money supply shock is small and expansionary; (ii) the impact of a money demand shock is larger and contractionary. The latter results appears to contradict King (2007), as it implies that we should take money demand shocks *more* seriously than money supply shocks.[25]

[24]Note however that the contribution of monetary policy shocks to the variability of consumption, in particular, is unusually low and counter-factual.

[25]It should be noted, however, that the money demand shock in this model has a meaning which may be quite different from the interpretation of Mervyn King. For example, shocks to payments technology may affect α but still be, loosely speaking, supply-driven.

Table 3 - Variance decomposition of selected variables in the baseline model

	Policy shock	Tech. shock	α_t shock	ω_t shock
Consumption	1.0	93.6	4.9	0.6
Investment	45.3	54.2	0.5	0.0
Output	2.8	93.4	3.7	0.1
Inflation	9.8	77.4	12.6	0.2
Nominal interest rate	91.9	7.2	0.9	0.0
Bank reserves	29.9	2.0	0.4	67.7
Real interest rate	97.7	1.8	0.5	0.0
Inside money premium	29.2	2.0	0.4	68.4
Bank intermed. costs	26.5	4.2	0.2	69.2

Note: Summing the contributions in the rows may not lead to exactly 100.0 due to rounding.

In addition, it may also be interesting to consider what happens, in the context of this model, with changes in the overall quality of banking intermediation. For example, what happens if there is a banking crisis and banks become less efficient in the intermediation process? To study this question, I consider a slight variant of the model, where the parameter σ driving the external finance premium becomes time-varying, as follows:

$$\sigma_t = \sigma + \omega_t - \omega \tag{39}$$

Now, a shock to ω_t leads to a *contemporaneous* increase in the external finance premium and in the inside money premium. In other words, our bank becomes less good in both offering liquidity services in the liabilities side of the balance sheet and in screening and monitoring lenders of the assets side.

The impact of such as shock on the key variables in the system is reported in **Figure 7**. It is interesting to note that the effect of the shock is now *unambiguously contractionary*. The reason is that the increase in banking services expenditure, which determined the overall expansionary effect of an inside money shock, is now overshadowed by the negative impact through the higher cost of external finance for firms. Hence, while the inside money supply shock may be good for economic activity, a banking crisis is bad.

4.2 Sensitivity analysis

I conduct two types of sensitivity analysis. First, I endeavour to establish what parameters crucially drive a role for inside money shocks as evident in the variance decomposition analysis in Table 3. Second, I clarify the role of the presence of inside money in the model for the transmission of monetary policy and technology shocks.

