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Banking and the role of money in the business cycle

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ABSTRACT

This paper enriches a standard New Keynesian model with a simple banking sector to investigate the role of money in the business cycle. Maximum likelihood estimation of the model suggests that money balances play a significant role in explaining the intertemporal allocation of consumption and the dynamics of inflation as described by the forward-looking IS and Phillips curves. Nonetheless, the responses of the model's variables to shocks remain qualitatively similar to a model without money, suggesting that the omission of money balances leaves the model's transmission mechanism unaffected.

1. Introduction

Over the past decade central banks around the world have been developing New Keynesian models of the business cycle to produce economic forecasts and support the conduct of monetary policy. The underlying framework is based on the dynamic stochastic general equilibrium (DSGE) paradigm, which posits that reduced form economic relationships can be obtained by solving the agents' dynamic optimization problems. The resulting model is able to separate out the policy parameters from those that are policy invariant, and therefore addresses the Lucas (1976) critique, allowing meaningful analysis of policy changes.

Despite the advantages and the general consensus on the use of this framework in central banks, it is unclear whether money aggregates should be included in DSGE models or could be safely ignored. On the one hand, Friedman's (1968) dictum "inflation is always and everywhere a monetary phenomenon", suggests that money plays a pivotal role for the conduct of monetary policy. On the other hand, Woodford (1998, 2008) documents that none of the many arguments for assigning an important role to money is convincing if monetary policy is implemented using an interest-rate feedback rule.[1]

This paper investigates the issue by taking a standard New Keynesian model enriched with a simple banking sector to the data. It uses maximum likelihood estimation to consider whether money plays an important role in explaining the business cycle. The presence of a banking sector introduces deposits, which the household uses to finance consumption and therefore assigns a supplemental role to money that could, in principle, strengthen the relevance of money in the business cycle.

The model provides some interesting insights. Similarly to Ireland (2004), who conducts an analogous exercise, the theoretical framework comprises forward-looking IS and Phillips curves, a money demand relationship, and a Taylor rule. The

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[1] An array of empirical studies has found evidence in support of both assertions. Friedman and Kuttner (1992), Estrella and Mishkin (1997), Rudebusch and Svensson (2002), Ireland (2004) and Andrés et al. (2006) find that money is irrelevant to predict output and inflation, while Stock and Watson (1989), Feldstein and Stock (1993), Nelson (2002), Peersman and Smets (2003), Reynard (2007), Andrés et al. (2009), Favara and Giordani (2009) and Canova and Menz (2011) find the opposite, just to mention a few.

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novel contribution here is the introduction of a simple banking sector, which collects deposits, in the form of money or loans, used by the household to finance consumption. Hence, compared to a standard New Keynesian model such as Ireland (2004), the household faces an additional constraint which restricts consumption to be proportional to deposits. The presence of a banking sector leaves the coefficients of the structural IS–Phillips–money–Taylor equations unchanged relative to the standard New Keynesian setting, apart from appending an additional term to the IS and money demand curves which captures the contribution of deposits to the household's utility. Hence, assuming that bank deposits are needed to finance consumption refines the model's specification without altering its underlying theoretical framework. Once the model is taken to the data, maximum likelihood estimation reveals that money balances play a significant role in explaining the intertemporal allocation of consumption and the dynamics of inflation, as encapsulated by the forward-looking IS and Phillips curves. Nonetheless, the findings also document that, despite the relevant role of money, the responses of the model's variables to shocks remain qualitatively similar to a model without money, suggesting that the omission of money balances would leave the transmission mechanism in the model substantially unchanged.

This paper directly relates to two studies which investigate the role of money using DSGE models. Ireland (2004) and Andrés et al. (2006) estimate a standard New Keynesian model to investigate the role of money in the business cycle. These studies assume that money contributes directly to utility and find that the data assign a minimal role to money balances, thereby suggesting that money could be safely ignored in the setting of the model. The contribution of the present paper is to enrich that framework with a banking sector which assigns a supplemental role to deposits that could, in principle, strengthen the relevance of money in the business cycle. This paper is also similar to Andrés et al. (2009) who also estimate a standard New Keynesian model and find that the data are unable to assign an important role to real balances, unless the model is modified to allow for either adjustment costs for holding real balances, or for a nonseparable utility between consumption and real balances, coupled with habit formation. The present paper shows that assuming a banking sector equally makes real balances important to describe the business cycle.

