Monetary and Fiscal Policies in Brazil and the Behavioral Approach

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Abstract: This research investigates the dynamic interaction between monetary and fiscal policies in the Brazilian economy, focusing on how different approaches (rational versus behavioral) influence selected macroeconomic variables. The central objective is to analyze the differential impacts of positive shocks to government consumption and interest rates on real GDP, inflation, private consumption, public debt, primary surplus, and nominal interest rates, contrasting the responses of rational and behavioral agents. The study utilizes a New Keynesian DSGE model with Bayesian estimation to analyze quarterly data from 2000Q1 to 2023Q4. By integrating behavioral elements into the model, the research provides a deeper understanding of how economic agents' responses to policy changes shape macroeconomic outcomes. The results emphasize the importance of incorporating behavioral insights into economic models to capture the diverse responses of agents to policy shocks. Increased predictability and transparency in government actions can mitigate initial impacts on the selected macroeconomic variables, leading to quicker stabilization. However, the slower adjustment observed in the behavioral approach highlights the need for complementary measures to address cognitive biases and enhance policy effectiveness. This paper contributes to the literature by offering a differentiated comparison between rational and behavioral approaches in the context of Brazilian macroeconomic policy. By emphasizing the importance of developing comprehensive and realistic models that reflect actual economic agent behavior, this research aids in formulating more effective public policies that promote sustained economic growth and stability in Brazil.

Keywords: Bayesian Estimations; Behavioral Agents; Fiscal Policy; Monetary Policy; New Keynesian DSGE Model.

Area: 01 – Macroeconomics.

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Resumo: Esta pesquisa investiga a interação dinâmica entre as políticas monetária e fiscal na economia brasileira, concentrando-se em como diferentes abordagens (racional versus comportamental) influenciam variáveis macroeconômicas selecionadas. O objetivo central é analisar os impactos diferenciais de choques positivos no consumo do governo e nas taxas de juros sobre o PIB real, a inflação, o consumo privado, a dívida pública, o superávit primário e as taxas de juros nominais, contrastando as respostas dos agentes racionais e comportamentais. O estudo utiliza um modelo DSGE novo-keynesiano com estimativa bayesiana para analisar dados trimestrais de 2000T1 a 2023T4. Ao integrar elementos comportamentais ao modelo, a pesquisa proporciona uma compreensão mais profunda de como as respostas dos agentes econômicos às mudanças nas políticas moldam os resultados macroeconômicos. Os resultados enfatizam a importância de incorporar percepções comportamentais aos modelos econômicos para capturar as diversas respostas dos agentes aos choques de políticas. O aumento da previsibilidade e da transparência nas ações do governo pode atenuar os impactos iniciais sobre as variáveis macroeconômicas selecionadas, levando a uma estabilização mais rápida. Entretanto, o ajuste mais lento observado na abordagem comportamental destaca a necessidade de medidas complementares para lidar com vieses cognitivos e aumentar a eficácia das políticas. Este artigo contribui para a literatura ao oferecer uma comparação diferenciada entre as abordagens racional e comportamental no contexto da política macroeconômica brasileira. Ao enfatizar a importância de desenvolver modelos abrangentes e realistas que reflitam o comportamento real dos agentes econômicos, esta pesquisa ajuda a formular políticas públicas mais eficazes que promovam o crescimento econômico sustentado e a estabilidade no Brasil.

Palavras-chave: Estimativas Bayesianas; Agentes Comportamentais; Política Fiscal; Política Monetária; Modelo DSGE Novo-Keynesiano.

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1 Introduction

The dynamic interaction between monetary and fiscal policies is a critical area of economic research, especially in emerging markets such as Brazil, where policy coordination and the behavior of economic agents significantly affect macroeconomic stability. This paper seeks to elucidate the specific dynamics of these policy interactions, focusing on how different structures of approaches - rational versus behavioral - affect selected macroeconomic variables, especially real GDP, inflation, private consumption, public debt, primary surplus, and nominal interest rate. The central objective of this research is to analyze the differential impacts of positive shocks to government consumption and nominal interest rate in the Brazilian economy, contrasting the responses of rational and behavioral agents.

The underlying hypothesis postulates that the behavioral approach, which incorporates elements of bounded rationality and cognitive biases, is more in line with the traditionally observed behavior of Brazilian economic policies than the purely rational approach. This hypothesis is based on the notion that Brazilian economic policies generally have characteristics that reflect a more gradual and adaptive response to policy changes, typical of behavioral dynamics.

To achieve this goal, the study employs a New Keynesian DSGE model with quarterly Bayesian estimation, covering the period from 2000Q1 to 2023Q4. The model was designed to reflect the idiosyncrasies of the Brazilian economy, incorporating both the rational and behavioral behavior of agents. The research uses Impulse Response Functions (IRF) to evaluate the dynamic effects of policy shocks, providing a comparative analysis of the two expectation structures. This paper focuses on understanding how the inclusion of behavioral elements in macroeconomic models can better capture the dynamics of policy transmission in Brazil.

The aim is not to explore scenarios of fiscal or monetary dominance, nor to address issues of a zero lower bound on nominal interest rates. Instead, the research highlights the need to consider the interaction between monetary and fiscal policies, recognizing that the results of one policy cannot be totally isolated from the influence of the other or from the broader economic environment. The basis of this research is built on seminal papers that have shaped the understanding of monetary and fiscal policy interactions, such as the rules versus discretion debate by Kydland and Prescott (1977) and the development of the inflation targeting regime, as discussed by Clarida, Galí and Gertler (1998, 1999, 2000, 2001), and Woodford (2003). In addition, the concept of fiscal dominance, as explored by Sargent and Wallace (1981), and Fiscal Theory of the Price Level provide a fundamental background for understanding the interdependence of fiscal and monetary policies. This study contributes to the existing literature by offering a differentiated comparison between the structures of rational and behavioral approaches in the context of Brazilian macroeconomic policy.

By integrating behavioral elements into the model, the research provides a deeper understanding of how economic agents' responses to policy changes can shape macroeconomic outcomes. This approach highlights the importance of developing more comprehensive and realistic models that reflect the actual behavior of economic agents, thereby increasing effectiveness in policy formulation and implementation. Exploring the differences between rational and behavioral approaches, the paper provides policymakers with a clearer understanding of how economic agents' expectations influence the effectiveness of monetary and fiscal policies. This means that the insights gained in this research contribute to the development of more effective public policies that promote sustained economic growth and stability in Brazil.

Besides this Introduction, this paper comprises an additional five sections. Section 2 provides a brief review of the literature, while Section 3 details the methodology and model overview, including sections on the representative agent, firms, monetary policy, fiscal policy, and the dichotomy between rational and behavioral approaches. Section 4 presents the data, covering descriptive statistics, seasonality, stationarity, and observed variables treatment. Section 5 discusses the results, focusing on the impacts of positive shocks to the nominal interest rate and government consumption. Finally, Section 6 offers concluding remarks.

2 A Brief Review of Literature

The effectiveness of monetary policy in strengthening the credibility of monetary authorities has been a pivotal area of study within macroeconomics. Seminal papers such as Kydland and Prescott (1977) on the rules versus discretion approach, Barro and Gordon (1983a, 1983b) on reputation, and Rogoff (1985) on the principles of autonomy, transparency, and delegation, have significantly influenced the evolution of monetary policy structures. This academic discourse paved the way for the adoption of inflation targeting regimes, with New Zealand's early 1990s model serving as a notable example. These frameworks aimed to enhance the credibility of monetary authorities through the establishment of clear policy guidelines, aligning with theoretical models like Taylor's Rule (Taylor, 1983) and Woodford's (2001) analysis of optimal interest rate rules.

The integration of fiscal policy into this discourse has increasingly gained traction, recognizing that monetary and fiscal policies can either counterbalance or complement each other. Expansionary fiscal policies can boost aggregate demand and potentially increase inflation, while contractionary monetary policies, through higher interest rates, can dampen aggregate demand and help control inflation. Uncoordinated policies may lead to undesirable outcomes such as excessive inflation or economic downturns. This growing awareness led to a surge in research focusing on the interactions between monetary and fiscal policies, such as the pioneering paper of Sargent and Wallace (1981), which introduced the concepts of monetary and fiscal dominance and highlighted the importance of policy coordination.

The theoretical landscape expanded with contributions from Alesina and Tabellini (1990), Leeper (1991), Sims (1994), Ball and Mankiw (1995), Woodford (1995, 2003), and Cochrane (2001), culminating in the development of the Fiscal Theory of the Price Level. This theory illustrates how public debt levels can influence price levels even in scenarios where monetary policy remains unaffected by fiscal dominance.

The New Keynesian Economics underscores the necessity of optimal coordination between monetary and fiscal policies, advocating for both to adhere to the same intertemporal government budget constraint. Researchers such as Bénassy (2003), Benigno and Woodford (2003), and Muscatelli, Tirelli, and Trecroci (2004) have furthered this line of inquiry, emphasizing the interdependence of policy implementation and its crucial role in achieving macroeconomic stability.

In Brazil, several studies have analyzed the interplay between monetary and fiscal policies and their impact on economic growth. For instance, Santos et al. (2015) examined the relationship between these policies and Brazilian GDP growth from 2000 to 2014, highlighting the significant role of policy variables. De Paula, Modenesi and Pires (2015) investigated policy coordination during the international financial crises, noting varying effectiveness across different crises. The evolution of monetary policy and its interaction with fiscal stimuli was further explored by Barros and Lima (2018), providing insights into policy dynamics over time.

Finally, the emergent field of Behavioral Economics, gaining prominence through the papers of Thaler (1980) and Kahneman (2003), and its extension into Behavioral Macroeconomics, challenge the traditional economic paradigms by emphasizing the role of cognitive and emotional biases in economic decision-making. Recent studies by Benchimol and Bounader (2023) delve into how these biases influence macroeconomic policies and their outcomes, advocating for a more holistic approach to economic policymaking that incorporates psychological insights.

3 Methodology and Model Overview

The methodological treatment that will be implemented is based on New Keynesian DSGE models with Bayesian estimation, widely employed by researchers and central banks. These models allow for a more in-depth analysis, since they are grounded in microeconomic optimization, as in the papers of Bénassy (2002), which pave the way for the analysis of price and wage rigidities, and Christiano, Eichenbaum and Evans (2005), which subsequently examine how these nominal rigidities affect the dynamic effects of a monetary policy. When estimating parameters in these models, as argued by Andrade, Cordeiro and Lambais (2019), one of the main challenges is the proper identification of these parameters. Identification refers to the ability to distinguish the effects of different parameters in the model and estimate them correctly. However, this type of modeling can present identification problems, especially when considering a limited number of observed variables. This is because different combinations of parameters can generate similar results in the observable variables, making it difficult to obtain accurate estimates. These models are characterized by a theoretical and stochastic structure that describes the interactions between different economic agents over time. In this context, according to Gabaix (2020), there are two main types of approaches: rational and behavioral.

Regarding the structure of the model proposed in this paper, it will be based on Gabaix (2020), respecting the Brazilian idiosyncrasy, with comparison between rational and behavioral approaches. This proposal opens space for the insertion of a behavioral approach, while presenting monetary and fiscal parameters commonly applied in Central Bank of Brazil's models, including contemporaneously. In addition, the proposed model is a medium-range, dynamically stable model with a non-negativity constraint. The equations related to aggregate demand, natural GDP, firms' marginal cost, the Taylor Rule, public debt, government consumption, and primary surplus are the same for both approaches. The distinction lies in the incorporation of behavioral parameters in the Euler equation and the Phillips Curve.

