Estimating the Evolution of Money's Role in the U.S. Monetary Business Cycle

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Abstract

Is money's role relevant to describing the post-WWII U.S. macroeconomic dynamics? Has this relevance changed over time? These questions are answered using both fixed-coefficient and rolling-window Bayesian estimations of a structural model of the business cycle with money. Our empirical evidence favors a specification with drifing parameters for money-consumption nonseparability and the Federal Reserve's reaction to nominal money growth. The role of money is estimated to have been important during the 1970s and declined afterwards. The omission of money produces severely distorted impulse response functions (relative to the model with money). Money is found to be important in replicating the U.S. output volatility during the Great Inflation. These results are shown to depend on the definition of the monetary aggregate employed in our analysis.

Keywords: Money in new-Keynesian frameworks, time-varying effects, Bayesian structural estimations, Taylor rules.

JEL classification: E31, E51, E52

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1 Introduction

This paper asks two questions: i) Is money's role relevant to describing the U.S. macroeconomic dynamics?[1] ii) Has this relevance changed over time?

The answer to the first question is shown to depend on the empirical strategy implemented by the econometrician. Fixed-coefficient estimation of a structural new-Keynesian model with money finds a significant role for portfolio adjustment costs in the post-WWII U.S. sample. By contrast, no evidence supporting nonseparability and the Federal Reserve's reaction to money growth is detected. Alternatively, rolling-window estimations reveal the role played by nonseparability and money growth in the Federal Reserve's policy rule. However, this role appears to be prominent in the 1970s, but tends to vanish as observations of the 1980s and 1990s are considered in the estimation. We confirm the time-varying nature of money's role in the U.S. monetary business cycle via two different exercises. First, impulse response functions conditional on the Great Inflation period and produced using a model with money are substantially different from those computed with a standard new-Keynesian model without money. By contrast, an impulse response comparison conditional on the Great Moderation period reveals no appreciable differences. Second, the instabilities in the estimated parameters turn out to be of key importance in replicating the fall in inflation and output volatilities occurred in the 1980s and 1990s. By contrast, fixed-coefficient models are ill-equipped to describe the Great Moderation. Importantly, we show that the model with money has an edge (over the standard new-Keynesian framework) in replicating the U.S. output volatility of the 1970s. This result is important, because it supports money as a

[1] 'Money's role' in this paper refers to the incremental information in money given standard variables. In standard New Keynesian models, money has a role in the sense that different sequences for the money stock imply different sequences for the policy rate, thus different paths for output and inflation. Nevertheless, money may typically have no role in the sense that monetary aggregates provide no information on output and inflation conditional on interest rates. For a discussion on this distinction, see Ireland (2004).

relevant variable for the description of the evolution of the U.S. output. We also note that the relevance of portfolio adjustment costs, which suggest a role for money as a leading indicator of the real natural interest rate (Andrés, López-Salido, and Nelson (2009)), is estimated to be fairly stable over time. Moreover, we find evidence in favor of the time-dependence of other 'structural' parameters, a notable example being the degree of habit formation. Such time dependence may be interpreted as time-varying preferences by American households, or as evidence in favor of breaks due to e.g. financial innovations. To summarize, our empirical findings i) support the role of money for the description of the U.S. business cycle, and ii) suggest that such role has varied over time.

Our results are shown to depend on the measure of money employed in our empirical exercise. If the monetary base is used (instead of the broader M2 aggregate employed in our benchmark exercises), the evidence in favor of nonseparability in the 1970s, the instability of the degree of habit formation, and the superiority of the model with money in replicating the volatility of output of the 1970s just disappear. This result suggests that the money multiplier is likely to play a big role in accounting for our results. Arguably, our estimated 'structural' parameters are functions of this money multiplier. Therefore, the instability of the estimated parameters could be due to the time-varying role played by financial frictions in the United States. Interestingly, when estimating our DSGE model with M2 and the monetary base jointly, we find results very similar to those obtained with the employment of M2 only. Therefore, we assign a higher weight to the set of findings obtained with a broad monetary aggregate.

The motivation of this paper is the following. Modern monetary New-Keynesian models of the business cycle typically consider money to be a 'sideshow', i.e. the equilibrium values of inflation and output are determined without any reference to the stock of money.[2] In fact, a variety of recent empirical studies challenge this view. Single-equation estimations supporting the role of money in explaining inflation and/or output for the U.S. are provided by Koenig (1990), Meltzer (2001), Nelson (2002), Hafer, Haslag, and Jones (2007), Reynard (2007), Hafer and Jones (2008), and D'Agostino and Surico (2009). Canova and de Nicoló (2002), Leeper and Roush (2003), Sims and Zha (2006), and Favara and Giordani (2009) employ multivariate SVARs models and find that 'LM' shocks trigger significant effects on prices and the business cycle. Also in light of the recent liquidity easing implemented by a variety of central banks in the attempt to tackle the real effects of the financial turmoil, a reconsideration of the role of money in monetary policy frameworks is clearly warranted.

A point of departure from the studies cited above is that this paper estimates a *structural* DSGE monetary model of the business cycle in which money is allowed, but not necessarily required, to play a relevant role. In our model, money may exert 'nonseparability', 'direct', and 'policy' effects. Preferences for nonseparability between consumption and real balances affect intratemporal choices, the real wage (via labor supply) and, consequently, marginal costs and inflation. Nonseparability also affects households' intertemporal rate of substitution of consumption, thus modifying the Euler equation for output (Ireland (2004)). The direct effect arises when portfolio adjustment costs, which are modeled as a direct loss of agents' utility, are present. Portfolio adjustment costs give rise to a lag and enhance the role of expectations in the money demand equation, thus making it dynamic. Moreover, they relate movements in contemporaneous real balances to future realizations of the natural real interest rate, thus assigning a role to money at low frequencies (Nelson (2002)). Finally, the policy effect refers to policymakers' systematic reaction to the growth rate of nominal money. Such a reaction may be welfare-enhancing if money concurs in determining the equilibrium

[2] For a detailed exposition of the New-Keynesian monetary policy model of the business cycle, see King (2000) and Woodford (2003).

values of inflation and output, and/or can be justified with money growth targeting *per se* (Svensson (1999)).

As indicated above, our exercise is designed to detect the possibly *time-varying* role played by money in shaping the post-WWII U.S. macroeconomic dynamics. Indeed, preferences over money-consumption nonseparability may very well be unstable over time. Structural relationships involving money and the natural interest rate are likely to have been affected by financial innovations. A drifting emphasis on monetary aggregates by the FOMC may have taken place in the course of moving from the Great Inflation to a more stable macroeconomic environment. Accounting for the possibly *evolving* role played by money is then of crucial importance to achieving a correct identification of the drivers of U.S. inflation and output. We tackle this issue by recursively estimating a small scale new-Keynesian DSGE model with Bayesian techniques. This methodology enables us to investigate parameter instabilities without appealing to the combination of perturbation methods/particle filter recently proposed by Fernández-Villaverde and Rubio-Ramírez (2007). While being potentially very powerful and econometrically neat, their methodology forces the econometrician to stick to a limited number of time-varying parameters. In contrast, rolling-window estimation accounts for instabilities in (possibly) *all* the estimated parameters. Moreover, with respect to a more standard subsample analysis, the rolling-window approach does not require any *a priori* specifications of the break-dates. To be clear, this comes at the cost of abstracting from the role that drifting parameters may play in influencing agents' expectations. In other words, given that each window is estimated independently, agents are assumed to have neither memory of the past windows nor the ability to use past and current information on parameters' drifts to form expectations on the future evolution of the economy. We see our approach as complementary to other estimation strategies (e.g. those based on the particle filter). To our knowledge, this paper represents the first exploration concerning parameter instabilities in a small scale DSGE model with money.

Before moving to the next Section, we note connections with some closely related studies in the literature. Working with a microfounded new-Keynesian framework, Ireland's (2004) seminal paper relaxes the typically imposed nonseparability assumption by allowing the cross-derivative of the utility function with respect to consumption and real balances to be non-zero. Dealing with 1980s and 1990s U.S. data, he cannot reject the null of separability, and concludes that the role of money, if any, is negligible. With a richer model embedding habit formation and a systematic reaction of the Fed to money, Canova and Menz (2011) perform an international analysis involving the U.S., the U.K., the Euro area, and Japan, and find support for nonseparability in these countries. Andrés, López-Salido, and Vallés (2006) consider a model with habit formation and price indexation, and confirm Ireland's (2004) results with Euro-data. Andrés, López-Salido, and Nelson (2009) find empirical support in favor of portfolio adjustment costs for the U.S. and the Euro Area with a model encompassing Andrés et al's (2006). This evidence is important, because it suggests a role for money in anticipating future variations in the natural interest rate. Similar evidence is obtained by Benati (2010). Arestis, Chortareas, and Tsoukalas (2010) show that money sharpens the estimate of the U.S. potential output in a structural DSGE framework, and that of the monetary policy shock in small-scale SVARs.

There are several differences between these studies and ours. Firstly, our investigation is designed to detect the possible instability of money's role over time. Secondly, in conducting our analysis we employ Bayesian techniques. These techniques allow for model comparison even in the case of misspecified models (An and Schorfheide (2007) and Canova (2007)), which is a likely scenario when dealing with small-scale DSGE models (for a comparison between Bayesian techniques and alternatives, see Canova and Sala (2009)). Finally, in our investigation we employ the model recently put forward by Andrés, López-Salido, and Nelson (2009), which encompasses most of the previously scrutinized frameworks. Methodologically, our analysis is very similar to the one proposed by Canova (2009), who explores instabilities in the post-WWII U.S. sample with a small-scale DSGE model in which, by assumption, money does not play any active role.

The structure of the paper is as follows. Section 2 presents the new-Keynesian monetary policy framework with money on which we focus when conducting our empirical analysis. Section 3 discusses our estimation strategy. Section 4 documents and interprets our empirical results. Section 5 concludes.

2 A sticky-price New-Keynesian model with money

We work with the DSGE model with money recently proposed by Andrés, López-Salido, and Nelson (2009). The main nonlinear equations formalizing households' problem, firms' production function and price setting, and the market clearing conditions are collected in Table 1. Table 2 collects the log-linearized optimality conditions of the model. Eq. (1) is a Euler equation for consumption obtained with the imposition of the aggregate resource constraint. It displays leads and lags of real GDP because of households' rational expectations and habit formation. Notably, in the case of non-separability, i.e. $\psi_2 \neq 0$, real balances enter the aggregate demand schedule both in current and expected terms because of their impact on consumption's marginal utility. The impact of real balances on output is magnified by habit formation in consumption owing to the link between current real balances and lagged consumption. Eq. (2) is a Phillips curve (NKPC) enriched with real balances which enter firms' marginal costs (defined by eq. (3)), the forcing variable capturing the demand push on prices. Again, the pressure exerted by real balances, operative only under $\psi_2 \neq 0$, is magnified by habit formation. The presence of money in firms' marginal costs is due to the effect exerted by real balances on households' labor supply decisions and, consequently, on real wages. An alternative interpretation of money in the NKPC is the cost-channel (Ravenna and Walsh (2006)), with money acting as a proxy for banks' lending rate. Importantly, the log-linearized first order conditions feature real balances in deviation from the money demand shock $\widehat{e}_t$, which is modeled as a structural disturbance affecting the households' demand for real balances. When a money demand shock hits, real balances move according to the money demand equation (4), but the Fed may neutralize the effect exerted on the short-term policy rate by varying money supply to keep the federal funds rate target constant. Consequently, real balances may move as a reflection of a monetary policy that stabilizes output and inflation. One must therefore take into account fluctuations of real money *on top of* those engineered to absorb money demand shocks. Eq. (4) is a dynamic money demand equation featuring the presence of output leads and lags as well as the contemporaneous opportunity cost of holding money and future expected real balances. Interestingly, the money demand equation remains dynamic even under separability, i.e. $\psi_2 = 0$, as long as portfolio adjustment costs affect households' utility, i.e. $\delta_0 > 0$.[3] In this case, money enters neither the IS curve nor the NKPC, and impulse responses of output and inflation to a money demand shock are flat (as long as the systematic reaction of the policymakers to money growth $\rho_\mu = 0$). Crucially, however, real balances act as leading indicators of future movements of the natural real interest rate, possibly interpretable as long-term rates (Nelson (2002)). In other words, there is a 'direct effect' of the stock of money as stressed by Andrés, López-Salido, and Nelson (2009). Eq. (5) models policymakers'

[3] As pointed out by Nelson (2002) and Andrés, López-Salido, and Nelson (2009), a forward-looking money demand term would appear also if we modeled portfolio adjustment costs in terms of nominal balances. But real balances, besides offering algebraic convenience, capture the notion that portfolio adjustment costs are not literally transaction costs, but instead capture the convenience of maintaining, *ceteris paribus*, some purchasing power in the form of money, e.g., as a 'reserve against contingencies'.

decisions with an augmented Taylor rule embedding the nominal growth rate of money (defined in equation (6)) among its arguments. A similar rule has been estimated by Ireland (2001), Sims and Zha (2006), Andrés, López-Salido, and Nelson (2009), and Canova and Menz (2011). We postpone a discussion on this rule to Section 4.2. We close the model with the four stochastic processes (7), which load (respectively) the shocks to household's preferences ε_{a_t}, money demand ε_{e_t}, technology ε_{z_t}, and monetary policy ε_{r_t}. These shocks are assumed to be mutually and serially uncorrelated.

To summarize, money's role in the business cycle may be due, in this model, to i) nonseparability between consumption and real balances, with real balances entering the NKPC and IS schedules; ii) portfolio adjustment costs, which create a link between real balances and the natural real interest rate; and iii) the interplay between money demand shocks and the policy rule.

3 Empirical strategy

This Section presents the methodology and the data source and treatment related to our empirical exercise.

3.1 Methodology

We conduct our econometric analysis as follows. As a benchmark exercise, we estimate the model (1)-(7) over the whole 1966:I-2007:II sample with a fixed-coefficient strategy. This enables us to compare our results with those already present in the literature, which hinge upon the assumption of stability of the structural parameters. We then move to the investigation of the possible instabilities affecting this model's relationships by implementing a rolling-window approach. In particular, we start from the 1966:I-1982:IV window and estimate the model, then we move the first and last observation of the window by four years and repeat the estimation. We keep the size of the window fixed (at 16 years) to minimize the differences in the precision of our estimates due to the sample-size. Our last window covers 1990:I-2006:IV, i.e. we consider seven different windows, which enable us to assess seven different posterior densities for all the parameters of interest.

As anticipated in the Introduction, we estimate the model with Bayesian techniques. We impose dogmatic priors on a subset of parameters. We set the discount factor β to 0.9925, corresponding to an annual steady-state real rate of approximately 3%, and we calibrate the gross steady-state quarterly nominal interest rate $\overline{r}$ to 1.0138. Both values are in line with Smets and Wouters' (2007) estimates. We also fix the capital-output elasticity α to 1/3 and the elasticity of substitution between goods ε to 6 (which implies a price markup equal to 1.2), i.e. a very standard calibration.