The remainder of the paper is organized as follows: Section 2 describes the model and derives the equilibrium, Section 3 presents the estimation and findings and Section 4 concludes.

2. The model

The theoretical framework is a standard New Keynesian model similar to those used by Ireland (2004), Andrés et al. (2006) and Andrés et al. (2009), with the addition of a banking sector similar to Goodfriend and McCallum (2007). The model economy consists of a representative household, a banking sector, a representative finished-goods-producing firm, a continuum of intermediate-goods-producing firms indexed by $i \in [0,1]$, and a monetary authority.

During each period $t = 0,1,2,\ldots$, the **representative household** maximizes the expected utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t a_t \{u[c_t, (M_t/P_t)/e_t] - \eta h_t\}, \tag{1}$$

where the variable c_t is consumption, M_t/P_t is real money balances, h_t is labor input, β is the discount factor $0 < \beta < 1$, a_t and e_t are the aggregate preference shocks that follow the autoregressive processes $\ln(a_t) = \rho_a \ln(a_{t-1}) + \varepsilon_{at}$, and $\ln(e_t) = (1 - \rho_e)\ln(e) + \rho_e \ln(e_{t-1}) + \varepsilon_{et}$, respectively, where $0 < [\rho_a, \rho_e] < 1$. The zero-mean, serially uncorrelated innovations ε_{at} and ε_{et} are normally distributed with standard deviation σ_a and σ_e. These two shocks, in equilibrium, as described in Ireland (2004) and documented below, translate into disturbances to the IS and money demand curve respectively. The representative household enters period t with nominal bonds B_{t-1} and nominal money M_{t-1}. At the beginning of the period, the household receives a lump-sum nominal transfer T_t from the monetary authority and nominal profits F_t from the intermediate-goods-producing firms. The household supplies h_t units of labor at the wage rate W_t to each intermediate-goods-producing firm $i \in [0,1]$ during period t. Then, the household's bonds mature, providing B_{t-1} additional units of currency. The household uses part of this additional currency to purchase B_t new bonds at nominal cost B_t/r_t, where r_t represents the gross nominal interest rate between t and $t + 1$, and carries M_t units of money into the next period $t + 1$. The household uses its income for consumption, c_t, and carries B_t bonds into period $t + 1$, subject to the budget constraint

$$c_t + B_t/(P_t r_t) + M_t/P_t = [B_{t-1} + M_{t-1} + W_t h_t + F_t + T_t]/P_t, \tag{2}$$

for all $t = 0,1,2,\ldots$.

To introduce the **banking sector**, during each period $t = 0,1,2,\ldots$, the household finances consumption using bank deposits held during the period, such that, similarly to Goodfriend and McCallum (2007), the household also faces a transaction constraint which imposes

$$c_t = v D_t/P_t, \tag{3}$$

where D_t is the nominal bank deposits and v accounts for the fact that the velocity of aggregate bank deposits is less than one on a quarterly basis. The deposits held by the bank are either in the form of money or loans, such that $D_t = M_t + L_t$, where L_t is loans to the household. Loans are proportional to production, which is used as a collateral, such that $L_t = \chi y_t^{\alpha}$, where χ is a scale factor and $\chi > 0$, and $0 < \alpha < 1$. Thus the household chooses $\{c_t, h_t, M_t, B_t\}_{t=0}^{\infty}$ to maximize its utility (1) subject to the budget (2) and the deposit (3) constraints for all $t = 0,1,2,\ldots$. Letting $\pi_t = P_t/P_{t-1}$ denote the gross inflation rate, and λ_t

and ξ_t the non-negative Lagrange multiplier on the budget (2) and the deposit (3) constraints respectively, the first-order conditions for this problem are

