Fiscal rules and the neutral interest rate in Brazil

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Abstract We estimate the natural rate of interest for Brazil over 2017Q1–2023Q4 using a Bayesian Two-Agent New Keynesian (TANK) DSGE model with Hand-to-Mouth households. We compare two fiscal regimes—the Spending Ceiling and the New Fiscal Framework—to assess their effects on the flexible-price equilibrium and the transmission of fiscal shocks. Technology and preference shocks dominate the unconditional variance of the natural rate (about 63% and 30%, respectively), in line with the literature. However, fiscal shocks are relevant for short-run dynamics, especially under procyclical rules. Counterfactual results indicate that the New Fiscal Framework generates higher volatility in the natural rate than the acyclical Spending Ceiling, driven by the strong consumption response of liquidity-constrained households. These findings suggest that procyclical fiscal rules amplify business cycle fluctuations in the natural rate, complicating inflation targeting by inducing systematic comovement with economic activity.

Keywords: Natural Rate of Interest; Fiscal Policy; TANK Model; DSGE; Brazil.

1 Introduction

Government debt in Brazil rose from 50% of GDP in 2014 to around 78% in 2024. Amid frequent and diverse macroeconomic shocks, fiscal rules play an important role in promoting fiscal discipline and shaping macroeconomic equilibrium. This paper evaluates how alternative fiscal regimes influence the natural rate of interest — the real interest rate consistent with output at its potential level in the absence of nominal rigidities Woodford (2003). Understanding how institutional fiscal frameworks affect this equilibrium variable is therefore a question of first-order importance for both fiscal and monetary policy.

We exploit the Brazilian institutional shift that replaced its acyclical fiscal rule with a procyclical one. To do so, following Galí, López-Salido and Vallés (2004), we develop and estimate a Two-Agent New Keynesian (TANK) DSGE model with fiscal rules calibrated to the Brazilian economy. The model compares two regimes: the Spending Ceiling, which freezes government spending growth in real terms, and the New Fiscal Framework, which links expenditure growth to the growth of revenues. More specifically, this paper addresses the following questions: (i) what are the determinants of the natural rate of interest in Brazil? (ii) how have fiscal policy shocks contributed to its dynamics? and (iii) which fiscal policy regime better supports the Central Bank's efforts to achieve the inflation target?

The results show that fiscal shocks play an important role in shaping the natural rate, consistent with Peterman and Sager (2025). In particular, the procyclical fiscal rule generates persistent upward pressure on the natural rate relative to the acyclical rule. These findings are also consistent with Bianchi, Faccini and Melosi (2024) and Laubach (2009), corroborating that fiscal shocks can substantially alter the equilibrium interest rate.

Within the model, the transmission mechanism through which fiscal policy shocks affect the natural rate operates via two main channels. First, an increase in government spending raises aggregate demand in the flexible-price equilibrium. To clear the goods market, this higher demand exerts upward pressure on the equilibrium interest rate through the intertemporal Euler condition—a standard crowding-out mechanism. Second, the presence of Hand-to-Mouth (HtM) households amplifies this effect. Since these agents consume their entire disposable income each period, any increase in income induced by fiscal expansion translates immediately into higher private consumption. This direct and contemporaneous response further strengthens aggregate demand, generating additional upward pressure on the natural rate of interest.

The findings of this paper carry important implications for the conduct of monetary policy in Brazil. The results suggest that a procyclical fiscal rule may not be the most effective in supporting the Central Bank's inflation-targeting efforts, as it systematically increases the natural rate of interest exactly when the economy is heating up. On the other hand, an expenditure-anchored rule proves more effective in stabilizing the natural rate and enhancing monetary policy transmission. These insights are crucial for policymakers when designing fiscal frameworks and coordinating fiscal and monetary policies to achieve macroeconomic stability.

The remainder of the project is organized as follows. Section 2 reviews the related literature on the natural rate of interest and its determinants, with a focus on the role of fiscal policy. Section 3 describes the DSGE model used for estimation, including the specification of the fiscal rules. Sections 4 outline the data and estimation methodology. Section 5 presents the results of the estimation and counterfactual analyses. Finally, Section 6 presents the robustness analysis and Section 7 concludes this work by discussing the policy implications of the findings.

2 Related Literature

The literature on the natural rate of interest is extensive and has expanded considerably over the past two decades. The concept was originally introduced by Wicksell (1936), who defined it as the real interest rate consistent with price stability. Since then, the natural rate has become a cornerstone of modern macroeconomics, particularly in the analysis of monetary policy transmission.

More recently, often referred to as the neutral or equilibrium real interest rate, it has been widely studied in the context of the zero lower bound (ZLB) and the challenges associated with unconventional monetary policy (DAUDIGNON; TRISTANI, 2023). This is because the natural rate serves as a benchmark for assessing the stance of monetary policy: when the policy rate is above the natural rate, policy is considered contractionary; when it is below, it is expansionary.

A substantial body of research identifies productivity growth, demographic shifts, and global savings patterns as the fundamental structural determinants of the natural rate of interest (HOLSTON; LAUBACH; WILLIAMS, 2017; FIORENTINI et al., 2018; JUáREZ, 2023). Indeed, the significant decline in the natural rate observed worldwide over the past three decades is largely attributed to these long-term trends (BRAND; BIELECKI; PENALVER, 2018). However, beyond these structural factors, recent literature emphasizes that cyclical components, particularly fiscal policy shocks and debt dynamics, also play a decisive role in shaping the equilibrium rate trajectory (BIANCHI; FACCINI; MELOSI, 2024; PETERMAN; SAGER, 2025; LAUBACH, 2009).

This nexus between fiscal variables and the natural interest rate has become a burgeoning area of inquiry. Empirical evidence provided by Laubach (2009) and Peterman and Sager (2025) suggests that public debt levels and divergent fiscal trajectories are key determinants of long-term interest rates. Several transmission channels justify this link. First, a classic crowding-out effect implies that increased government borrowing displaces productive physical capital, thereby raising its marginal productivity and the equilibrium rate (ENGEN; HUBBARD, 2004). Second, in the context of Two-Agent New Keynesian (TANK) models, Bianchi, Faccini and Melosi (2024) demonstrate that 'funded' fiscal expansions elevate real rates by stimulating demand among hand-to-mouth households, generating inflationary pressures that require a tighter monetary stance. From a coordination perspective, Bassetto and Sargent (2020) argue that fiscal-monetary interdependence links government liabilities to future surpluses, meaning fiscal policy effectively dictates the interest rate path necessary for nominal stability. Most recently, Campos et al. (2024) employ a Heterogeneous-Agent New Keynesian (HANK) framework to confirm that the natural rate is an increasing function of public debt.

Moreover, because the natural rate is not directly observable, it is typically estimated using a variety of macroeconomic models (BRAND; BIELECKI; PENALVER, 2018). Methodologically, the literature typically employs three approaches to estimate the natural rate: time-series models, structural models, and semi-structural models (BRAND; BIELECKI; PENALVER, 2018). In the Brazilian context, semi-structural models have predominated. (PERRELLI; ROACHE, 2014) document a sharp secular decline in Brazil's neutral rate using semi-structural methods. They find that both global and domestic factors, particularly financial deepening, declining public debt, and lower sovereign risk, contributed to the fall in Brazil's neutral rate, while also documenting substantial cyclical variation in short-run equilibrium rates driven by domestic and external output gaps. Miranda and Muinhos (2005) estimated the natural rate for Brazil using a variety of methods, including historical averages and long-term rate extractions, concluding that Brazil's equilibrium rate was structurally higher than that of its peers. Borges and Silva (2006) utilized a structural VAR to find a natural rate of approximately 10% between 2000 and 2003. More recently, Moreira (2019) applied the seminal framework of Laubach and Williams (2003), documenting a consistent decline in Brazil's natural rate over the last decades, with a notable trough during the 2015-2016 recession.

This work is in line with the strand of literature that favors structural estimation via DSGE models. Unlike semi-structural frameworks that often focus on low-frequency trends, the DSGE approach tracks the natural rate based on a model-consistent measure of natural output. This allows natural rate to adjust to structural shocks at business-cycle frequencies, often resulting in higher volatility than trend-based measures (BRAND; BIELECKI; PENALVER, 2018). Recent structural estimates for Brazil include Alves (2024), who employs an open-economy DSGE model to show that the country risk premium and foreign interest rates are the primary drivers of the domestic natural rate. Similarly, Junior, Garcia-Cintado and Junior (2023) documents the significant downward trajectory of the Brazilian natural rate in recent decades. Finally, Farina (2025) uses an open-economy DSGE framework to identify that, in addition to the risk premium, foreign productivity, investment shocks, and domestic permanent shocks to the growth path are the fundamental forces driving the movements of the natural interest rate in Brazil.

This paper contributes to the literature by adopting a structural approach based in a TANK model in order to examine how fiscal shocks, under alternative fiscal regimes, impact the natural rate of interest in the Brazilian institutional arrangements.

3 Model

We consider a standard Two-Agent New Keynesian (TANK) model following Galí, López-Salido and Vallés (2004). Households are divided into two groups: Ricardian and non-Ricardian. The model features a small closed economy in which households maximize utility by choosing consumption and labor supply and, in the case of Ricardian households, holdings of risk-free government bonds. Nominal rigidities are introduced through the staggered price-setting mechanism proposed by Calvo (1983). Moreover, the economy features a monetary authority that sets the nominal interest rate according to a Taylor rule, and a government that finances its spending through debt and lump-sum taxes. Next, we describe the objectives and constraints of the different agents.

3.1 Households

As in Galí, López-Salido and Vallés (2004), We assume a continuum of infinitely-lived households, indexed by $i \in [0, 1]$. A fraction $1-\lambda$ of these households are Ricardian and can trade a full set of state-contingent bonds, while the remaining fraction λ are non-Ricardian and consume their entire current income. Galí, López-Salido and Vallés (2004) also refers to Ricardian households as "optimizers"because of their ability to smooth consumption over time, while non-Ricardian households are referred to as "rule-of-thumb"or "hand-to-mouth"agents. These are interpreted by Castro et al. (2011) as households with a lack of access to financial markets, credit, and firm dividends. Let $C_{i,t}$ and $N_{i,t}$ denote the consumption and labor of the i household. The utility function for both types of households is given by:

$$U^i(C_{i,t}, N_{i,t}, Z_t) = \left(\frac{C_{i,t}^{1-\sigma} - 1}{1-\sigma} - \frac{N_{i,t}^{1+\varphi}}{1+\varphi} \right) Z_t, \tag{1}$$

where $z_t \equiv \log Z_t$ follows an exogenous $AR(1)$ process:

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

with $\rho_z \in [0, 1)$. The parameter $\sigma \geq 0$ is the coefficient of relative risk aversion, and $\varphi \geq 0$ is the inverse of the Frisch elasticity of labor supply. The term Z_t is a preference shock that affects both consumption and leisure; together with β, it may be interpreted as a discount rate shock because it affects intertemporal choices (GALÍ, 2015).

3.1.1 Ricardian Households

Let $C_{o,t}$ and $N_{o,t}$ denote, respectively, the consumption and labor supply of optimizing households. Preferences are characterized by a discount factor $\beta \in (0,1)$ and a per-period utility function $U(C_{o,t}, N_{o,t})$. A representative household of this type chooses sequences of consumption and labor supply to maximize its expected lifetime utility:

$$E_0 \sum_{t=0}^{\infty} \beta^t U(C_{o,t}, N_{o,t}, Z_t), \tag{2}$$

subject to the sequence of budget constraints:

$$P_t C_{o,t} + Q_t B_{o,t+1} = W_t N_{o,t} + B_{o,t} + D_{o,t} - P_t T_t. \tag{3}$$

At the start of each period, the household earns labor income $W_t N_{o,t}$, where W_t denotes the nominal wage, P_t the aggregate price level, and $N_{o,t}$ the hours worked. $B_{o,t}$ represents holdings of one-period nominally risk-free bonds carried over from period $t-1$, which pay one unit of the numeraire in period t. The price of bonds purchased in period t is denoted by Q_t. Households also obtain dividends $D_{o,t}$ from firm ownership and pay lump-sum taxes T_t. Consumption expenditures are denoted by $C_{o,t}$.

