Monetary Policy Objectives and Money's Role in U.S. Business Cycles*

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Abstract

Assuming that the Fed sets monetary policy optimally under commitment in a timeless perspective, I estimate monetary policy preference parameters in a sticky-price model in which money can be a relevant factor in business cycles. Irrespective of the role of real money balances in the description of the equilibrium, results suggest that inflation variability and interest rate smoothing are the main objectives of monetary policy, with a less important role for the output gap stabilization. The presence of the money growth rate in the Fed's objective function, despite of its small weight, improves the fit of the model in the full sample and in the "Great Inflation" subsample. Finally, model's comparisons based on marginal likelihood show that the data favor the Taylor-type rule over the optimal policy specification.

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1 Introduction

In the standard sticky-price new Keynesian model, as described by Galí (2008), monetary aggregates do not affect the equations describing the equilibrium of the model. Furthermore, the central bank sets the interest rate and supplies any quantity of money demanded by economic agents at the given target rate. In sum, the canonical new Keynesian model, which is a frequently employed framework to discuss and understand monetary policy in academia and policy institutions, makes no reference to monetary aggregates. In other words, the new Keynesian model is block-recursive in money balances; and the equilibrium of the model is independent of the presence of a money demand equation.

Evidences from estimated vector auto-regressions, such as Roush and Leeper (2003) and Favara and Giordani (2009), challenge this view that neglects the role of money in business cycles. To further investigate the role of money in domestic cyclical fluctuations, researchers constructed and estimated Dynamic Stochastic General Equilibrium models with money. Therefore, the empirical model used to assess the relevance of monetary aggregates is in line with the new Keynesian monetary theory; and results could be easily interpreted in the light of this theoretical framework.

Ireland (2004) proposed a new Keynesian model that relaxed the typically employed assumption that household's preferences are separable in consumption and real money balances. Working with U.S. data, Ireland (2004) could not find empirical evidence to reject the assumption of separable preferences. Andrés, López-Salido and Vallés (2006) used Euro-area data and reached the same conclusions as Ireland (2004).

In these papers, however, the specification of preferences that are nonseparable in consumption and real money balances was the only channel through which money might play a role in business cycles. Using both U.S. and Euro-area data, Andrés, López-Salido and Nelson (2009) found empirical support for money as a relevant factor in business cycles when they introduced portfolio adjustment costs in addition to the nonseparable preference channel.

Canova and Menz (2011), Castelnuovo (2012) and Poilly (2010) confirmed the evidence in favor of money as an important factor in cyclical fluctuations. In fact, Canova and Menz (2011) also showed that the role of money in business cycles varied over time and across countries. In addition, Castelnuovo (2012) documented instabilities in the parameters governing money's role in U.S. business cycles across different subsamples.

Following a common practice in the literature, these papers favoring the importance of monetary aggregates used a Taylor-type monetary policy rule to summarize monetary policy behavior, and documented the central bank's systematic reaction to the growth rate of nominal money. This finding may indicate that the money growth rate is one of the objectives of monetary policy, i.e., a target variable in the central bank's loss function. Unfortunately, as discussed in Svensson (2003), there are pitfalls in trying to infer what central banks may care about from the coefficients of simple monetary policy rules. In fact, a significant coefficient associated with the money growth rate may only signal that money is a useful indicator to forecast inflation and the output gap, which are the only variables that the central bank cares about.

Indeed, a Taylor-type rule links central bank's instruments to state variables that determine the target variables, providing monetary policy with information needed to achieve its objectives. In other words, Taylor-type rules focus on a subset of the information available to the central bank to which it responds in order to achieve its objective of stabilizing a set of target variables around specific values. In short, a statistically significant variable in a Taylor-type rule is not necessarily a target variable. For instance, Kam, Lees and Liu (2009) showed that, for inflation-targeting small open economies, real exchange rates were significant macroeconomic variables in Taylor rules, but did not enter monetary authority's objective function.

In this paper, I estimate the model studied in Andrés, López-Salido and Nelson (2009) by replacing the estimated Taylor rule with optimal monetary policy under commitment. According to Dennis (2004, 2006), I therefore specify the central bank's objective function as an inter-temporal loss function to be minimized subject to the central bank's information about the state of the economy and its view on the transmission mechanism. I also compare the optimal policy estimates with the outcomes of the model in which the Taylor rule describes monetary policy.

Specifically, I estimate the parameters of a quadratic loss function which assigns weights to the target variables. The relative weights therefore reflect the preferences of the central bank with respect to the corresponding target variables. In this context, this paper asks the following questions:

- Is nominal money growth rate a target variable entering the central bank's loss function?

- Are the weights assigned to target variables in the central bank's loss function invariant to the presence of money in the equations describing private agents' behavior?

- Does the assumption of optimal policy provide a plausible account of the data when compared with Taylor rules?

To answer these questions, in light of the evidences of parameter instability reported in Canova and Menz (2011) and Castelnuovo (2012), I estimate the model for three different samples. The first sample uses data from 1966:2 to 2007:2 (the full sample estimation). In addition, I consider the "Great Inflation" (1966:2 to 1979:2) and the "Great Moderation" (1984:1 to 2007:2) periods.

The main findings are:

- In spite of its small weight in the central bank's loss function, the presence of the money growth rate as a monetary policy objective improves the fit of the model, suggesting that the Fed cares about this variable, though it is far less important than inflation and interest rate smoothing. However, this is not the case during the "Great Moderation".

- The weights on the output gap stabilization and interest rate smoothing seem reasonably stable, irrespective of the role of money in the equations describing private agents' behavior.

- The data favor a model in which a Taylor-type rule describes monetary policy.

The rest of this paper proceeds as follows. Section 2 sets out the model. Section 3 discusses the empirical methodology. Section 4 presents the main findings. Finally, the last section concludes.

2 A sticky-price model with money

In this section, I present the log-linear approximation of the sticky price economy developed by Andrés, López-Salido and Nelson (2009), henceforth the ALSN model. This artificial economy, in contrast to the canonical new Keynesian model, features an explicit role for money.

In the ALSN model, money affects the description of the equilibrium through the specification of nonseparable preferences and portfolio adjustment costs.