$$a_t u_{1t} = \lambda_t + \xi_t, \tag{4}$$

$$\eta a_t/\lambda_t = W_t/P_t, \tag{5}$$

$$\lambda_t = \beta r_t E_t(\lambda_{t+1}/\pi_{t+1}), \tag{6}$$

and

$$(a_t/e_t)u_{2t} = \lambda_t - \beta E_t(\lambda_{t+1}/\pi_{t+1}) - \nu\xi_t, \tag{7}$$

where u_{1t} and u_{2t} denote the derivatives of the utility function with respect to its first and second arguments, respectively. Eq. (4) states that the marginal utility of consumption equates the Lagrange multiplier on the household's budget constraint, as in the standard model, plus the Lagrange multiplier on the household's deposit constraint, since deposits also finance consumption. Eq. (5) states that the marginal rate of substitution between consumption and leisure equates the real wage. Eq. (6) is the optimal bonds holding condition, which links present and expected marginal utility of consumption with the real interest rate. Finally, Eq. (7) is the optimal money holding condition, which states that the marginal utility of money equates the marginal utility of consumption adjusted for the discounted marginal utility of consumption in period $t+1$ and the Lagrange multiplier on the deposit constraint. Note that Eqs. (4) and (7) differ from Ireland (2004) since they account for the extra deposit constraint that affects consumption and money holdings.

As in Ireland (2004), the production sector is comprised of a representative finished-goods-producing firm, and a continuum of intermediate-goods-producing firms indexed by $i \in [0,1]$, characterized by staggered price-setting as in Rotemberg (1982). During each period $t = 0,1,2,\ldots$, the **representative finished-goods-producing firm** uses $y_t(i)$ units of each intermediate good $i \in [0,1]$, purchased at nominal price $P_t(i)$, to produce y_t units of the finished product at constant returns to scale technology $\left[\int_0^1 y_t(i)^{(\theta-1)/\theta} di\right]^{\theta/(\theta-1)} \geqslant y_t$, where θ is the elasticity of substitution among intermediate goods. Hence, the finished-goods-producing firm chooses $y_t(i)$ for all $i \in [0,1]$ to maximize its profits $P_t\left[\int_0^1 y_t(i)^{(\theta-1)/\theta} di\right]^{\theta/(\theta-1)} - \int_0^1 P_t(i)y_t(i)di$, for all $t = 0,1,2,\ldots$. The first order conditions for this problem are

$$y_t(i) = [P_t(i)/P_t]^{-\theta} y_t \tag{8}$$

for all $i \in [0,1]$and $t = 0,1,2,\ldots$. Competition drives the finished-goods-producing firm's profit to zero at equilibrium. This zero profit condition implies that $P_t = \left[\int_0^1 P_t(i)^{1-\theta} di\right]^{1/(1-\theta)}$ for all $t = 0,1,2,\ldots$.

During each period $t = 0,1,2,\ldots$, each **representative intermediate-goods-producing firm** hires $h_t(i)$ units of labor from the representative household, in order to produce $y_t(i)$ units of intermediate good i, according to the production technology

$$y_t(i) = z_t h_t(i), \tag{9}$$

where z_t is the aggregate technology shock that follows the autoregressive processes $\ln(z_t) = \rho_z \ln(z_{t-1}) + \varepsilon_{zt}$, where $0 < \rho_z < 1$. The zero-mean, serially uncorrelated innovation ε_{zt} is normally distributed with standard deviation σ_z.

Since the intermediate goods are not perfect substitutes in the production of the final goods, each intermediate-goods-producing firm faces an imperfectly competitive market. During each period $t = 0,1,2,\ldots$ it sets the nominal price $P_t(i)$ for its output, subject to satisfying the representative finished-goods-producing firm's demand. The intermediate-goods-producing firm faces a quadratic cost to adjusting nominal prices, measured in terms of the finished goods and given by $(\phi_p/2)\{P_t(i)/[\pi P_{t-1}(i)] - 1\}^2 y_t$, where $\phi_p > 0$ is the degree of adjustment cost and π is the steady-state gross inflation rate. This relationship, as stressed in Rotemberg (1982), accounts for the negative effects of price changes on customer-firm relationships. These negative effects increase in magnitude with the size of the price change and with the overall scale of economic activity, y_t. The problem for each intermediate-goods-producing firm is to maximize its total market value given by

