Monetary and fiscal policies in Brazil and the behavioral approach

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Abstract

Purpose – This study aims to elucidate the dynamics of monetary and fiscal policy interactions in Brazil, focusing on the impacts of positive shocks in government consumption and interest rates. By comparing rational and behavioral agent responses, it clarifies how these frameworks influence gross domestic product (GDP), inflation, private and government consumption and nominal interest rates.

Design/methodology/approach – The study employs a new Keynesian dynamic stochastic general equilibrium (DSGE) model with Bayesian estimation from 2000Q1 to 2022Q4, capturing rational and behavioral behaviors with adjustments for Brazilian economic idiosyncrasies. Impulse response functions (IRF) assess the dynamic effects of policy shocks, providing a comparative analysis of the two frameworks.

Findings – Behavioral agents show greater initial sensitivity to policy shocks, causing more pronounced fluctuations in GDP, inflation and private consumption compared to rational agents. Over time, the behavioral approach leads to a more robust recovery, while the rational approach results in a quicker return to equilibrium but less pronounced long-term recovery. The study also finds fiscal policy can partially offset the negative impacts of monetary tightening, with a more delayed effect in the behavioral model.

Originality/value – This paper provides insights into the interplay between monetary and fiscal policies under different agent expectations, emphasizing the importance of incorporating behavioral elements into macroeconomic models to better capture policy dynamics in emerging markets.

Keywords Bayesian estimates, Bounded rationality, Macroeconomic indicators,
New Keynesian DSGE model

Paper type Research paper

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 article seeks to elucidate the specific dynamics of these policy interactions, focusing on how different structures of expectations – rational versus behavioral – affect the main macroeconomic variables, especially gross domestic product (GDP), inflation, private consumption, government consumption and nominal interest rates. The central objective of this research is to analyze the differential impacts of positive shocks to government consumption and interest rates 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

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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 Bayesian estimation, covering the period from 2000Q1 to 2022Q4. 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 or 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 the fiscal theory of the price level provide a fundamental background for understanding the interdependence of fiscal and monetary policies. This article contributes to the existing literature by offering a differentiated comparison between the structures of rational and behavioral expectations 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 expectation structures, the article 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.

In addition to this introduction, the manuscript has four more sections. Section 2 presents the model, detailing its theoretical foundations and the incorporation of behavioral parameters. Section 3 describes the data sources and the specific treatments applied to each variable observed. Section 4 presents the results of the research, with a detailed comparison between the rational and behavioral approaches. Finally, Section 5 presents the concluding remarks, highlighting the implications of the results for economic policy in Brazil.

2. 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 DSGE 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, DSGE models can present identification

problems, especially when considering a limited number of observable 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, comparing rational and behavioral approaches. This proposal opens space for the insertion of a behavioral approach while presenting monetary and fiscal parameters commonly applied in the Central Bank of Brazil's models contemporaneously. In addition, the proposed model is a medium-range, dynamically stable model with a non-negativity constraint. The equations relating to aggregate demand, natural GDP, the marginal cost of firms, the Taylor rule and government consumption are the same for both types of approaches. The nuance lies in the receipt of behavioral parameters for the Euler equation and the Phillips curve.

2.1 Representative agent

First, I start with the intertemporal optimization of consumers based on Clarida *et al.* (1999), Woodford (2003) and Christiano *et al.* (2005), with some adjustments. I consider a representative agent who maximizes his intertemporal utility subject to a budget constraint:

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

where U is the utility function, β 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 hours worked $(l_t = 1)$ and T_t is the taxes paid.

The Euler equation will be given by:

$$\frac{c_{t+1}}{c_t} = [\beta(1 + r_{t+1})]^{\frac{1}{\nu}} \tag{3}$$

where c_{t+1} is the consumption in the immediately subsequent period, c_t is the consumption, β 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 Araújo Júnior, Fasolo, Kornelius, Marinho and Valli Jorge (2024), the aggregate demand equation will be given by:

$$y_t = s_c c_t + s_g g_t + \epsilon_t^y \tag{4}$$

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 they are imperfect. The aim is for the dynamics presented to converge more closely with real economic dynamics.

2.2 Firms

The natural GDP equation will be given by:

$$y_t^n = \left[\frac{s_c(1+\phi)}{\sigma(1-\alpha)+s_c(\phi+\alpha)}\right]\left(\epsilon_t^a+1\right)+m_c+\log(1-\alpha)-\epsilon_t^c \tag{5}$$

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. It should be noted that this equation is from Gabaix (2020) and has its parameters calibrated as in Araújo Júnior *et al.* (2024) to capture the idiosyncrasy of the Brazilian economy.

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

$$m_c = \left(\frac{\sigma}{s_c}+\frac{1+\phi}{1-\alpha}-1\right)\left(y_t^n\right)+\epsilon_t^{mc} \tag{6}$$

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 this equation is from Gabaix (2020) and has its parameters calibrated as in Araújo Júnior *et al.* (2024) to capture the idiosyncrasy of the Brazilian economy.