First, the model assumes that household preferences are nonseparable in consumption and real money balances. This nonseparability assumption affects households' intertemporal rate of substitution in consumption. Consequently, the Euler equation characterizing the output gap dynamics depends on real money balances.

In addition, nonseparable preferences alter intratemporal choices. In this context, real money balances affect labor supply and real marginal costs. Therefore, the new Keynesian Phillips curve, which describes inflation dynamics, depends on the evolution of real money balances over time.

Second, the presence of portfolio adjustment costs makes the demand for money a forward-looking equation. In the canonical new Keynesian model, the demand for money is a static equation; and real money balances carry no additional information beyond the information contained in the remaining macroeconomic variables. For this reason, the analysis of the canonical new Keynesian model does not need an explicit money demand equation.

In contrast, in the ALSN model, real money balances convey extra information about the actual state of the economy. In particular, Andrés, López-Salido and Nelson (2009) showed that real money balances are informative about the natural rate of interest, acting as a leading indicator for future changes in this variable. In addition, according to Arestis, Chortareas and Tsoukalas (2010), the informative value of real money balances enhances the precision of the estimation of the potential output.

An appendix provides more details of the model. I also describe how the central bank conducts monetary policy. Specifically, I present a quadratic loss function that summarizes the Fed's policy preferences.

2.1 The log-linear equilibrium conditions

The following equations define a linear rational expectations model, approximately describing the equilibrium conditions of the ALSN model.

$$\begin{aligned}\widehat{y}_t = & \frac{\phi_1}{\phi_1+\phi_2}\widehat{y}_{t-1} + \frac{\beta\phi_1+\phi_2}{\phi_1+\phi_2}E_t\widehat{y}_{t+1} - \frac{\phi_1}{\phi_1+\phi_2}\left(\widehat{r}_t - E_t\widehat{\pi}_{t+1}\right) \\ & -\frac{\beta\phi_1}{\phi_1+\phi_2}E_t\widehat{y}_{t+2} + \frac{\psi_2}{\psi_1}\left(\frac{1}{1-\beta h}\right)\left(\frac{1}{\phi_1+\phi_2}\right)\widehat{m}_t \\ & -\frac{\psi_2}{\psi_1}\left(\frac{1}{1-\beta h}\right)\left[\left(\frac{1+\beta h}{\phi_1+\phi_2}\right)E_t\widehat{m}_{t+1} - \left(\frac{\beta h}{\phi_1+\phi_2}\right)E_t\widehat{m}_{t+2}\right] \\ & +\frac{\psi_2}{\psi_1}\left(\frac{1-\beta h\rho_e}{1-\beta h}\right)\left(\frac{1-\rho_e}{\phi_1+\phi_2}\right)\widehat{e}_t + \left(\frac{1-\beta h\rho_a}{1-\beta h}\right)\left(\frac{1-\rho_a}{\phi_1+\phi_2}\right)\widehat{a}_t\end{aligned} \tag{1}$$

$$\widehat{\pi}_t = \frac{\beta}{1+\beta\kappa}E_t\widehat{\pi}_{t+1} + \frac{\kappa}{1+\beta\kappa}\widehat{\pi}_{t-1} + \lambda\widehat{mc}_t \tag{2}$$

$$
\begin{aligned}
\widehat{mc}_t \;=\;& (\chi+\phi_2)\widehat{y}_t - \phi_1\widehat{y}_{t-1} - \beta\phi_1 E_t\widehat{y}_{t+1} \\
& -\frac{\psi_2}{\psi_1}\left(\frac{1}{1-\beta h}\right)\left[\widehat{m}_t - \beta h E_t\widehat{m}_{t+1}\right] + \frac{\psi_2}{\psi_1}\left(\frac{1-\beta h\rho_e}{1-\beta h}\right)\widehat{e}_t \\
& +\left(\frac{\beta h}{1-\beta h}\right)(1-\rho_a)\,\widehat{a}_t - (1+\chi)z_t
\end{aligned}
\tag{3}
$$

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

$$
\widehat{\mu}_t = \widehat{m}_t - \widehat{m}_{t-1} + \widehat{\pi}_t \tag{5}
$$

$$
\widehat{a}_t = \rho_a\widehat{a}_{t-1} + \varepsilon_{at} \tag{6}
$$

$$
\widehat{e}_t = \rho_e\widehat{e}_{t-1} + \varepsilon_{et} \tag{7}
$$

$$
\widehat{z}_t = \rho_z\widehat{z}_{t-1} + \varepsilon_{zt} \tag{8}
$$

The variables $\widehat{y}_t$, $\widehat{r}_t$, $\widehat{\pi}_t$, $\widehat{m}_t$, $\widehat{mc}_t$ and $\widehat{\mu}_t$ are output, the nominal interest rate, inflation, real money balances, real marginal costs and nominal money growth, respectively. The disturbances $\widehat{a}_t$, $\widehat{e}_t$ and $\widehat{z}_t$ are an aggregate demand shock, a money demand shock and a technology shock, respectively. All variables are measured in deviations from their steady-state values. In addition, $\overline{r}$ denotes the steady-state value for the gross nominal interest rate.

Equation (1) is the Euler equation that arises from the household's choice problem and describes the aggregate demand in the artificial economy. Because preferences exhibit nonseparability between consumption and real money balances, terms involving real money balances and their expected values are part of the aggregate demand equation. The presence of habit persistence introduces a role for the lagged value of output as a factor explaining current output.

Equations (2) and (3) characterize the supply side of the model. Equation (2) is the new Keynesian Phillips curve that arises from firm's price-setting behavior as described in the appendix. Equation (3) is an expression defining real marginal costs, which are an important driving force for inflation dynamics, according to equation (2).

The introduction of portfolio adjustment costs and the nonseparability across real money balances and consumption shape the form of money demand relationship. In contrast to the traditional static money demand schedule, equation (4) shows that the real money balance is a forward-looking variable. In addition, this equation can be solved forward to express the real money balance as a present discounted value formula.

Andrés, López-Salido and Nelson (2009) derive the present discounted value formula for real money balances, which depends on natural output levels, natural real interest rates, output gaps, real interest rate gaps and expected future inflation rates. Money is thus informative about natural-rate values.