The first-order conditions for the Ricardian household's optimization problem yield the following Euler equation:

$$Q_t = \beta E_t \left\{ \frac{{C_{o,t}}^{-\sigma}}{{C_{o,t+1}}^{-\sigma}} \frac{P_t}{P_{t+1}} \frac{Z_{t+1}}{Z_t} \right\}. \tag{4}$$

We assume a competitive labor market, as in Galí, López-Salido and Vallés (2004). This results in the following labor supply condition:

$$-\frac{N_{o,t}^{\varphi}}{C_{o,t}^{-\sigma}} = \frac{W_t}{P_t}. \tag{5}$$

The resulting log-linear versions of the above optimality conditions take the form:

$$w_t - p_t = \sigma c_{o,t} + \varphi n_{o,t} \tag{6}$$

and

$$c_{o,t} = E_t\{c_{o,t+1}\} - \frac{1}{\sigma}(i_t - E_t\{\pi_{t+1}\} - \rho) + \frac{1}{\sigma}(1-\rho_z)z_t, \tag{7}$$

where $i_t \equiv -\log Q_t$ denotes the short-term nominal interest rate and $\rho \equiv -\log \beta$ represents the discount rate. Lowercase variables correspond to the logarithms of their original (level) counterparts.

3.1.2 Non-Ricardian Households

Rule-of-thumb households, on the other hand, consume their entire current income each period. As in Galí, López-Salido and Vallés (2004), these consumers neither smooth their consumption path nor respond to changes in interest rates. Let $C_{r,t}$, $N_{r,t}$, and T_t denote consumption, labor, and taxes for this type of household, respectively. The budget constraint for these households is given by:

$$P_t C_{r,t} = W_t N_{r,t} - P_t T_t, \tag{8}$$

and

$$-\frac{N_{r,t}^{\varphi}}{C_{r,t}^{-\sigma}} = \frac{W_t}{P_t}. \tag{9}$$

The resulting log-linear version of the above conditions is given by:

$$w_t - p_t = \sigma c_{r,t} + \varphi n_{r,t} \tag{10}$$

and

$$c_t^r = \frac{WN}{PC^r}(w_t - p_t + n_t^r) - \frac{\gamma_t}{\gamma_c} t_t, \tag{11}$$

where W, N,P, C^r are the steady state values of the nominal wage, labor, price and non-ricardian consumption, respectively. γ_t and γ_c are the steady-state ratios of taxes to output and consumption, respectively. The above equation indicates that the consumption of rule-of-thumb households is directly influenced by changes in their labor income and tax payments, without any intertemporal smoothing.

In the steady state, the ratio of nominal labor income to nominal consumption expenditure is determined by the structural parameters of the model:

$$\frac{WN}{PC} = \frac{1-\alpha}{(1+\mu)\gamma_c} = \chi, \tag{12}$$

where $1 + \mu$ is the gross price markup.

3.1.3 Aggregation

Aggregating across the two types of households, we define linearized aggregate consumption and labor supply as follows:

$$c_t \equiv \lambda c_{r,t} + (1-\lambda) c_{o,t} \tag{13}$$

and

$$n_t \equiv \lambda n_{r,t} + (1-\lambda) n_{o,t}. \tag{14}$$

It is now possible to aggregate the labor supply conditions for both types of households, resulting in the following expression:

$$w_t - p_t = \sigma c_t + \varphi n_t. \tag{15}$$

We then substitute the real wage into the consumption function of the rule-of-thumb households. Moreover, the aggregate Euler equation is derived by combining the Euler equation for the optimizing households with the consumption function of the rule-of-thumb households, resulting in:

$$\begin{aligned} c_t = E_t\{c_{t+1}\} - \lambda E_t &\left\{\chi\left(\sigma c_{t+1} + (1+\varphi) n_{t+1}\right) - \frac{T}{C^r} t_{t+1}\right\} \\ &+ \lambda \left[\chi\left(\sigma c_t + (1+\varphi) n_t\right) - \frac{T}{C^r} t_t\right] \\ &- \frac{1-\lambda}{\sigma}\left[i_t - E_t\{\pi_{t+1}\} - \rho\right] + (1-\lambda)(1-\rho_z) z_t. \end{aligned} \tag{16}$$

The aggregate consumption dynamics can be expressed more compactly by grouping the structural parameters into composite coefficients. The reduced-form Euler equation is given by:

$$c_t = E_t\{c_{t+1}\} - \Theta_n E_t\{\Delta n_{t+1}\} + \Theta_t E_t\{\Delta t_{t+1}\} - \Theta_i (i_t - E_t\{\pi_{t+1}\} - \rho) + \Theta_z z_t, \tag{17}$$

where the composite parameters are defined as follows:

$$\begin{aligned} \Theta_n &\equiv \frac{\lambda \chi (1+\varphi)}{1-\lambda\chi\sigma} \\ \Theta_t &\equiv \frac{\lambda \frac{T}{C^r}}{1-\lambda\chi\sigma} \\ \Theta_i &\equiv \frac{\frac{1-\lambda}{\sigma}}{1-\lambda\chi\sigma} \\ \Theta_z &\equiv \frac{(1-\lambda)(1-\rho_z)}{1-\lambda\chi\sigma}. \end{aligned}$$

3.2 Firms

Following the approach of Galí, López-Salido and Vallés (2004), firms are divided into final-good producers and intermediate-good producers.

3.2.1 Final Good Producers

The final good is produced by perfectly competitive firms that combine a continuum of intermediate goods, indexed by $j \in [0,1]$, using a constant returns technology:

$$Y_t = \left(\int_0^1 X_t(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{,}\varepsilon-1} \tag{18}$$

where $X_t(j)$ indicates the input of intermediate good j. Profit maximization yields the demand for each intermediate good, given the final good price P_t and the prices for the intermediate goods $P_t(j)$, all $j \in [0,1]$, as follows:

$$X_t(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\varepsilon} Y_t, \tag{19}$$

as well as the zero profit condition $P_t = \left(\int_0^1 P_t(j)^{1-\varepsilon} dj \right)^{\frac{1}{1-\varepsilon}}$.

3.2.2 Intermediate Good Producers

The intermediate-good producers are monopolistically competitive firms that produce differentiated products. Each firm j produces output according to the following technology:

$$Y_t(i) = A_t N_t(i)^{1-\alpha}, \tag{20}$$

where $N_t(i)$ denotes the labor input and A_t represents a productivity factor common to all producers. The log of technology, $a_t \equiv \ln A_t$, follows an exogenous AR(1) process:

$$a_t = \rho_a a_{t-1} + \varepsilon_t^a, \tag{21}$$

with the persistence parameter $\rho_a \in [0,1]$ and a white noise shock ε_t^a.

Regarding price dynamics, the model incorporates nominal rigidities through the framework of Calvo (1983). In each period, a firm can adjust its price with a constant probability $1-\theta$, independent of the time elapsed since the last update. Consequently, a fraction θ of firms keep their prices fixed. This mechanism implies that the expected duration of a price level is given by $(1-\theta)^{-1}$, making θ a direct measure of price stickiness in the economy.

The evolution of the aggregate price level is determined by a weighted average of the prices set by firms that remain constrained and those that are able to reoptimize. The law of motion for the aggregate price index P_t is given by the linearized equation:

$$\pi_t = (1-\theta)(p_t^* - p_{t-1}), \tag{22}$$

where P_t^* denotes the optimal price chosen by reoptimizing firms in period t.

In the presence of staggered price competition, a firm that receives a price adjustment signal in period t chooses an optimal price, P_t^*, to maximize the expected discounted value of future profits for as long as that price remains in effect. Following, firm's intertemporal optimization problem is given by:

$$\max_{P_t^*} \sum_{k=0}^{\infty} \theta^k E_t \left\{ \Lambda_{t,t+k} \left(\frac{1}{P_{t+k}} \right) \left(P_t^* Y_{t+k|t} - \mathcal{C}_{t+k}(Y_{t+k|t}) \right) \right\}, \tag{23}$$

where $\theta \in [0,1]$ denotes the probability of not being able to reset prices in any given period, $\Lambda_{t,t+k}$ is the stochastic discount factor $\Lambda_{t,T} \equiv \beta^{T-t} \frac{U_{c,T}}{U_{c,t}}$, and $\mathcal{C}_{t+k}(\cdot)$ represents the nominal cost function.

The first-order condition (FOC) derived from the firm's intertemporal optimization problem characterizes the optimal price P_t^* as follows:

$$\sum_{k=0}^{\infty} \theta^k E_t \left\{ \Lambda_{t,t+k} Y_{t+k|t} \left(\frac{1}{P_{t+k}} \right) (P_t^* - \mathcal{M} \Psi_{t+k|t}) \right\} = 0, \tag{24}$$

where $\mathcal{M} \equiv \frac{\varepsilon}{\varepsilon-1}$ represents the desired gross markup and $\Psi_{t+k|t}$ denotes the nominal marginal cost at time $t+k$ for a firm that last reset its price at time t.

The linearization of the above FOC around the steady state is given by:

$$p_t^* = \mu + (1-\beta\theta) \sum_{k=0}^{\infty} (\beta\theta)^k E_t\{\psi_{t+k|t}\}, \tag{25}$$

where μ denotes the log of the desired gross markup, and $\psi_{t+k|t}$ is the log of the nominal marginal cost at period $t+k$ for a firm that last adjusted its price in period t.

3.3 Monetary Authority

We assume the central bank follows a simple interest rate rule where the nominal interest rate, i_t, responds to fluctuations in inflation and output:

$$i_t = \rho + \phi_\pi \pi_t + \phi_y \tilde{y}_t + v_t, \tag{26}$$

in which ρ is the log of the discount rate, $\tilde{y}_t \equiv y_t - y^n$ represents the log deviation of output from its potential level, and ρ is the intercept. The coefficients ϕ_π and ϕ_y are non-negative weights chosen by the monetary authority. The term v_t denotes an exogenous policy shock, which is assumed to follow a first-order autoregressive process:

$$v_t = \rho_v v_{t-1} + \varepsilon_t^v, \tag{27}$$

where ε_t^v is a white noise innovation. Under this specification, a positive realization of ε_t^v is interpreted as a contractionary monetary policy shock, as it induces an increase in the nominal interest rate for any given level of inflation and output.

3.4 Government

The government's period budget constraint, expressed in nominal terms, is given by:

$$P_t G_t + B_{t-1} \leq Q_t B_t + P_t T_t, \tag{28}$$

where P_t is the price level, G_t denotes real government expenditures, B_t is the quantity of one-period nominal bonds issued at price Q_t, and T_t represents real lump-sum tax revenues.

To express the dynamics in real terms, we divide the identity by P_t and define $b_t \equiv B_t/P_t$. Recognizing that $B_{t-1}/P_t = (B_{t-1}/P_{t-1})(P_{t-1}/P_t) = b_{t-1}/\Pi_t$, we obtain:

$$Q_t b_t = \frac{b_{t-1}}{\Pi_t} + T_t - G_t. \tag{29}$$

We log-linearize this relation around a zero-inflation steady state ($\Pi = 1$), where $Q = \beta$. Applying a first-order Taylor expansion ($X_t \approx X(1 + \hat{x}_t)$) and removing steady-state terms, the linear dynamics of the debt-to-GDP ratio are given by:

$$\beta b(\hat{b}_t + \hat{q}_t) = b(\hat{b}_{t-1} - \pi_t) + T\hat{t}_t - G\hat{g}_t. \tag{30}$$

Using the relation $\hat{q}_t = -i_t$ and dividing by βb, we reach the final law of motion for debt:

$$\hat{b}_t = i_t + \frac{1}{\beta}(\hat{b}_{t-1} - \pi_t) + \frac{1}{\beta \gamma_b}\left[s_g \hat{g}_t - \gamma_t \hat{t}_t\right]. \tag{31}$$

where s_g, γ_b, and γ_t denote the steady-state ratios of spending, debt, and taxes to output, respectively.

In addition, in all specifications of the fiscal policy, We assume that the government follows a tax rule where the tax revenue avoids debt explosions by responding to the level of public debt (LEEPER, 1991; GALÍ; LÓPEZ-SALIDO; VALLÉS, 2004). The tax rule is given by:

$$t_t = \phi_g g_{t-1} + \phi_b b_t, \tag{32}$$

where ϕ_g and ϕ_b are non-negative parameters that capture the responsiveness of tax revenues to government spending and the debt level, respectively:

We specify the fiscal rule for the Spending Ceiling and for the New Fiscal Framework following Alesina, Campante and Tabellini (2008), Clemente (2024), whereby real government expenditure g_t, expressed as a share of its steady-state level, evolves according to its lagged value adjusted by lagged output growth.

$$g_t = \rho_g g_{t-1} + \phi_{g,y} \Delta y_t + \epsilon_t^g, \tag{33}$$

where, g_t denotes the log-deviation of real government expenditure from its steady-state trend. The parameter $\rho_g \in [0, 1)$ represents the persistence of government spending. The term $\Delta y_t = y_t - y_{t-1}$ represents the output growth rate. Consequently, the parameter ϕ_g measures the sensitivity of government spending to cyclical fluctuations. The parameter is set as zero for the Spending Ceiling, and for the New Fiscal Framework equals 0.7. As previously outlined, this parameter is crucial for distinguishing between the fiscal regimes. Finally, ϵ_t^g represents an exogenous government spending shock, assumed to follow an i.i.d. process with zero mean and constant variance σ_g^2.

