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MONETARY POLICY ANALYSIS IN A NEW KEYNESIAN MODEL WITH MONEY

Módulo: Análisis Económico

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ABSTRACT

This paper examines the stabilizing performance of two alternative monetary policy rules, being the first one based on the nominal interest rate and the second one on the rate of nominal money growth. The analysis is based on a calibrated New Keynesian model with money. The model includes several features such as a transaction cost technology, sticky prices and a monopolistic competitive industry. The methodology entails an analysis of the performance of two monetary policy regimes, where we evaluate social welfare from the expected household intertemporal utility. We seek for the optimized coefficient on the response of the policy instrument to inflation deviations and compare the results between the policy rules as well as with the baseline calibration. The results obtained show that the optimized Taylor rule is obtained with a coefficient on inflation equal to 4, which outperforms the original Taylor (1993) rule coefficient of 1.5. In a nominal money growth rule, the optimized coefficient on inflation is significantly higher (around 11) and the social welfare obtained is slightly lower than in the case of an interest-rate rule.

KEY WORDS

Optimal Monetary Policy; Sticky prices; Welfare-based Monetary Policy; DSGE model, Taylor-rule.

INDEX

1. INTRODUCTION

The New Keynesian (NK) Model emerged a few decades ago in the US during the post-war period with the intention of examining some micro and macro foundations that other models did not truly cover (Rotenberg and Woodford, 1996; King and Wolman, 1996). Since then, it has been dominant in macroeconomics, all in classrooms, academic research and in policy modeling. It combines some aspects of the Real Business Cycle Theory with others derived from Keynesian economics. The latter focuses on the total spending of an economy, and the implications of this on output and inflation. The followers of this theory placed heavy emphasis on the concept of full employment, as well as on sporadic & indirect state intervention, while New-Keynesians rather focused on economic growth and stability, insisting on the fact that the market is not self-regulating. Some of its most characteristic (as well as commonly criticized) factors include: the assumptions of rational expectations, monopolistic competition, and an infinitely-lived representative household.

The Neo-Keynesians extended Keynes's propositions to dynamic growth and business cycle models. In addition, this model includes rational expectations. The development of such theory significantly modified the dynamic macroeconomics. On the one hand, there are some economic variables, that are indeed influenced by previous years. On the other hand, though, there are others that are related to the future through the agents' expectations on the future of such or other variables: for instance, this month's consumption will not only depend on our monthly income, but also on the income we expect to receive in the following months, and so on. This is also the case of financial variables such as interest rate, which is closely dependent on future expectations.

There is a first discrepancy between New Classical and New Keynesian economists, that lies on how quickly wages and prices adjust. The first assume that prices and wages are flexible, which permits the clearing of the market. The second, however, believe in a model with sticky wages and prices, rather than flexible. They place a big importance on monetary policy, which, they believe, strongly influences the economic activity.

This New Keynesian model identifies various actors in the economy, who interact and exchange goods and services in order to maximize their own wellbeing. These are the households, firms, and government (state). In this study, we will define them individually, citing commonly stablished macroeconomic terms and relations with the aim of constructing the model that will serve as a basis of our monetary policy analysis. Moreover, we will define and explain the role of the Central Bank under these specifications. Therefore, this paper will first review the New Keynesian Macroeconomic model and then simulate the implementation of a monetary shock (monetary policy) which will be followed by an analysis of the resulting situation. The basic New Keynesian model that we will lay out below (and which is laid out in Woodford (2003) and Gali (2007)) has no investment or capital. This simplifies the analysis quite a bit and permits us to get better intuition.

The model here presented includes money, which is perceived by individuals as a medium of exchange that allows them to consume, exchange and trade their resources (labor time) for others (goods or services). Moreover, individuals' utility does not include their leisure utility, but their labor disutility, in order for the time allocation and model to be simpler.

Another important aspect that the model of this paper exhibits is the habit persistence. Put another way, consumers' utility depends on past consumption. Tus, the marginal utility of consumption depends on past consumption.

Prices, which will be described and presented in next sections, are derived with rigidities *a la Calvo* (1983): there is a constant probability that the price cannot be reset optimally by a single firm. In this case, prices are updated by applying an indexation rule based on lagged inflation.

New Keynesian DSGE models generally use a Taylor-rule monetary policy. In this paper, we will aim to compare that regime to a money-growth rule, in order to assess their validity.

2. LITERATURE REVIEW

A Monetary policy is a set of actions through which the monetary authority determines the conditions under which it supplies the money that circulates in the economy. Most studies confirm that over the medium term there is an extremely high correlation between the growth rate of the money supply and the inflation rate (McCandless and Webert, 1995). However, when authors address the short term, their conclusions differ vastly. On the one hand, some of them support the idea that an increase in the money supply cannot affect real wages or economic growth (Chaitip et al.,2015) . Put another way, money is deemed neutral in the short and in the medium-long run. On the other hand, economists in the new Keynesian school believe in the power of money as a tool to promote economic growth (Erceg, Henderson and Levin, 2000). They support that money is far from being neutral, at least in the short run.

Many authors have focused their studies on the effect of monetary policies on the economy, following different models and specifications. Money is a known medium of exchange, that permits and facilitates transactions. Thus, individuals do not necessarily get higher utility when holding money per se. Individuals get utility from correctly using that money in buying goods (or services). If we stop and think about it, goods do not buy other goods, so the actual value of money is no other than giving individuals the opportunity of yielding utility through the purchase of goods. Clower (1967) emphasized the important value of a medium of exchange that helps the process of transacting. This was first presented by Baumol (1952) and Tobin (1956).

The main problem faced by the individual is the balance between the opportunity cost of holding money, against the value of leisure. Thus, consumers need to decide how they will combine both time and money to purchase consumption goods. The relationship between money holdings, time and leisure is the following; the higher the money holdings an individual owns, the lower the time needed for shopping, which leads to enjoying higher leisure time. The idea of transaction costs function arose with Niehans (1978) and is now included in the main economic models. We will also include it in the model used in this paper.

The ability of central banks to achieve a high degree of credibility with the public for their policy commitments ought to be greater in an era of price stability (Woodford, 1999). Such an era, we could presume, would be one in which the goals of macroeconomic stabilization policy were reasonably well achieved, so that there would be no need for dramatic policy experiments. Moreover, the public will come to understand the objectives of the central bank under this scenario.

Yun (1996) studied the ability of nominal price rigidity to explain the movement of inflation under a standard real business cycle model using post-war US data. Others, such as Erceg, Henderson and Levin (2000) sought to find the optimal monetary policy, in an economy where both labor and product markets exhibit monopolistic competition and staggered nominal contracts. Most of them used Calvo (1983) sticky price specifications, as well as Taylor (1993) monetary policy rule.

Therefore, taking the aforementioned studies into account as well as commonly believed macroeconomic theory, our objective is to analyze the extent of the impact of monetary policy on economic stability under sticky prices. In order to address this question, this paper introduces the extension of the New Keynesian model into a DSGE model that is estimated with Bayesian econometric techniques (Smets and Wouters, 2003 for the Euro Area and 2007, for the US). Section 4 of the paper will attempt to give reasonable calibration to the parameters in the model. The main analysis will evaluate the performance of two alternative monetary policy rules to check their effectiveness. The last section concludes by summarizing key results and highlighting their implications.

3. THE MODEL

3.1. Households.

Household Preferences

Macroeconomic models generally use a representative household to depict their behavior in the economy. This representative figure consumes goods, supplies labor, accumulates bonds, holds shares in firms, and accumulates money. It gets utility from effectively allocating consumption and leisure time. However, since we do not regard the individuals' leisure time, we will focus on their labor disutility rather than their leisure utility. The household has rational expectations and its utility maximization problem includes three main components. First, we define the household preferences, commonly addressed as utility function, where t stands for units of time:

$$Period\ t \rightarrow \frac{(c_t - hc_{t-1}^{A})^{1-\sigma}}{1-\sigma} - \Psi\frac{n_t^{1+\gamma}}{1+\gamma}$$

This function, household preferences in period t, is composed of two parts: consumption utility and labor disutility. These arguments are a consumption index, c_t, and labor hours, n_t. On the one hand, Consumption utility accounts for the positive impact of consumption on one's utility. The household gets utility from increasing consumption with respect to external consumption habits, thus, aggregate lagged consumption (c_{t-1}^{A}), being h the consumption habits parameter, which relates both consumption patterns (present and aggregate), which is a value between 0 and 1. The risk aversion parameter σ is greater than 0, for decreasing marginal utility of consumption. Labor disutility, on the other hand, shows the negative impact of time spent at work rather than at leisure activities. Thus, we can infer the relationship between both household decisions (consumption and labor supply) and the household's utility, it being positive and negative, respectively. Households are both consumers and service (labor) suppliers. They buy consumption goods at given prices in the markets and sell their time to the firms (labor) in exchange for income. The income they receive is allocated between purchasing consumption goods, investment goods and government bonds.

