# Business Cycles in the Brazilian Economy in the Post-Real Period: an Analysis from Technological and Monetary Shocks

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*Abstract:* - This study is an examination of the dynamic properties of the Brazilian economy in the period following the implementation of the Real plan in the presence of technological and monetary shocks. The money-in-the-utility function model (MIU) has been used, which assumes that utility generates money by incorporating real money balances in the utility function of economic agents. To identify how business cycles respond to shocks, simulations that consider a benchmark economy and a monetary economy were conducted. The results show that in the benchmark economy the adherence was found only for real variables, while the volatility of nominal variables' was estimated in comparison to the stylized facts of the real economy; the simulation of monetary economy produced a better adjustment of monetary variables and the movements over the cycle, indicating the non-rejection of real effects in the long-term dynamics in the economy from monetary shocks.

*Key-Words:* business cycles, monetary and technological shocks, Brazilian economy in the post-Real period.

## 1 Introduction

The mitigation of the inflationary process and price stabilization has been the main important fact of the Brazilian economy in the period since the implementation of the Real plan. This context has determined an inversion in the trajectory of economic growth, with the real aggregate product evolving positively, despite the gradual expansion. However, the changes occasioned by the economic stability have not been broaden enough or completed to keep the economy on a constant trajectory and growing in the long term.

This fact has been emphasized by the pace of the economy in the fifteen years since the implementation of the plan, which has been characterized by a process of irregular growth that has been occasioned mainly by the disequilibrium and macroeconomic adjustment from the economy policy adopted. Furthermore, the international economic crisis has contributed to this scenario to a smaller or larger extent.

Additionally, the productive gains have contributed to the continuous expansion of the aggregate product and withdrawal period. As technological changes have been occurring, the economic policy that focuses on monetary and fiscal instruments has played an important role in explaining the cyclical fluctuations, which is ratified by the fact that the consequences generated by the economic policy are linked to the dynamic trajectory of economic activity; this makes it difficult to release the economic policy to the evolution process of the aggregate product.

With the purpose of subsidizing this discussion, the objective of this study is to examine the dynamic proprieties of the Brazilian economy since the implementation of the Real plan in the presence of monetary and technological shocks by considering the theory and methodology of business cycle theory and allowing the analysis of cyclical properties in the economy and monetary variables.

Thus, two points must be emphasized: the first point refers to Real plan, which presupposes that changes in agents' decisions have determined changes in the cyclical fluctuations of the Brazilian economy; and the second point refers to the model money-in-the-utility function (MIU), which was proposed by [1] and assumes that money generates utility by the incorporation of real monetary balances in the utility function as far as it reduces the transition costs of economic agents; this model has been used to study a variety of problems related to monetary economies.

The majority of studies about business cycles emphasize technological shocks as the main reason for cyclical fluctuations as proposed by the Real

Business Cycle Theory (RBC). However, in this study, technological and monetary shocks have been included jointly as a source of changes in the dynamical behavior of economy, which follows the models of the New Neo-Classic Synthesis (see [2]). This Dynamic Stochastic General Equilibrium (DSGE) class of models adds characteristics such as monetary shocks to the basic structure of RBC models.

This approach is characterized by adding aspects of Keynesian theory to business cycle models to allow the analysis of dynamic behavior of the real economy in the presence of monetary shocks and the relationship between the monetary variables and economic cycles. For [2], the New Neoclassical Synthesis involves temporal optimization's systematic application and rational expects that allow for discussions of prices' products (Keynesian theory), consumption and investment (RBC models). Analytic aspects are the main contribution of the study because previous studies with the same focus are still incipient for the analysis of the Brazilian economy. Among the studies in this line, the research of Sin and [3][4][5] are mentioned. Although they use a DSGE structure, they do not investigate the importance of technological and monetary shocks for the economic cycle.

In addition to this introduction, this study is structured into three sections. In the second section, the theoretical foundations of the money-in-the-utility function's model, aleatory shocks and proposed simulations are exposed. The third section presents the parameters' calibration, the results and important discussions. The primary conclusions are presented in the final section.

# 2 The Money-in-the- model (MIU)

## 2.1 Preferences and technology

The representative utility function represents a continuum of homogenous families who live infinitely in the interval [0,1], with $u(c_t, m_t, l_t)$, where $c_t$ is the consumption per capita, $m_t$ is the real money balances per capita and $l_t$ is leisure. It is assumed that the utility function is growing, concave, continuously different and fulfils the following conditions: $u_c(c_t, m_t, l_t) > 0$, $u_m(c_t, m_t, l_t) > 0$; $u_l(c_t, m_t, l_t) > 0$, $u_{cc}(c_t, m_t, l_t) < 0$ $u_{mm}(c_t, m_t, l_t) < 0$; and $u_{ll}(c_t, m_t, l_t) < 0$.

In this function, $m_t$ is defined as the service flow generated by the holding of real money. When the service flow is proportional to the money stock, $m_t$ is equal to the holding of money, with $m_t = M_t / P_t N_t$, where $M_t$ is the quantity of monetary units, $P_t$ is the level of prices and $N_t$ is normalized for unit. By hypothesis, the population grows at a constant rate. The agent allocates his time to work $(h_t)$ and leisure $(l_t)$ in a way that it is normalized by the unit $l_t + h_t = 1 \Rightarrow h_t = 1 - l_t$.

