Does money matter in shaping domestic business cycles? An international investigation.

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Abstract

We study the contribution of money to business cycle fluctuations in the US, the UK, Japan, and the Euro area using a small scale structural monetary business cycle model. Constrained likelihood-based estimates of the parameters are provided and time instabilities analyzed. Real balances are statistically important for output and inflation fluctuations. Their contribution changes over time. Models giving money no role provide a distorted representation of the sources of cyclical fluctuations, of the transmission of shocks and of the events of the last 40 years.

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1 Introduction

There has been considerable interest in recent years in analyzing the monetary aspects of the business cycle; stylized facts about the transmission of monetary policy shocks have been collected (see Christiano et al., 1999 for an early summary of the evidence) and researchers have constructed dynamic stochastic general equilibrium (DSGE) models which replicate these facts and help guiding monetary policy decisions.

The majority of the monetary models nowadays employed in academics and in policy institutions share similar New-Keynesian microfundations and similar frictions and attribute to the stock of money a minimal role in amplifying cyclical fluctuations. Given the conventional wisdom that the nominal interest rate is the instrument of monetary policy, these models in fact provide a coherent determination of the equilibrium level of output, inflation and the nominal rate, without any reference to monetary aggregates. When a money demand equation is present, it only determines how much money needs to be supplied, given predetermined levels of output, inflation and the nominal rate.

The dichotomy that these models display is hard to accept as working paradigm for monetary policy for those trained in the quantity theory orthodoxy of the 1970s-1980s (see e.g. Alvarez, et. al., 2001), and those who believe that transaction frictions are important, that liquidity constraint could be binding, and/or that balance sheet effects matter (Meltzer, 2001). It also appears to be grossly inconsistent with a large body of VAR evidence (see e.g. Gordon and Leeper, 1994, Canova and De Nicolo', 2002, or Sims and Zha, 2006) highlighting the importance of liquidity effects and of credit markets for the propagation of monetary policy disturbances. Furthermore, monetary policy discussions, which typically emphasizes the expectational channel built into the term structure of interest rates, or credit-induced effects, are hard to communicate in models where policy matters because it affects the intertemporal rate of substitution of consumption expenditure (the so-called "IS channel"), Finally, the existing specifications provide little guidance to evaluate the effects of unconventional quantitative and credit easing measures that Japan, the US, and Europe have recently undertaken.

Are these models providing an accurate description of the role of money in propagating and/or amplifying cyclical fluctuations in output and inflation? Is the IS channel the main mechanism of monetary policy transmission? Can we safely neglect (the stock of) money when studying domestic cyclical fluctuations and evaluating the desirability of monetary policy actions? Despite the relevance of these issues for monetary policy discussions, the literature on the topic is surprisingly scant. McCallum, 2001, and Woodford, 2003, have calibrated New-Keynesian models where money has a transaction role and found that neglecting liquidity premia is, to a first approximation, appropriate. Ireland (2004), on the other hand, has estimated the parameters of general specification within the class of New-Keynesian models, and found little statistical role for money (a similar result is obtained by Andres, et al., 2009). In addition, and as far as we know, no one has investigated whether economic analyses could be distorted when models without money are used nor whether institutional features (and their differences across time and across country) matter for the conclusions one reaches.

This paper brings fresh evidence to these issues by examining four interrelated questions. First, what is the role of money in transmitting cyclical fluctuations to output and inflation in four large industrialized countries (the US, Japan, the Euro area and the UK)? Second, does this role change over time? Third, can variations in the role of money explain certain changes in output and inflation dynamics observed over the last 40 years? Fourth, is economic inference distorted when models where money plays no role are used? To answer these questions, we take a standard small scale New Keynesian model and give money a role via a somewhat reduced form device. The specification we employ is sufficiently general to capture several neglected channels though which money could affect output and inflation. For example, it can capture transaction fictions, asset market segmentation, working capital requirements or indirect balance sheets effects. In our model, money matters for three reasons. Since it affects the marginal rate of substitution between consumption and leisure, the stock of money influence the real wage, and thus marginal costs and the Phillips curve. Moreover, since it alters the intertemporal rate of substitution of output at different points in time, it creates a new wedge in the Euler equation. Finally, the stock of money provides the monetary authority with an additional level to react to inflation. Each of these three channels may contribute to amplify the magnitude of cyclical fluctuations the model can account for and stretch their persistence over time.

We estimate the parameters with a constrained maximum likelihood (ML) technique and test, both statistically and economically, the relevance of money for output and inflation fluctuations. A structural approach is needed to interpret the evidence in light of existing theories and for this purpose, a ML technique are preferable to Generalize Method of Moment or similar limited information methods because it provides a natural framework to test restrictions on the general specification we estimate. We refrain from employing (informative) a-priori restrictions on the parameter space to make the information content of the data and its ability to distinguish interesting theoretical specifications as transparent as possible. While it is common nowadays to estimate DSGE models with a prior, the constraints used are often so tight and so much data-based that the data is not allowed to speak, making formal testing difficult, if not impossible (see Canova, 2007).

Our investigation reaches four main conclusions. First, money is statistically important for domestic fluctuations in output and inflation. Depending on the country and the time period, money may matters directly, by affecting Euler equation and the Phillips curve, indirectly, by influencing the determination of nominal interest rate, or both. Second, the role of money is changing over time, both in the sense that estimates change magnitude and significance and that different channels become important. Since money does not stand-in for standard omitted suspects and since alternative monetary aggregates give similar conclusions, specification and measurement problems are unlikely to be crucial in delivering results. Third, the estimates we obtain suggest that liquidity premia have limited importance and highlight the presence of time varying wedge between consumption and output. This wedge could be influenced by the money stock, for example, because of asset market segmentation or participation constraints. Our results are also consistent with the idea that balance sheet effects, working though either working capital requirements or direct credit constraints, affect the determination of marginal costs and the link between marginal costs and the output gap. Finally, we show that the interpretation of the evidence is altered when money is not allowed to play a role in the model. Researchers could mistakenly interpret the pattern of impulse responses in the US in the pre 1980 period; erroneously measure the causes of inflation volatility in Japan up to 1990 and the reasons for the sustained output recovery after the early 1990s recession in the UK. Furthermore, they would have hard time to account for the fall in inflation variability and persistence experienced in the US over the last 40 years.

The rest of the paper is organized as follows. The next section presents the theoretical model used to organize the data. Section 3 describes the data and its sources. Section 4 presents full sample estimates, test restrictions, studies subsample evidence and examine whether money may proxy for omitted factors. Section 5 examines the role of money in interpreting the events of the last 40 years. Section 6 concludes.

2 The model

The theoretical framework used builds on the small scale New-Keynesian model without capital accumulation described in Gali (2008). The structure is extended in three ways: we allow for habit in consumption; permit real balances to enter non-additively in utility; and posit a monetary policy rule where the growth rate of nominal balances matters for the determination of the nominal rate.

Contrary to the recent literature examining source of business cycle fluctuations (see e.g. Smets and Wouters, 2007), we prefer to study the questions of interest using a small scale model. A number of reasons justify our choice. First, in a small scale model, the channels though which money may matter for output and inflation fluctuations are easier to identify and the dynamics simpler to interpret. Second, population identification problems, of the type emphasized by Canova and Sala, 2009, are likely to be eased, making estimation more reliable and inference more transparent. Finally, since we are interested in comparing our results with the existing literature, a comparable model should be used. The drawbacks of employing a small scale model are clear: the likelihood of the data may be misspecified, making parameter estimate inconsistent. It is unclear to us however whether larger scale models are less misspecified as far as the likelihood is concerned - adding extra equations may not necessarily reduce misspecification, especially when black-box frictions are employed to capture missing features. The fact that estimation is reasonably successful and the shocks of the model sufficiently well behaved indicates that misspecification is probably less of an issue in our exercise.