We assume prior densities for the remaining 20 parameters. As previously stressed, ψ_2, ρ_μ, and δ_0 are key-parameters in this study.[4] As far as nonseparability is concerned, we assume $\psi_2 \sim N(0, 0.5)$, i.e. a zero-mean, symmetric distribution (we indicate mean and standard deviation in brackets). The prior mean is centered on the value obtained by Andrés, López-Salido, and Vallés (2006) and Andrés, López-Salido, and Nelson (2009), and it lies between the maximum likelihood point estimate of Ireland (2001) - i.e. -0.0199 - and his calibration of the same parameter - i.e. 0.25. As for the Federal Reserve's reaction to nominal money growth fluctuations, we assume $\rho_\mu \sim Gamma(0.8, 0.4)$, a diffuse prior centered at the point estimate obtained by Ireland (2001) and statistically in line with that proposed by Andrés, López-Salido, and Nelson (2009). Notice that we do not discard *a priori* the scenarios featuring $\psi_2 = 0$ (separable utility function) and/or $\rho_\mu = 0$ (no reaction of the Fed to fluctuations in the money

[4] In fact, ψ_1, ψ_2, γ_1, and γ_2 are also convolutions of deep parameters. However, one would need to specify the exact form of the nonseparability between consumption and real balances to pin down ψ_1 and ψ_2, a step that might bias our estimates in the case of wrong specification of the utility function. Moreover, γ_1 and γ_2 have a clear interpretation as elasticity and semi-elasticity of money demand with respect to real GDP and the nominal interest rate. Following Ireland (2001) and (2004), Andrés et al (2006), and Andrés et al (2009), we treat ψ_1, ψ_2, γ_1, and γ_2 as free parameters.

growth rate). In terms of portfolio adjustment costs, we assume $\delta_0 \sim Gamma(6, 2.85)$, i.e. a prior whose mean is very close to the point estimate by Andrés, López-Salido, and Nelson (2009), and whose variance is large enough for the data to 'reject' the relevance of adjustment costs if that is the case. As for the parameter ψ_1, which regulates the impact of money on inflation and output in case of nonseparability, we assume a $Gamma(0.8, 0.1)$, which is consistent with the calibration by Ireland (2004). As regards money demand elasticities, we assume $\gamma_1 \sim Gamma(0.5, 0.25)$ (elasticity to output) and $\gamma_2 \sim Gamma(0.2, 0.15)$ (semi-elasticity to the nominal interest rate), thus aligning with the estimates proposed by Ball (2001).[5] Table 3 collects these and the remaining priors, which are very standard. Finally, c and d, which are parameters characterizing the portfolio adjustment costs δ_0, are not separately identified. Therefore, we set $c = 1$ and estimate δ_0 directly as in Andrés, López-Salido, and Nelson (2009).

We estimate the posterior distribution of the model as follows. Given the vector of parameters $\xi = [\beta, \alpha, \overline{r}, \varepsilon, \psi_1, \psi_2, h, \gamma_1, \gamma_2, \theta, \omega, \varphi, \rho_R, \delta_0, \rho_y, \rho_\pi, \rho_\mu, \rho_a, \rho_e, \rho_z, \sigma_a, \sigma_e, \sigma_z, \sigma_r]'$, endogenous variables $z_t = [\widehat{y}_t, \widehat{r}_t, \widehat{\pi}_t, \widehat{m}_t]'$, exogenous shocks $\eta_t = [\widehat{a}_t, \widehat{e}_t, \widehat{z}_t]'$, innovations $\varepsilon_t = [\varepsilon_{a_t}, \varepsilon_{e_t}, \varepsilon_{z_t}, \varepsilon_{r_t}]'$, and observable variables we aim at tracking $Y_t = [\widehat{y}_t^{obs}, \widehat{r}_t^{obs}, \widehat{\pi}_t^{obs}, \widehat{m}_t^{obs}]'$, we write the model in state space form, we relate the latent processes to the observable variables via the measurement equation, we employ the Kalman filter to evaluate the likelihood $L(\{Y_t\}_{t=1}^T \mid \xi)$, and we estimate the posterior distribution $p(\xi \mid \{Y_t\}_{t=1}^T)$, which is proportional to the product of the likelihood function $L(\{Y_t\}_{t=1}^T \mid \xi)$ and the priors $\Pi(\xi)$, by employing a standard random-walk Metropolis-Hastings algorithm. We add serially and mutually independent $InverseGamma(0.01, 1.5)$ distributed measurement errors to control for high-frequency oscillations in the data that the business cycle model at hand might not be able to capture.[6]

[5] Given that we employ the quarterly (as opposed to annual, or annualized) short-term interest rate in our empirical analysis, we rescaled the estimated value of the semi-elasticity γ_2 obtained by Ball (2001) - i.e. 0.05 in absolute value - by a factor of 4.

[6] To perform our Bayesian estimation we employed DYNARE, a set of algorithms developed by

3.2 Data: Source and treatment

We employ U.S. quarterly data on real output, real money balances, inflation, and the short-term nominal interest rate spanning the sample 1966:I-2007:II. The data set is the same as in Ireland (2004). Output is measured by real GDP, real balances are constructed by dividing the M2 money stock by the GDP deflator, inflation is the quarterly percent change in the GDP deflator, and the interest rate is measured by the federal funds rate (quarterly counterpart). M2 and the federal funds rate are in quarterly averages. Virtually identical results are obtained with end-of-quarter M2 observations. All data but the interest rate are seasonally adjusted. Output and real balances are expressed in per-capita terms (computed by employing the civilian non-institutional population, over 16). We feed the measurement equation with demeaned series. The source of the data is the Federal Reserve Bank of St. Louis' FRED database.

Given the clear historical upward trend displayed by real per-capita output and money, and the change in trends experienced by inflation and the federal funds rate in the post-WWII sample, we treat such series (log-series as for real output and real money) by applying the Hodrick-Prescott filter (weight: 1,600). The reason for this choice is twofold. First, it extracts the cyclical component of the series at hand, which allows us to focus on the frequencies that the new-Keynesian model is designed to replicate. Second, it enables us to compare our results to the literature that has worked with *detrended* series (Ireland (2004), Andrés, López-Salido, and Vallés (2006), Andrés, López-Salido, and Nelson (2009), Canova and Menz (2011)). Alternatively, one could postulate a unit root in technology and implement model-consistent stationarity-inducing transformations of the observables, which would be employed in growth rates and/or ratios (e.g. Smets and Wouters (2007), Justiniano and Primiceri (2008)). While

Michel Juillard and collaborators. DYNARE is freely available at http://www.dynare.org . Details on the computation of the posterior mode and on the Metropolis-Hastings algorithm may be found in an Appendix available upon request.

being theoretically appealing, this approach would force output and money to display a common (possibly stochastic) growth rate, an assumption which does not necessarily square with the data. Moreover, it is unclear whether low frequencies come from the technological process or, instead, by time-varying preferences (Chang, Doh, and Schorfheide (2007)). Our agnostic filtering naturally endows each detrended series with its own flexible trend.

4 Empirical findings

We first present the results stemming from our fixed-coefficient investigation. This exercise is conducted to get baseline results comparable with the existing literature. Then, we show that there is evidence in favor of instabilities in the estimated relationships, which call for a subsample investigation. Hence, we move to the rolling-window analysis, and concentrate on i) the evolution of the key-structural parameters of the model, ii) the estimated, subsample specific impulse response functions of the macroeconomic aggregates to the four identified structural shocks, and iii) the role of drifts in the model's structural parameters.

4.1 Fixed-coefficients

Table 3 collects the posterior median along with the $[5th, 95th]$ posterior percentiles of the estimated structural parameters. We contrast the standard New-Keynesian model estimated under $\psi_2 = \delta_0 = \rho_\mu = 0$ - i.e. nonseparability, no direct effect, no policy reaction to monetary aggregates - to the model that allows, but does not necessarily require, money to shape the macro-dynamics of interest. We label the former 'standard NK model', and the latter 'model with money'.[7] Several results are worth commenting

[7] To be clear, both models are estimated by considering money among the observables. The differences between these two models are due to some parametric constraints. The 'standard NK model' is estimated by imposing $\psi_2 = \delta_0 = \rho_\mu = 0$. Differently, the 'model with money' is estimated without imposing such constraints. Both models, however, feature a money demand equation whose parameters

on. First and foremost, the marginal likelihood clearly favors the model with money, with a deterioration associated with the restricted framework of about 12 log-points, which translates into a Bayes factor equal to $exp(2615.1 - 2603.2) = 147,240$.[8] This is very strong evidence in favor of the model with money. Digging deeper, it turns out that the deterioration of the fit is mainly due to the restriction imposed on the portfolio adjustment cost parameter. In fact, under the restriction $\psi_2 = 0$ (only), the model's fit, in terms of Marginal Likelihood, increases to 2616.3. This may be explained by the negligible role played by nonseparability, which is 'rejected' by the automatic penalization for overparameterization embedded in the computation of the marginal likelihood. By contrast, when imposing $\delta_0 = 0$ (only), the model's fit dramatically drops to 2600.8, clearly 'rejecting' the imposition of no portfolio adjustment costs. These comparisons square with the posterior densities of the key parameters. The posterior median of ψ_2 is very small, i.e. 0.05, and its credible set clearly contains the zero value. The posterior of δ_0 reads 3.2. This value is slightly smaller than the point estimate proposed by Andrés, López-Salido, and Nelson (2009), but it is statistically in line with it. As for the reaction of the Fed to money, the posterior median reads 0.10, a value lower than that found in previous contributions. Indeed, in this last case, the marginal likelihood favors the restricted model with a standard Taylor rule displaying no monetary aggregates a la Ireland (2004), with a value equal to 2621.9.[9]

As regards other money-related parameters, ψ_1, which affects the impact of money on output and inflation, has an estimated posterior distribution equal to 0.69, a value

are estimated jointly with the rest of the economic framework.

[8] We compute the marginal likelihood *via* the modified harmonic mean estimator developed by Geweke (1998). In computing model comparisons via the Bayes factor, we keep the priors on the common parameters fixed across models, as done by e.g. Rabanal and Rubio-Ramírez (2005), Rabanal (2007), and Canova (2009). For a different strategy, see Del Negro and Schorfheide (2008).

[9] This discussion aims at linking our results to the literature. However, in light of the highly likely misspecification of households' preferences, and the fact that portfolio adjustment costs are likely to represent a reduced form of a more complex portfolio allocation decision, the structural interpretation of the estimates offered here must be regarded as tentative.

resembling the estimate proposed by Andrés, López-Salido, and Nelson (2009). The posterior median of the money-output elasticity is 0.88, slightly lower than the point-estimate provided by Ball (2001).[10] As far as the money-interest rate semi-elasticity is concerned, our estimated figure, normalized in order to account for the quarterly (vs. annualized) nominal interest rate, amounts to about 0.35, larger than the point estimate provided by Ball (2001) but statistically in line with the one by Andrés, López-Salido, and Nelson (2009).

The posterior distributions of the remaining parameters suggest values very close to those typically found in the literature. In particular, the posterior median of the habit formation parameter reads 0.86, a value close to those in Rabanal (2007), Christiano, Eichenbaum, and Evans (2005), and Smets and Wouters (2007). The median of the Calvo parameter is 0.66, a standard figure in the macroeconomic literature. Also the inverse of the Frisch labor elasticity assumes the conventional value of 1. The estimated Taylor rule coefficients suggest an aggressive, gradually implemented long-run reaction of the Fed to inflation fluctuations, in line with some previous literature (Clarida, Galí, and Gertler (2000), Lubik and Schorfheide (2004), Boivin and Giannoni (2006), Benati and Surico (2009)), at least as regards the post-1982 sample. Interestingly, the autoregressive parameters of the structural shocks are all below 0.9, which suggests that the model features an internal propagation mechanism able to capture the persistence of the observed macroeconomic series.

To summarize, our full sample *fixed-coefficient* estimates i) offer clear statistical support to the role of portfolio adjustment costs, ii) reject the relevance of nonseparability, and iii) cast doubts on the role played by monetary aggregates at business cycle frequencies in the post-WWII U.S. monetary policy conduct.

[10] In making this comparison, one should take into account the fact that our model is estimated with a *detrended* measure of output, as opposed to the undetrended log-output measure that Ball (2001) focuses on.

4.2 Evidence in favor of instabilities

Instabilities affecting the post-WWII U.S. macroeconomic relationships have been detected by several authors. Boivin and Giannoni (2006) document them with trivariate reduced-form monetary VARs. They interpret such instabilities as due to a change of the Federal Reserve's systematic monetary policy that occurred at the end of the 1970s. Benati and Surico (2009) show the effects of monetary policy breaks on the covariance matrix of similar reduced-form VARs. McConnell and Perez-Quiros (2000) find a break in the volatility of output growth in 1984:I. Evidence in favor of a change in the volatilities of a variety of identified structural shocks is provided by Sims and Zha (2006) and Justiniano and Primiceri (2008). Canova (2009) documents instabilities in the posterior of the parameters describing the private sector, the policy rule, and the variance of the shocks in a model abstracting from money.

We provide our own evidence by estimating a reduced-from VAR and conducting standard Chow-breakpoint tests. We model our four observables (output, inflation, real balances, and the policy rate) with a VAR(4). We select the break date 1979:III, which corresponds to the advent of Paul Volcker at the Federal Reserve's Chairmanship. We find compelling evidence against the stability of the estimated VAR relationships. The p-values associated to the Wald statistic of the null hypothesis of absence of a break in 1979:III read 0.01, 0.00, 0.01, and 0.09 as for the equation of inflation, the federal funds rate, real balances, and output, respectively. We take this evidence, jointly with the one provided in the literature cited above, as sufficient to motivate our investigation on instabilities, which we undertake in the next subsections.

4.3 Recursive estimates

Figure 1 displays the evolution of (selected) structural parameters constructed by considering seven different (partly overlapping) windows. Top-row parameters are those characterizing money's role in the estimated model. Firstly, unlike the indications stemming from our full sample estimates, nonseparability (namely, complementarity) is clearly supported in subsamples heavily influenced by the 1970s. Focusing on the first window as the reference for the 1970s, it is interesting to note that the (log) marginal likelihood of the unrestricted model, which reads 936.1, drops (moderately) when forcing separability between consumption and money to take place (934.2), remarkably deteriorates when assuming no adjustment costs (925.0), and collapses to 921.6 in correspondence to the standard, 'cashless' new-Keynesian framework. Then, the impact of monetary aggregates is pervasive when conditioning on the Great Inflation observations. This result is in line with Canova and Menz's (2009), at least as far as nonseparability and policy effects are concerned. A quite different picture emerges when conditioning on the last window, which we take as representative of the dynamics during the Great Moderation. The estimated median of the nonseparability parameter reads 0.13, a value much smaller than 0.62, i.e. that of the first window. The posterior median of the adjustment costs moves from 1.98 to 4.00, but the uncertainty surrounding it is very large. Also the systematic reaction of the Fed to money growth declines from 0.61 to 0.26, signaling lower attention to monetary aggregates as measured by M2. Overall, the restricted model performs better in the last window, with a (log) marginal likelihood reading 1081.6 vs. 1080.0 (the latter being that of the money-endowed model).

Other parameters display a significant evolution over time. In particular, the money demand elasticity to output shows a clear downward trend. In contrast, the money-interest rate semi-elasticity is estimated to be fairly stable. Habit formation increases remarkably over time, a result that may signal shifts in preferences by American households and/or capture the effects of financial innovations, which have possibly favored consumption smoothing for the last 25 years. Somewhat contrary to the financial innovation interpretation, portfolio adjustment costs display an upward trend, but the uncertainty surrounding our posterior estimates is large. Financial innovations notwithstanding, we note that the estimated volatility of the money demand shock is fairly constant over time. As for other shocks' volatilities, we record a non-monotonic pattern for preference shocks, which contrasts with the somewhat declining path followed by both policy rate and technological shocks.

The Taylor rule parameters do not display much instability, a finding in line with those of Smets and Wouters (2007) and Justiniano and Primiceri (2008). Recall that our results are conditional on a Taylor-type rule displaying money growth among its policy arguments. One may notice that the posteriors of the parameters of the policy rule do not differ much from the priors. Our empirical exercise assumes the existence of a unique equilibrium under rational expectations. Hence, the instability in the money parameters of the model may be capturing the omitted parameter instability of monetary policy associated with (neglected) indeterminacy. In this respect, a money growth rule would be more attractive because it is less subject to indeterminacy than an interest rate rule (Christiano and Rostagno (2001)).