Equation (5) defines nominal money growth rate, and equations (6) to (8) specify the stochastic disturbances for the shocks, which follow AR(1) processes with normal innovations ε_{at}, ε_{et} and ε_{zt}, with zero mean and variance σ_j^2 for $j \in \{a, e, z\}$. The persistence parameters for the shocks are ρ_j for $j \in \{a, e, z\}$.

The compound parameters of the model are:
$\psi_1 = \left(\frac{-\Psi_1}{\overline{y}^{1-h}\Psi_{11}}\right)$, $\psi_2 = \left(\frac{-\Psi_{12}}{\overline{y}^{1-h}\Psi_{11}}\right)\left(\frac{\overline{m}}{\overline{e}}\right)$, $\phi_1 = \frac{\left(\frac{1}{\psi_1}-1\right)h}{1-\beta h}$, $\phi_2 = \frac{\frac{1}{\psi_1}+\left(\frac{1}{\psi_1}-1\right)\beta h^2-\beta h}{1-\beta h}$, $\chi = \frac{\varphi+\alpha}{1-\alpha}$, $\lambda = \left(\frac{(1-\theta)(1-\beta\theta)}{\theta}\right)\left(\frac{1-\alpha}{1+\alpha(\epsilon-1)}\right)$ and $\delta_0 = \frac{dc^2}{\overline{m}}$.

The variables $\overline{y}$, $\overline{m}$ and $\overline{e}$ are steady-state figures. The coefficients γ_1 and γ_2 are the long-run real income and interest rate response parameters.

The terms Ψ_1, Ψ_{11} and Ψ_{12} are the partial derivatives of the function $\Psi(\cdot)$ that summarizes how consumption and real money balances interact in the utility function of the representative household. The parameter β is the household's discount factor, φ is the inverse of the Frisch labor supply elasticity, and h is a parameter controlling the degree of habit persistence in consumption. Finally, the coefficients c and d determine the shape of the portfolio adjustment cost function.

The technology parameter in the production function of intermediate goods is α, and the coefficient ϵ characterizes the aggregator function describing the final good production in terms of intermediate goods. The Calvo parameter, which measures the degree of price stickiness, is θ. Additionally, the parameter κ measures the degree of price indexation.

The role of money in equations (1) to (3), which describe aggregate demand and aggregate supply, depends on the parameter ψ_2. If $\psi_2 = 0$, the terms involving real money balances and their expectations vanish in expressions (1) to (3). The forward-looking nature of the money demand equation depends on ψ_2 and δ_0. Even if preferences are separable across consumption and real money balances ($\psi_2 = 0$), the presence of portfolio adjustment costs ($\delta_0 \neq 0$) guarantees that future expected real money balances continue to matter for current values of that variable.

2.2 Monetary Policy

To close the model, I have to specify the behavior of the central bank. I treat the central bank as an optimizing agent in the same way I treat households and firms. In fact, the central bank chooses the best policy subject to the constraints imposed by private agents' behavior; it minimizes an intertemporal quadratic loss function under commitment.

I follow Ilbas (2010), Ilbas (2012) and Adolfson et. al. (2011) and assume that the central bank optimizes under commitment in a timeless perspective. Consequently, I consider that the commitment occurred some time in the past; and, since the central bank does not disregard any previous commitment in a timeless perspective, the initial values of the Lagrange multipliers related to the optimal monetary policy problem are different from zero. In this case, the optimal policy is thus time consistent.

The central bank minimizes $E_t \sum_{i=0}^{\infty} \beta^i Loss_{t+i}$ with $0 < \beta < 1$, subject to the equations describing the behavior of households and firms. The one-period ad hoc loss function includes inflation, a measure of the output gap, a smoothing component for the interest rate and money growth. The central bank targets these variables, which are the objectives or goals of monetary policy, according to the following objective function.

$$Loss_t = \widehat{\pi}_t^2 + q_y \widehat{y}_t^2 + q_r(\widehat{r}_t - \widehat{r}_{t-1})^2 + q_\mu \widehat{\mu}_t^2$$

The weights q_y, q_r and q_μ summarize the central bank preferences concerning these objectives. When estimating the ALSN model under optimal policy, I allow these parameters to be estimated freely, subject only to non-negativity constraints.

The approach of specifying an ad hoc loss function assumes that the central bank acts according to a specific mandate. As a consequence, the central bank is not a benevolent planner and the policy objective function is not welfare-based.

The formulation of a Ramsey Policy problem, in which a benevolent planner maximizes the utility of the representative household, is theoretically the best approach from a public finance perspective. Nevertheless, households' preferences constrain the welfare-based objective function by imposing highly nonlinear structural restrictions, which are most likely misspecified with respect to the data-generating process.

Therefore, from an empirical perspective, assuming that the monetary authority follows a mandate is a sensible strategy if the research goal is to infer the relative importance of targets that the central bank may care about. This strategy leads to free parameters in the loss function which improves the fit of the model.

I compare the ALSN model estimates under optimal policy with the results obtained assuming that the Fed followed a simple Taylor-type rule. Because the Taylor-type rule is less restrictive than the optimal policy specification, big differences in model fit favoring the Taylor rule suggest that the assumption of optimal policy under commitment is incompatible with the data employed in the estimation.

Furthermore, big differences between the parameter estimates under alternative specifications for the conduct of monetary policy challenge the implicit assumption that the ALSN model is structural, i.e., its parameters are invariant to distinct formulations to modelling monetary policy. The estimation under different monetary policy specifications may indicate how plausible is the assumption that the ALSN model parameters are structural.

I estimate the Taylor-type rule given by the following equation.

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

The parameters describing the rule are ρ_r, capturing interest rate inertia and the coefficients ρ_y, ρ_π and ρ_μ, capturing the response of the interest rate to the macroeconomic variables $\widehat{y}_t$, $\widehat{\pi}_t$ and $\widehat{\mu}_t$. The monetary policy shock is ε_{rt}. This rule is widely used in papers that investigate the role of money in sticky-price models, such as Andrés, López-Salido and Nelson (2009), Arestis, Chortareas and Tsoukalas (2010), Poilly (2010), Castelnuovo (2012) and Canova and Menz (2011).