In [1], the utility depends only on consumption decisions and the holding of real money. In this study, utility depends on decisions related to labor supply, which is necessary to study the fluctuations of business cycle, and changes in labor are considered to be an important characteristic of economic cycles [6]. Considering the utility, it assumes the functional form of CES (Constant Elasticity Substitution). The utility function can be written as follows:

$$u(c_t, m_t, l_t) = \frac{C_t^{1-\Phi}}{1-\Phi} + \Psi \frac{(1-h_t)^{1-\eta}}{1-\eta} \qquad (1)$$

where $C$ is the composed consumption goods, $\Phi$ is the inverse of elasticity of the intertemporal substitution in consumption (aversion coefficient related to risk), $\eta$ is the inverse of labor supply elasticity and $\Psi$ is a positive parameter associated with the leisure contingency. The parameters follow the conditions $\eta, \Phi, \Psi > 0$ and $\eta, \Phi \neq 1$. The composed consumer goods depend on the level of consumer goods per capita $(c)$ and the real money balances per capita $(m)$ and are associated with the elasticity consumption of currency demand $(a)$ and the elasticity rate of currency demand $(b)$:

$$C_t = [ac_t^{1-b} + (1-a)m_t^{1-b}]^{1/1-b} \qquad (2)$$

with $0 < a < 1$, $b > 0$ and $b \neq 1$

The preferences of CES form are consistent with the steady state growth and, in the limit case when $\Phi = b = 1$, the preferences for consumption and real money balances are log-linear. Accordingly, the trajectories are independent of the money supply because the substitution marginal rate is independent of real money balances.

The technology follows the standardized specification in the neoclassical model of dynamic and stochastic general equilibrium, which assumes that the economy produces a unique product that is produced via inputs, capital and labor, according to the Cobb-Douglas production function with constant returns to scale; this is defined as:

$$y_t = f(k_t, h_t, z_t) = z_t k_t^{\alpha} h_t^{1-\alpha}, 0 < \alpha < 1, \qquad (3)$$

where $k$ is the capital stock per capita, $h$ is the total quantity of hours worked, $\alpha$ is the parcel of capital in the national product (income), $(1-\alpha)$ is the parcel of labor in national income and $z$ is the exogenous disorder that follows a stochastic technology process. It is assumed that the production function satisfies the conditions of $f_k > 0$ e $f_h > 0$ with $f_{kk} < 0$, $f_{hh} < 0$ and $f_{kh} > 0$.

The production function is under the capital movement law as follows:

$$k_{t+1} = (1-\delta)k_t + i_t, \quad (4)$$

whose restriction possibility is determined by

$$f(k_t, h_t, z_t) \geq c_t + i_t, \quad (5)$$

where $\delta$ is the depreciation rate with an interval between 0 and 1, and $i$ is the aggregate investment.

## 2.2 The decision problem

Through functional forms, the problem of familiar decisions has been defined to obtain first-order conditions for exogenous variables consistent with these conditions. The representative agent's objective is to maximize the discounted utility conditioned to restrictions:

$$\max E_0\left[\sum_{t=0}^{\infty}\beta^t\left(\frac{C_t^{1-\Phi}}{1-\Phi}+\Psi\frac{l_t^{1-\eta}}{1-\eta}\right)\right], 0<\beta<1, \quad (6)$$

which is subject to budgetary restriction determined:

$$f(k_t, h_t, z_t) + (1-\delta)k_{t-1} + \omega_t \geq c_t + k_t + d_t + m_t \quad (7)$$

$$\omega_t = \tau_t + \left[(1+j_{t-1})/(1+\pi_t)\right]d_{t-1} + m_{t-1}/1+\pi_t \quad (8)$$

where $E$ is the expectation operator, $\beta$ is the intertemporal discount rate with $0<\beta<1$, $\omega_t$ is the real financial wealth, $\tau_t$ is the real transference received by the government, $d_t$ is the stock of free risk securities, $j_t$ is the nominal interest rate and $\pi_t$ is the inflation rate.

This can be considered a dynamic optimization problem, and the model can be written as a Bellman equation in a way that the value function (V) represents the maximum present value of utility that the representative familiar agent can achieve:

$$V(\omega_t, k_{t-1}) = \max_{c_t, m_t, n_t, d_t, k_t}\{u(c_t, m_t, 1-h_t) + \beta E_t V(\omega_{t+1}, k_t)\} \quad (9)$$

with maximization subject to the budgetary restriction in (7) evaluated at *t* + 1, where $\omega_t$, $k_{t-1}$ and $z_t$ are the state variables and [$c_t$, $m_t$, $h_t$, $d_t$ e $k_t$] are the variables of control. The treatment of $\omega_t$ as a state variable determines that the monetary growth rate is known as soon as families make decisions about consumption, capital stock, securities and real money balances. In the same way, the productivity disturbance $z_t$ is known at the beginning of the period *t*.

### 2.3 Shocks

According to the New Neoclassical Synthesis, business cycles are occasioned by technological, monetary or tax shocks. In these terms, a model with multiple shocks has been used where the shocks are related to productivity and money stock. In the case of a technological shock, the parameter $z$ has been defined from the first-order autoregressive process

$$z_t = \rho z_{t-1} + \varepsilon_t, \text{ with } 0<\rho<1, \quad (10)$$

where $\rho$ is a parameter of the shock's persistence and $\varepsilon_t$ is not correlated with the medium zero in a serial manner. Conceptually, a technological shock is obtained by the estimation of the Solow residual $(z)$ based on the production function.

The stochastic process for the nominal monetary shock has been determined by the definition of the nominal monetary average growth rate in the long term, which is denoted by $\Theta^{SS}$, with $u_t = \Theta_t - \Theta^{SS}$ and where $u_t$ is the deviation in period *t* of the growth rate in its average equilibrium value in the steady state as defined by [1][7].

$$u_t = \gamma u_{t-1} + \phi z_{t-1} + \zeta_t, \ 0 \leq \gamma < 1, \quad (11)$$

where $\zeta_t$ is the uncorrelated error term, $\gamma$ is the stochastic persistence parameter of the stochastic process and $\phi$ is the coefficient of technological shock on monetary growth. If this parameter assumes a positive value, $(\phi > 0)$, the nominal money supply tends to respond to the real shocks of productivity, $z$, and is subjected to aleatory disturbances associated with $\zeta$.