While the assumption of *a priori* independence among parameters' densities is standard, *ex-post* correlation is often the case when conducting Bayesian estimations. Our exercises are no exceptions. When comparing sets of common coefficients under two versions of the model, i.e. the unrestricted model with money vs. the restricted, standard new-Keynesian framework without money, interesting findings arise. Figure 2 shows how money may be of help in detecting instabilities in structural parameters that would not otherwise arise. In particular, when estimating a money demand function which has no feedbacks on the remaining part of the system, one finds a quite stable elasticity to output. Also the degree of habit formation is estimated to be constant when money is omitted from the model. As regards the parameters of the Taylor rule, one may notice some mild differences across the two scenarios but, given the large uncertainty surrounding the estimated Taylor parameters, such differences are hardly meaningful from a statistical standpoint. Again, this might be due to our decision to discard draws leading to multiple equilibria.[11] Interestingly, the absence of money induces a monotonic decline in the preference shock's volatility, which instead exhibits an inverted U-shape when money is allowed to enter the picture.

To summarize, the interactions between money and the remaining aggregates strongly influence the evolution of some key-structural parameters. However, this mainly occurs when observations from the 1970s are dominant in the windows considered in our analysis. Indeed, for our last window, i.e. 1990:I-2006:IV, differences in the estimated parameters appear negligible.

4.4 Estimated parameters

The relevance of money may also be gauged by looking at the estimated parameters of our models. Table 4 considers the first and the last windows of our rolling-window analysis. The 1966:I-1982:IV window puts in clear evidence the impact of money as for the posterior densities of the parameters of interest. Money clearly affects the estimated degrees of habit formation, price indexation, and the standard deviation of the preference shock, which basically double when the constraints characterizing the standard new-Keynesian framework are imposed. Differently, the money-output elasticity is estimated to be more than five times larger in the model with money. The systematic reaction to inflation and the volatilities of three structural shocks, i.e. shocks to money demand, technology, and monetary policy, are also estimated to be larger when money is allowed to influence the macroeconomic equilibrium.

The impact of money on the estimated parameters is larger in the first window (Table 4) than in the full sample (Table 3). This may be due to the very mild role

[11] This choice is widely adopted in this empirical literature. For some notable exceptions, see Lubik and Schorfheide (2004), Boivin and Giannoni (2006), and Benati and Surico (2009).

played by both nonseparability and the policy reaction to money growth in the full sample. Perhaps not surprisingly (in light of our results discussed in the previous subsection), money plays basically no role in the last window we consider, i.e. 1990:I-2006:IV. Consistently, the marginal likelihoods suggest that the model with money and the standard new-Keynesian model enjoy an equivalent fitting power.

4.5 Impulse response function analysis

We contrast the estimated impulse responses of the benchmark vs. money-endowed frameworks. Indeed, time-dependent parameters imply window-specific impulse responses. The responses associated with the first window 1960:I-1982:IV are depicted in Figure 3. Evidently, the omission of money may indeed bias the estimated responses in an economically relevant manner. In terms of magnitude, the model without money clearly dampens the effects of a monetary policy shock to output, inflation, and real balances, of the preference shock to inflation and the policy rate, and of the technological shock to all our endogenous variables. Moreover, money demand shocks, which have (by construction) zero effects on all variables (except money) in the restricted model, are estimated to induce quantitatively important reaction by output. By contrast, and in line with Canova and Menz (2011), the reaction of inflation to such shocks is very mild.

This picture dramatically changes when moving to the sample 1990:I-2006:IV, whose estimated responses are depicted in Figure 4. The role of money is clearly dampened, if not altogether absent. Moreover, the effects of money demand shocks are also moderate. A change in the transmission mechanism of all structural shocks is likely to have occurred, with money losing much of its influence on U.S. output and inflation. However, money may still be important in an empirical analysis conducted over the Great Moderation sample, possibly to control for omitted information-induced biases otherwise affecting the structural parameters of the Euler-equation for output (Hafer, Haslag, and Jones (2007)). Moreover, it is worth recalling that our evidence supports the presence of portfolio adjustment costs, which make money relevant as a leading indicator of future movements in the real interest rate at low frequencies (Andrés, López-Salido, and Nelson (2009)).

4.6 Drifts in parameters and model-consistent volatilities

One of the most closely scrutinized macroeconomic facts of the past decades has surely been the 'Great Moderation'. When referring to our estimated models, two questions naturally arise: i) Are the estimated *drifts* in parameters *relevant* to describing the evolution of the post-WWII U.S. volatilities? ii) Do these drifting parameters suggest an *evolution* of money's role in replicating such volatilities?

To answer these questions, we compute the standard deviations of actual inflation and output over seven 16 year-windows. Then, we compute a) the population values of the standard deviations of inflation and output implied by our estimated fixed-coefficient model (with money), and b) the population values of the standard deviations of inflation and output implied by our rolling-window estimates (model with money and standard NK model without money). Finally, we contrast a) and b) with the standard deviations computed with actual data.

Figure 5 collects the outcome of this exercise. Several considerations are in order. The standard deviations computed with actual data display a dramatic decline when moving from the 1970s to the 1980s and 1990s. This evidence confirms that the 'Great Moderation' is embedded in our sample. Clearly, this evidence cannot be replicated by a fixed-coefficient model. In fact, our fixed-coefficient model obviously implies constant population volatilities (depicted in Figure 5 by the magenta horizontal lines with circles), a prediction clearly at odds with the facts. By contrast, our rolling-window strategy allows for drifting parameters and, consequently, time-varying population volatilities. Interestingly, Figure 5 shows that our 'time-varying coefficient' models nicely replicate the pattern of the post-WWII U.S. macroeconomic volatilities. Therefore, the answer to our first question is: Yes, drifts in parameters are relevant (indeed, crucial) for replicating the U.S. facts.

Consequently, question ii) becomes of interest. Again, the evidence portrayed in Figure 5 leads to a positive answer. The left panel of Figure 5 reveals that monetary aggregates have a clear role in enhancing the model's ability to replicate the standard deviation of the U.S. business cycle when the 1970s dominate the windows considered. As time goes by, however, money's contribution to replicating the U.S. business cycle diminishes. In fact, the last four windows (1978-1994 up to 1990-2006) show that the standard new-Keynesian model without money performs equally well in replicating U.S. detrended output's volatility. This evidence is in line with our statistical support for the new-Keynesian model with money, which is limited to the windows featured by the dynamics of the 1970s. As far as inflation is concerned, the right-panel of Figure 5 shows that money does not appear to play a role as substantial as the one played for output. In particular, the model with money slightly underperforms in the first two windows, then overperforms in the remaining ones, but in a very mild fashion with respect to the model without role for money. However, our marginal likelihood evidence considers the *overall* performance of the model with money superior to that of the standard NK framework in the first windows.

To summarize, our evidence suggests that i) drifts in parameters are relevant for replicating the post-WWII U.S. volatilities, and ii) the role of money has evolved over time, being clearly important as regards the 1970s (above all to replicate the U.S. output volatility), and less relevant in subsequent subsamples.

4.7 M2 vs. monetary base: Empirical results

In our benchmark analysis, we use M2 for the computation of real balances. As a matter of fact, the literature is largely silent on the 'right' measure of money, especially in the money-in-the-utility -cofunction specification. Since monetary aggregates frequently move differently from one another, our results might be specific to M2. We then repeat our exercises by employing the monetary base.[12] It is worth recalling that our sample ends before the near-zero lower bound period as well as the advent of interest on reserves and the financial crisis. All of these factors have increased commercial banks' reserve demand, and so made the monetary base harder to interpret. Our 2006 cutoff for the sample avoids these problems of interpretation.

Table 5 collects our posterior estimates conditional on the full sample investigation. All previous findings are confirmed. In particular, the model with money has a higher marginal likelihood than the standard new-Keynesian model; nonseparability is not supported by the data; portfolio adjustment costs are comparable to previous studies (Andrés, López-Salido, and Nelson (2009)); the policy reaction to money growth is mild; model comparisons based on the Bayes factor suggest that the only 'money-related' element supported by the data is portfolio adjustment costs (the Bayes factors are not reported because of their similarity with those referring to our benchmark analysis).

Interestingly, not all findings are robust to the employment of the monetary base. Figures 6-8 depicts the outcome of our rolling-window investigations. Some comments are in order. Figure 6 shows that the credible sets of the nonseparability parameter contain the zero value in all the windows we consider. Moreover, the degree of habit formation and the money-output elasticity are stable over time. Figure 7 shows that the constraints identifying the standard new-Keynesian model do not imply any relevant

[12] We thank two anonymous referees for suggesting us to undertake this investigation. The monetary base measure we employ is adjusted for changes in reserve requirements. Source: Federal Reserve Bank of St. Louis' website.

difference in terms of estimated parameters over time, the only exception being the money demand shock, which is slightly underestimated. Figure 8 shows that the two versions of our model imply the same unconditional volatilities of inflation and output. Interestingly, Figures 5 and 8 reveal that the use of a broader definition of money leads to an estimated model with money which replicates the U.S. output volatility better than i) the standard NK model, and ii) the model with money estimated with the monetary base. Further simulations reveal that this result is driven by the difference in the estimated degree of nonseparability, which is positive in our benchmark analysis involving M2, and basically zero when the narrower monetary base indicator is considered. This result suggest that households' portfolio decisions i) may have played a role in shaping the U.S. macroeconomic dynamics during the phase preceding the Great Moderation, and ii) they are hardly captured by the monetary base indicator.

4.8 M2 vs. monetary base: A discussion

Our baseline analysis exploits a broad definition of monetary aggregate. This choice is very common in the empirical macroeconomic literature.[13] The previous subsection, however, has documented the sensitivity of our results to the employment of the monetary base. This finding is not new as for the U.S. economy. Favara and Giordani (2009) conduct a VAR analysis and show that shocks to broad monetary aggregates exert substantial and persistent effects on output and inflation. Such effects turn out to be substantially weaker when narrow measures of money are considered. Hafer, Haslag, and Jones (2007) estimate dynamic IS curves and find money to be a significant regressor just when a broad measure of money is taken into account. Šustek (2010) shows that a broad monetary aggregate including currency and zero-maturity deposits tends to anticipate future output. In contrast, base money does not show this tendency. In

[13] See, among others, Ireland (2004), Sims and Zha (2006), Andrés, López-Salido, and Vallés (2006), Hafer, Haslag, and Jones (2007), Favara and Giordani (2009), Arestis, Chortareas, and Tsoukalas (2010), Sargent and Surico (2011), and Canova and Menz (2011)

light of these findings, how much weight should we place on our results with M2? How should we interpret the different findings obtained with M2 vs. M0? We analyze these two questions in turn.

We believe our M2-based results should be given more credit, at least conditional on our structural model. Firstly, as already pointed out, the model estimated with M2 is more successful in replicating the Great Moderation. The root-mean-squared error (RMSE) computed by considering the deviations of the simulated standard deviations of output from the actual ones reads 0.55 conditional on M2 (Figure 5) vs. 0.87 conditional on M0 (Figure 8), i.e., the extra-information embedded by M2 leads to an improvement of about 36% in terms of RMSE. As for inflation, the improvement amounts to 18%. Secondly, estimations à la Canova and Ferroni (2011) conducted by employing M2 and the monetary base *jointly* return estimates of our structural parameters very similar to those obtained with M2 *only*, and clearly different with respect to those obtained with M0 *only*.[14] Therefore, the model estimated with M2 i) fits the Great Moderation facts better, and ii) implies estimated parameters in line with those obtained with multiple monetary indicators. This evidence suggests that, from an empirical standpoint, we should place a larger weight on the results obtained with the broader aggregate M2.

Established that different results arise when employing M2 vs. M0, what do these differences tell us as for the interaction between monetary aggregates and the business cycle? Arguably, the money multiplier is playing a big role in accounting for our results. Its evolution is likely to be picked up by the evolution of our structural parameters, in particular our nonseparability parameter ψ_2. In our model, money affects the marginal rate of substitution between consumption and leisure, the real wage, and thus marginal costs and inflation. Then, money in the Phillips curve may capture firm's effects related to the evolution of working capital requirements. Evidence in favor of a substantially re-

[14] Details on this exercise conducted with multiple monetary indicators are available upon request.

duced importance of the working capital requirements for inflation is provided by Barth and Ramey (2001) and Tillmann (2009), who interpret it as a consequence of financial innovations and deregulation occurred at the beginning of the 1980s. More generally, empirical evidence about the expanded access to credit for firms is documented by Gertler and Lown (1999), who relate it to the development of a market for bonds with below-investment grade ratings, and by Jermann and Quadrini (2006), who link it to the decline in the cost of new equity issuances. Money also alters the intertemporal rate of substitution of output at different points in time, therefore creating a wedge in the IS equation. From households' side, a much easier access to external financing was also possible after the above mentioned financial deregulation - for a discussion, see Justiniano and Primiceri (2008). Such a easier access may have enabled households to smooth consumption more efficiently, therefore leading to a reduction in the volatility of output. A precise assessment of the relative importance of all these elements would require the development of a structural model properly accounting for liquidity provision and financial frictions, an endeavour that we leave to future research.[15]

5 Conclusions

We estimated a DSGE model featuring nonseparability in real balances and consumption, portfolio adjustment costs, and a systematic reaction of policymakers to money growth with post-WWII U.S. data. Our findings are as follows. Money plays a significant role in shaping the U.S. business cycle. Interestingly, its role proves to be time-varying. In particular, nonseparability and policymakers' responses to money are estimated to be more important during the Great Inflation. Crucially, the estimation of a business cycle model omitting money is shown to produce severely distorted inferences (relative to the model with money) as regards impulse response functions. Drifts

[15] Interesting efforts in this direction have recently been undertaken by Christiano, Motto, and Rostagno (2010), Cúrdia and Woodford (2010), and Šustek (2010).

in the estimated parameters are shown to importantly shape the simulated macroeconomic volatilities. Again, money is relevant, in particular for describing the U.S. output volatility of the 1970s. Our results depend on the monetary indicator used in the estimation. In particular, money helps in tracking the U.S. macroeconomic volatilities in the 1970s if measured with M2, but not when the monetary base indicator is used. However, an estimation conducted with multiple monetary indicators confirms the findings obtained with M2 only. Therefore, our results support M2 as a better empirical counterpart (than the monetary base) of our theoretical concept of money.

Our results rely upon the investigation of an extended version of the model proposed by Ireland (2004). In general, while giving money a chance to play an active role in the determination of inflation and the business cycle, current monetary models do not explicitly embed ingredients such as asymmetric information in the lending market, imperfect substitutability between financial assets, and so on. We interpret our findings as a call for a more satisfactory attempt to deal with the process of liquidity provision and financial frictions. In light of the liquidity boom triggered by a variety of central banks to tackle the real effects of the financial turmoil, this call appears to be warranted.

From an empirical standpoint, our analysis has dealt with the identification of the cyclical components of the aggregates under investigation. In a recent paper, Canova and Ferroni (2011) show that the role of money may turn out to be downplayed by the choice of the 'wrong' statistical filter. We see Canova and Ferroni's (2011) methodology as very promising in detecting the role of money in monetary models of the business cycle. As for frequency-decompositions, more attention should be paid to the possible link between systematic policy drifts and the money-inflation low-frequency relationship as dictated by the quantity theory (Sargent and Surico (2011)). We see the assessment of money's role in monetary business cycle models as an exciting area for future research.

References

An, S., and F. Schorfheide (2007): "Bayesian Analysis of DSGE Models," *Econometric Reviews*, 26, 113–172.

Andrés, J., J. López-Salido, and E. Nelson (2009): "Money and the Natural Rate of Interest: Structural Estimates for the United States and the Euro Area," *Journal of Economic Dynamics and Control*, 33, 758–776.

Andrés, J., J. López-Salido, and J. Vallés (2006): "Money in an Estimated Business Cycle Model of the Euro Area," *Economic Journal*, 116, 547–477.

Arestis, P., G. Chortareas, and J. D. Tsoukalas (2010): "Money and Information in a New Neoclassical Synthesis Framework," *Economic Journal*, 120, F101–F128.

Ball, L. (2001): "Another Look at Long-Run Money Demand," *Journal of Monetary Economics*, 47, 31–44.

Barth, M., and V. Ramey (2001): "The Cost Channel of Monetary Transmission," *NBER Macroeconomics Annual*, 16, 199–240.

Benati, L. (2010): "Are Policy Counterfactuals Based on Structural VARs Reliable?," European Central Bank Working Paper No. 1188.