3 Estimation

This section discusses the Bayesian approach to estimate dynamic stochastic general equilibrium models (DSGE) and presents the data set and the priors used in the estimation.

3.1 Econometric Strategy

I estimate the parameters using likelihood-based Bayesian methods, which combine prior information with information contained in a given data set. Consider the vector Φ with elements that are parameters of the DSGE model. The prior density $p(\Phi)$ summarizes the non-sample information. An advantage of the Bayesian method is the possibility of incorporating additional information about the range of plausible values for the parameters through the specification of the prior distribution. In fact, in DSGE models, past knowledge accumulated among macroeconomists suggest reasonable ranges for the structural parameters.

Let Y_T denote the observed macroeconomic series of length T. The likelihood function $p(Y_T|\Phi)$ contains all the information in Y_T. The Bayes rule allows the researcher to update the prior using the likelihood function. Therefore, the posterior distribution is $p(\Phi|Y_T) = \frac{p(Y_T|\Phi)p(\Phi)}{p(Y_T)}$.

In general, analytical expressions for posterior distributions are rare, especially for the class of DSGE models. The best a researcher can do is to find a numerical approximation by drawing elements belonging to the posterior distribution and build a smoothed version of the histogram associated with these elements.

Bayesian simulation techniques allow the econometrician to obtain draws from the posterior distribution of the parameter vector. Therefore, it is possible to characterize numerically the posterior distribution of any object that is a function of the parameters such as variance decompositions and impulse responses to shocks. These objects are useful tools in assessing the economic significance of a model.

The Metropolis-Hastings algorithm is a widely used numerical method to obtain draws from the posterior distribution. In this paper, I use the Metropolis-Hastings algorithm, running separate chains composed of 400,000 draws, discarding the first 50% as initial burn-in. I assess the convergence of the estimations using diagnostic statistics described in Brooks and Gelman (1998).

The use of Bayesian methods to estimate DSGE models has increased in applied macroeconomics. An and Schorfheide (2007) survey the application of Bayesian techniques in structural macroeconometrics. Under reasonable priors, Bayesian methods offer advantages over alternative system estimators such as maximum likelihood, which is based on the strong assumption that the DSGE model is the data-generating process. Thus, the Bayesian approach can deal with potential misspecification problems in a better way than maximum likelihood; and this is the main reason why it is a popular method among empirical macroeconomists.

The equation $p(Y_T) = \int p(Y_T|\Phi)p(\Phi)d\Phi$ defines the marginal data density, which is the denominator of the Bayes rule. Moreover, the fit of a particular model to the data can be measured by the marginal data density. In addition, model comparison, in the Bayesian framework, hinges on the computation of the Bayes factor, which is the ratio of marginal data densities for different models. In sum, Bayesian methods allow the assessment of the economic and statistical significance of a model in a flexible way.

Chapter 9 in Dave and DeJong (2007) and An and Schorfheide (2007) provide complete accounts of the Bayesian estimation methodology applied to dynamic macroeconomic models. These references complement the brief discussion I have presented about Bayesian methods for DSGE models. Next, I discuss the data and priors used in the estimation of the ALSN model.

3.2 Data

I collected quarterly U.S. data from the FRED database, which is housed by the Federal Reserve Bank of St. Louis. The variables are real output, real money balances, inflation and short-term interest rate. Real GDP is the measure of real output, real money balances equals nominal M2 money stock divided by GDP deflator, inflation is the quarterly variation in GDP deflator and the Fed funds rate measures nominal interest rate.

I seasonally adjusted the data, except the nominal interest rate, and expressed real output and real money balances in per-capita terms, employing the civilian non-institutional population. I used logarithmic scale for real output and real money balances. As suggested by Castelnuovo (2012), I detrended all series applying the Hodrick-Prescott filter. These transformations ensure consistency between data and model's concepts, which measures variables in terms of gaps between their actual and their steady-state values. In addition, because the literature on new Keynesian models with money, which I reviewed in the introduction, usually employed detrended data, my results are comparable with the findings in these papers.

The sample of the quarterly data set ranges from 1966:2 to 2007:2. I estimate the model using the full sample and two subsamples. The first subsample corresponds to the "Great Inflation" (1966:2 to 1979:2) as defined in Smets and Wouters (2007). The second subsample is the "Great Moderation" period, which starts in 1984:1 according to Smets and Wouters (2007) and ends in 2007:2, the last quarter prior to the beginning of the global financial crisis in August 2007.

The subsample analysis takes into account the evidence in Castelnuovo (2012) that points to the declining importance of money over time. In fact, money was more important during the 1970's and its presence is necessary to replicate the output volatility during the "Great Inflation" period. Therefore, the estimation strategy acknowledge that different macroeconomic environments may lead to different estimates.

The assumption of optimal monetary policy under commitment leads to a time-inconsistent policy. To interpret the results as the outcome of an optimal policy from the timeless perspective, which is time-consistent, I initialize the estimation according to a pre-sample period of 20 quarters for the full sample and subsamples. This method for dealing with time-inconsistency follows the econometric strategy in Ilbas (2010) and Ilbas (2012).

3.3 Calibration and Priors

I calibrate some of the parameters in the ALSN model. Specifically, I follow the calibrated values reported in Castelnuovo (2012), setting $\beta = 0.9925$, $\alpha = \frac{1}{3}$ and $\epsilon = 6$. Additionally, $\overline{r}$ equals the mean of the gross nominal interest rate in each sample I consider for estimation.

The second columns in tables 1 to 4 show the priors for the parameters and reports the mean and standard deviation of each prior distribution. I use beta distributions for the parameters restricted to the interval $[0,1]$, inverse gamma distributions for standard errors of the shocks and gamma distributions for the remaining parameters.

I center the priors in values consistent with the estimated parameters reported in Andrés, López-Salido and Nelson (2009) and Castelnuovo (2012).

4 Empirical Results

This section presents and discusses the main findings of this paper. I first present the results from the estimation under optimal policy. Next, I move to the analysis of the estimation results concerning the model in which the Taylor-type rule describes monetary policy. Finally, I compare the fit of alternative models using marginal likelihoods and Bayes factors.