In this context, it is understood that unanticipated changes in productivity can affect the growth of the nominal money supply rate when it is assumed that technological shocks increase the level of real aggregate output. With the increase in the aggregate product when the income is proportional to the money supply, the agents' demand for higher liquidity assets follows the same growth tendency, and, as a consequence, the monetary supply rate will be affected.

The monetary shock has been calibrated by the first-order autoregressive model estimation for M in concept M2[1] as suggested by [7] by estimating the standard deviation of $u_t$ obtained from $M_t = \gamma M_{t-1} + (1-\gamma)\Theta + u_t$.

### 2.4 The steady state

The steady values are expressed in the basic parameters model with output, consumption, capital stock and worked hours represented by $y^{SS}, c^{SS}, k^{SS}$ and $h^{SS}$. Initially, Euler's equation for the steady state of the intertemporal discount rate is determined by the inverse of the real rate return over the capital (or the inverse of the real interest rate):

$$\beta = 1/R^{SS}, \text{ with } R^{SS} = \alpha(y/k) + 1 - \delta \qquad (12)$$

where $R^{SS}$ is the real interest equilibrium rate.

Considering the intertemporal discount rate defined in (12), the capital/product rate in steady state is defined as

$$\left(y^{SS}/k^{SS}\right) = \frac{1}{\alpha}\left(\frac{1}{\beta} - 1 + \delta\right) \qquad (13)$$

From the production function $(y^{SS}/k^{SS}) = (h^{SS}/k^{SS})^{1-\alpha}$ and when considering the long term equilibrium, the technological shock is $z_t = 1$.

The steady state values show the proprieties of the MIU model and the way changes in inflation rates affect the output and the aggregate consumption. The levels of capital stock, output and consumption will depend on the monetary growth rate with inflation changes in h, which will affect the output of the steady state, consumption and capital stock proportionally. However, $h^{SS}$ can be obtained from the functional forms of utility and production:

$$\frac{\left(h^{SS}\right)^{\Phi}}{\left(1-h^{SS}\right)^{\eta}} = H\left[1 + \left(\frac{a}{1-a}\right)^{-\frac{1}{b}}\left(\frac{\Theta-\beta}{\Theta}\right)^{\frac{b-1}{b}}\right]^{\frac{b-\Phi}{1-b}} \qquad (14)$$

This expression is independent of the money supply growth rate in the steady state; the left side is increasing in $h^{SS}$, and so the effect of the right side depends on the signal of $\xi = (b - \Phi)$. If positive, $(b - \Phi > 0)$, higher inflation rates reduce the marginal utility of consumption, increase leisure demand and reduce the labor supply. As a consequence, the product's steady state tends to fall. In this situation, consumption and money are complementary.

If negative, $(b - \Phi < 0)$, high inflation rates lead to labor supply growth by increasing the marginal consumption of utility, and this tends to increase the level of the aggregate product in the steady state. If $b - \Phi = 0$, neither the marginal utility of consumption nor the marginal utility of leisure depend on the real money balance, and the hypothesis of neutrality of money is not rejected.

### 2.5 Simulations

The simulations are defined with the purpose of verifying how the proprieties of business cycles in the Brazilian economy behave when technological and monetary shocks are considered. Two groups were considered, which allows the effects of the isolated shocks and the joint shocks to be analyzed.

When it is assumed that the monetary growth rate is persistent and the answer of this rate to unpredictable changes in productivity are null, economic fluctuations occur due to only technological shocks, which are defined as Group 1 – Constant monetary growth: $\gamma = 0$ e $\phi = 0$. It is emphasized that the shock is not null but positive, which is similar to the original real business cycles.

For Group 2 - Stochastic monetary growth: $\gamma > 0$ e $\phi = 0$, the monetary growth rate shows a positive persistence but does not correspond to changes in productivity. The aim of this simulation is to examine how business cycles in the Brazilian economy are affected when the monetary growth rate in the period is influenced by the growth rate in previous periods.

## 3 Results and discussion

### 3.1 Calibration

The model's calibration has been obtained from the parameters presented in the equations that characterize the steady state. Table 1 shows the correspondent values of the respective parameters in which the benchmark economy simulations have been made and which yielded other results. In the calibration process, the parameters $\alpha$, $\delta$, $\beta$ and $\Theta$ have been obtained from Brazilian economic data, from the economic series, and from ($a$, $b$, $\eta$, $\Phi$, $\rho$, $\phi$, $\gamma$, $\sigma_\varepsilon$ e $\sigma_\varphi$) by econometric estimations and expressions calculated by the

[1] In the original model of MIU, the real monetary balances are obtained from the nominal money supply in concept M1. However, in the Brazilian economy, the assets that would provide the most immediate liquidity can be short-term deposits and financial investments. Thus, the money supply in concept M2 would better represent monetary balances in the economy analyzed.

mathematical model. For the estimate, monthly data from 1995 to 2009 were used.

The participation of capital returns in income, $\alpha$, has been obtained from the Gross Operating Surplus (GOS) and GDP from the National Accountancy System of IBGE [7]; the value obtained was 0.3392. Nevertheless, it has been claimed that the GOS discounts the self-employed payment. According to [9], the payment parcel is not included because it would overestimate the results. In the Brazilian economy, this parameter's value is not unanimous because there is not a capital series officially calculated and studies have used values that range from 0.33 [10] to 0.66 [11].

For capital depreciation, it was found that $\delta = 0.0580$, which was obtained from Euler's equation for the steady state of capital movement law by dividing the parcel of investment-output by capital-product ratio $(i^{SS} / y^{SS}) = \delta(k^{SS} / y^{SS})$. The average ratio of $i^{SS} / y^{SS}$ was 17.10%, and the average ratio of $k^{SS} / y^{SS}$ was 2.95%.

The intertemporal discount rate, $\beta$, which measures the representative impatient agent, obtained from the optimality condition of family choices in the long term was 0.9460. This value is near the one used by [12][13][14]. This rate links consumption decisions in the present and future in a way that reductions in $\beta$ increase the future consumption of agents' utility, which represents a stimulus to savings targets.