$$E_0 \sum_{t=0}^{\infty} (\beta^t \lambda_t/P_t) F_t(i) \tag{10}$$

where the term $\beta^t \lambda_t/P_t$ measures the marginal utility value to the representative household of an additional dollar in profits received during period t, and $F_t(i)$ is profits and is equal to

$$F_t(i) = P_t(i)y_t(i) - [y_t(i)/z_t]W_t - (\phi_p/2)[P_t(i)/[\pi P_{t-1}(i)] - 1]^2 y_t P_t, \tag{11}$$

for all $t = 0,1,2,\ldots$. Thus the firm chooses $\{P_t(i)\}_{t=0}^{\infty}$ to maximize its total market value (10) subject to the demand function (8) and the production technology (9). The first-order condition for this problem is

$$\begin{aligned} 0 = {} & (1-\theta)[P_t(i)/P_t]^{-\theta} y_t/P_t + \theta[P_t(i)/P_t]^{-\theta-1}(y_t/z_t)(W_t/P_t) - \phi_p[P_t(i)/\pi P_{t-1}(i) - 1][y_t/\pi P_{t-1}(i)] \\ & + \beta\phi_p E_t\left\{(\lambda_{t+1}/\lambda_t)[P_{t+1}(i)/\pi P_t(i) - 1][y_{t+1}P_{t+1}(i)/\pi P_{t+1}(i)^2]\right\}. \end{aligned} \tag{12}$$

Eq. (12) determines the firm's optimal price and it is the non-linearized Phillips curve.

During each period $t = 0, 1, 2, \ldots$, the **monetary authority** conducts monetary policy using the modified Taylor (1993) rule

$$\ln(r_t/r) = \rho_r \ln(r_{t-1}/r) + \rho_y \ln(y_t/y) + \rho_\pi \ln(\pi_t/\pi) + \varepsilon_{rt}, \tag{13}$$

where r, y and π are the steady-state values of the nominal interest rate, output, and inflation respectively. The zero-mean, serially uncorrelated policy shock ε_{rt} is normally distributed, with a standard deviation σ_r. According to Eq. (13), the monetary authority gradually adjusts the nominal interest rate in response to movements in output and inflation from their steady-states. As pointed out in Clarida et al. (1998), this modeling strategy for the central bank consistently describes the conduct of monetary policy in the US.

2.1. Equilibrium and solution

In a symmetric, dynamic, equilibrium, all intermediate-goods-producing firms make identical decisions, so that $y_t(i) = y_t$, $h_t(i) = h_t$, $D_t(i) = D_t$, $F_t(i) = F_t$, and $P_t(i) = P_t$, for all $i \in [0,1]$ and $t = 0, 1, 2, \ldots$. In addition, the market clearing conditions $T_t = M_t - M_{t-1}$ and $B_t = B_{t-1} = 0$, and the aggregate resource constraint $y_t = c_t + (\phi_p/2)(\pi_t/\pi - 1)^2 y_t$ must hold for all $t = 0, 1, 2, \ldots$. These conditions, together with the agents' first order conditions, the production technology and the autoregressive shocks describe the equilibrium of the model. By using Eqs. (4), (5), (9), and (11) to eliminate λ_t, W_t, h_t, and F_t, the system can be rewritten more compactly. The equilibrium conditions do not have an analytical solution. Instead, the model's dynamics is characterized by log-linearizing them around the steady-state. The behavior of the variables $\{\hat{y}_t, \hat{\pi}_t, \hat{m}_t, \hat{r}_t, \hat{\xi}_t\}_{t=0}^{\infty}$ is described by the log-linearized equilibrium conditions

$$\hat{y}_t = E_t\hat{y}_{t+1} - \omega_1(\hat{r}_t - E_t\hat{\pi}_{t+1}) + \omega_2(\hat{m}_t - E_t\hat{m}_{t+1}) - \omega_2(\hat{e}_t - E_t\hat{e}_{t+1}) + \omega_3(\hat{a}_t - E_t\hat{a}_{t+1}) + \xi(\hat{\xi}_t - E_t\hat{\xi}_{t+1}), \tag{14}$$