4.1 Estimates with Optimal Policy

Tables 1 to 3 show the results from the estimation of the ALSN model under optimal monetary policy. For each sample, I report three specifications under optimal monetary policy. The first specification, in the third columns of these tables, with label "No Money" is the ALSN model subject to the following restrictions: $q_\mu = \psi_2 = \delta_0 = 0$. The specification with label "PA only" refers to the case in which money affects just private agents' behavior, corresponding to the restriction $q_\mu = 0$. Finally, the specification with label

"PA and CB" allows money to influence the behavior of private agents and the central bank's policy preference.

INSERT TABLE 1

INSERT TABLE 2

INSERT TABLE 3

According to tables 1 to 3, the structural parameters are more or less stable across specifications. The main objectives of monetary policy, irrespective of the role of real money balances in the description of the equilibrium, are inflation variability and interest rate smoothing.

Estimation results suggest that the Fed cares about the growth rate of money in the full sample and during the "Great Inflation", though it is far less important than inflation and interest rate smoothing. During the "Great Moderation", the money growth rate is virtually negligible as a monetary policy objective. The output gap stabilization is a far less important objective compared with inflation and interest rate smoothing.

In all samples, the interest rate smoothing parameter in the central bank's loss function is somewhat high, suggesting that this objective is more important than inflation variability. Though estimated policy preference parameters, in medium-scale models, suggest a prominent role for inflation variability, the range of values I found for the interest smoothing parameter is consistent with the findings reported in Dennis (2004, 2006). In addition, the importance of interest rate smoothing diminishes as I incorporate a role for money in the models.

I estimate the models assuming that the interest rate is subject to measurement errors under optimal policy. These errors are more volatile during the "Great Inflation", which is an unstable period of the recent economic history of the U.S.

4.2 Estimates with Taylor-type rules

I compare the ALSN model estimates under optimal policy with the results obtained assuming that the Fed followed a simple Taylor-type rule. I also stress the differences in the estimation results across subsamples.

INSERT TABLE 4

Compared with the optimal policy models, the estimated structural parameters are relatively stable. Further, monetary policy shocks in the Taylor rule are less volatile than the measurement error in the optimal policy models. The money growth rate coefficient is smaller during the "Great Moderation", which is in line to the virtual absence of this variable in the Fed's loss function.

The posterior means of the shocks suggest that they were more persistent and more volatile in the "Great Inflation" period. The posterior means of the coefficients of the Taylor rule show more aggressive responses to inflation and less intensity in responding to the money growth rate in the "Great Moderation" subsample compared to the "Great Inflation" period. Though the posterior means of the structural parameters point to a high degree of price stickiness and less inertia in output and inflation during the "Great Moderation", the structural parameters are more or less stable across subsamples.

4.3 Model Comparison

I compare the fit of the models under the optimal policy assumption for each subsample with the benchmark specification in which a Taylor-type rule describes monetary policy. I use marginal data densities or marginal likelihoods to compare the empirical performance of these models.

Table 5 reports marginal likelihoods as well as the Bayes factor, which is the ratio of marginal likelihoods associated with alternative models. I report the Bayes factor in decibels (BF_{db}), that is, I compute the following expression $BF_{db} = 10 \log_{10} \left(\frac{p(Y_T|M_1)}{p(Y_T|M_2)} \right)$, where $p(Y_T|M_j)$ is the marginal likelihood of model M_j. In this way, I can express orders of magnitude in a more compact scale since the ratio between marginal data densities may involve large ranges of numerical values.

In all samples, I normalize the scale using the model without money ($q_\mu = \psi_2 = \delta_0 = 0$), which is the specification with the worst empirical fit as measured by the marginal likelihood. To compare two alternative models, just take the differences between their Bayes factors. An improvement greater than 20 is considered decisive evidence in favor of the model with the highest BF_{db} measure.

INSERT TABLE 5

Table 5 shows that the model with the Taylor rule dominates all the models in each period considered. In fact, the data provide decisive evidence in favor of this specification. This is not a surprise since the Taylor-type rule does not impose the cross-equation restrictions associated with optimal policy. In addition, this result may indicate that the assumption of a central bank behaving according to the optimal monetary policy under commitment is not the best way to describe the data. This fact opens the door to alternative specifications for monetary policy, which could be conducted under discretion in an optimal way or could not be characterized by any optimization problem. Alternatively, this result suggests also the possibility of a misspecified central bank's loss function.

Model's comparison shows that the presence of the money growth rate as a monetary policy objective improves the fit of the model in the full sample and during the "Great Inflation". During the "Great Moderation", the estimated Fed's preference is consistent with a flexible inflation target strategy. Again, evidences favoring these results are decisive.

In sum, incorporating money in the structural equations improves the fit of the model under optimal policy. This evidence supports a relevant role for money in small scale macroeconomic models. Moreover, there is evidence of a role for money also as a monetary policy objective, especially during the "Great Inflation".

5 Conclusion

Empirical research based on Dynamic Stochastic General equilibrium models indicated that money played an important role in explaining U.S. business cycles. This research also documented that the Fed has reacted systematically to the growth rate of nominal money when a Taylor-type rule described monetary policy. This response to money growth rates might be rationalized in two alternative ways. First, money growth could be a target variable in the Fed's loss function. Alternatively, money could be just an indicator variable, with no role as a monetary policy objective, being useful in forecasting inflation and economic activity. To gauge the plausibility of these alternative interpretations, I estimated the model studied in Andrés, López-Salido and Nelson (2009), in which money is a relevant factor, by replacing the Taylor rule with optimal monetary policy.

According to the empirical evidence, the presence of the money growth rate as a monetary policy objective improves the fit of the model, suggesting that the Fed cares about this variable, though it is far less important than inflation and interest rate smoothing. During the "Great Moderation", however, this was not true. Moreover, inflation variability and interest rate smoothing are the main objectives of monetary policy, irrespective of the role of money in the equations describing private agents' behavior. Finally, the data favor a model in which a Taylor-type rule describes monetary policy.