Since the economy is quite standard, we only briefly describe its features. There is a representative household, a representative final good producing firm, a continuum of intermediate goods firms each producing a differentiated good $i \in [0, 1]$ and a monetary authority. At each t the representative household maximizes

$$E_t \sum_t \beta^t a_t \left[U\left(x_t, \frac{M_t}{p_t e_t} \right) - \eta n_t \right] \tag{1}$$

where $x_t = c_t - hc_{t-1}$, $0 < \beta < 1$, $h, \eta > 0$ [1] subject to the sequence of constraints

$$M_{t-1} + T_t + B_{t-1} + W_t n_t + D_t = p_t c_t + \frac{B_t}{R_t} + M_t \tag{2}$$

[1] We have also experimented with a specification where external habits enter multiplicatively in utility, i.e. $x_t = \frac{c_t}{c_{t-1}^h}$ but discarded it since the likelihood displays severe numerical problems.

where c_t is consumption, n_t are hours worked, p_t is the price level, M_t are nominal balances, W_t is the nominal wage, B_t are one period nominal bonds with gross nominal rate R_t, T_t are lump sum nominal transfers from the monetary authority at the beginning of each t and D_t are dividends distributed by the intermediate firms. a_t and e_t are disturbances to preferences and to the money demand, whose properties will be described below. Let $m_t \equiv \frac{M_t}{p_t}$ denote real balances and $\pi_t \equiv \frac{p_t}{p_{t-1}}$ the gross inflation rate during period t.

The representative final good producing firm uses y_t^i units of intermediate good i, purchased at the price p_t^i to manufacture y_t units of the final good according to the constant returns to scale technology $y_t = [\int_0^1 (y_t^i)^{(\theta-1)/\theta} di]^{\theta/(1-\theta)}$ with $\theta > 1$. Profit maximization yields demand functions for each i of the form

$$y_t^i = \left(\frac{p_t^i}{p_t}\right)^{-\theta} y_t \tag{3}$$

so that θ measures the constant price elasticity of demand for each intermediate good. Competition within the sector implies that $p_t = (\int_0^1 (p_t^i)^{1-\theta} di)^{1/(1-\theta)}$.

An intermediate goods producing firm i hires n_t^i units of labor to produce y_t^i units of intermediate good using the production function $y_t^i = z_t n_t^i$, where z_t is an aggregate productivity shock. Since intermediate goods substitute imperfectly for one another in finished goods production, the intermediate firms act as monopolistic competitors in their pricing decisions. We assume that, when firms change prices, they face cost of adjustment, measured in terms of finished goods, of the form $\frac{\phi}{2}\left(\frac{p_t^i}{\pi^s p_{t-1}^i} - 1\right)^2 y_t$ where $\phi > 0$ and π^s measures steady state inflation. The pricing problem faced by the representative firm is therefore to maximize

$$E_t \sum_t [\beta^t a_t U_1\left(x_t, \frac{M_t}{p_t e_t}\right)]\left(\frac{D_t^i}{p_t}\right) \tag{4}$$

subject to (3), where $\beta^t a_t U_1(x_t, \frac{M_t}{p_t e_t})$ measures the marginal utility value to the household of an additional unit of profits received at t and real dividends are

$$\frac{D_t^i}{p_t} = \left(\frac{p_t^i}{p_t}\right)^{1-\theta} y_t - \left(\frac{p_t^i}{p_t}\right)^{-\theta}\left(\frac{w_t y_t}{z_t}\right) - \frac{\phi}{2}\left(\frac{p_t^i}{\pi^s p_{t-1}^i} - 1\right)^2 y_t \tag{5}$$

The monetary authority is characterized by a set of rules, normalized on the nominal rate, which allows it to respond to past values of the interest rate and to either current, past or future values of output, of inflation and of the growth rate of nominal balances:

$$R_t = R_{t-1}^{\rho_r} E_t y_{t-p}^{(1-\rho_r)\rho_y} E_t \pi_{t-p}^{(1-\rho_r)\rho_\pi} E_t \Delta M_{t-p}^{(1-\rho_r)\rho_m} \epsilon_t \tag{6}$$

where ϵ_t is a monetary policy shock, $-4 \leq p \leq 4$. The rule in (6) is similar in spirit to the one employed by Christiano et al. (2006) and does not allow, for example, for a time varying inflation objective or a learning mechanism. Adding these features requires potentially debatable assumptions (the law of motion of the inflation target or the constant gain in the learning function need to be arbitrarily specified). Furthermore, without further restrictions, the likelihood function is unable to separate disturbances driving the time varying inflation target from the monetary policy shocks ϵ_t or to assess the credibility of the learning mechanism.

The flexibility we built in (6) is important for two reasons. A model featuring a backward looking relationship is superior, both in terms of fit and properties of the estimated shocks (see Canova, 2008), to one that considers a contemporaneously looking or even a forward looking specification for US data. Moreover, since the samples span up to 50 years of data, allowing for the possibility that monetary policy was, on average, backward or forward looking avoids important specification errors. p is treated as a free parameter, jointly estimated with the others structural parameters of the model.

For the UK a interest rate rule we use is probably inappropriate since open economy considerations may have mattered for interest rate determination during (part of) the sample. In an earlier version, we have also allowed the growth rate of the dollar exchange rate to enter (6) and closed the model with an interest parity relationship, driven by a risk premium shock. Since the exchange rate is estimated to be insignificant in the policy rule and the UIP relationship dichotomizes from the rest of the equations, open economy considerations are not crucial in our exercises.

The four disturbances $v_t = (a_t, e_t, z_t, \epsilon_t)$ are assumed to follow an AR(1) process of the type $\log v_t = \bar{v} + N \log v_{t-1} + u_t$, where N is a diagonal matrix with entries $(\rho_a, \rho_e, \rho_z, 0)$, respectively. The covariance matrix of the u_t (denoted by Σ) is diagonal, with entries $\sigma_a^2, \sigma_e^2, \sigma_z^2, \sigma_\epsilon^2$. In a symmetric equilibrium $y_t^i = y_t$, $n_t^i = n_t$, $p_t^i = p_t$, and $D_t^i = D_t$. Thus log-linearizing the equilibrium conditions around the steady states leads to:

$$\begin{aligned} \hat{y}_t &= \frac{1}{1+h} E_t \hat{y}_{t+1} + \frac{h}{1+h} \hat{y}_{t-1} - \frac{\omega_1}{1+h} \left[\hat{R}_t - E_t \hat{\pi}_{t+1} - (\hat{a}_t - E_t \hat{a}_{t+1}) \right] \\ &+ \frac{\omega_2}{1+h} \left[(\hat{m}_t - \hat{e}_t) - (E_t \hat{m}_{t+1} - E_t \hat{e}_{t+1}) \right] \qquad (7) \\ \hat{m}_t &= \gamma_1 (\hat{y}_t - h \hat{y}_{t-1}) - \gamma_2 \hat{R}_t + (1 - (R^s - 1)\gamma_2) \hat{e}_t \qquad (8) \\ \hat{\pi}_t &= \beta E_t \hat{\pi}_{t+1} + \psi \left(\frac{1}{\omega_1} (\hat{y}_t - h \hat{y}_{t-1}) - \frac{\omega_2}{\omega_1} (\hat{m}_t - \hat{e}_t) - \hat{z}_t \right) \qquad (9) \end{aligned}$$

$$\begin{aligned}\hat{R}_t &= \rho_r \hat{R}_{t-1} + (1-\rho_r)\rho_y \hat{y}_{t-p} + (1-\rho_r)\rho_\pi \hat{\pi}_{t-p} \\ &+ (1-\rho_r)\rho_m \Delta(\hat{m}_{t-p} + \hat{\pi}_{t-p}) + \hat{\epsilon}_t \end{aligned} \tag{10}$$

where

$$\omega_1 = -\frac{U_1(x^s, \frac{m^s}{e^s})}{y^s U_{11}(x^s, \frac{m^s}{e^s})} \tag{11}$$

$$\omega_2 = -\frac{m^s}{e^s} \frac{U_{12}(x^s, \frac{m^s}{e^s})}{y^s U_{11}(x^s, \frac{m^s}{e^s})} \tag{12}$$

$$\gamma_2 = \frac{R^s}{(R^s-1)(m^s/e^s)} \left(\frac{U_2(x^s, \frac{m^s}{e^s})}{(R^s-1)e^s U_{12}(x^s, \frac{m^s}{e^s}) - R^s U_{22}(x^s, \frac{m^s}{e^s})} \right) \tag{13}$$

$$\gamma_1 = (R^s - 1 + R^s \omega_2 \frac{y^s}{m^s})(\frac{\gamma_2}{\omega_1}) \tag{14}$$

$$\psi = \frac{\theta - 1}{\phi} \tag{15}$$

The superscript s denotes steady state values of the variables, U_j is the first derivative of U with respect to argument $j = 1, 2$ and U_{ij} is the second order derivative of the utility function, $i, j = 1, 2$.