2.3 Monetary authority

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

$$r_t = (r_{t-1})^{\gamma_r}\left[\left(r_t^n\frac{\pi_t}{\pi_t^*}\right)^{\gamma_\pi}\left(y_t-y_t^n\right)^{\gamma_y}\right]^{1-\gamma_r}+\epsilon_t^r \tag{7}$$

where r_t is the nominal interest rate, r_{t-1} is the lagged nominal interest rate, $\boldsymbol{\gamma_r}$ is the interest rate smoothing ($\boldsymbol{\gamma_r} = 0.5$), r_t^n is the natural interest rate, π_t is the consumer price index (CPI) inflation, π_t^* is the inflation target, $\boldsymbol{\gamma_\pi}$ is the inflation parameter ($\boldsymbol{\gamma_\pi} = 1.5$), y_t is the real GDP, y_t^n is the natural GDP, $\boldsymbol{\gamma_y}$ is the GDP parameter ($\boldsymbol{\gamma_y} = 0.5$) and ϵ_t^r captures monetary shocks.

This rule already includes a parameter for interest rate smoothing. Monetary authorities, including the Central Bank of Brazil, 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.

2.4 Government

Finally, the government consumption equation will be given by:

$$g_t = \gamma_g g_{t-1} + \left(1 - \gamma_g\right)\left(\phi_s s^*_{t-1}\right) - \phi_b b^{\gamma}_{t-1} + \epsilon^g_t \tag{8}$$

where g_t is government consumption; γ_g is the smoothing parameter of government consumption ($\gamma_g = 1$); g_{t-1} is the lagged value of government consumption; ϕ_s is the parameter of the primary surplus ($\phi_s = 0.5$); 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^{γ}_{t-1} is the lagged government deficit and ϵ^g_t captures fiscal shocks.

It should be noted that this equation is an idiosyncratic addition to Gabaix's (2020) model and has its parameters calibrated like Araújo Júnior *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.

2.5 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 includes 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 *et al.* (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. The rational model is 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 (3) can be extended to incorporate rational expectations and consumption shocks, resulting in a form that is consistent with Gabaix's (2020) formulation:

$$c_t = E_t[c_{t+1}] - \frac{1}{\sigma}(r_t - E_t[\pi_{t+1}]) + \frac{1}{\sigma}\left(\epsilon_t^c - \epsilon_{t+1}^c\right) \tag{9}$$

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:

$$\pi_t = \beta E_t[\pi_{t+1}] + \lambda_t + \left(\frac{\sigma}{s_c} + \frac{1+\phi}{1-\alpha} - 1\right)\left(y_t - y_t^n\right) + \epsilon_t^\pi \tag{10}$$

where π_t is the CPI inflation, β is the intertemporal discount factor ($\beta = 0.989$), E is an 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.

2.6 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 models 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 include 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:

$$c_t = ME_t[c_{t+1}] - \frac{1}{\sigma}(r_t - E_t[\pi_{t+1}]) + \frac{1}{\sigma}\left(\epsilon_t^c - \epsilon_{t+1}^c\right) \tag{11}$$

where c_t is private consumption, M is an inattention macro-parameter measuring cognitive discounting of the future ($M = 0.8$), E is an 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 are 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, I use a value that considers the expectations period adopted by the Central Bank of Brazil, which is up to four years (see BCB, 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:

$$\pi_t = M\beta E_t[\pi_{t+1}] + \lambda_t + \left(\frac{\sigma}{s_c} + \frac{1+\phi}{1-\alpha} - 1\right)\left(y_t - y_t^n\right) + \epsilon_t^\pi \tag{12}$$

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 (11) and (12) 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 expectation horizon is smoothed. It brings a smaller influence of expectations about the future in relation to present behavior. Supplementary Material G provides a summary of the model's key equations, while Supplementary Materials E and F present the smoothing of the model's shocks under the rational and behavioral approaches, respectively.

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 Araújo Júnior *et al.* (2024) on the Brazilian economy, ensuring the model accurately reflects the specific idiosyncrasies of the analyzed economic behavior.

3. Data

For the estimations of this paper, the Dynare/Matlab package will be used, together with a quarterly database ranging from 2000Q1 to 2022Q4, and equations were already log linearized. It is important to note that, although there is a set of parameters to be estimated, the full proposed model also consists of calibrated equations. In continuity, the set of variables to be observed is as follows:

(1) Government consumption (g_t): quarterly government consumption (% of GDP). Source: IBGE (2023b).

(2) Brazilian CPI (IPCA) inflation (π_t): quarterly accumulated IPCA inflation. Source: IBGE (2023a).

(3) The Selic nominal interest rate (r_t): quarterly rate. Source: BCB (2023b).

(4) Real GDP (y_t): quarterly GDP, seasonally adjusted by IBGE. Source: IBGE (2023b).