Benati, L., and P. Surico (2009): "VAR Analysis and the Great Moderation," *American Economic Review*, 99(4), 1636–1652.

Boivin, J., and M. Giannoni (2006): "Has Monetary Policy Become More Effective?," *Review of Economics and Statistics*, 88(3), 445–462.

Canova, F. (2007): *Methods for Applied Macroeconomic Research*. Princeton University Press, Princeton, New Jersey.

——— (2009): "What Explains the Great Moderation in the US? A Structural Analysis," *Journal of the European Economic Association*, 7(4), 697–721.

Canova, F., and G. de Nicoló (2002): "Monetary Disturbances Matter for Business Fluctuations in the G-7," *Journal of Monetary Economics*, 49, 1131–1159.

Canova, F., and F. Ferroni (2011): "Multiple Filtering Devices for the Estimation of Cyclical DSGE Models," *Quantitative Economics*, 2, 73–98.

Canova, F., and T. Menz (2011): "Does Money Have a Role in Shaping Domestic Business Cycles? An International Investigation," *Journal of Money, Credit and Banking*, 43(4), 577–607.

Canova, F., and L. Sala (2009): "Back to Square One: Identification Issues in DSGE Models," *Journal of Monetary Economics*, 56(4), 431–449.

Chang, Y., T. Doh, and F. Schorfheide (2007): "Non-Stationary Hours in a DSGE Model," *Journal of Money, Credit and Banking*, 39(6), 1357–1373.

Christiano, L., M. Eichenbaum, and C. Evans (2005): "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy," *Journal of Political Economy*, 113(1), 1–45.

Christiano, L., R. Motto, and M. Rostagno (2010): "Financial Factors in Business Cycle," European Central Bank Working Paper No. 1192.

Christiano, L., and M. Rostagno (2001): "Money Growth Monitoring and the Taylor Rule," NBER Working Paper No. 8539.

Clarida, R., J. Galí, and M. Gertler (2000): "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory," *Quarterly Journal of Economics*, 115, 147–180.

Cúrdia, V., and M. Woodford (2010): "Credit Spreads and Monetary Policy," *Journal of Money, Credit and Banking*, 42, 3–35.

D'Agostino, A., and P. Surico (2009): "Does Global Liquidity Help to Forecast US Inflation?," *Journal of Money, Credit and Banking*, 41(2-3), 479–489.

Del Negro, M., and F. Schorfheide (2008): "Forming Priors for DSGE Models (And How It Affects the Assessment of Nominal Rigidities)," *Journal of Monetary Economics*, 55(7), 1191–1208.

Favara, G., and P. Giordani (2009): "Reconsidering the Role of Money for Output, Prices and Interest Rates," *Journal of Monetary Economics*, 56(3), 419–430.

Fernández-Villaverde, J., and J. Rubio-Ramírez (2007): "How Structural are Structural Parameters?," in (Eds.) D. Acemoglu, K. Rogoff, and M. Woodford: NBER Macroeconomics Annual, Vol. 22, 83–137.

Gertler, M., and C. Lown (1999): "The Information in the High-Yield Bond Spread for the Business Cycle: Evidence and Some Implications," *Oxford Review of Economic Policy*, 15(3), 132–150.

Geweke, J. (1998): "Using Simulation Methods for Bayesian Econometric Models: Inference, Development and Communication," Federal Reserve Bank of Minnesota Staff Report No. 249.

Hafer, R., J. Haslag, and G. Jones (2007): "On Money and Output: Is Money Redundant?," *Journal of Monetary Economics*, 54, 945–954.

Hafer, R., and G. Jones (2008): "Dynamic IS Curves with and Without Money: An International Comparison," *Journal of International Money and Finance*, 27, 609–616.

Ireland, P. (2001): "Money's Role in the Monetary Business Cycle," NBER Working Paper No. 8115.

——— (2004): "Money's Role in Monetary Business Cycle," *Journal of Money, Credit, and Banking*, 36(6), 969–983.

Jermann, U., and V. Quadrini (2006): "Financial Innovations and Macroeconomic Volatility," mimeo.

Justiniano, A., and G. Primiceri (2008): "The Time-Varying Volatility of Macroeconomic Fluctuations," *American Economic Review*, 98(3), 604–641.

KING, R. G. (2000): "The New IS-LM Model: Language, Logic and Limits," *Federal Reserve Bank of Richmond Economic Quarterly*, 86(3), 45–103.

KOENIG, E. (1990): "Real Money Balances and the Timing of Consumption: An Empirical Investigation," *The Quarterly Journal of Economics*, 105(2), 399–425.

LEEPER, E., AND J. ROUSH (2003): "Putting 'M' Back in Monetary Policy," *Journal of Money, Credit and Banking*, 35(2), 1217–1256.

LUBIK, T., AND F. SCHORFHEIDE (2004): "Testing for Indeterminacy: An Application to U.S. Monetary Policy," *American Economic Review*, 94(1), 190–217.

MCCONNELL, M., AND G. PEREZ-QUIROS (2000): "Output Fluctuations in the United States: What Has Changed Since the Early 1980s?," *American Economic Review*, 90, 1464–1476.

MELTZER, A. (2001): "The Transmission Process," in Deutsche Bundesbank (Ed.): The Monetary Transmission Process: Recent Developments and Lessons for Europe, Palgrave, London, pp. 112-130.

NELSON, E. (2002): "Direct Effects of Base Money on Aggregate Demand: Theory and Evidence," *Journal of Monetary Economics*, 49, 687–708.

RABANAL, P. (2007): "Does Inflation Increase After a Monetary Policy Tightening? Answers Based on an Estimated DSGE Model," *Journal of Economic Dynamics and Control*, 31, 906–937.

RABANAL, P., AND J. RUBIO-RAMÍREZ (2005): "Comparing New Keynesian Models of the Business Cycle: A Bayesian Approach," *Journal of Monetary Economics*, 52, 1151–1166.

RAVENNA, F., AND C. WALSH (2006): "Optimal Monetary Policy with the Cost Channel," *Journal of Monetary Economics*, 53, 199–216.

REYNARD, S. (2007): "Maintaining Low Inflation: Money, Interest Rates, and Policy Stance," *Journal of Monetary Economics*, 54(5), 1441–1471.

SARGENT, T. J., AND P. SURICO (2011): "Two Illustrations of the Quantity Theory of Money: Breakdowns and Revivals," *American Economic Review*, 101, 113–132.

SIMS, C., AND T. ZHA (2006): "Were There Regime Switches in U.S. Monetary Policy?," *American Economic Review*, 96(1), 54–81.

SMETS, F., AND R. WOUTERS (2007): "Shocks and Frictions in US Business Cycle: A Bayesian DSGE Approach," *American Economic Review*, 97(3), 586–606.

ŠUSTEK, R. (2010): "Monetary aggregates and the business cycle," *Journal of Monetary Economics*, 57, 451–465.

SVENSSON, L. (1999): "Inflation Targeting as a Monetary Policy Rule," *Journal of Monetary Economics*, 43(3), 607–654.

TILLMANN, P. (2009): "The time-varying cost channel of monetary transmission," *Journal of International Money and Finance*, 28, 941–953.

WOODFORD, M. (2003): *Interest and Prices: Foundations of a Theory of Monetary Policy.* Princeton University Press. Princeton, New Jersey.

Households' problem

$$\max_{C_t,N_t,M_t,B_t} E_0 \sum_{t=0}^{\infty} \beta^t a_t \left[\Psi \left(\frac{C_t}{C_{t-1}^h}, \frac{M_t}{e_t P_t} \right) - \frac{N_t^{1+\varphi}}{1+\varphi} \right] - G(\bullet)$$

with $G(\bullet) = \frac{d}{2} \left\{ \exp \left(c \left\{ \frac{M_t/P_t}{M_{t-1}/P_{t-1}} - 1 \right\} \right) + \exp \left(-c \left\{ \frac{M_t/P_t}{M_{t-1}/P_{t-1}} - 1 \right\} \right) - 2 \right\}$

s.t. $\frac{M_{t-1}+B_{t-1}+W_t N_t+T_t+D_t}{P_t} = C_t + \frac{B_t/r_t+M_t}{P_t}$

where

$C_t = \int_0^1 \left(C_t(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}}$: CES aggregator of the different goods consumed; $\frac{M_t}{P_t}$: real balances; N_t: hours;

a_t: preference shock; e_t: money demand shock; β: discount factor; φ: inv. of Frisch lab. elasticity; h: degree of habit formation; c, d: portfolio adj. costs' parameters; B_t: bonds; r_t: gross interest rate; W_t: wages; T_t: lump sum transfer; D_t: firms' dividends ε: goods' elasticity of substitution; P_t: aggregate price level.

Firms' production function and price setting

$Y_t(j) = z_t N_t(j)^{1-\alpha}$

$P_t = \left[\theta \left(P_{t-1}\pi_{t-1}^{\omega} \right)^{1-\varepsilon} + (1-\theta)\, P_t^{*1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}$

where

$Y_t = \int_0^1 \left(Y_t(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}}$: CES aggregator of the different goods produced; $N_t(j)$: hours hired by firm j; z_t: technology shock;

$1-\alpha$: elasticity of output w.r.t. hours; $1-\theta$: measure of producers resetting their prices each period;
ω: degree of price indexation by non-reoptimizing firms; P_t^*: optimal price set by reoptimizers.

Market-clearing conditions

Goods market: $Y_t = C_t$

Labor market: $N_t = \int_0^1 N_t(j) dj$

Table 1: **Description of the DSGE Model with Money - Nonlinear Equations.** This Table collects the non-linear equations regarding households' problem, firms' production function and price setting, and market-clearing conditions. The definitions of the structural parameters are given in Table 3.

Variables in percentage deviations from their steady-state values
$\widehat{y}_t$: Output, $\widehat{\pi}_t$: Inflation, $\widehat{r}_t$: Nominal rate, $\widehat{m}_t$: Real balances

Log-linearized equations of the model

$$\widehat{y}_t = \frac{\phi_1}{\phi_1+\phi_2}\widehat{y}_{t-1} + \frac{\beta\phi_1+\phi_2}{\phi_1+\phi_2}E_t\widehat{y}_{t+1} - \frac{1}{\phi_1+\phi_2}(\widehat{r}_t - E_t\widehat{\pi}_{t+1}) - \frac{\beta\phi_1}{\phi_1+\phi_2}E_t\widehat{y}_{t+2} + \frac{\psi_2}{\psi_1(1-\beta h)(\phi_1+\phi_2)}(\widehat{m}_t - \widehat{e}_t)$$
$$-\frac{\psi_2(1+\beta h)}{\psi_1(1-\beta h)(\phi_1+\phi_2)}E_t(\widehat{m}_{t+1} - \widehat{e}_{t+1}) + \frac{\psi_2\beta h}{\psi_1(1-\beta h)(\phi_1+\phi_2)}E_t(\widehat{m}_{t+2} - \widehat{e}_{t+2}) + \frac{(1-\beta h\rho_a)(1-\rho_a)}{(1-\beta h)(\phi_1+\phi_2)}\widehat{a}_t \quad (1)$$

$$\widehat{\pi}_t = \gamma_f E_t\widehat{\pi}_{t+1} + \gamma_b\widehat{\pi}_{t-1} + \lambda\widehat{mc}_t \quad (2)$$

$$\widehat{mc}_t = (\chi+\phi_2)\widehat{y}_t - \phi_1\widehat{y}_{t-1} - \beta\phi_1 E_t\widehat{y}_{t+1} - \frac{\psi_2}{\psi_1(1-\beta h)}(\widehat{m}_t - \widehat{e}_t)$$
$$+\frac{\psi_2\beta h}{\psi_1(1-\beta h)}E_t(\widehat{m}_{t+1} - \widehat{e}_{t+1}) - \frac{\beta h(1-\rho_a)}{(1-\beta h)}\widehat{a}_t - (1+\chi)\widehat{z}_t \quad (3)$$

$$(1+\delta_0(1+\beta))\widehat{m}_t = \gamma_1\widehat{y}_t - \gamma_2\widehat{r}_t + [\gamma_2(\overline{r}-1)(h\phi_2 - \phi_1) - h\gamma_1]\widehat{y}_{t-1} - [\gamma_2(\overline{r}-1)\beta\phi_1]E_t\widehat{y}_{t+1}$$
$$+\delta_0\widehat{m}_{t-1} + \left[\frac{\psi_2(\overline{r}-1)\beta h\gamma_2}{\psi_1(1-\beta h)} + \delta_0\beta\right]E_t\widehat{m}_{t+1} - \frac{(\overline{r}-1)\beta h(1-\rho_a)}{(1-\beta h)}\gamma_2\widehat{a}_t$$
$$+\left\{1 - (\overline{r}-1)\gamma_2\left[\frac{\psi_2\beta h\rho_e}{\psi_1(1-\beta h)} + 1\right]\right\}\widehat{e}_t \quad (4)$$

$$\widehat{r}_t = \rho_r\widehat{r}_{t-1} + (1-\rho_r)(\rho_y\widehat{y}_t + \rho_\pi\widehat{\pi}_t + \rho_\mu\widehat{\mu}_t) + \varepsilon_r \quad (5)$$

$$\widehat{\mu}_t = \widehat{m}_t - \widehat{m}_{t-1} + \widehat{\pi}_t \quad (6)$$

$$\widehat{\zeta}_t = \rho_\zeta\widehat{\zeta}_{t-1} + \varepsilon_{\xi_t}, \zeta \in \{a,e,z\}; \varepsilon_{\xi_t} \sim N(0,\sigma_{\varepsilon_\xi}), \xi \in \{a,e,z,r\} \quad (7)$$

Compound parameters of the model

$\psi_1 \equiv -\frac{U_1}{\overline{y}^{(1-h)}U_{11}}, \psi_2 \equiv -\frac{U_{12}}{\overline{y}^{(1-h)}U_{11}}\left(\frac{m}{e}\right), \gamma_f \equiv \beta\theta\{\theta + \omega[1-\theta(1-\beta)]\}^{-1},$
$\gamma_b \equiv \omega\{\theta + \omega[1-\theta(1-\beta)]\}^{-1}\ \lambda \equiv (1-\theta)(1-\beta\theta)(1-\omega)\xi, \chi \equiv \frac{\varphi+\alpha}{1-\alpha},$
$\xi \equiv \frac{(1-\alpha)}{1+\alpha(\varepsilon-1)}\{\theta + \omega[1-\theta(1-\beta)]\}^{-1}, \phi_1 \equiv \frac{(\psi_1^{-1}-1)h}{1-\beta h}, \phi_2 \equiv \frac{\psi_1^{-1}+(\psi_1^{-1}-1)\beta h^2 - \beta h}{1-\beta h}, \delta_0 \equiv -\frac{c^2 d}{U_{22}m^2}$

Calibrated parameters

$\beta = 0.9925$: discount factor; $\overline{r} = 1.0138$: gross-steady-state quarterly nominal interest rate;
$1-\alpha = 2/3$: labor income share; $\varepsilon = 6$: goods' elasticity of substitution;
$c = 1$: coefficient regulating the portfolio adjustment costs.

Table 2: **Description of the DSGE Model with Money - Log-linearized Equations.** Hatted variables identify log-deviations of variables from their steady-state values. The definitions of the structural parameters are given in Table 3.