The log-linearized Euler condition (equation (7)) includes, in addition to standard arguments, terms involving real money balances and money demand shocks. These terms are irrelevant for output determination if and only if real balances do not create a wedge between intertemporal consumption and output decisions. This, in turns, occurs when the utility function is separable in consumption and real balances, i.e. $U_{12} = 0$ (see equation (12)). Equation (8) is a money demand equation: real balances depend positively on current output and negatively on lagged output and the nominal rate. There are important cross coefficient restrictions in this equation and, for example, the output elasticity of money demand depends on the interest semi-elasticity. Real balances enter the Phillips curve (equation (9) because they affect the marginal rate of substitution between consumption and leisure which, in equilibrium, is equal to the real wage and the real wage is a crucial determinant of the marginal costs of the model. $U_{12} \neq 0$ is again necessary for real balances to play a role in the determination of the inflation rate [2]. Finally, the policy rule allows, but does not require, the growth rate of real balances to be an important determinant of interest rate decisions.

[2] The implications summarized by equation (9) hold also under an alternative pricing scheme, such as Calvo. In this latter case, however, the determinants of ψ will be different - it will depend of the fraction of firms allowed to changes prices and the discount factor. A flexible price model is not nested in our specification (we require that $\phi > 0$). Nevertheless, since a small ϕ makes the Phillips curve steeper, $\psi \to 0$, approximates, in a reduced form sense, a flexible price speciication

This paper focuses attention on estimates of ω_2 and ρ_m. The first measures the direct role of money in determining the magnitude and the persistence of output and inflation fluctuations; the second, the long run indirect effects that money has on these two variables through the nominal rate. When ω_2 is zero, real balances have no direct role in propagating monetary business cycles. When both ω_2 and ρ_m are zero, money could be omitted from business cycle and monetary policy analyses without statistical or interpretation losses. Our a-priori expectation is that both ω_2 and ρ_m vary across countries and time periods. Our empirical analysis will shed light on the cross-country and cross-time heterogeneities in these effects.

2.1 The role of money for inflation and output dynamics: an overview

Before estimating the structural parameters, it is useful to highlight what difference money may make in the model and along which dimensions we should expect giving money a role may help us to understand better certain real world phenomena.

It is well known that the US economy witnessed a significant decline in the volatility of output and inflation and a considerable fall in the persistence of inflation over the last 30 years (see e.g. Stock and Watson, 2002). Canova et al., 2007, show that such a phenomenon is also present in the UK and, to a smaller extent, in the Euro area. Since the explanations put forward to account for these changes generally abstract from money (see e.g. Clarida, et al., 2000, Sims and Zha, 2006, Campbell and Herkowitz, 2006), we want to investigate i) whether allowing ω_2 and ρ_m to be different from zero may make a quantitative difference for the variability and the persistence of output and inflation; and ii) whether changes in these two parameters could account for the observed changes in these moments.

We parameterize the model as follows: the rule is specified to be backward looking, and $p = 1$. We set $\beta = .99, \psi = 0.74, \omega_1 = 2.0, \gamma_2 = 0.07, \sigma_a = 0.16, \sigma_z = 0.0059, \sigma_e = 0.009, \sigma_\epsilon = 0.009$ $h = 0.71, \rho_r = 0.68, \rho_y = 0.17, \rho_\pi = 4.37$, and $\rho_a = 0.90, \rho_z = 0.70, \rho_e = 0.97$. These values are close to those we obtain estimating the model with US data and comparable to those estimated or calibrated by Ireland, 2004. We then let ω_2 and ρ_m vary within a range and trace out how the volatility of output and inflation and the persistence of inflation change - volatility is measured here by the unconditional population standard deviation of the series. For ω_2 the interval is [-1.0,1.0], which allows for complementarity and substitutability of consumption and real balances in utility; for ρ_m the interval is also [-1.0,1.0], where negative values capture the possibility that

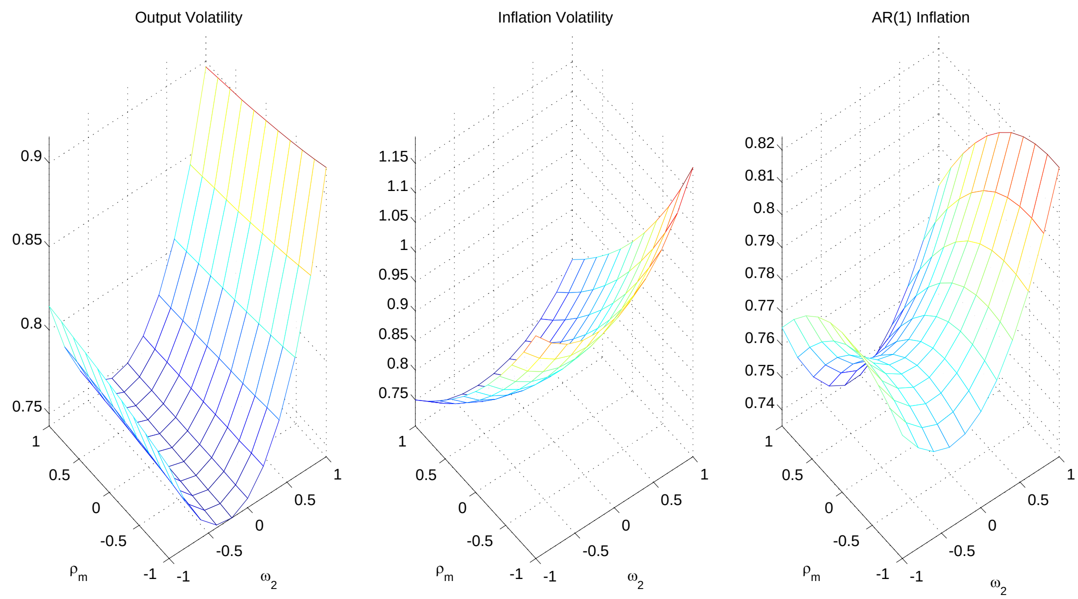

Figure 1: Surface plots

reacting to nominal balances is a way to temper a possibly too strong policy reaction to inflation.

Figure 1 shows that allowing ω_2 and ρ_m to be different from zero affects the magnitude of the unconditional moments of output and inflation. Furthermore, variations in both parameters may account for some of the time variations in the variability of output and inflation and in the persistence of inflation observed in the real world. For example, when ω_2 is different from zero the variability of output considerably increases and variations in both ω_2 and ρ_m matter for inflation variability. In general, if both parameters are different from zero, the portion of inflation fluctuations accounted by the model significantly increases. Inflation persistence also depends on the size of ω_2 and ρ_m and two forces determine the shape of the surface. When ω_2 is different from zero, the persistence of marginal cost rises, making inflation persistence increase. On the other hand, when ρ_m is different from zero, inflation persistence is reduced since variations in the money stock, produced by changes in, e.g., the money demand function, make interest rate move and inflation react. These two channels provide conflicting forces which, depending on the parameterization used, may produce a complicated structure for inflation persistence. With the one we have used the nonlinear effect is relatively mild - the indirect interest rates effect is small.

In sum, a-priori forcing ρ_m and ω_2 to be zero is restrictive and variations over time in these two parameters represent unexplored channels which may help us to better understand the changes advanced economies have experienced over time.

3 The data and the estimation approach

We assume that the investigator observes data for output, the inflation rate, the nominal rate and real balances. The sample differs across countries: it goes from 1959:1 to 2008:2 for the US, from 1970:1 to 2007:4 for the Euro area, from 1965:1 to 2008:2 for the UK and from 1980:1 to 2007:4 for Japan. US data is from the FRED database at the Federal Reserve Bank of St. Louis; Euro data is from the Eurowide model dataset (update 7) available at the ECB web page; UK data comes from the Bank of England; data for Japan is collected from IMF and OECD data bases. The inflation rate in all four countries is measured by the growth rate of the GDP deflator; the nominal rate is the three month T-bill rate in the US and the UK, the call rate in Japan, and three month rate in the Euro area. The M2 stock in the US and the Euro area, M2 plus certificate of deposits in Japan and the M4 stock in the UK are our nominal monetary aggregates. GDP and nominal monetary aggregates are scaled by the GDP deflator and by civilian population in the 16-65 group to transform them in real per-capita terms. M2 is employed as the relevant monetary aggregate to be consistent with the literature and to avoid, as best as possible, well known instabilities. The sensitivity of the results to changes in the measure of monetary aggregate used is examined below.