3.5 Market Clearing and Equilibrium

To close the model, we define the aggregate employment and the market clearing conditions for both intermediate and final goods. Total labor demand, N_t, is obtained by integrating the labor employed by each firm j:

$$N_t = \int_0^1 N_t(j)\, dj. \tag{34}$$

Equilibrium in the intermediate goods market requires that the production of each variety j equals its respective demand:

$$Y_t(j) = X_t(j), \quad \forall j \in [0,1]. \tag{35}$$

Finally, the aggregate resource constraint for the economy ensures that total output is allocated among private consumption, and government expenditures:

$$Y_t = C_t + G_t. \tag{36}$$

We linearize this resource constraint around the steady state to obtain the following expression:

$$y_t = (1 - s_g)c_t + s_g g_t, \tag{37}$$

replacing the above equation into the aggregate Euler equation, we obtain the aggregate IS curve

$$\begin{aligned} y_t = E_t\{y_{t+1}\} &- s_g E_t\{\Delta g_{t+1}\} \\ &- \Theta_n(1 - s_g)E_t\{\Delta n_{t+1}\} + \Theta_t(1 - s_g)E_t\{\Delta t_{t+1}\} \\ &- \Theta_i(1 - s_g)(i_t - E_t\{\pi_{t+1}\} - \rho) + \Theta_z(1 - s_g)z_t \end{aligned} \tag{38}$$

On the supply side, the aggregate production function for the intermediate firms in log-linearized form relates total output y_t to labor input n_t and productivity a_t:

$$y_t = (1 - \alpha)n_t + a_t. \tag{39}$$

As in Galí (2015) given the technology, the nominal marginal cost Ψ_t is defined as the ratio of the nominal wage to the marginal product of labor:

$$\Psi_t = \frac{W_t}{MPN_t} = \frac{W_t}{A_t(1 - \alpha)N_t^{-\alpha}}. \tag{40}$$

By substituting the linearized cost and production relations into the firm's optimal pricing rule, we obtain the expression for the reset price p_t^*:

$$p_t^* = (1 - \beta\theta)\sum_{k=0}^{\infty}(\beta\theta)^k E_t\left\{p_{t+k} - \Theta\hat{\mu}_{t+k}\right\}, \tag{41}$$

where $\hat{\mu}_{t+k} \equiv \mu_{t+k} - \mu$ denotes the deviation of the markup from its steady state, and $\Theta \equiv \frac{1-\alpha}{1-\alpha+\alpha\varepsilon}$ accounts for decreasing returns to scale. Combining this with the aggregate price dynamics yields the dynamic equation for inflation:

$$\pi_t = \beta E_t\{\pi_{t+1}\} - \Theta_\pi \hat{\mu}_t, \tag{42}$$

where the composite coefficient is defined as $\Theta_\pi \equiv \frac{(1-\theta)(1-\beta\theta)}{\theta}\Theta$.

Finally, the log-linearized markup μ_t can be expressed as a function of output, government spending, and technology:

$$\mu_t = -\left[\frac{(1-\alpha)\sigma + (1-s_g)(\varphi+\alpha)}{(1-s_g)(1-\alpha)}\right] y_t + \frac{\sigma s_g}{1-s_g} g_t + \frac{1+\varphi}{1-\alpha} a_t + \ln(1-\alpha). \tag{43}$$

The natural level of output, y_t^n, is defined as the equilibrium output that would prevail under flexible prices (i.e., when the markup is constant at its steady-state value). By solving for y_t in the markup identity, we obtain:

$$y_t^n = \psi_{yg}^n g_t + \psi_{ya}^n a_t + \psi_y^n, \tag{44}$$

where the composite parameters represent the weights of fiscal shocks and technology on natural output:

$$\begin{aligned} \psi_{yg}^n &\equiv \frac{\sigma s_g(1-\alpha)}{\sigma(1-\alpha) + (1-s_g)(\varphi+\alpha)} \\ \psi_{ya}^n &\equiv \frac{(1-s_g)(1+\varphi)}{\sigma(1-\alpha) + (1-s_g)(\varphi+\alpha)} \\ \psi_y^n &\equiv \frac{(1-s_g)(1-\alpha)(\ln(1-\alpha)-\mu)}{\sigma(1-\alpha) + (1-s_g)(\varphi+\alpha)}. \end{aligned}$$

Let $\tilde{y}_t \equiv y_t - y_t^n$ denote the output gap. The deviation of the markup from its steady state, $\hat{\mu}_t$, is inversely related to the output gap according to:

$$\hat{\mu}_t = -\left[\frac{(1-\alpha)\sigma + (1-s_g)(\varphi+\alpha)}{(1-s_g)(1-\alpha)}\right] \tilde{y}_t. \tag{45}$$

Substituting this into the inflation dynamics equation yields the New Keynesian Phillips Curve in terms of the output gap:

$$\pi_t = \beta E_t\{\pi_{t+1}\} + \kappa \tilde{y}_t, \tag{46}$$

where the slope of the Phillips curve is $\kappa \equiv \frac{(1-\alpha)\sigma+(1-s_g)(\varphi+\alpha)}{(1-s_g)(1-\alpha)}\Theta_\pi$.

Finally, we derive the dynamic IS curve in terms of the output gap. First, we define the natural rate of interest, r_t^n, as the real interest rate consistent with output remaining at its natural level, satisfying:

$$\begin{aligned} y_t^n = {} & E_t\{y_{t+1}^n\} - s_g E_t\{\Delta g_{t+1}\} - \Theta_n(1-s_g)E_t\{\Delta n_{t+1}^n\} + \Theta_t(1-s_g)E_t\{\Delta t_{t+1}\} \\ & - \Theta_i(1-s_g)(r_t^n - \rho) + \Theta_z(1-s_g)z_t. \end{aligned} \tag{47}$$

By subtracting the equation above from the aggregate IS curve, we obtain the dynamic IS equation

$$\tilde{y}_t = E_t\{\tilde{y}_{t+1}\} - \frac{\Theta_i(1-s_g)}{1-\Theta_n(1-s_g)}[i_t - E_t\{\pi_{t+1}\} - r_t^n]. \tag{48}$$

The Wicksellian natural rate of interest, r_t^n, can be analytically derived by substituting the natural level of output and the labor market clearing condition into the aggregate IS curve. The expanded expression is given by:

$$\begin{aligned} r_t^n = \rho & + \left[\frac{\psi_{yg}^n - s_g}{\Theta_i(1-s_g)} - \frac{\Theta_n \psi_{yg}^n}{\Theta_i(1-\alpha)}\right] E_t\{\Delta g_{t+1}\} \\ & + \left[\frac{\psi_{ya}^n}{\Theta_i(1-s_g)} - \frac{\Theta_n(\psi_{ya}^n - 1)}{\Theta_i(1-\alpha)}\right] E_t\{\Delta a_{t+1}\} \\ & + \frac{\Theta_t}{\Theta_i}E_t\{\Delta t_{t+1}\} + \frac{\Theta_z}{\Theta_i}(1-\rho_z)z_t. \end{aligned} \tag{49}$$

The equation above relates the natural rate of interest to expected future changes in government spending, technology, taxes, and preference shocks. The coefficients on these variables capture the sensitivity of the natural rate to different types of shocks, which is crucial for understanding how fiscal policy and other factors influence the equilibrium real interest rate in the economy.

4 Estimation Strategy

To estimate the model, we employ Bayesian methods, which allow the incorporation of prior information about the structural parameters and yield the full posterior distribution conditional on the data, following An and Schorfheide (2007). The posterior distribution is approximated using Markov Chain Monte Carlo (MCMC) techniques. We implement the Random Walk Metropolis–Hastings algorithm to generate draws from the posterior distribution. In particular, the random-walk Metropolis-Hastings sampler we employed generates 610,000 draws from this posterior from each of the four chains; the first seventy percent are discarded as burn-in.

The estimation strategy was first to calibrate the parameters that are not identified by the data, such as the discount factor, the elasticity of intertemporal substitution, and the parameters governing the fiscal rules. The remaining parameters are estimated using the data on output, inflation, and interest rates. Then we conduct a historical decomposition of the natural rate of interest to assess the contribution of fiscal policy shocks to its evolution. Finally, we perform counterfactual analyses to evaluate the impact of different fiscal rules on the natural rate of interest and compare the gaps between the model's implied natural rate and the ex-ante real interest rate under each fiscal rule.

4.1 Data

We use quarterly time series data for four Brazilian macroeconomic variables spanning the period from 2002Q1 to 2023Q4. We choose this sample because the first fiscal rule in Brazil in this paper was introduced in 2002, followed by the approval of the Spending Ceiling in 2017, which remained in force until the end of 2023.

We used real GDP for output, public administration consumption expenditure for government spending, the SELIC rate for the nominal interest rate, and the IPCA inflation index as the main variables for estimation. The real GDP and public administration consumption expenditure transformed in logarithims and had the cyclical component extracted by the difference between the log of the series and its trend component from one-sided Hodrick-Prescott (HP) filter; while the SELIC rate and the IPCA inflation index are in departures from their sample means.

Both real GDP and public administration consumption expenditure are seasonally adjusted and were obtained from the Brazilian Institute of Geography and Statistics (IBGE), likewise, the IPCA inflation index was obtained from the IBGE. The SELIC rate was obtained from the Central Bank of Brazil (BCB).

4.2 Calibrated Parameters

The parameters that are not identified by the data are calibrated based on values commonly used in the Brazilian literature on DSGE modeling. The discount factor β is set to 0.988, which implies a steady-state real interest rate of approximately 5% per year, consistent with the value calibrated by Castro et al. (2015). The elasticity of intertemporal substitution σ is set to 1.63, following Moura (2015). Regarding the production side, we follow Alves (2024) and set the capital share α to 0.30. The share of hand-to-mouth households λ is set to 0.4, following Castro et al. (2015), while the inverse Frisch elasticity of labor supply φ is 1.5, in line with Nobrega, Besarria and Aragón (2022).

Monetary policy parameters follow Fasolo et al. (2024), with an inflation response ϕ_π of 2.21 and an output gap response ϕ_y of 0.125. The reaction of government revenue to debt ϕ_b is set to 0.22 to satisfy the Blanchard-Kahn conditions for a passive fiscal regime (LEEPER, 1991), and the reaction to spending ϕ_g is 0.12 (GALÍ; LÓPEZ-SALIDO; VALLÉS, 2004). Regarding steady-state ratios, I follow Fasolo et al. (2024) to set government spending at 20% of output ($S_g = 0.2$) and tax revenue at 18.7% ($\gamma_t = 0.187$). The public debt-to-GDP ratio is set to 61% annually, which corresponds to a quarterly ratio γ_b of 2.46. Finally, demand elasticity ϵ and price stickiness θ are set to 6 and 0.65, respectively (CASTRO et al., 2015).

Tabela 1 – Calibrated Parameters

Param.	**Description**	**Value**	**Source**
Preferences and Technology			
β	Discount factor	0.988	(CASTRO et al., 2015)
σ	Inverse elasticity of intertemporal substitution	1.63	(MOURA, 2015)
α	Capital share in production	0.30	(ALVES, 2024)
λ	Share of hand-to-mouth households	0.40	(CASTRO et al., 2015)
φ	Inverse Frisch elasticity	1.50	(NOBREGA; BESARRIA; ARAGóN, 2022)
ϵ	Demand elasticity	6.00	(CASTRO et al., 2015)
θ	Price stickiness (Calvo)	0.65	(CASTRO et al., 2015)
Monetary and Fiscal Policy			
ϕ_π	Taylor rule response to inflation	2.21	(FASOLO et al., 2024)
ϕ_y	Taylor rule response to output gap	0.125	(FASOLO et al., 2024)
ϕ_b	Reaction of revenue to debt	0.22	(LEEPER, 1991)
ϕ_g	Reaction of revenue to spending	0.12	(GALÍ; LÓPEZ-SALIDO; VALLÉS, 2004)
ϕ_{gy}	Reaction of spending to output growth	0	
Steady State Ratios			
S_g	Government spending share in output	0.20	(FASOLO et al., 2024)
γ_t	Government revenue share in output	0.187	(FASOLO et al., 2024)
γ_b	Public debt-to-GDP (Quarterly)	2.46	(FASOLO et al., 2024)

Note: The table summarizes the baseline calibration for the structural parameters governing preferences and technology, monetary and fiscal policy rules, and steady-state ratios. **Source:** Own elaboration (2026)

4.3 Priors and Posterior Distributions

The priors for the estimated parameters are specified based on the existing literature on DSGE modeling for the Brazilian economy, largely following Castro et al. (2015) and Fasolo et al. (2024).