The objective function of the representative household in period t is, therefore:

$$Max.\ \sum_{j=0}^{\infty} E_t \beta^j \left[\frac{\left(c_{t+j} - hc_{t-1+j}^{A}\right)^{1-\sigma}}{1-\sigma} - \Psi \frac{n_t^{1+\gamma}}{1+\gamma} \right]$$

Subject to the budget constraint

In period t, the household chooses $b_{t+1,}$ c_t, m_t and n_t to maximize the expected utility. Here, we introduce rational expectations, as we believe that households will use all the available information to take into account what the future holds. Put another way, their outcome somewhat depends on what households expect to happen (Muth,1961). As we can observe, the function to maximize includes the rational expectation operator (E_t), followed by a discount factor of period j+1, β, which is a number lower than 1, as it represents the rate of intertemporal preference. This discount factor is in fact β=1/(1+ρ), where $\rho > 0$ is the discount rate. In equilibrium, ρ equals the market real interest rate. It is thought that 'ρ' is a measure of substitutability (Dingel, 2009).

Budget Constraint

Second, we introduce the household budget constrain in nominal terms that limits the optimizing program of the representative household in period t:

$$D_t + W_t n_t - TAX_t = P_t C_t + (1 + R_t)^{-1} B_{t+1} - B_t + M_t - M_{t-1} + H_t$$

From the equation we can infer the following: the amount destined to consumption and portfolio allocation cannot exceed the budget of the household, which is the labor income, net of taxes ($W_t n_t - TAX_t$), where $W_t$is the nominal wage, n_t is the labor supplied by the individual and TAX_trepresents the taxes paid, plus the dividends obtained from the holdings of monopolistically competitive firms (D_t). This amount should cover the household's consumption (C_t) at a price P_t, the net purchases of government bonds (which is represented by $(1 + R_t)^{-1} B_{t+1} - B_t$), with a nominal interest rate R_t, the increase of money holdings, $M_t - M_{t-1}$ and the transaction costs, H_t. If we now divide the nominal budget constraint by P_t (aggregate price level), we obtain the budget constraint faced by the representative household in real terms.

$$w_t n_t - tax_t + d_t = c_t + (1 + r_t)^{-1} b_{t+1} - b_t + m_t - (1 + \pi_t)^{-1} m_{t-1} + h_t$$

In each period t=0,1,2, ..., the representative household possesses m_{t-1} real units of money and b_{t-1} real units of bonds, issued in period t-1, and maturity in period t. In addition, r_t is the real interest rate on bonds, and b_{t+1} is the amount of government bonds that the household purchases in period t, which will be reimbursed in period t+1.Then, the household brings to period t+1 m_t units of money. Finally, π_t is the rate of inflation in period t, which can be understood as $\pi_t = (P_t/P_{t-1})-1$.

Transactions technology.

Finally, we consider the transactions technology, that provides the transaction costs h_t, depending on the level of consumption, c_t and the amount of real money holdings, m_t. This function shows that households not only devote money to carrying out consumption activities, but also time. Therefore, intuitively, the transaction cost function $h_t = h(c_t, m_t)$ increases with consumption and decreases with money holdings. This can be accounted for by the fact that holding money facilitates consumption, and it prevents from incurring in transaction costs (time, selling something in exchange of money, taking out a loan or bank credit…).

From the transaction cost function, we can obtain the partial derivatives with respect to m_t and c_t , which reflects the relationships between these variables and transaction costs (Proof is available upon request) The first derivative of transaction costs with respect to money ($\frac{\partial h(c_t,m_t)}{\partial m_t}$) is negative, which indicates that having money in hand prevents households from increasing the total and marginal transaction costs. Conversely, the relationship between consumption and transaction costs ($\frac{\partial h(c_t,m_t)}{\partial c_t}$) is positive, since higher consumption entails higher costs in terms of time, product search, availability of resources that permit the purchase etc. Finally, the crossed derivative ($\frac{\partial h(c_t,m_t)}{\partial m_t \partial c_t}$) is negative, meaning that an increase in real money would reduce the marginal transaction cost of consumption.

Representative Household Optimizing Program

In period t, the representative household seeks to maximize her utility by solving this optimizing program:

$$Max. E_t \sum_{j=0}^{\infty} \beta^j \left[\frac{e^{b_{t+j}} \left(c_{t+j} - h c_{t-1+j}^A \right)^{1-\sigma}}{1-\sigma} - \Psi \frac{n_t^{1+\gamma}}{1+\gamma} \right]$$

Where $e^{b_{t+j}}$ is an exogenous consumption preference shock. The utility function is subject to:

$$w_{t+j} n_{t+j} + d_{t+j} - tax_{t+j} - c_{t+j} - \left(1 + r_{t+j}\right)^{-1} b_{t+1+j} + b_{t+j} - m_{t+j} + \left(1 + \pi_{t+j}\right)^{-1} m_{t-1+j} - h\left(c_{t+j}, m_{t+j}\right) = 0 \qquad \text{For j=0,1,2,…}$$

Therefore, we can observe that the households' utility depends on consumption and labor time. We just learnt that increasing money holdings has a positive impact on the household's utility: having money in hand reduces time spent shopping, which leaves more time for leisure, thus increasing utility.

The maximization program first order conditions with respect to consumption lead to obtaining the Lagrange multiplier associated with the budget constraint.

$$\lambda_t = \frac{(c_t - hc_{t-1}^A)^{-\sigma}}{1 + h_{c_t}},$$

which represents the shadow value of one unit of income. As the marginal utility of consumption divided by the marginal cost of purchasing consumption goods. The first-order-condition of bonds b_{t+1}, can be used to substitute the Lagrange multiplier obtained before and get the following consumption Euler equation:

$$\frac{(c_t - hc_{t-1})^{-\sigma}}{(1 + h_{c_t})(1 + r_t)} = \beta \, \frac{E_t(c_{t+1} - hc_t)}{1 + E_t h_{c_{t+1}}}$$

From here, we can obtain the first equation of our model. The marginal benefit of current consumption equals the discounted expected marginal benefit of future consumption. That is, β represents the weight the household assigns to the future. In a similar way, the labor supply function derived from the corresponding first-order-condition is the following:

$$\lambda_t w_t = \Psi \mathrm{n}_\mathrm{t}^{\gamma}$$

This shows that the marginal benefit of "one unit of work" (left-hand-side of the equation) equals the marginal utility loss on "one unit of work" (right-hand-side). Following the same procedure as before, we substitute the first Lagrange multiplier into the first-order condition of n_t, and obtain the following:

$$\frac{(c_t - hc_{t-1})^{-\sigma}}{1 + h_{c_t}} w_t = \Psi \mathrm{n}_\mathrm{t}^{\gamma},$$

Where solving for labor supply:

$$n_t = \left[\frac{1}{\Psi} \frac{(c_t - hc_{t-1})^{-\sigma}}{1 + h_{c_t}} w_t\right]^{\frac{1}{\gamma}}$$

Finally, we derive the next equation in the model from combining the first order condition of real money (m_t) and that of bonds (b_{t+1}).

$$-h_{m_t} = \frac{R_t}{1 + R_t}$$

From this third relationship we learn that the marginal benefit of one unit of money (which saves transaction costs when purchasing consumption goods) equals the marginal opportunity cost (instead of holding one unit of money, the household could hold bonds and make an interest return equal to R_t. This equation represents the general transaction cost function, but, as stated before, this function can be specified into the following:

$$h(c_t, m_t) = a_0 + a_1 C_t \left(\frac{c_t}{m_t}\right)^{a_2}, \qquad \text{where } a_0\,, a_1 > 0 \text{ and } a_2 > 1$$

Then, we can obtain the partial derivatives of the transaction cost function $h_t = h(c_t, m_t)$ with respect to both consumption and real money holdings:

$$h_{c_t} = \frac{\partial h(c_t, m_t)}{\partial c_t} = a_1\,(1 + a_2)\left(\frac{C_t}{m_t}\right)^{a_2}$$

$$h_{m_t} = \frac{\partial h(c_t, m_t)}{\partial m_t} = -a_1 a_2 \left(\frac{C_t}{m_t}\right)^{1+a_2}$$

which we can combine to obtain the specific money demand function as follows:

$$m_t = c_t \left[\frac{a_1 a_2}{R_t/1 + R_t}\right]^{\left(1/1+a_2\right)}$$

Up to this point we have 7 equations and 7 variables that constitute the household's model we will use in this study. The variables are: $c_t, n_t, m_t, h_t, hc_t, hm_t, y_t$.