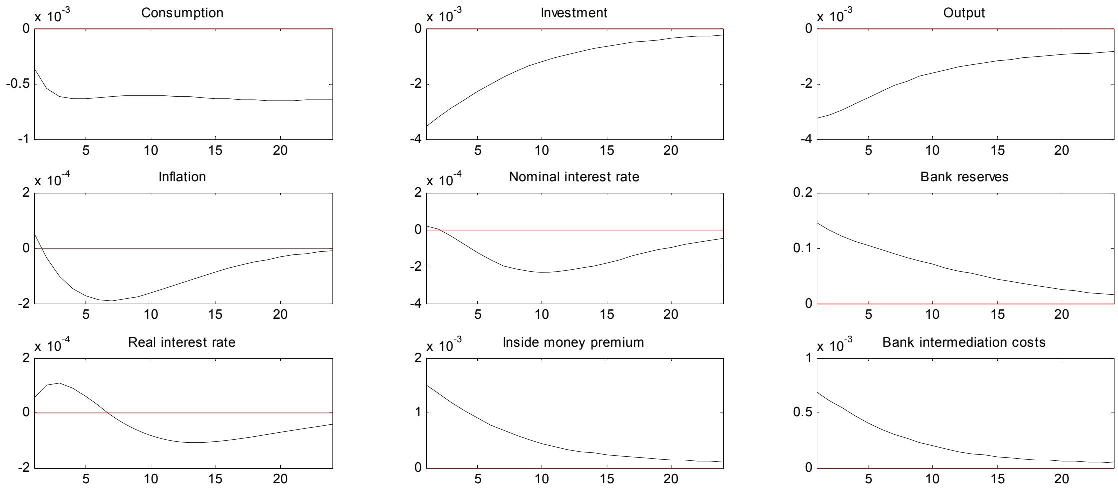

Figure 7: Impact of a one standard deviation shock to j_t (inside money supply shock), when also $\sigma_t = \sigma + \omega_t - \omega$.

The answer to the first question is straightforward: the size of the impact of both money demand and money supply shocks is closely related to ϕ_d, the parameter controlling the deposit adjustment costs. If $\phi_d = 0$, the impact of both shocks on the variables of interest is marginal. For given ϕ_d, higher (lower) values of α, the steady state ratio between inside money and consumption, are linked to stronger (weaker) effects of inside money shocks. Not surprisingly, the size of ω (which only acts on the supply side of inside money) does not matter nearly as much. The finding that the results are sensitive to ϕ_d should not, however, be seen as suggesting some doubts on the importance of inside money in the model; in fact, there is quite strong evidence in empirical money demand models that adjustment costs are indeed substantial.

Turning to the second sensitivity analysis, in **Figure 8** I report the impact of a positive *technology* shock on four variables, i.e. consumption, investment, output and inflation, in the baseline case as well as in an alternative calibration where the inside money channel is practically switched off, by imposing $\phi_d = 0$. It is evident that the inside money channel results in an *attenuation* of the effect of the shock on consumption, output and thus inflation. The reason is again twofold: first, the positive technology shock raises optimal consumption and therefore also the consumption tax implicit in the inside money premium; second, and far more important quantitatively, the household has to incur deposit adjustment costs, which dampen the impact of the technology shock. In **Figure 9** the impact of a contractionary *monetary policy* shock on the same variables is reported. Again, we find that the inside money channel results in a dampening of the impact of the shock. In this case, however, this is the result of two separate components. First, the attenuation due to the existence of