$Param.$	$Definition$	$Prior(mean, std.)$	Model with money $Posterior\ Median$ $[5th,\ 95th]$	Standard NK model $Posterior\ Median$ $[5th,\ 95th]$
ψ_1	Ratio of derivat. of hh's util.	$G(0.80, 010)$	0.69 [0.58,0.80]	0.68 [0.57,0.79]
ψ_2	Money-output nonseparab.	$N(0.00, 0.50)$	0.05 [−0.03,0.19]	–
h	Habit formation	$B(0.70, 010)$	0.86 [0.76,0.95]	0.88 [0.78,0.96]
θ	Price stickiness	$B(0.65, 010)$	0.66 [0.53,0.78]	0.67 [0.54,0.79]
ω	Price indexation	$B(0.50, 0.15)$	0.76 [0.65,0.86]	0.77 [0.66,0.86]
φ	Inv. of Frisch lab. elasticity	$G(1.00, 0.25)$	0.95 [0.55,1.33]	0.94 [0.59,1.34]
γ_1	Money-output elast.	$G(0.50, 0.25)$	0.88 [0.29,1.51]	0.39 [0.22,0.59]
γ_2	Money-nom. rate semielast.	$G(0.20, 0.15)$	0.35 [0.02,0.86]	0.37 [0.04,0.73]
δ_0	Portfolio adj. cost	$G(6.00, 2.85)$	3.20 [1.22,5.61]	–
ρ_R	Policy rate smoothing	$B(0.50, 0.10)$	0.44 [0.32,0.56]	0.40 [0.27,0.52]
ρ_y	Policy resp. to output	$G(0.15, 0.05)$	0.13 [0.08,0.18]	0.11 [0.07,0.16]
ρ_π	Policy resp. to inflation	$G(1.50, 0.25)$	1.67 [1.38,1.96]	1.63 [1.36,1.92]
ρ_μ	Policy resp. to mon. growth	$G(0.80, 0.40)$	0.10 [0.03,1.18]	–
ρ_a	Preference shock pers.	$B(0.75, 0.10)$	0.74 [0.65,0.83]	0.75 [0.66,0.84]
ρ_e	Money dem. shock pers.	$B(0.75, 0.10)$	0.79 [0.71,0.88]	0.88 [0.83,0.93]
ρ_z	Tech. shock pers.	$B(0.75, 0.10)$	0.71 [0.57,0.84]	0.72 [0.59,0.84]
σ_a	Preference shock st. dev.	$IG(0.01, 1.50)$	0.0105 [0.0062,0.0152]	0.0104 [0.0062,0.0153]
σ_e	Money dem. shock st. dev.	$IG(0.01, 1.50)$	0.0175 [0.0115,0.0250]	0.0077 [0.0049,0.085]
σ_z	Technology shock st. dev.	$IG(0.01, 1.50)$	0.0091 [0.0050,0.0146]	0.0081 [0.0064,0.0131]
σ_r	Policy rate shock st. dev.	$IG(0.01, 1.50)$	0.0020 [0.0016,0.0024]	0.0019 [0.0016,0.0023]
$Marg.Lik.$			2615.1	2603.1

Table 3: **Model Comparison: Full Sample Estimates - M2 Indicator.** Sample: 1966:I-2007:II. 'Ratio of derivat. of hh's util.': Ratio of derivatives of household's utility. Priors: 'G' stands for Gamma, 'N' - Normal, 'B' - Beta, 'IG' - Inverse Gamma. The computation of the Marginal Likelihoods are performed by employing the Modified Harmonic Mean estimator proposed by Geweke (1998). The Table reports posterior medians and the [5th,95th] posterior percentiles. The posterior summary statistics are calculated from the output of the Metropolis algorithm. Details on estimation procedure are given in the text.

			1966:I-1982:IV		1990:I-2006:IV	
Param.	*Definition*	*Prior(mean, std.)*	Model with money *Posterior Median* [*5th, 95th*]	Standard NK model *Posterior Median* [*5th, 95th*]	Model with money *Posterior Median* [*5th, 95th*]	Standard NK model *Posterior Median* [*5th, 95th*]
ψ_1	Ratio of derivat. of hh's util.	$G(0.80, 010)$	0.70 [0.56,0.84]	0.73 [0.60,0.84]	0.72 [0.60,0.84]	0.73 [0.62,0.86]
ψ_2	Money-output nonseparab.	$N(0.00, 0.50)$	0.62 [0.46,0.80]	–	0.13 [0.00,0.29]	–
h	Habit formation	$B(0.70, 010)$	0.40 [0.26,0.54]	0.76 [0.60,0.91]	0.85 [0.74,0.94]	0.85 [0.74,0.94]
θ	Price stickiness	$B(0.65, 010)$	0.63 [0.51,0.75]	0.65 [0.51,0.78]	0.74 [0.60,0.86]	0.79 [0.68,0.87]
ω	Price indexation	$B(0.50, 0.15)$	0.41 [0.19,0.68]	0.75 [0.60,0.87]	0.62 [0.42,0.81]	0.61 [0.41,0.79]
φ	Inv. of Frisch lab. elasticity	$G(1.00, 0.25)$	0.98 [0.60,1.42]	0.96 [0.57,1.37]	0.91 [0.55,1.28]	0.90 [0.55,1.29]
γ_1	Money-output elast.	$G(0.50, 0.25)$	2.20 [1.62,2.83]	0.38 [0.14,0.61]	0.50 [0.14,0.93]	0.40 [0.14,0.67]
γ_2	Money-nom. rate semielast.	$G(0.20, 0.15)$	0.29 [0.01,0.67]	0.21 [0.01,0.50]	0.21 [0.00,0.52]	0.33 [0.01,0.75]
δ_0	Portfolio adj. cost	$G(6.00, 2.85)$	1.98 [1.08,3.00]	–	4.40 [1.40,7.97]	–
ρ_R	Policy rate smoothing	$B(0.50, 0.10)$	0.39 [0.26,0.52]	0.40 [0.27,0.54]	0.54 [0.39,0.66]	0.56 [0.43,0.68]
ρ_y	Policy resp. to output	$G(0.15, 0.05)$	0.17 [0.10,0.26]	0.13 [0.08,0.19]	0.17 [0.10,0.24]	0.16 [0.09,0.24]
ρ_π	Policy resp. to inflation	$G(1.50, 0.25)$	1.91 [1.54,2.31]	1.47 [1.17,1.80]	1.62 [1.21,2.04]	1.58 [1.18,2.00]
ρ_μ	Policy resp. to mon. growth	$G(0.80, 0.40)$	0.61 [0.28,0.94]	–	0.26 [0.09,0.47]	–
ρ_a	Preference shock pers.	$B(0.75, 0.10)$	0.76 [0.63,0.90]	0.75 [0.63,0.85]	0.80 [0.70,0.89]	0.79 [0.69,0.88]
ρ_e	Money dem. shock pers.	$B(0.75, 0.10)$	0.81 [0.71,0.91]	0.87 [0.81,0.94]	0.80 [0.70,0.91]	0.85 [0.78,0.92]
ρ_z	Tech. shock pers.	$B(0.75, 0.10)$	0.77 [0.61,0.90]	0.74 [0.59,0.88]	0.74 [0.60,0.86]	0.70 [0.55,0.83]
σ_a	Preference shock st. dev.	$IG(0.01, 1.50)$	0.0066 [0.0038,0.0100]	0.0104 [0.0062,0.0153]	0.0069 [0.0040,0.0103]	0.0069 [0.0040,0.0101]
σ_e	Money dem. shock st. dev.	$IG(0.01, 1.50)$	0.0136 [0.0096,0.0178]	0.0077 [0.0049,0.085]	0.0106 [0.0062,0.0158]	0.0049 [0.0040,0.059]
σ_z	Technology shock st. dev.	$IG(0.01, 1.50)$	0.0123 [0.0064,0.0207]	0.0081 [0.0064,0.0131]	0.0047 [0.0025,0.0076]	0.0049 [0.0024,0.0083]
σ_r	Policy rate shock st. dev.	$IG(0.01, 1.50)$	0.0031 [0.0022,0.0042]	0.0019 [0.0016,0.0023]	0.0017 [0.0014,0.0020]	0.0017 [0.0013,0.0020]
Marg.Lik.			936.10	921.64	1080.00	1081.60

Table 4: **Model Comparison: Selected Windows - M2 Indicator.** 'Ratio of derivat. of hh's util.': Ratio of derivatives of household's utility. Priors: 'G' stands for Gamma, 'N' - Normal, 'B' - Beta, 'IG' - Inverse Gamma. The computation of the Marginal Likelihoods are performed by employing the Modified Harmonic Mean estimator proposed by Geweke (1998). The Table reports posterior medians and the [5th,95th] posterior percentiles. The posterior summary statistics are calculated from the output of the Metropolis algorithm. Details on estimation procedure are given in the text.

$Param.$	$Definition$	$Prior(mean, std.)$	Model with money $Posterior\ Median$ [$5th$, $95th$]	Standard NK model $Posterior\ Median$ [$5th$, $95th$]
ψ_1	Ratio of derivat. of hh's util.	$G(0.80, 010)$	0.68 [0.58,0.79]	0.68 [0.57,0.79]
ψ_2	Money-output nonseparab.	$N(0.00, 0.50)$	-0.05 [-0.13,0.02]	–
h	Habit formation	$B(0.70, 010)$	0.88 [0.79,0.96]	0.86 [0.77,0.95]
θ	Price stickiness	$B(0.65, 010)$	0.66 [0.53,0.85]	0.66 [0.55,0.78]
ω	Price indexation	$B(0.50, 0.15)$	0.74 [0.63,0.85]	0.76 [0.67,0.86]
φ	Inv. of Frisch lab. elasticity	$G(1.00, 0.25)$	0.94 [0.55,1.31]	0.95 [0.57,1.32]
γ_1	Money-output elast.	$G(0.50, 0.25)$	0.58 [0.16,0.99]	0.26 [0.12,0.39]
γ_2	Money-nom. rate semielast.	$G(0.20, 0.15)$	0.26 [0.01,0.53]	0.13 [0.00,0.26]
δ_0	Portfolio adj. cost	$G(6.00, 2.85)$	4.62 [2.04,7.20]	–
ρ_R	Policy rate smoothing	$B(0.50, 0.10)$	0.46 [0.33,0.58]	0.40 [0.27,0.52]
ρ_y	Policy resp. to output	$G(0.15, 0.05)$	0.12 [0.08,0.17]	0.11 [0.07,0.15]
ρ_π	Policy resp. to inflation	$G(1.50, 0.25)$	1.64 [1.33,1.92]	1.63 [1.33,1.88]
ρ_μ	Policy resp. to mon. growth	$G(0.80, 0.40)$	0.13 [0.04,0.21]	–
ρ_a	Preference shock pers.	$B(0.75, 0.10)$	0.73 [0.63,0.82]	0.74 [0.65,0.83]
ρ_e	Money dem. shock pers.	$B(0.75, 0.10)$	0.76 [0.67,0.85]	0.88 [0.84,0.93]
ρ_z	Tech. shock pers.	$B(0.75, 0.10)$	0.71 [0.58,0.84]	0.72 [0.59,0.84]
σ_a	Preference shock st. dev.	$IG(0.01, 1.50)$	0.0104 [0.0057,0.0148]	0.0108 [0.0064,0.0152]
σ_e	Money dem. shock st. dev.	$IG(0.01, 1.50)$	0.0195 [0.0124,0.0265]	0.0069 [0.0062,0.076]
σ_z	Technology shock st. dev.	$IG(0.01, 1.50)$	0.0092 [0.0048,0.0139]	0.0086 [0.0045,0.0129]
σ_r	Policy rate shock st. dev.	$IG(0.01, 1.50)$	0.0020 [0.0021,0.0023]	0.0019 [0.0016,0.0022]
$Marg.Lik.$			2635.5	2620.4

Table 5: **Model Comparison: Full Sample Estimates - Monetary Base Indicator.** Sample: 1966:I-2007:II. 'Ratio of derivat. of hh's util.': Ratio of derivatives of household's utility. Priors: 'G' stands for Gamma, 'N' - Normal, 'B' - Beta, 'IG' - Inverse Gamma. The computation of the Marginal Likelihoods are performed by employing the Modified Harmonic Mean estimator proposed by Geweke (1998). The Table reports posterior medians and the [5th,95th] posterior percentiles. The posterior summary statistics are calculated from the output of the Metropolis algorithm. Details on estimation procedure are given in the text.

Households' problem

$$\max_{C_t,N_t,M_t,B_t} E_0 \sum_{t=0}^{\infty} \beta^t a_t \left[\Psi\left(\frac{C_t}{C_{t-1}^h}, \frac{M_t}{e_t P_t}\right) - \frac{N_t^{1+\varphi}}{1+\varphi} \right] - G(\bullet)$$

with $G(\bullet) = \frac{d}{2}\left\{ \exp\left(c\left\{ \frac{M_t/P_t}{M_{t-1}/P_{t-1}} - 1 \right\}\right) + \exp\left(-c\left\{ \frac{M_t/P_t}{M_{t-1}/P_{t-1}} - 1 \right\}\right) - 2 \right\}$

s.t. $\frac{M_{t-1}+B_{t-1}+W_t N_t + T_t + D_t}{P_t} = C_t + \frac{B_t/r_t + M_t}{P_t}$

where

$C_t = \int_0^1 \left(C_t(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}}$: CES aggregator of the different goods consumed; $\frac{M_t}{P_t}$: real balances; N_t: hours;

a_t: preference shock; e_t: money demand shock; β: discount factor; φ: inv. of Frisch lab. elasticity; h: degree of habit formation; c, d: portfolio adj. costs' parameters; B_t: bonds; r_t: gross interest rate; W_t: wages; T_t: lump sum transfer; D_t: firms' dividends ε: goods' elasticity of substitution; P_t: aggregate price level.

Firms' production function and price setting

$Y_t(j) = z_t N_t(j)^{1-\alpha}$

$P_t = \left[\theta \left(P_{t-1}\pi_{t-1}^{\omega}\right)^{1-\varepsilon} + (1-\theta)\, P_t^{*1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}$

where

$Y_t = \int_0^1 \left(Y_t(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}}$: CES aggregator of the different goods produced; $N_t(j)$: hours hired by firm j; z_t: technology shock;

$1-\alpha$: elasticity of output w.r.t. hours; $1-\theta$: measure of producers resetting their prices each period;
ω: degree of price indexation by non-reoptimizing firms; P_t^*: optimal price set by reoptimizers.

Market-clearing conditions

Goods market: $Y_t = C_t$

Labor market: $N_t = \int_0^1 N_t(j) dj$

Table 1: **Description of the DSGE Model with Money - Nonlinear Equations.** This Table collects the non-linear equations regarding households' problem, firms' production function and price setting, and market-clearing conditions. The definitions of the structural parameters are given in Table 3.