3.1 Representative agent

First, we start with the intertemporal optimization of consumers based on Clarida, Galí and Gertler (1999), Woodford (2003), and Christiano, Eichenbaum and Evans (2005), with some adjusts. We consider a representative agent who maximizes his intertemporal utility subject to a budget constraint. In this sense, the utility function U depends on consumption c_t:

$$U = \sum_{t=0}^{\infty} \beta^t \left(\frac{c_t^{1-\nu} - 1}{1-\nu} \right) \tag{1}$$

where U is the utility function, β^t is the intertemporal discount factor $(0 < \beta < 1)$, c_t is private consumption, and ν is the risk aversion parameter.

The utility function shown in Equation (1) is subject to the budget constraint given by:

$$c_t = B_{t+1} = (1 + R_t)B_t + w_t l_t - T_t \tag{2}$$

where c_t is the consumption, B_{t+1} is the stock of securities in the immediately subsequent period, R_t is the rate of return on securities, B_t is the stock of securities, w_t is the real salary, l_t is the leisure, and T_t are the taxes paid.

Thus, the Lagrangean for this problem becomes:

$$L = \sum_{t=0}^{\infty} \beta^t \left\{ \frac{c_t^{1-\nu} - 1}{1-\nu} + \lambda_t [(1 + R_t)B_t + w_t l_t - T_t - c_t - B_{t+1}] \right\} \tag{3}$$

where L is the Lagrangean, β^t is the intertemporal discount factor $(0 < \beta < 1)$, c_t is the consumption, ν is the risk aversion parameter, λ_t is the Lagrange multiplier, R_t is the rate of return on securities, B_t is the stock of securities, w_t is the real salary, l_t is the leisure, T_t are the taxes paid, and B_{t+1} is the stock of securities in the immediately subsequent period.

The First Order Conditions (FOCs) for c_t are:

$$\beta^t c_t^{-\nu} - \lambda_t = 0 \tag{4}$$

$$-\lambda_t + \beta^{t+1} \lambda_{t+1} (1 + R_{t+1}) = 0 \tag{5}$$

where β^t is the intertemporal discount factor $(0 < \beta < 1)$, c_t is the consumption, ν is the risk aversion parameter, λ_t is the Lagrange multiplier, β^{t+1} is the intertemporal discount factor in the immediately subsequent period $(0 < \beta < 1)$, λ_{t+1} is the Lagrange multiplier in the immediately subsequent period, and R_{t+1} is the rate of return on securities in the immediately subsequent period.

Substituting λ_t into the FOCs [Equations (4) and (5)], we obtain Euler equation:

$$\frac{c_{t+1}}{c_t} = [\beta^t(1 + R_{t+1})]^{\frac{1}{\nu}} \tag{6}$$

where c_{t+1} is the consumption in the immediately subsequent period, c_t is the consumption, β^t is the intertemporal discount factor $(0 < \beta < 1)$, R_{t+1} is the rate of return on securities in the immediately subsequent period, and ν is the risk aversion parameter.

Considering the idiosyncrasy of the Brazilian economy, the deductions above and the paper of Fasolo *et al.* (2024), the aggregate demand equation will be given by:

$$y_t = s_c c_t + s_g g_t + \epsilon_t^y \tag{7}$$

where y_t is real GDP, s_c is a parameter for private consumption $(s_c = 0.8)$, c_t is private consumption, s_g is the steady state of government consumption $(s_g = 0.2)$, g_t is government consumption and ϵ_t^y captures demand shocks. Regarding the apparent overestimation of the parameter for private consumption, the consumption parameters, both private and government, were calibrated to cover the behavior of the economic data observed in an open economy, even if imperfectly. The aim is for the dynamics presented to converge more closely with real economic dynamics.

3.2 Firms

The natural GDP equation will be given by:

$$y_t^n = \left[\frac{s_c(1 + \phi)}{\sigma(1 - \alpha) + s_c(\phi + \alpha)}\right](\epsilon_t^a + 1) + m_c + \log(1 - \alpha) - \epsilon_t^c \tag{8}$$

where y_t^n is natural GDP, s_c is a parameter for private consumption $(s_c = 0.8)$, ϕ is the inertia of the marginal cost/GDP ratio $(\phi = 1)$, σ is the Intertemporal Elasticity of Substitution (IES) $(\sigma = 1.3)$, α is a parameter for the share of capital in defining natural GDP $(\alpha = 0.448)$, ϵ_t^a captures random technology shocks with a 50% inertia with respect to lagged shocks, m_c is the marginal cost of firms as a function of natural GDP and ϵ_t^c captures random consumption shocks.

The equation for the marginal cost of firms as a function of natural GDP will be given by:

$$m_c = \left(\frac{\sigma}{s_c} + \frac{1 + \phi}{1 - \alpha} - 1\right)(y_t^n) + \epsilon_t^{mc} \tag{9}$$

where m_c is the marginal cost of firms as a function of natural GDP, σ is the IES $(\sigma = 1.3)$, s_c is a parameter for private consumption $(s_c = 0.8)$, ϕ is the inertia of the marginal cost/GDP ratio $(\phi = 1)$, α is a parameter for the share of capital in defining natural GDP $(\alpha = 0.448)$, y_t^n is natural GDP and ϵ_t^{mc} captures random shocks not predicted by the marginal cost equation of firms. It should be noted that Equations (8) and (9) come from Gabaix (2020) and have their parameters calibrated according to Fasolo *et al.* (2024) to capture the idiosyncrasies of the Brazilian economy.

3.3 Monetary policy

Considering the idiosyncrasy of the Brazilian economy, and the paper of Fasolo *et al.* (2024), the monetary authority follows a Taylor rule to determine interest rates, which is given by:

$$r_t = (r_{t-1})^{\gamma r}\left[\left(r_t^n \frac{\pi_t}{\pi_t^*}\right)(y_t - y_t^n)^{\gamma y}\right]^{1-\gamma r} + \epsilon_t^r \tag{10}$$

where r_t is the nominal interest rate, r_{t-1} is the lagged nominal interest rate, γr is the interest rate smoothing $(\gamma r = 0.5)$, r_t^n is the natural interest rate, π_t is the CPI inflation, π_t^* is the inflation target, $\gamma\pi$ is the inflation parameter $(\gamma\pi = 1.5)$, y_t is the real GDP, y_t^n is the natural GDP, γy is the GDP parameter $(\gamma y = 0.5)$ and ϵ_t^r captures monetary shocks.

This rule already includes a parameter for interest rate smoothing. Monetary authorities do not act with jolts and tend not to cause big surprises to economic agents. It is this institutional communication mechanism, whether in reports or minutes, that makes it possible for important economic variables to converge, given an authority's reaction in terms of interest rates. Thus, monetary shocks happen in a more moderate process, either with cycles of interest rate hikes or interest rate cuts. And this is seen in the process of interest rate smoothing that generates, therefore, more attenuated responses of the variables in question.

3.4 Fiscal policy

Drawing upon the findings of Fasolo *et al.* (2024), the Brazilian fiscal framework can be articulated, comprising the public debt equation, the government consumption equation, and the primary surplus equation. In this context, the public debt equation will be given by:

$$b_t = r_t + \rho(b_{t-1} - \pi_{t-1} + y_{t-1} - y_t) - (\rho - 1)s_t + \epsilon_t^b \tag{11}$$

where b_t is the public debt, r_t is the nominal interest rate, ρ is the nominal interest accumulation factor ($\rho = 1.011$), b_{t-1} is the lagged government deficit, r_{t-1} is the lagged nominal interest rate, y_{t-1} is the lagged real GDP, y_t is the real GDP, s_t is the primary surplus/GDP, and ϵ_t^b captures random shocks not foreseen by the public debt equation. This equation models the variation in public debt in response to changes in the interest rate, inflation, GDP growth and the primary surplus.

The government consumption equation will be given by:

$$g_t = \gamma_g g_{t-1} + (1 - \gamma_g)(\phi_s s_{t-1}^*) - \phi_b b_{t-1} + \epsilon_t^g \tag{12}$$

where g_t is government consumption, γ_g is the government consumption smoothing parameter ($\gamma_g = 0.2$), g_{t-1} is the lagged value of government consumption, ϕ_s is the primary surplus parameter ($\phi_s = 0.5$), s_{t-1}^* is the deviation of the surplus from its target - where both values are lagged, γ_b is the government deficit parameter ($\phi_b = 0.05$), b_{t-1} is the lagged government deficit and ϵ_t^g captures fiscal shocks.

Finally, the equation for the primary surplus will be given by:

$$s_t = \overline{b} + \phi_s(s_{t-1} - \overline{b}) + \phi_{\overline{s}}(\overline{s}_t - \overline{b}) + s_g \epsilon_t^s \tag{13}$$

where s_t is the primary surplus/GDP, $\overline{b}$ is the long-term value of the primary deficit/GDP, ϕ_s is the primary surplus primary surplus ($\phi_s = 0.5$), s_{t-1} is the lagged value of the primary surplus/GDP, $\phi_{\overline{s}}$ is the parameter for the primary surplus/GDP target ($0 < \phi_{\overline{s}} < 1$), $\overline{s}_t$is the primary surplus/GDP target, s_g is the steady state of government consumption ($s_g = 0.2$), and ϵ_t^s captures shocks from government consumption but given in the primary surplus. This equation reflects how the primary surplus in the current period is influenced by the surplus in the previous period, adjusting towards a steady-state level.

It should be noted that these equations are an idiosyncratic addition to Gabaix (2020)'s model and has its parameters calibrated like Fasolo *et al.* (2024). In rational models, as argued by Gabaix (2020), Ricardian Equivalence holds, and fiscal policy has no impact. However, when there are behavioral parameters, the agent cannot perfectly anticipate future taxes. This suggests that tax cuts and transfers have a stimulative effect not expected by the economic literature, especially in the present. The agent's partial myopia shows that tax implementation is more effective when done in the present.

3.5 Rational approach

Rational approach models are characterized by the representation of economic agents as rational optimizers that maximize an objective function subject to constraints. These models are widely used in the economic literature due to their simplicity and ability to generate accurate analytical results. They are useful for analyzing specific economic issues, such as the effects of monetary or fiscal policies under different scenarios.

Monetary policy adopted include inflation targeting, even if implicit, to reinforce the commitment to economic agents. In response to a cost shock, this policy seeks to restore the price level and nominal GDP to pre-shock values. Clarida, Galí and Gertler (1999) argue that the monetary authority's commitment in this case is backed by the benefits of its anchor being the future. However, in a behavioral model, the situation is different. The benefits of the monetary authorities' commitment to economic agents are reduced. After a positive cost shock, the authority no longer sees a need to promote deflation and return to the initial inflationary level. This suggests that an inflation targeting regime is not desirable when economic agents adopt a non-rational behavior.

Moreover, it is worth noting that the rational model is widely employed to analyze economic behavior over the lifetime of agents. Within this broader context is the inheritance model. In this model, economic agents make decisions considering the prospect of passing on resources or wealth to future generations, such as their descendants. These decisions involve issues such as investments, consumption, savings, insurance, intergenerational transfers, and other forms of resource allocation [see Marglin (2021)].

Using a rational model, it is possible to investigate these inheritance and life-cycle related choices. In this sense, economic agents are assumed to be utility maximizers, considering their preferences over time, budget constraints and rational expectations. Importantly, not all rational models are explicitly formulated to incorporate inheritance as a central element. These models are a broad framework, applicable to diverse economic contexts, including the study of lifetime behavior and the analysis of inheritance-related decisions.

