Fiscal Policy in an SNA-Compliant DSGE Model for Emerging Markets

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Abstract

Fiscal policy is often one of the economic Achilles heels of emerging markets. Therefore, adequately modeling it becomes crucial to understanding the effects of shocks impacting this class of economies. This paper seeks to make a new proposal on how to model an emerging market such as Brazil, with a particular emphasis on the fiscal side. To that end, we build a medium-scale open-economy DSGE model, enriched with a detailed government structure and a comprehensive array of fiscal tools. We then compare the effects of some relevant shocks to those generated by the Central Bank of Brazil's DSGE workhorse model, SAMBA. Additionally, we analyze several fiscal structural reforms that have been suggested or implemented within the last decade. Our results show that our model does a good job of reproducing the movements of key economic variables, shedding light on the fiscal dynamics and their interactions with monetary policy and external shocks.

1 Introduction

Emerging markets and developing economies often confront significant challenges concerning the sustainability of their fiscal policies, especially amidst high economic volatility and pressing social needs. Effective governance is then somehow compromised in the face of frequent and intense shocks hitting these economies. In light of these difficulties, policymakers in these countries should rely on robust models to diagnose the problems and make informed decisions about the more fitting measures to promote economic growth and social justice. Any sound analysis seeking to assess the impact of fiscal reforms and shocks on economic activity should thus be grounded in models of sufficient rigor and depth.

This article attempts to accomplish that task by putting forth a DSGE model that provides a comprehensive framework for understanding and predicting the interactions between shocks and overall economic performance in emerging markets. This setup features an open economy where the fiscal block is thoroughly detailed so as to capture the complexities of government policy and its impacts. It incorporates various fiscal instruments, allowing for the examination of policy responses under different economic conditions.

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This fiscal module draws from the System of National Accounts (SNA)-compliant structure embeded into an otherwise frictionless DSGE model developed by Fernandez-de-Cordoba et al. (2022). We believe the advantages of such an approach are several-fold:

1. DSGE models usually employ simplifying frameworks on the fiscal front, which may omit relevant transmission mechanisms. Our model, however, incorporates a detailed government sector as defined by the SNA, fully representing the breadth and diversity of government activities and their impact on the economy.

2. The detailed representation of the government sector enables the model to better assess the economy-wide impact of specific components of public expenditure and taxation. It provides a valuable perspective for evaluating fiscal consolidation measures, making it an indispensable tool for policymakers.

3. The model's compliance with SNA makes it suitable for use in international comparisons and studies, adhering to the data collection and reporting standards of major organizations like the OECD or the IMF.

The model's fiscal unit incorporates a rich variety of taxes and government expenditures. Distortionary taxes include those on consumption, imports, labor income, and capital income. Additionally, the model encompasses social security contributions from households and firms, as well as lump-sum taxes. On the expenditure side, it covers current spending, infrastructure investment, and public wages.

In addition to that, we explicitly account for the following frictions or building blocks:

1. Consumer heterogeneity: Ricardian versus non-Ricardian (or hand-to-mouth) households.

2. Habit formation in consumption.

3. Price and private wage rigidity.

4. Investment adjustment costs.

5. International trade in both final and intermediate goods and services, as well as in financial assets.

In order to credibly assess the validity of our model, we compare its results to those generated by the Central Bank of Brazil (BCB)'s well-known workhorse DSGE model, SAMBA (Stochastic Analytical Model with a Bayesian Approach)[1]. This comparison allows us to verify that our model's performance aligns well with most of the outcomes that the widely used BCB model yields. The advantage of our SNA-compliant DSGE model over SAMBA lies primarily in its more detailed fiscal framework, allowing users to conduct thorough analyses of fiscal shocks and their ensuing effects. We believe that it constitutes a powerful tool for the careful examination of much-needed reforms and policies in emerging markets.

As alluded to above, the results of our experiments are, by and large, quite satisfactory. For the same shocks included in de Castro *et al.* (2015), we find that most of the variables across both models exhibit similar behavior. As for the shocks not included in the aforementioned article, all of which are fiscal in nature, the impulse response functions (IRFs) generally offer realistic patterns and reliable representations of the economic dynamics. Some Brazil-specific policies

[1]For this comparative analysis, we rely solely on the shocks studied in the published article where SAMBA was presented (de Castro *et al.*, 2015).

were also simulated, such as the 'administrative reform' -reducing the wage premium of the public sector vis-à-vis the private sector-, and the 'emergency aid payment' –a lump-sum transfer to household to help them cope with the pandemic shock–, revealing important insights on efficient resource allocation, productivity gains, and welfare transfers among different household groups.

This work contributes to the literature on DSGE models applied to emerging economies, standing out for its innovative approach and the practical relevance of its results for economic policy. In addition to this introductory section, this paper is organized as follows: section 2 examines the literature review, section 3 describes the model, section 4 presents a detailed discussion about the results, and section 5 concludes.

2 Literature review

The relationship between fiscal policy and macroeconomic performance has sparked intense academic debate, especially in the aftermath of recent economic crises. This literature review aims to synthesize key theoretical and empirical contributions, exploring how various fiscal policies influence economic growth, macroeconomic stability, and public debt sustainability.

DSGE models allow for precise simulation of various fiscal policy scenarios, aiding policymakers in anticipating the impacts of fiscal changes before implementation. Bhattarai and Trzeciakiewicz (2017) emphasize that these models analyze both short- and long-term effects of fiscal instruments, such as public consumption and investment, and assess their effectiveness under different economic conditions, including scenarios where interest rates are constrained by the zero lower bound (ZLB).

Empirical evidence suggests that high levels of public debt can exert adverse pressures on the economy through various channels. Firstly, a high level of indebtedness makes the economy more vulnerable to macroeconomic shocks, limiting the government's ability to implement effective countercyclical fiscal policies. This can exacerbate economic volatility and retard recovery during recession periods (Bi, 2012; Bi and Leeper, 2010).

Additionally, high public debt can increase borrowing costs due to sovereign risk premiums, creating a "diabolic loop" between sovereign risk and bank credit risk (Brunnermeier *et al.*, 2016). This phenomenon was particularly acute throughout the sovereign debt crisis in the eurozone periphery.

Studies using DSGE models show that expansive fiscal policies can have significant effects on GDP during economic crises. Coenen *et al.* (2012) find that discretionary fiscal measures implemented during the global financial crisis increased the annualized growth rate of real quarterly GDP by up to 1.6 percentage points. However, the effectiveness of these policies crucially hinges on coordination with monetary policy and the specific economic context (Davig and Leeper, 2011; Leeper *et al.*, 2015).

The interaction between monetary and fiscal policies is particularly relevant in an environment where interest rates are near zero. During such periods, fiscal policies can be more effective owing to the limited capacity of monetary policy to stimulate the economy (Hills and Nakata, 2014).

Public debt sustainability is a central concern in fiscal policy formulation. Studies such as Bouabdallah *et al.* (2017) develop methodologies to assess debt sustainability in the euro area, considering factors like risk premium responses and the types of taxation used to finance debt. Implementing structural reforms is often recommended to mitigate the risks associated with high public debt levels and improve long-term fiscal sustainability (Batini *et al.*, 2018).

To provide a comprehensive overview of the various strands of literature on the effects of fiscal policy on macroeconomic outcomes, it is useful to categorize numerous studies into distinct building blocks:

The international literature is rich in studies on fiscal policy effects, but there is no consensus on the size or sign of government spending multipliers. Early studies, such as Baxter and King (1993), using RBC models, showed that an increase in government spending negatively affects household wealth as a result of higher future taxes, leading to increased labor supply and reduced private consumption and real wages. New Keynesian models, incorporating real and nominal frictions, show similar wealth effects but with potentially higher real wages due to increased labor demand.

Recent studies recognize consumer behavior heterogeneity, moving away from the restrictive assumption of the infinitely-lived, rational representative agent. Mankiw (2000) argues for models with both Ricardian and non-Ricardian agents, who lack access to financial markets. Galí et al. (2007) incorporated rule-of-thumb (non-Ricardian) agents into a New Keynesian model, finding significant positive fiscal multipliers due to these consumers, sticky prices, and deficit financing.