We estimate the persistence parameters of the exogenous shocks using Beta distributions with prior means ranging from 0.6 to 0.7. The standard deviations of the structural shocks are estimated with Inverse Gamma priors, with mean values specified between 0.003 and 0.017, accommodating the typical volatility observed in Brazilian macroeconomic series. Table 3 summarizes the prior specifications and the resulting posterior distributions obtained via MCMC sampling.

The posterior results are consistent with the Brazilian empirical evidence. The technology shock persistence ($\rho_a = 0.985$) is notably high, a feature even more pronounced than in Castro et al. (2015). The preference shock persistence ($\rho_z = 0.765$) and monetary policy shock persistence ($\rho_\nu = 0.664$) remain within the expected range for demand-side shocks. The government shock persistence ($\rho_g = 0.510$) is lower than those found in the literature. Regarding volatility, the technology and monetary policy shocks appear as the most volatile components ($\hat{\sigma}_a = 0.026$ and $\hat{\sigma}_\nu = 0.026$), followed by the fiscal shock, reflecting the significant impact of supply and policy innovations on the Brazilian business cycle.

5 Results

In this section we present the results of the estimation of the DSGE model and the implications for the natural rate of interest under different fiscal rules. First, we present the results of the impulse response functions to the estimated shocks, which provide insights into the dynamic effects of the shocks on the economy. Then, we present the historical decomposition of the natural rate of interest, which allows assessing its determinants and the weight of fiscal policy shocks in its evolution. In addition, we present the results of the counterfactual analysis, which evaluates the natural rate of interest under alternative fiscal rules and compares it to the ex-ante real interest rate. Finnaly, we discuss the stance

Tabela 3 – Results from Metropolis-Hastings (Parameters and Shocks)

		Prior		Posterior			
Parameter	Dist.	Mean	Stdev.	Mean	Stdev.	HPD inf	HPD sup
Persistence Parameters							
ρ_a	beta	0.600	0.2000	0.985	0.0060	0.9751	0.9942
ρ_ν	beta	0.700	0.1000	0.664	0.0135	0.6429	0.6869
ρ_z	beta	0.700	0.0500	0.765	0.0401	0.7008	0.8317
ρ_g	beta	0.500	0.1000	0.510	0.0790	0.3824	0.6427
Standard Deviation of Structural Shocks							
ε_a	invg	0.011	0.0050	0.026	0.0034	0.0207	0.0316
ε_ν	invg	0.003	0.0020	0.026	0.0034	0.0204	0.0312
ε_z	invg	0.008	0.0040	0.007	0.0010	0.0053	0.0084
ε_g	invg	0.017	0.0080	0.017	0.0021	0.0132	0.0200

Source: Own elaboration (2026)

of the monetary policy under the different fiscal regimes based on the gaps between the model's implied natural rate and the ex-ante real interest rate, and the implications for the conduct of monetary policy in Brazil.

5.1 Impulse Response Functions

5.1.1 Government Spending Shocks

Figure 1 presents the effects of an innovation of 1.7% in the government spending. This shock leads to a substantial effect on the natural rate of interest, which constitutes the central mechanism of interest in this work.

This fiscal shock increases the GDP and the demand for goods and labor. The rise in the employment leads to an expressive increase in the consumption of hand-to-mouth households, which respond by 1.29% per unit of the shock, reflecting the amplification role of liquidity-constrained agents in the TANK framework. The higher demand for labor raises the real wage by 0.43%, which pushes inflation upwards by 0.22 percentage points (annualized). To stabilize the economy and bring inflation back to target, the Central Bank increases the nominal interest rate by 0.55 percentage points.

The most relevant channel for this dissertation is the response of the natural rate of interest. On impact, the annualized natural rate rises by approximately 0.75 percentage points per unit of the fiscal shock, or equivalently, 1.28 percentage points given the estimated shock size of 1.7%. This result reflects the standard crowding-out mechanism in New Keynesian models: a fiscal expansion raises aggregate demand in the flexible-price equilibrium, increasing the real rate of return required to clear the goods market. In the TANK framework, this effect is amplified by the presence of hand-to-mouth households, as the immediate consumption response generates additional upward pressure on the natural rate beyond what optimizing households alone would produce.

In terms of magnitude, a 1.7% shock in government spending raises output by approximately 0.20%, implying a fiscal multiplier of 1.00 — given the government consumption share of 20% of GDP. This result lies closer to the estimate of 1.3 found by (CASTRO et al., 2015). The amplification relative to the standard representative-agent New Keynesian model is consistent with the theoretical predictions of (GALÍ; LÓPEZ-SALIDO; VALLÉS, 2004), who show that the presence of rule-of-thumb consumers raises the fiscal multiplier by generating a positive co-movement between government spending and private consumption — a result confirmed here by the positive response of c^r alongside the negative response of c^o.

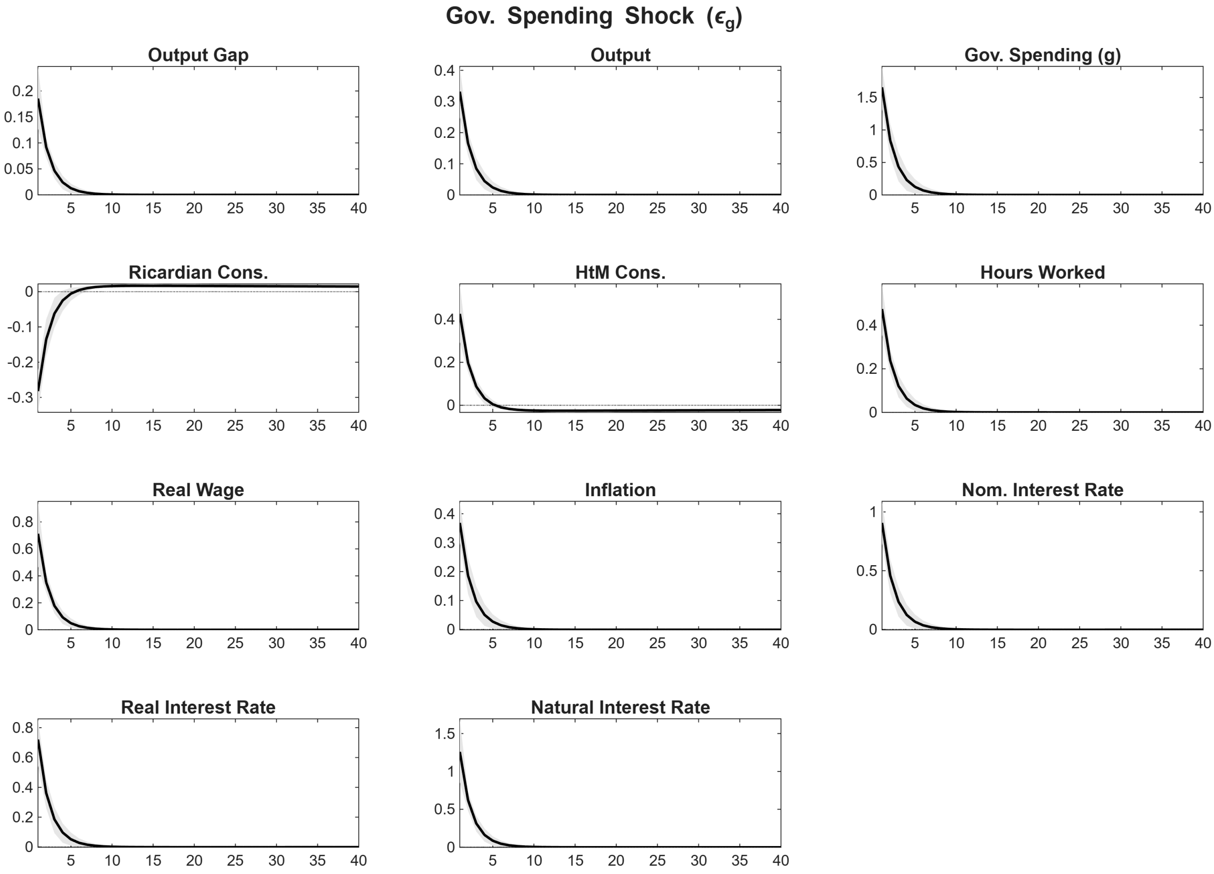


Figura 1 – Bayesian IRF: Orthogonalized shock to ε_g.

Note: The solid black line represents the posterior mean response, while the shaded gray areas indicate the 90% Highest Posterior Density (HPD) intervals. All responses are measured in percentage deviations from their respective steady states. The horizontal axis represents quarters after the shock.
Source: Own elaboration (2026)

5.1.2 Monetary Policy Shocks

Figure 2 presents the dynamic effects of a contractionary monetary policy shock (ε_ν) on a set of macroeconomic variables. Consistent with the literature and the analytical results derived in the theoretical section, the shock leads to a decline in output, consumption for both types of households, employment, real wages, and inflation. On the other hand, an interesting result is that the shock leads to an unconventional increase in the natural rate of interest, which is consistent with the recent literature on the effects of monetary policy shocks on the natural rate (see Garabedian (2025), McKay and Wieland (2021)). In addition, the increase in the nominal interest rate is lower than the increase in the real rate, which is consistent with the predictions of Galí (2015). This occurs as a result of the endogenous downward adjustment of the Taylor rule in response to the decline in inflation and output.

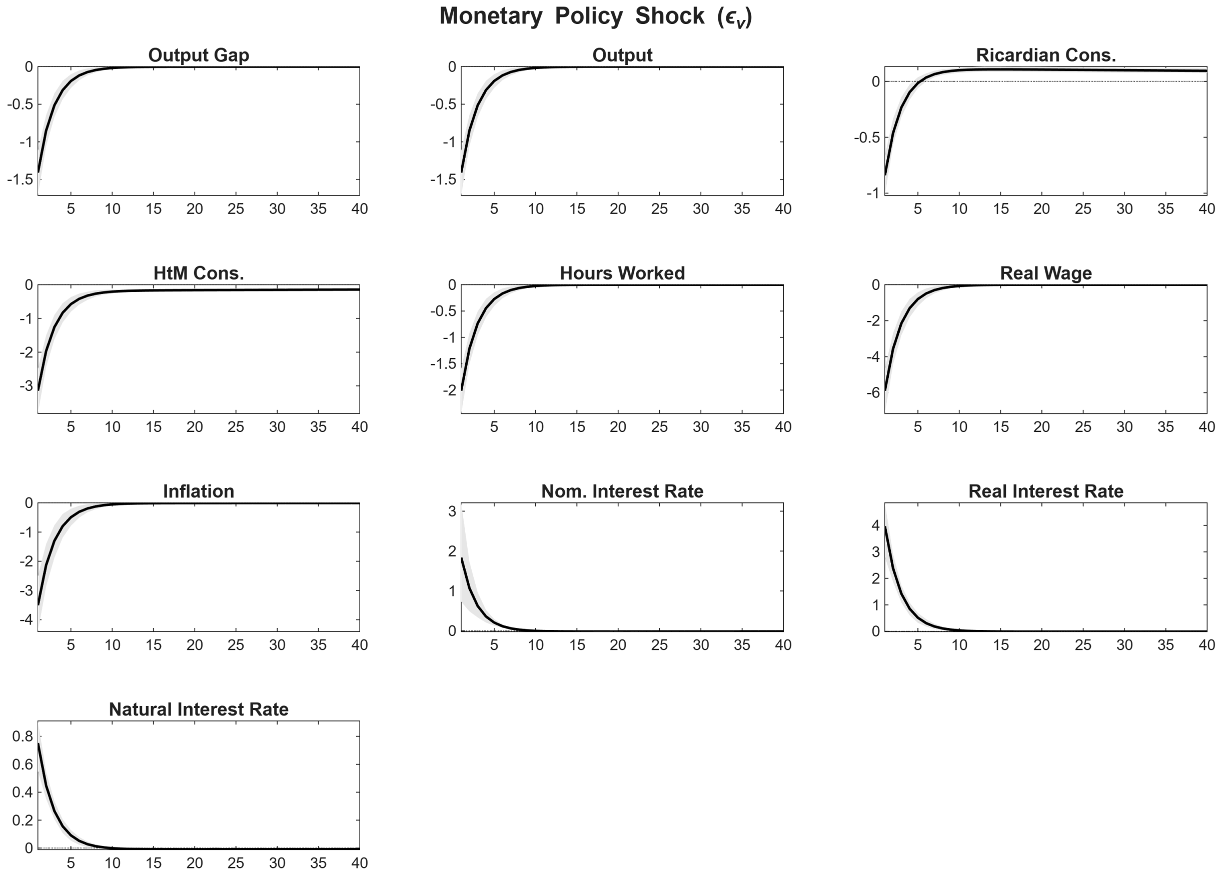


Figura 2 – Bayesian IRF: Orthogonalized shock to ε_ν.