3.2. Firms.

Firms produce a differentiated consumption good that is sold in a monopolistically competitive industry as first described by Dixit and Stiglitz (1997). The representative firm maximization problem is subject to three constraints. The first constraint (1) is the production function:

$$y_t(i) = e^{z_t}\, n_t^{1-\alpha}(i) \tag{1}$$

The production of firm i expressed in equation (1) entails that there is no capital accumulation or stock of capital considered, just as mention in the introduction. Each firm-specific labor demand, $n_t^{1-\alpha}(i)$, represents the level that permits firm i to obtain the firm-specific output, $y_t(i)$. The second constraint (2) is the Dixit and Stiglitz (1977) demand curve faced by each firm:

$$y_t(i) = \left(\frac{Pt(i)}{Pt}\right)^{-\theta} y_t \qquad (2)$$

This function corresponds to the optimal substitution across differentiated consumption goods in a monopolistic competition market. Finally, the third constraint is that each period some firms are not able to adjust their price. Thus, each firm sets the price of the good it produces, but not all firms reset their price in each period.

Price stickiness, thus, arises when setting the selling price, and we are going to use the model presented by Calvo (1983) in order to better explain this stickiness scheme. Many papers use the Calvo specification in the New Keynesian Models. Some examples are Yun (1996), Erceg, Henderson and Levin (2000), and Casares (2007), among others. In order to get price-stickiness in the model, we must have firms as price-setters, which means we need to move away from the perfectly competitive benchmark. Calvo (1983) assumed that firms adjust their prices infrequently and that opportunities to adjust arrive with constant probability. Each new period, thus, there is a constant probability (1- η) that the firm can and will adjust its price. There is an expected time between adjustments of about 1/(1- η). The main explanation for this is that not every firm can adjust prices at the same time. The adjustment of prices is indeed staggered, which complicates the price changes, as firms are not indifferent to the prices charged by their competitors. Thus, taking η as the Calvo probability, we find two types of firms in the model: those who do not get to adjust prices, represented by η, and those who get to adjust prices, represented by $(1-\eta)$. On the one hand, those firms that cannot adjust prices, rather than leaving them unchanged (and thus, $P_t(i) = P_{t-1}(i)$), the price is automatically adjusted by applying an indexation factor as follows,

$$P_t(i) = \left[(1+\pi_{t-1})^{\kappa_p}(1+\pi+v_t)^{1-\kappa_p}\right]P_{t-1}(i),$$

being $[(1+\pi_{t-1})^{\kappa_p}(1+\pi+v_t)^{1-\kappa_p}]$ the indexation factor, where $v_t = \rho_t v_{t-1} + \varepsilon_t^v$ is an AR(1) process with white-noise innovations, $\varepsilon_t^v \sim N(0, \sigma_v^2)$. In the equation, $P_t(i)$ is the optimal selling price during period t.

On the other hand, if firm i can set the optimal price in period t, the price will be set at the value that maximizes the intertemporal profit function:

$$E_t \sum_{j=0}^{\infty} \beta^j \eta^j \left(\frac{(1+idx_{t+j})P_t(i)}{P_{t+j}}\right)^{1-\theta} y_{t+j} - w_{t+j} n_{t+j}(i)$$

Subject to the production function and the Dixit-Stiglitz demand constraints. Following Walsh (2017), the first order condition on $P_t(i)$ results in the following optimal price:

$$P_t(i) = \frac{\theta}{\theta-1}\left[\frac{E_t \sum_{j=0}^{\infty} \beta^j \eta^j mc_{t+j}(i)\left(\frac{P_{t+j}}{1+idx_{t+j}}\right)^{\theta} y_{t+j}}{E_t \sum_{j=0}^{\infty} \beta^j \eta^j \left(\frac{P_{t+j}}{1+idx_{t+j}}\right)^{\theta-1} y_{t+j}}\right]$$

where $(1+idx_{t+j})$ is the indexation factor described above and mc_{t+j} is the real marginal cost. When trying to set their prices, then, firms need to pick a price $P_t(i)$ that allows them to maximize the expected profit considering the costs they incur. The following auxiliary variables were first introduced by Schmitt-Grohe and Uribe (2005), and they are generally used to obtain the equations for the inflation dynamics:

$$A_t = y_t mc_t + \beta\eta E_t\left[A_{t+1}\left(\frac{(1+\pi_{t+1})}{(1+\pi_t)^{kp}(1+\pi+v_t)^{1-kp}}\right)^{\frac{\theta}{1-\alpha}}\right]$$

$$B_t = y_t + \beta\eta E_t\left[B_{t+1}\left(\frac{(1+\pi_{t+1})}{(1+\pi_t)^{kp}(1+\pi+v_t)^{1-kp}}\right)^{\theta-1}\right]$$

Which allows us to express the relative price function in the following way:

$$\left[\frac{P_t(i)}{P_t}\right]^{1+\frac{\theta\alpha}{1-\alpha}} B_t = \frac{\theta}{\theta-1} A_t$$

At the same time, the Dixit-Stiglitz price aggregation shows:

$$[P_t]^{1-\theta} = (1-\eta) + \eta\left[(1+idx_t)\frac{P_{t-1}}{P_t(i)}\right]^{1-\theta},$$

Which, by using $1+\pi_t = \frac{P_t}{P_{t-1}}$ as well as the price indexation factor in period t, $(1+idx_t) = (1+\pi_{t-1})^{\kappa_p}(1+\pi+v_t)^{1-\kappa_p}$, leads to obtaining the following and equivalent expression:

$$\left[\frac{P_t(i)}{P_t}\right]^{\theta-1} = (1-\eta) + \eta[(1+\pi_{t-1})^{\kappa_p}(1+\pi+v_t)^{1-\kappa_p}]^{1-\theta}\left[(1+\pi_t)\frac{P_t(i)}{P_t}\right]^{\theta-1}$$

These last four derived equations comprise the Inflation dynamics block, for given values of $y_t$and c_t.

Finally, it is important to note that the monopolistically competitive firms we are describing are owned by the households, who, in turn, receive dividends. The aggregate real dividend, d_t (which appeared in the households' budget constraint) can be obtained as follows:

$$d_t = \int_0^1 \frac{Pt(i)}{Pt} y(i)di - \int_0^1 w_t n_t(i)di = \int_0^1 \frac{P_t(i)}{P_t}\left(\frac{P_t(i)}{P_t}\right)^{-\theta} y_t - w_t\int_0^1 n_t(i)di$$

where we can distinguish the Dixit-Stiglitz Demand Constraint, $y_t(i) = \left(\frac{Pt(i)}{Pt}\right)^{-\theta} y_t$. Inserting aggregate labor $\int_0^1 n_t(i)di$ and taking y_t out of the integral gives:

$$d_t = y_t\int_0^1 \left(\frac{Pt(i)}{Pt}\right)^{1-\theta} di - w_t n_t$$

where we can introduce $PD_t = \int_0^1 \left(\frac{Pt(i)}{Pt}\right)^{1-\theta} di$ as the price dispersion indicator[1] (Schmitt-Grohe and Uribe, 2005), which corresponds to the sum of all firms (those who set the

[1] [1] Using the price dispersion indicator definition proposed by Schmitt-Grohe and Uribe (2005): $PD_t \equiv \int_0^1 \left(\frac{P_t(i)}{P_t}\right)^{1-\theta} di$

optimal price in period t plus those who did it in t-1, plus those who did it in t-2…and so on).

$$PD_t = (1-\eta)\left(\frac{Pt(i)}{Pt}\right)^{1-\theta} + \eta[(1+idx_t)]^{1-\theta} PD_{t-1}.$$

Output Gap

It is usual to find in the New Keynesian literature the concept of output gap. This term is generally defined as the fractional deviation of current output from the flexible-price level of output (see Woodford, 2003). Thus, under these circumstances, all prices can be adjusted by all agents of the economy.

$$\widetilde{y_t} = \frac{y_t}{\bar{y}_t} - 1$$

Where $\widetilde{y_t}$ represents the output gap in period t and the term $\bar{y}_t$ is the flexible-price level of output (also known as potential output or natural-rate level of output). If we use the Calvo probability, η, this scenario of flexible prices would be represented by η =0. This situation implies that prices are fully-flexible to adjust optimally every period. Thus, all firms are able to attain the optimal price, which is the same for all of them. The results are the following: first, the mark-up of prices over the marginal costs is constant, and represented by $mc_t = \frac{\theta-1}{\theta}$ and second, the real marginal costs show no fluctuations since real wage is a fraction of the marginal product of labor:

$$\frac{\overline{w_t}}{f_{\bar{n}_t}} = \frac{\theta - 1}{\theta},$$

Where $f_{\bar{n}_t} = e^{z_t}(1-\alpha)\bar{n}_t^{-\alpha}$, which represents the labor function. Not only this is true, but at the same time, households supply the level of labor that makes the marginal rate of substitution between hours (including transaction costs) and consumption equal to the real wage, which is observed in the following:

$$\widehat{\overline{w_t}} = \frac{(1+h_{\bar{c}_t})}{e^{bt}\left(\bar{c}_t - h_{\bar{c}_t}\right)^{-\sigma}} \psi(\overline{n_t})^{\gamma}$$