Future research may extend this paper in at least three directions. First, researchers may perform a cross country analysis on the role of money as a monetary policy objective. Second, an extension of this paper may evaluate the role of money in the central bank's objective function in the context of the model put forth by Canova and Ferroni (2012), which is a version of medium-size structural macroeconometric model of Smets and Wouters (2007) with money. Finally, an additional study may revisit the empirical evidence on the effect of monetary policy shocks on macroeconomic variables by using the model in Andrés, López-Salido and Nelson (2009) to generate sign restrictions for a structural vector auto-regression.

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TABLES

Table 1. Model with Optimal Policy – Full Sample

Parameters	Priors Shape (mean, std.dev.)	Posterior Distribution Mean [90% Interval]		
		No Money	Money – PA only	Money – PA and CB
ψ_1	Gamma (1.2, 0.1)	1.21 [1.04, 1.36]	1.19 [1.04, 1.36]	1.16 [1.00, 1.34]
ψ_2	Gamma (0.2, 0.1)	0 (calibrated)	0.15 [0.04, 0.26]	0.17 [0.04, 0.31]
h	Beta (0.7,0.2)	0.67 [0.38, 0.99]	0.70 [0.46, 0.98]	0.68 [0.41, 0.97]
θ	Beta (0.7, 0.2)	0.70 [0.43, 0.99]	0.78 [0.39, 0.99]	0.67 [0.32, 0.99]
κ	Beta (0.7, 0.2)	0.72 [0.45, 0.99]	0.70 [0.39, 0.99]	0.71 [0.40, 0.99]
φ	Gamma (0.95, 0.1)	0.96 [0.78, 1.12]	0.97 [0.81, 1.12]	0.93 [0.75, 1.09]
γ_1	Gamma (0.9, 0.1)	0.91 [0.75, 1.07]	0.84 [0.71, 1.01]	0.91 [0.74, 1.07]
γ_2	Gamma (0.3, 0.1)	0.29 [0.13, 0.44]	0.33 [0.18, 0.48]	0.32 [0.16, 0.44]
δ_0	Gamma (3.5, 0.1)	0 (calibrated)	3.44 [3.31, 3.57]	3.48 [3.26, 3.67]
q_y	Gamma (0.5, 0.4)	0.13 [0.10, 0.15]	0.12 [0.10, 0.14]	0.11 [0.10, 0.14]
q_r	Gamma (0.25, 0.4)	5.77 [2.26, 8.30]	4.10 [2.50, 5.89]	4.18 [3.33, 5.20]
q_μ	Gamma (0.25, 0.4)	0 (calibrated)	0 (calibrated)	0.04 [0.00, 0.07]
ρ_a	Beta (0.7, 0.2)	0.96 [0.91, 0.99]	0.96 [0.93, 0.99]	0.96 [0.90, 0.99]
ρ_e	Beta (0.7, 0.2)	0.91 [0.81, 0.98]	0.94 [0.85, 0.99]	0.96 [0.91, 0.99]
ρ_z	Beta (0.7, 0.2)	0.93 [0.85, 0.99]	0.95 [0.90, 0.99]	0.94 [0.91, 0.99]
σ_a	Inverse Gamma (0.1, 2)	0.28 [0.02, 0.63]	0.21 [0.02, 0.47]	0.27 [0.02, 0.62]
σ_e	Inverse Gamma (0.1, 2)	0.16 [0.02, 0.34]	0.31 [0.02, 0.81]	0.21 [0.02, 0.47]
σ_z	Inverse Gamma (0.1, 2)	0.2 [0.02, 0.45]	0.15 [0.02, 0.31]	0.19 [0.02, 0.43]
σ_r	Inverse Gamma (0.1, 2)	1.63 [1.48, 1.78]	1.65 [1.50, 1.80]	1.63 [1.48, 1.78]

Note: PA stands for private agents and CB denotes Central Bank

Table 2. Model with Optimal Policy – Great Inflation

Parameters	Priors Shape (mean, std.dev.)	Posterior Distribution Mean [90% Interval]		
		No Money	Money – PA only	Money – PA and CB
ψ_1	Gamma	1.20	1.21	1.18
	(1.2, 0.1)	[1.05, 1.37]	[1.05, 1.36]	[1.02, 1.34]
ψ_2	Gamma	0	0.21	0.22
	(0.2, 0.1)	(calibrated)	[0.05, 0.35]	[0.04, 0.40]
h	Beta	0.66	0.72	0.71
	(0.7,0.2)	[0.35, 0.99]	[0.42, 0.99]	[0.42, 0.99]
θ	Beta	0.67	0.70	0.72
	(0.7, 0.2)	[0.37, 0.99]	[0.43, 0.99]	[0.44, 0.99]
κ	Beta	0.66	0.70	0.71
	(0.7, 0.2)	[0.35, 0.99]	[0.40, 0.99]	[0.42, 0.99]
φ	Gamma	0.94	0.97	0.92
	(0.95, 0.1)	[0.78, 1.09]	[0.81, 1.12]	[0.76, 1.07]
γ_1	Gamma	0.87	0.91	0.91
	(0.9, 0.1)	[0.73, 1.01]	[0.73, 1.08]	[0.75, 1.08]
γ_2	Gamma	0.29	0.32	0.31
	(0.3, 0.1)	[0.14, 0.44]	[0.15, 0.48]	[0.15, 0.46]
δ_0	Gamma	0	3.48	3.51
	(3.5, 0.1)	(calibrated)	[3.33, 3.64]	[3.34, 3.66]
q_y	Gamma	0.15	0.13	0.11
	(0.5, 0.4)	[0.10, 0.20]	[0.08, 0.18]	[0.06, 0.16]
q_r	Gamma	2.63	2.73	2.39
	(0.25, 0.4)	[1.42, 3.94]	[1.59, 4.14]	[0.94, 3.65]
q_μ	Gamma	0	0	0.08
	(0.25, 0.4)	(calibrated)	(calibrated)	[0.00, 0.15]
ρ_a	Beta	0.97	0.97	0.95
	(0.7, 0.2)	[0.95, 0.99]	[0.94, 0.99]	[0.86, 0.99]
ρ_ε	Beta	0.92	0.96	0.96
	(0.7, 0.2)	[0.83, 0.99]	[0.90, 0.99]	[0.91, 0.99]
ρ_z	Beta	0.94	0.94	0.95
	(0.7, 0.2)	[0.86, 0.99]	[0.87, 0.99]	[0.91, 0.99]
σ_a	Inverse Gamma	0.19	0.22	0.39
	(0.1, 2)	[0.03, 0.43]	[0.02, 0.47]	[0.02, 1.08]
σ_ε	Inverse Gamma	0.18	0.28	0.27
	(0.1, 2)	[0.02, 0.41]	[0.02, 0.71]	[0.02, 0.64]
σ_z	Inverse Gamma	0.24	0.22	0.19
	(0.1, 2)	[0.02, 0.56]	[0.02, 0.51]	[0.02, 0.41]
σ_r	Inverse Gamma	1.86	1.84	1.85
	(0.1, 2)	[1.56, 2.16]	[1.54, 2.13]	[1.55, 2.16]