Note: The solid black line represents the posterior mean response, while the shaded gray areas indicate the 90% Highest Posterior Density (HPD) intervals. All responses are measured in percentage deviations from their respective steady states. The horizontal axis represents quarters after the shock.
Source: Own elaboration (2026)

5.1.3 Technology Shocks

In Figure 3, an exogenous technology shock affects the whole economy positively. The output gap declines, as actual output increases less than natural output. Both types of households experience an increase in their consumption. Employment declines, whereas real wages rise. Regarding interest rates, all of them are reduced, including the natural interest rate, for which technology shocks are an important driver (HOLSTON; LAUBACH;

WILLIAMS, 2017; FIORENTINI et al., 2018; JUáREZ, 2023). The results for this dynamic response were consistent with the literature, especially with Galí (2015).

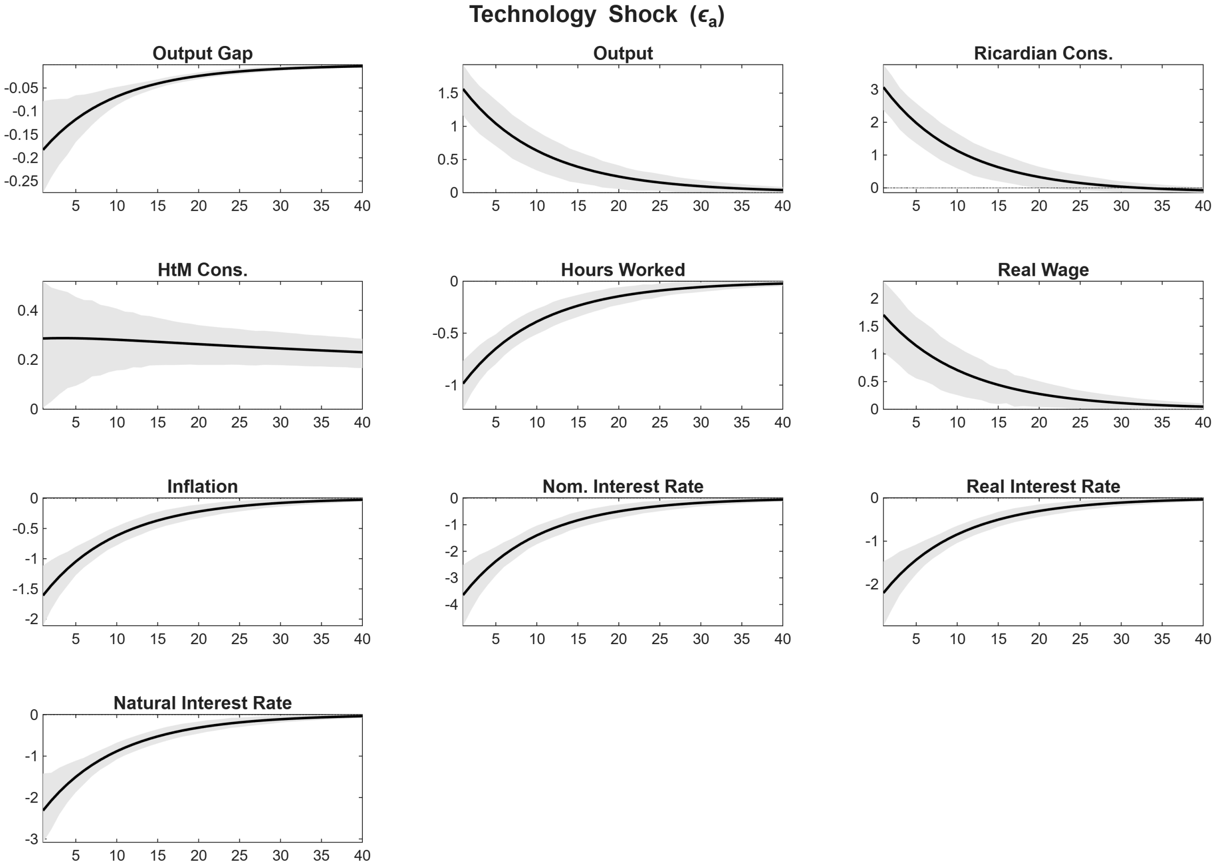


Figura 3 – Bayesian IRF: Orthogonalized shock to ε_a.

Note: The solid black line represents the posterior mean response, while the shaded gray areas indicate the 90% Highest Posterior Density (HPD) intervals. All responses are measured in percentage deviations from their respective steady states. The horizontal axis represents quarters after the shock.
Source: Own elaboration (2026)

5.1.4 Discount Rate Shocks

Regarding the dynamic responses to a positive preference shock (ε_z), all macroeconomic variables increase (see Figure 4). The shock raises consumption for both types of households, generating demand pressure. Firms respond by increasing labor demand, which leads to higher real wages. The output gap widens as actual output rises above potential.

Since this is a temporary demand shock, it does not affect natural output. The resulting inflationary pressure induces a monetary policy response, leading to an increase in the natural rate of interest.

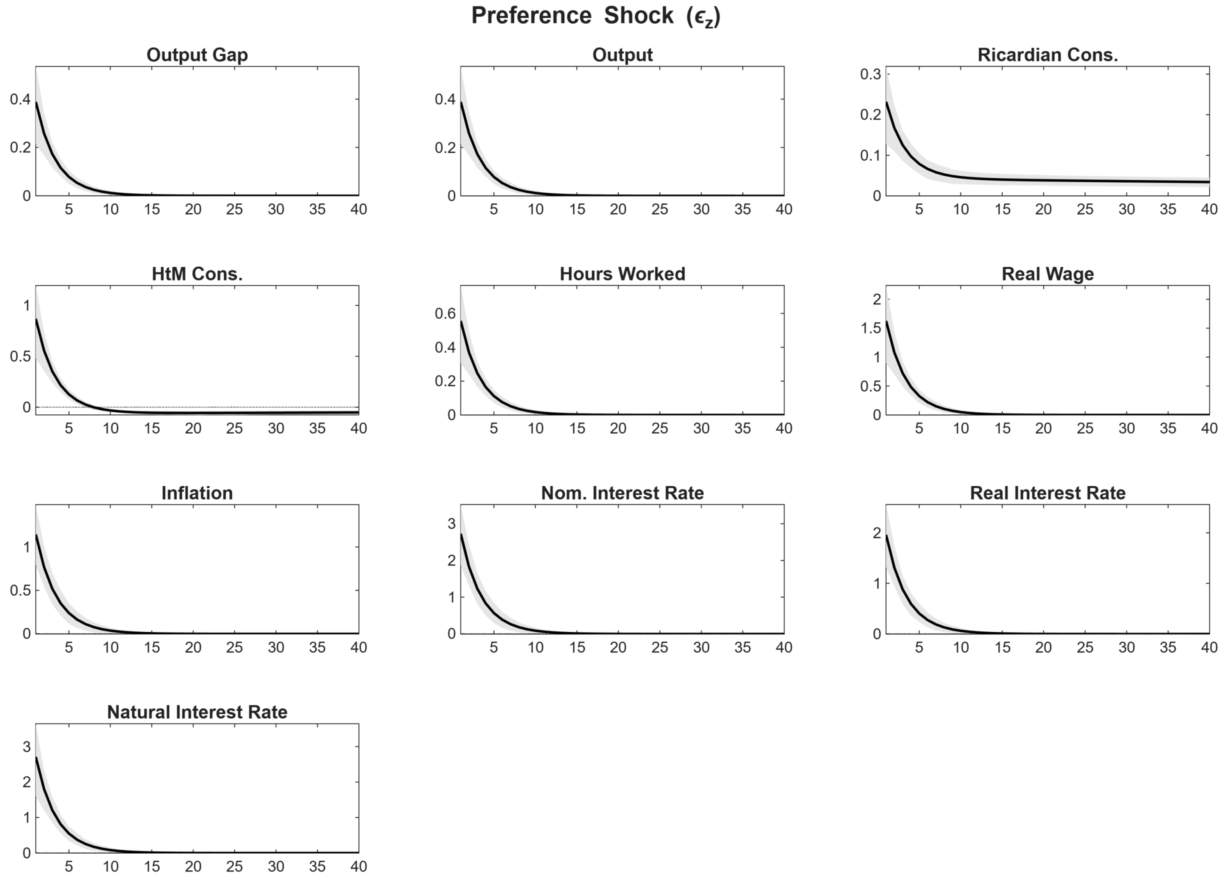


Figura 4 – Bayesian IRF: Orthogonalized shock to ε_z.

Note: The solid black line represents the posterior mean response, while the shaded gray areas indicate the 90% Highest Posterior Density (HPD) intervals. All responses are measured in percentage deviations from their respective steady states. The horizontal axis represents quarters after the shock.7
Source: Own elaboration (2026)

5.2 Counterfactual Analysis

In this section we present the results of the counterfactual analysis, which evaluates the natural rate of interest under alternative fiscal rules and compares it to the ex-ante real interest rate estimated.

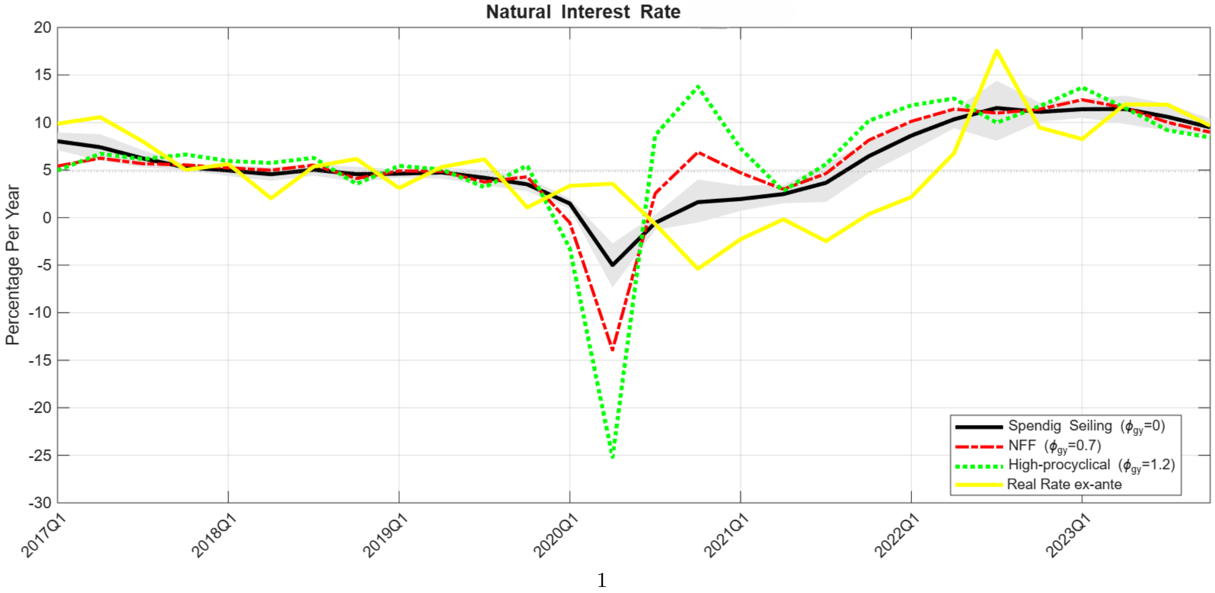


Figura 5 – Counterfactual Simulations of the Natural Rate of Interest under Alternative Fiscal Rules.

Note: The solid black line represents the estimated historical natural rate under the Spending Ceiling ($\phi_{gy} = 0$). The red dashed line and the green dotted line show counterfactual simulations for the New Fiscal Framework ($\phi_{gy} = 0.7$) and a highly procyclical rule ($\phi_{gy} = 1.2$), respectively. **Source:** Own elaboration (2026)

As Figure 5 illustrates, during the pre-pandemic period (2017–2019), the natural rate trajectories exhibit similar behavior across all rules, hovering around 5% p.a. However, the onset of the COVID-19 shock in early 2020 reveals differences between the fiscal regimes. Under the Spending Ceiling, government spending is inelastic to the business cycle. This rigidity acts as a macroeconomic stabilizer, because it maintains the public expenditure despite the GDP collapse. Consequently, the natural rate drops to approximately -5% to restore the flexible-price equilibrium.

In contrast, Figure 5 shows that the procyclical regimes force the government to drastically cut spending during recessions. The reduction in government demand lowers employment and real wages, directly reducing the income of non-Ricardian households who cannot smooth consumption. To compensate for this decline in aggregate demand and clear the goods market, the natural rate must downward to levels nearly -14% under the New Fiscal Framework and -25% under the highly procyclical rule, that induces Ricardian agents to increase current consumption.