Subsequent literature integrated rule-of-thumb consumers into richer models, such as those by Smets and Wouters (2005, 2007) and Christiano et al. (2005), which include sticky prices and wages, investment adjustment costs, and habit persistence. These models effectively capture macroeconomic variations and quantify the importance of rule-of-thumb consumers. Examples include Coenen and Straub (2005), Erceg et al. (2006), Rabanal and López-Salido (2006), and Forni et al. (2009).

Mountford and Uhlig (2009) found substantial multipliers for the US, emphasizing that tax cuts are more effective in stimulating demand than increased government spending, which has an insignificant effect on private consumption. Coenen et al. (2012) found that discretionary fiscal measures during the global financial crisis increased annualized real quarterly GDP growth by up to 1.6 percentage points.

The interaction between monetary and fiscal policies is crucial for fiscal multiplier size. Davig and Leeper (2011) found that monetary and fiscal policies in the US oscillate between active and passive states, with government spending shocks inducing positive consumption responses under certain regimes. Leeper et al. (2015) identified different multiplier sizes under varying monetary-fiscal policy regimes.

3 Model

3.1 Households

In this model, there is a continuum of households indexed by $j \in [0,1]$. A fraction ω_R of these households, indexed by $R \in [0,\omega_R)$, can save and behave like Ricardian households, meaning they maximize their intertemporal utility. The remaining households, indexed by $NR \in [\omega_R, 1]$, simply consume their current disposable income and are referred to as non-Ricardian households.

3.1.1 Definition of Consumption and Savings for Ricardian Households

This representative household chooses consumption, savings, and leisure so as to maximize its intertemporal utility. Consumption includes domestically produced goods (subject to consumption tax) and imported goods (subject to import tax), with public services affecting the level of utility. Savings can be carried out in the form of domestic public bonds, external bonds, and physical assets (private investment). Finally, by choosing the number of working hours (in the private sector[2] or the government), the household also chooses leisure. This model differentiates labor in the utility function, allowing preferences to vary between sectors through different marginal disutilities of labor. Given these features, Ricardian households must solve the following problem:

$$\max_{C_t^{R,D,D},C_t^{R,F,D},L_t^{R,P},L_t^G,B_{t+1},B_{t+1}^F,K_{t+1}^P} E_t \sum_{t=0}^{\infty} \beta^t S_t^P \left[\frac{\left(C_t^R + \gamma_{servG} Serv_t^G\right)^{1-\sigma}}{1-\sigma} - S_t^L \left(\frac{L_t^{R,P\,1+\varphi_P}}{1+\varphi_P} + \Xi_G \frac{L_t^{G\,1+\varphi_G}}{1+\varphi_G} \right) \right] \quad (1)$$

subject to a budget constraint,

$$\begin{aligned} (1+\tau_t^C) C_t^{R,D,D} P_t^{C,D} + (1+\tau_t^{imp}) C_t^{R,F,D} S_t P_t^{C,F} + I_t^P P_t^{C,D} + \frac{B_{t+1}}{R_t^B} + B_t^F S_t R_{t-1}^F \\ = (1-\tau_t^L - \tau_t^{H,S})(W_t^P L_t^{R,P} + W_t^G L_t^G) + (1-\tau_t^K) R_t^K K_t^P + B_t + B_{t+1}^F S_t \\ - \frac{\chi_F}{2}\left(B_{t+1}^F - B_{ss}^F\right)^2 S_t - \omega_R (T_t P_t^{C,D}) \end{aligned} \quad (2)$$

where E_t is the rational expectations operator, β is the intertemporal discount parameter, σ is the relative risk aversion, φ_P and φ_G represent the marginal disutilities of labor in the private and government sectors, respectively, Ξ_G is an adjustment parameter for the public-private labor relationship, γ_{servG} is the parameter for the sensitivity of public service utility, C is consumption, $C^{R,D,D}$ is consumption of domestically produced goods[3], $C^{R,F,D}$ is consumption of foreign-produced goods, the prices[4] of these two goods are $P^{C,D}$ and $P^{C,F}$, respectively, I^P is private investment, $Serv^G$ is public service, B denotes domestic public bonds, with a return given by R^B, , and net external bonds[5] are represented by B^F with a return R_F, S is the nominal exchange rate, $L^{R,P}$ and L^G are the quantities of hours worked in the private and government sectors, respectively, with remunerations W^P and W^G, K^P is private capital with a return R^K. Taxes on domestic consumption, imported consumption, labor remuneration, capital service remuneration, social security contributions, and lump-sum taxes are τ^C, τ^{imp}, τ^L, τ^K, $\tau^{H,S}$ and T, respectively. The term $\left[\frac{\chi_F}{2}\left(B_{t+1}^F - B_{ss}^F\right)^2 S_t\right]$ is used to induce model stationarity (Schmitt-Grohé and Uribe, 2003).

The model introduces two shocks on the household preference side. First, S^P is the intertemporal preference shock, altering the household's choice between present and future consumption, following the rule:

$$\log S_t^P = \rho_P \log S_{t-1}^P + \epsilon_{P,t} \quad (3)$$

[2]There is an assumption of nominal rigidity in the private labor market, which is addressed separately.

[3]We use the following naming convention for consumption and input variables: $X^{A,B}$, where A represents where the product is produced and B represents where the product is consumed.

[4]We use the following naming convention for prices: $P^{A,B}$ where A represents the sector (C for consumer goods and INS for inputs) and B represents the country (D for domestic and F for the rest of the world).

[5]Acquisition of domestic bonds by foreign households minus acquisition of external bonds by domestic households.

where ρ_P is the autoregressive component, and $\epsilon_{P,t} \sim N(0, \sigma_P)$. The second shock is the labor supply shock, S^L, which affects the household's willingness to work. The rule governing this shock is:

$$\log S_t^L = \rho_L \log S_{t-1}^L + \epsilon_{L,t} \tag{4}$$

where ρ_L is the autoregressive component of this shock, and $\epsilon_{L,t} \sim N(0, \sigma_L)$.

We still need a capital accumulation rule, a labor aggregation, and a consumption aggregation:

$$K_{t+1}^P = (1-\delta)K_t^P + I_t^P \left[1 - \frac{\nu}{2}\left(\frac{I_t^P}{I_{t-1}^P S_t^I} - 1\right)^2\right] \tag{5}$$

onde ν is the investment adjustment cost sensitivity parameter and S_t^I is the private investment productivity shock given by:

$$\log S_t^I = \rho_I \log S_{t-1}^I + \epsilon_{I,t} \tag{6}$$

where ρ_I is the autoregressive component, and $\epsilon_{I,t} \sim N(0, \sigma_I)$.

$$L_t^R = L_t^{R,P} + L_t^G \tag{7}$$

$$C_t^R = \bar{C}_t^R - \gamma_C \bar{C}_{t-1}^R \tag{8}$$

where γ_C is the habit formation parameter with aggregation:

$$\bar{C}_t^R = C_t^{R,D,D^{1-\omega_C^D}} C_t^{R,F,D^{\omega_C^D}} \tag{9}$$

First-order conditions for the problem are:

$$\left(\frac{1-\omega_C^D}{\omega_C^D}\right)\frac{C_t^{R,F,D}}{C_t^{R,D,D}} = \left(\frac{1+\tau_t^C}{1+\tau_t^{imp}}\right)\frac{P_t^{C,D}}{P_t^{C,F} S_t} \tag{10}$$

$$\left(\frac{1}{1-\omega_C^D}\right)\left[\frac{S_t^L \Xi_G L_t^{G^{\varphi_G}} C_t^{R,D,D}}{\left(C_t^R + \gamma_{servG} Serv_t^G\right)^{-\sigma} C_t^R}\right] = \left(\frac{1-\tau_t^L - \tau_t^{H,S}}{1+\tau_t^C}\right)\frac{W_t^G}{P_t^{C,D}} \tag{11}$$