Note: PA stands for private agents and CB denotes Central Bank

Table 3. Model with Optimal Policy – Great Moderation

Parameters	Priors Shape (mean, std.dev.)	Posterior Distribution Mean [90% Interval]		
		No Money	Money – PA only	Money – PA and CB
ψ_1	Gamma	1.19	1.19	1.19
	(1.2, 0.1)	[1.04, 1.36]	[1.03, 1.34]	[1.06, 1.33]
ψ_2	Gamma	0	0.21	0.18
	(0.2, 0.1)	(calibrated)	[0.06, 0.35]	[0.07, 0.28]
h	Beta	0.63	0.52	0.70
	(0.7,0.2)	[0.28, 0.99]	[0.18, 0.93]	[0.43, 0.99]
θ	Beta	0.69	0.71	0.57
	(0.7, 0.2)	[0.38, 0.99]	[0.43, 0.99]	[0.28, 0.88]
κ	Beta	0.71	0.64	0.69
	(0.7, 0.2)	[0.42, 0.99]	[0.32, 0.99]	[0.37, 0.99]
φ	Gamma	0.95	0.94	0.94
	(0.95, 0.1)	[0.80, 1.09]	[0.78, 1.10]	[0.87, 1.05]
γ_1	Gamma	0.88	0.93	0.81
	(0.9, 0.1)	[0.72, 1.04]	[0.77, 1.00]	[0.69, 0.96]
γ_2	Gamma	0.30	0.25	0.30
	(0.3, 0.1)	[0.14, 0.45]	[0.14, 0.37]	[0.17, 0.44]
δ_0	Gamma	0	3.45	3.58
	(3.5, 0.1)	(calibrated)	[3.31, 3.62]	[3.47, 3.69]
q_y	Gamma	0.12	0.12	0.12
	(0.5, 0.4)	[0.09, 0.15]	[0.09, 0.15]	[0.09, 0.15]
q_r	Gamma	3.99	4.45	2.44
	(0.25, 0.4)	[2.14, 5.89]	[2.86, 6.05]	[0.94, 3.65]
q_μ	Gamma	0	0	0.006
	(0.25, 0.4)	(calibrated)	(calibrated)	[0.00, 0.01]
ρ_a	Beta	0.89	0.93	0.92
	(0.7, 0.2)	[0.60, 0.99]	[0.84, 0.99]	[0.81, 0.99]
ρ_ε	Beta	0.88	0.94	0.95
	(0.7, 0.2)	[0.77, 0.97]	[0.86, 0.99]	[0.90, 0.99]
ρ_z	Beta	0.90	0.85	0.93
	(0.7, 0.2)	[0.77, 0.99]	[0.64, 0.98]	[0.84, 0.98]
σ_a	Inverse Gamma	0.48	0.27	0.31
	(0.1, 2)	[0.02, 1.79]	[0.02, 0.65]	[0.02, 0.80]
σ_ε	Inverse Gamma	0.13	0.22	0.17
	(0.1, 2)	[0.03, 0.27]	[0.02, 0.50]	[0.02, 0.35]
σ_z	Inverse Gamma	0.20	0.29	0.16
	(0.1, 2)	[0.02, 0.46]	[0.02, 0.74]	[0.02, 0.33]
σ_r	Inverse Gamma	1.13	1.13	1.16
	(0.1, 2)	[0.99, 1.27]	[0.99, 1.26]	[1.02, 1.31]

Note: PA stands for private agents and CB denotes Central Bank

Table 4. Model with Taylor Rule

Parameters	Priors Shape (mean, std.dev.)	Posterior Distribution Mean [90% Interval]		
		Full Sample	Great Inflation	Great Moderation
ψ_1	Gamma	1.19	1.15	1.19
	(1.2, 0.1)	[1.06, 1.31]	[1.00, 1.29]	[1.035, 1.37]
ψ_2	Gamma	0.24	0.17	0.19
	(0.2, 0.1)	[0.06, 0.40]	[0.04, 0.29]	[0.04, 0.35]
h	Beta	0.65	0.71	0.73
	(0.7,0.2)	[0.41, 0.96]	[0.42, 0.99]	[0.48, 0.99]
θ	Beta	0.73	0.68	0.71
	(0.7, 0.2)	[0.41, 0.99]	[0.39, 0.99]	[0.45, 0.99]
κ	Beta	0.69	0.65	0.77
	(0.7, 0.2)	[0.39, 0.99]	[0.34, 0.98]	[0.55, 0.99]
φ	Gamma	0.97	0.97	0.96
	(0.95, 0.1)	[0.79, 1.14]	[0.79, 1.13]	[0.77, 1.12]
γ_1	Gamma	0.90	0.89	0.90
	(0.9, 0.1)	[0.75, 1.06]	[0.73, 1.05]	[0.74, 1.06]
γ_2	Gamma	0.31	0.29	0.31
	(0.3, 0.1)	[0.17, 0.43]	[0.14, 0.44]	[0.15, 0.46]
δ_0	Gamma	3.49	3.51	3.5
	(3.5, 0.1)	[3.32, 3.69]	[3.33, 3.68]	[3.35, 3.65]
ρ_r	Beta	0.26	0.31	0.33
	(0.8, 0.2)	[0.17, 0.33]	[0.20, 0.42]	[0.23, 0.43]
ρ_y	Gamma	0.41	0.55	0.60
	(0.5, 0.1)	[0.31, 0.51]	[0.42, 0.67]	[0.45, 0.73]
ρ_π	Gamma	1.75	1.59	1.68
	(1.5, 0.1)	[1.59, 1.71]	[1.42, 1.76]	[1.52, 1.85]
ρ_μ	Gamma	0.16	0.15	0.12
	(0.2, 0.1)	[0.04, 0.31]	[0.04, 0.25]	[0.03, 0.22]
ρ_a	Beta	0.97	0.97	0.96
	(0.7, 0.2)	[0.95, 0.99]	[0.93, 0.99]	[0.90, 0.99]
ρ_e	Beta	0.95	0.94	0.93
	(0.7, 0.2)	[0.89, 0.99]	[0.86, 0.99]	[0.86, 0.99]
ρ_z	Beta	0.94	0.94	0.91
	(0.7, 0.2)	[0.88, 0.99]	[0.89, 0.99]	[0.82, 0.98]
σ_a	Inverse Gamma	0.19	0.29	0.26
	(0.1, 2)	[0.02, 0.43]	[0.02, 0.69]	[0.02, 0.61]
σ_e	Inverse Gamma	0.24	0.35	0.21
	(0.1, 2)	[0.02, 0.56]	[0.02, 0.93]	[0.02, 0.47]
σ_z	Inverse Gamma	0.16	0.18	0.18
	(0.1, 2)	[0.02, 0.35]	[0.02, 0.40]	[0.02, 0.38]
σ_r	Inverse Gamma	1.01	0.94	0.59
	(0.1, 2)	[0.89, 1.14]	[0.77, 1.12]	[0.49, 0.69]