Per-capita real GDP and real money balances display an upward trend which looks almost deterministic in all countries. Since the drift is idiosyncratic, both across variables and countries, we separately eliminate it from the log of the series using a linear specification. The inverted U-shaped patterns that interest rates and inflation display are more difficult to deal with. Consistent with the literature, we demean both series.

One feasible alternative to the strategy we use to match the data to the model's counterparts is to allow one of the shocks (typically, the technology shock z_t) to be non-stationary and remove the upward trend in per-capita real output and real balances using a model consistent methodology. We do not follow this approach for two reasons. On the one hand, when technology shocks have a unit root, per-capita output and real balances share the same trend, which is not the case here in any of the countries. On the other, it is unclear whether all non-cyclical fluctuations can be safely attributed to non-stationary technology shocks. Chang et al., 2006, for example, have recently fit a model with non-stationary preference shocks to US data with good results.

The model (7)-(10) contains 19 parameters; 5 structural ones $\eta_1 = (h, \rho_r, \rho_y, \rho_\pi, \rho_m)$, 4 semi-structural ones $\eta_2 = (\psi, \omega_1, \omega_2, \gamma_2)$ and 7 auxiliary ones, $\eta_3 = (\rho_a, \rho_z, \rho_e, \sigma_a, \sigma_z, \sigma_e, \sigma_\epsilon)$ plus the discount factor, the steady state values of the nominal interest rate and the output to real balance ratio, $\eta_4 = (\beta, R^s, \frac{y^s}{m^s})$. Our exercise is geared to obtain likelihood-based estimates of $\eta = (\eta_1, \eta_2, \eta_3)$, conditional on selected values for η_4 [3].

The model is solved using standard methods. Its solution has the format:

$$x_{1t+1} = A_1(\eta)x_{1t} + A_2(\eta)u_t \tag{16}$$

$$x_{2t} = A_3(\eta)x_{1t} + A_4(\eta)u_t \tag{17}$$

where $x_{2t} = [\hat{y}_t, \hat{\pi}_t, \hat{R}_t, \hat{m}_t]$, $x_{1t} = [\hat{y}_{t-1}, \hat{\pi}_{t-1}, \hat{R}_{t-1}, \hat{m}_{t-1}, \Delta\hat{M}_{t-p-1}, \hat{v}_{1t}, \hat{v}_{2t}, \hat{v}_{3t}, \hat{v}_{4t}]$ and the matrices $A_i(\eta), i = 1, 2$ are complicated functions of the structural parameters η.

Likelihood-based estimation of the parameters entering (16) and (17) is simple: given some η, and a sample $[t_1, \ldots, t_2]$, the likelihood, denoted by $f(y_{[t_1,t_2]}|\eta)$, is computed by means of the Kalman filter and the prediction error decomposition and the original η values updated using gradient methods. The Kalman filter is easy to use since (16) and (17) form a linear state space system where (16) is a transition equation and (17) an observation equation.

Unfortunately, the likelihood function is ill-behaved with the data of any of the countries and displays multiple peaks, sharp cliffs and large flat areas. This is due, in part, to uninformative samples and, in part, to the fact that the coefficients of the solution are complicated nonlinear function of the structural parameters. To find the maximum of the function, we employ the following multi-step approach:

1. For each data set and each country, we randomly draw a set of 500 initial conditions. If the model does not have a solution, the draw is discarded. For the remaining draws, the likelihood function is maximized using the csminwel.m routine written by Chris Sims [4]. We take as an estimate of η the vector producing

[3] We read R^s for each country and each sample from the average level of inflation, once we set $\beta = 0.99$. For all countries and samples, $\frac{m}{y}$ is fixed to 1.5 (following Chari et. al., 2002). Changing this ratio from 1.5 to 2.5 has minor consequences on the estimates of ω_2 and ρ_m we obtain. We do not estimate η_4 jointly with η because the likelihood has little information for these parameters.

[4] Standard Matlab routines (such as fminunc.m or fminserach.m) fail to move from the initial conditions in more than 90 percent of the draws.

the largest likelihood value across draws, excluding runs where convergence of the optimization routine failed.

2. We repeat step 1 for each specification of the monetary policy rule. To compare the maximum across specifications, the Schwarz approximation to the log Bayes factor (see Canova, 2007) is employed. The preferred specification satisfies two conditions: optimizes this criteria and results in estimated residuals which deviate less from the mean zero, iid assumption.

3. The output produced in step 2 is screened to eliminate specifications that violate basic economic principles (e.g. specifications for which the risk aversion or adjustment costs become negative) or produce unreasonable standard errors for the structural shocks.

4. For each country and each data set, steps 1-3 are repeated changing the values of η_4 within a reasonable range. In all cases, the selected values of η_4 have little influence on the conclusions reached.

Bayesian methods have an edge over classical likelihood methods in situations like ours where the likelihood function is poorly behaved. However, when the likelihood has problematic features, inference crucially depends on the shape, the location and the spread of the multivariate prior density. Our choice of letting the data speak and of employing an ex-post criteria to eliminate economically non-interpretable estimates is equivalent to assume that the prior for the parameter vector is multivariate uniform with truncation in the area of the parameter space which does not produce a determinate solution or gives economically unreasonable results (as e.g. in Fernandez Villaverde, 2009).

4 The results

4.1 Specification issues

Before discussing the estimates of the parameters of interest, it is useful to document the properties of the model to make sure it fits the data reasonably well and that no predictable pattern is left in the residuals. Figure 2 plots the residuals of the model computed using point estimates of the parameters. the Kalman filter and the solution of the model. Residuals appear to be reasonably behaved: the mean is not statistically

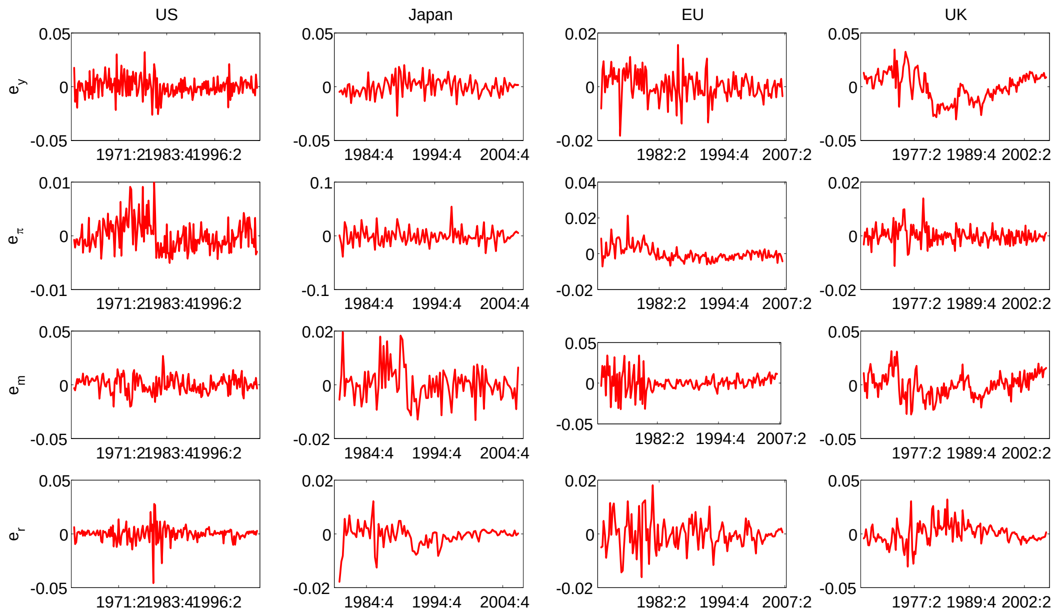

Figure 2: Model residuals.

different from zero and serial correlation appears to be absent, except perhaps with the residuals of the UK output equation and the EU inflation equations. However, the volatility of certain residuals is changing over time (see, for example, EU money demand equation and the US inflation equation) and outliers are present at some dates (see the policy rule residuals in the US in the middle of the sample).

Volatility changes and unexpected outliers could, in principle, be due to breaks in the long run properties of the per-capita output and money series. To check for this possibility, we have re-estimated the model allowing for a segmentation in the trend of these two variables at 1980:1 for the US; at 1992:4 for the UK and the Euro area, and at 1990:4 for Japan. It turns out that allowing for a break in the trend adds noise to the estimate but does not change the basic features of estimated residuals. Furthermore, since the exact location of the break does not matter - we can move the break dates within a year (backward or forward) of the selected ones without much changes - volatility changes are unlikely to be due specification errors.