Seasonal patterns often lurk within time series data, and uncovering these patterns is crucial for making accurate forecasts and informed decisions. The Census X-13 method, an advanced technique, provides a robust framework for dissecting time series into its fundamental components, such as trend, seasonality and error. This method is particularly valuable in the context of economic data analysis, where some variables exhibit complex seasonal behaviors (US Census Bureau, 2017). It is noteworthy that the original trajectory of each aforementioned variable was compared with its seasonal adjustment made by the mentioned method to assess the need for deseasonalization.

Time series analysis plays a crucial role in understanding trends and patterns underlying economic data. When dealing with time series, it is essential to assess the presence of stationarity and seasonality to establish a solid foundation for future analysis and forecasting. In this context, I delve into the augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests, widely used statistical procedures for testing the stationarity of a time series. These tests will be applied to the variables observed in this research. The stationarity of these variables is fundamental for an accurate and robust analysis, providing valuable information for the formulation of economic policies and forecasts.

I will provide a detailed examination of the stationarity test procedures, including calculating the t-statistic, determining the critical values and interpreting the results. In these tests, the null hypothesis (H0) is that the time series has a unit root, indicating non-stationarity. The alternative hypothesis (H1) posits that the time series lacks a unit root and is stationary (Patterson, 2011).

Supplementary Material A displays the application of the tests to the observable variables in the proposed model. The test results confirm that government consumption and IPCA inflation are originally stationary, i.e. I(0), and the other variables are stationary when the first differentiation is applied, i.e. I(1).

Once all the stationarity and seasonality analyses have been carried out, the variables presented in the Preamble finally receive the treatment shown in Supplementary Material B. The Selic nominal interest rate received first-difference treatment, which involves subtracting the previous period's value from the current one. This common technique in time series analysis helps make the data stationary, reducing long-term trends. Government consumption was subjected to seasonal adjustment using the Census X-13 method, ensuring that seasonal patterns are removed, making the data more suitable for analysis. No treatment was applied to IPCA inflation, which aligns with the standard practice in Brazilian macroeconomic literature. GDP data underwent two treatments: first, it was seasonally adjusted by IBGE (2023b), which removed seasonality from the data, and then the first-difference transformation was applied, further enhancing the stationarity of the series. These treatments are essential for removing seasonal influences and long-term trends from GDP data.

It should be noted that although the model does not explicitly include a 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 *et al.* (1999), Woodford (2003) and Christiano *et al.* (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.

4. Results

4.1 Priors and posteriors of the parameters

Table 1 shows the results of the Bayesian estimations of the priors and posteriors of the parameters, with the calibrated average values reflected in Equations (4)–(12) and in Supplementary Materials C and D. 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 the literature relevant to this paper: Gabaix (2020) and Araújo Júnior *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 the a posteriori distribution. These a posteriori values represent the adjusted estimates based on the empirical evidence.

Consistency with the structural model is evident, as the intertemporal discount factor (β) is fundamental to the utility function of households and showed little variation between the rational and behavioral approaches, indicating robust consistency of the intertemporal discount factor. The IES (σ), crucial for the Euler equation and consumption dynamics, also showed stability in the estimates, reinforcing the model's consistency in capturing intertemporal elasticity. Similar stability is observed for the primary surplus parameter (ϕ_s), which is essential for the government consumption equation, reflecting the robustness

				Rational approach		Behavioral approach	
Parameter	Prior mean	Post sd	Dist.	Post mean	Prior sd	Post mean	Prior sd
Intertemporal discount factor (β)	0.989	0.05	normal	0.9897	0.0005	0.9896	0.0005
IES (σ)	1.3	0.05	normal	1.2911	0.0485	1.2724	0.0486
Interest rate smoothing (γ_r)	0.5	0.25	beta	0.9138	0.0185	0.9529	0.0141
Inflation (γ_π)	1.5	0.75	gamma	1.4571	0.2656	1.884	0.7394
GDP (γ_y)	0.5	0.25	gamma	1.3017	0.98	0.6231	0.2135
Primary surplus (ϕ_s)	0.5	0.05	beta	0.4766	0.0475	0.4721	0.0472
Government deficit (ϕ_b)	0.05	0.05	Inverse gamma	0.0493	0.0075	0.0544	0.0089

Table 1.
Estimated parameters of the proposed model

Note(s): 90% confidence interval
Source(s): Data derived from the conducted estimates