The procyclical nature of the New Fiscal Framework is further exposed during the 2021 economic return. As GDP growth accelerates, the fiscal rule allows for a rapid expansion in public spending. This sudden fiscal impulse boosts the current income of rule-of-thumb consumers, who immediately translate it into higher consumption. To prevent inflationary pressures in the flexible-price equilibrium, the natural interest rate must increase to crowd out Ricardian private demand. Conversely, the Spending Ceiling yields a much smoother path for the natural rate, due to its acyclical nature.

The yellow solid line in Figure 5 represents the actual ex-ante real interest rate. The gap between this rate and natural rate defines the monetary policy stance. Under procyclical fiscal rules, the natural rate is more volatile and often significantly distant of the ex-ante real interest rate, which implies a more challenging environment for the Central Bank to achieve its inflation target. In contrast, the Spending Ceiling provides a more stable natural rate trajectory that is closer to the ex-ante real interest rate, facilitating the conduct of monetary policy. Figure 6 shows that in moments of economic upswings, the procyclical fiscal rules lead to a significant increase in the natural rate of interest, which can generate inflationary pressures (Equation 46) and force the Central Bank to adopt a more aggressive tightening stance. Conversely, during downturns, these rules can lead to a sharp decline in the natural rate, which may limit the effectiveness of monetary policy and hinder economic recovery. The Spending Ceiling, by contrast, provides a more stable environment for monetary policy to operate effectively across the business cycle.

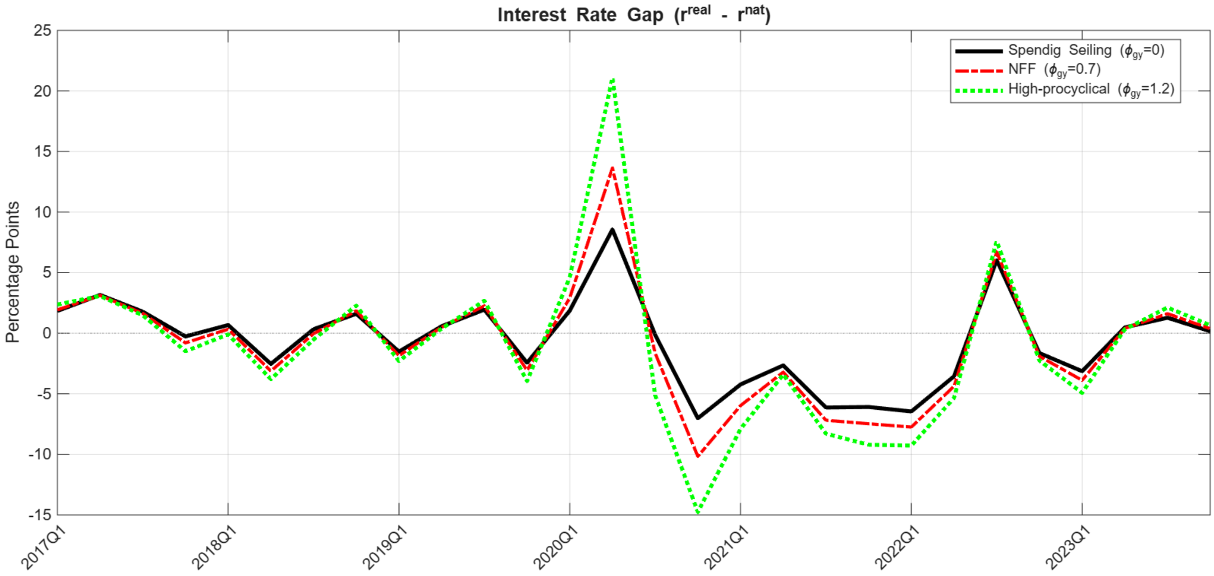


Figura 6 – Counterfactual Simulations of the Interest Rate Gap under Alternative Fiscal Rules.

Note: The solid black line represents the estimated historical natural rate under the Spending Ceiling ($\phi_{gy} = 0$). The red dashed line and the green dotted line show counterfactual simulations for the New Fiscal Framework ($\phi_{gy} = 0.7$) and a highly procyclical rule ($\phi_{gy} = 1.2$), respectively. **Source:** Own elaboration (2026)

5.3 Historical Decomposition

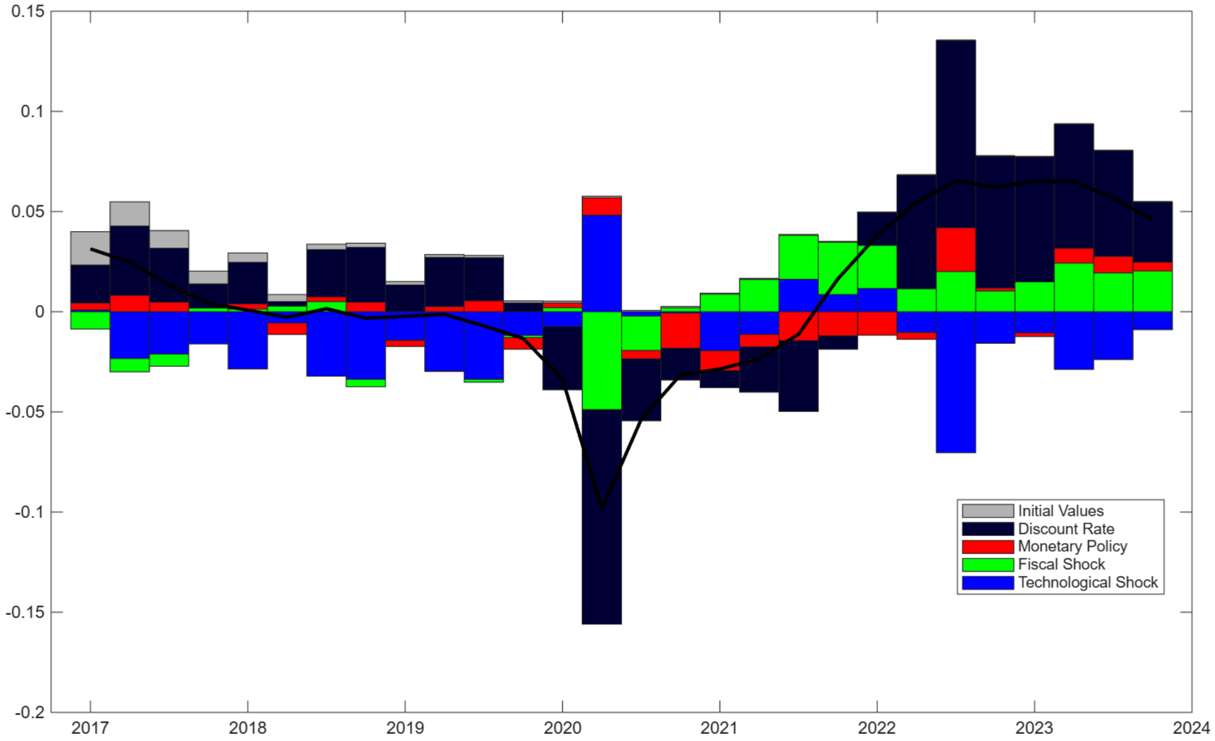


Figura 7 – Historical Decomposition of the Natural Interest Rate.

Note: The solid black line represents the overall trajectory of r^{nat} in deviations from its steady state. The dark blue bars represent shocks to the discount rate (preference shocks); the green bars denote fiscal shocks (government spending); the light blue bars show technological (TFP) shocks; and the red bars represent the contribution of monetary policy shocks. The gray bars correspond to the effect of initial state values in the Kalman filter. **Source:** Own elaboration (2026)

Figure 7 illustrates the historical decomposition of the natural rate of interest. The results highlight that the primary drivers of the natural rate's dynamics are shocks to the discount factor and technology shocks, as documented by Holston, Laubach and Williams (2017), Fiorentini et al. (2018), and fiscal shocks, as emphasized by Peterman and Sager (2025), Laubach (2009).

During the 2020 pandemic episode, the natural rate was predominantly driven downward by a negative discount rate shock, reflecting a sharp increase in households' liquidity preference amid heightened uncertainty. In addition, fiscal shocks also contributed to this decline, as government spending does not react to the business cycle, which is consistent with the acyclical feature of the Spending Ceiling.

In the recovery period from 2021 onward, fiscal shocks became a stronger driver of the natural rate. The expansion of public expenditures, amplified through the income channel of hand-to-mouth households, increased aggregate demand in the flexible-price equilibrium, exerting sustained upward pressure on r^{nat}. Even under the Spending Ceiling, realized fiscal shocks were sufficient to keep the natural rate elevated. This may help explain the Central Bank's difficulty in bringing inflation back to target despite the high nominal interest rate, possibly reflecting the flexibilization of the Spending Ceiling that allowed additional government spending beyond the rule. In the post-2022 period, the sustained positive contribution of the discount rate component suggests that shifts in household preferences have also played a significant role in pushing the Brazilian natural rate to higher levels. Finally, the historical contribution of technological shocks shows that these shocks played an important role in stabilizing the natural interest rate over time. When upward pressure arose, mainly due to preference shocks, technological shocks offset these effects by exerting downward pressure on the natural rate.

Tabela 4 – Unconditional Variance Decomposition (in percent)

	ε_a	ε_ν	ε_z	ε_g
$\tilde{y}$	4.68	86.45	7.59	1.28
y	78.69	18.78	1.65	0.89
y^{nat}	99.82	0.00	0.00	0.18
c^o	94.98	4.23	0.54	0.25
c^r	25.50	67.93	5.55	1.03
n	41.36	51.66	4.54	2.44
$\frac{w}{p}$	20.89	71.90	6.31	0.90
π^{ann}	38.72	53.98	6.79	0.52
i^{ann}	77.94	5.76	15.06	1.23
$r^{nat,ann}$	63.51	1.99	29.80	4.71
b	65.92	29.63	3.75	0.70

Note: The table displays the percentage of the unconditional variance of each variable explained by the respective structural shocks: technology (ε_a), monetary policy (ε_ν), preference (ε_z), and government spending (ε_g).**Source:** Own elaboration (2026)

It is also worth noting that monetary policy shocks exert an indirect influence on the natural rate of interest through the fiscal channel. As shown in the analytical derivation of r_t^{nat}, the natural rate is increasing in expected changes in tax revenues, captured by the term $\frac{\Theta_t}{\Theta_i}\mathbb{E}_t\{\Delta t_{t+1}\}$. Since the tax rule responds to the public debt level (Equation 32) a contractionary monetary shock that raises the nominal interest rate mechanically increases the debt-to-GDP ratio due to higher interest payments on outstanding public debt, which in turn induces higher future tax revenues.

Since higher future taxes are required to finance the increased interest payments on public debt, the liquidity-constrained households face a reduction of their expected future disposable income. To restore goods market equilibrium in the flexible-price environment, the natural rate of interest must rise. This higher rate induces Ricardian households to substitute intertemporally their consumption toward the future, thereby absorbing the debt issuance today and compensating for the future demand shortfall generated by non-Ricardian agents.

This feedback from monetary policy to debt, and from debt to taxes, generates upward pressure on the natural rate, that is a result consistent with the recent literature on the interaction between monetary policy and the neutral rate (GARABEDIAN, 2025; MCKAY; WIELAND, 2021).

6 Robustness Analysis

This section assesses the reliability of the results presented in previous chapters through two complementary procedures: (i) verification of the identification of the estimated parameters; (ii) convergence diagnostics for the Markov chains.

6.1 Parameter Identification

The validity of Bayesian inference in DSGE models depends fundamentally on the identification of the estimated parameters. Unidentified parameters tend to generate posterior distributions that are collinear with the priors. To verify identification, we employ Dynare's `identification` command, which simultaneously evaluates four distinct criteria in the neighborhood of the prior values.

The results confirm that all eight estimated parameters are identified according to the criteria of Iskrev (2010). The Jacobian matrix exhibited full rank, and no parameters were flagged as problematic.

6.2 MCMC Convergence

The Bayesian estimation utilized the Random-Walk Metropolis-Hastings algorithm, running four independent chains of 610,000 draws each, with the first 70% discarded as burn-in, resulting in 90,000 effective draws per chain. The acceptance rate remained close to the 25% target across all chains, with an optimal scale of $jscale = 0.80$ for the jumping distribution.

Brooks and Gelman (1998) Diagnostic. The univariate and multivariate criteria of Brooks and Gelman, illustrated in Appendix B, confirm the convergence of all estimated parameters. The interval and moment measures stabilize throughout the iterations, indicating that the posterior space has been sufficiently explored.