Households are the consumers who receive income from businesses. They pay fixed taxes to the government and can invest in government bonds. The derivation of the Euler equation made initially in Equation (6) can be extended to incorporate rational expectations and consumption shocks, resulting in a form that is consistent with Gabaix (2020)'s formulation:

$$c_t = E_t[c_{t+1}] - \frac{1}{\sigma}(r_t - E_t[\pi_{t+1}]) + \frac{1}{\sigma}(\epsilon_t^c - \epsilon_{t+1}^c) \tag{14}$$

where c_t is private consumption, E is a expectation operator, c_{t+1} is consumption in the immediately subsequent period, σ is the IES ($\sigma = 1.3$), r_t is the nominal interest rate, π_{t+1} is the CPI inflation in the immediately subsequent period, ϵ_t^c captures consumption shocks and ϵ_{t+1}^c captures consumption shocks in the immediately subsequent period. In a rational perspective, agents believe that their expectations can accurately capture the behavior of the economy over a long, although not infinite, time horizon.

Firms use labor to produce final goods, which are consumed by households and the government. In this sense, based on Gabaix (2020), the New Keynesian Phillips Curve will be given by:

$$\pi_t = \beta E_t[\pi_{t+1}] + \lambda_t + \left(\frac{\sigma}{s_c} + \frac{1+\phi}{1-\alpha} - 1\right)(y_t - y_t^n) + \epsilon_t^\pi \tag{15}$$

where π_t is the CPI inflation, β is the intertemporal discount factor $(\beta = 0.989)$, E is a expectation operator, π_{t+1} is the CPI inflation in the immediately following period, λ_t is a Lagrange multiplier $(\lambda = 1.13)$, σ is the IES $(\sigma = 1.3)$, α is a parameter for the share of capital in setting inflation $(\alpha = 0.448)$, ϕ represents the inertia of the marginal cost/GDP ratio $(\phi = 1)$, y_t is real GDP, y_t^n is natural GDP and ϵ_t^π captures the given shocks to inflation.

3.6 Behavioral transformation

Behavioral models incorporate psychological and behavioral elements of economic agents. These models consider that individuals are not perfect rational optimizers, but rather make decisions based on heuristic rules, adaptive expectations, or social interactions. This approach considers the influence of non-purely economic factors on agents' decisions, such as cultural influences, cognitive biases, and social learning. Behavioral models can better capture the characteristics of human behavior and provide deeper insights into complex economic phenomena such as speculative bubbles and confidence cycles. This differentiation between rational and behavioral approaches can be seen, for example, in Gabaix (2020), where the author argues that economic inequality can have a significant impact on the economy as a whole and that policy measures to reduce inequality can be beneficial for social welfare. Behavioral Macroeconomics seeks to incorporate behavioral characteristics of economic agents into macroeconomic models. One way to capture these characteristics is through estimations of behavioral parameters using time series techniques or cross-section analysis. These parameters represent the preferences, expectations, and decision-making of economic agents, allowing for a more realistic analysis of macroeconomic behavior. Examples of papers that have done this capture of behavioral parameter values are Carroll (2003), Duflo and Saez (2003), Angeletos, Collard and Dellas (2018), and Gabaix (2020).

The Euler equation, in the case of the behavioral approach, receives the inclusion of a behavioral parameter and the new equation is given by:

$$c_t = ME_t[c_{t+1}] - \frac{1}{\sigma}(r_t - E_t[\pi_{t+1}]) + \frac{1}{\sigma}(\epsilon_t^c - \epsilon_{t+1}^c) \tag{16}$$

where c_t is private consumption, M is an inattention macro-parameter measuring cognitive discounting of the future $(M = 0.8)$, E is a expectation operator, c_{t+1} is consumption in the immediately subsequent period, σ is the IES ($\sigma = 1.3$), r_t is the nominal interest rate, π_{t+1} is the CPI inflation in the immediately subsequent period, ϵ_t^c captures consumption shocks and ϵ_{t+1}^c captures consumption shocks in the immediately subsequent period.

Regarding the use of the inattention parameter (M), it represents a non-standard feature of cognitive discounting. Accordingly, it is inferred that the economy and its trajectory over time is not fully understood by agents. This becomes clearer when it comes to events that are far away on the time horizon, calling into question how far expectations can absorb from economic behavior. Gabaix (2020) assumes that agents simulate the future, but these simulations are limited by a convergence to the steady state of the economy. To mathematically capture this process, we use a value that considers the expectations period adopted by Central Bank of Brazil, which is up to four years [see Central Bank of Brazil (2023a)]. This implies that, after this period, the expectations of economic agents cease to influence their decisions. This approach reflects the behavioral aspect of the proposed model. The existence of a perceived limit on the horizon suggests that expectations cease to be rational. As a result, the impact of future behavior on present expectations is limited.

The inattention parameter is also included in the New Keynesian Phillips Curve and the new equation is given by:

$$\pi_t = M\beta E_t[\pi_{t+1}] + \lambda_t + \left(\frac{\sigma}{s_c} + \frac{1+\phi}{1-\alpha} - 1\right)(y_t - y_t^n) + \epsilon_t^\pi \tag{17}$$

where π_t is the CPI inflation, M is an inattention macro-parameter $(M = 0.8)$, β is the intertemporal discount factor $(\beta = 0.989)$, E is a expectation operator, π_{t+1} is the CPI inflation in the immediately following period, λ_t is a Lagrange multiplier $(\lambda = 1.13)$, σ is the IES $(\sigma = 1.3)$, α is a parameter for the share of capital in setting inflation $(\alpha = 0.448)$, ϕ represents the inertia of the marginal cost/GDP ratio $(\phi = 1)$, y_t is real GDP, y_t^n is natural GDP and ϵ_t^π captures the given shocks to inflation.

It is worth noting that the inattention parameter (M) has the same value in Equations (16) and (17) because it is an expectational parameter and not a parameter related to a specific variable. Moreover, when the macro-parameter of inattention (M) and the intertemporal discount factor (β) are linked, the expectations horizon is smoothed. It brings a smaller influence of expectations about the future in relation to present behavior.

Finally, it should be noted that the modeling is based on Gabaix (2020), a macroeconomic model applicable even to smaller economies like Brazil. Additionally, the parameter values have been updated in line with the recent findings of Fasolo *et al.* (2024) on the Brazilian economy, ensuring the model accurately reflects the specific idiosyncrasies of the analyzed economic behavior.

4 Data

For the estimations of this paper, the Dynare/Matlab package will be used, together with a quarterly database ranging from 2000Q1 to 2023Q4, and equations already log linearized. In continuity, the set of variables to be observed is as follows:

- Government consumption (g_t): quarterly government consumption (% of GDP). Source: Brazilian Institute of Geography and Statistics (2024b).

- IPCA CPI inflation (π_t): quarterly accumulated IPCA CPI inflation. Source: Brazilian Institute of Geography and Statistics (2024a).
- Selic nominal interest rate (r_t): quarterly Selic nominal interest rate. Source: Central Bank of Brazil (2024b).
- Real GDP index (y_t): quarterly real GDP index, seasonally adjusted by Brazilian Institute of Geography and Statistics, base year of 1995. Source: Brazilian Institute of Geography and Statistics (2024b).

4.1 Descriptive statistics of observed variables

Table 1 presents descriptive statistics of the observed economic variables in our model: government consumption (g_t), IPCA CPI inflation (π_t), Selic nominal interest rate (r_t), and real GDP index (y_t).

The mean government consumption is 18.73% of GDP, indicating that this expenditure represents almost one-fifth of the Brazilian GDP. The median, very close to the mean, at 18.57% of GDP, suggests a balanced distribution of government consumption around this central value, with observations ranging from a minimum of 17.45% to a maximum of 20.51% of GDP. This shows that variable remained relatively stable throughout the observed period.

Table 1 - Descriptive statistics of the observed variables

Statistics	**Government consumption** (g_t)	**IPCA CPI inflation** (π_t)	**Selic nominal interest rate** (r_t)	**Real GDP index** (y_t)
Mean	18.73 % of GDP	1.53% per quarter	2.91% per quarter	152.62
Median	18.57% of GDP	1.42% per quarter	2.88% per quarter	163.49
Minimum	17.45% of GDP	-1.06% per quarter	0.47% per quarter	109.00
Maximum	20.51% of GDP	6.19% per quarter	6.02% per quarter	183.94
SD	0.79% of GDP	0.95% per quarter	1.16% per quarter	23.11

Note: 96 observations (from 2000Q1 to 2023Q4).
Sources: Brazilian Institute of Geography and Statistics (2023a, 2023b) and Central Bank of Brazil (2024c).

Regarding IPCA CPI inflation, the mean is 1.53% per quarter, with a slightly lower median of 1.42%. The minimum recorded was a deflation of -1.06% per quarter, while the maximum reached was an inflation of 6.19% per quarter. This wider variation in inflation suggests periods of significant volatility in consumer prices. As for the Selic nominal interest rate, the quarterly mean was 2.91%, with the median close at 2.88%. The minimum rate was only 0.47% per quarter, contrasting with a maximum of 6.02%, indicating substantial fluctuations in monetary policy to respond to variable economic conditions.

The real GDP index showed a mean of 152.62, with a higher median of 163.49, reflecting variations in economic performance over time. The minimum recorded was 109.00 and the maximum was 183.94, demonstrating considerable fluctuations in the country's economic activity during the analyzed period.

The standard deviation, which measures the dispersion of data around the mean, varies according to the variable: 0.79% of GDP for government consumption, 0.95% per quarter for IPCA CPI inflation, 1.16% per quarter for the Selic nominal interest rate, and 23.11 for the real GDP index. These values indicate different levels of volatility among the variables, with inflation and the Selic rate showing greater instability compared to government consumption and real GDP. These data, derived from 96 observations (from 2000Q1 to 2023Q4), are crucial for understanding the nuances of the Brazilian economy and were collected from reliable sources: Central Bank of Brazil and the Brazilian Institute of Geography and Statistics.

4.2 Seasonality

Seasonal patterns are often embedded within time series data, and identifying these patterns is crucial for accurate forecasting and informed decision-making. The Census X-13 method is a sophisticated technique that provides a robust framework for breaking down time series into their core components: trend, seasonality, and irregularities. This method is especially useful in economic data analysis, where variables frequently display complex seasonal behaviors. This overview delves into the mathematical foundations of the method and its application in detecting and adjusting for seasonality in time series data, offering a thorough exploration of its significance in empirical research (U.S. Census Bureau, 2017).

The method decomposes the original time series into three primary components:

$$Y_t = T_t + S_t + E_t \tag{18}$$

where Y_t is the original time series, T_t is the trend component, S_t is the seasonal component, and E_t is the error component.

The data are adjusted to remove calendar and outlier effects. This may involve applying various transformations or corrections to the original time series (Y_t). Spectral analysis is performed to identify periodicity in the series and estimate seasonal factors. This analysis typically involves the use of Fourier analysis techniques. The spectral density function of a time series (Y_t) can be estimated to reveal the frequency components present in the data. The periodogram is used to represent the spectral density. It is defined as follows:

$$I(f) = \frac{1}{2\pi}\left[\int Y_t\, e^{-2\pi i f t} dt\right]^2 \tag{19}$$

where $I(f)$ is the periodogram, π is a mathematical constant $(\pi = 3.14159)$, f is the frequency, $\int$ is used to perform the Fourier transform over time, Y_t is the original time series, t is the time variable, $e^{-2\pi i f t}$ is a complex exponential function that plays a fundamental role in Fourier analysis which helps decompose the time series into its frequency components, i is the imaginary unit, and dt is an infinitesimally small change in time. The periodogram provides information about the power of different frequencies in the time series.