$$\hat{\pi}_t = (\pi/r)E_t\hat{\pi}_{t+1} + \varphi\{(1/\omega_1)\hat{y}_t - (\omega_2/\omega_1)\hat{m}_t + (\omega_2/\omega_1)\hat{e}_t - \hat{z}_t + [1 + (\omega_3/\omega_1)]\hat{a}_t\}, \tag{15}$$

$$\hat{m}_t = \gamma_1\hat{y}_t - \gamma_2\hat{r}_t + \gamma_3\hat{e}_t + \gamma_4\hat{a}_t + \gamma_5\hat{\xi}_t, \tag{16}$$

$$\hat{r}_t = \rho_r\hat{r}_{t-1} + \rho_y\hat{y}_{t-1} + \rho_\pi\hat{\pi}_{t-1} + \varepsilon_{rt}, \tag{17}$$

$$\hat{y}_t = (vm/c)\hat{m}_t + (\alpha v\chi y^\alpha/c)\hat{y}_t, \tag{18}$$

together with the shocks processes: $\hat{a}_t = \rho_a\hat{a}_{t-1} + \varepsilon_{at}$, $\hat{e}_t = \rho_e\hat{e}_{t-1} + \varepsilon_{et}$, and $\hat{z}_t = \rho_z\hat{z}_{t-1} + \varepsilon_{zt}$, where a hat on a variable denotes the logarithmic deviation from its steady-state and a variable without the time index represents its value at the steady-state. Table 1 summarizes the reduced-form parameters of Eqs. (14)–(16). Similarly to McCallum and Nelson (1999) and Ireland (2004), Eqs. (14)–(17) are the forward-looking IS, Phillips curves, money demand curves, and the Taylor rule respectively. In addition, similarly to Goodfriend and McCallum (2007), Eq. (18) is the household's deposit constraint. The numerical solution to the system is derived using Klein (2000), which is a modification of Blanchard and Kahn (1980), and takes the form of a state-space representation. This latter can be conveniently used to compute the likelihood function in the estimation procedure.

3. Estimation and findings

The econometric estimation uses maximum likelihood methods on US quarterly data for real output, real money balances, inflation, and the nominal interest rate for the sample period 1980:1 through 2010:4.[2] Real output is defined as the quarterly real GDP; real money balances is derived by dividing the M2 money stock by the GDP deflator[3]; inflation is measured by changes in the GDP deflator; and the interest rate is defined as quarterly averages of daily readings on the three-month Treasury bill rate. All the data are taken from the FRED database and are demeaned prior to the estimation. Additionally, output and real balances are expressed in per capita terms by dividing them by the civilian noninstitutional population and are linearly detrended to remove their upward trends.[4]

[2] This paper uses maximum likelihood estimation methods to provide a straightforward comparison with Ireland's (2004) results. However, an alternative approach is to estimate the model using Bayesian methods, which combine the information from the model's likelihood function with some prior distributions on the model's parameters to provide the parameters' posterior distribution. Smets and Wouters (2003, 2007) are prominent examples on the application of Bayesian methods to study the business cycle. Other alternative estimation methods used to estimate macroeconomic models are the generalized method of moments, the simulated method of moments and indirect inference. Ruge-Murcia (2007) provides a detailed assessment of the strengths and weaknesses of these different methods and finds that moment-based methods compare very favorably to the more widely used maximum likelihood and Bayesian methods. In general, Bayesian methods are useful to address identification issues which are difficult to resolve using maximum likelihood estimation. Extending the analysis to estimate the model using alternative methods would certainly be a useful task for future research.

[3] As a robustness check, the estimation also used the measure of M1 money stock. Results remain qualitatively unchanged.

[4] Canova and Ferroni (2011) estimate Ireland's (2004) model using Bayesian methods that employ eight procedures to extract the cyclical component of real output and real money balances. Differently from Ireland (2004), their method finds that money plays a moderate influence on output and inflation fluctuations. As a robustness check, we have estimated the model using Hodrick and Prescott, band pass and first order difference filtering procedures and established that the results hold. Extending the analysis to estimate the model using Bayesian methods and apply the procedure by Canova and Ferroni (2011) would certainly be an important venue for future research.