The production under flexible-prices and natural-rate labor, taking into consideration that we ignore capital accumulation and the stock of capital, is the following:

$$\bar{y}_t = e^{z_t}\bar{n}_t^{1-\alpha}$$

Thus, from the first equation, we can rewrite:

$$\bar{w}_t = \frac{\psi\bar{n}_t^{\alpha}(1+h_{\bar{c}_t})}{e^{b_t}(\bar{c}_t - h\bar{c}_{t-1})^{-\sigma}}$$

Moreover, potential income equals potential private consumption plus public spending (adjusted for an external shock, e^{b_t}), just as follows:

$$\bar{y}_t = \bar{c}_t + g_t + \bar{h}_t$$

where $g_t = e^{\chi_t}$ and χ_t is an AR(1) process described as follows: $\chi_t = \rho_\chi \chi_{t-1} + \varepsilon_t^{\chi}$, being $\varepsilon_t^{\chi} \sim N\left(0, \sigma_{\varepsilon^{\chi}}^2\right)$. Since we include $\bar{c}_t$ we need to find an equation that includes it, which is the partial derivative of the transaction costs with respect to consumption goods,

$$h_{\bar{c}_t} = a_1(1+a_2)\left(\frac{\bar{c}_t}{\bar{m}_t}\right)^{a_2}$$

The same happens with $\bar{m}_t$, for which we derive the partial derivative of transaction cost with respect to potential real money, and get:

$$a_1 a_2\left(\frac{\bar{c}_t}{\bar{m}_t}\right)^{1+a_2} = \frac{\bar{R}_t}{1+\bar{R}_t}$$

In order to include the last variable, $\bar{R}$, we use the Fisher relation, which relates both real and nominal interest rates, through inflation:

$$1+\bar{r}_t = \frac{1+\bar{R}_t}{1+E_t\bar{\pi}_{t+1}}$$

The next equation to consider is the Euler condition, that includes the real interest rate $\bar{r}_t$:

$$\frac{e^{bt}(\bar{c}_t - h\bar{c}_{t-1})^{-\sigma}}{(1+h_{\bar{c}_t})(1+\bar{r}_t)} = \beta E_t\left[\frac{e^{bt}(\bar{c}_{t+1} - h\bar{c}_t)^{-\sigma}}{(1+h_{\bar{c}_{t+1}})}\right]$$

The Euler equation essentially implies that the household must be indifferent between consuming one more unit today, on the one hand, and saving that unit and consuming in the future on the other. If the household chooses to consume today, he gets the marginal utility of consumption today — the left-hand side of the equation, put another way, he gets the utility of today's consumption. If, instead, the household saves that unit, he gets to consume 1+R units in the future, each giving him extra units of utility. Because this utility comes in the future, it is discounted by the discounting factor β. That is the right side of the Euler equation. The fact that these two sides must be equal is what guarantees that the household will be indifferent between consuming today versus in the future (Jones, 2009).

Finally, we reference the transaction cost function, $h_t(c_t, m_t)$, as follows,

$$h_t(c_t, m_t) = a_0 + a_1 C_t \left(\frac{c_t}{m_t}\right)^{a_2},$$

with which we complete the set of equations necessary to solve the potential (or natural-rate) level of output ($\hat{y}$). Thus, we have 10 new variables : $\overline{w}_t, \overline{n}_t, \overline{y}_t, \overline{c}_t, h\overline{c}_t, \overline{m}_t, \overline{R}_t, \overline{\pi}_t, \overline{r}_t$ and $\overline{h}_t$, which we solve through the 10-equation system we just presented.

This system we presented follows the New Keynesian optimization scheme, a model with money and sticky prices. Applying Calvo (1983) pricing specifications, the rigidity of prices depends on the value of the η probability. Literature reveals that the usual calibration of this probability lies between 0.66< η <0.75. Hence, if η = 0.75 (Lhuissier and Zabelina, 2014) and if one period equals one quarter, then the average (or expected) lifetime of a nominal price chosen today is equal to: $(1/1-\eta) = (1/1-0.75) = 4$ quarters = 1 year. Put another way, $\eta = 0.75$ implies that on average prices remain constant (unchanged) for one year.

3.3. Government and Central Bank

The next agent contemplated in the economy is the Government. This agent acts as the representative of the general public. Along the years, there have been differing schools of thought on the role of the government in a country's economy. The classical economists, such as Adam Smith, Say and others, advocated the doctrine of non-intervention of the government in economic matters, commonly known as "laissez faire". Adam Smith was the first one to introduce the concept of the "invisible hand", which accounts for the free functioning of the price (market) system in the absence of government intervention. These classical economists believe that a self-regulating economy is the most effective system, since individuals will allocate the available resources in the most efficient manner in order to meet their needs and those of the firms.

The Great Depression forced to implement a different approach in the market, referred to as the "visible hand" of the government. The existence of imperfection in the markets (imperfect information, imperfect competition...) forces the state to take part in the correct development of the country's economy. Thus, it seems obvious that the government should intervene in economic affairs, given that the market mechanism is imperfect. Therefore, Keynesians deem the government as an essential figure that helps the economy succeed. They place great important on both the private and public sectors, who influence the economic activity. In fact, they believe government spending is the best economic stimulator, since they believe that it could even replace private spending on both goods and services or business investments.

For all the reasons above mentioned, we include the government in the model, as we believe it has four main functions in the economy. However, the role of the government (and thus, its fiscal policy) is secondary in our model. It will just comply with the budget constraint.

The government budget constraint introduces three ways to raise public revenue. The first one is through taxes (tax_t); the government can require their citizens to pay some income to finance public spending. The second source of income is through borrowing. In this case, governments request an amount of funds and issue bonds with a promise to repay the funds with some amount of interest. , which in real terms is $(1+r_t)^{-1}b_{t+1} - b_t$. Households will purchase these bonds, helping the government to raise the income it needs while getting some interest in return. Finally, the third option the government has is printing new money, which in real terms is expressed as $m_t - (1+\pi_t)^{-1}m_{t-1}$. If we put this as an equation, we have:

$$g_t = tax_t + (1 + r_t)^{-1}b_{t+1} - b_t + m_t - (1 + + \pi_t)^{-1}m_{t-1}$$

Overall Budget Constraint.

Since there is no capital accumulation in our model, consequently, no investment is considered; plus, the overall budget constraint is obtained by combining both the households (private) and government (public) income and spending. Remember that:

Households Budget Constraint:

$$w_t n_t + d_t - tax_t = c_t + (1 + r_t)^{-1} b_{t+1} - b_t + m_t - (1 + \pi_t)^{-1} m_{t-1} + h(ct, mt)$$

Government Budget Constraint:

$$g_t = tax_t + (1 + r_t)^{-1} b_{t-1} - b_t + m_t - (1 + \pi_t)^{-1} m_{t-1}$$

The resulting equation is the overall budget constraint, which shows that total income (public and private) equals total spending (public and private) plus any transaction costs incurred:

$$w_t n_t + d_t = c_t + g_t + h(c_t, m_t),$$

Where the left part represents total income ($w_t n_t + d_t$), and the right-hand side represents total spending ($c_t + g_t$) plus transaction costs $h(c_t, m_t)$.

Finally, we will describe the behavior of the central bank. Central banks are independent national institutions that provide financial and banking services. The main role of a central bank is to conduct monetary policy to achieve price stability (low and stable inflation, generally around 2%) and to help manage economic fluctuations.

Monetary policy analysis implies testing the performance of alternative monetary policy rules applied to the economies. Monetary policy functions as follows: an increase in money supply (i.e. an expansionary monetary policy) stimulates the economic activity, whereas a decrease in money supply (i.e. a contractionary monetary policy) slows down the economy. Central banks usually have three main tools of monetary control: (1) open-market operations, with which they buy and sell government bonds in the open market, (2) the interest rate and (3) reserve requirements for commercial banks. The latter, (2) and (3), define the conditions at which commercial banks can borrow money from the central banks.

However, even though central banks' role is very important, they can only have indirect control of the overall money supply. Commercial banks also lend money, even more than they hold, thus increasing the existing money supply. Even though these banks also influence the economy, some believe that central banks have never been more powerful as they are today (Richard Layard, 2005). Monetary policy has become the main instrument of macroeconomic stability, and in a growing number of countries monetary policy is in the hands of independent central banks. They hold the monopoly on issuing money. Since money plays a great role in every country's economy, the significant role of central banks arises accordingly.