$$\left[\frac{S_t^P \left(C_t^R + \gamma_{servG} Serv_t^G\right)^{-\sigma} C_t^R}{(1+\tau_t^C)P_t^{C,D} C_t^{R,D,D}}\right] = R_t^B \beta E_t \left[\frac{S_{t+1}^P \left(C_{t+1}^R + \gamma_{servG} Serv_{t+1}^G\right)^{-\sigma} C_{t+1}^R}{(1+\tau_{t+1}^C)P_{t+1}^{C,D} C_{t+1}^{R,D,D}}\right] \tag{12}$$

$$R_t^B = R_t^F E_t \left\{\frac{S_{t+1}}{S_t}\right\}\left[\frac{1}{1-\chi_F(B_{t+1}^F - B_{ss}^F)}\right] \tag{13}$$

$$Q_t = \beta E_t \left\{(1-\delta)Q_{t+1} + \left[\frac{\left(1-\omega_C^D\right)\left(C_{t+1}^R + \gamma_{servG} Serv_{t+1}^G\right)^{-\sigma} C_{t+1}^R}{(1+\tau_{t+1}^C)P_{t+1}^{C,D} C_{t+1}^{R,D,D}}\right]\left(R_{t+1}^K - P_{t+1}^{C,D}\right)\right\} \tag{14}$$

$$\left[\frac{\left(1-\omega_C^D\right) S_t^P \left(C_t^R + \gamma_{servG} Serv_t^G\right)^{-\sigma} C_t^R}{C_t^{R,D,D}}\right] = Q_t \left[1 - \frac{\nu}{2}\left(\frac{I_t^P}{I_{t-1}^P S_t^I} - 1\right)^2 - \nu\left(\frac{I_t^P}{I_{t-1}^P S_t^I}\right)\left(\frac{I_t^P}{I_{t-1}^P S_t^I} - 1\right)\right]$$

$$+\nu\beta E_t\left[Q_{t+1}\left(\frac{I^P_{t+1}}{I^P_t S^I_{t+1}}\right)^2\left(\frac{I^P_{t+1}}{I^P_t S^I_{t+1}}-1\right)\right] \tag{15}$$

where Q is the Lagrange multiplier associated with capital stock movement.

Equations 10-15 represent the relative consumption between domestic and imported goods, public labor supply, Euler equations for domestic and foreign bonds[6], physical capital, and private investment demand.

3.1.2 Definition of Consumption for Non-Ricardian Households

This representative non-Ricardian household maximizes its intertemporal utility by choosing consumption and leisure[7], restricted to intratemporal choices due to its liquidity constraint that prevents intertemporal maximization. Their consumption can be on domestically produced goods ($C_t^{NR,D,D}$) (subject to consumption tax) and imported goods ($C_t^{NR,F,D}$) (subject to import tax), with public services affecting the level of utility. Given these features, non-Ricardian households must solve the following problem:

$$\max_{C_t^{NR,D,D},C_t^{NR,F,D},L_t^{NR,P}} E_t\sum_{t=0}^{\infty}\beta^t S_t^P\left[\frac{\left(C_t^{NR}+\gamma_{servG}Serv_t^G\right)^{1-\sigma}}{1-\sigma}-S_t^L\frac{L_t^{NR,P^{1+\varphi_P}}}{1+\varphi_P}\right] \tag{16}$$

subject to a budget constraint,

$$\begin{aligned}&(1+\tau_t^C)C_t^{NR,D,D}P_t^{C,D}+(1+\tau_t^{imp})C_t^{NR,F,D}S_tP_t^{C,F}\\&=(1-\tau_t^L-\tau_t^{H,S})W_t^PL_t^{NR,P}-(1-\omega_R)(T_tP_t^{C,D})\end{aligned} \tag{17}$$

with,

$$C_t^{NR}=C_t^{\bar{N}R}-\gamma_C C_{t-1}^{\bar{N}R} \tag{18}$$

$$C_t^{\bar{N}R}=C_t^{NR,D,D^{1-\omega_C^D}}C_t^{NR,F,D^{\omega_C^D}} \tag{19}$$

The first-order condition for the previous problem is:

$$\left(\frac{1-\omega_C^D}{\omega_C^D}\right)\frac{C_t^{NR,F,D}}{C_t^{NR,D,D}}=\left(\frac{1+\tau_t^C}{1+\tau_t^{imp}}\right)\frac{P_t^{C,D}}{P_t^{C,F}S_t} \tag{20}$$

3.1.3 Definition of Private Wage (Ricardian and Non-Ricardian Households)

The choice of the private wage level by both Ricardian and non-Ricardian households implies that these agents provide differentiated labor under a monopolistic competition framework. These services are sold to a representative labor aggregator, which combines all these different labor services ($L_j^{Z,P}$) into a single input ($L^{Z,P}$) through a Dixit-Stiglitz technology (Dixit and Stiglitz, 1977), where $Z := \{R, NR\}$.

[6]Uncovered interest rate parity (UIP).

[7]Unlike Ricardian households, non-Ricardian households do not supply labor to the public sector.

$$\max_{L_{j,t}^{Z,P}} W_t^P L_t^{Z,P} - \int_0^1 W_{j,t}^P L_{j,t}^{Z,P} dj \tag{21}$$

subject to the following technology:

$$L_t^{Z,P} = \left(\int_0^1 L_{j,t}^{Z,P}{}^{\frac{\psi_{W,t}-1}{\psi_{W,t}}} dj \right)^{\frac{\psi_{W,t}}{\psi_{W,t}-1}} \tag{22}$$

where $\psi_{W,t}$ is the elasticity of substitution between different labor types, whose movement follows:

$$\log \psi_{W,t} = \rho_{\psi_W} \log \psi_{W,t-1} + \epsilon_{\psi_W,t} \tag{23}$$

where ρ_{ψ_W} is the autoregressive component of this shock and $\epsilon_{\psi_W,t} \sim N(0, \sigma_{\psi_W})$.

The first-order condition for the previous problem is:

$$L_{j,t}^{Z,P} = L_t^{Z,P} \left(\frac{W_t^P}{W_{j,t}^P} \right)^{\psi_{W,t}} \tag{24}$$

This equation represents the demand for the labor of household j. Substituting this expression into equation (22) results in the aggregate wage level:

$$W_t^P = \left(\int_0^1 W_{j,t}^P{}^{1-\psi_W} dj \right)^{\frac{1}{1-\psi_W}} \tag{25}$$

Additionally, each period, a fraction $1 - \theta_W$ of households -chosen randomly and independently— set their wages optimally. The remaining households, θ_W, follow a fixed wage rule ($W_{j,t}^P = W_{j,t-1}$). When setting their wage level in period t households that set wages are aware of the probability θ_W^N that the wage will remain fixed for N periods into the future, regardless of the household making the optimal choice $W_{j,t}^{P\,*}$ in the current period. Therefore, the household seeks to solve the following problem:

$$\max_{W_{j,t}^{P\,*}} E_t \sum_{i=0}^{\infty} (\beta\theta_W)^i \left\{ -S_{t+i}^P S_{t+i}^L \frac{L_{j,t+i}^{Z,P}{}^{1+\varphi_p}}{1+\varphi_p} - \lambda_{Z,t+i} \left[-W_{j,t}^{P\,*} L_{j,t+i}^{Z,P} \left(1 - \tau_{t+i}^L - \tau_{t+i}^{H,S}\right) \right] \right\} \tag{26}$$

subject to the labor demand of household j (equation (24)).

Solving this problem yields the following first-order condition for both Ricardian and non-Ricardian households:

$$W_{j,t}^{P\,*} = \left(\frac{\psi_{W,t}}{\psi_{W,t}-1} \right) E_t \sum_{i=0}^{\infty} (\beta\theta_W)^i \left[\frac{S_{t+i}^P S_{t+i}^L L_{j,t+i}^{Z,P}{}^{\varphi_p}}{\lambda_{Z,j,t+i}(1 - \tau_{t+i}^L - \tau_{t+i}^{H,S})} \right] \tag{27}$$

where $markupW_t = \left(\frac{\psi_{W,t}}{\psi_{W,t}-1} \right)$.