This spectral analysis helps identify seasonal patterns within the time series. The components with significant power at specific frequencies correspond to the periodicity of the seasonality. In the context of the Census X-13 method, spectral analysis plays a crucial role in characterizing seasonal factors and understanding their influence on the data. The seasonal component (S_t) is further decomposed into its constituent seasonal frequencies, such as monthly, quarterly, and other seasonals, denoted as S_{t_m}, S_{t_q}, and others. Growth rates of the seasonal components are calculated to remove trends in the series. For example, the growth rate for quarterly data can be calculated as:

$$G_t = \frac{S_{t_q} - S_{t_q - 4}}{S_{t_q - 4}} \tag{20}$$

where G_t is the quarterly growth rate, S_{t_q} is the quarterly constituent seasonal, and S_{t_m} is the monthly constituent seasonal.

The trend components (T_t) are re-adjusted to account for changes in the growth rates of the seasonal components. Finally, the deseasonalized trend component $(\widehat{T_t})$ and deseasonalized seasonal components $\hat{S}_{t_m}$, $\hat{S}_{t_q}$, and others are re-aggregated to obtain the seasonally adjusted data:

$$Y_t = \hat{T}_t + \hat{S}_{t_m} + \hat{S}_{t_q} + \sum \hat{S}_{t_n} \tag{21}$$

where Y_t is the original time series, $\hat{T}_t$ is the deseasonalized trend component, $\hat{S}_{t_m}$ is the deseasonalized seasonal monthly components, $\hat{S}_{t_q}$ is the deseasonalized seasonal quarterly components, and $\sum \hat{S}_{t_n}$ is other deseasonalized components.

Again, the observed variables for the model analysis include government consumption, IPCA CPI inflation, the Selic nominal interest rate, and GDP. A crucial step in this analysis is examining the seasonality of these variables, as understanding their seasonal characteristics is essential for proper model development.

It is important to note that GDP has already been deseasonalized by the Brazilian Institute of Geography and Statistics, eliminating the need for further deseasonalization of this variable. Regarding government consumption, a comparison between the adjusted and original series using the Census X-13 method reveals patterns with a high degree of symmetry, indicating the absence of significant seasonality. Similarly, both the Selic nominal interest rate and IPCA CPI inflation show a great degree of symmetry between the original and adjusted series, as expected from macroeconomic literature, suggesting these variables also lack evident seasonality.

The Selic nominal interest rate, which is the basic interest rate for the Brazilian economy, is set by the Central Bank of Brazil and adjusted according to the needs of monetary policy, not seasonal factors. It is used to control inflation and stabilize the currency, reacting more to macroeconomic and political conditions than to seasonal patterns.

Similarly, the IPCA CPI inflation can show variations due to changes in commodity prices or administered price adjustments, but these are not necessarily seasonal. In Brazil, although there may be some seasonality in food prices due to harvest issues, the index is designed to minimize these effects, reflecting an overall view of inflation without clear seasonal patterns. Consequently, the original series of all these observable variables were used in the analysis.

4.3 Stationarity

When analyzing time series, it is vital to evaluate stationarity and seasonality to establish a robust foundation for further analysis and forecasting. In this paper, we focus on the Augmented Dickey-Fuller (ADF) test, a widely adopted statistical method for testing the stationarity of a series. This test will be applied to selected economic observable variables: real GDP, government consumption, IPCA CPI inflation, and the Selic nominal interest rate. Establishing the stationarity of these variables is essential for conducting accurate and reliable economic analysis, which in turn, informs policymaking and forecasting.

We will delve into the ADF test procedure, examining how the t-statistic is calculated, how critical values are determined, and how results are interpreted. This discussion will highlight the pivotal role of the ADF test in confirming the stationarity of our selected variables and in understanding the economic dynamics they represent. The test begins with the Null Hypothesis $(H0)$ that the time series possesses a unit root, suggesting non-stationarity. The Alternative Hypothesis $(H1)$ contends that the series does not have a unit root, indicating it is stationary.

The detailed application of the ADF test, according to Patterson (2011), involves calculating the t-statistic as follows:

$$t_{ADF} = \frac{\hat{\rho} - 1}{SE(\hat{\rho})} \tag{22}$$

where t_{ADF} is the t-statistic, $\hat{\rho}$ is the estimate of the autoregressive coefficient from the ADF regression, and $SE(\hat{\rho})$ is the standard error of the estimate.

The estimated $\hat{\rho}$ is obtained through a least squares regression model. Specifically, it is the parameter resulting from regressing the first difference of the time series (Δy_t) on its lagged value (y_{t-1}). These ordinary least squares estimate of $\hat{\rho}$ is crucial for assessing stationarity, as values significantly different from 1 indicate non-unit root behavior. For a simple autoregressive model in the context of the ADF test, the regression can be represented as follows:

$$\Delta y_t = \alpha + \beta y_{t-1} + \epsilon_t \tag{23}$$

where Δy_t is the first difference of the time series, α is the intercept, β is the parameter to be estimated, y_{t-1} is the lagged value of the time series, and ϵ_t is the error term.

For this test, the t-critical value is set at -2.89 at a 5% significance level. The critical value depends on factors such as the number of observations, the type of test (with or without a deterministic trend), and the number of lags included. To decide, if $|t_{ADF}| >$ critical value, we reject $H0$ in favor of $H1$, indicating that the series is stationary. Conversely, if $|t_{ADF}| \leq$ critical value, the results do not provide sufficient evidence to reject the null hypothesis, suggesting non-stationarity.

To calculate the p-value in the ADF test, first obtain the t-statistic (t_{ADF}). The next step is to determine the degrees of freedom, which are often equal to the number of observations minus the number of estimated coefficients. For a basic ADF test with an intercept and lagged differences, the degrees of freedom would typically be the number of observations minus 2. Refer to the t-distribution table for the corresponding degrees of freedom and your chosen significance level, such as 0.01, 0.05, or 0.10. Look for the critical t-value that corresponds to your significance level, which represents the critical region boundary.

For the p-value calculation, assess the probability of obtaining a t-statistic as extreme as the one calculated under $H0$, where the time series has a unit root (non-stationary). This probability is computed by finding the Cumulative Distribution Function (CDF) of the t-distribution, using your t-statistic and degrees of freedom. The cumulative probability is calculated as follows:

$$p(t) = \sum_{-\infty}^{t} f(x, df)dx \tag{24}$$

where $p(t)$ is the cumulative probability up to t, $f(x, df)$ is the probability density function of the t-distribution, and dx is the infinitesimally small change in the variable x.

To calculate the p-value in the ADF test, integrate the probability density function over the specified range $(-\infty\ to\ t)$ to find $p(t)$. This requires numerical integration techniques such as Simpson's rule, the trapezoidal rule, or other integration methods. The result of this integration will give you the cumulative probability up to t, which corresponds to the p-value. The p-value quantifies the strength of evidence against $H0$. If the p-value is less than your chosen significance level, reject $H0$ in favor of $H1$, indicating that the series is stationary. Conversely, if the p-value exceeds the significance level, it provides insufficient evidence to reject $H0$, suggesting non-stationarity. Keep in mind that this manual calculation may require access to statistical tables or specialized software for the CDF calculations.

Table 2 - ADF stationarity test of the observed variables

Statistics	**Government consumption (g_t)**	**IPCA CPI inflation (π_t)**	**Selic nominal interest rate (r_t)**	**Real GDP index (y_t)**
Critical value at 5%	-2.89	-2.89	-2.89	-2.89
t-statistic at 5% (level)	-2.09 (0.25)	-5.75** (0.0)	-2.55 (0.1079)	-1.36 (0.6002)
t-statistic at 5% (first difference)	-10.88** (0.0001)	-7.59** (0.0)	-6.23** (0.0)	-8.92** (0.0)
Inference	I(1)	I(0)	I(1)	I(1)

Note: ** denotes statistical significance at the 5% level. Values in brackets represent p-values. All tests were conducted using only the intercept, and $H0$ represents the unit root hypothesis.
Sources: Brazilian Institute of Geography and Statistics (2023a, 2023b) and Central Bank of Brazil (2024c).

Table 2 presents the results of the ADF stationarity test for the observed economic variables in our model: government consumption (g_t), IPCA CPI inflation (π_t), Selic nominal interest rate (r_t), and real GDP (y_t). The critical value for a 5% significance level is -2.89 across all variables, which is the threshold below which the $H0$ of the ADF test (presence of a unit root, indicating non-stationarity) can be rejected.

At the level, government consumption (g_t) has a t-statistic of -2.09 with a p-value of 0.25, indicating that the $H0$ cannot be rejected at the 5% significance level, suggesting that the series is likely non-stationary. The IPCA CPI inflation (π_t), with a t-statistic of -5.75 and a p-value of zero, strongly rejects the $H0$, suggesting that the inflation series is stationary. The Selic nominal interest rate (r_t) has a t-statistic of -2.55 with a p-value of 0.1079, suggesting that the $H0$ cannot be rejected at the 5% level, indicating potential non-stationarity. Real GDP index (y_t) with a t-statistic of -1.36 and a p-value of 0.6002 also fails to reject the $H0$ at the 5% level, suggesting non-stationarity.

When differenced, all variables show t-statistics significantly below the critical value and with p-values close to zero, indicating rejection of the $H0$ and confirming that the first differences of these series are stationary. Government consumption (g_t), Selic nominal interest rate (r_t), and real GDP index (y_t) are classified as I(1), meaning they become stationary after the first differencing. For this reason, the first difference will be applied to these variables to work with stationary series in our model. IPCA CPI inflation (π_t) is classified as I(0), indicating that it is stationary at its level and, therefore, will not require differencing for subsequent analysis.

The double asterisks $(**)$ denote statistical significance at the 5%, supporting the inferences made. The data for this analysis come from reputable sources: Brazilian Institute of Geography and

Statistics and the Central Bank of Brazil, enhancing the credibility of the results. This analysis is crucial for understanding the characteristics of these economic time series, particularly in modeling economic relationships or forecasting, where stationarity is a necessary assumption for many techniques.

4.4 Treatment

After completing all the necessary stationarity and seasonality analyses, the treatment applied to each of the variables is outlined in Table 3. These modifications are crucial for preparing the data for robust economic analysis by removing seasonal patterns and stabilizing long-term trends.

The Selic nominal interest rate (r_t) and government consumption (g_t) underwent a first-difference treatment. This technique, which subtracts the previous period's value from the current one, is a standard approach in time series analysis to achieve stationarity by mitigating the impact of lingering trends and cyclical variations. IPCA CPI inflation (π_t) did not receive any specific treatment. This decision is supported by the inflation series' inherent stationarity, as evidenced by previous tests indicating no need for further transformation to stabilize the series for analytical purposes.

Real GDP index (y_t) was treated comprehensively, beginning with seasonal adjustment performed by the Brazilian Institute of Geography and Statistics, followed by a first-difference transformation. These dual treatments effectively remove seasonal patterns and stabilize the series, making the product data more reliable for evaluating economic conditions and trends.

Table 3 - Treatment of the observed variables

Variable	Treatment
Real GDP index (y_t)	Seasonal adjustment by source and first difference.
Government consumption (g_t)	First difference.
IPCA CPI inflation (π_t)	No treatment.
Selic nominal interest rate (r_t)	First difference.