Monetary policy decisions affect expectations for the future performance of the economy and, in particular, of prices. Economic agents determine their prices based on these expectations. Woodford (1999) contemplated the fact that when the private sector is forward-looking, and perceive the central bank's commitments as credible, commitments regarding future policy indeed affect the short-run constraints, only when these are able to affect the expectations that determine private behavior in the present.

Thus, since monetary authorities are to follow a monetary policy rule either on the nominal interest rate instrument or on a money-growth instrument, our model will try to evaluate which instrument is more appropriate. We will follow a Taylor-type monetary rule as follows:

$$1 + R_t = \left((1+r)(1+\pi)^{1-\mu_\pi}\right)^{1-\mu_R}(1+R_{t-1})^{\mu_\pi}(1+\pi_t)^{(1-\mu_R)\mu_\pi}(1+\tilde{y}_t)^{(1-\mu_R)\mu_y}e^{\varepsilon_t^R}$$

where $\tilde{y}_t$ is the output gap, and ε_t^R is a white-noise policy shock. Moreover, $\mu_\pi > 1, 0 < \mu_R < 1$, and $\mu_y > 0$ are the Taylor Rule coefficients on inflation, output gap and interest-rate smoothing, respectively. The money growth monetary rule applied will be of the type:

$$1 + gM_t = \left(\frac{m_t}{m_{t-1}}\right)(1+\pi)$$

3.4 Equations of the New Keynesian model with money.

The model we just presented includes a total of 36 equations[2], and 36 endogenous variables, respectively. These are: y, $\bar{y}$, c, $\bar{c}$, n, $\bar{n}$, R, r, $\bar{r}$, w, $\bar{w}$, π, mc, fn, dy, $\tilde{y}$, A, B, P, PD, m, h, h_c, $\bar{m}$, $\bar{h}$, $\overline{h_c}$, $\bar{R}$, $\bar{\pi}$, gM, u_t^c, u_t^n, wel_t z, v, χ, and b. There are as well some exogenous variables: e^{z_t}, ε^v, ε^b, ε^R and ε^χ. Finally, the parameters we use are: β, σ, α, h, ψ, gy, γ, θ, η, kp, μ_π, μ_y, μ_R, π, a_0, a_1, a_2, ρ_z, ρ_v, ρ_χ and ρ_b; The corresponding equations described and derived along this paper correspond to:

The Inflation Block.

[2] There are 33 equations described in this section; the 3 remaining equations will be derived in the following section, together with the corresponding variable definitions.

$$A_t = y_t mc_t + \beta \eta E_t \left[A_{t+1} \left(\frac{(1+\pi_{t+1})}{(1+\pi_t)^{kp}(1+\pi+v_t)^{1-kp}} \right)^{\frac{\theta}{1-\alpha}} \right]$$

$$B_t = y_t + \beta \eta E_t \left[B_{t+1} \left(\frac{(1+\pi_{t+1})}{(1+\pi_t)^{kp}(1+\pi+v_t)^{1-kp}} \right)^{\theta-1} \right]$$

$$\left[\frac{P_t(i)}{P_t}\right]^{1+\frac{\theta\alpha}{1-\alpha}} B_t = \frac{\eta}{\eta-1} A_t$$

$$\left[\frac{P_t(i)}{P_t}\right]^{\theta-1} = (1-\eta) + \eta\left[(1+\pi_{t-1})^{k_p}(1+\pi+v_t)^{1-k_p}\right]^{1-\theta}\left[(1+\pi_t)\frac{P_t(i)}{P_t}\right]^{\theta-1}$$

The real marginal cost (labor demand):

$$mc_t = \frac{w_t}{fn(i)}.$$

$$f_{\bar{n}_t} = e^{z_t}(1-\alpha)\bar{n}_t^{-\alpha}$$

The Price Dispersion indicator and overall resources constraint:

$$PD_t = (1-\eta)\left(\frac{Pt(i)}{Pt}\right)^{1-\theta} + \eta[(1+idx_t)]^{1-\theta} PD_{(t-1)}$$

$$PD_t Y_t = c_t + g_t + h(c_t, m_t).$$

Aggregate Output:

$$y_t(i) = e^{zt}\, n_t^{1-\alpha}(i)$$

The household optimal choices of consumption and labor supply[1]:

$$\frac{(c_t - hc_{t-1})^{-\sigma}}{(1+h_{c_t})(1+r_t)} = \beta \frac{E_t(c_{t+1} - hc_t)}{1 + E_t h_{c_{t+1}}}$$

$$w_t = \frac{\psi n_t^{\alpha}(1+h_{c_t})}{e^{b_t}(c_t - hc_{t-1})^{-\sigma}}$$

Real interest rate, through the Fisher relationship (1 equation)

[1] Recall capital accumulation is not considered in the model.

$$1 + r_t = \frac{1 + R_t}{1 + E_t \pi_{t+1}}$$

Taylor-type monetary Rule for monetary policy (1 equation)

$$1 + R_t = \left((1 + r)(1 + \pi)^{1-\mu_\pi}\right)^{1-\mu_R} (1 + R_{t-1})^{\mu_\pi} (1 + \pi_t)^{(1-\mu_R)\mu_\pi} (1 + \tilde{y}_t)^{(1-\mu_R)\mu_y} e^{\varepsilon_t^R}$$

Money demand, transaction costs function and marginal transaction cost of consumption:

$$\frac{R_t}{1 + R_t} = a_1 a^2 \left(\frac{c_t}{m_t}\right)^{1+a_2}$$

$$h_t = a_0 + a_1 c_t \left(\frac{c_t}{m_t}\right)^{a_2}$$

$$h_{c_t} = \frac{\partial h_t}{\partial c_t} = a_1 \, (1 + a_2) \left(\frac{c_t}{m_t}\right)^{a_2}$$

The natural-rate block:

$$\widehat{\overline{w}_t} = \frac{(1 + h_{\bar{c}_t})}{e^{bt}(\overline{c_t} - h\bar{c}_{t-1})^{-\sigma}} \, \psi_t (\overline{n_t})^{\gamma}$$

$$\overline{w}_t = \frac{\psi \bar{n}_t^{\alpha} (1 + h_{\bar{c}_t})}{e^{b_t}(\overline{c_t} - h\bar{c}_{t-1})^{-\sigma}}$$

$$\bar{y}_t = \bar{c}_t + e^{x_t} g + \bar{h}_t$$

$$\bar{y}_t(i) = e^{zt} \, \bar{n}_t^{1-\alpha}(i)$$

$$\frac{\bar{R}_t}{1 + \bar{R}_t} = a_1 a_2 \left(\frac{\bar{c}_t}{\bar{m}_t}\right)^{1+a_2}$$

$$\bar{h} = a_0 + a_1 \bar{c}_t \left(\frac{\bar{c}_t}{\bar{m}_t}\right)^{a_2}$$

$$1 + \bar{r}_t = \frac{1 + \bar{R}_t}{1 + E_t \bar{\pi}_{t+1}}$$

$$1 + \bar{R}_t = \left((1 + \bar{r})(1 + \bar{\pi})^{1-\mu_\pi}\right)^{1-\mu_R} (1 + \bar{R}_{t-1})^{\mu_\pi} (1 + \bar{\pi}_t)^{(1-\mu_R)\mu_\pi} (1 + \tilde{y}_t)^{(1-\mu_R)\mu_y} e^{\varepsilon_t^R}$$

The output gap:

$$\widetilde{y_t} = \frac{y_t}{\overline{y_t}} - 1$$

Output growth and money growth:

$$dy_t = \frac{y_t}{y_{t-1}} - 1$$

$$1 + gM_t = \left(\frac{m_t}{m_{t-1}}\right)(1 + \pi),$$

where $m_t = \frac{M_t}{P_t}$ and $gM_t = \frac{M_t}{M_{t-1}} - 1.$

AR(1) Exogenous processes (white-noise innovations)

$$z_t = \rho_z z_{t-1} + e_t^z$$

$$v_t = \rho_v v_{t-1} + e_t^v$$

$$\chi_t = \rho_\chi \chi_{t-1} + e_t^\chi$$

$$b_t = \rho_b b_{t-1} + e_t^b$$

4. CALIBRATION

The calibration given to the parameters of the model relies on already available empirical works that similarly study the effect of monetary shocks. Some of the authors referenced and used as basis are: Bernanke and Mihov (1995), Christiano, Eichenbaum, and Evans (1996, 1998), Rotemberg and Woodford (1997), Casares (2007), and specially, Smets and Wouters (2007). For the parameters included in our model, we use a calibration that is generally accepted among these authors and proven to be effective.