Since $1-\theta_W$ of households set the same nominal wage, $W_{j,t}^{P\,*} = W_t^{P*}$, and the remaining θ_W, receive the same wage as the previous period, the aggregate nominal wage can be written as follows:

$$W_t^P = \left[\theta_W W_{t-1}^{P}{}^{1-\psi_{W,t}} + (1-\theta_W) W_t^{P*1-\psi_{W,t}}\right]^{\frac{1}{1-\psi_{W,t}}} \tag{28}$$

The gross wage inflation rate can be defined as:

$$\pi_{W,t} = \frac{W_t^P}{W_{t-1}^P} \tag{29}$$

3.1.4 Aggregating consumption and labor

The aggregate values for consumption and labor are given by:

$$C_t = \omega_R C_t^R + (1-\omega_R) C_t^{NR} \tag{30}$$

$$L_t^P = \omega_R L_t^{R,P} + (1-\omega_R) L_t^{NR,P} \tag{31}$$

3.2 Firms

3.2.1 Final Goods Producing Firms

From an aggregate perspective, monopolistic competition involves, among other things, the fact that consumers purchase a wide variety of goods. However, for modeling purposes, it is assumed that they buy only one specific (aggregate) good. This good is sold by final goods producing firms under a perfect competition structure.

To produce this aggregate good, the firm must buy a large quantity of intermediate goods. These are the inputs used in this production process. Therefore, the firm must solve the following problem:

$$\max_{Y_{j,t}} P_t^{C,D} Y_t - \int_0^1 P_{j,t}^{C,D} Y_{j,t} dj \tag{32}$$

subject to the following technology given by the Dixit-Stiglitz aggregator,

$$Y_t = \left(\int_0^1 Y_{j,t}^{\frac{\psi_t - 1}{\psi_t}} dj \right)^{\frac{\psi_t}{\psi_t - 1}} \tag{33}$$

where Y_t is the final (aggregate) product in period t whose price is $P_t^{C,D}$, and $Y_{j,t}$ for $j \in [0,1]$ is the intermediate good j with price $P_{j,t}^{C,D}$. And $\psi > 1$ is the elasticity of substitution between intermediate goods, whose movement follows:

$$\log \psi_t = \rho_\psi \log \psi_{t-1} + \epsilon_{\psi,t} \tag{34}$$

where ρ_ψ is the autoregressive component of this shock and $\epsilon_{\psi,t} \sim N(0, \sigma_\psi)$.

Solving the previous problem yields the demand for the product $Y_{j,t}$:

$$Y_{j,t} = Y_t \left(\frac{P_{j,t}^{C,D}}{P_t^{C,D}} \right)^{-\psi_t} \tag{35}$$

substituting equation (35) into equation (33), we arrive at the general price level:

$$P_t^{C,D} = \left(\int_0^1 P_{j,t}^{C,D^{1-\varphi}} dj \right)^{\frac{1}{1-\varphi}} \tag{36}$$

3.2.2 Intermediate Goods Producing Firms

Considering that domestic production is given by $Y = \{C^{D,D}, I^P, G, I^G, C^{D,F}\}$, an intermediate goods producing firm solves its problem in three stages: first, it chooses private labor and private capital for the production of domestic inputs—public capital enters the production function as a given input; next, to determine its production level, it chooses between domestic and imported inputs; finally, it sets the price of the good it produces.

In the first stage, the firm operates under perfect competition and produces a domestic input, $INS_{j,t}^D$, using the following technology:

$$INS_{j,t}^D = A_t \left[\alpha_1^{\frac{1}{\psi_f}} K_{j,t}^{P\,\frac{\psi_f - 1}{\psi_f}} + \alpha_2^{\frac{1}{\psi_f}} L_{j,t}^{P\,\frac{\psi_f - 1}{\psi_f}} + \alpha_3^{\frac{1}{\psi_f}} K_{j,t}^{G\,\frac{\psi_f - 1}{\psi_f}} \right]^{\frac{\psi_f}{\psi_f - 1}} \tag{37}$$

where α_1, α_2 and α_3 are the shares of private capital, private labor, and public capital in the production of the domestic input, ψ_f is the elasticity of substitution between these inputs, and A_t captures the technological level of the economy, with the following law of motion:

$$\log A_t = \rho_A \log A_{t-1} + \varepsilon_{A,t} \tag{38}$$

where $\varepsilon_{A,t} \sim N(0, \sigma^A)$.

Thus, the firm's problem is to minimize its production cost subject to a tax on hiring labor, $\tau_t^{F,s}$:

$$\min_{K_{j,t}^P, L_{j,t}^P} (1 + \tau_t^{F,s}) W_t^P L_{j,t}^P + R_t^K K_{j,t}^P \tag{39}$$

subject to the technology given in equation (37).

The first-order conditions for the previous problem are:

$$\frac{(1 + \tau_t^{F,S}) W_t^P}{P_t^{INS,D}} = \left(\alpha_2 \frac{INS_{j,t}^D}{L_{j,t}^P} \right)^{\frac{1}{\psi_f}} \tag{40}$$

$$\frac{R_t^K}{P_t^{INS,D}} = \left(\alpha_1 \frac{INS_{j,t}^D}{K_{j,t}^P} \right)^{\frac{1}{\psi_f}} \tag{41}$$

The domestically produced input is used domestically, $INS^{D,D}$, or used abroad, $INS^{D,F}$, so:

$$INS_t^D = INS_t^{D,D} + INS_t^{D,F} \tag{42}$$

In the second stage, the firm must decide between using domestic and imported inputs through the following technology:

$$Y_{j,t} = INS_t^{D,D^{1-\omega_{INS}^D}} INS_t^{F,D^{\omega_{INS}^D}} \tag{43}$$

where ω_{INS}^{D} represents the share of imported input in the production of the intermediate good.

Therefore, the intermediate goods producing firm's problem (at this stage, firms also pay the ITF) at this stage is:

$$\min_{INS_{j,t}^{D,D}, INS_{j,t}^{F,D}} INS_{j,t}^{D,D} P_t^{INS,D} + INS_{j,t}^{F,D} S_t P_t^{INS,F} \tag{44}$$

subject to the technology given in equation (45).

Solving the previous problem, we arrive at the following first-order conditions:

$$INS_{j,t}^{D,D} = (1 - \omega_{INS}^{D}) CM_{j,t} \left[\frac{Y_{j,t}}{P_t^{INS,D}} \right] \tag{45}$$

and,

$$INS_{j,t}^{F,D} = \omega_{INS}^{D} CM_{j,t} \left[\frac{Y_{j,t}}{S_t P_t^{INS,F}} \right] \tag{46}$$

The third stage of the intermediate goods producing firm's problem is to set the price of its good. This firm decides how much to produce each period according to a Calvo rule (Calvo, 1983). There is a probability θ that the firm will keep the price of the good fixed in the next period ($P_{j,t} = P_{j,t-1}^{C,D}$) and the probability $(1-\theta)$ of setting the price optimally ($P_{j,t}^{C,D^*}$). Once the price is set in period t, there is a probability θ that this price will remain fixed in period $t+1$, a probability θ^2 that this price will remain fixed in period $t+2$, and so on. Therefore, the firm must consider these probabilities when setting the price of its good. The firm's problem that adjusts the good's price in period t is:

$$\max_{P_{j,t}^{C,D^*}} E_t \sum_{i=0}^{\infty} (\beta\theta)^i (P_{j,t}^{C,D^*} - CM_{j,t+i}) Y_{j,t+i} \tag{47}$$

subject to the demand for the good $Y_{j,t}$ (35).

Then, we arrive at the following first-order condition:

$$P_{j,t}^{C,D^*} = \left(\frac{\psi_t}{\psi_t - 1} \right) E_t \sum_{i=0}^{\infty} (\beta\theta)^i CM_{j,t+i} \tag{48}$$

where $markupP_t = \left(\frac{\psi_t}{\psi_t - 1} \right)$.