Table 1
Reduced form parameters.

$\omega_1 = -(aU_1 - \xi)/aU_{11}c$
$\omega_2 = -(m/e)U_{12}/aU_{11}c$
$\omega_3 = -U_1/U_{11}c$
$\varphi = (\theta - 1)/\phi$
$\gamma_0 = a(m/e)[(r-1)U_{12} - rU_{22}/e]$
$\gamma_1 = \{r(a/e)[U_{22}(m/e) - U_{21}c] + (1-r)aU_{12}(m/e)\}/\gamma_0$
$\gamma_2 = r[(aU_1 - \xi) - (a/e)U_2 - \xi v]/\gamma_0$
$\gamma_3 = \{r[(a/e)(m/e)U_{22} - (a/e)U_2] + (1-r)(m/e)aU_{12}\}/\gamma_0$
$\gamma_4 = a[(r/e)U_2 + (1-r)U_1]/\gamma_0$
$\gamma_5 = \xi[rv + (r-1)]/\gamma_0$

Table 2
Maximum likelihood estimation and standard errors.

Parameters	Estimates	Standard Errors
ω_1	0.9921	0.6814
ω_2	0.1224	0.0590
ω_3	0.0013	0.0941
φ	0.0989	0.1412
γ_1	0.6201	0.0389
γ_2	0.2897	0.1429
γ_3	0.8890	0.6319
γ_4	1.4701	0.2941
ρ_r	0.7173	0.4114
ρ_y	0.0011	0.0006
ρ_π	0.3218	0.1084
v	0.2391	0.0219
χ	0.9999	0.2219
α	0.9849	0.0121
ρ_a	0.9877	0.0199
ρ_e	0.8934	0.4219
ρ_z	0.9374	0.0081
σ_a	0.0596	0.0524
σ_e	0.3128	0.0922
σ_r	0.1094	0.0212
σ_z	0.0193	0.0029
$\ln(y)$	8.8474	0.4926
$\ln(m)$	8.2911	0.5317
$\ln(\pi)$	0.0081	0.1524
$\ln(r)$	0.0168	0.2811

As in other similar studies, such as Ireland (2004) and Zanetti (2008), a first attempt to estimate the model produced implausible values for the discount factor, β. Thus assuming that the real interest rate is 4% annually, a value commonly used in the literature, pins down the quarterly discount factor β to 0.99. Of special interest is the parameter ξ, that, as mentioned, is the Lagrange multiplier on the deposit constraint (3) and represents the effect of deposits on the household's utility. The estimation was unable to precisely estimate this parameter. Consequently, ξ is set equal to 0.001, which guarantees the highest value of the likelihood function for the other estimated parameters. Another parameter that the estimation procedure was unable to estimate is the parameter γ_5 in the money demand Eq. (16), which represents to what extent a marginal change in deposits would affect the money demand. Also for this parameter, its numerical value of 0.01 maximizes the model's likelihood to match the data.[5]

Table 2 displays the maximum likelihood estimates of the model's parameters together with their standard errors. As in Ireland (2004), Andrés et al. (2006), and Andrés et al. (2009), the parameter ω_2 is key to evaluate the importance of money in the IS and Phillips curves, since it determines whether money balances are important for the system dynamics. Unlike these studies, this parameter estimate is equal to 0.1224 and statistically different from zero, thereby supporting the view that money plays a significant role in describing the business cycle dynamics in the data, in accordance with the empirical evidence in Peersman and Smets (2003), Reynard (2007) and Favara and Giordani (2009). What explains this result is the presence of a banking sector, which adds a deposit constraint to the household's problem, as this additional feature is the sole departure from the standard New Keynesian model. The other parameters that characterize the dynamics of the IS and Phillips curves are ω_1, ω_3, and φ, respectively. The estimate of the elasticity of output to the real interest rate, represented by the parameter ω_1, is equal to 0.9921. This estimate is in line with the degree of risk aversion of a logarithmic utility function in

[5] Note that although we experimented with different measures of money, the estimation procedure was unable to estimate these parameters.

consumption, in line with Ireland (2004). The estimate of the parameter ω_3, which captures the importance of preference shocks to output, is 0.0013, whose small value suggests that preference shocks have a limited direct effect on output. Finally, the estimate of the parameter φ equal to 0.0989 in the Phillips curve Eq. (15) is consistent with a fraction of firms that do not adjust prices instantaneously of approximately 10%, in line with King and Watson (1996). It is worth noticing that, given the sizeable standard error surrounding this parameter, considerable uncertainty remains about the degree of nominal price rigidities.