The aggregate output has been obtained by adding the consumption variables and the aggregate investment and reducing net exports. This definition is important because the simulated economy does not consider the external sector. By assuming this sector, its importance is not considered because Brazil is an open place, but it is adequate for the model's restrictions. Therefore, this limitation is minimized by the fact that Brazilian net exports represent approximately 2.0% of the product. The investment series were built from adding the gross fixed capital formation and stocks' variation, which are both deflated by IPCA.

The elasticity of money demand consumption, $a$, and the inverse of the money demand income elasticity, $b$, were obtained from the specification proposed by [15][16]:

$$\log\frac{M_t}{P_t N_t} = \frac{1}{b}\log\left(\frac{1-a}{a}\right) + \log C_t - \frac{1}{b}\log\left(\frac{j}{1-j}\right) + \mu_t \quad (15)$$

where $M$ is the nominal money stock in concept M2, $P$ is the level of prices defined by IPCA's accumulation and $N$ has been standardized for unit, $C$ is the aggregate consumption good, which is considered the sum of the final consumption of families and is calculated by IBGE/SCN, and $j$ is the nominal rate income, which is defined from the over-SELIC rate at the end of the period.

This specification presupposes that the real money demand log is a positive function of the aggregate consumption and a negative function of the income nominal rate's log. It has been assumed that the error is not correlated, its average is zero and its variance is $\sigma_\mu^2$. Because neither series are stationary in level, the Johansen test of cointegration was applied, which indicated that they are cointegrated at the level of 5% (see Table 2). The structured estimations were obtained from the difference model including the parameter associated with the error's correction as presented in Table 3.

The estimates indicate that the elasticity consumption for money demand was $a = 0.39$, and the interest elasticity for money demand was $j = 0.65$, which is significant at the 1% and 10% levels. The results were elastic for neither the consumption nor nominal interest in relation to the money supply in the post-Real period. From the interest estimation, the inverse parameter of elasticity was obtained, $b = 1.52$. The diagnostic tests suggest that the residuals meet the presuppositions of normality and autocorrelation, and no evidence for heteroscedasticity was found. Furthermore, no endogeneity was detected among the variables.

The parameter associated with the inverse of the money supply, $\eta$, was obtained from the estimation of the labor supply function. For Real Business Theory, the amount of work offered depends on the real salary and the real interest rate [17]. The formal expression is

$$s = s(w, r), \text{ with } w = W / P \quad (16)$$

were $s$ is the quantity of work offered, $w$ is the real salary and $r$ is the real interest rate. In this specification, workers make their own decisions in relation to the labor supply considering the real salary and the future.

The expression for labor supply was defined from $\log s_t = c + \upsilon \log w_t + \nu \log r + \varepsilon_t$, where $\upsilon$ and $\nu$ are the parameters associated with income and real interests, $\sigma_\varepsilon^2$ is the variance and $\varepsilon$ is the error, which assumes a zero average and. The series were stationary in only the first difference but integrated in the same order, I(1). So, the Johansen cointegration test indicated at least one cointegrated vector (see Table 4). The parameters have been obtained by introducing the mechanism of error correction as shown in Table 5.

In the estimation, the total of hours worked, $s$, the average real salary, $w$, obtained by the monthly average income of the main work escalated by IPCA, and the real interest rate, $r$, obtained by the difference between the nominal interest rate–overnight-SELIC–and the general price index—IPCA—have been used. An estimation of 0.89, which is significant at the 1% level, implies a value of 1.13 for $\eta$ and has been obtained for the parameter related to labor supply-elasticity.

The parameters related to the real interest rate were positive, and the correction mechanism defined by $\varepsilon_{t-1}$ was significant at the 1% level following the cointegration test. The diagnostic tests (normality, autocorrelation and heteroscedasticity) indicate that the model approaches the statistic presuppositions of the Ordinary Least Squares model.

The inverse elasticity of the inter-temporal consumption substitution, $\Phi$, was obtained by considering labor's indivisibility because it is presupposed that the representative agent allocates a third of its time (eight hours) to the labor market in the steady state and that $h^{SS} = 1/3$. So, an inverse elasticity parameter of temporal consumption substitution has been obtained, $\Phi = 1.77$, which is persistent with $\left[\eta h^{ss}/(1-h^{ss})\right]^{-1}$.

This parameter indicates the agent's consumption standard sensibility in response to variations in the nominal interest rate. A risk averse agent changes its consumption pattern quickly in response to changes in the interest rate, see [18]. The values of this parameter should be between 0 and 1 [19] and between 0.5 and 1.5 [20]. In the Brazilian economy, [21] suggests values near zero. [18] obtained an interval between 0.59 and 6.82 with a median of 4.89, and [22] used a value of 0.7. This last value is near the value found in this study, 0.6.

The productivity persistence, $\rho$, and the productivity shock, $\sigma_\varepsilon$, have been obtained from estimating the Solow residual, $z$. Complementary, diagnostic tests of residuals have been conducted and indicated that they distribute themselves normally and do not present heteroscedasticity or serial correlation (ver Table 6).

The estimate for the persistence of the parameter, $\rho$, was 0.311 and 0.016 or 1.63% for technological shock as measured by the filtered standard deviation from the first-order autoregressive model for the total production factors. In the Brazilian economy, there is no uniformity of these values due to the difficulty to obtain data to estimate the productivity function. [23] obtained values of 0.589 and 0.046 (or 4.60%) for $\rho$ and $\sigma_\varepsilon$, respectively. [24][9] used values estimated by [25] for the U.S. economy: 0.095, for the persistence process and 0.0089 (or 0.089%), for technological shock. Due to difficulties, in many cases, the parameters are adjusted to reduce the volatility of the real business cycles.