Note: 96 observations (from 2000Q1 to 2023Q4).
Sources: Brazilian Institute of Geography and Statistics (2023a, 2023b) and Central Bank of Brazil (2024c).

It should be noted that although the model does not explicitly include series of inflation and production expectations in the data, it does incorporate these expectations implicitly through the structure of the equations and the estimated parameters. The model maintains theoretical consistency by following the traditional approach of New Keynesian DSGE models, which incorporate rational expectations implicitly. This is supported by relevant literature, such as the papers by Clarida, Galí and Gertler (1999), Woodford (2003), and Christiano, Eichenbaum and Evans (2005). Calibration of the parameters based on the literature and subsequent Bayesian estimation ensure that the model adequately captures the agents' rational expectations, even without explicit expectations series. This approach ensures that the model's predictions are consistent with the observed behavior of economic agents. The structure of the model was adjusted to reflect the specificities of the Brazilian economy, incorporating shocks and parameters that capture local economic dynamics. This includes the consideration of inertia in marginal costs and fiscal policies, which reflect agents' implicit expectations about the economy.

5 Results

Table 4 shows the results of the Bayesian estimations of the priors and posteriors of the parameters, with the calibrated mean values reflected in Equations (8) to (15) and in Appendices A and B. It is important to note that the proposed model was estimated using two approaches: rational and behavioral.

This process involved defining a priori distributions for the parameters based on previous literature and economic knowledge, followed by updating these distributions from the observed data to obtain the a posteriori distribution. The priori values were defined based on literature relevant to this paper: Gabaix (2020) and Fasolo *et al.* (2024). These values reflect the initial knowledge of the parameters before considering the data. After incorporating the observed data, the a priori distributions were updated to generate posteriori distributions. These posteriori values represent the adjusted estimates based on the empirical evidence.

Table 4 - Estimated parameters of the proposed model

Parameter	Prior mean	Post. SD	Dist.	Rational approach		Behavioral approach	
				Post. mean	Prior SD	Post. mean	Prior SD
Intertemporal discount factor (β)	0.989	0.05	normal	0.8864	0.0191	0.8802	0.0216
IES (σ)	1.3	0.05	normal	1.2551	0.0491	1.2585	0.0491
Interest rate smoothing (γr)	0.5	0.25	beta	.9147	0.0272	0.9464	0.0227
Inflation ($\gamma \pi$)	1.5	0.75	gamma	2.0247	0.7707	1.7776	0.7033
GDP (γy)	0.5	0.25	gamma	0.2793	0.1339	0.2461	0.1181
Primary surplus (ϕ_s)	0.5	0.05	beta	0.477	0.0547	0.4596	0.0495
Government deficit (ϕ_b)	0.05	0.05	inverse gamma	0.5365	0.1772	0.6658	0.0618

Note: 90% confidence interval.
Source: Data derived from the conducted estimates.

The analysis of the estimated parameters in the proposed model, as presented in Table 4, reveals consistency with the structural model across several key dimensions. The intertemporal discount factor (β), crucial for the utility function of households, shows minimal variation between rational and behavioral approaches, underscoring robust consistency of this parameter. Additionally, the IES (σ), essential for the consumption dynamics, remained stable in the estimates, reinforcing the model's capability to capture intertemporal elasticity accurately.

The primary surplus parameter (ϕ_s), vital for the government consumption equation, also exhibited stability, reflecting the robustness of the modeled fiscal policy. Although there is a slight variation in estimates between the approaches for the government deficit parameter (ϕ_b), this suggests nuances in the perception of fiscal policies under different behavioral assumptions.

Posterior estimates were integrated into the model equations to ensure that the dynamics presented are consistent with observed data and underlying economic theories. Key equations, such as the Euler Equation, utilize the intertemporal discount factor (β) and IES (σ) to define the intertemporal consumption relationship, while aggregate demand incorporates calibrated parameters for both private and government consumptions, and the marginal cost includes IES (σ) and the inertia of the marginal cost/GDP ratio (ϕ) to model firms' costs. The analysis indicates that the adopted model approach does not significantly alter key parameters, suggesting that the main characteristics of the Brazilian economy are consistently captured in both approaches. The slight variation in the government deficit parameter (ϕ_b) indicates greater sensitivity in perceptions of government deficit across different behavioral assumptions.

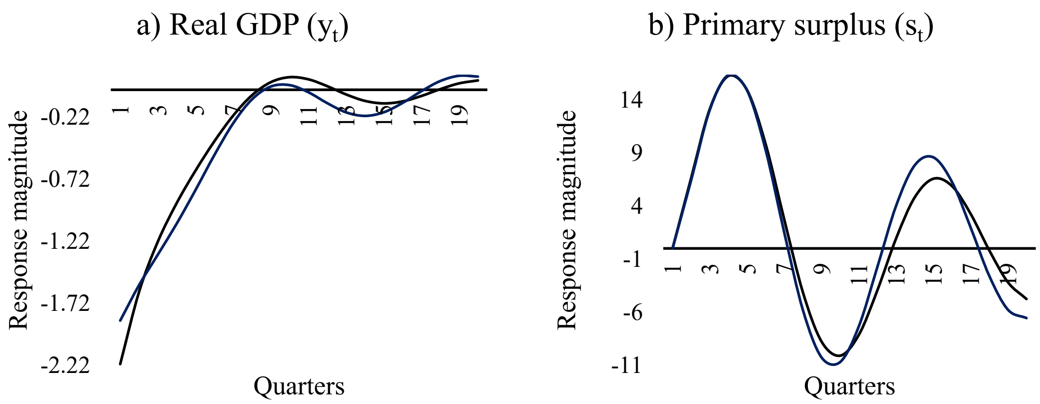
In conclusion, the results of the estimated parameters of the proposed model, as presented in Table 4, are in close conformity with the parameters described in the structural model. The combined approach of a priori definitions based on literature and a posteriori updating with observed data ensures that the estimates are robust and relevant to the proposed analysis. This methodology reinforces the consistency and validity of the model equations and their economic forecasts.

5.1 Interest rate positive shocks

To deepen the analysis of the interaction between monetary and fiscal policies, an analysis of the behavior of Brazilian monetary policy is pertinent. From this point on, the behavior of Brazilian monetary policy is examined (Figures 1 to 3). The responses are grouped by variable, meaning that each chart represents the responses to the same shock for both the rational and behavioral approaches. The responses of the selected macroeconomic variables to a contractionary fiscal policy, specifically positive interest rate shocks, are presented. The vertical axis of the graphs indicates the magnitude of the response, while the horizontal axis represents the time in quarters. The smooth black line represents the IRF of the rational approach, with horizontal lines denoting the transition from positive to negative territory or vice versa. The blue line corresponds to the IRF of the behavioral approach. The shocks applied are of one standard deviation, and the analyzed responses include those of real GDP, primary surplus, IPCA CPI inflation, private consumption, and public debt.

Initially, both the rational and behavioral approaches show a sharp decline in GDP following an increase in interest rates. The rational approach exhibits a substantial drop of -2.2111 in the first quarter, reflecting immediate adjustments in consumption and investment plans due to higher capital costs. In contrast, the behavioral approach records a smaller initial decline of -1.8607, indicating a delayed sensitivity, possibly due to a lag in adjusting expectations. Over time, both approaches exhibit a gradual recovery, but the rational approach is more consistent and less volatile. In the final quarters, both approaches converge, returning to more positive values. This suggests a renewed sensitivity to other macroeconomic factors and indicates that the initial impulse has completely dissipated. This analysis aligns with Brazil's historical sensitivity to monetary policy changes, particularly fluctuations in the Selic rate. The immediate responses capture prevalent concerns among Brazilian businesses and consumers about rising capital costs and credit accessibility. The divergent recovery trajectories also reflect historical observations: the quicker recovery of the rational approach may represent an idealized behavior of economic agents, whereas the more realistic and slower recovery of the behavioral approach reflects the economic uncertainties often observed in Brazilian economy. While both approaches converge towards long-term recovery after the initial shock, the rational approach suggests a faster and less volatile recovery, whereas the behavioral approach illustrates a more gradual recovery process (Figure 1, chart "a").

Figure 1 - IRF: Interest rate positive shocks (GDP and primary surplus)

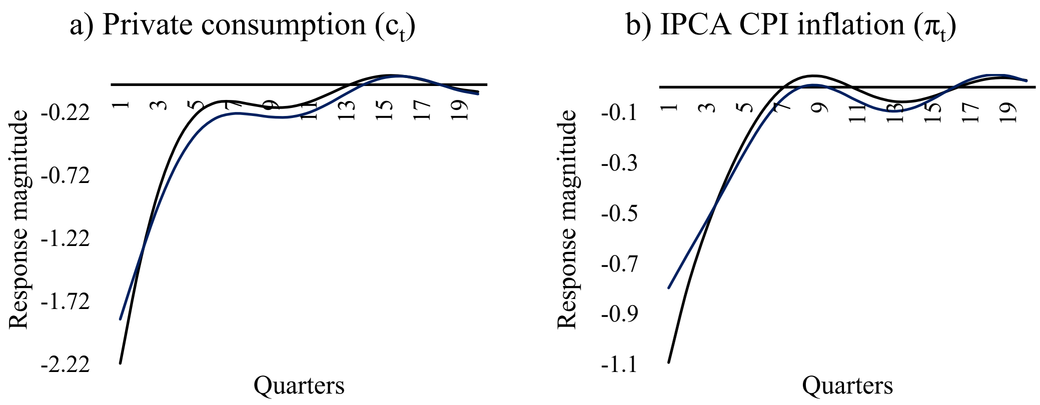


Notes: 95% confidence interval. The smooth black line represents the IRF of the rational approach, with horizontal lines denoting the transition from positive to negative territory or vice versa. The blue line corresponds to the IRF of the behavioral approach. Source: Graphs generated from the conducted estimates.

About primary surplus, the minimal differences in values between the approaches suggest similar responses to the interest rate shock, due to the immediate effect of higher rates reducing investment and consumption. Over time, the divergence in responses becomes more apparent. The rational approach shows a more constant and controlled increase, peaking around 16.25, suggesting rational agents gradually adjust their expectations and fiscal behavior, seeking stability. Conversely, the behavioral approach shows a more erratic progression, peaking at 16.34 with sharper fluctuations, reflecting the heuristic nature of behavioral agents who react intensely to immediate policy changes. In the later stages, both approaches show a decline, but the behavioral approach declines more sharply, indicating greater vulnerability of behaviorally driven fiscal policies to changes in economic perceptions and conditions (Figure 1, chart "b").

Regarding private consumption, both rational and behavioral approaches show a sharp initial drop after the interest rate shock. The rational approach registers a larger decline of -2.2111 compared to -1.8607 in the behavioral approach, suggesting rational agents react more swiftly to interest rate increases due to faster adjustments in economic expectations. Over time, both approaches show a gradual decrease in the rate of decline. By the fourth period, the rational approach indicates a reduction of -0.4667 in consumption, while the behavioral approach shows -0.6296. This slower adjustment by behavioral agents could be due to inertia in their consumption habits. In the later quarters, both approaches exhibit a recovery trend, with responses approaching zero and turning positive. From the fourteenth period onward, both approaches begin to show positive increases, with the behavioral approach slightly outperforming the rational approach. This could indicate overcompensation by behavioral agents as they adjust to the new interest rate environment. In the final quarters, both approaches converge, returning to more negative values This suggests renewed sensitivity to other macroeconomic factors and indicates that the initial impulse has completely dissipated. The rational approach suggests a faster, more pronounced reaction followed by a smoother recovery, while the behavioral approach shows slower adjustments and potentially more pronounced recoveries (Figure 2, chart "a").