Turning to the estimation of the money demand Eq. (16), the estimate of the elasticity of output, γ_1, of 0.6201 is higher than the value of 0.01 in Ireland (2004) and is aligned with the findings in Chari et al. (2000) of a value around unity. The estimate of the interest rate elasticity, γ_2, is equal to 0.2897, which is close to the estimate of 0.5 by Lucas (2000) and Ball (2001). Finally, the estimate of γ_4 equal to 1.4701 suggests that preference shocks are important for the dynamics of money. Note, however, that the degree of uncertainty surrounding these estimates is sizeable, in line with the identification issues detected by Ireland (2004) and Andrés et al. (2006).

The parameters' estimates of Eq. (17) characterize the conduct of monetary policy. The estimate of the reaction coefficient to the fluctuations of output from its steady-state, ρ_y, is 0.0011, and the estimate of the reaction coefficient to the fluctuations of inflation from its steady-state, ρ_π, is 0.3218. Finally, the estimate of the interest rate smoothing parameter, ρ_r, is equal to 0.7173. On the one hand, the strong long-run response to inflation is close to the estimates in Ireland (2004) and in line with the empirical evidence in Clarida et al. (1998). On the other hand, the fairly weak response to output, as in Ireland (2004), suggests that the specification of the model is unable to assign an important role to output to determine the nominal interest rate. Similar considerations are raised in Favara and Giordani (2009).

The parameters' estimates of Eq. (18) describe the banking sector. The estimate of the velocity of bank deposits, v, is equal to 0.2391, consistent with the ratio of output and monetary base in the data, as reported in Goodfriend and McCallum (2007). The estimates of the parameters pertaining to the loans' production function, $\chi$and α, are equal to 0.9999 and 0.9849 respectively. Although these estimates maximize the likelihood of the model to match the data, there is not direct comparison of these parameters with similar studies.

The estimates of the exogenous disturbances show that preference shocks are highly persistent, with ρ_a equal to 0.9877, ρ_e equal to 0.8934, and ρ_z equal to 0.9374. These values are in line with Ireland (2004) and Zanetti (2008). The estimates of the volatility of the exogenous disturbances shows that preference shocks are highly volatile, with σ_a and σ_e equal to 0.0596 and 0.3128, respectively, while shocks to the technological process and the monetary policy rule display lower volatility, with σ_r and σ_z equal to 0.1094 and 0.0193, respectively. Finally, similarly to Ireland (2004), the estimates of $ln(y)$, $ln(m)$, $ln(\pi)$, and $ln(r)$ help the model to match the average level of each variable in the data. These estimates are remarkably close to Ireland (2004) and imply that the coefficient of the expected inflation term in the Phillips curve (15) is around 0.99, since $\pi/r \approx 0.99$, which is in line with the estimates in the literature.

To investigate how the variables of the model react to each shock, Fig. 1 plots the impulse responses of selected variables to a one-standard-deviation of each of the exogenous shock. The first column in Fig. 1 shows that after a one-standard-deviation preference shock ε_{at} both output and the real money fall, while inflation increases. The raise in inflation, due to the modified Taylor rule, leads to an increase in the nominal interest rate. The second column in Fig. 1 shows that a one-standard-deviation preference shock ε_{et} causes a fall in inflation and the nominal interest rate, output, and real money. The third column in Fig. 1 shows that after a one-standard-deviation technology shock ε_{zt}, output and real money both rise, while