There is also little evidence that the residuals of the model are predictable using lags of the endogenous variables. For example, in the US, a regression of the residuals over lags of the endogenous variables yield coefficients which are very small - the largest point estimate (-0.16) is the one obtained regressing the residuals of the inflation equation on the second lag of inflation. For other countries, the regression coefficients are even smaller. Thus, apart for the volatility changes, the small scale model we use appears to be sufficiently well specified for all four countries we consider.

4.2 Full sample evidence

Table 1 reports point estimates and the standard deviation (in parenthesis) of ω_2, the direct effect of real balances on output and inflation fluctuations and of ρ_m, the long term indirect effect of real balances growth on output and inflation fluctuations. Standard deviations are computed from the Hessian of the function at the maximum. The first panel contains estimates for the US, the second for Japan, the third for the EU and the forth for the UK. The row labelled "LR-test p-value" reports the p-value of a test that both coefficients are statistically equal to zero; the row labelled " Log Bayes factor" reports the value of this statistic. The complete set of estimates for each country and each specification is available in the accompanying materials.

The coefficient measuring the direct impact of money is negative in three of the four countries, but all estimates are statistically insignificant. Taken literally this indicates that, the direct role of money in amplifying fluctuations of output and inflation is small.

The coefficient measuring the indirect effect of real balances is estimated to be positive and moderate in all countries and is everywhere significant, except in the UK. Two reasons may explain why this coefficient is insignificant in the UK: the bank of England may look at smaller monetary aggregates when deciding the nominal rate - we can not verify this hypothesis since such aggregates are not publicly available - and the M4 series displays a visible break around the 1992:4. The point estimates we obtain imply that a one percent deviation of real balances from their steady state value has short run effects on interest rates ranging from 0.25 to 0.50 percentage points, depending on the country, in line with the estimates of Barthelemy et al., 2008.

In section 2 we mentioned that the monetary policy rule is allowed to have a backward looking, contemporaneously looking or a forward looking format to avoid specification errors. In agreement with Canova, 2008, for the US a backward rule is preferable and $p = 1$ is selected. For the other countries, a contemporaneous rule is instead selected. Interestingly, in no countries a forward looking specification produces the highest likelihood value.

The joint significance of the direct and indirect effects of money is examined using a likelihood ratio (LR) test and the Schwarz approximation to the log Bayes factor. For each country, two specifications are estimated; one where the parameters are all free; and one which forces ω_2 and ρ_m to be zero, while leaving the other parameters free to adjust. Since both statistics employed take into account the fit of the whole system of equations, they are more powerful than t-statistics in evaluating the role of money in the model. In addition, while the log Bayes factor takes into account potential small sample distortions, the LR test does not.

The joint test for the importance of ω_2 and ρ_m give a stronger role to the stock of money to the model. In all countries, money is statistically important in explaining data fluctuations. The likelihood ratio test strongly rejects the hypothesis that both coefficients are zero, while the Bayes factor is conclusively against this hypothesis except in the US where the evidence only mildy in favor of the hypothesis that money matters. Since the LR test and Schwarz criteria give similar conclusions, small sample biases are unlikely to be important for full sample estimates.

4.3 Subsample evidence

There is considerable evidence that the time series features of output, inflation, nominal rate and money have significantly changed over time and figure 2 confirms, to a large extent, that this is the case in all the countries. Therefore, we have re-estimated the specification allowing both the trend and the cyclical relationships to be varying over time. This exercise, besides allowing us to make stronger statements about the role of money in the four economies, permits us to examine whether time variations in the role of money have any possibility to explain the changes in output and inflation dynamics experienced since the mid 1980s. However, since both the likelihood ratio and the t-tests are considerably biased in small samples, care should be exercised in interpreting the results one obtains.

The second and the third columns of table 1 present estimates of the parameters of interest using the samples 1959:1-1979:4 and 1980:1-2008:2 for the US, the samples 1980:1-1990:4 and 1991:1-2007:4 for Japan, the samples 1970:1-1992:4 and 1993:1-2007:4 for the Euro area, and the samples 1965:1-1992:4 and 1993:1-2008:2 for the UK. The location of the breaks reflect the history of the individual countries: for the US, 1980 was the year when inflation and the nominal rate started declining from their

		Full sample	Sample 1	Sample 2
US	ω_2	-0.5125	24.1444(*,+)	-0.9781
		(0.5226)	(8.1261)	(0.1989)
	ρ_m	1.5814	-0.0363(*)	1.8107
		(0.2964)	(0.2187)	(0.28416)
	LR-test p-value	0.0000	0.0000	0.0000
	Log Bayes factor	4.79	30.24	18.50
Japan	ω_2	-0.2251	1.2148	0.6241(+)
		(0.135)	(0.2093)	(1.1793)
	ρ_m	1.0471	-1.3553	1.0130
		(0.0447)	(0.5408)	(2.5827)
	LR-test p-value	0.0000	0.0090	1.0000
	Log Bayes factor	22.94	0.87	-13.85
EU	ω_2	-1.9986	-0.8097(*,+)	-0.0272
		(1.3404)	(0.2178)	(0.0671)
	ρ_m	0.6695	0.5959	0.8109
		(0.2347)	(0.3828)	(0.6799)
	LR-test p-value	0.0000	1.0000	1.0000
	Log Bayes factor	7.79	-6.50	-8.14
UK	ω_2	0.0535	0.3266	-0.2878
		(2.9466)	(2.8526)	(0.0562)
	ρ_m	1.7168	1.1502	1.1808
		(3.0029)	(3.2265)	(0.3111)
	LR-test p-value	0.0000	1.0000	0.0714
	Log Bayes factor	49.94	-153.37	-1.48

Table 1: Parameter estimates and tests of significance. The LR-test and the Log Bayes factor jointly test $\omega_2 = 0$ and $\rho_m = 0$. The LR-test statistic uses: $2 * (\log L_u - \log L_r)$ and is compared to a $\chi^2(2)$. The log Bayes factor is approximated with $(\log L_u - \log L_r) - 0.5 * (k_u - k_r) * log(T)$ where k_u and k_r are the number of unrestricted and restricted parameters estimated. A '*' indicates that estimates in the two subsamples are significantly different, a '+' that subsample estimates are different from full sample estimates.

peak levels; for the Euro area, the break roughly corresponds to the time when the Maastricht Treaty was implemented and to the beginning of the decline of inflation and the nominal rate from the 1980s levels. For the UK, the break is selected to separate the inflation targeting period from previous monetary policy experiences. Finally, the second subsample in Japan starts in correspondence with the explosion of the land bubble which, by many, was considered the trigger of the so-called "Lost Decade". We a-priori select a break date (and analyze the sensitivity of the estimates moving the break date backward and forward) rather than formally test for breaks for two reasons. Standard break tests are of univariate nature and when applied to the four variables used here do not select a single break date. Therefore, considerable judgment needs to be used also after formal testing. Moreover, since the data does not necessarily fit the assumptions underlying these tests, classical type II errors are likely to make structural estimates problematic. These errors can be in part avoided with the selected strategy.

The structural relationships appear to have changed over time in all the countries; variations are present in the parameters governing the private sector behavior; the monetary policy rule; and the variance of certain shocks. For the parameters regulating the role of money in the economy, conclusions depend on the country considered.

For the US, the coefficient regulating the direct role of money in transmitting fluctuation to output and inflation is significant in both subsamples. Since this coefficient was insignificant in the full sample, time heterogeneities appear to be important. Notice also that the sign and the magnitude of the estimated coefficient depend on the sample: consumption and real balances are complement in the utility function in the pre-1980 sample, but they are substitute in the post-1980 sample. The coefficient regulating the indirect effect of money displays similar variations. It is negative and insignificant in the pre-1980 sample but becomes positive and significant in the post 1980 sample. Since both the LR test and the log Bayes factor suggest that money matters and rejection of the null hypothesis is stronger in the two subsamples than for the full sample, it is reasonable to conjecture that i) the channels through which the stock of money affects output and inflation fluctuations may have changed over time, and ii) full sample estimates provide a misleading picture of the role of money in the US economy.