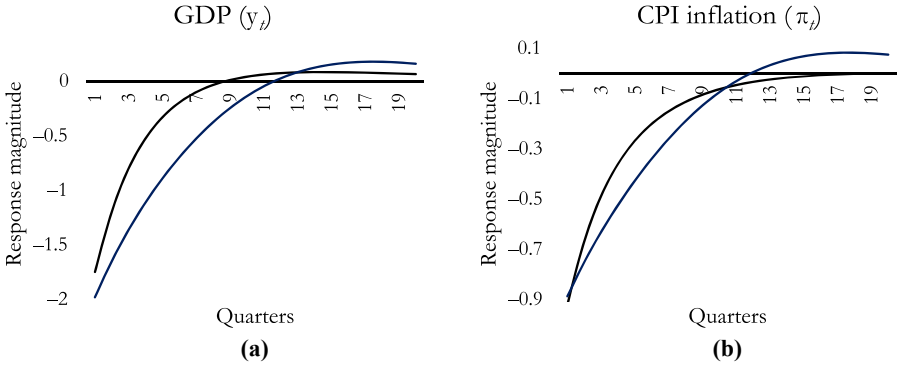
of the fiscal policy modeled. Although there was a slight variation in the estimates between the approaches for the government deficit parameter (ϕ_b), this suggests nuances in the perception of fiscal policies under different behavioral assumptions.

The posteriori estimates were integrated into the model equations to ensure that the dynamics presented are consistent with the observed data and the underlying economic theories. Key equations, such as the Euler equation (Equation 11), use intertemporal discount factor (β) and IES (σ) to define the intertemporal consumption relationship, while aggregate demand (Equation 4) integrates calibrated parameters for private consumption (s_c) and steady state of government consumption (s_g), and marginal cost (Equation 6) includes IES (σ) and inertia of the marginal cost/GDP ratio (ϕ) to model firms' costs. The analysis showed that the model approach (rational versus behavioral) does not significantly alter the key parameters, suggesting that the main characteristics of the Brazilian economy are captured consistently in both approaches. The slight variation in government deficit parameter (ϕ_b) indicates a greater sensitivity in perceptions of government deficit between the different assumptions of agent behavior.

In conclusion, the results of the estimated parameters of the proposed model, as presented in Table 1, 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.

4.2 IRF: interest rate positive shocks

To deepen the analysis of the interaction between monetary and fiscal policies, an analysis of the behavior of the Brazilian monetary rule is pertinent. In this sense, the behavior of the Brazilian monetary rule is examined from this point on (Figures 1 and 2). The responses are grouped by variables. This means 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, more 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



Note(s): 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(s): Graphs generated from the conducted estimates

Figure 1.
IRF: interest rate positive shocks (GDP and CPI inflation)

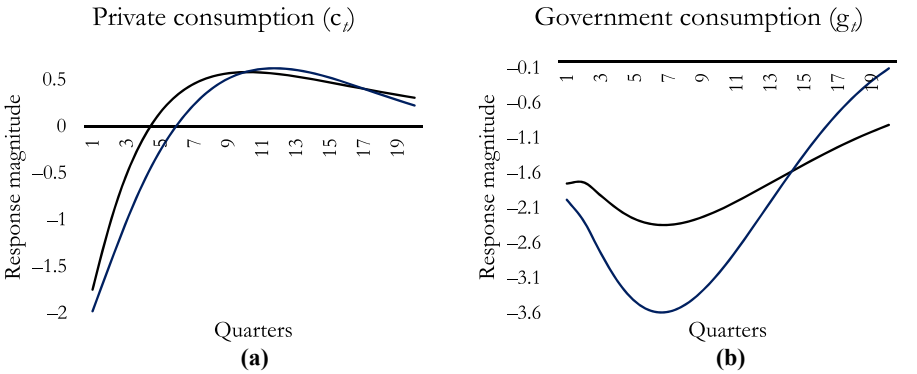


Figure 2.
IRF: interest rate positive shocks (private consumption and government consumption)

Note(s): 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(s): Graphs generated from the conducted estimates

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 are 100 basis points (0.25% per quarter), and the analyzed responses include those of real GDP, CPI inflation, private consumption and government consumption.

In the first quarter, considering the responses to a contractionary monetary policy, the GDP response under the behavioral approach is more negative compared to the rational approach. Specifically, in the first quarter, the behavioral approach shows a drop of −1.9787, while the rational approach shows a drop of −1.7478. This suggests that, initially, behavioral agents, due to their more myopic perception or heightened sensitivity to changes in interest rates, react more pronouncedly, resulting in a more intense economic contraction. As time progresses, both approaches show a pattern of recovery. However, the recovery in the rational model occurs more quickly, becoming positive from the ninth quarter onwards, while the behavioral approach remains negative until the 12th quarter, where it becomes slightly positive. This indicates that the rational approach, which assumes fully informed expectations and optimized reactions to changes in interest rates, tends to recover equilibrium more quickly. In the final quarters of the observation (15th to 20th), both approaches converge to positive values. However, the values are consistently higher in the behavioral approach than in the rational one. This suggests that, in the long term, behavioral agents adjust their expectations and responses, resulting in a more robust and sustained recovery compared to rational agents. The behavioral approach shows wider fluctuations and a sharper initial variation, reflecting a greater sensitivity to changes in interest rates. In contrast, the rational approach shows a more moderate variation, consistent with the assumption that agents have full information and adjust their expectations more smoothly. These first results indicate that, although more sensitive in the short term, behavioral agents adjust their expectations in a way that eventually leads to a stronger recovery. On the other hand, rational agents, with a more stable and less-volatile response, recover equilibrium more quickly, but with a less-marked recovery in the long term.