Figure 2 - IRF: Interest rate positive shocks (private consumption and CPI inflation)

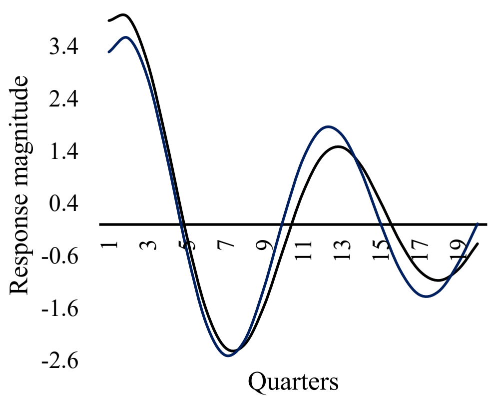


Notes: 95% confidence interval. The smooth black line represents the IRF of the rational approach, with horizontal lines denoting the transition from positive to negative territory or vice versa. The blue line corresponds to the IRF of the behavioral approach. Source: Graphs generated from the conducted estimates.

On inflation, both approaches initially show a significant reduction, with the rational approach registering a sharper decline of -1.0922 compared to -0.7964 in the behavioral approach. This indicates that rational agents anticipate the effects of interest rate increases more sharply, adjusting prices quickly in expectation of reduced consumer spending and lower economic activity. As quarters progress, the decline in inflation slows and stabilizes. By the seventh period, the rational approach nearly stabilizes at -0.0075, while the behavioral approach still shows a modest drop at -0.0503, reflecting a slower adjustment process possibly due to behavioral tendencies to react to perceived economic conditions. In the final quarters, both approaches converge, returning to more positive values. This suggests renewed sensitivity to other macroeconomic factors and indicates that the initial impulse has completely dissipated. The rational approach generally shows a faster adjustment to the new interest rate environment, integrating changes in monetary policy into pricing strategies more immediately. In contrast, the behavioral approach shows a delayed reaction, likely influenced by current market sentiment and slower updates of economic expectations (Figure 2, chart "b").

In addressing public debt, both the rational and behavioral approaches initially show an increase immediately following the interest rate hike. The rational approach peaks at 3.9557, while the behavioral peaks slightly lower at 3.5587 (Figure 3). This initial rise contradicts traditional macroeconomic theory, which generally posits that higher interest rates should reduce the variable by discouraging borrowing and encouraging fiscal consolidation. However, the Brazilian context presents a different narrative, aligning more closely with recent observed dynamics than traditional expectations. Over recent years, Brazil has seen a significant decoupling between monetary and fiscal policies. Despite increases in the Selic interest rate, public debt has remained around one-fifth of GDP, attributable to the lack of synchronization between aforementioned policies. This mismatch often resulted in increased government spending or failed consolidation efforts following interest rate hikes, exacerbating rather than containing public debt levels. This divergence from expectations is documented in papers such as Carvalho *et al.* (2016), Barros and Lima (2018), Melo and Gomes da Silva (2019), Besarria, Maia and Nóbrega (2020), and Fasolo *et al.* (2024).

Figure 3 - IRF: Interest rate positive shocks (public debt)



Notes: 95% confidence interval. The smooth black line represents the IRF of the rational approach, with horizontal lines denoting the transition from positive to negative territory or vice versa. The blue line corresponds to the IRF of the behavioral approach. Source: Graphs generated from the conducted estimates.

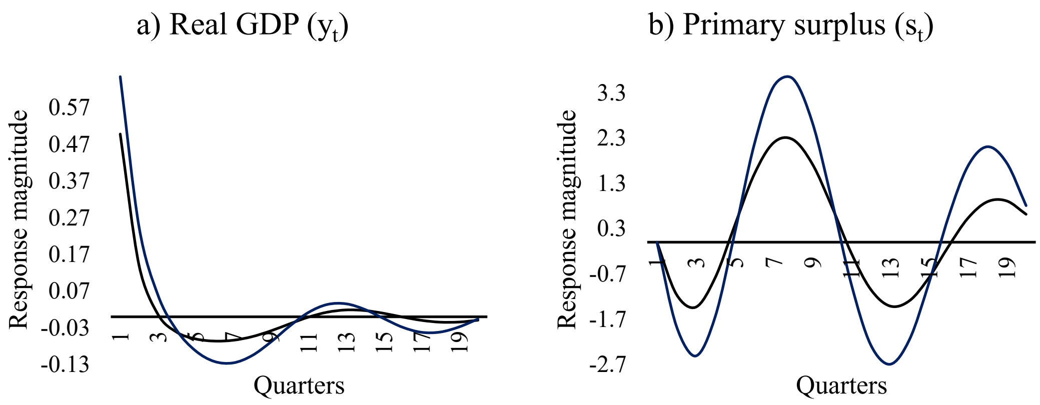
As the quarters progress, both approaches demonstrate a decline in public debt, with the behavioral approach typically indicating a sharper reduction, dropping to -2.4978 compared to -2.2895 in the rational approach. This pattern may reflect the delayed impact of fiscal adjustments. Subsequently, both approaches depict a recovery in public debt levels, transitioning from negative to positive values. The behavioral model exhibits a faster and more pronounced recovery, potentially indicative of more responsive fiscal adjustments. This recovery phase suggests that fiscal mechanisms might be realigning more closely with monetary policy over time. In the final quarters, both approaches converge, returning to more negative values. This suggests renewed sensitivity to other macroeconomic factors and indicates that the initial impulse has completely dissipated. The observed increase in public debt, despite a nominal interest rate positive shock, reflects the recent fiscal-monetary decoupling, highlighting the urgent need for more synchronized policy frameworks. Effective synchronization can help manage public debt levels more effectively, ensuring that fiscal policies complement rather than counteract monetary interventions (Figure 3).

5.2 Government consumption positive shocks

To deepen the analysis of the interaction between monetary and fiscal policies, an analysis of the behavior of Brazilian fiscal policy is pertinent. As was done for the monetary policy (Figures 1 to 3), the behavior of Brazilian fiscal policy is examined from this point on (Figures 4 to 6). The research process follows a similar procedure. The responses are grouped by variable, meaning that each chart represents the responses to the same shock for both the rational and behavioral approaches. The responses of the selected macroeconomic variables to an expansionary fiscal policy, specifically positive government consumption shocks, are presented. Again, the vertical axis of the graphs indicates the magnitude of the response, while the horizontal axis represents the time in quarters. The smooth black line represents the IRF of the rational approach, with horizontal lines denoting the transition from positive to negative territory or vice versa. The blue line corresponds to the IRF of the behavioral approach. The shocks applied are of one standard deviation, and the analyzed responses include those of real GDP, IPCA CPI inflation, private consumption, primary surplus, and the Selic nominal interest rate.

In the initial quarter, there is a notable increase in GDP following a positive shock in government consumption, more pronounced in the behavioral approach (0.6543) than in the rational approach (0.498). This suggests that behavioral agents react more intensely to increased government spending, likely due to a heightened sensitivity to fiscal policies expected to boost economic activity. From the second to the tenth quarter, both approaches show a gradual decrease in GDP responses, with the behavioral approach exhibiting a sharper decline. This may reflect the faster dissipation of initial multiplier effects and concerns about potential increases in government debt and future taxes, which could dampen confidence. From the eleventh quarter onwards, GDP tends to recover and stabilize, with the rational approach displaying a more stable and sustained upturn, while the behavioral approach remains more volatile, alternating between minor declines and recoveries. This pattern suggests that initial fiscal impulses provide a temporary boost, but long-term effects depend on broader economic conditions and other policies. By the fifteenth quarter, the impact of the fiscal shock appears to dissipate, with GDP responses converging to consistently negative values in both approaches. The behavioral approach shows a more dramatic response throughout, indicating greater sensitivity to fiscal stimuli and economic consequences, while the rational approach suggests a more moderated response and smoother adaptation over time. These observations underscore the complexity of fiscal policy impacts, highlighting the need to consider the timing and scale of such policies to optimize benefits and mitigate long-term adverse effects (Figure 4, chart "a").

Figure 4 - IRF: Gov't consumption positive shocks (GDP and primary surplus)

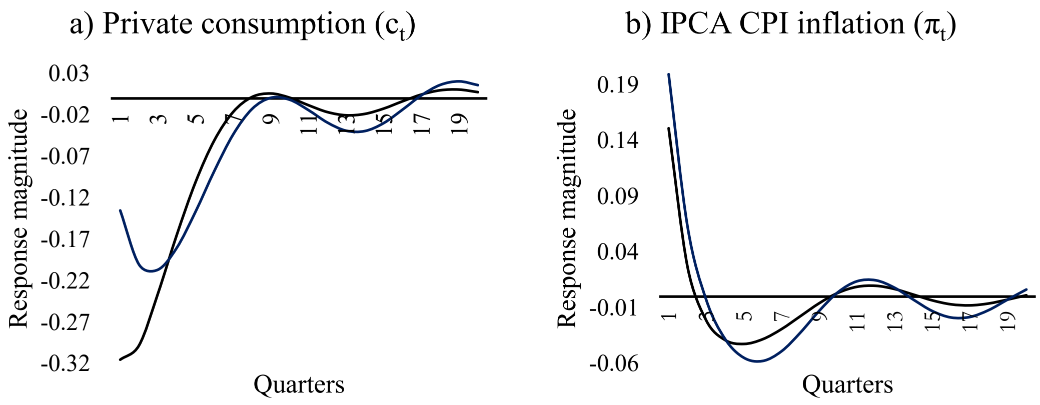


Notes: 95% confidence interval. The smooth black line represents the IRF of the rational approach, with horizontal lines denoting the transition from positive to negative territory or vice versa. The blue line corresponds to the IRF of the behavioral approach. Source: Graphs generated from the conducted estimates.

Regarding the primary surplus, both approaches initially show a deterioration, with the behavioral approach exhibiting a more pronounced decline. This suggests that behavioral agents are more reactive to initial increases in government spending due to concerns about fiscal sustainability and future taxes. Over time, the responses diverge further. The primary surplus begins to recover in both approaches, but the recovery is faster and more pronounced in the behavioral approach, potentially due to the perception that increased government consumption will stimulate faster economic growth and higher revenues. However, this rapid recovery is not sustainable in the long term for the behavioral approach, as responses eventually decline again, albeit remaining positive. This decline may result from reevaluating long-term effects, such as public debt and inflationary pressures, requiring restrictive fiscal measures. In contrast, the rational approach shows a gradual and stable recovery, suggesting more consistent adjustment of expectations over time, considering both short-term effects and long-term economic and fiscal implications. This more moderate adjustment reflects a cautious and deliberate fiscal stance. In summary, while both approaches show a recovery of the primary surplus after an initial negative response to increased government consumption, they differ significantly in speed and volatility. The behavioral approach reacts quickly and more volatilely, reflecting sharp sensitivity to fiscal policy changes, whereas the rational approach demonstrates a balanced response, considering long-term effects, which may be more advantageous for sustainable fiscal stability (Figure 4, chart "b").