Variables in percentage deviations from their steady-state values
$\widehat{y}_t$: Output, $\widehat{\pi}_t$: Inflation, $\widehat{r}_t$: Nominal rate, $\widehat{m}_t$: Real balances

Log-linearized equations of the model	
$\widehat{y}_t = \frac{\phi_1}{\phi_1+\phi_2}\widehat{y}_{t-1} + \frac{\beta\phi_1+\phi_2}{\phi_1+\phi_2}E_t\widehat{y}_{t+1} - \frac{1}{\phi_1+\phi_2}(\widehat{r}_t - E_t\widehat{\pi}_{t+1}) - \frac{\beta\phi_1}{\phi_1+\phi_2}E_t\widehat{y}_{t+2} + \frac{\psi_2}{\psi_1(1-\beta h)(\phi_1+\phi_2)}(\widehat{m}_t - \widehat{e}_t)$ $- \frac{\psi_2(1+\beta h)}{\psi_1(1-\beta h)(\phi_1+\phi_2)}E_t(\widehat{m}_{t+1} - \widehat{e}_{t+1}) + \frac{\psi_2\beta h}{\psi_1(1-\beta h)(\phi_1+\phi_2)}E_t(\widehat{m}_{t+2} - \widehat{e}_{t+2}) + \frac{(1-\beta h\rho_a)(1-\rho_a)}{(1-\beta h)(\phi_1+\phi_2)}\widehat{a}_t$	(1)
$\widehat{\pi}_t = \gamma_f E_t\widehat{\pi}_{t+1} + \gamma_b\widehat{\pi}_{t-1} + \lambda\widehat{mc}_t$	(2)
$\widehat{mc}_t = (\chi+\phi_2)\widehat{y}_t - \phi_1\widehat{y}_{t-1} - \beta\phi_1 E_t\widehat{y}_{t+1} - \frac{\psi_2}{\psi_1(1-\beta h)}(\widehat{m}_t - \widehat{e}_t)$ $+ \frac{\psi_2\beta h}{\psi_1(1-\beta h)}E_t(\widehat{m}_{t+1} - \widehat{e}_{t+1}) - \frac{\beta h(1-\rho_a)}{(1-\beta h)}\widehat{a}_t - (1+\chi)\widehat{z}_t$	(3)
$(1+\delta_0(1+\beta))\widehat{m}_t = \gamma_1\widehat{y}_t - \gamma_2\widehat{r}_t + [\gamma_2(\overline{r}-1)(h\phi_2 - \phi_1) - h\gamma_1]\widehat{y}_{t-1} - [\gamma_2(\overline{r}-1)\beta\phi_1]E_t\widehat{y}_{t+1}$ $+\delta_0\widehat{m}_{t-1} + \left[\frac{\psi_2(\overline{r}-1)\beta h\gamma_2}{\psi_1(1-\beta h)} + \delta_0\beta\right]E_t\widehat{m}_{t+1} - \frac{(\overline{r}-1)\beta h(1-\rho_a)}{(1-\beta h)}\gamma_2\widehat{a}_t$ $+\left\{1 - (\overline{r}-1)\gamma_2\left[\frac{\psi_2\beta h\rho_e}{\psi_1(1-\beta h)} + 1\right]\right\}\widehat{e}_t$	(4)
$\widehat{r}_t = \rho_r\widehat{r}_{t-1} + (1-\rho_r)(\rho_y\widehat{y}_t + \rho_\pi\widehat{\pi}_t + \rho_\mu\widehat{\mu}_t) + \varepsilon_r$	(5)
$\widehat{\mu}_t = \widehat{m}_t - \widehat{m}_{t-1} + \widehat{\pi}_t$	(6)
$\widehat{\zeta}_t = \rho_\zeta\widehat{\zeta}_{t-1} + \varepsilon_{\xi_t}, \zeta \in \{a,e,z\}; \varepsilon_{\xi_t} \sim N(0,\sigma_{\varepsilon_\xi}), \xi \in \{a,e,z,r\}$	(7)

Compound parameters of the model
$\psi_1 \equiv -\frac{U_1}{\overline{y}^{(1-h)}U_{11}}, \psi_2 \equiv -\frac{U_{12}}{\overline{y}^{(1-h)}U_{11}}\left(\frac{m}{e}\right), \gamma_f \equiv \beta\theta\{\theta + \omega[1-\theta(1-\beta)]\}^{-1},$ $\gamma_b \equiv \omega\{\theta + \omega[1-\theta(1-\beta)]\}^{-1} \lambda \equiv (1-\theta)(1-\beta\theta)(1-\omega)\xi, \chi \equiv \frac{\varphi+\alpha}{1-\alpha},$ $\xi \equiv \frac{(1-\alpha)}{1+\alpha(\varepsilon-1)}\{\theta + \omega[1-\theta(1-\beta)]\}^{-1}, \phi_1 \equiv \frac{(\psi_1^{-1}-1)h}{1-\beta h}, \phi_2 \equiv \frac{\psi_1^{-1}+(\psi_1^{-1}-1)\beta h^2 - \beta h}{1-\beta h}, \delta_0 \equiv -\frac{c^2 d}{U_{22}m^2}$

Calibrated parameters
$\beta = 0.9925$: discount factor; $\overline{r} = 1.0138$: gross-steady-state quarterly nominal interest rate; $1-\alpha = 2/3$: labor income share; $\varepsilon = 6$: goods' elasticity of substitution; $c = 1$: coefficient regulating the portfolio adjustment costs.

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$Param.$	$Definition$	$Prior(mean, std.)$	Model with money $Posterior\ Median$ [$5th$, $95th$]	Standard NK model $Posterior\ Median$ [$5th$, $95th$]
ψ_1	Ratio of derivat. of hh's util.	$G(0.80, 010)$	0.69 [0.58,0.80]	0.68 [0.57,0.79]
ψ_2	Money-output nonseparab.	$N(0.00, 0.50)$	0.05 [−0.03,0.19]	–
h	Habit formation	$B(0.70, 010)$	0.86 [0.76,0.95]	0.88 [0.78,0.96]
θ	Price stickiness	$B(0.65, 010)$	0.66 [0.53,0.78]	0.67 [0.54,0.79]
ω	Price indexation	$B(0.50, 0.15)$	0.76 [0.65,0.86]	0.77 [0.66,0.86]
φ	Inv. of Frisch lab. elasticity	$G(1.00, 0.25)$	0.95 [0.55,1.33]	0.94 [0.59,1.34]
γ_1	Money-output elast.	$G(0.50, 0.25)$	0.88 [0.29,1.51]	0.39 [0.22,0.59]
γ_2	Money-nom. rate semielast.	$G(0.20, 0.15)$	0.35 [0.02,0.86]	0.37 [0.04,0.73]
δ_0	Portfolio adj. cost	$G(6.00, 2.85)$	3.20 [1.22,5.61]	–
ρ_R	Policy rate smoothing	$B(0.50, 0.10)$	0.44 [0.32,0.56]	0.40 [0.27,0.52]
ρ_y	Policy resp. to output	$G(0.15, 0.05)$	0.13 [0.08,0.18]	0.11 [0.07,0.16]
ρ_π	Policy resp. to inflation	$G(1.50, 0.25)$	1.67 [1.38,1.96]	1.63 [1.36,1.92]
ρ_μ	Policy resp. to mon. growth	$G(0.80, 0.40)$	0.10 [0.03,1.18]	–
ρ_a	Preference shock pers.	$B(0.75, 0.10)$	0.74 [0.65,0.83]	0.75 [0.66,0.84]
ρ_e	Money dem. shock pers.	$B(0.75, 0.10)$	0.79 [0.71,0.88]	0.88 [0.83,0.93]
ρ_z	Tech. shock pers.	$B(0.75, 0.10)$	0.71 [0.57,0.84]	0.72 [0.59,0.84]
σ_a	Preference shock st. dev.	$IG(0.01, 1.50)$	0.0105 [0.0062,0.0152]	0.0104 [0.0062,0.0153]
σ_e	Money dem. shock st. dev.	$IG(0.01, 1.50)$	0.0175 [0.0115,0.0250]	0.0077 [0.0049,0.085]
σ_z	Technology shock st. dev.	$IG(0.01, 1.50)$	0.0091 [0.0050,0.0146]	0.0081 [0.0064,0.0131]
σ_r	Policy rate shock st. dev.	$IG(0.01, 1.50)$	0.0020 [0.0016,0.0024]	0.0019 [0.0016,0.0023]
$Marg.Lik.$			2615.1	2603.1

Table 3: **Model Comparison: Full Sample Estimates - M2 Indicator.** Sample: 1966:I-2007:II. 'Ratio of derivat. of hh's util.': Ratio of derivatives of household's utility. Priors: 'G' stands for Gamma, 'N' - Normal, 'B' - Beta, 'IG' - Inverse Gamma. The computation of the Marginal Likelihoods are performed by employing the Modified Harmonic Mean estimator proposed by Geweke (1998). The Table reports posterior medians and the [5th,95th] posterior percentiles. The posterior summary statistics are calculated from the output of the Metropolis algorithm. Details on estimation procedure are given in the text.

			1966:I-1982:IV		1990:I-2006:IV	
Param.	*Definition*	*Prior(mean, std.)*	Model with money *Posterior Median* [5th, 95th]	Standard NK model *Posterior Median* [5th, 95th]	Model with money *Posterior Median* [5th, 95th]	Standard NK model *Posterior Median* [5th, 95th]
ψ_1	Ratio of derivat. of hh's util.	$G(0.80, 010)$	0.70 [0.56,0.84]	0.73 [0.60,0.84]	0.72 [0.60,0.84]	0.73 [0.62,0.86]
ψ_2	Money-output nonseparab.	$N(0.00, 0.50)$	0.62 [0.46,0.80]	–	0.13 [0.00,0.29]	–
h	Habit formation	$B(0.70, 010)$	0.40 [0.26,0.54]	0.76 [0.60,0.91]	0.85 [0.74,0.94]	0.85 [0.74,0.94]
θ	Price stickiness	$B(0.65, 010)$	0.63 [0.51,0.75]	0.65 [0.51,0.78]	0.74 [0.60,0.86]	0.79 [0.68,0.87]
ω	Price indexation	$B(0.50, 0.15)$	0.41 [0.19,0.68]	0.75 [0.60,0.87]	0.62 [0.42,0.81]	0.61 [0.41,0.79]
φ	Inv. of Frisch lab. elasticity	$G(1.00, 0.25)$	0.98 [0.60,1.42]	0.96 [0.57,1.37]	0.91 [0.55,1.28]	0.90 [0.55,1.29]
γ_1	Money-output elast.	$G(0.50, 0.25)$	2.20 [1.62,2.83]	0.38 [0.14,0.61]	0.50 [0.14,0.93]	0.40 [0.14,0.67]
γ_2	Money-nom. rate semielast.	$G(0.20, 0.15)$	0.29 [0.01,0.67]	0.21 [0.01,0.50]	0.21 [0.00,0.52]	0.33 [0.01,0.75]
δ_0	Portfolio adj. cost	$G(6.00, 2.85)$	1.98 [1.08,3.00]	–	4.40 [1.40,7.97]	–
ρ_R	Policy rate smoothing	$B(0.50, 0.10)$	0.39 [0.26,0.52]	0.40 [0.27,0.54]	0.54 [0.39,0.66]	0.56 [0.43,0.68]
ρ_y	Policy resp. to output	$G(0.15, 0.05)$	0.17 [0.10,0.26]	0.13 [0.08,0.19]	0.17 [0.10,0.24]	0.16 [0.09,0.24]
ρ_π	Policy resp. to inflation	$G(1.50, 0.25)$	1.91 [1.54,2.31]	1.47 [1.17,1.80]	1.62 [1.21,2.04]	1.58 [1.18,2.00]
ρ_μ	Policy resp. to mon. growth	$G(0.80, 0.40)$	0.61 [0.28,0.94]	–	0.26 [0.09,0.47]	–
ρ_a	Preference shock pers.	$B(0.75, 0.10)$	0.76 [0.63,0.90]	0.75 [0.63,0.85]	0.80 [0.70,0.89]	0.79 [0.69,0.88]
ρ_e	Money dem. shock pers.	$B(0.75, 0.10)$	0.81 [0.71,0.91]	0.87 [0.81,0.94]	0.80 [0.70,0.91]	0.85 [0.78,0.92]
ρ_z	Tech. shock pers.	$B(0.75, 0.10)$	0.77 [0.61,0.90]	0.74 [0.59,0.88]	0.74 [0.60,0.86]	0.70 [0.55,0.83]
σ_a	Preference shock st. dev.	$IG(0.01, 1.50)$	0.0066 [0.0038,0.0100]	0.0104 [0.0062,0.0153]	0.0069 [0.0040,0.0103]	0.0069 [0.0040,0.0101]
σ_e	Money dem. shock st. dev.	$IG(0.01, 1.50)$	0.0136 [0.0096,0.0178]	0.0077 [0.0049,0.085]	0.0106 [0.0062,0.0158]	0.0049 [0.0040,0.059]
σ_z	Technology shock st. dev.	$IG(0.01, 1.50)$	0.0123 [0.0064,0.0207]	0.0081 [0.0064,0.0131]	0.0047 [0.0025,0.0076]	0.0049 [0.0024,0.0083]
σ_r	Policy rate shock st. dev.	$IG(0.01, 1.50)$	0.0031 [0.0022,0.0042]	0.0019 [0.0016,0.0023]	0.0017 [0.0014,0.0020]	0.0017 [0.0013,0.0020]
Marg.Lik.			936.10	921.64	1080.00	1081.60

Table 4: **Model Comparison: Selected Windows - M2 Indicator.** 'Ratio of derivat. of hh's util.': Ratio of derivatives of household's utility. Priors: 'G' stands for Gamma, 'N' - Normal, 'B' - Beta, 'IG' - Inverse Gamma. The computation of the Marginal Likelihoods are performed by employing the Modified Harmonic Mean estimator proposed by Geweke (1998). The Table reports posterior medians and the [5th,95th] posterior percentiles. The posterior summary statistics are calculated from the output of the Metropolis algorithm. Details on estimation procedure are given in the text.

Param.	*Definition*	*Prior(mean, std.)*	Model with money *Posterior Median* [5th, 95th]	Standard NK model *Posterior Median* [5th, 95th]
ψ_1	Ratio of derivat. of hh's util.	$G(0.80, 010)$	0.68 [0.58,0.79]	0.68 [0.57,0.79]
ψ_2	Money-output nonseparab.	$N(0.00, 0.50)$	−0.05 [−0.13,0.02]	–
h	Habit formation	$B(0.70, 010)$	0.88 [0.79,0.96]	0.86 [0.77,0.95]
θ	Price stickiness	$B(0.65, 010)$	0.66 [0.53,0.85]	0.66 [0.55,0.78]
ω	Price indexation	$B(0.50, 0.15)$	0.74 [0.63,0.85]	0.76 [0.67,0.86]
φ	Inv. of Frisch lab. elasticity	$G(1.00, 0.25)$	0.94 [0.55,1.31]	0.95 [0.57,1.32]
γ_1	Money-output elast.	$G(0.50, 0.25)$	0.58 [0.16,0.99]	0.26 [0.12,0.39]
γ_2	Money-nom. rate semielast.	$G(0.20, 0.15)$	0.26 [0.01,0.53]	0.13 [0.00,0.26]
δ_0	Portfolio adj. cost	$G(6.00, 2.85)$	4.62 [2.04,7.20]	–
ρ_R	Policy rate smoothing	$B(0.50, 0.10)$	0.46 [0.33,0.58]	0.40 [0.27,0.52]
ρ_y	Policy resp. to output	$G(0.15, 0.05)$	0.12 [0.08,0.17]	0.11 [0.07,0.15]
ρ_π	Policy resp. to inflation	$G(1.50, 0.25)$	1.64 [1.33,1.92]	1.63 [1.33,1.88]
ρ_μ	Policy resp. to mon. growth	$G(0.80, 0.40)$	0.13 [0.04,0.21]	–
ρ_a	Preference shock pers.	$B(0.75, 0.10)$	0.73 [0.63,0.82]	0.74 [0.65,0.83]
ρ_e	Money dem. shock pers.	$B(0.75, 0.10)$	0.76 [0.67,0.85]	0.88 [0.84,0.93]
ρ_z	Tech. shock pers.	$B(0.75, 0.10)$	0.71 [0.58,0.84]	0.72 [0.59,0.84]
σ_a	Preference shock st. dev.	$IG(0.01, 1.50)$	0.0104 [0.0057,0.0148]	0.0108 [0.0064,0.0152]
σ_e	Money dem. shock st. dev.	$IG(0.01, 1.50)$	0.0195 [0.0124,0.0265]	0.0069 [0.0062,0.076]
σ_z	Technology shock st. dev.	$IG(0.01, 1.50)$	0.0092 [0.0048,0.0139]	0.0086 [0.0045,0.0129]
σ_r	Policy rate shock st. dev.	$IG(0.01, 1.50)$	0.0020 [0.0021,0.0023]	0.0019 [0.0016,0.0022]
Marg.Lik.			2635.5	2620.4

Table 5: **Model Comparison: Full Sample Estimates - Monetary Base Indicator.** Sample: 1966:I-2007:II. 'Ratio of derivat. of hh's util.': Ratio of derivatives of household's utility. Priors: 'G' stands for Gamma, 'N' - Normal, 'B' - Beta, 'IG' - Inverse Gamma. The computation of the Marginal Likelihoods are performed by employing the Modified Harmonic Mean estimator proposed by Geweke (1998). The Table reports posterior medians and the [5th,95th] posterior percentiles. The posterior summary statistics are calculated from the output of the Metropolis algorithm. Details on estimation procedure are given in the text.