This more intense reaction in the behavioral approach is consistent with the hypothesis that behavioral agents are more reactive to changes in immediate monetary conditions, leading to a sharper contraction than rational agents. The structure of the model assumes

that fiscal policy can be activated to mitigate the restrictive effects of an increase in interest rates. However, the smoothing of the economic cycle may not be immediately visible in the charts due to the magnitude and timing of fiscal responses in relation to monetary changes. In other words, while fiscal policy acts to offset the negative effects, this offset may occur with some delay, reflecting the reality that fiscal responses are not always instantaneous or perfectly synchronized with changes in monetary policy. As noted, real GDP under rational expectations returns to normal levels more quickly, which is in line with the assumption that rational agents have fully informed expectations and optimize their reactions to changes in interest rates. This faster recovery is consistent with traditional economic theory, where well-informed agents adjust their consumption and investment decisions more efficiently, leading to a faster return to economic equilibrium. Although the behavioral approach shows a slower recovery, it eventually leads to a more robust and sustained recovery in the long term. This reflects a more gradual adaptation of the expectations and responses of behavioral agents, who, despite their greater initial sensitivity, adjust their perceptions and behaviors over time, resulting in a stronger and less-volatile economic recovery in the final quarters (Figure 1, chart "a").

In terms of inflation, in the first few quarters, both approaches show a significant drop. This indicates that, initially, raising interest rates reduces inflationary pressure, but the effect is slightly more pronounced in the rational approach. As time progresses, both approaches show a pattern of recovery in inflation. From the 12th quarter, inflation in the behavioral approach turns positive, while the rational approach remains slightly negative. From the 13th quarter onward, the behavioral approach continues to show positive and increasing inflation figures, indicating a faster recovery in inflation compared to the rational approach. In the final quarters (15th to 20th), inflation in the behavioral approach stabilizes at positive values, with 0.0750 in the 20th quarter, suggesting that behavioral agents eventually adjust their expectations and inflationary pressures return to a more balanced level. In contrast, the rational approach shows a slower recovery path, with inflation returning to positive values more gradually. The behavioral approach shows sharper fluctuations and a faster recovery of inflation. For example, inflation increases significantly from the 13th quarter, with a peak of 0.0826 in the 18th quarter. The rational approach, on the other hand, shows a smoother and more stable recovery without sharp peaks, reflecting less volatility in the inflationary response (Figure 1, chart "b").

In the first quarters, both approaches show a sharp drop in private consumption. In the first quarter, the behavioral approach shows a more pronounced drop of −1.9787 compared to −1.7478 in the rational approach. This difference suggests that behavioral agents are more sensitive to changes in interest rates, resulting in a greater contraction in initial consumption. As time progresses, the recovery in consumption occurs more quickly and robustly in the rational approach compared to the behavioral approach. In the 4th quarter, the rational approach already shows a positive value, while the behavioral approach is still negative. In the 6th quarter, the behavioral approach turns positive, indicating a slower recovery. In the final quarters (15th to 20th), the rational approach maintains stable positive values that are higher than those of the behavioral approach. This indicates that, in the long term, rational agents with more adjusted expectations can sustain a higher level of consumption in response to the interest rate shock. The behavioral approach shows a sharper initial variation followed by a more gradual recovery. From the 8th quarter onward, the recovery in the behavioral approach reaches a peak of 0.5118 in the 9th quarter before stabilizing. In contrast, the rational approach shows a more consistent and less-volatile recovery, reflecting a lower sensitivity to changes in interest rates (Figure 2, chart "a").

About government consumption, in the first quarters, both approaches show a significant reduction. In the first quarter, the behavioral approach shows a sharper drop of −1.9787 compared to −1.7478 in the rational approach. This indicates that, initially, behavioral

agents respond more sensitively to rising interest rates, resulting in a greater contraction in government consumption. The recovery of the variable in the rational approach begins in the 8th quarter, where the drop reduces to −2.3011, while in the behavioral approach the recovery is slower, with a less-pronounced reduction of −3.4761 in the same period. From the 12th quarter onward, the difference between the approaches becomes more evident, with the rational approach showing a drop of −1.8771, while the behavioral approach still shows −2.3655. In the final quarters (15th to 20th), both approaches converge to values closer to zero, indicating a continued recovery in government consumption. In the 20th quarter, the rational approach registers a reduction of −0.9106, while the behavioral approach shows a less pronounced drop of −0.1035. This suggests that in the long term, behavioral agents adjust their expectations in such a way that government consumption approaches equilibrium more quickly. The behavioral approach shows wider fluctuations and a later recovery, with a more pronounced drop in the first few quarters and a gradual recovery thereafter. In contrast, the rational approach shows a more constant and less-volatile recovery path, reflecting a lower initial sensitivity but a continuous and stable adjustment over time (Figure 2, chart "b").