Complementary, the average growth rate of the nominal money stock in concept M2 was 0.0182. For the values used in the simulations, the expression $1+\theta^{SS}$ was used for the nominal money supply in the steady state, whose value $\Theta$ was 1.0182 (ver Table 7). The monetary growth rate has been calibrated by estimating a first-order autoregressive process for the nominal money demand stock. The diagnostic tests indicated that the residuals distribute themselves in a normal way and that there is no heteroscedasticity or autocorrelation.

The value 0.66 was found for the persistence parameter, $\gamma$, and parameter $\phi$ indicates that the effect of productivity on the monetary growth rate was negative but statistically equal to zero; thus, it will not be presented in the simulations. The monetary shock obtained by the filtered standard deviation from the monetary growth residual of regression was 0.0235 (or 2.35%).

### 3.2 Benchmark economy and the business cycles in the Brazilian economy in the post-Real period

Economic changes are observed after the 1990s after the implementation of the Real plan and are extremely relevant to the process of macroeconomic stability because they represent the dynamic created by the stabilization obtained by the new plan. Thus, this section examines the way this new context has influenced the behavior of business cycles in the Brazilian economy.

The business cycles in the Brazilian economy (volatility, relative volatility and correlations) for the period analyzed are shown in Tables 8 and 9. The cyclic proprieties of the real economy have been obtained via the HP filtering method with a smoothing parameter of 1600, and the artificial economies were obtained from a standard-economy simulation with only a technological shock introduced. The monetary economy was obtained by introducing monetary and technological shocks. Computational techniques have been used to approximate log-linear, see [26][6], and the simulations for the software MatLab 7, whose algorithm is found in [6][2].

For the benchmark economy and monetary economy simulations, a set of parameters has been used. The negative relationship between the inverse of the monetary rate demand and the inverse of the elasticity of inter-temporal consumption substitution $(1.5237 - 1.7712) < 0$. This relationship indicates that agents are disposed to work more when their salary increases, and this will increase the marginal utility of consumption. For the parameter related to persistence, the value of 0.6593 has been obtained, but the relationship between monetary growth and unanticipated changes in productivity was statistically null. Both parameters were obtained by estimating the monetary growth autoregressive process in the first order. For the monetary shock, the value obtained was 0.0253 (or 2.35%) with the other two parameters defined above, which were defined in this simulation of the monetary economy.

To obtain the benchmark economy results, a deviation of the nominal growth of the average growth rate of 1.82 per year was considered, $(\Theta = 1.0182)$, and this does not present a correlation with real shocks does not present persistence in the monetary growth rate ($\gamma = 0$). In this simulation, the business cycles are determined exclusively by the technological shocks as proposed by the Real Business Cycle theory. Where $u_t = \zeta_t$ in equation (11), unanticipated changes in the monetary growth rate do not affect the future values of the nominal money supply growth in a way that the expected inflation do not suffer changes. The economy shows a constant monetary growth as suggested by [8].

The results obtained verify that the behavior of the real macroeconomic variables presented more adherence to the cyclic properties of the Brazilian economy and differed from the nominal variables when the benchmark economy did not capture the volatile behavior of the real economy.

The exception in cyclic behavior for the real variables was found in the hours worked variable, whose cycle standard deviation presented considerably less volatility compared to the real economy (volatility of approximately 52%). Furthermore, its cyclical long-term pro-cyclical movement is near the actual case. Moreover, it is possible to verify that, although the model has shown good adequacy to the real variables, it overestimated the contemporaneous correlations for all the series analyzed.

In relation to the nominal variables' non-compliance, [27] emphasize that the specific characteristics of monetary economies might be incorporated into the nominal variables' proprieties. On the other hand, [28] state that, when nominal variables are incorporated into real cycle models, the structure of covariance becomes stable in contrast to the real series structure, which tends to present a higher stability in the long term.

The economic cycle of the aggregate output found in the benchmark economy was 1,95, which is near the volatility of 1.78 found in the real economy. This result suggests that the benchmark economy reproduced the business cycle of the Brazilian economy in a satisfactory way during the period analyzed. For aggregate consumption, the cycle's standard deviation was less volatile in the benchmark economy simulation than in the real economy (0.95 vs. 1.15).

When the aggregate investment behavior is observed, the cycle standard deviation is 6.32 in the benchmark economy, which is similar to the volatility of 6.24 found in the Brazilian economy. The aggregate investment is characterized by presenting a more volatile cycle than the aggregate output; this characteristic has been found for stylized facts and the benchmark economy.

When analyzing the variables' contemporaneous correlation degree with the economic cycle, it is verified that investment was the variable with the highest association level in both the real and benchmark economies. In the cyclical properties of the Brazilian economy, the correlation was 0.86, but it was 0.96 for the benchmark economy. Although the results indicate that investment follows the economic cycle in a similar way to the one found for the stylized facts, they showed a strict relationship between investment and products' movement.

Consistent with the earlier discussion, it is suggested that the technological shock has reflected the Brazilian economic dynamic in a more direct way in post-stabilization years. In this direction, increased stability has provided more ways to reduce installment costs and gradually allowed for investments to incorporate the presence of productivity improvements in a more intensified way,see [29]. There is a tendency to soften the economic agents' consumption because the economic cycle tends to absorb part of the volatility of investment, which leads to a reduction of consumption fluctuations and product correlation.

[2] A computational routine compatible to software MatLab can be found in: http://people.ucsc.edu/~walshc/mtp3e/miu_uhlig_3e.m.

The benchmark economy has not reduced some of the stylized facts of the Brazilian economy in an adequate way, specially the volatility and correlations for the nominal variables. In this sense, monetary and technological shocks were introduced together, which produces a monetary economy. Moreover, the previous period's growth was considered to be a fact that influenced monetary growth in the recent period with a persistence of 0.6593, but the nominal money growth supply has not answered the changes in productivity, where $\phi = 0$. The other parameters in the model have not suffered changes when simulating this new artificial economy.

From the simulation results of the monetary economy (see Table 9), expressive adjustments in the cyclic macroeconomic variables' behavior were verified, both nominal and real. However, changes in the standard deviation occurred with co-movements along the cycle, which demonstrates great adherence with the absolute values near the ones found in the real economy.