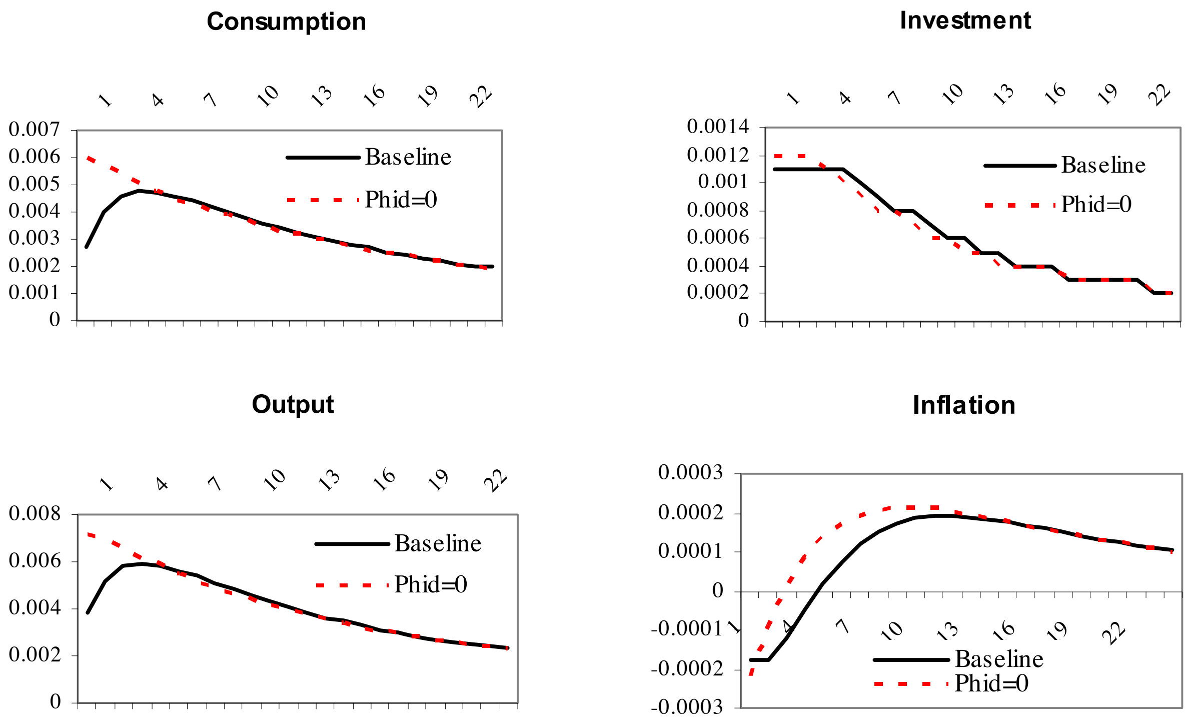

Figure 8: Impulse resposes to a one standard deviation technology shock.

deposit adjustment costs and of the "consumption tax", as for a technology shock. Second, an attenuation due to the positive impact on output through a larger expenditure on banking intermediation due to the positive effect of the rise in the nominal interest rate on the inside money premium.

Finally, in **Figure 10** I report the impact of a contractionary monetary policy shock in the baseline case and in an alternative case in which the parameter driving the inside money premium, ω, is set to a value very close to zero. I still find an overall attenuation of the inside money channel, but this time for different reasons. The role of a smaller (larger) ω is actually to dampen (magnify) the impact of the shock, i.e. it has an accelerationist impact, albeit very small (in fact hardly visible on the graph). This reflects the fact that with a higher inside money premium the impact of a monetary policy shock on the "consumption tax" is larger. On the other hand, the monetary policy tightening has a positive impact on banking intermediation costs if ω is higher, and this dampens the contractionary impact of the shock.