The responses of private consumption to a government consumption shock reveal distinct dynamics between the rational and behavioral approaches, reflecting both economic theory and the characteristics of the Brazilian economy. Initially, both approaches show a decline in the variable, with the rational approach experiencing a sharper drop (-0.3154) compared to the behavioral approach (-0.1352). This suggests that rational agents anticipate a stronger crowding-out effect from increased government consumption. Over time, the rational approach shows a gradual recovery, turning positive from the sixteenth quarter onwards. This indicates that rational agents adjust their consumption expectations, anticipating that the increase in government spending is temporary. Conversely, the behavioral approach demonstrates a slower and less pronounced recovery, with negative values persisting longer and a smaller magnitude of positive values when they do appear. This reflects behavioral inertia and a slower adjustment to new economic conditions, consistent with literature suggesting that non-rational behaviors are more resistant to rapid changes. The rational approach's faster recovery, turning positive earlier, aligns with the rational expectations mechanism, where agents adjust their consumption decisions based on anticipated future reversals or compensations for government spending increases. In contrast, the delayed and less intense recovery in the behavioral approach highlights the need for policies that can accelerate expectation adjustments and consumption among less rational agents. In the context of Brazil's frequent fiscal adjustments and macroeconomic volatility, the rational approach's faster response may reflect greater sensitivity to fiscal stabilization expectations, while the behavioral approach's slower adjustment underscores the importance of increasing predictability and confidence among agents (Figure 5, chart "a").

Figure 5 - IRF: Gov't consumption positive shocks (private consumption and CPI inflation)

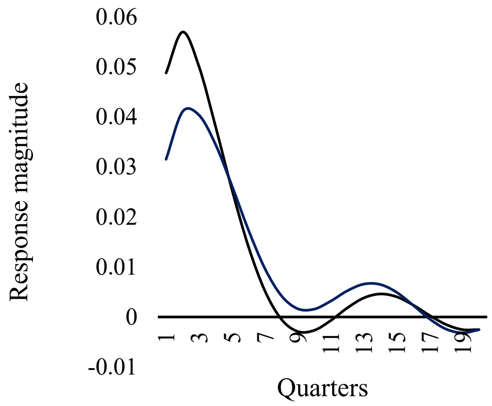


Notes: 95% confidence interval. The smooth black line represents the IRF of the rational approach, with horizontal lines denoting the transition from positive to negative territory or vice versa. The blue line corresponds to the IRF of the behavioral approach. Source: Graphs generated from the conducted estimates.

Regarding inflation, both approaches initially show a positive response to a government consumption shock. In the first quarter, the rational approach increases by 0.150976, while the behavioral approach rises by 0.199462, suggesting that behavioral agents are more sensitive to immediate price level changes. Over time, the rational approach's inflationary impact diminishes quickly, turning negative by the third quarter and stabilizing near zero. This indicates that rational agents anticipate the temporary nature of the shock and adjust expectations, accordingly, aligning with the rational expectations hypothesis. Conversely, the behavioral approach exhibits a more pronounced and persistent inflationary response, with effects lingering longer. In the medium and long term, the rational approach shows a smoother and faster adjustment, while the behavioral approach's slower adjustment reflects cognitive biases and heuristics delaying normalization. In Brazil's context of fiscal volatility, the rational approach's faster inflation normalization can be seen as a response to fiscal stabilization efforts. The behavioral approach's prolonged inflationary response indicates greater uncertainty and lower confidence in government policies. This analysis suggests that increasing predictability and transparency in government actions can help mitigate initial inflationary impacts and facilitate quicker stabilization. The behavioral approach's slower adjustment highlights the need for measures addressing cognitive biases to improve fiscal policy's effectiveness in stabilizing inflation (Figure 5, chart "b").

About Selic nominal interest rate, in the first quarter, the rational approach indicates an increase of 0.048759, while the behavioral approach shows a slightly lower increase of 0.031512. This difference suggests that rational agents might be more sensitive to immediate monetary policy adjustments, anticipating tighter policy to counteract inflationary pressures. In subsequent quarters, both approaches continue to exhibit positive but declining impacts. The rational approach maintains a higher response, peaking at 0.056945 in the second quarter and then gradually declining. This pattern suggests rational agents quickly adjust their expectations, anticipating a temporary rise in interest rates to control inflation. The behavioral approach shows a more muted response, with a smaller initial increase that declines more gradually. This slower adjustment aligns with Behavioral Economics literature, indicating that agents with cognitive biases react less aggressively to policy changes. In the final quarters, both approaches converge, returning to more negative values. This suggests renewed sensitivity to other macroeconomic factors and indicates that the initial impulse has completely dissipated. These differences underscore the varying dynamics between rational and behavioral agents. Rational agents anticipate the temporary nature of the shock and monetary policy responses, leading to quicker adjustments and eventual correction. Behavioral agents exhibit a more persistent but subdued response, reflecting slower adjustment processes and potential underestimation of the Central Bank's reaction (Figure 6).

Figure 6 - IRF: Gov't consumption positive shocks (Selic nominal interest rate)



Notes: 95% confidence interval. The smooth black line represents the IRF of the rational approach, with horizontal lines denoting the transition from positive to negative territory or vice versa. The blue line corresponds to the IRF of the behavioral approach. Source: Graphs generated from the conducted estimates.

In the context of the Brazilian economy, characterized by fiscal volatility and frequent policy shifts, these findings are particularly relevant. The quicker normalization of the nominal interest rate in the rational approach aligns with sensitivity to stabilization efforts, where rational agents swiftly adjust to expected policy interventions. The more prolonged positive response in the behavioral approach may reflect higher uncertainty and perceived volatility, as well as a lag in confidence in the Central Bank's ability to manage inflation through interest rate adjustments. Overall, these IRFs suggest that enhancing predictability and transparency in government actions could mitigate the initial impact on the nominal interest rate by aligning agent expectations with anticipated policy measures. This could lead to quicker stabilization and reduce prolonged inflationary or deflationary pressures. The slower adjustment in the behavioral approach highlights the need for complementary measures to address cognitive biases and improve the effectiveness of monetary policy in stabilizing the economy. Considering these behavioral factors, policymakers can better design strategies to accommodate varied responses, leading to more robust and resilient economic outcomes (Figure 6).

6 Concluding Remarks

This study explored the interaction between monetary and fiscal policies in the Brazilian context, focusing on the implications of bounded rationality in economic modeling. The main investigation centered on the differential impacts of rational and behavioral approaches on selected macroeconomic aggregates following policy shocks. Using a New Keynesian DSGE model with Bayesian estimation, the research analyzed quarterly data from 2000Q1 to 2023Q4, providing a comprehensive comparison between the two approaches.

Overall, the results emphasize the importance of integrating behavioral insights into economic models to capture the diverse responses of agents to policy shocks. The findings suggest that increasing predictability and transparency in government actions can mitigate the initial impacts on selected macroeconomic variables, leading to quicker stabilization. However, the slower adjustment observed in the behavioral approach highlights the need for complementary measures to address cognitive biases and improve policy effectiveness.

The paper's insights align with observed behaviors and responses to policy changes in Brazil, where fiscal volatility and frequent policy adjustments prevail. The rational approach's emphasis on predictability and quicker recovery contrasts with the behavioral approach's focus on flexibility and adaptive responses. These findings underscore the need for a coordinated policy framework to enhance the effectiveness of economic interventions.

For policymakers, the results underscore the critical need for synchronized fiscal and monetary policies to promote sustainable economic growth. The choice between rational and behavioral approaches should consider the specific characteristics of the economy and the relative importance of flexibility versus predictability in policy design. This means the choice should be made positively, depending on the objective and economic scenario, rather than imposing one approach over the other.

This analysis aligns with the Lucas Critique, which warns that the effectiveness of economic policies depends on how agents' expectations change in response to these policies. Integrating behavioral elements into the model allows for a better capture of these shifts in expectations, thereby providing a more robust basis for policy formulation.

Future research could explore scenarios involving fiscal or monetary dominance, examine the implications of a zero lower bound on nominal interest rates, and investigate the interaction between exchange rate policy and other economic policies. Such studies would deepen the understanding of economic policy dynamics and contribute to the formulation of more effective public policies.

In conclusion, this study enhances the understanding of economic policy dynamics through the lens of bounded rationality, providing valuable perspectives on the interaction between monetary and fiscal policies in the Brazilian context. The insights gained from this research contribute significantly to offer guidance for strengthening Brazil's path toward sustainable economic development.

Acknowledgements

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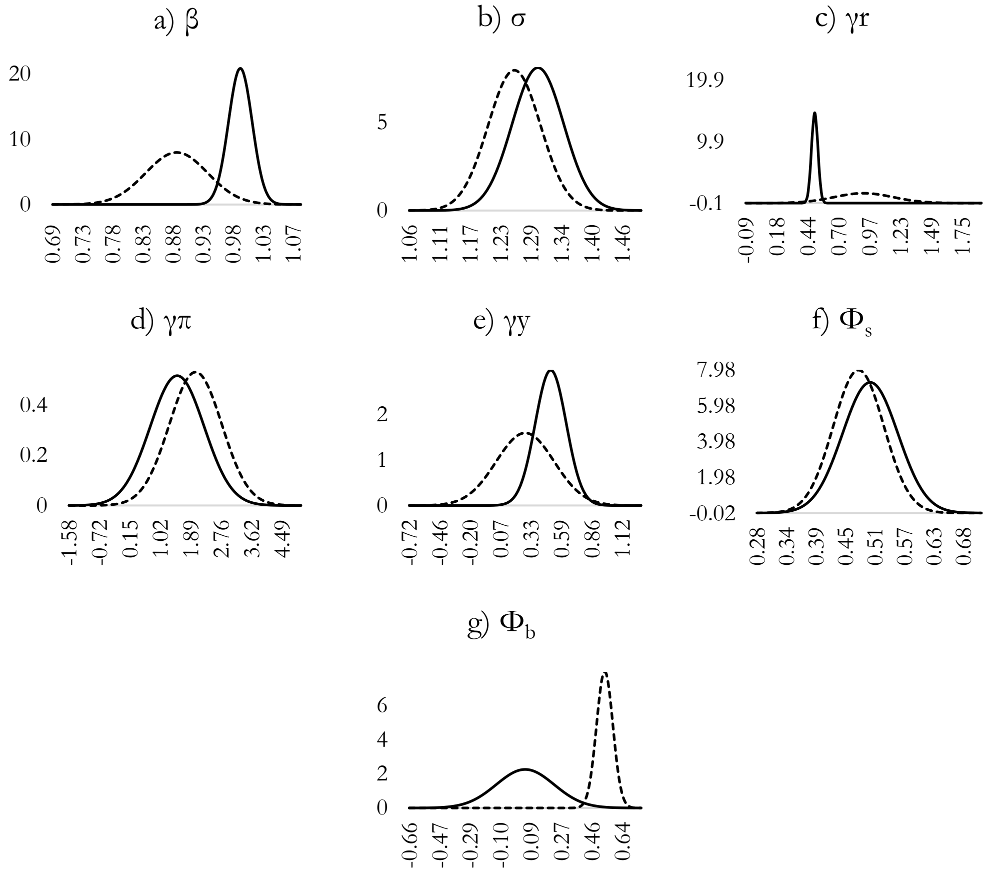
Appendix A - Parameters from Rational Approach