The characterize behavior found was the macroeconomic variables' elevation of volatility in comparison to the one observed when the benchmark economy was simulated, and the more pronounced growth occurred in the nominal aggregate fluctuations. This occurred because the shocks were introduced together such that the monetary shock tends to amplify the volatility of the economic variables. On the other side, the contemporaneous correlations on the cycle life were lower for all the variables analyzed. This evidence suggests that the correlation with the product tends to reduce itself and the nominal variables in moments with higher economic stability.

In relation to real variables, the economic cycle has shown marginal changes because of investment, and consumption and worked hours have indicated more relevant changes with volatility near 5%. Consumption was the variable with the highest change, and the standard-deviation grew from 0.95 to 1.00, which is near the fluctuations found in the real economy. The same occurred with the correlation along the economic cycle in the long term, which reduced from 0.86 to 0.82 with the introduction of the monetary shock.

The cyclical behavior of hours worked, which was not adjusted in an adequate way for the benchmark economy simulation, showed better adherence that passed from 0.65 to approximately 0.69, however, this is still lower than the standard deviation found for the stylized facts. The pro-cyclical correlation was almost stable in relation to the one found in the benchmark economy when only the technological shock was introduced. The changes were meaningful for the nominal variables mainly in the cyclical behavior of the real money balance and inflation, but the variables' nominal rate and interest tax rate showed less expressive changes.

In real money balances case, the volatility was one and a half times higher than the one found for benchmark economy. When compared to the standard deviation found in the characteristic data for the Brazilian economy in the post-Real period, it has been emphasized that the volatile behavior of the real balances has been reproduced with the introduction of a monetary shock. Moreover, the fluctuations in $m$ were observed more commonly compared to the economic cycle in this situation and were similar to the fluctuation observed in the real economy.

In the cross-correlation analysis, a significant reduction in the simulated monetary economy was observed compared to the benchmark economy. This reduction suggests that the stability in prices has modified agents' decisions to hold real money balances because they will keep more money (increase in well-being level) as the uncertainty in relation to the economy reduces. This makes the correlation with the aggregate product less negative. The integration of monetary stock has enabled the identification of the better dynamics of m and reproduced the relationship with the economic cycle in a more accurate way.

The cyclical proprieties of inflation were significantly changed in the monetary economy simulation compared to the benchmark economy results, and volatility was approximately thirty times higher. Despite the improvements in adherence, the monetary economy reproduced approximately 65% of the fluctuations in the inflationary movements found in the characteristic data of the Brazilian economy between 1995 and 2009.

When the long term relationship is analyzed, the introduction of unobserved changes in monetary growth made inflation less countercyclical. This fact has led the approximation of the contemporaneous correlation obtained by simulating the monetary economy to approach the one found in the real economy. This result suggests that the dynamic generated by the stabilization of price levels reduced the inflationary effects of the economic cycle, but the variables presented movements with a lower level of similarity.

The introduction of the nominal shock as a generator source of business cycles did not allow for the achievement of cyclical movements (volatility) in the nominal interest rate observed in the real economy, but the cycles' standard deviation was similar to the ones obtained for the real tax rate. When analyzing the contemporaneous correlations, the monetary shock had fewer countercycles compared to both variables in the economic cycle as was the case for the other nominal variables.

The introduction of the nominal shock as a source of business cycles did not allow for the achievement of cyclical movements (volatility) of the nominal interest rate observed in the real economy, but the standard deviation of the cycle did not increase more than ten times in the simulation of the monetary economy, which is a similar result to that obtained for the real interest rate. By analyzing the contemporaneous correlations, the monetary shock became less countercyclical than the relations of both variables in the economic cycle as was the case for the other nominal variables.

The analysis of the cyclical fluctuations in the post-stabilization period, which is a monetary economy that presented a new economic dynamic, produced results with a degree of compliance to those found to relatively better simulate the economy with the productivity shock, but it did not show significant changes in the adjustment of the nominal and real interest rate.

In synthesis, the introduction of a monetary shock better reproduced the fluctuations of the real and nominal macroeconomic variables and clearly captured the relationship of variables over the business cycle, mainly the nominal ones, which showed a lower distance of the trajectory of the aggregate output (a weaker countercyclical relationship). From these results, it can be noted that, in times of greater economic stability (or less economic uncertainty), the real variables tend to be more sensitive to unanticipated changes in the nominal aggregate (nominal money supply), and the volatility of the nominal variables generates less significant impacts on the economic cycle.

# 5 Conclusion

The observation of cyclic properties in the Brazilian economy in the post-stabilization period was the principal goal of this study. However, this objective was approached in an appropriate way by considering the specialty in the economy analyzed through the use of business cycle models, with money being one of the arguments, which enables monetary shocks and technological shocks as the primary cause of cyclic movements.

Within the framework, a money-in-utility function model assumes that money generates utility by incorporating the real money balance and reducing the costs of economic agents' transactions. By its characteristics, this model follows the proposal of New Neo-Classical Synthesis, which combines aspects of the neo-classical and Keynesian theories to explain the dynamical behavior of the economy.

So, various artificial economies were simulated. First, the benchmark economy was simulated in line with the real business cycle models and the introduction of a technological shock. In the following step, the monetary economy was simulated by adding technological and monetary shocks, which allowed for the examination of whether there was cyclical movement linked to unpredicted changes in the monetary growth rate.

Simulations in both economies allowed for the identification of the way and the standard of how business cycles answer to monetary and technological shocks but in an incomplete way. In the benchmark economy, adherence was found for only the real variables, but the nominal variables' volatility was estimated in comparison to the stylized facts of the real economy. The simulation of the monetary economy produced a better adjustment of the monetary variables and the movements over the life cycle.