It is important to note that all intermediate goods producing firms that set their prices share the same markup over the same marginal cost. This means that in every period, $P_{j,t}^{C,D^*}$ the price is the same for all firms $(1-\theta)$ that adjust their prices. Combining the pricing rule (36) with the assumption that all firms that change prices set an equal price, and that firms keeping prices constant do not affect the price—since they share the same technology—results in the overall final price level:

$$P_t^{C,D} = \left[\theta P_{t-1}^{C,D^{1-\psi_t}} + (1-\theta) P_t^{C,D^{*1-\psi_t}} \right]^{\frac{1}{1-\psi_t}} \tag{49}$$

3.3 Government

In this model, the government is divided into two different entities: the fiscal authority and the monetary authority. The former is responsible for conducting fiscal policy, while the latter seeks price stability through a Taylor rule. Additionally, the government is responsible for producing a service that is consumed by households at no cost.

3.3.1 Fiscal Authority

The fiscal authority is tasked with taxing and issuing debt to finance its expenditures, namely: current expenses, G_t; public investment, I_t^G; and payroll, $L_t^G W_t^G$. Therefore, the government's budget constraint can be depicted as:

$$\frac{B_{t+1}}{R_t^B} - B_t + Taxes_t = P_t^{C,D} G_t + P_t^{C,D} I_t^G + L_t^G W_t^G \tag{50}$$

Total taxation is given by:

$$\begin{aligned} Taxes_t = {} & \tau_t^C P_t^{C,D}(C_t^{R,D} + C_t^{NR,D}) + \tau_t^{imp} P_t^{C,F} S_t (C_t^{R,F} + C_t^{NR,F}) \\ & + \left[(\tau_t^L + \tau_t^{H,S} + \tau_t^{F,S})(W_t^P L_t^{R,P} + W_t^P L_t^{NR,P}) + (\tau_t^L + \tau_t^{H,S}) W_t^G L_t^G\right] + \tau_t^K R_t^K K_t^P + T_t P_t^{C,D} \end{aligned} \tag{51}$$

Since 1999, Brazil has resorted to the primary surplus regime of the non-financial public sector to stabilize the public sector net debt-to-GDP ratio. For this purpose, following Fernández-Villaverde et al. (2015), except for the ITF, all fiscal policy instruments follow the same public debt sustainability rule:

$$\frac{Z_t}{Z_{ss}} = \left(\frac{Z_{t-1}}{Z_{ss}}\right)^{\gamma_Z} \left(\frac{B_t}{Y_{t-1} P_{t-1}} \quad \frac{Y_{ss} P_{ss}}{B_{ss}}\right)^{(1-\gamma_Z)\phi_Z} S_t^Z \tag{52}$$

where γ_Z and ϕ_Z are parameters that capture the importance of these fiscal tools in public debt sustainability, and $Z = \{\tau_t^C, \tau_t^{imp}, \tau_t^L, \tau_t^{H,S}, \tau_t^{F,S}, \tau_t^K, T, I_t^G, W_t^G, G_t\}$.

The fiscal shock can be expressed as:

$$\log S_t^Z = \rho_Z \log S_{t-1}^Z + \varepsilon_{Z,t} \tag{53}$$

where $\varepsilon_{Z,t} \sim N(0, \sigma^Z)$.

The public capital stock evolves according to the following law of motion:

$$K_{t+1}^G = (1 - \delta_G) K_t^G + I_t^G \tag{54}$$

where δ_G denotes the depreciation rate of public capital.

The government is assumed to combine public spending on goods and services, G_t, and public labor, L_t^G, to produce public services, $Serv_t^G$, using the following production function:

$$Serv_t^G = G_t^{\alpha_G} L_t^{G\,1-\alpha_G} \tag{55}$$

where α_G indicates the share of public spending in the production of public services.

3.3.2 Monetary Authority

The central bank's dual mandate is to promote output growth and achieve price stability. To fulfill this dual objective, it follows a simple Taylor rule:

$$\frac{R_t^B}{R_{ss}^B} = \left(\frac{R_{t-1}^B}{R_{ss}^B}\right)^{\gamma_R} \left[\left(\frac{\pi_t^{C,D}}{\pi_{ss}^{C,D}}\right)^{\gamma_\pi} \left(\frac{Y_t}{Y_{ss}}\right)^{\gamma_Y}\right]^{(1-\gamma_R)} S_t^m \tag{56}$$

where γ_Y and γ_π reflect the sensitivities of the interest rate to output and inflation, respectively, γ_R is a smoothing parameter, and S_t^m is the monetary shock, which follows:

$$\log S_t^m = \rho_m \log S_{t-1}^m + \varepsilon_{m,t} \tag{57}$$

where $\varepsilon_{m,t} \sim N(0, \sigma^m)$.

3.4 Rest of the world's economy

The exports of the domestic economy are considered homogeneous goods before they leave the dock but differentiated goods in the global market. The goods exported to the rest of the world include consumer goods and inputs used in the production process of the rest of the world.

3.4.1 Rest of the world's households

There is a continuum of households in the rest of the world indexed by $j \in [0,1]$. This representative household maximizes its intertemporal utility by choosing consumption of the exported good from the domestic country, $C^{D,F}$ or the good produced in the rest of the world, $C^{F,F}$:

$$\max_{C_{j,t}^{D,F}, C_{j,t}^{F,F}} E_t \sum_{t=0}^{\infty} \beta^t \left(\frac{{C_{j,t}^F}^{1-\sigma}}{1-\sigma}\right) \tag{58}$$

with the following aggregation technology:

$$C_{j,t}^F = {C_t^{F,F}}^{1-\omega_C^F} {C_t^{D,F}}^{\omega_C^F} \tag{59}$$

subject to the following budget constraint,

$$C_t^{D,F} P_t^{C,D} + C_t^{F,F} S_t P_t^{C,F} = Y_t^F S_t P_t^{C,F} \tag{60}$$

The solution to the previous problem is:

$$\left(\frac{\omega_C^F}{1-\omega_C^F}\right)\left(\frac{C_t^{F,F}}{C_t^{D,F}}\right) = \frac{P_t^{C,D}}{S_t P_t^{C,F}} \tag{61}$$

3.4.2 Rest of the world's intermediate goods production

In the production process of the rest of the world, imported inputs from the domestic economy and internally produced inputs are used:

$$\min_{INS_t^{D,F}, INS_t^{F,F}} INS_t^{D,F} P_t^{INS,D} + INS_t^{F,F} S_t P_t^{INS,F} \tag{62}$$

subject to,

$$Y_{j,t}^{F} = INS_t^{F,F\,1-\omega_{INS}^F} INS_t^{D,F\,\omega_{INS}^F} \tag{63}$$

The first-order conditions for the previous problem are:

$$\left(\frac{\omega_{INS}^F}{1-\omega_{INS}^F}\right)\left(\frac{INS_t^{F,F}}{INS_t^{D,F}}\right) = \frac{P_t^{INS,D}}{S_t P_t^{INS,F}} \tag{64}$$

3.4.3 Balance of Payments equilibrium, income shocks, interest rates, and prices in the rest of the world

The balance of payments equilibrium is given by:

$$S_t\left(B_{t+1}^F - R_{t-1}^F B_t^F\right) = S_t\left[(C_t^{R,F,D} + C_t^{NR,F,D})\tau_t^{imp} P_t^{C,F} + INS_t^{F,D} P_t^{INS,F}\right]$$
$$-\left(C_t^{D,F} P_t^{C,D} + INS_t^{D,F} P_t^{INS,D}\right) \tag{65}$$

The movement rules for global income, external interest rate, and the levels and prices of final goods and input imports are respectively:

$$\log Y_t^F = \rho_{Y^F} \log Y_{t-1}^F + \epsilon_{Y^F,t} \tag{66}$$

where $\epsilon_{Y^F,t} \sim N(0, \sigma_{Y^F})$.

$$\log R_t^F = \rho_{R^F} \log R_{t-1}^F + \epsilon_{R^F,t} \tag{67}$$

where $\epsilon_{R^F,t} \sim N(0, \sigma_{R^F})$.

$$\log P_t^{C,F} = \rho_{P^{C,F}} \log P_{t-1}^{C,F} + \epsilon_{P^{C,F},t} \tag{68}$$

where $\epsilon_{P^{C,F},t} \sim N(0, \sigma_{P^{C,F}})$.

$$\log P_t^{INS,F} = \rho_{P^{INS,F}} \log P_{t-1}^{INS,F} + \epsilon_{P^{INS,F},t} \tag{69}$$

where $\epsilon_{P^{INS,F},t} \sim N(0, \sigma_{P^{INS,F}})$.