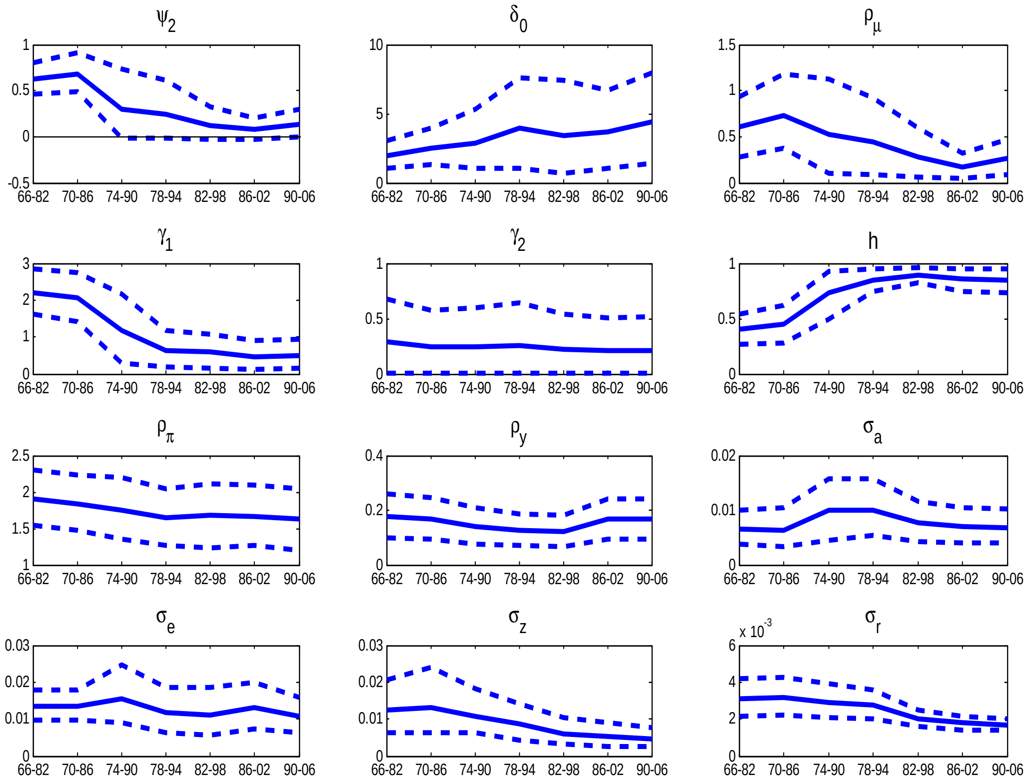

Figure 1: **Evolution of Structural Parameters over Time - M2 Aggregate.** Structural parameters of the DSGE model with money presented in the text. Definitions of the structural parameters given in Table 3. Solid line: Posterior median. Dotted lines: 5th and 95th posterior percentiles. Evolution of the parameters constructed by employing seven rolling windows of 16-year constant length. Windows: [1966:I-1982:IV, 1970:I-1986:IV, ..., 1990:I-2006:IV].

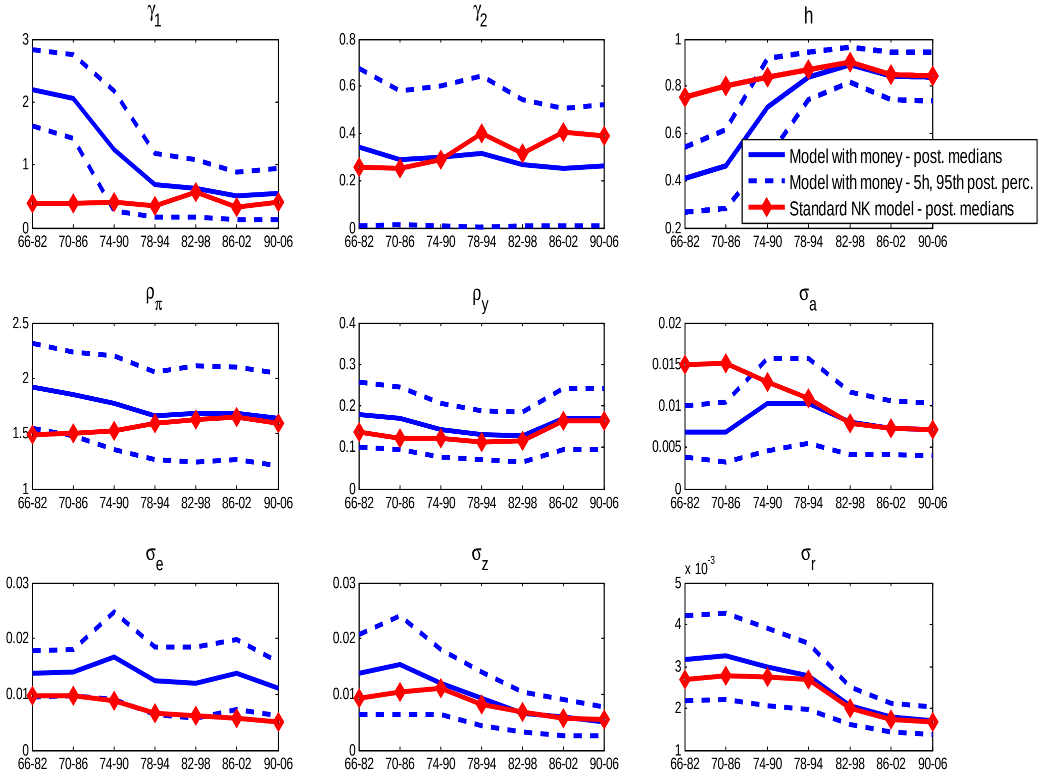

Figure 2: **Evolution of Structural Parameters over Time: Model Comparison - M2 Aggregate.** Structural parameters of the DSGE model with money and the standard NK model presented in the text. Definitions of the structural parameters given in Table 3. Solid line: Model with money, posterior medians. Dotted lines: Model with money, 5th and 95th posterior percentiles. Solid line with diamonds: Standard new-Keynesian model (no relevant role for money), posterior medians. Evolution of the parameters constructed by employing seven rolling windows of 16-year constant length. Windows: [1966:I-1982:IV, 1970:I-1986:IV, ..., 1990:I-2006:IV].

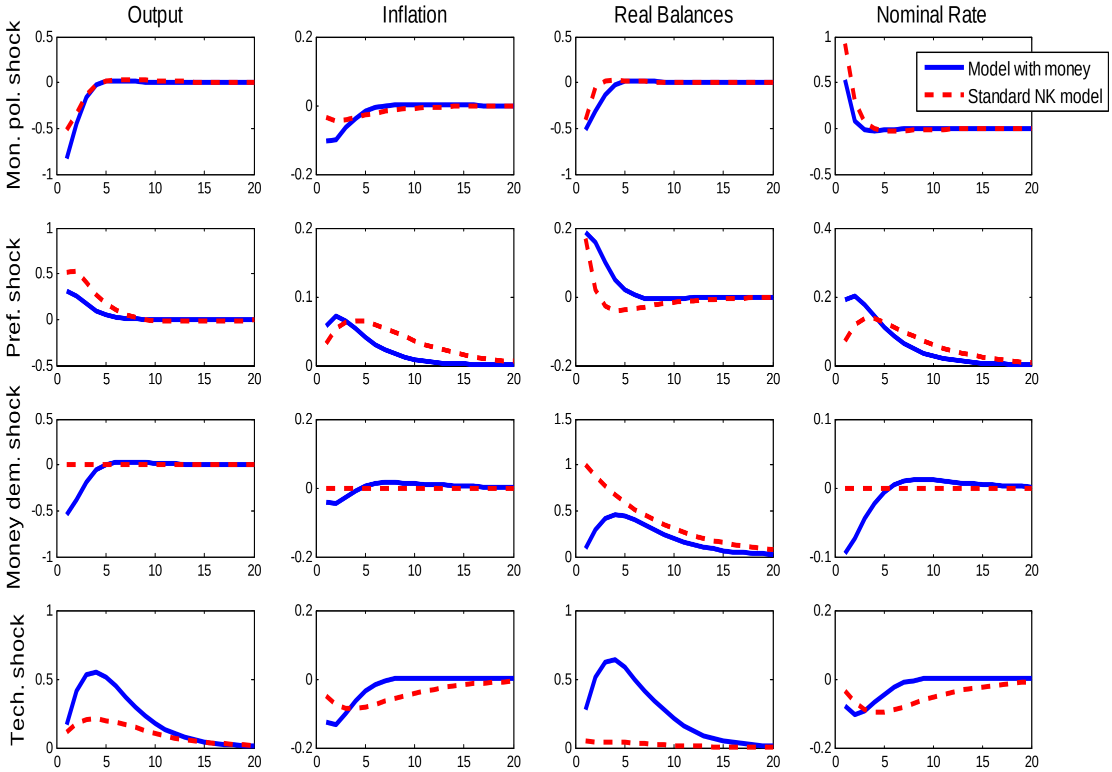

Figure 3: **Responses to Shocks: 1966:I-1982:IV - M2 Aggregate.** Impulse responses to normalized shocks. Shocks' standard deviations normalized to unity. Shocks of each structural DSGE model assumed to be orthogonal.

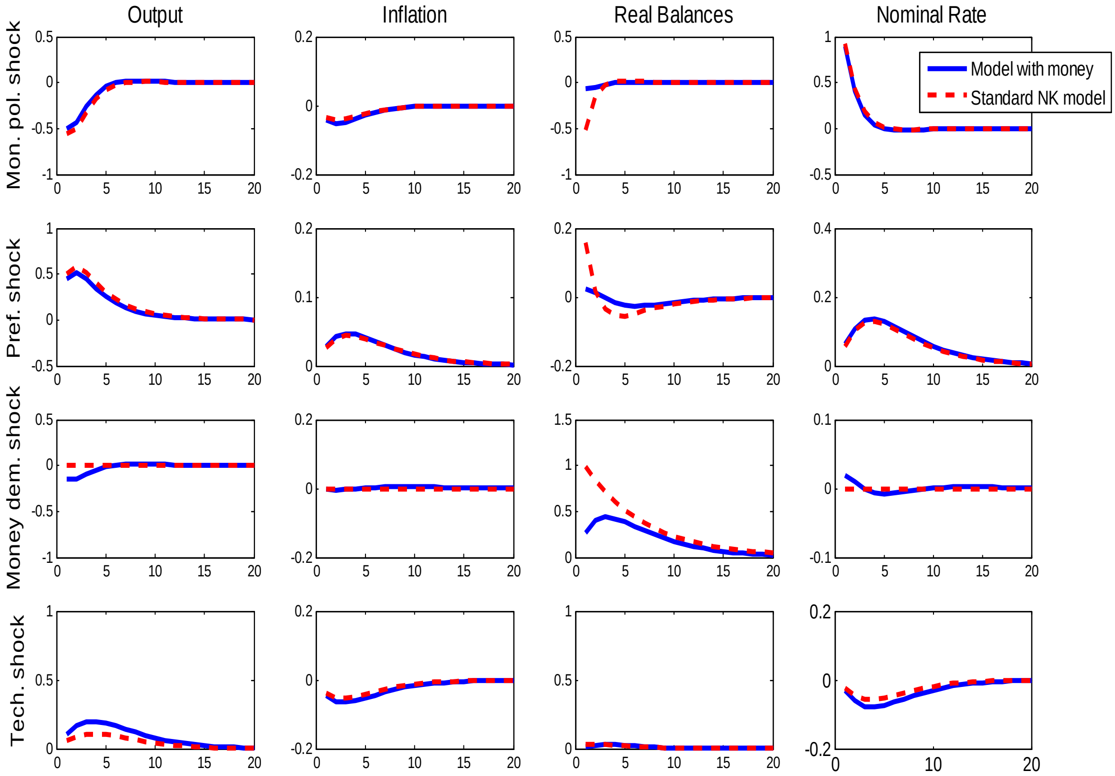

Figure 4: **Responses to Shocks: 1990:I-2006:IV - M2 Aggregate.** Impulse responses to normalized shocks. Shocks' standard deviations normalized to unity. Shocks of each structural DSGE model assumed to be orthogonal.

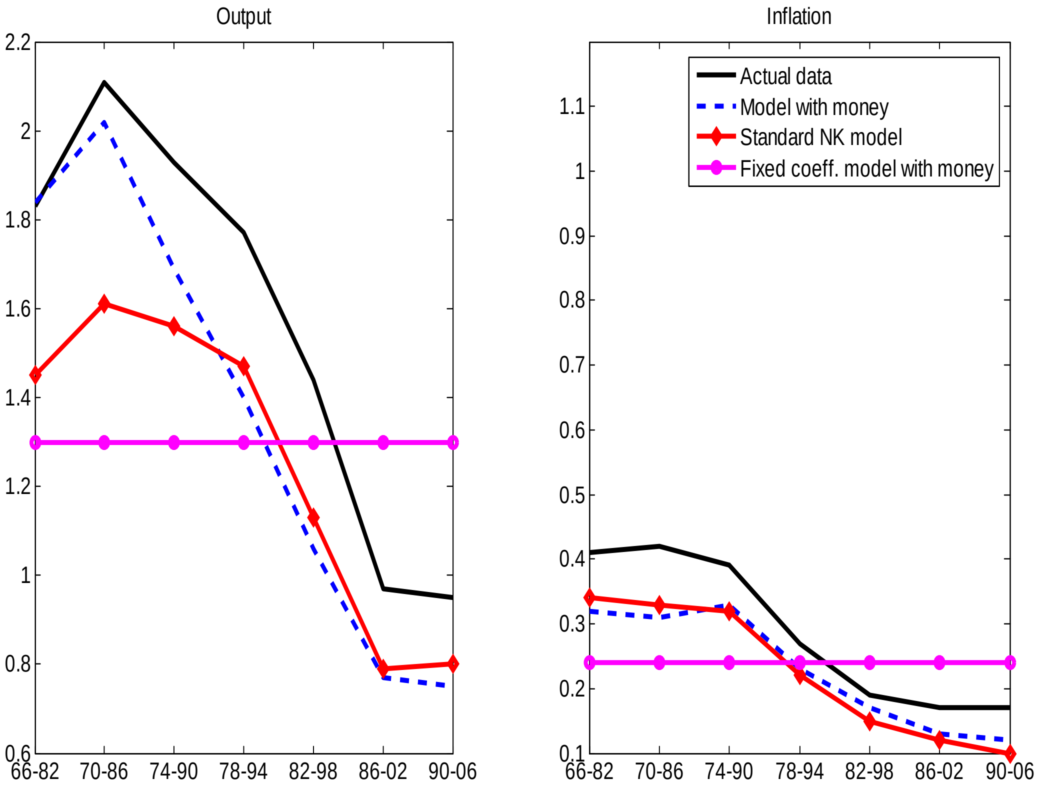

Figure 5: **Actual and Population Standard Deviations - M2 Indicator.** Actual data: (Window-specific) standard deviations of the observables employed in the estimation of the business cycle models. Population Standard Deviations: Computed by calibrating our models with their estimated posterior medians. Model with money and Standard NK model allow for drifts in parameters. Fixed-coefficient model with money: Model estimated over the sample 1966:I-2006:IV.