This set of results suggests the non-rejection of the hypothesis in absence the real effects in the long term in economy as a result of monetary shocks. There was higher stability and a lower level of uncertainty in the Brazilian economy in the period after price stabilization. In this scenario, the possibility that change in the cyclical properties' characteristics occur due to changes in the economy from changes related to expected inflation formed by the agents can be explored.

Furthermore, when considering monetary shocks as a part of the economic structure, the effects of the economic dynamic could be better identified, which is largely attributed uniquely to technological shocks but derives from a group of disturbances.

Although the model is considered to be representative of a closed economy that is consistent with a limitation, the results allow the conclusion related to cyclical movements in the Brazilian economy by incorporating the external scenario. New studies that follow this line and improve the results' adherence by incorporating new aspects, such as external shocks and/or fiscal policies, would provide a better explanation for the cyclical behavior of the economy.

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# Appendix

**Table 1.** Values for the parameters of the MIU for the Brazilian economy, in the period between 1995 and 2009.

| Parameters | Values |
|---|---|
| **Calculated parameters** | |
| $\alpha$ | 0.3392 |
| $\delta$ | 0.0580 |
| $\beta$ | 0.9460 |
| $\Theta$ | 1.0182 |
| **Estimated parameters** | |
| $a$ | 0.3930 |
| $b$ | 1.5237 |
| $\eta$ | 1.1292 |
| $\Phi$ | 1.7712 |
| $\rho$ | 0.3114 |
| $\sigma_\varepsilon$ | 0.0163 |
| $\phi$ | 0.0000 |
| $\gamma$ | 0.6593 |
| $\sigma_\varphi$ | 0.0235 |
| **Specifications for the monetary growth** | |
| Group 1 | Constant money growth |
| | $\gamma = 0.0000 \quad \sigma_\varphi = 0.0000$ |
| Group 2 | Stochastic money growth |
| | $\gamma = 0.6593 \quad \sigma_\varphi = 0.0235$ |

Source: The research’s results, author.

**Table 2.** Results of the cointegration test (Johansen Test) for money demand in the Brazilian economy between 1995 and 2009.

| Hypothesis<br>N. eq. coint. | Eigenvalue | Statistic<br>Trace | Critical value<br>5% | Probability |
|---|---|---|---|---|
| None * | 0.369470 | 55.83147 | 42.91525 | 0.0016 |
| At most 1 * | 0.216015 | 27.69864 | 25.87211 | 0.0293 |
| At most 2 * | 0.189992 | 12.85334 | 12.51798 | 0.0439 |
| **Hypothesis<br>N. eq. coint.** | **Eigenvalue** | **Statistic<br>Max-Eigen** | **Critical value<br>5%** | **Probability** |
| None * | 0.369470 | 55.83147 | 42.91525 | 0.0016 |
| At most 1 * | 0.216015 | 27.69864 | 25.87211 | 0.0293 |
| At most 2 * | 0.189992 | 12.85334 | 12.51798 | 0.0439 |

Source: The research’s results, elaborated by the authors.
Note * denotes the non-rejection of the null hypothesis at the 5% level.

**Table 3.** Estimate and diagnostic test for money demand in the Brazilian economy from 1995 to 2009.

| $\log \Delta M_t / P_t N_t$ = | $6.2131^{***}$ | + $0.3930 \log \Delta C_t^{***}$ | $-0.6563 \log \Delta j_t^{*}$ | $1.0656 \varepsilon_{t-1}^{*}$ |
|---|---|---|---|---|
| *Standard error* | (2.0835) | (0.1163) | (0.3588) | (1.0293) |
| $R^2 = 0.4100$ | | | | |
| $d = 2.0234$ | | | | |
| | | Normality | Autocorrelation | Heteroscedasticity |
| | | *Jarque-Bera Test* | *LM Breusch-Godfrey Test* | *White Test* |

| | | | |
|---|---|---|---|
| Statistics | 0.5793 | 0.1384[§] | 0.4197 |
| *Prob.* | 0.7485 | 0.9672 | 0.9796 |

Source: The research's results, elaborated by the authors.
Notes: ***,** and*, 1%, 5% and 10% significant, respectively.[§] estimated with 4 lags.

**Table 4.** Results of the cointegration test (Johansen Test) for labor supply in the Brazilian economy between 1995 and 2009.

| Hypothesis N. eq. coint. | Eigenvalue | Statistic Trace | Critical value 5% | Probability |
|---|---|---|---|---|
| None * | 0.467313 | 57.56636 | 42.91525 | 0.0010 |
| At most 1 | 0.179641 | 19.14726 | 25.87211 | 0.2721 |
| At most 2 | 0.109414 | 7.068435 | 12.51798 | 0.3374 |
| **Hypothesis N. eq. coint.** | **Eigenvalue** | **Statistic Max-Eigen** | **Critical value 5%** | **Probability** |
| None * | 0.467313 | 38.41909 | 25.82321 | 0.0007 |
| At most 1 | 0.179641 | 12.07883 | 19.38704 | 0.4079 |
| At most 2 | 0.109414 | 7.068435 | 12.51798 | 0.3374 |

Source: The research's results, elaborated by the authors.
Note * denotes the non-rejection of the null hypothesis at the 5% level.

**Table 5.** Estimative and diagnostic test for the labor supply in the Brazilian economy from 1995 to 2009.

| | | | | |
|---|---|---|---|---|
| $\Delta \log s$ = | $-0.0114$** | $+\ 0.8856 \log \Delta w$*** | $+0.1204 \log \Delta r$*** | $-0.2442\varepsilon_{t-1}$*** |
| *Standard error* | (0.0052) | (0.0339) | (0.0328) | (0.0642) |

$R^2 = 0.9981$
$d = 1.5177$

| | Normality *Jarque-Bera Test* | Autocorrelation *LM Breusch-Godfrey Test* | Heteroscedasticity *White Test* |
|---|---|---|---|
| Statistics | 0.2429 | 1.0233[§] | 0.3954 |
| *Prob.* | 0.8857 | 0.4035 | 0.9319 |

Source: The research's results, elaborated by the authors.
Notes: ***,** and *, 1%, 5% e 10% significant, respectively. [§] estimated with 4 lags.