Inefficiency Factors. The MCMC inefficiency factors ranged between 27 and 41 across the four blocks (Table 5), with an average of approximately 30. These values indicate that for each parameter, the number of effective independent draws is approximately $90,000/30 = 3,000$ per chain, which is sufficient for precise inference regarding the posterior distributions.

Priors and Posteriors. Posteriors are formed based on the priors and the likelihood (CANOVA, 2007). Appendix A reports the prior and posterior distributions for the estimated parameters. In most cases, the posterior densities differ noticeably from the priors, indicating that the data are informative about the parameters. Moreover, several posterior distributions are more concentrated than their corresponding priors, suggesting that the estimation procedure reduces parameter uncertainty. For some parameters, the posterior modes are also shifted relative to the prior means, reflecting the contribution of the data in updating prior beliefs. Overall, the comparison between priors and posteriors indicates that the model is well identified and that the data play an important role in shaping the posterior distributions.

7 Conclusion

This paper estimates the natural rate of interest for the Brazilian economy over the period 2017Q1–2023Q4 using a Two-Agent New Keynesian DSGE model. By incorporating Hand-to-Mouth households and three distinct fiscal regimes: the Spending Ceiling and the New Fiscal Framework. The model allows understanding how fiscal policy affects the equilibrium real interest rate, and what the implications are for the conduct of monetary policy.

In line with the existing literature, we find that technology and preference shocks are the primary determinants of the natural rate, accounting for approximately 63% and 30% of its unconditional variance, respectively (HOLSTON; LAUBACH; WILLIAMS, 2017; FIORENTINI et al., 2018). However, the main contribution of this work is to show that fiscal shocks play a significant role in the short-run dynamics of the natural rate, particularly when government spending is governed by a procyclical rule.

The counterfactual analysis reveals interesting differences across fiscal regimes. Under the Spending Ceiling, government expenditure is insensitive to the business cycle: during the 2020 recession, spending was maintained despite the GDP collapse, preventing a sharper decline in the natural rate. In contrast, the New Fiscal Framework, by linking expenditure growth to output, forces procyclical adjustments that amplify the natural rate's volatility. During downturns, the fiscal contraction deepens the decline in r^{nat}. During expansions, the spending impulse raises the natural rate sharply, forcing the Central Bank to adopt a more aggressive tightening stance to close the gap between the policy rate and the natural rate.

The presence of Hand-to-Mouth households is central to this amplification mechanism. Since these agents consume their entire current income and cannot smooth consumption intertemporally, any fiscal expansion translates immediately into higher aggregate demand, generating additional upward pressure on the natural rate. Conversely, fiscal contractions under procyclical rules reduce the disposable income of liquidity-constrained households, amplifying the decline in aggregate demand and requiring a sharper adjustment in the natural rate to restore equilibrium.

These findings carry important implications for the coordination of fiscal and monetary policy in Brazil. A procyclical fiscal rule complicates the Central Bank's task, because it structurally shifts the natural rate in the same direction as the business cycle, creating an environment where monetary policy must work harder to achieve price stability precisely when the economy is most vulnerable. The Spending Ceiling, despite its rigidity, provides a more stable anchor for the natural rate and a more predictable environment for monetary policy.

Bibliography

ALESINA, A.; CAMPANTE, F. R.; TABELLINI, G. Why is fiscal policy often procyclical? *Journal of the European Economic Association*, v. 6, n. 5, p. 1006–1036, 09 2008. ISSN 1542-4766. Available at: <https://doi.org/10.1162/JEEA.2008.6.5.1006>.

ALVES, R. Measuring and identifying the natural rate of interest drivers in an Emerging Economy: a DSGE perspective for Brazil. 2024.

AN, S.; SCHORFHEIDE, F. Bayesian Analysis of DSGE Models. *Econometric Reviews*, v. 26, n. 2-4, p. 113–172, Apr. 2007. ISSN 0747-4938, 1532-4168. Available at: <https://www.tandfonline.com/doi/full/10.1080/07474930701220071>.

BASSETTO, M.; SARGENT, T. J. Shotgun Wedding: Fiscal and Monetary Policy. *Annual Review of Economics*, Annual Reviews, v. 12, n. Volume 12, 2020, p. 659–690, 2020. ISSN 1941-1391. Type: Journal Article. Available at: <https://www.annualreviews.org/content/journals/10.1146/annurev-economics-091319-050022>.

BIANCHI, F.; FACCINI, R.; MELOSI, L. *Fiscal policy and real interest rates.* Copenhagen, 2024. Available at: <https://hdl.handle.net/10419/310401>.

BORGES, B. L.; SILVA, M. B. d. Estimando a taxa de juros natural para o brasil: uma aplicação da metodologia var estrutural. *Estudos Econômicos (São Paulo)*, SciELO Brasil, v. 36, n. 1, p. 87–114, 2006.

BRAND, C.; BIELECKI, M.; PENALVER, A. The Natural Rate of Interest: Estimates, Drivers, and Challenges to Monetary Policy. *SSRN Electronic Journal*, 2018. ISSN 1556-5068. Available at: <https://www.ssrn.com/abstract=3328536>.

CALVO, G. A. Staggered prices in a utility-maximizing framework. *Journal of Monetary Economics*, v. 12, n. 3, p. 383–398, Sep. 1983. ISSN 0304-3932. Available at: <https://www.sciencedirect.com/science/article/pii/0304393283900600>.

CAMPOS, R. G.; FERNÁNDEZ-VILLAVERDE, J.; BARRAU, G. N.; PAZ, P. *Navigating by Falling Stars: Monetary Policy with Fiscally Driven Natural Rates.* [S.l.], 2024. Working Paper. Available at: <https://www.bis.org/publ/work1172.pdf>.

CANOVA, F. Bayesian Analysis of DSGE Models by S. An and F. Schorfheide. *Econometric Reviews*, v. 26, n. 2-4, p. 187–192, Apr. 2007. ISSN 0747-4938, 1532-4168. Available at: <http://www.tandfonline.com/doi/abs/10.1080/07474930701220162>.

CASTRO, M. R. d.; GOUVEA, S. N.; MINELLA, A.; SANTOS, R. C. d.; SOUZA-SOBRINHO, N. F. *SAMBA: Stochastic Analytical Model with a Bayesian Approach*. [S.l.], 2011. Banco Central do Brasil Working Paper Series. Available at: <https://www.bcb.gov.br/pec/wps/ingl/wps239.pdf>.

CASTRO, M. R. D.; GOUVEA, S. N.; MINELLA, A.; SANTOS, R.; SOUZA-SOBRINHO, N. F. SAMBA: Stochastic Analytical Model with a Bayesian Approach. *Brazilian Review of Econometrics*, v. 35, n. 2, p. 103–170, Mar. 2015. ISSN 1980-2447. Available at: <https://periodicos.fgv.br/bre/article/view/57573>.

CLEMENTE, L. P. Harmonizing fiscal and monetary: optimal monetary policy under expenditure fiscal rules. May 2024. Available at: <https://hdl.handle.net/10438/35370>.

DAUDIGNON, S.; TRISTANI, O. Monetary Policy and the Drifting Natural Rate of Interest. *SSRN Electronic Journal*, 2023. ISSN 1556-5068. Available at: <https://www.ssrn.com/abstract=4366502>.

ENGEN, E. M.; HUBBARD, R. G. Federal government debt and interest rates. *NBER Macroeconomics Annual*, v. 19, p. 83–138, 2004. Available at: <https://doi.org/10.1086/ma.19.3585331>.

FARINA, B. P. C. The natural interest rate in brazil: an open economy dsge approach. 2025.

FASOLO, A. M.; ARAUJO, E.; JORGE, M. V.; KORNELIUS, A.; MARINHO, L. S. G. Brazilian macroeconomic dynamics redux: Shocks, frictions, and unemployment in SAMBA model. *Latin American Journal of Central Banking*, v. 5, n. 2, p. 100110, Jun. 2024. ISSN 2666-1438. Available at: <https://www.sciencedirect.com/science/article/pii/S2666143823000315>.

FIORENTINI, G.; GALESI, A.; PEREZ-QUIROS, G.; SENTANA, E. The Rise and Fall of the Natural Interest Rate. *SSRN Electronic Journal*, 2018. ISSN 1556-5068. Available at: <https://www.ssrn.com/abstract=3214487>.

GALÍ, J.; LÓPEZ-SALIDO, D.; VALLÉS, J. *Understanding the Effects of Government Spending on Consumption*. Frankfurt am Main, Germany, 2004. ECB Working Paper Series No. 339, April 2004. Available at: <https://www.ecb.europa.eu/pub/pdf/scpwps/ecbwp339.pdf>.

GALí, J. *Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework and Its Applications Second edition*. 2. ed. Princeton University Press, 2015. (Economics Books, 10495). Available at: <https://ideas.repec.org/b/pup/pbooks/10495.html>.

GARABEDIAN, G. *Star-struck: Monetary Policy and the Neutral Rate*. Dublin, Ireland, 2025. Available at: <https://www.centralbank.ie/docs/default-source/publications/research-technical-papers/04rt25-star-struck-monetary-policy-and-the-neutral-rate-(garabedian).pdf?sfvrsn=af03681a_4>.

HOLSTON, K.; LAUBACH, T.; WILLIAMS, J. C. Measuring the natural rate of interest: International trends and determinants. *Journal of International*

Economics, v. 108, p. S59–S75, May 2017. ISSN 0022-1996. Available at: <https://www.sciencedirect.com/science/article/pii/S0022199617300065>.

ISKREV, N. Local identification in dsge models. *Journal of Monetary Economics*, v. 57, n. 2, p. 189–202, March 2010. Available at: <https://ideas.repec.org/a/eee/moneco/v57y2010i2p189-202.html>.

JUNIOR, C. J. C.; GARCIA-CINTADO, A. C.; JUNIOR, K. M. A taxa de juros natural em modelos DSGE: o caso do Brasil. *Economia Aplicada*, v. 27, n. 4, p. 433–453, Dec. 2023. ISSN 1980-5330. Available at: <https://revistas.usp.br/ecoa/article/view/189734>.

JUáREZ, C. A. Z. Understanding the natural rate of interest for a small open economy. *Latin American Journal of Central Banking*, v. 4, n. 3, p. 100093, 2023. ISSN 2666-1438. Available at: <https://www.sciencedirect.com/science/article/pii/S2666143823000145>.

LAUBACH, T. New Evidence on the Interest Rate Effects of Budget Deficits and Debt. *Journal of the European Economic Association*, Oxford University Press, v. 7, n. 4, p. 858–885, 2009. ISSN 15424766, 15424774. Available at: <http://www.jstor.org/stable/40282791>.

LAUBACH, T.; WILLIAMS, J. C. Measuring the Natural Rate of Interest. *Review of Economics and Statistics*, v. 85, n. 4, p. 1063–1070, Nov. 2003. ISSN 0034-6535, 1530-9142. Available at: <https://direct.mit.edu/rest/article/85/4/1063-1070/57446>.

LEEPER, E. M. Equilibria under ‘active’ and ‘passive’ monetary and fiscal policies. *Journal of Monetary Economics*, v. 27, n. 1, p. 129–147, Feb. 1991. ISSN 03043932. Available at: <https://linkinghub.elsevier.com/retrieve/pii/030439329190007B>.

MCKAY, A.; WIELAND, J. F. Lumpy Durable Consumption Demand and the Limited Ammunition of Monetary Policy. *Econometrica*, v. 89, n. 6, p. 2717–2749, 2021. ISSN 0012-9682. Available at: <https://www.econometricsociety.org/doi/10.3982/ECTA18821>.

MIRANDA, P. C. D.; MUINHOS, M. K. A taxa de juros de equilíbrio: uma abordagem múltipla. *Economia Aplicada*, v. 9, n. 2, p. 171–186, Apr. 2005. ISSN 1980-5330, 1413-8050. Available at: <https://www.revistas.usp.br/ecoa/article/view/221399>.

MOREIRA, J. R. R. Natural rate of interest estimates for Brazil after adoption of the inflation-targeting regime. *Bank of Brazil staff paper*, 2019.

MOURA, G. V. Multiplicadores Fiscais e Investimento em Infraestrutura. *Revista Brasileira de Economia*, Fundação Getúlio Vargas, v. 69, p. 75–104, 2015. ISSN 0034-7140, 1806-9134. Available at: <https://www.scielo.br/j/rbe/a/VWbbPkzS4qkMzKmGMgB4pTK/?format=html&lang=pt>.

NOBREGA, W. C. L.; BESARRIA, C. D. N.; ARAGóN, E. K. D. S. B. Public debt management and the interaction between fiscal and monetary policies. *Journal of Economic Studies*, v. 49, n. 6, p. 1092–1116, Aug. 2022. ISSN 0144-3585. Available at: <http://www.emerald.com/jes/article/49/6/1092-1116/432622>.