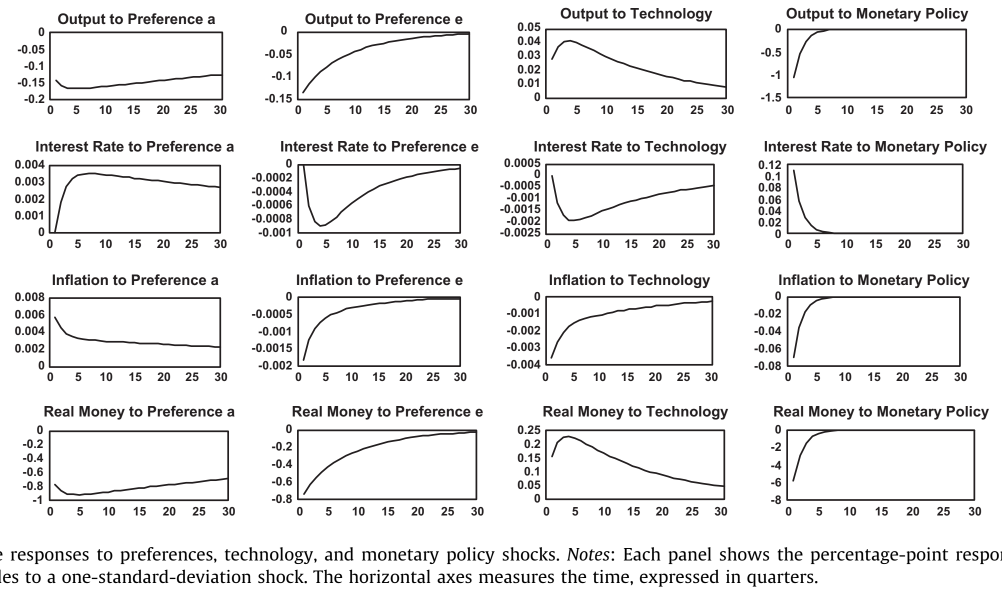

Fig. 1. Impulse responses to preferences, technology, and monetary policy shocks. *Notes*: Each panel shows the percentage-point response of selected models' variables to a one-standard-deviation shock. The horizontal axes measures the time, expressed in quarters.

inflation falls. The fall in inflation allows for an easing in monetary policy such that the nominal interest rate falls. The last column in Fig. 1 shows that a one-standard-deviation monetary policy shock ε_{rt} translates into an increase in the nominal interest rate and into a fall in output and real money. Since the monetary policy disturbance is serially uncorrelated, the reaction of each variable dies off over a period of approximately 2 years.

Looking across all these impulse responses also provides some insights into how the presence of a banking sector affects the transmission mechanism of the standard New Keynesian framework. For all shocks, the baseline transmission mechanism of a New Keynesian setting is qualitatively unaffected: all the variables respond to shocks similarly to a standard New Keynesian model without a banking sector, as in Ireland (2004). This corroborates the findings in Goodfriend and McCallum (2007) who also find that in a model with a more sophisticated banking sector the qualitative responses of the underlying New Keynesian model remain substantially unchanged. Nonetheless, the presence of a banking sector affects model's quantitative response to disturbances.

4. Conclusion

This paper has investigated the role of money in the business cycle by using a standard New Keynesian model enriched with a simple banking sector that makes bank deposits needed to finance consumption. This setting therefore assigns a supplemental role to money that could, in principle, strengthen the importance of real balances in the model. Maximum likelihood estimation of the model has assigned a significant role to money in explaining the intertemporal allocation of consumption and the dynamics of inflation as described by the forward-looking IS and Phillips curves. Results also point out that, despite the relevance of real balances, the responses of the model's variables to shocks remains qualitatively unchanged compared to a standard New Keynesian model, suggesting that the omission of money leaves the model's transmission mechanism substantially unaffected.

But while the results do support the significant role of real balances to accurately describe business cycle dynamics despite their minimal impact on the transmission mechanism, it should also be noted that the model developed here could be extended to include a more detailed description of the economy and the banking sector, which might account for additional sources of frictions, and that could unveil alternative channels through which money could play a role and materially affect the model's transmission mechanism. Also, a more complex model may address the identification issues inherent in this simple framework. Moreover, although the simple model developed here attributes importance to money as a medium of exchange, the same notion could be accomplished using different underlying assumptions. The extension of the model to detail more accurately the functioning of the economy and the assessment of alternative ways to assign a role to money remain outstanding tasks for future research.

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