The household's utility function included in the model comprises several parameters that we calibrate as follows: the household discount factor is β = 0.995, which implies a 2% real interest rate in steady state. We set the consumption habit term at h = 0.7, as it brings moderate inertia of consumption dynamics consistent with consumption fluctuations (autocorrelation of consumption at 0.96 in model simulations). The following two parameters are calibrated following the posterior estimates of Smets and Wouters (2007), where they conduct a Bayesian estimation of a DSGE model using US data. The risk aversion coefficient takes a value σ =1.38, and that of the inverse of Frisch labor supply elasticity takes a value γ =1.83, following their findings. Finally, the weight of labor disutility is given a value Ψ = 4.5425. The criterion for the calibration is that this value enables to normalize labor at n=1 in steady state.

The transaction cost function in our model includes three parameters, that we calibrate as follows: the constant term of the transaction's technology is a_0 =0.01, as it gives a realistic size of transaction costs over GDP, h/y = 0.0107 (1.07%). The term a_1 captures the weight of variable term of transactions technology. Assigning a value a_1=0.02 enables to obtain a realistic steady-state share of real money over GDP, m/y=0.94 (94%). Finally, the transaction cost elasticity on c/m ratio term is calibrated to match relative volatility of nominal money growth with respect to real GDP growth (in order to replicate std(gM)/std(dy) = 3, as observed in US data). We get this when a_2=15.

In the production function, the Cobb-Douglas capital share is calibrated at α =0.36, which is a standard value in RBC literature (Cooley and Hansen, 1999). As previously explained along the paper, prices are sticky, and follow Calvo (1983) specification. Each period, only a share of the firms gets to adjust their prices, which is described by the Calvo probability for sticky prices. Setting Calvo probability at η = 0.75 implies that, on average, firms set the optimal price every 4 periods (quarters), once per year (Erceg, Henderson and Levin, 2000). Moreover, the ratio of government purchases to output in steady state is set at g/y= 0.25, since 25% is a reasonable rate for a model without investment.

The Dixit-Stiglitz elasticity takes a value θ = 10, which leads to obtaining a markup in steady-state at 11.1%. As for the coefficients in the inflation equation, we give the parameters involved the following calibration: k_p=0.5, which stands for the price indexation on lagged inflation, as it is evenly weighted between lagged inflation and steady state inflation. Moreover, it gives a reasonable autocorrelation of inflation in model simulations (0.79). The next term is set at μ_π = 1.5, since it is the Taylor (1993) rule original coefficient of inflation. Similarly, μ_y =0.5/4, as it is the Taylor (1993) rule original coefficient on the output gap. The next parameter is μ_R = 0.8, which represents the Taylor Rule coefficient on interest-rate smoothing. It gives a reasonable inertial behavior of central banks as well as an autocorrelation of the nominal interest rate at 0.90. Finally, in order to obtain a steady state value of inflation at 2% annualized, π =0.005.

The last parameters in our model correspond to the different shocks. The persistence of the technology shock is given a value ρ_z = 0.9. Meanwhile, the persistence of the price-push shock is calibrated at ρ_v = 0.5; the persistence of consumption preference shock takes a value ρ_b = 0.8, and the persistence of fiscal shock is set at ρ_χ = 0.8. the selection of numerical values for the model parameters brings a fair match of model-generated data and actual US data on the relative volatility (represented by the standard deviations) and persistence (coefficient of autocorrelation) of dy, π, R and gM observed in quarterly US data 1993-2018 model (see Table 1 below).

Table 1- Second-moment statistics. Model vs data.

Parameter	*Std Deviation*		*Autocorrelation*	
	Model	*Data*	*Model*	*Data*
Output growht, dy	0.6217	0.5842	0.3001	0.3699
Inflation, π	0.4721	0.2085	0.7929	0.4564
Nominal Interest Rate, R	0.5315	0.6995	0.8973	0.9851
Nominal Money growth, gM	1.6929	1.5860	0.1141	0.6847

The following table summarizes the calibration of all the model parameters.

Table 2- Parameter Assigned Values and Definition

Parameter	*Value*	*Definition*
β	0.995	Household discount factor.
h	0.7	Consumption habits.
σ	1.38	Risk aversion coefficient.
γ	1.83	Inverse of Frisch labor supply elasticity
Ψ	4.5425	Weight of labor disutility
θ	10	Dixit-Stiglitz elasticity.
α	0.36	Cobb-Douglas capital share.

η	0.75	Calvo probability for sticky prices.
k_p	0.5	Price indexation on lagged inflation.
μ_π	1.5	Taylor (1993) Rule original coefficient on inflation.
μ_y	0.5/4	Taylor (1993) Rule coefficient on the output gap.
μ_R	0.8	Taylor (1993) Rule coefficient on interest-rate smoothing
π	0.005	Steady state inflation at 2% annualized
g/y	0.25	Ratio of government purchases to output in steady state
a_0	0.01	Constant term of transactions technology.
a_1	0.02	Weight of variable term of transactions technology.
a_2	15	Transaction cost elasticity on c/m ratio.
ρ_z	0.9	Persistence of Technology shock.
ρ_v	0.5	Persistence of price-push shock.
ρ_b	0.8	Persistence of consumption preference shock.
ρ_χ	0.8	Persistence of fiscal shock.

5. MONETARY POLICY ANALYSIS

As mentioned in previous sections, this paper examines the stabilizing performance of two different monetary policy rules. The model does not try to represent any particular economy; it can just be thought as a representation of the empirical fluctuations of today's modern economies. The first monetary policy is the Taylor (1993) rule on the nominal interest rate. Taylor (1993) estimated a linear policy rule for the US that included adjustments of the short-term interest rate of the Federal Reserve that follows deviations of current inflation from a specified target rate and output deviations with respect to its trend.

Alternatively, the central bank can choose to modify the quantity of money in circulation (thus, the money supply) or the interest rates in the market, which can be accommodated in a (nominal) money growth monetary policy rule.

Our analysis aims at determining which of the two monetary policies is best for the economy. There are different ways in which this could be evaluated, but following existing literature, we will use a welfare-based evaluation method (Rotemberg and Woodford (1999) and Schmitt-Grohé and Uribe (2007)). This approach permits to isolate the effects of a monetary policy in terms of the welfare of the private agents in the economy, thus, the households. This, we believe, is important because the central bank acts as a social planner in the benefit of the households. In our model, the best approximation to households' welfare is their utility function. Thus, we are able to measure the effectiveness of both monetary policies by analyzing their impact on households' intertemporal utility.

Since the steady state value of household welfare under both monetary policy rules is the same, we need to conduct second-order approximations of the utility function. In order to achieve this, we use the Taylor series expansion. Therefore, we not only approximate the households' utility by adding the first-order derivative to the steady state value (which represents what the welfare would be like if all shocks were inexistent, thus, 0). Consumers seek smoothing in the long run, which applies to consumption, labor hours supplied, etc. Thus, what we aim to obtain is a low variance of the expected households' welfare, which we evaluate through the second-order approximation.

The Instantaneous Utility Function (IUF), that is, the household's utility in the current period, is composed of two parts: the instantaneous utility of consumption (that we refer to as u_t^c) and the instantaneous disutility of labor (denoted as u_t^n). Other important elements that we need to pre-define are the habit-adjusted consumption, which is represented by $ch_t = c_t - hc_{t-1}$, and the unit-mean consumption preference shock, $bh_t = e^{b_t}$.

The IUF can be transformed as follows: we first take the second-order approximation for u_t^c and u_t^n and obtain:

$$u_t^c \cong \frac{ch^{1-\sigma}}{1-\sigma} + ch^{-\sigma}(ch_t - ch) + \frac{ch^{1-\sigma}}{1-\sigma}(bh_t - bh) - \frac{\sigma ch^{-\sigma-1}}{2}(ch_t - ch)^2 + ch^{-\sigma}(ch_t - ch)(bh_t - bh)$$ and

$$u_t^n \cong \Psi \frac{n^{1+\gamma}}{1+\gamma} + \Psi \mathrm{n}^{\gamma}(n_t - n) + \Psi\gamma n^{\gamma-1}(n_t - n)^2$$

Welfare, in fact, not only entails households' utility at a particular moment in time (say period t), but also considers the present value of expected future utility. Thus, taking the unconditional expectation of household intertemporal utility (welfare), we get:

$$E[wel_t] = (u_t^c - u_t^n) + E_t(u_{t+1}^c - u_{t+1}^n) + \beta^2 E_t(u_{t+2}^c - u_{t+2}^n) + \cdots$$

which coincides with $E[wel_t] = (1 + \beta + \beta^2 + \cdots)[u^c - u^n]$. Put another way,

$$E[wel_t] = \left(\frac{1}{1-\beta}\right)[u^c - u^n].$$

Therefore, we can compute the unconditional expectation of household intertemporal utility (that we call welfare) as:

$$E[wel_t] = \left(\frac{1}{1-\beta}\right)[\frac{ch^{1-\sigma}}{1-\sigma} - \frac{\sigma ch^{-\sigma-1}}{2}VAR(ch) + ch^{-\sigma}COV(ch, bh) - \Psi\frac{n^{1+\gamma}}{1+\gamma} - \Psi\gamma n^{\gamma-1}VAR(n)]$$

where VAR stands for variance and COV refers to the covariance. We include these three relevant equations in our model, which allows us to complete the entire model comprised of 36 equations and 36 endogenous variables.