However, it is worth noting that the DSGE model used in this study is based on microfoundations that consider an endogenous interaction between monetary and fiscal policies. This structure implies that government spending decisions are influenced by monetary policy in a more direct way than can be observed empirically in economies such as Brazil. This assumption allows for a clear and coherent analysis of policy interactions within the model but can simplify the complexity of fiscal relations observed in practice. In the context of the model, strict coordination between monetary policy and fiscal policy is assumed to simplify the analysis and focus on the efficiency of economic policy. This coordination implies that an increase in interest rates, designed to control inflation and stabilize the economy, would be accompanied by an adjustment in public spending to maintain fiscal sustainability. Although this coordination is ideal in theory, I recognize that in practice, especially in the Brazilian context, fiscal policy has shown a greater degree of autonomy and is less sensitive to variations in interest rates.

Historically, public spending in Brazil has been less restricted and more geared toward meeting social demands, even in periods of restrictive monetary policy. This reflects structural challenges and the need for supportive policies in a context of economic development. However, the theoretical model assumes a more disciplined approach, where the government adjusts their spending in response to changes in interest rates to avoid additional fiscal risks. The predicted reduction in public spending in response to a positive interest rate shock in the model is an abstraction that facilitates the analysis of policy interactions. This simplification allows us to explore the potential effects of optimal coordination between policies, highlighting the importance of fiscal adjustments in response to tighter monetary conditions. However, it is important to recognize that this simplification may not capture all the nuances of the Brazilian economic reality, where political, social and economic factors influence the trajectory of public spending in a more complex way (Carvalho, Diniz, Pedrosa and Rossi, 2016; Barros and Lima, 2018; Melo and Silva, 2019; Besarria, Maia and Nobrega, 2020; Araújo Júnior *et al.,* 2024).

4.3 IRF: government consumption positive shocks

To deepen the analysis of the interaction between monetary and fiscal policies, an analysis of the behavior of the Brazilian fiscal rule is pertinent. As was done for the monetary policy rule (Figures 1 and 2), the behavior of the Brazilian fiscal rule is examined from this point on (Figures 3 and 4). The research process follows a similar procedure. The responses are grouped by variable. This means that each chart represents the responses to the same shock

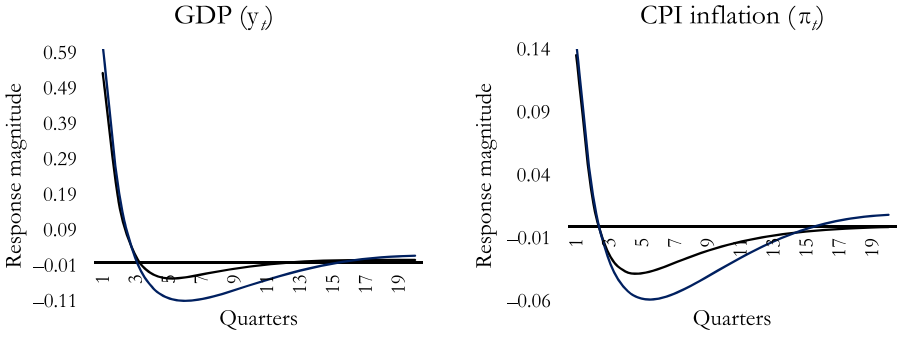


Figure 3.
IRF: government consumption positive shocks (GDP and CPI inflation)

Note(s): 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(s): Graphs generated from the conducted estimates

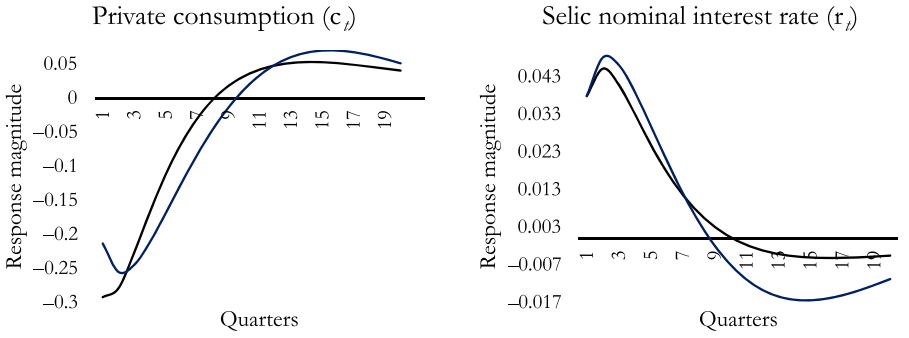


Figure 4.
IRF: government consumption positive shocks (private consumption and the Selic nominal interest rate)

Note(s): 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(s): Graphs generated from the conducted estimates

for both the rational and behavioral approaches. The responses of the selected macroeconomic variables to an expansionary fiscal policy, more 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 are 100 basis points (0.25% per quarter), and the analyzed responses include those of real GDP, CPI inflation, private consumption and the Selic nominal interest rate.