Money has a marginal role in explaining the fluctuations of output and inflation in Japan in the first sample, with the Bayes factor being inconclusive about the relevance of money in the model. Here, the direct and the indirect effects of money are individually statistically significant and the point estimate of ρ_m is negative. As we have mentioned, a negative value is economically meaningful once it is taken into account that by reacting to nominal balances the central bank may temper a possibly too strong policy reaction to inflation. In the second subsample, estimates of both parameters are smaller and insignificant and both the LR and the Bayes factor give money a rather limited role in the propagating cyclical fluctuations. Since for part of this sample, the nominal interest rate reached the zero bound and the experience of quantitative easing occupies only the last five years of the sample, our empirical results are in line with the conventional wisdom. For our purposes, it is important to emphasize that the role of money has dramatically changed over time also in Japan, making full sample estimates somewhat dubious.

Money does not seem to matter much in the Euro area in the first sample. Here estimates of ω_2 are significant and imply substitutability between consumption and real balances in utility but the overall role of money in the model is rather marginal. In the second subsample, the estimate of the direct effect of money becomes smaller and insignificant, while the estimate of the indirect effect becomes larger but remains insignificant. Overall, the role of money in transmitting fluctuations to output and inflation in the EU is quite small in both subsamples. While the heterogeneity in the structure of the EU economies could be responsible, in part, for the result, it is also true that repeating estimation over the two subsamples using Germany data only marginally affects the conclusions. Hence, while estimates do change over time in a direction consistent with expectations, the overall conclusions seems to be that money has little role in propagating cyclical fluctuations in the Euro area [5]

The UK is the only country where the role of money appears to have increased over time. Estimates of ω_2 and ρ_m are insignificant in the first subsample, while they become significant in the inflation targeting sample. As with the US, the point estimate of ω_2 is positive in the first sample and negative in the second sample; the point estimate of ρ_m is roughly unchanged over time but the standard deviation is considerably smaller in the second subsample. As in the US, subsample estimates are also very different from those obtained in the full sample, indicating the existence of a pattern in the time variations regulating the role of money in Anglo-Saxon countries. Interestingly, the signal that monetary aggregates provide to the Fed and the Bank of England becomes

[5] This result should be contrasted with Barthelemy et al, 2008, who instead find a significant role for money in propagating cyclical fluctuations in the Euro area. Differences could be due to three factors: the model specification is different; the sample they use cut across our two samples and the estimation details are different.

clearer and louder as time went by.

We have examined the sensitivity of the conclusions to changes in the break date in two ways. First, we have moved the break date forward or backward by up to two years and found very little changes in the properties of the estimates. Second, for the EU and Japan we have considered an additional break point in correspondence of the creation of the ECB (1998) and the separation of the Bank of Japan from the Ministry of Finance (1997). While the main features of our conclusions remain, point estimates turn out to be very imprecise due to the small size of the last two samples.

In sum, while not uniform across countries and time periods, the evidence suggests that money matters in shaping monetary business cycles or, more mildly, that matters more than the literature is willing to assume. Since statistical significance does not necessarily imply large distortions when interpreting the evidence, designing optimal policies, or conducting conditional forecasting exercises, section 5 examines the economic relevance of our findings.

4.4 Discussion

A few important points can be made from the estimates we have obtained. First, money matters for output and inflation fluctuations, because it affects the marginal rate of substitution between consumption and leisure and creates a time varying wedge between consumption and output. The complementarity between consumption and real balances in the utility found, for example, in the US and in Japan in the pre-1980 sample, it is easily reconcilable with models where money has a transaction role. The substitutability we have found in some countries and time periods, for example the US and the UK in the second subsample, indicates that money has instead a store-of-value role and is consistent with the segmented market approach of Alvarez et al. (2001). In that setup, only a fraction of consumers have access to asset markets and the limited participation constrain implies that real balances become a proxy for future consumption, making real balances substitutable with current consumption.

It is worth also mentioning that a negative ω_2 could be generated with a utility function of the form $\frac{c_t^{1-\sigma_c}}{1-\sigma_c}\frac{m_t^{1-\sigma_m}}{1-\sigma_m}$ with $\sigma_m > 1$ and a strong concavity of the utility function with respect to real balances. With this utility function, a shock that increases inflation increases the the nominal rate as well, leading to a fall in the money demand. Since consumption and real balances are substitute, consumption rises and leisure fall. Hence work effort and output increase.

Recall that our model restricts real balances to enter with the same coefficient in the Euler equation and the Phillips curve. Therefore, an alternative explanation for the substitutability between real balances and consumption comes from looking at the role that money may have in the determination of marginal costs. When firms face a cash-in-advance or a working capital constraint, the production function can be written as a function of labor and real balances (as e.g. in Benhabib and Farmer (2000)). Hence, if real balances become an input in the production process, they can contribute to the marginal costs. Future work in the area should try to disentangle alternative explanations for the substitutability between consumption and real balances in utility since they provide alternative views about the mechanics of transmission in monetary economies. The switch in the sign of ω_2 we have obtained across subsamples in some countries also deserves careful scrutiny since it may indicate interesting changes in the way the economy works.

Second, money also matters in the economy because variations of the growth rate of the nominal quantity of money alter the equilibrium interest rate, which is a crucial determinant of output and inflation fluctuations. As far as we know, the typical Taylor rules nowadays estimated in the literature do not include the growth rate of nominal balance among the regressors. Since reacting to nominal balances is also, indirectly, a way to react to inflation, it is likely that, in typical rules neglecting money, the inflation coefficient is biasedly estimated and the richness of second round dynamics due to money muffled. Given the estimated effects are typically important in all countries, analyzing monetary policy rules leaving money out of the model may have important repercussions for the interpretation of the evidence.

Taken together these two observations indicate that the IS channel it is not necessarily the main mechanism through which monetary policy affects the economy. The two additional channels the model possesses constitute alternative and unexplored mechanisms through which a larger portion of the cyclical fluctuations present in the data could be accounted for.

Third, perhaps more interestingly from a policy point of view, money is important not only in the 1970s and 1980s, when central banks were explicitly or implicitly employing the growth rate of nominal aggregates as the main indicator for monetary policy decisions, but also nowadays, when the dynamics of monetary aggregates are hardly mentioned by Federal Reserve officials and the inflation targeting rhetoric has moved monetary aggregates to the back burner of the policy discussion. Below we investigate whether this effect could be spuriously due to the fact that certain variables are measured with error and/or the model omits features that could be important for output and inflation fluctuations.

Fourth, although the estimates obtained indicate that real balances play an important coincident indicator role for output and inflation fluctuations in three countries, one should be careful in translating such evidence into a statement concerning the use of real (or nominal) balances in unconditional forecasting regressions of output and inflation. The model used is stylized and, for forecasting purposes, it is not as successful as time series specifications which leave real or nominal money out. Thus, our results should be interpreted as giving money a conditional role. That is, conditional on this model, giving or not giving money a role may lead to different policy conclusions. Section 5 investigates to what extent this is the case.

Fifth, our results for the US stand in contrast with the findings of Ireland, 2004, who estimated ω_2 to be positive and insignificant using post 1980 data (and set ρ_m identically to zero). There are a few reasons which may account for the differences: the model specification is slightly different - we use a model with consumption habit, while Ireland's model does not - and the sample is slightly longer. Table 2 shows that in the longer sample, setting $h = \rho_m = 0$ recovers Ireland results (see the last column) [6].

However, the likelihood of this specification is considerably smaller than the likelihood of our basic setup and conditioning on not having nominal balances growth in the interest rate rule makes it more likely that ω_2 is small and insignificant. Thus, to properly measure the role of money in the economy one needs to jointly consider the direct and the indirect effects of money. Without the latter the likelihood function is twisted in the direction of giving money no direct role [7].

Finally, one should mention that in almost all the specifications we have estimated (across countries and time period) estimates of ψ are significant. If we treat θ, the elasticity of substitution between varieties fixed in the estimation and calibrate it to a standard value, one can conclude that the costs of adjusting prices are important. Therefore, some nominal rigidities are necessary to understand the mechanics of trans-

[6] Since Ireland forces ω_2 to be positive, and the ML estimate is negative, is not surprising that he concludes that money does not matter. The estimates presented in the last column mimic Ireland's result in the sense that a confidence interval of standard length would include the zero value.

[7] One should also mention that, during the search with US data, we have encountered one or more local peaks where estimates of the effect of real balances in the Euler equation and the Phillips curve is indeed positive and small and the growth rate of nominal balances is marginally insignificant in the interest rule. Hence, the procedure employed to maximize the function is important to deliver proper conclusions and the strategy outlined in section 3 helps in locating where its global maximum is.