4 Results

In presenting the results, the initial idea is to test the reliability of the model. Thus, impulse response functions (IRFs) for the model's "quality control" shocks are presented, comparing some shocks from our model with equivalent shocks from SAMBA (Castro *et al.*, 2015)[8]. Therefore, we

[8] Castro *et al.* (2015) developed the SAMBA model to be used as part of the macroeconomic modeling framework of the Central Bank of Brazil. The model incorporates: 1) a fiscal authority that targets an explicit primary surplus/GDP ratio, according to the fiscal regime in place since 1999; and 2) a significant portion of consumer prices regulated by the government, according to contractual rules. The model also includes two other less common features in DSGE models but relevant in the case of the Brazilian economy. First, in Brazil and many other countries with relatively large manufacturing sectors, most imports are inputs used in the production function rather than consumer goods.

will focus on the analysis of four shocks (two supply-side and two demand-side shocks)[9]: productivity shock; price markup shock; monetary shock; and preference shock. Basically, the criterion used to determine if the shock results are similar involves the initial movement of the variable, the amplitude, and the time propagation of their effects[10].

It is important to note that while the two models have similarities, they are very different in some aspects. While SAMBA develops an advanced pricing structure and simplifies fiscal issues, the SNA-compliant model's main feature is the fiscal side and uses basic price and wage frictions. Furthermore, the designs of the external sector differ between the models. In SAMBA, international trade occurs only in inputs used in the production of intermediate goods. In the SNA-compliant model, in addition to this trade in inputs, it is also possible to acquire imported consumer goods and export such goods. Thus, in Figures figuras 1, 2, 3, 4, 5, 6, 7 and 8, the IRFs associated with international trade represent only input exchanges between the domestic and foreign countries. Another caveat is the timing of the models' estimations. SAMBA was estimated in 2011, while the SNA-compliant model was estimated in 2021 —- much has changed in those ten years, especially on the fiscal side.

4.0.1 Productivity shock

This subsection outlines a comparison of the temporary productivity shocks in the models, with an initial shock of 1% in both cases (figures 1 and 2). This shock influences the production of domestic inputs and their marginal cost (price of domestic inputs), operating through two main channels. The first channel is the goods channel, where the productivity gain boosts the production of domestic inputs. This increase in production means less labor is required to maintain the same level of output. Since domestic inputs affect the production of intermediate goods, their increase positively impacts aggregate demand. The second channel is the cost channel. Higher productivity reduces the marginal cost of producing domestic inputs. As these inputs are used in the production of intermediate goods, the price of intermediate goods falls, which in turn reduces consumer inflation (via the Phillips curve). Consequently, following the Taylor rule, the interest rate decreases.

The shock results were notably similar across the models, as the initial movements coincided in almost all the variables analyzed. In the SNA-compliant model, output increases by approximately 0,2%, which falls within the acceptance range of the SAMBA result. Employment also shows a very similar pattern, with a decrease of about 1% and a return to the steady state within a few periods. However, there were some differences in the responses of government consumption and private investment, which had lower amplitudes and were less persistent compared to SAMBA. This lower effect on government consumption is due to differences in how this variable is treated in the models. In the SNA-compliant model, current government spending is an input used in producing public services provided to families, while in SAMBA, this variable is a final good that is "discarded." Regarding private investment, in the former model, the production of domestic inputs also involves public capital, which partly accounts for this movement, thus mitigating the impact on private investment.

Therefore, the model treats imports as inputs used to produce differentiated sectoral goods. Second, the model assumes that a fraction of imports must be financed abroad, so that shocks to external financial conditions have an extra transmission channel to the domestic economy. Additionally, other frictions in SAMBA include wage and sectoral price rigidity, consumption habit persistence, non-Ricardian agents, and adjustment costs in investments, exports, and imports.

[9]Other equivalent shocks between the models are presented in the appendix of this paper.

[10]Green marks indicate that the effects are equivalent, while red marks indicate that they are not.

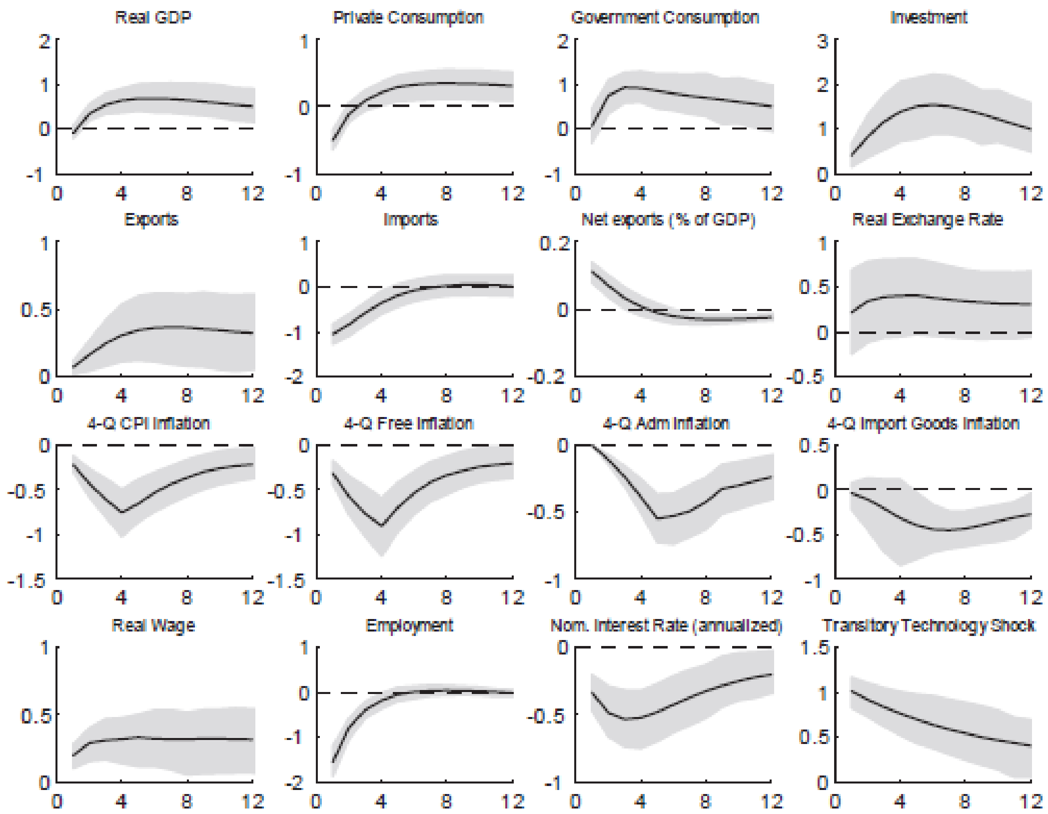

Figure 1: IRF of the productivity shock in SAMBA. Source: Castro et al. (2015).

4.0.2 Price markup shock (supply shock)

The second supply-side shock is a price markup shock—an increase in firms' market power—with an initial shock of 1% in both models (Figures 3 and 4). This shock essentially has the opposite effect to that of a productivity shock in the cost channel, as it directly impacts the Phillips curve, leading to an increase in the inflation rate. Given the higher cost of producing intermediate goods, there is a decrease in the production of these goods, which in turn lowers the value of demand variables. Additionally, according to the Taylor rule, the interest rate increases to stabilize the price level. Regarding the compatibility between the models, the result was quite satisfactory, with the only differing variable being private investment. The explanation for this result is similar to that given for this variable in the previous exercise (but in the opposite direction).