**Table 6.** Estimative and diagnostic test for the productivity persistence process in the Brazilian economy between 1995 and 2009.

| | | |
|---|---|---|
| $z$ = | $-0.0048$ | $+\ 0.3114 z_{t-1}$*** |
| *standard error* | (0.0039) | (0.1172) |

$R^2 = 0.4808$

*standard deviation* ($\sigma_\varepsilon$) = 0.0163

| | Normality *Jarque-Bera Test* | Autocorrelation *LM Breusch-Godfrey Test* | Heteroscedasticity *White Test* |
|---|---|---|---|
| Statistics | 0.4370 | 1.8643[§] | 1.4634 |
| *Prob.* | 0.8037 | 0.1307 | 0.1876 |

Source: The research's results, elaborated by the authors.
Notes: ***,** and *, 1%, 5% e 10% significant, respectively. [§] estimated with 4 lags

**Table 7.** Estimative and diagnostic tests for the monetary growth persistence process for the Brazilian economy between 1995 and 2009

| | | | |
|---|---|---|---|
| $\Delta \log m_t$ = | $0.0087$** | $+\ 0.6593 \Delta \log m_{t-1}$*** | $-\ 0.0060 \Delta \log z_{t-1}$ |
| *standard error* | (0.0033) | (0.1530) | (0.0046) |

| $R^2 = 0.3714$ | | | |
|---|---|---|---|
| *standard deviation* ($\sigma_\varphi$) = 0.0235 | | | |
| | Normality<br>*Jarque-Bera Test* | Autocorrelation<br>*LM Breusch-Godfrey Test* | Heteroscedasticity<br>*White Test* |
| Statistics | 2.9873 | 0.8370§ | 0.7939 |
| *Prob.* | 0.2245 | 0.5082 | 0.5342 |

Source: The research's results, elaborated by the authors.
Notes: ***,** and *, 1%, 5% e 10% significant, respectively.§ estimated with 4 lags.

**Table 8.** Benchmark economy with a technological shock and with constant monetary growth and a marginal utility of decreasing consumption $(b - \Phi < 0)$ between 1995 and 2009.

| *Variable* | Real economy | | |
|---|---|---|---|
| | DP[*x*]*(%)* | DP[*x*]*(%)* | DP[*x*]*(%)* |
| *y* | 1.7779 | 1.0000 | 1.0000 |
| *c* | 1.1502 | 0.6469 | 0.6806 |
| *i* | 6.2368 | 3.5080 | 0.8595 |
| *h* | 1.2431 | 0.6992 | 0.3612 |
| *m* | 2.1387 | 1.2029 | 0.2310 |
| *j* | 7.4655 | 4.1991 | -0.2821 |
| *r* | 7.6849 | 4.3225 | -0.0898 |
| $\pi$ | 16.5247 | 9.2945 | -0.2367 |
| *Variable* | Benchmark economy | | |
| | DP[*x*]*(%)* | DP[*x*]*(%)* | DP[*x*]*(%)* |
| *y* | 1.9458 | 1.0000 | 1.0000 |
| *c* | 0.9470 | 0.4867 | 0.8597 |
| *i* | 6.3214 | 3.2487 | 0.9603 |
| *h* | 0.6546 | 0.3364 | 0.2903 |
| *m* | 1.1315 | 0.5815 | 0.8264 |
| *j* | 0.1181 | 0.0607 | -0.6192 |
| *r* | 0.2866 | 0.1473 | -0.1101 |
| $\pi$ | 0.7235 | 0.3718 | -0.7889 |

Source: The research's results, elaborated by the authors.

**Table 9.** Monetary economy with a technological shock and stochastic monetary growth–persistence and monetary shock–between 1995 and 2009

| | Variables | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | *y* | *c* | *i* | *h* | *m* | *j* | *r* | $\pi$ |
| | Real economy | | | | | | | |
| DP[*x*]*(%)* | 1.7779 | 1.1502 | 6.2368 | 1.2431 | 2.1387 | 7.4655 | 7.6849 | 16.5247 |
| DP[*x*]/DP[*y*] | 1.0000 | 0.6469 | 3.5080 | 0.6992 | 1.2029 | 4.1991 | 4.3225 | 9.2945 |
| CORR[*x, y*] | 1.0000 | 0.6806 | 0.8595 | 0.3612 | 0.2310 | -0.2821 | -0.0898 | -0.2367 |
| | Benchmark economy with technological shock* | | | | | | | |
| DP[*x*]*(%)* | 1.9458 | 0.9470 | 6.3214 | 0.6546 | 1.1315 | 0.1181 | 0.2866 | 0.7235 |
| DP[*x*]/DP[*y*] | 1.0000 | 0.4867 | 3.2487 | 0.3364 | 0.5815 | 0.0607 | 0.1473 | 0.3718 |
| CORR[*x, y*] | 1.0000 | 0.8597 | 0.9603 | 0.2903 | 0.8264 | -0.6192 | -0.1101 | -0.7889 |
| | Monetary economy with persistence and monetary shock** | | | | | | | |
| DP[*x*]*(%)* | 1.9494 | 1.0015 | 6.3535 | 0.6806 | 2.7899 | 1.3515 | 0.2896 | 10.1237 |
| DP[*x*]/DP[*y*] | 1.0000 | 0.5137 | 3.2592 | 0.3491 | 1.4312 | 0.6933 | 0.1486 | 5.1932 |
| CORR[*x, y*] | 1.0000 | 0.8266 | 0.9453 | 0.2945 | 0.3721 | -0.1149 | -0.1012 | -0.1165 |

Source: The research's results, elaborated by the authors.
Notes: * $\gamma = 0$, $(b - \Phi) < 0$; ** $\gamma = 0.6593$, $(b - \Phi) < 0$