	Basic	$\omega_2 = 0$	$\rho_m = 0$	$\Omega_2 = h = 0$	$\rho_m = h = 0$
ω_2	-0.9781	0.0000	-0.1441	0.000	-0.198
	(0.198)		(0.1940)		(0.181)
ρ_m	1.810	1.875	0.000	1.852	0.000
	(0.284)	(0.278)		(0.283)	
$\log L$	1589.29	1578.41	1562.75	1573.87	1569.21

Table 2: Comparison with Ireland (2004), US, 1980:1-2008:2.

mission of shocks and a flexible price model where money has a role appears to be insufficient to account for the richness of the cross country and cross time evidence.

4.5 Does money stand-in for something else?

It is not difficult to argue that a small scale model is likely to be only an approximation to the true DGP of the data, making estimates of ω_2 and ρ_m hard to interpret. Is it possible that money truly does not matter but it is significant in our specifications because it captures influences omitted from the model? Could it be possible that switches in the importance of money over time comes from the fact that in certain samples, nominal balances proxy for exchange rates, credit, oil or even asset prices, all of which enter the determination of the nominal interest rate? To properly answer these questions a much more complicated model ought to be developed and one needs to understand under what conditions money may capture effects which are due the potential omission of these factors. Such an investigation is beyond the scope of this paper, but one can guess that a very complex set of circumstances is needed to make nominal balances proxying for certain variables in one sample but not in another one.

Here we are concerned with the much modest task of clarifying some doubts raised by commentators about the role played by real balances in the model. To do this we repeat estimation substituting M2 with different monetary aggregates and add features or variables to the model. Because of data limitations, these sensitivity checks are limited to the US, but we do not have reasons to believe that the data of other countries will behave differently.

We conduct a number of exercises. First, we use M1 or M0 in place of M2. If the effects of money are due to interest bearing assets or time deposits, they should

	M2	M1	M0	Credit	SP500	House Prices	Oil
ω_2	-0.9781	-0.9454	-1.0499	-1.1056	0.3817	0.1307	0.1986
	(0.1989)	(0.2646)	(0.2976)	(0.4825)	(0.3546)	(0.0895)	(1.5340)
ρ_m	1.8107	0.8487	1.7138	1.1908	0.9229	2.0508	1.8687
	(0.2816)	(0.2186)	(0.2946)	(0.1874)	(0.1986)	(0.4496)	(3.1508)
$\log L$	1589.93	1516.48	1456.78	1514.66	1704.94	1869.09	1438.36

Table 3: Robustness checks, US sample 2

be eliminated when smaller monetary aggregates are used in the estimation. Second, we use total consumer credit outstanding in place of M2. If the outside component of monetary aggregates matters more than the inside component, one should observe significant changes in the estimates. Third, we allow oil to enter the production function, following Nakov and Pescatori, 2007, and assume an exogenous process for the price of oil. The resulting specification implies that, in addition to the standard arguments appearing in (9), the Phillips curve also depends on the oil price variable (since it is a component of marginal costs). If money stands-in for oil, the significant effects we have found should disappear in this specification. Finally, we add stock price growth or house price growth to the interest rule and close the model assuming an exogenous process for these prices. If nominal money growth proxies for these omitted factors, ρ_m should become insignificant when these variables are allowed in the specification.

Table 3 indicates that changing the monetary aggregate used has little effects on the estimates of ω_2 and ρ_m: both coefficients remain significant in all the specifications. Hence, it is unlikely that the results are driven by the presence of interest bearing assets in the monetary aggregates. Furthermore, the inside and the outside component of money play a similar role. Results appear to change somewhat when asset prices are added to the Taylor rule. In this case point estimates of ω_2 become positive but statistically insignificant, while estimates of ρ_m remain statistically significant and economically important. Thus, the direct role of money could be alternatively captured by inserting asset prices in the interest rate rule, a result which is again consistent with the idea that asset markets could be segmented. Finally, when we add oil to the model, estimates of both parameters become insignificant. However, the noise that the oil variable adds is large and estimates of many crucial structural parameters, such as the habit coefficient, the output elasticity and the interest semi-elasticity of money demand become insignificant. We conjecture that the large swing in oil prices at the end of the sample, which are unrelated to the economic conditions of the four economies, combined with a small sample is responsible for this outcome. In fact, when the full sample is used, having or not having oil to the model does not change either the magnitude or the significance of the two relevant parameters.

In sum, our analysis confirms the earlier conclusion. Money is important to explain output and inflation fluctuations on its own and not because it proxies for standard omitted suspects.

5 The economic relevance of money

The evidence so far collected indicates that money statistically matters. But, is money economically important? In other words, can we safely neglect money when studying domestic business cycles and designing optimal monetary policies?

To study whether the omission of money from the model is crucial for understanding certain economic phenomena, we first present responses to the four shocks for the US in the sample 1959-1979, when money is allowed to play a role and when it does not (i.e. ω_2 and ρ_m are identically set to zero). This sample/country combination is chosen since it could tell us something about the causes of the Great Inflation of the 1970s.

There are important differences in the responses to the shocks in the two specifications. For example, technology shocks have different effects on output and inflation and an interest rate disturbance induces more persistent output and inflation fluctuations in a model with money. In addition, while in response to contractionary interest shocks output falls in both specifications, inflation instantaneously fall when money matters and it is instantaneously unchanged when money does not matter. Hence, a VAR specification where interest rate is instantaneously causally prior to inflation is consistent with the evidence obtained in a model without but not with money. Finally, while interest rate shocks do not induce liquidity effects in any specifications (real balances positively comove with the nominal rate), money demand shocks have this feature in a model with money.

One important aspect of figure 2 is not affected by the role given to money in the model: inflation in the 1970s is not a monetary phenomena. Technology shocks, in fact, dominate the forecast error variance of inflation at the 5 year horizon in both specifications (they explain 94 percent of the forecast error variance of inflation when money matters and 92 percent when money does not matter). The contribution of both money demand and interest rate shocks is instead negligible.

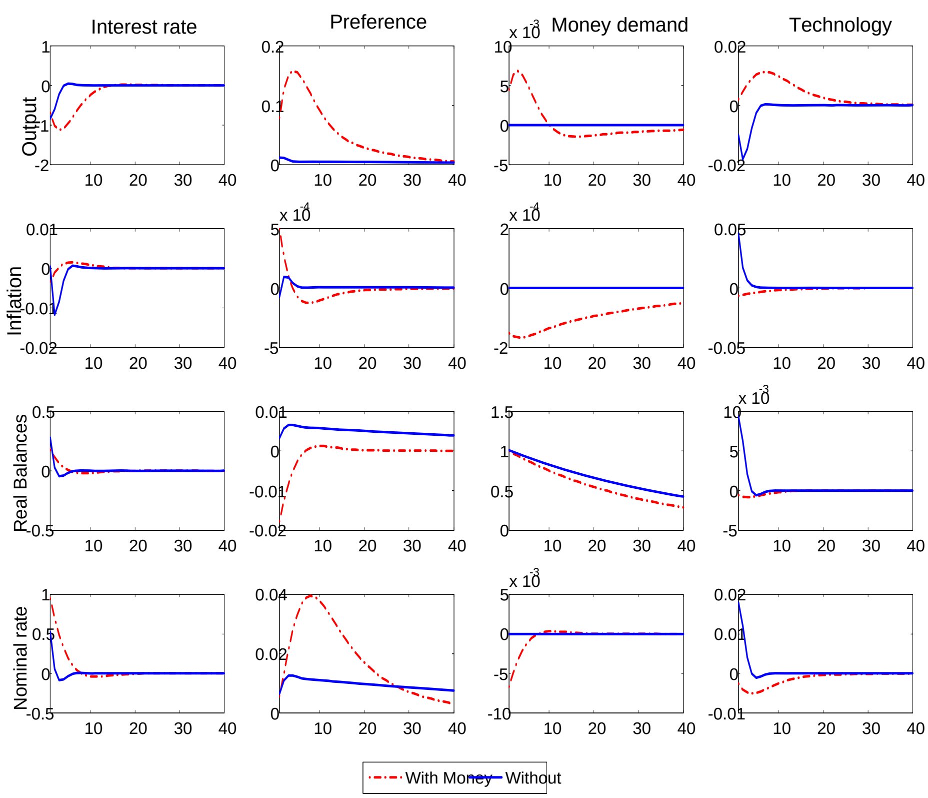

Figure 3: Responses to shocks US, 1959-1979

Distortions are obtained in interpreting the evidence in other instances. For illustration, we consider two. First, we study source of inflation variability in Japan in the pre-1990 sample. In a model without money, the five year ahead forecast error variance of inflation is due primarily to technology shocks (92 percent); in a model with money money, demand shocks have the dominant role (69 percent). This difference could be due to two reasons: the size of the shocks is different in the two specifications; the transmission mechanism of various shocks is altered. The relative variance of technology shocks is indeed different in the two specifications. However, it is the transmission of money demand shocks which is mainly altered: when money is not allowed to matter, money demand shocks have no effect on inflation at any horizon and their effect is spuriously captured by technology and preference shocks.