PERRELLI, R.; ROACHE, S. Time-Varying Neutral Interest Rateâ€”The Case of Brazil. *IMF Working Papers*, International Monetary Fund (IMF), v. 14, n. 84, p. 1, 2014. ISSN 1018-5941. Available at: <http://dx.doi.org/10.5089/9781484385210.001>.

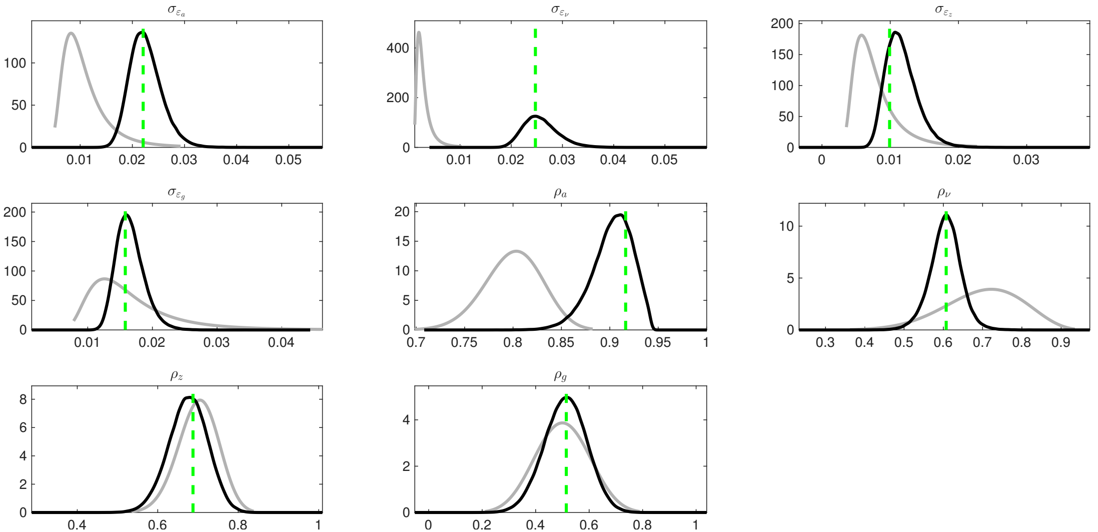
PETERMAN, W. B.; SAGER, E. *Public Debt and Interest Rates*. [S.l.], 2025. Preliminary draft, December 9, 2025. Available at: <https://www.ericksager.com/uploads/3/8/0/3/3803061/ps_debt_interest.pdf>.

WICKSELL, K. *Interest and Prices: A Study of the Causes Regulating the Value of Money*. London: Macmillan, 1936. Translated by R. F. Kahn from the 1898 German edition.

WOODFORD, M. Optimal Interest-Rate Smoothing. *The Review of Economic Studies*, v. 70, n. 4, p. 861–886, Oct. 2003. ISSN 0034-6527. Available at: <https://doi.org/10.1111/1467-937X.00270>.

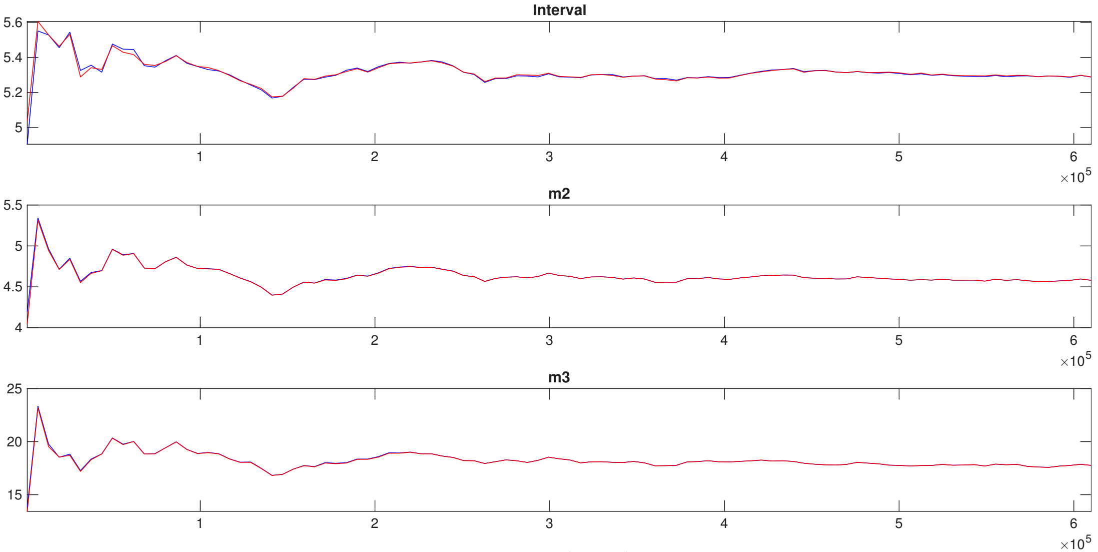
Apêndices

Appendix A – Priors and Posteriors

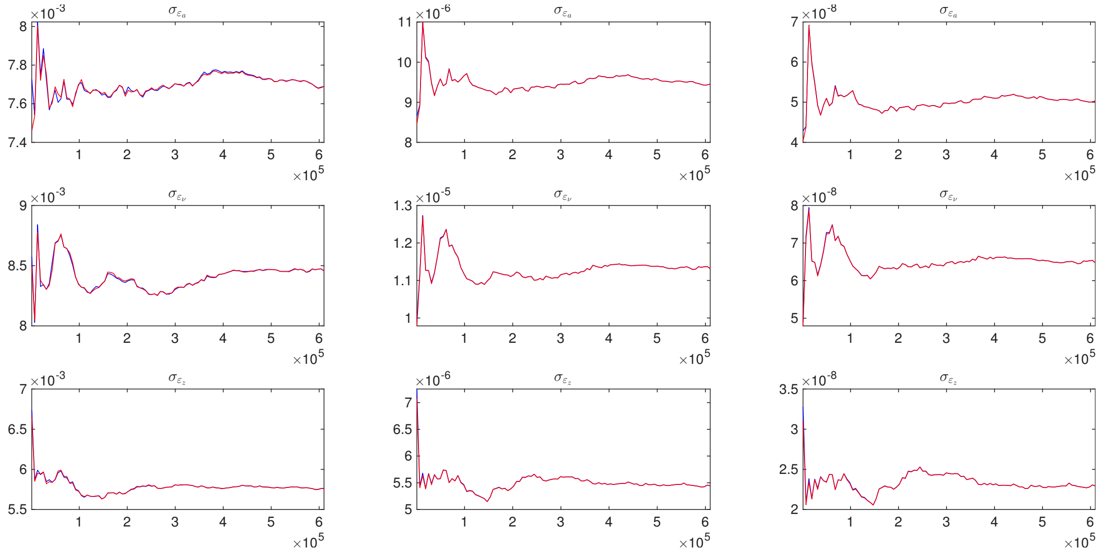


Note: The figure compares the prior distributions (gray lines) with the estimated posterior distributions (black lines). The green dashed line indicates the posterior mode. A significant difference between the prior and posterior distributions suggests that the data provided substantial information for the estimation of the structural parameters. **Source:** Own elaboration (2026).

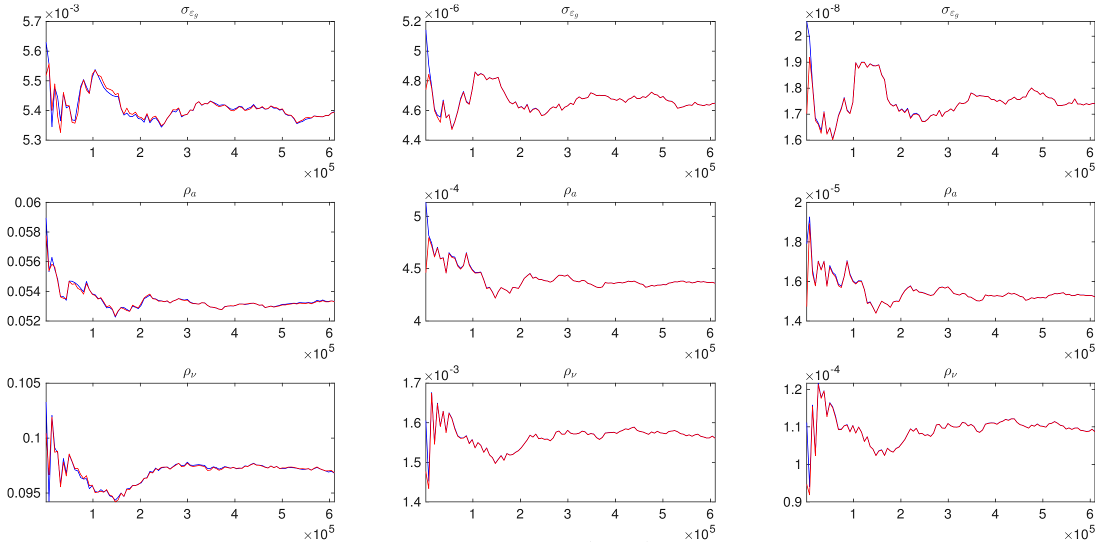
Appendix B – Convergence Diagnostics (Brooks and Gelman)



Note: This figure displays the Brooks and Gelman (1998) convergence diagnostics. The multivariate measures are based on the analysis of 80% of the MCMC draws. Convergence is achieved when the red line and the blue line stabilize and track each other closely for the Interval, m2, and m3 measures. **Source:** Own elaboration (2026).

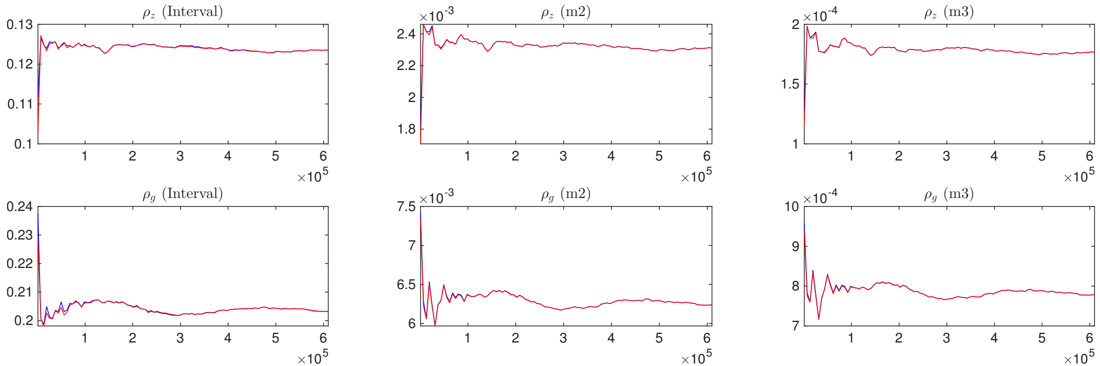


Note: This figure displays the Brooks and Gelman (1998) convergence diagnostics. The univariate measures are based on the analysis of 80% of the MCMC draws. Convergence is achieved when the red line and the blue line stabilize and track each other closely for the Interval, m2, and m3 measures. **Source:** Own elaboration (2026).



Note: This figure displays the Brooks and Gelman (1998) convergence diagnostics. The univariate measures are based on the analysis of 80% of the MCMC draws. Convergence is achieved when the red line and the blue line stabilize and track each other closely for the Interval, m2, and m3 measures. **Source:** Own elaboration (2026).

Appendix C – MCMC Inefficiency Factors



Note: This figure displays the Brooks and Gelman (1998) convergence diagnostics. The univariate measures are based on the analysis of 80% of the MCMC draws. Convergence is achieved when the red line and the blue line stabilize and track each other closely for the Interval, m2, and m3 measures. **Source:** Own elaboration (2026).

Tabela 5 – MCMC Inefficiency Factors (Integrated Autocorrelation Time)

Parameter	Chain 1	Chain 2	Chain 3	Chain 4
σ_{ε_a}	31.253	32.163	32.117	30.272
σ_{ε_ν}	35.488	36.872	34.525	34.579
σ_{ε_z}	39.929	41.745	41.825	39.361
σ_{ε_g}	37.240	39.836	35.618	33.975
ρ_a	37.582	41.065	40.692	37.184
ρ_ν	33.734	33.052	33.858	29.311
ρ_z	33.903	33.023	33.306	38.958
ρ_g	30.819	28.783	34.140	27.795

Source: Own elaboration (2026).

Note: The Inefficiency Factor (or Integrated Autocorrelation Time) measures the mixing properties of the MCMC chains. It represents the number of draws required to obtain the equivalent of one independent draw from the posterior distribution. Lower values indicate better mixing and more efficient sampling.