Firstly, in the first quarters, both approaches show an increase in GDP in response to the positive shock in government consumption. In the first quarter, the behavioral approach

shows a more pronounced increase of 0.6124 compared to 0.5345 in the rational approach. This suggests that, initially, behavioral agents, due to their more reactive perception of changes in government spending, promote a more intense economic stimulus. As time progresses, both approaches show a decrease in the positive effects on product, with the behavioral approach showing a sharper drop in the first quarters. In the 4th quarter, the rational approach registers a value of −0.0316, while the behavioral approach shows a more pronounced drop of −0.0688. This difference indicates that while the rational approach smooths out impacts more quickly, the behavioral approach tends to show greater volatility in the GDP response. In the final quarters (15th to 20th), both approaches show a recovery in product charts. From the 16th quarter onward, the product in the rational approach becomes positive at 0.0067, while the behavioral approach already shows a positive value of 0.0047. In the 20th quarter, the behavioral approach shows a value of 0.0193, while the rational approach shows a slightly lower value of 0.0074. This suggests that, in the long term, behavioral agents, despite their greater initial volatility, manage to adjust their expectations and promote more robust GDP growth in response to increased government spending. The behavioral approach exhibits wider fluctuations and greater variability in the effects on product, especially in the first few quarters (Figure 3, chart "a").

Regarding inflation, in the first quarters, both approaches show an increase in response to the positive shock in government consumption. In the first quarter, the behavioral approach shows a slightly larger increase of 0.1459 compared to 0.1358 in the rational approach. This suggests that, initially, behavioral agents, due to their greater sensitivity to changes in government spending, promote a more intense inflationary impact. As time progresses, both approaches show a decrease in the positive effects on inflation, with the behavioral approach showing a sharper drop in the first quarters. In the 4th quarter, the rational approach registers a value of −0.0361, while the behavioral approach shows a more pronounced drop of −0.0499. This difference indicates that while the rational approach smooths out inflationary impacts more quickly, the behavioral approach tends to show greater volatility in the inflation response. In the final quarters (15th to 20th), both approaches show a recovery in inflation dynamics. From the 16th quarter onward, inflation in the rational approach remains negative at −0.0033, while the behavioral approach already shows a positive value of 0.0014. In the 20th quarter, the behavioral approach shows a value of 0.0089, while the rational approach shows a negative value of −0.0008. This suggests that, in the long term, behavioral agents, despite their greater initial volatility, manage to adjust their expectations and promote a slight increase in CPI inflation in response to the increase in government spending. Thus, the behavioral approach exhibits wider fluctuations and greater variability in the inflationary effects, especially in the first few quarters. In contrast, the rational approach shows a more contained variation and a more stable recovery, reflecting a lower initial sensitivity but a more gradual adjustment over time. In response to the observations on the relationship between interest rates and the short-term economic cycle, the results suggest that although the behavioral approach shows greater initial sensitivity, it also shows a more robust and sustained recovery in the long term. This can be interpreted as an indication that, although a theoretical fiscal adjustment is not clearly represented in the charts, the behavioral dynamic allows for a gradual adaptation that leads to a more pronounced stabilization of economic variables over time. The difference between the rational and behavioral approaches illustrates how agents' expectations and reactions influence macroeconomic responses, with the rational approach promoting a faster recovery and the behavioral approach a stronger recovery in the long term (Figure 3, chart "b").

In the first quarters, both approaches show a reduction in private consumption in response to the positive shock in government consumption. In the first quarter, the rational approach shows a more pronounced drop of −0.2921 compared to −0.2134 in the behavioral approach. This suggests that, initially, rational agents are more sensitive to changes in

government spending, resulting in a greater contraction in private consumption. As time progresses, both approaches show a decrease in the negative effects on private consumption, with the behavioral approach showing a faster recovery. In the 4th quarter, the rational approach registers a value of −0.1674, while the behavioral approach shows a less-pronounced drop of −0.2116. This indicates that while the behavioral approach softens negative impacts more quickly, the rational approach shows a more gradual recovery. In the final quarters (15th to 20th), both approaches show a recovery in private consumption charts. From the 9th quarter onward, private consumption in the rational approach becomes positive at 0.0176, while the behavioral approach already shows a positive value of 0.0124 in the 10th quarter. In the 20th quarter, the behavioral approach shows a value of 0.0512, while the rational approach shows a slightly lower value of 0.0406. This suggests that, in the long term, behavioral agents, despite their greater initial recovery, promote a more robust increase in private consumption in response to the increase in government spending. The behavioral approach shows more contained fluctuations and less variability in the effects on the variable, especially in the first few quarters. In contrast, the rational approach shows a more pronounced variation and a more stable recovery, reflecting greater initial sensitivity but a more gradual adjustment over time (Figure 4, chart "a").