Second, we have computed a historical decomposition of UK output in the second subsample and examined which factors have contributed most to the recovery following the deep recession of the early 1990s. To do this, the model is estimated with data up to 1992:4 and the sequence of one-step ahead forecast errors is computed for the next 10 years using the Kalman filter. These errors are then decomposed into the component attributable to each of the four structural shocks. Figure 3 plots the time path of these forecast errors due to each structural shock, when money has a role (left panel) and when it does not have one (right panel).

Clearly, the two panels interpret the experience differently. The contribution of policy shocks is roughly unchanged in the two specifications, but in a model without money, the contribution of technology and money demand shocks is negligible over the entire forecasting horizon. Hence, the model without money makes the predictable component of output absorb the contribution of these shocks; that is, researchers would infer that most of the post 1992 output recovery in the UK was predictable. Including money in the model instead tell us that unexpected variations play a larger role and that technology and interest rate shocks almost equally contribute to make output recover in the first 3-4 years of the sample.

Finally, we want to see to what extent a specification with money is better endowed than the alternative one without money in interpreting the time profile of output and inflation volatility and persistence observed in the US over the last 40 years. As mentioned in section 2 variations over time in ω_2 and ρ_m do affect these unconditional moments. Here we are interested in examining whether the interpretation of the episode is also different.

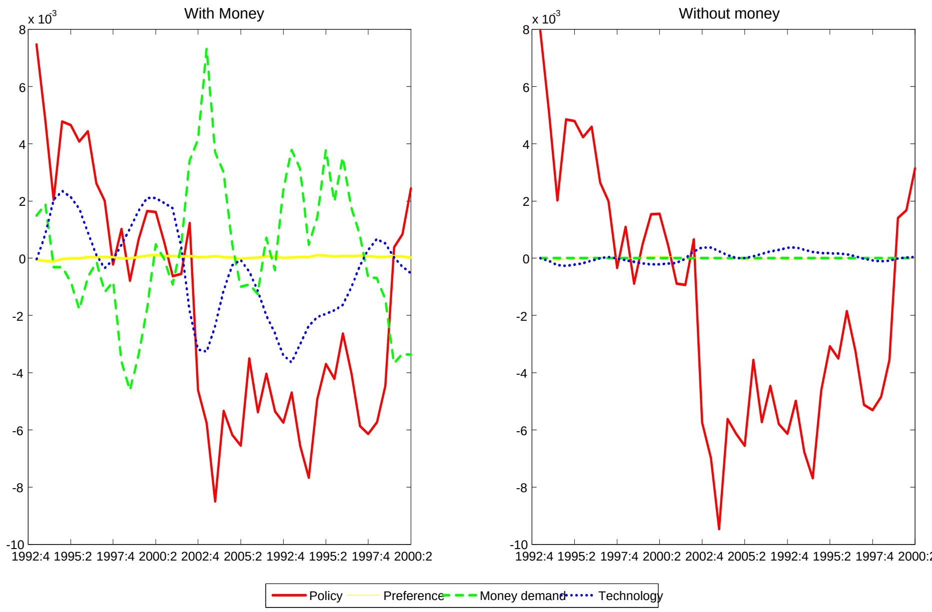

Figure 4: One step ahead historical decomposition of UK output

When analyzing how certain features of the model affect important functions of the data, it is typical to conduct counterfactuals where, for example, part of the parameters are changed and others are kept fixed at some values. Such a procedure is clearly inappropriate when parameters are jointly estimated with system-wide methods. There is in fact a correlation structure among estimates and if some parameters are changed, the remaining parameters must be adjusted using the estimated covariance matrix. Furthermore, the alternative values that are selected may be "unreasonable" or highly unlikely from the point of view of the sample under consideration, making the results difficult to interpret. Both of these problems are absent if one compares, as we do here, a specification where all parameters are unrestrictedly estimated with anther where both ω_2 and ρ_m are set to zero and the remaining parameters free to adjust.

Table 4 indicates that the model with money captures both the decline in the volatility of output and inflation and in the persistence of inflation across the two subsamples. Apart from changes in ω_2 and ρ_m, the parameters that change most across subsamples are ψ, which increases from 0.0009 to 2.03, h which falls from 0.88 to 0.14, ρ_π which increases from 2.15 to 6.07 and the standard deviation of the technology shock which falls from 0.49 to 0.02. Hence, the so-called Great Moderation episode is due

	With Money		Without Money	
	Sample 1	Sample 2	Sample 1	Sample2
Output volatility	21.84	8.14	3.73	3.21
Inflation volatility	1.21	0.68	0.37	0.56
Inflation persistence	0.99	0.72	0.71	0.78
ψ	0.0009	2.0342	0.1065	0.1071
h	0.8846	0.1469	0.9410	0.9574
ρ_r	0.8080	0.6284	0.5441	0.7268
ρ_π	2.1510	6.0769	2.5050	5.4809
σ_z	0.4911	0.0029	0.0125	0.0072

Table 4: Volatility is measured by the standard deviation of the variables computed using the solution of the model at the parameter estimates. Sample 1 goes from 1959:1 to 1979:4 and sample 2 from 1980:1-2008:2.

to a number of reasons: the parameters regulating private sector decisions change, the parameters of the interest rate rule are altered and the variability of at least one shock falls. The model without money produces a fall in output volatility across subsamples, but fails to capture the reduction in the volatility and the persistence of inflation. Here the only parameters that significantly changes across specifications is the interest rate smoothness parameter ρ_m and the inflation coefficient ρ_π, both of which increase. Thus, giving money a role in the model allow to fit the time variations in moments of the inflation process better.

6 Conclusions

The role that money has in shaping monetary business cycles is a crucial but insufficiently investigated issue within the class of models nowadays used in academic discussions and policy analyses. To fill the gap, this paper investigates a number of questions using a small scale model where money plays a somewhat reduced form role and its parameters estimated by maximum likelihood. We refrain from using a-priori restrictions on the parameter space to make the information content of the data and its ability to distinguish theoretical specifications as transparent as possible.

Our results bring new light in several dimensions. We show that money is statistically important for domestic fluctuations in output and inflation. Depending on the country and the time period, money may matters directly, by affecting Euler equation and the Phillips curve, indirectly, by influencing the determination of nominal interest rate, or both. We also document that the role of money is changing over time, both in the sense that estimates change magnitude and significance and that different channels become important. Since money does not stand-in for standard omitted suspects and since alternative monetary aggregate give similar conclusions, specification and measurement problems are unlikely to be crucial in delivering results. Overall, our estimates suggest that liquidity premia have limited importance and highlight the presence of time varying wedge between consumption and output. This wedge could be influenced by the money stock, for example, because of asset market segmentation or participation constraints. Our estimates are also consistent with the idea that balance sheet effects, working though either working capital requirements or direct credit constraints, affect the determination of marginal costs and the link between marginal costs and the output gap. Finally, we show that the interpretation of the evidence may be distorted when money is not allowed to play a role in the model. Researchers could mistakenly interpret the pattern of impulse responses; erroneously measure the causes of inflation volatility and the reasons for output fluctuations; and they would have hard time to account for the fall in inflation variability and persistence that the US has experienced over the last 40 years if money is excluded from the model.

While our investigation delivers sharp conclusions, more works needs to be done to understand better the role that money may have in various economies. As we have mentioned, the specification used is consistent with several "structural" interpretations of money and disentangling them is crucial for policy purposes. Does money matter because balance sheet effects are important or because working capital requirements bind? Is asset segmentation a relevant feature of industrialized economies? Furthermore, our evidence is consistent with different channels being important at different point in time. Why this is the case? What kind of institutional changes are necessary to alter the channels through which money matter? Does financial market liberalizations, both within and across countries, have anything to do with what we observe? We plan to study these issues in future work.

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