$$u_t^c \cong \frac{ch^{1-\sigma}}{1-\sigma} + ch^{-\sigma}(ch_t - ch) + \frac{ch^{1-\sigma}}{1-\sigma}(bh_t - bh) - \frac{\sigma ch^{-\sigma-1}}{2}(ch_t - ch)^2 + ch^{-\sigma}(ch_t - ch)(bh_t - bh)$$

$$u_t^n \cong \Psi\frac{n^{1+\gamma}}{1+\gamma} + \Psi \mathrm{n}^{\gamma}(n_t - n) + \Psi\gamma n^{\gamma-1}(n_t - n)^2$$

$$E[Wel] = \left(\frac{1}{1-\beta}\right)[u_t^c - u_t^n]$$

5.1 Baseline Model.

The first model we are going to analyze serves as our baseline for monetary policy evaluation. The baseline model is obtained by using a Taylor-type monetary policy and giving a value 1.5 to μ_π, which stands for the Taylor (1993) original coefficient on inflation. The results obtained will be contrasted with those obtained by applying the two different monetary policies (Taylor-rule and (nominal) money growth rule with the optimized coefficient μ_π), in order to evaluate which of them improves overall households' social welfare. Under this baseline model, the 2nd order approximation of the unconditional expected welfare value is -13.776.

Table 3 – Baseline Model - Stabilizing performance

μ_π	std(c)	std(c-hc(-1))	std(n)	u^c	u^n	.01*Mean(W)	.01*E[Welfare]	std(R)	std(gM)
1.50	1.8516	0.6944	2.7785	-2.757	65.779	-1.26	-13.7757	0.5315	1.6929

The values presented correspond to the Taylor (1993) rule coefficient on inflation, μ_π, the standard deviation of consumption, std(c), the standard deviation of the habits-adjusted consumption std(c-hc(-1)), the standard deviation of labor, std(n), the unconditional expectation of the instantaneous utility of consumption (u^c) the unconditional expectation of the instantaneous disutility of labor (u^n), one hundredth of the average welfare 0.01*Mean(W), one hundredth of the expected social welfare, 0.01*E[Welfare], and the standard deviations of both nominal interest rate, std(R) and nominal money growth, std(gM). Under the baseline calibration, with ε^R=0.2^2 and $\mu_\pi = 1.5$, the expected welfare provided is -13.7757.

5.2. Taylor-Rule Monetary Policy.

In order to evaluate the Taylor-type monetary policy, we first need to adjust the model so that it meets several specifications. The methodology employed is the following: other things being equal, we vary the value of μ_π in order to see which value of this variable leads to the optimal social utility welfare. In this case, the variance of ε^R=0.002^2. Once we vary the value of μ_π we see that the one leading to the highest (least negative) expected social welfare is $\mu_\pi = 4$. Other things being equal, this value enables the central bank to obtain an expected social welfare equal to $E[Wel] = -12.61124626$.

Table 4- Taylor-Rule Monetary Policy - Stabilizing Performance

μ_π	std(c)	std(c-hc(-1))	std(n)	u^c	u^n	.01*Mean(W)	.01*E[Wel]	std(R)	std(gM)
1.25	1.8330	0.6918	2.8854	-4.6635	1.612	-12.6005	-12.6139	0.5275	1.6751
1.50	1.8516	0.6944	2.7785	-4.6636	1.611	-12.6005	-12.6130	0.5315	1.6929
1.75	1.8681	0.6978	2.7042	-4.6636	1.611	-12.6005	-12.6124	0.5391	1.7200
2	1.8833	0.7019	2.6499	-4.6637	1.611	-12.6005	-12.6121	0.5486	1.7532
2.50	1.911	0.7107	2.5774	-4.6638	1.610	-12.6005	-12.6116	0.57	1.8308
3.50	1.9588	0.7292	2.5052	-4.6639	1.610	-12.6005	-12.61127563	0.6155	2.0079
4	1.9798	0.7383	2.4874	-4.6640	1.610	-12.6005	-12.61124626	0.6381	2.1008
4.25	1.9898	0.7428	2.4813	-4.6640	1.610	-12.6005	-12.61125007	0.6492	2.1477
4.50	1.9994	0.7471	2.4764	-4.6640	1.610	-12.6005	-12.6113	0.6602	2.1947
6	0.0205	0.0077	0.0247	-4.6642	1.610	-12.6005	-12.6115	0.7234	2.4747
8	0.0211	0.0080	0.0248	-4.6643	1.610	-12.6005	-12.6119	0.8002	2.8344
10	0.0215	0.0083	0.0250	-4.6645	1.610	-12.6005	-12.6123	0.8697	3.1745

5.3. (Nominal) Money Growth Monetary Policy.

We now need to recalibrate the model in order to fit it to the new monetary policy we are going to apply, the (nominal) money growth policy. We achieve this by finding the value of the monetary shock (variance of ε^R) that leads to obtaining dy = 0.62. This way, we ensure all other variables take the same value as under the Taylor-rule monetary policy, so the analysis of $\mu_\pi$can take place. The value we found to meet this requirement is ε^R=0.0075^2. Similarly, we closely examined the values of μ_π that would exhibit highest welfare among households. In this case, under a (nominal) money growth monetary policy, the greatest expected welfare ($E[Wel] = -12.613062$) is obtained with a value $\mu_\pi = 11$.

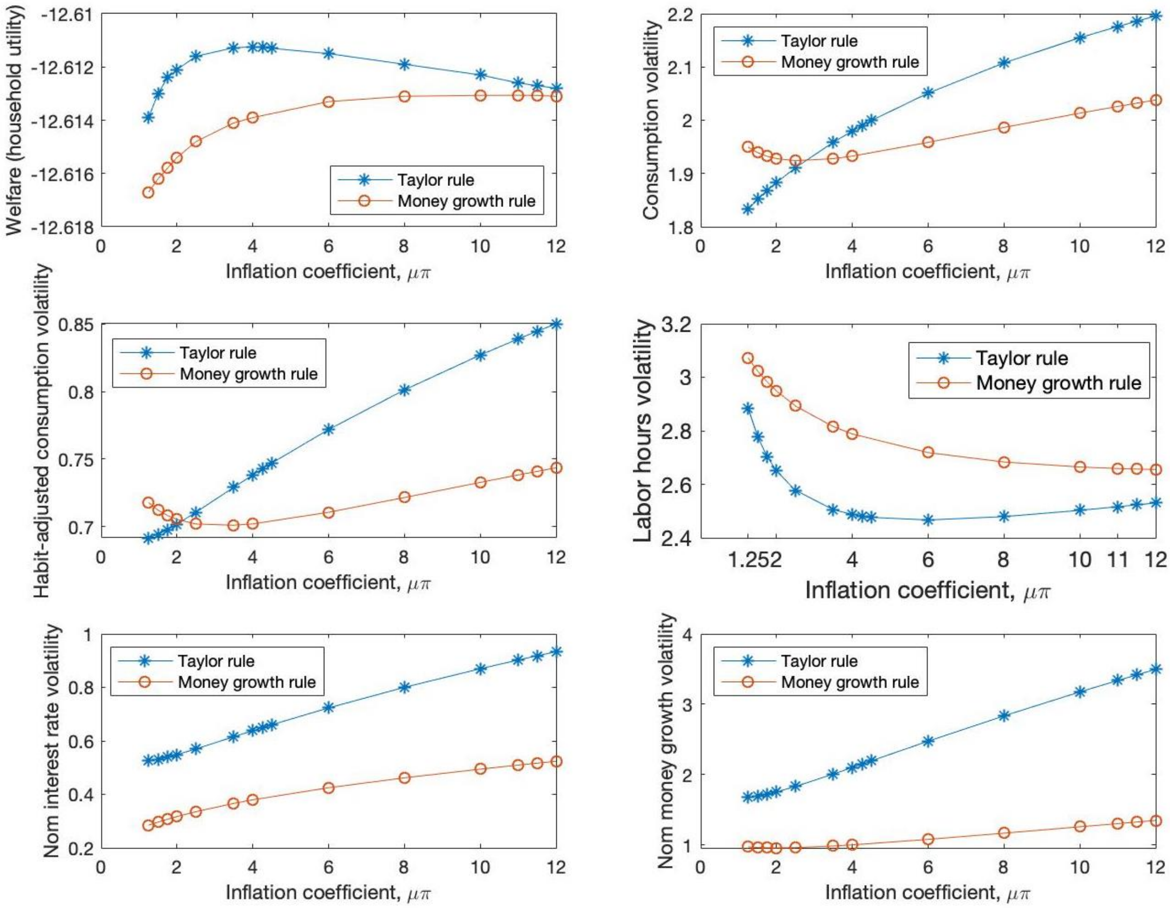
Table 5- Money growth monetary policy - Stabilizing Performance