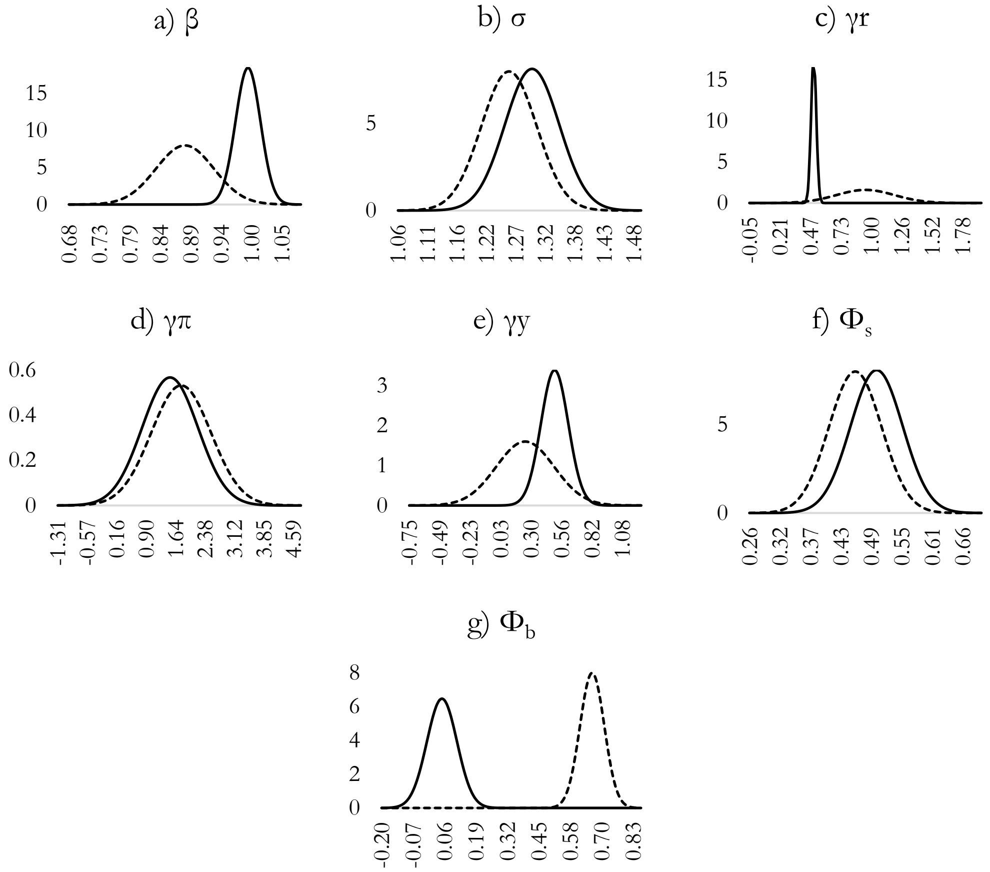
Figure 1 - Priors and posteriors of the parameters from rational approach



Notes: The solid line refers to the priors, while the dashed line refers to the posteriors. Probability distribution functions based on 100 points.
Source: Graphs generated from the conducted estimates.

Appendix B - Parameters from Behavioral Approach

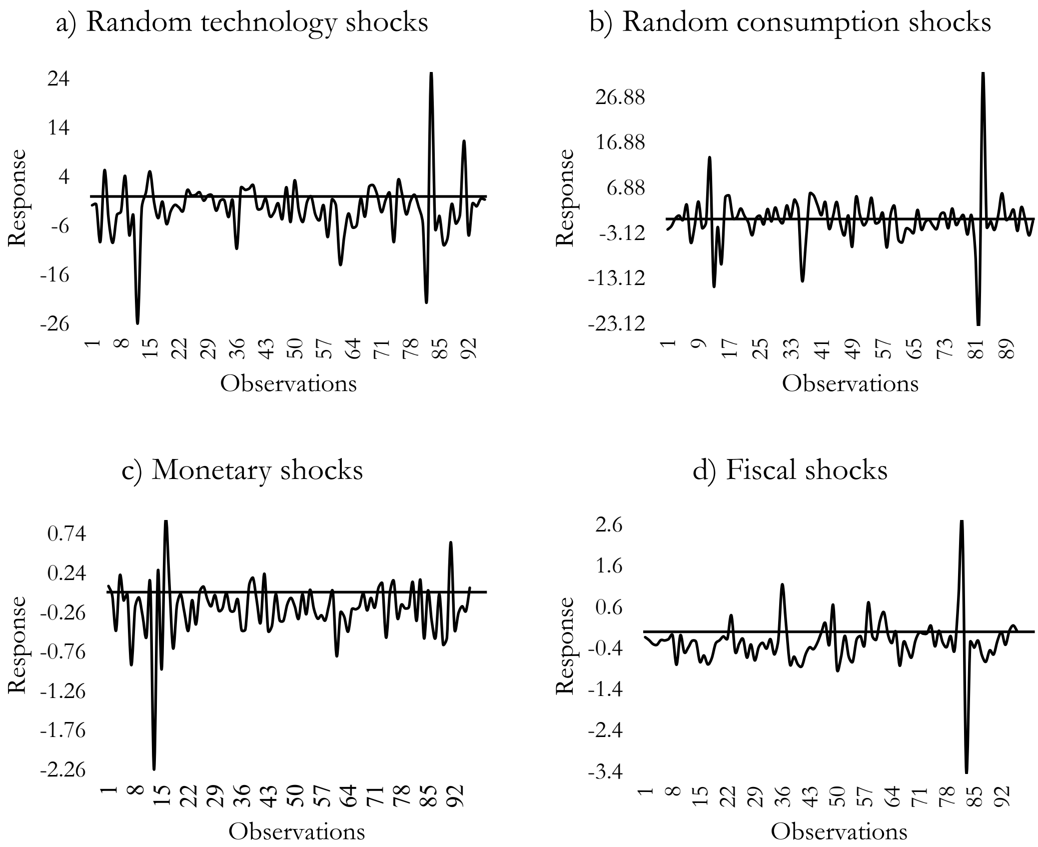
Figure 2 - Priors and posteriors of the parameters from behavioral approach



Notes: The solid line refers to the priors, while the dashed line refers to the posteriors. Probability distribution functions based on 100 points.
Source: Graphs generated from the conducted estimates.

Appendix C - Smoothed Shocks from Rational Approach

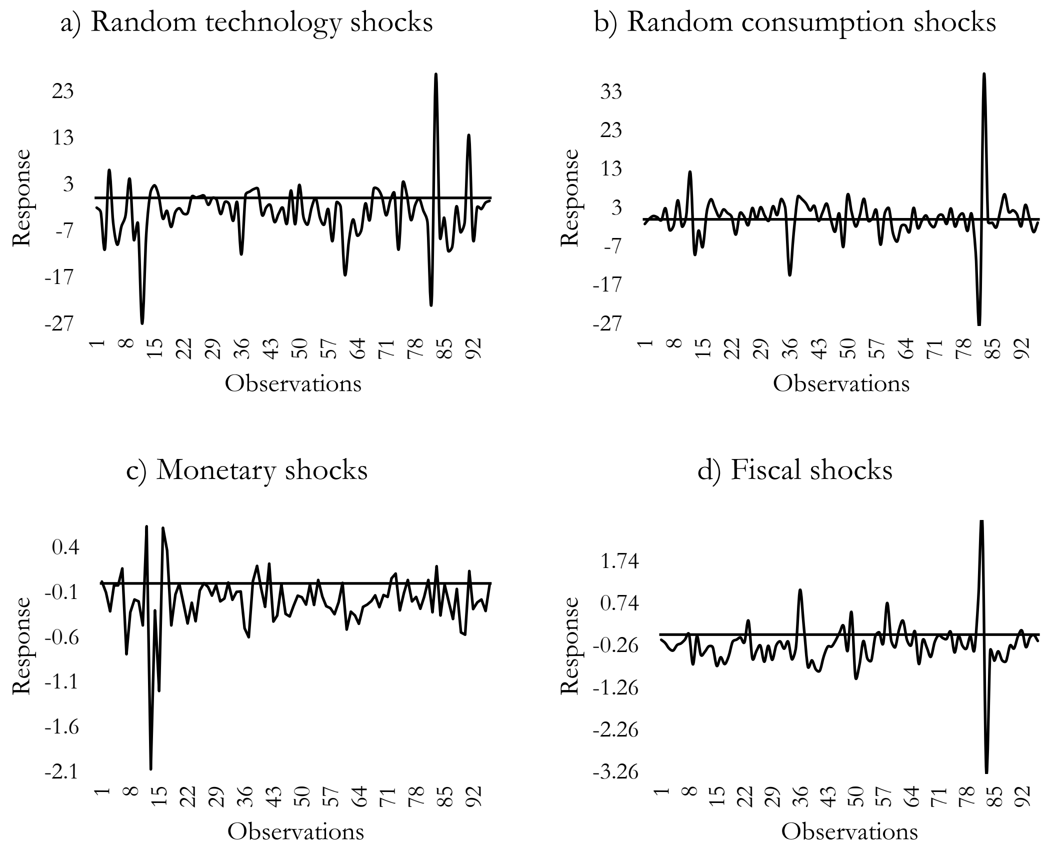
Figure 3 - Smoothed shocks from rational approach



Source: Graphs generated from the responses to structural shocks of one standard deviation in magnitude.

Appendix D - Smoothed Shocks from Behavioral Approach

Figure 4 - Smoothed shocks from behavioral approach



Source: Graphs generated from the responses to structural shocks of one standard deviation in magnitude.

Appendix E - Equations of the Proposed Model

Table 5 - Equations of the proposed model

Equation	
Block 1. Common equations of the proposed model	
$y_t = s_c c_t + s_g g_t + \epsilon_t^y$	(AD)
$y_t^n = \left[\frac{s_c(1+\phi)}{\sigma(1-\alpha)+s_c(\phi+\alpha)}\right](\epsilon_t^a + 1) + m_c + \log(1-\alpha) - \epsilon_t^c$	(GDP Natural)
$m_c = \left(\frac{\sigma}{s_c} + \frac{1+\phi}{1-\alpha} - 1\right)(y_t^n) + \epsilon_t^{mc}$	(MCF)
$r_t = (r_{t-1})^{\gamma r}\left[\left(r_t^n \frac{\pi_t}{\pi_t^*}\right)(y_t - y_t^n)^{\gamma y}\right]^{1-\gamma r} + \epsilon_t^r$	(TR)
$g_t = \gamma_g g_{t-1} + (1-\gamma_g)(\phi_s s_{t-1}^*) - \phi_b b_{t-1}^{\gamma} + \epsilon_t^g$	(G)
Block 2. Rational approach equations only	
$c_t = E_t[c_{t+1}] - \frac{1}{\sigma}(r_t - E_t[\pi_{t+1}]) + \frac{1}{\sigma}(\epsilon_t^c - \epsilon_{t+1}^c)$	(EE)
$\pi_t = \beta E_t[\pi_{t+1}] + \lambda_t + \left(\frac{\sigma}{s_c} + \frac{1+\phi}{1-\alpha} - 1\right)(y_t - y_t^n) + \epsilon_t^\pi$	(NKPC)
Block 3. Behavioral transformation equations	
$c_t = M E_t[c_{t+1}] - \frac{1}{\sigma}(r_t - E_t[\pi_{t+1}]) + \frac{1}{\sigma}(\epsilon_t^c - \epsilon_{t+1}^c)$	(EE)
$\pi_t = M\beta E_t[\pi_{t+1}] + \lambda_t + \left(\frac{\sigma}{s_c} + \frac{1+\phi}{1-\alpha} - 1\right)(y_t - y_t^n) + \epsilon_t^\pi$	(NKPC)

Notes: AD = Aggregate Demand, MCF = marginal cost of firms, TR = Taylor rule, G = government consumption, EE = Euler equation, and NKPC = New Keynesian Phillips Curve. Sources: Gabaix (2020) and Fasolo *et al.* (2024).