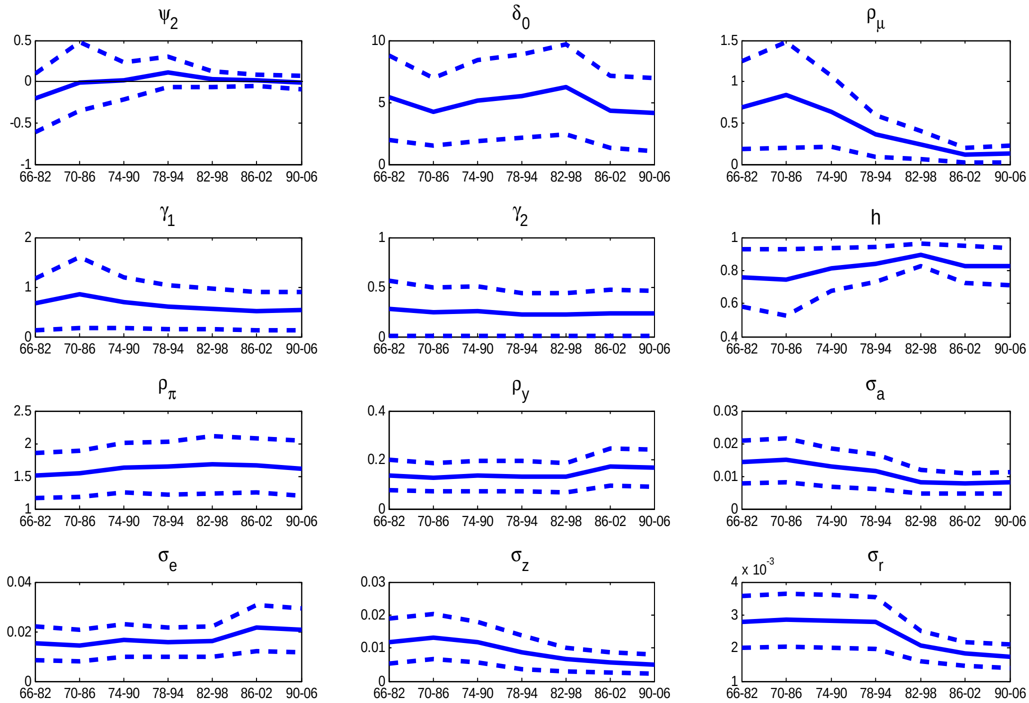

Figure 6: **Evolution of Structural Parameters over Time - Monetary Base Aggregate.** Structural parameters of the DSGE model with money presented in the text. Definitions of the structural parameters given in Table 3. Solid line: Posterior median. Dotted line: 5th and 95th posterior percentiles. Evolution of the parameters constructed by employing seven rolling windows of 16-year constant length. Windows: [1966:I-1982:IV, 1970:I-1986:IV, ..., 1990:I-2006:IV].

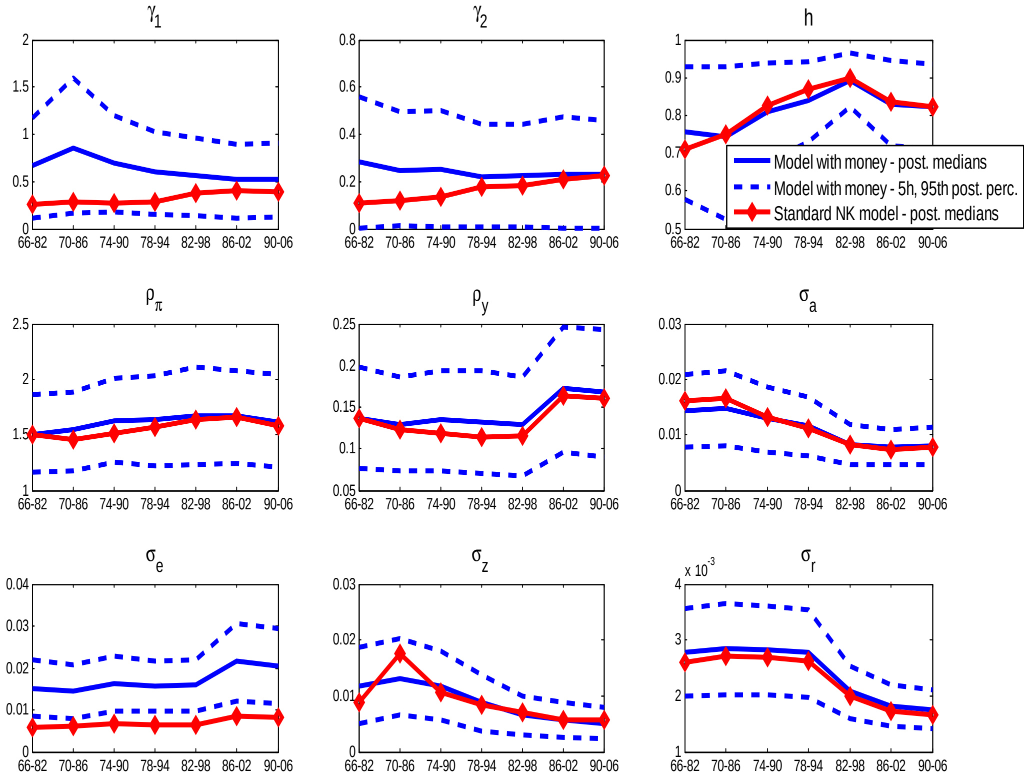

Figure 7: **Evolution of Structural Parameters over Time: Model Comparison - Monetary Base Aggregate.** Structural parameters of the DSGE model with money and the standard NK model presented in the text. Definitions of the structural parameters given in Table 3. Solid line: Model with money, posterior medians. Dotted lines: Model with money, 5th and 95th posterior percentiles. Solid line with diamonds: Standard new-Keynesian model (no relevant role for money), posterior medians. Evolution of the parameters constructed by employing seven rolling windows of 16-year constant length. Windows: [1966:I-1982:IV, 1970:I-1986:IV, ..., 1990:I-2006:IV].

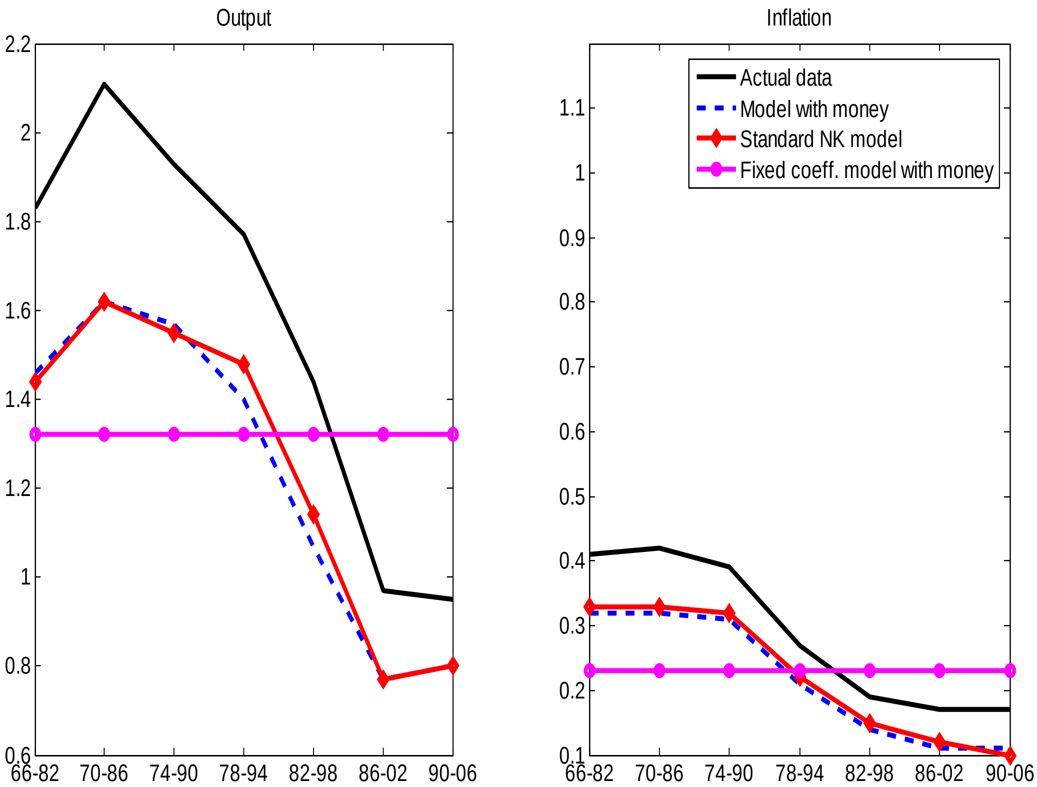

Figure 8: **Actual and Population Standard Deviations - Monetary Base Aggregate.** Actual data: (Window-specific) standard deviations of the observables employed in the estimation of the business cycle models. Model with money and Standard NK model allow for drifts in parameters. Fixed-coefficient model with money: Model estimated over the sample 1966:I-2006:IV. Population standard deviations computed by calibrating our models with the estimated posterior medians.

Additional results: Estimation of our DSGE model with multiple monetary indicators - not for publication

The joint employment of different indicators in macroeconometric applications regarding DSGE frameworks has recently been proposed by Canova and Ferroni (2011). The idea is to exploit the information content of different indicators to obtain sharper econometric estimates. Inspired by Canova and Ferroni's proposal, we manipulate the set of measurement equations involving money to allow, but not necessarily require, each monetary aggregate to influence the likelihood of the DSGE model at hand. Such measurement equations take this form:

$$\begin{aligned} \widehat{m}_t^{M0obs} &= \lambda_{M0}\widehat{m}_t + \eta_t^{M0obs}, \\ \widehat{m}_t^{M2obs} &= \lambda_{M2}\widehat{m}_t + \eta_t^{M2obs}, \end{aligned}$$

where $\widehat{m}_t$ is the model-consistent, theoretical monetary aggregate, $\widehat{m}_t^{M0obs}$ is its M0-based empirical counterpart whose weight is λ_{M0}, $\widehat{m}_t^{M2obs}$ is the M2-based empirical counterpart whose weight is λ_{M2}, and η_t^{M0obs} and η_t^{M2obs} are idiosyncratic, mutually and serially uncorrelated measurement errors. As in Canova and Ferroni (2011), we normalize one weight to reduce the number of parameters to estimate (in our case, we set $\lambda_{M0} = 1$) and estimate the model endowed with both M0 and M2 as observables. Therefore, the estimated relative weight λ_{M2} (as well as the idiosyncratic measurement errors) provides an assessment on the information content carried by M2. Given the presence of M0, if M2 did not provide any valuable extra information as for the structural relationships of our DSGE model, the data would locate the posterior mean of λ_{M2} around zero. Then, we interpret this exercise as an attempt to quantify the relevance of the information carried by the M2 multiplier.

We assume $\lambda_{M2} \sim N(0,1)$, i.e., a Normally-distributed density centered in zero and with a variance large enough to let the data speak freely as for M2's role. In terms of measurement errors, we stick to our baseline choice and assume them to be $InverseGamma(0.01, 1.5)$ distributed. Given that M2 is a broad monetary aggregate embedding the information coming from M0, one should expect the estimated posterior mean of the parameter λ_{M2} to move away from the zero value if and only if the M2 money multiplier carries relevant information as for the relationships modeled via the structural DSGE model we focus on. To be clear, this exercise aims at assessing which monetary indicator(s) one should use when conducting empirical exercises with small-scale models like ours. This is a different question with respect to the main question of the paper, which regards the role of money in the U.S. business cycle.

Our results are the following. We find the posterior mean of the estimated relative weight λ_{M2} to be positive in all windows, with the zero value never contained in any of the 90% credible sets. The mean value of the posterior means of λ_{M2} across windows reads 0.70. Interestingly, the measurement error associated to M2 features a lower estimated volatility than the one associated to M0 in almost all windows. Importantly, the model estimated with both monetary indicators returns estimates of our structural parameters very similar to those obtained with M2 only, and clearly different with respect to those obtained with M0 only. Therefore, our results support M2 as a monetary indicator carrying relevant information to describe the theoretical concept of money defined in the structural model and its interactions with the remaining macroeconomic aggregates.

References

Canova, F., and F. Ferroni (2011): "Multiple Filtering Devices for the Estimation of Cyclical DSGE Models," *Quantitative Economics*, 2, 73–98.

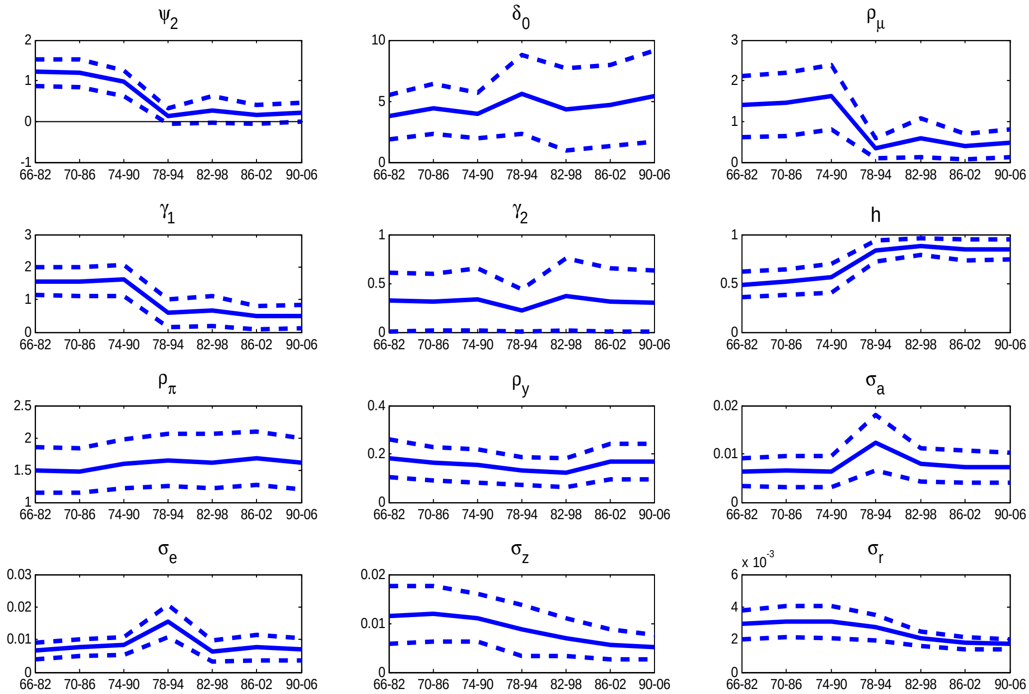

Figure A1: **Evolution of Structural Parameters over Time - Multiple Monetary Aggregates.** Model estimated with two monetary aggregates jointly, i.e., M0 and M2. The relative weight of M2 was estimated along with the rest of the model. Structural parameters of the DSGE model with money presented in the text. Definitions of the structural parameters given in Table 3. Solid line: Posterior median. Dotted lines: 5th and 95th posterior percentiles. Evolution of the parameters constructed by employing seven rolling windows of 16-year constant length. Windows: [1966:I-1982:IV, 1970:I-1986:IV, ..., 1990:I-2006:IV].

$Window$	λ_{M2} $Posterior\ Median$ $[5th,\ 95th]$	$\sigma_{\eta,M0}$ $Posterior\ Median$ $[5th,\ 95th]$	$\sigma_{\eta,M2}$ $Posterior\ Median$ $[5th,\ 95th]$
1966:I-1982:IV	0.42 [0.36,0.48]	0.0094 [0.0079,0.0109]	0.0021 [0.0015,0.0028]
1970:I-1986:IV	0.46 [0.39,0.53]	0.0109 [0.0092,0.0127]	0.0026 [0.0019,0.0033]
1974:I-1990:IV	0.60 [0.49,0.70]	0.0112 [0.0094,0.0132]	0.0036 [0.0023,0.0051]
1978:I-1994:IV	1.70 [1.36,2.01]	0.0063 [0.0018,0.0149]	0.0125 [0.0024,0.0260]
1982:I-1998:IV	0.58 [0.42,0.76]	0.0183 [0.0157,0.0212]	0.0029 [0.0020,0.0041]
1986:I-2002:IV	0.58 [0.41,0.76]	0.0201 [0.0171,0.0213]	0.0024 [0.0017,0.0032]
1990:I-2006:IV	0.59 [0.41,0.75]	0.0191 [0.0165,0.0220]	0.0023 [0.0017,0.0030]

Table A1: **Multiple Monetary Aggregates - Estimated Relative Weight of the M2 indicator.** Model estimated with M0 and M2 jointly. Relative Weight of the M2 indicator: Normally distributed prior featuring zero mean and unitary standard deviation. Measurement errors: Inverse Gamma distributed prior featuring 0.01 mean and 1.5 standard deviation. The Table reports posterior medians and the [5th,95th] posterior percentiles. The posterior summary statistics are calculated from the output of the Metropolis algorithm. Details on estimation procedure are given in the text.