μ_π	std(c)	std(c-hc(-1))	std(n)	u^c	u^n	.01*Mean(W)	.01*E[Wel]	std(R)	std(gM)
1.25	1.9496	0.7179	3.0720	-4.6640	1.6129	-1.26	-12.6167	0.2851	0.9711
1.5	1.9393	0.7123	3.0238	-4.6640	1.6127	-1.26	-12.6162	0.2963	0.9628
2	1.9280	0.7054	2.9485	-4.6640	1.6123	-1.26	-12.6154	0.3171	0.9572
3.5	1.9279	0.7011	2.8154	-4.6640	1.6117	-1.26	-12.6141	0.3664	0.9840
4	1.9327	0.7021	2.7880	-4.6640	1.6116	-1.26	-12.6139	0.3798	1.0001
6	1.9585	0.7107	2.7185	-4.6640	1.6113	-1.26	-12.6133	0.4249	1.0786
8	1.9865	0.7216	2.6833	-4.6641	1.6111	-1.26	-12.6131	0.4619	1.1667
10	2.0133	0.7328	2.6647	-4.6641	1.6110	-1.26	-12.613064	0.4944	1.2572
11	2.0259	0.7383	2.6591	-4.6642	1.6110	-1.26	-12.613062	0.5095	1.3024
11.5	2.0320	0.7409	2.6570	-4.6642	1.6110	-1.26	-12.613067	0.5167	1.3249
12	2.0380	0.7436	2.6553	-4.6642	1.6110	-1.26	-12.6131	0.5239	1.3473

5.4. Optimized interest rate rule vs. optimized money growth rule.

When aiming to compare the two of them, we can first compare the expected social welfare that each monetary policy provides and observe that the optimized Tylor-type monetary policy leads to higher (less negative) welfare than the optimized money growth monetary policy. This first evaluation, thus, leads to favoring a Taylor-type monetary policy ($E[Wel] = -12.61124626$) against the money growth monetary policy ($E[Wel] = -12.613062$). A different way to compare both monetary policies would entail evaluating their performance with respect to other indicators. Tables 4 and 5 gather the data used to construct table 6, which includes 6 graphs that depict the volatility of several variables of our interest.

Table 6- Taylor rule vs. Money growth rule



Source: MATLAB output

It is a known fact that lower volatility of consumption and labor hours will be preferred by individuals. This is true because households, as well as firms, seek stability. Thus, our next analysis focuses on evaluating which of the policies leads to obtaining lower volatilities. Taking into consideration the optimized values for both monetary policies, $\mu_\pi = 4$ for the Taylor-rule and $\mu_\pi = 11$ for the money growth rule, we observe that consumption volatility is lower under the first scenario (Taylor-type monetary policy), as it lies below 2, whereas that volatility under a money growth monetary policy takes a value greater than 2 (Graph 2). If we now look at the habit-adjusted consumption volatility, both policies lead to the same value (0.7383) (Graph 3). The next variable under discussion is the labor hours volatility

(Graph 4). While both values are relatively close to each other, the Taylor-type monetary policy yields a lower value (2.4874) than that provided by the money growth policy (2.6591). Therefore, our initial conclusion that the Taylor-type monetary policy outperforms the money growth monetary policy is aligned with the second part of the evaluation.

Finally, we can evaluate both policies in connection with the volatility of the monetary policy instruments, thus, R and gM. The values that these policies exhibit can be found in tables 4 and 5. The results obtained indicate that both standard deviations (volatilities) are lower under the optimized money growth monetary policy (0.5095 and 1.3024) than under the optimized interest rate rule (0.6381 and 2.1008). Put another way, in terms of monetary policy instruments, R and gM, the money growth policy provides higher stability in the fluctuations of such variables than the Taylor rule. However, it is of great importance to note that these instrumental volatilities do not affect households' welfare, since R and gM do not appear in the inter-temporal utility function and its second-order approximation.

6. CONCLUSIONS.

As already mentioned along the paper, the aim of this study is to discuss the convenience of using two alternative representations of monetary policy: a conventional rule based on the nominal interest rate and an unconventional monetary policy that takes the rate of money growth as the policy instrument. In the former case, monetary policy is of the Taylor type, which represents the relationship between interest rate and expected inflation. In the second, monetary policy is represented as a given growth rate of money supply, that we referred to as (nominal) money growth monetary policy. We do so by using a simple general equilibrium monetary model which entails sticky prices.

The analysis is based on a calibrated New Keynesian model with money featuring a transaction cost technology, sticky prices a la Calvo (1983) and a monopolistically competitive industry. The model consists of households, firms, the government and the central bank, each of them trying to maximize their objective functions subject to their budget constraints, being the overall objective that of maximizing households' welfare. In addition, we conduct an exercise of calibrating the model parameters, which demonstrates consistency with empirical evidence and complies with the desired variable outcomes. Moreover, the methodology applied in this paper appears to be appropriate, since it entails an analysis of the performance of two monetary policy regimes, where we evaluate social welfare from the expected household intertemporal utility. We seek for the optimized coefficient on the response of the policy instrument to inflation deviations and compare the results between the policy rules as well as with the baseline calibration.

The following table depicts optimized coefficients of the three possible scenarios, being the first one the baseline calibrated New Keynesian model with a Taylor-rule monetary policy (and a coefficient on inflation μ_{π}=1.5); the second one is the optimized Taylor (1993) rule (where μ_{π}=4) and the third one is the optimized money growth rule (where μ_{π}=11).

Table 7 – Baseline model vs. Optimized Taylor rule vs. Optimized money growth rule

μ_{π}	Std(c)	std(c-hc(-1))	std(n)	u^c	u^n	.001*Mean(W)	.001*E[Welfare]	std(R)	std(gM)
1.5	1.8516	0.6944	2.7785	-2.7569	65.779	-1.26	-13.7757	0.5315	1.6929
4	1.9798	0.7383	2.4874	-4.6640	1.610	-12.6005	-12.61124626	0.6381	2.1008
11	2.0259	0.7383	2.6591	-4.6642	1.611	-12.6005	-12.613062	0.5095	1.3024

The evaluation method used consists on comparing the expected social welfare provided by the three regimes, in order to analyze which of the three leads to obtaining the best social outcome. Therefore, as exhibited in the table, we can conclude that implementing a Taylor-rule monetary policy leads to achieving the highest social welfare. This is possible when the Taylor (1993) coefficient on inflation takes the optimized value (μ_{π}=4).

Furthermore, the interest rate rule outperforms the money growth rule in terms of consumption and labor hours stability. Since these variables are included in the utility function, and thus, in the second-order approximation, we want to minimize their volatility, allowing households to gain stability. Consider the fact that households, as well as firms, seek stability.

Finally, we evaluate the effect of both monetary policy regimes with respect to the policy instruments volatility (nominal interest rate, R and nominal money growth, gM). In this case, the money growth rule leads to lower monetary instrument volatilities than the interest rate rule. However, these variables do not directly affect the households' welfare, and thus, do not constitute a central factor in the analysis of the two representations of monetary policy.

In conclusion, our estimates show that the optimized Taylor rule (with a coefficient on inflation equal to 4) benefits households the most, since it provides them with the highest welfare as well as lower consumption and labor hours volatility than the money growth monetary policy.

Moreover, our results are in line with existing literature. Woodford (2001) concluded that the Taylor rule incorporates several features of an optimal monetary policy, from the perspective of at least one simple class of optimizing models. Our findings, based on a simple optimizing model, lead to the same conclusions. However, just as stated by Erceg, Henderson and Levin (2000), the monetary policy implemented does not enable households to achieve the Pareto-optimal equilibrium that would occur under completely flexible wages and prices; Put another way, the model presents a tradeoff in lowering the volatility of the output gap, nominal interest rates, nominal money growth and price inflation

The most relevant limitation of this paper is that the model is very simple. Further extensions considering endogenous capital accumulation, sticky wages and financial frictions, among others, could be implemented in order to better give an estimation of the true model. While further research is needed, the main point is that the stabilizing performance of the optimized Taylor-rule monetary policy regime appears to outperform the optimized monetary policy that takes the rate of money growth as the policy instrument. This is true for a welfare-based evaluation method, which aims at enhancing households' intertemporal utility, as well as consumption and labor hours stability.

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