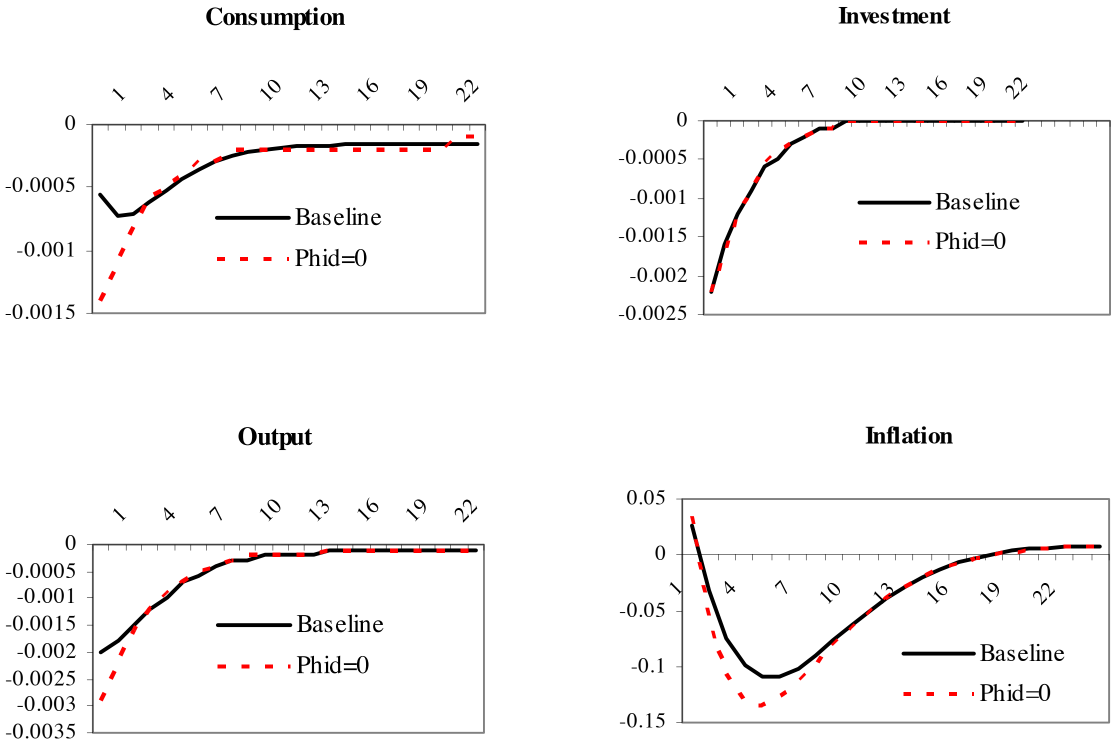

Figure 9: Impulse responses to a one standard deviation contractionary monetary policy shock.

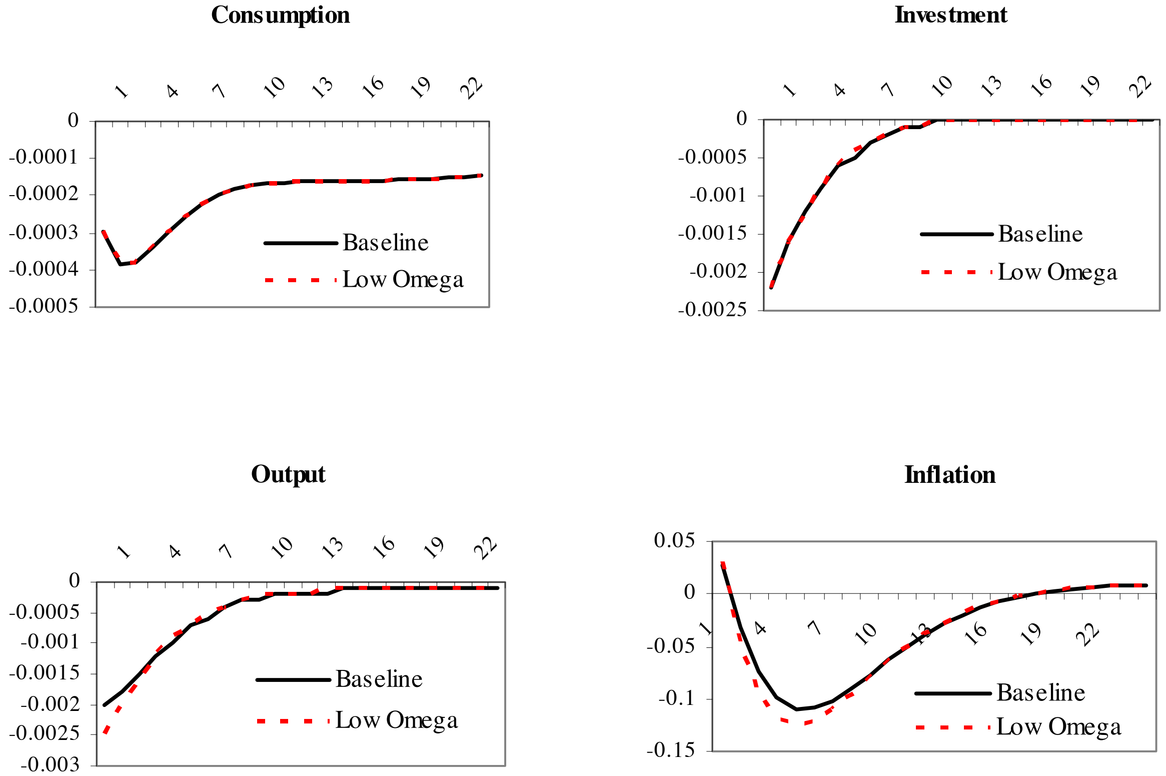

Figure 10: Impulse resposes to a one standard deviation contractionary monetary policy shock.