4.0.3 Monetary Shock

The analysis now shifts to the demand side. The first shock to be examined is a contractionary monetary shock of 1 percentage point in the annual interest rate (0,25 percentage points in the quarterly rate) in both models (figures 5 and 6). In this scenario, the main transmission channel is the intertemporal choice of Ricardian households; as the interest rate increases, the cost of present consumption rises. The model results are similar, except for the real exchange rate and exports. The explanation lies in the decrease in economic activity, which reduces imports (since households are consuming less and firms are using fewer inputs), and the surplus production is

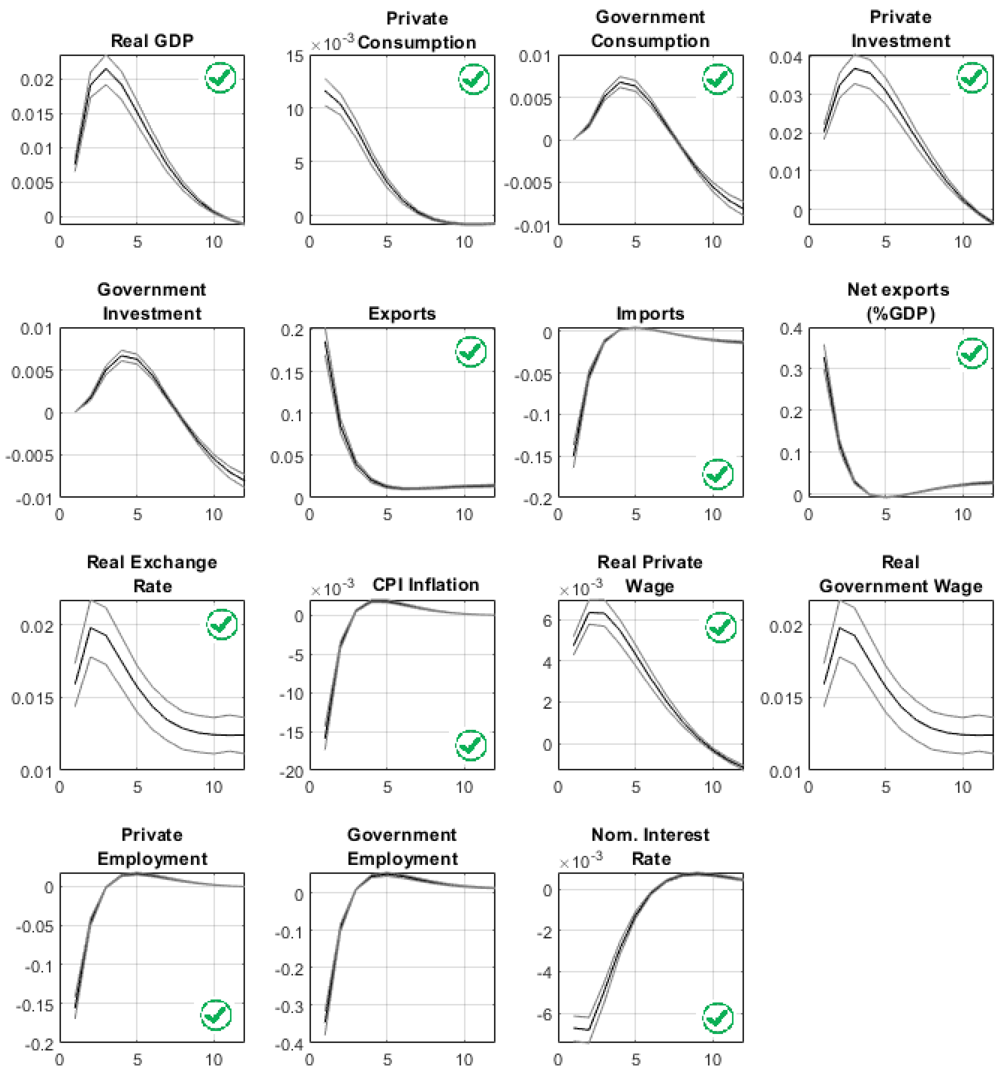

Figure 2: IRF of the productivity shock in the SNA-compliant model. Source: Authors' elaboration.

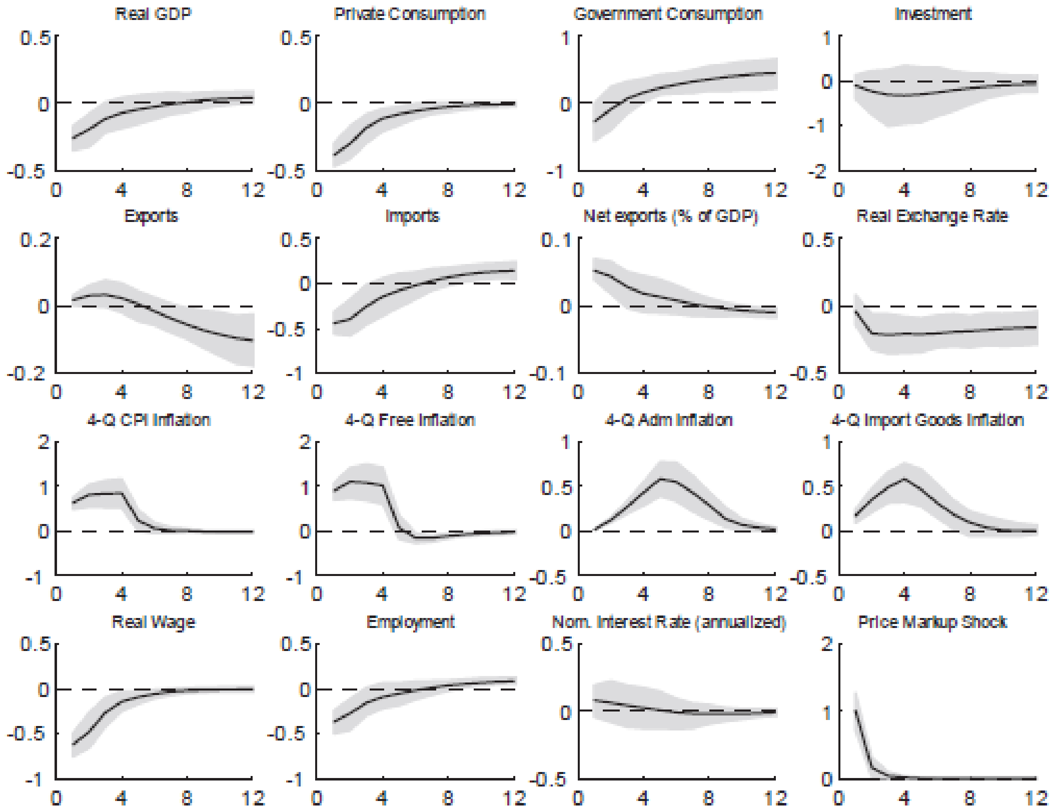

Figure 3: IRF of the price markup shock in the SAMBA model. Source: Castro et al. (2015).

exported, explaining the rise in exports in the SNA-compliant model. Additionally, the higher interest rate attracts foreign capital. Coupled with the increase in exports (both goods and inputs), the nominal exchange rate appreciates. However, the drop in the price level is sufficient to depreciate the real exchange rate.

4.0.4 Preference shock (demand shock)

The second demand-side shock is a preference shock, meaning that households change their intertemporal preference for consumption. In this exercise, there is a 1% decrease in the preference for present consumption in both models (figures 7 and 8). Similar to the monetary shock, the preference shock propagates its effects through the intertemporal choice of Ricardian households. However, unlike the monetary shock, here, households shift from consumption to savings (as there is no evident income effect), resulting in a positive response in private investment. Concerning the compatibility between the models, all variables exhibited similar behavior, even for the two variables that diverged in the previous exercise: exports and the real exchange rate.