Finally, about the nominal interest rate, in the first quarters, both approaches show an increase in the rate in response to the positive shock in government consumption. In the first quarter, both the rational and behavioral approaches show a very similar increase of approximately 0.0379. In the second quarter, the behavioral approach shows a slightly higher increase of 0.0481 compared to 0.0452 for the rational approach. This suggests that, initially, both approaches react similarly to the fiscal stimulus, with a slight tendency towards greater sensitivity in the behavioral approach. As time progresses, both approaches show a decrease in the positive effects on the nominal interest rate, with the behavioral approach showing a faster recovery. In the 4th quarter, the rational approach registers a value of 0.0332, while the behavioral approach shows a value of 0.0391. From the 9th quarter onward, the behavioral approach shows negative values (−0.0018), while the rational approach remains positive (0.0032), indicating a difference in interest rate adjustment dynamics. In the final quarters (15th to 20th), both approaches show negative values for the nominal interest rate. From the 15th quarter onward, the rational approach shows a rate of −0.0050, while the behavioral approach is at −0.0164. In the 20th quarter, the behavioral approach shows a value of −0.0108, while the rational approach shows a value of −0.0045. This suggests that, in the long term, behavioral agents, despite a greater initial reduction, adjust their expectations to a more negative interest rate level in response to the increase in government spending. The behavioral approach exhibits wider fluctuations and greater variability in the effects on the nominal interest rate, especially in the first few quarters. About the relationship between interest rates and the short-term economic cycle, the results suggest that while the behavioral approach shows greater initial resilience, it also exhibits a more robust and sustained recovery in the long term. This can be interpreted as an indication that, although a theoretical fiscal adjustment is not fully captured by the charts, the behavioral dynamic allows for a gradual adaptation that leads to a more pronounced stabilization of economic variables over time (Figure 4, chart "b").

5. 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 focused on the differential impacts of the 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 2022Q4, providing a comprehensive comparison between the two approaches.

In the rational approach, a contractionary monetary policy, indicated by an increase in interest rates, led to a fall in economic activity and a reduction in inflation. The contraction in GDP was driven by falls in private consumption and investment, with the economy subsequently beginning to recover. This approach demonstrated the effectiveness of monetary policy in controlling inflation and maintaining the expected behavior of GDP. However, the persistent procyclicality after the economic recovery highlights limitations in promoting sustained economic growth, suggesting the need for more coordinated economic policies.

On the other hand, under the behavioral approach, the implementation of a contractionary monetary policy also resulted in a decline in economic activity, but with different dynamics. The fiscal response was initially procyclical, followed by a reversal, indicating strict fiscal control and a focus on achieving primary surplus targets in the first two years. Although monetary policy, marked by rising interest rates, effectively reduced inflation, the absence of a clear turning point suggests a delayed effect of monetary policy on the economy. The initially procyclical fiscal response, followed by a reversal, underlines a more flexible and adaptive approach, potentially favorable to sustaining long-term growth.

The findings suggest that the behavioral approach offers greater flexibility in the fiscal response, aligning itself dynamically with economic conditions. This adaptability is particularly valuable in the face of uncertainty and changing expectations among economic agents. However, the effectiveness of monetary policy remains dependent on the timely manifestation of its effects on the economy.

The results should be interpreted positively, reflecting observed behaviors and responses to policy changes, rather than normatively prescribing one approach over the other. The comparison between rational and behavioral models demonstrates the variability in sensitivity and adaptability of economic agents to policy shocks, providing insights for policymakers. Recent Brazilian economic policies often exhibit a lack of cooperation between the fiscal and monetary dimensions, with fiscal policy showing less alignment with macroeconomic stability and predictability. The findings of this study are in line with this observation, highlighting the importance of a coordinated approach to increase policy effectiveness. While the rational model emphasizes predictability and faster recovery to equilibrium, the behavioral model stresses the benefits of flexibility and adaptive responses to economic shocks.

For policymakers, these results can highlight the importance of integrating behavioral insights into economic models to better capture the realities of agents' behavior and the impacts of policies. The effective synchronization of monetary and fiscal policies is crucial to fostering sustainable economic growth. The choice between rational and behavioral approaches must consider the specific characteristics of the economy and the relative importance of flexibility versus predictability in policy design.

Although not the focus of this study, several areas merit further exploration: analyzing scenarios involving fiscal or monetary dominance in the economy, examining scenarios with a zero nominal interest rate lower bound, aligning fiscal targets with fiscal policy strategies and the interaction between exchange rate policy and other economic policies. These areas offer promising opportunities to deepen the understanding of economic policy dynamics and improve the formulation of more effective public policies.

Finally, this study aimed to improve the understanding of economic policy dynamics through the lens of bounded rationality, providing new perspectives on the interaction between monetary and fiscal policies in the Brazilian context. The insights gained from this research should contribute significantly to the literature on strengthening the country's path toward sustainable economic development.

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Further reading

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Supplementary material

The supplementary material for this article can be found online.

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