4.3 Optimal monetary policy

The final part of the analysis is the impact of the inside money channel on the optimal conduct of monetary policy. The exercise is the following: suppose that a central bank wanted to minimise a loss function defined in the usual manner, as

$$LOSS = \eta_\pi Var(\pi_t) + \eta_y Var(y_t - y_t^*) + \eta_R Var(R_t) \tag{40}$$

where y_t^* is the flexible prices level of output, and η_π, η_y and η_R are respectively the weights of inflation, the output gap and of the nominal interest rate in the loss function. It should be noted that we are using this loss function in an *ad hoc* manner and without any link to the welfare of the representative household, which in the present model is not assured to lead to the same result. Let us assume that the monetary authority follows a linear rule of the type[26]

$$R_t = (1-\rho)(\frac{1}{\beta} + \varphi_\pi(\pi_t - 1) + \varphi_j j_t + \varphi_q q_t) + \rho R_{t-1} \tag{41}$$

i.e. including a reaction to inside money supply and demand shocks (assuming a rather unrealistic complete real-time knowledge of the shocks by the central banker). The coefficients ρ, φ_π, φ_j , and φ_q are chosen so as to minimise the loss function in (40), using the OSR routine in DYNARE. I give the relatively standard values of $\eta_\pi = \frac{1}{2}$, $\eta_y = \frac{1}{2}$ and $\eta_R = \frac{1}{4}$ to the parameters of the central bank loss function.

Table 4 below reports the optimal values of the coefficients as well as the value of the loss function in two cases, namely the unconstrained case and a restricted case where the central bank cannot react to inside money shocks, i.e. $\varphi_j = \varphi_q = 0$. Two results are noteworthy. First, the reaction to the two inside money shocks is as expected: the interest rate rises ceteris paribus after a money supply shock, which is expansionary, but falls after a money demand shock, which is contractionary. Second, the inclusion of the two inside money shocks does not lead to a noticeable increase in performance: the value of the loss function is only 1 per cent lower in the unrestricted case than in the restricted case. Overall, then, it does not seem to matter too much whether the central bank reacts to the inside money shocks and the performance can be practically replicated by reacting to the inflation rate only.

Table 4 – Optimal linear policy rules

	ρ	φ_π	φ_j	φ_q	Loss
Restricted	-0.59	1.86	/	/	0.1137
Unrestricted	-0.46	1.77	0.02	-0.08	0.1124

[26] Given that in the present model monetary policy affects potential output via the cost channel, I do not include the output gap in the policy rule. I also tried to include lagged values in the rule, but the results were very similar.

5 Conclusions

The main objective of this paper is to build a general equilibrium model where inside money play a structural, active role. The paper has shown that based on realistic modelling assumptions and conservative calibration it is possible to give a non-negligible, albeit relatively small, structural role to inside money. It is the ambition of this paper that future discussions on the role of money in the economy could take this model, or a variant of it, as the starting point for more focused and hence more productive analysis.

The main results of the analysis of the model are five. First, inside money supply shocks are found to have a small expansionary impact on output, inflation and interest rates. Second, money demand shocks are found to have a more significant, but contractionary impact. Third, the presence of inside money in the model leads to an attenuation of technology and monetary policy shocks on key variables such as output and inflation. Fourth, simulating a banking crisis as a simultaneous increase in the cost of bank lending to firms and of producing deposits leads to an unambiguous contraction of economic activity and inflation and to a fall in interest rates. Finally, the inside money shocks enter in an optimal simple linear monetary policy rule, but their contribution to the overall central bank loss is found to be minimal. In other words, it appears that reacting to inflation is sufficient for stabilization purposes.

Needless to say, the analysis may be improved in several dimensions. Two of them appear particularly promising. First, integrating the rich dynamics in the liabilities side of the banking sector in this paper with a more elaborated mechanism on the external finance premium, as for example in Goodfriend and McCallum (2007). Second, the model may be estimated rather than calibrated.

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