Table 5. Model Comparison

Models	Full Sample		Great Inflation		Great Moderation	
	Marginal Likelihood (natural log)	Bayes Factor (db)	Marginal Likelihood (natural log)	Bayes Factor (db)	Marginal Likelihood (natural log)	Bayes Factor (db)
Taylor Rule	-830.848	672.605	-312.128	310.568	-327.043	369.406
Money - PA and CB	-886.096	432.666	-350.913	142.127	-362.614	214.924
Money - PA only	-888.072	424.084	-351.912	137.788	-357.095	238.892
No Money	-985.721	0	-383.639	0	-412.102	0

Notes: PA stands for Private Agents, CB for Central Bank and db represents decibel units

APPENDIX

The ALSN Model

This appendix presents details of the model developed by Andrés, López-Salido and Nelson (2009). The economy consists of a representative household and a continuum of firms indexed by $j \in [0, 1]$. The model abstracts from capital accumulation and features price stickiness.

- **Households**

The representative household maximizes the expected flow of utility given by the expression:

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

The variable C_t stands for aggregate consumption, $\frac{M_t}{P_t}$ represents real money balances and N_t denotes hours worked. The preference shock is a_t and the shock to the household's demand for real balances is e_t. The parameter β, restricted to be in the unity interval, is the discount factor. The parameter φ, a positive number, is the inverse of the Frisch labor supply elasticity. Finally, h is a parameter controlling the degree of habit persistence in consumption.

The preference specification allows for nonseparability between consumption and real money balances, as well as habit persistence in consumption. The function $\Psi(\cdot)$ summarizes all these features. Specifically, the intratemporal nonseparability between consumption and real money balances gives rise to an explicit real money balance term in the equations describing the supply and demand sides of the artificial economy.

In addition to the nonseparability channel, the presence of portfolio adjustment costs generates an alternative mechanism which gives money a role in the dynamic equations of the model. Moreover, the money demand equation becomes a dynamic forward-looking equation in which expectations of future interest rate matter. The portfolio adjustment cost function $G(\cdot)$ follows the specification bellow.

$$G(\cdot) = \frac{d}{2}\left\{\exp\left[c\left(\frac{\frac{M_t}{P_t}}{\frac{M_{t-1}}{P_{t-1}}} - 1\right)\right] + \exp\left[-c\left(\frac{\frac{M_t}{P_t}}{\frac{M_{t-1}}{P_{t-1}}} - 1\right)\right] - 2\right\}$$

Each period, the household faces the budget constraint given by the equation:

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

The representative household enters the current period with money holdings M_{t-1} and bonds B_{t-1}, receiving lump-sum transfers T_t, dividends D_t and labor income $W_t N_t$, where W_t stands for nominal wages. The household purchases new bonds at nominal cost $\frac{B_t}{R_t}$, where R_t denotes the gross nominal interest rate between the current period and $t+1$. Finally, the household will enter the next period with money holdings M_t.

The choices variables for the household are consumption (C_t), hours (N_t), money holdings (M_t) and bonds (B_t).

- **Firms and Price-Setting Behavior**

The production function $Y_t(j) = z_t N_t^{1-\alpha}(j)$ describes the technology for firm j. The variables $Y_t(j)$ and $N_t(j)$ represent output and work-hours hired from households. The technology shock is z_t and the parameter $(1-\alpha)$ measures the elasticity of output with respect to hours worked. The aggregate output is given by $Y_t = \left(\int_0^1 Y_t^{\frac{\epsilon-1}{\epsilon}}(j)dj \right)^{\frac{\epsilon}{\epsilon-1}}$, where ϵ is the elasticity of substitution.

Firms operate in a monopolistic competitive market and set prices in a staggered fashion using the scheme proposed by Calvo (1983). According to Calvo (1983), only a fraction of firms, given by $(1-\theta)$, is able to adjust prices. Therefore, each period, these firms reset their prices to maximize expected profits.

Following, Christiano, Eichenbaum and Evans (2005), I introduce an indexation mechanism in which firms that do not set prices optimally at time t will adjust their prices to lagged inflation, according to the equation $P_{t+i}(j) = P_{t+i-1}(j)(\pi_{t+i-1})^{\kappa}$, where the parameter κ indicates the degree of price indexation; and the notation P_t and π_t denote the price level and inflation.

The optimal price set by firms allowed to change prices is P_t^* and the aggregate price level evolves as follows:

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

This framework for price-setting behavior leads to a hybrid specification for inflation dynamics. Thus, inflation is a forward-looking variable, but some backward-looking component is necessary to describe inflation dynamics.