In summary, the compatibility exercise met expectations, indicating that the SNA-compliant model exhibited behavior consistent with the SAMBA model in equivalent scenarios.

4.1 Fiscal shocks

According to Cavalcanti and Santos (2020), an administrative reform that reduces the public-private wage premium from 19% to 15% and aligns the retirement conditions of public sector

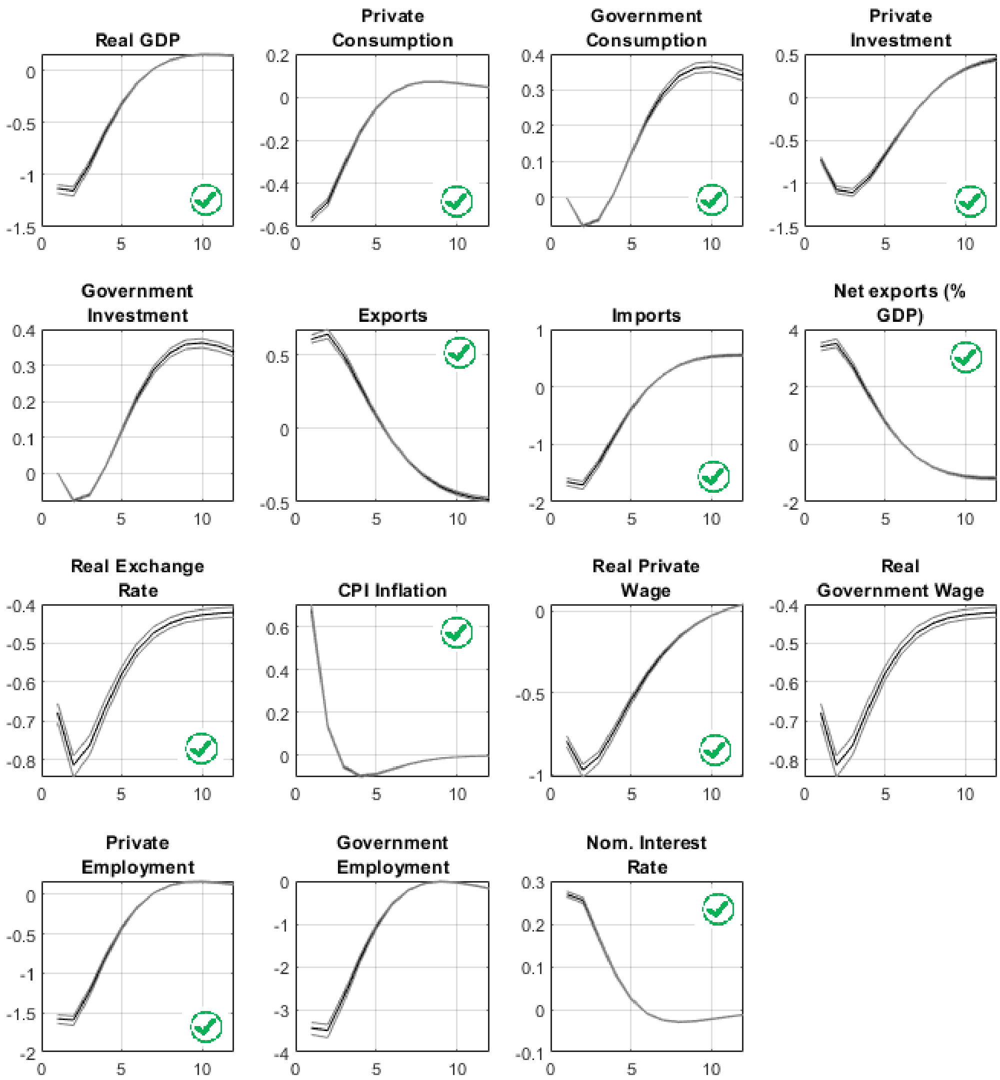

Figure 4: IRF of the price markup shock in the SNA-compliant model. Source: Authors' elaboration.

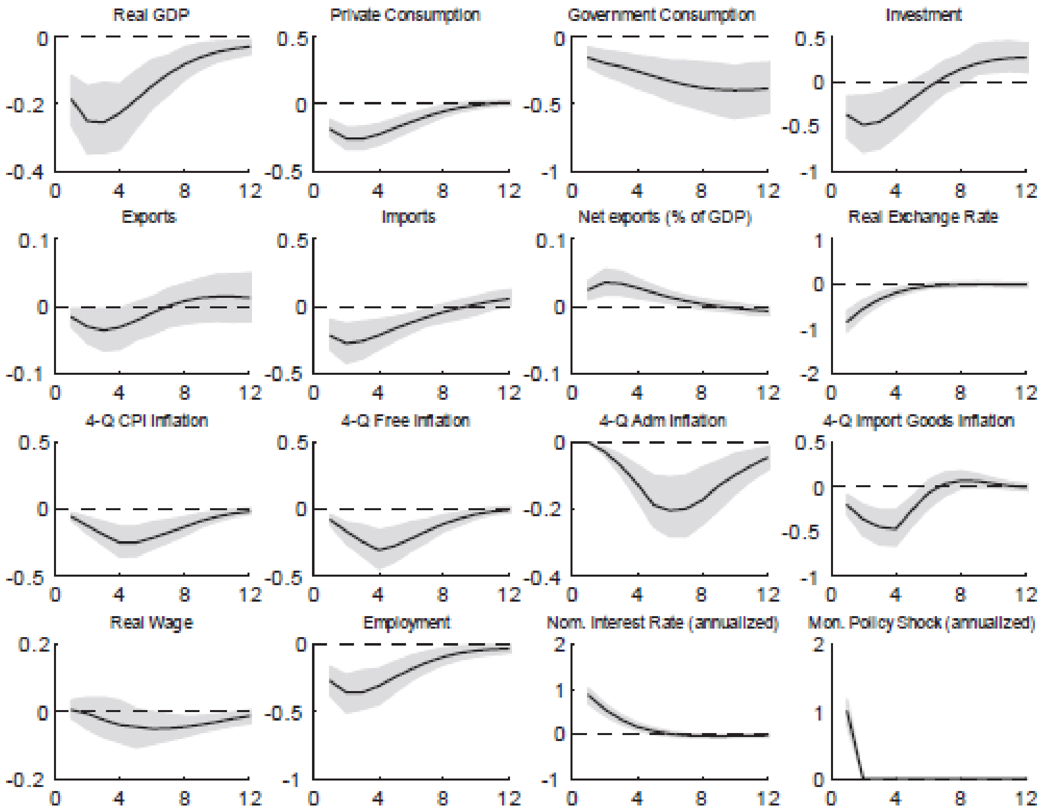

Figure 5: IRF of the monetary shock in the SAMBA model. Source: Castro et al. (2015).

workers with those of private sector workers could increase aggregate production by 11,2% in the long run. Even considering only the reduction of the wage premium, long-term output would increase by 4,65%.Figure 9 illustrates the shock of a reduction in public wages by the proportion suggested by Cavalcanti and Santos (2020), i.e., a reduction of $3,4\% = (1,15/1,19-1)*100$.

The reduction in public wages shows positive results; output continuously rises, reaching 0,3% by the 6th quarter, consistent with the results obtained by Cavalcanti and Santos (2020). Additionally, there is a reduction in resource misallocation as public sector labor is substituted with private sector labor. On the fiscal side, despite the decrease in revenue due to a smaller public workforce, public debt as a proportion of GDP decreases by approximately 2% in the 4th period, with this effect showing some persistence. This improvement in public debt sustainability allows for an increase in public investment spending, reaching 1% in the sixth period post-shock, which acts as a productivity gain in domestic input production within the model, thus increasing output. Finally, the decrease in public sector employment "forces" a shift in the composition of public service production, increasing current spending on goods and services to compensate for the reduction in other inputs, which may represent a gain in flexibility by potentially working with service provision contracts instead of relying on public servants, also related to reduced resource misallocation.

In the context of the shock to government consumption of goods and services (figure 10), it is important to remember that this consumption functions as an input in the production of public services within the model. With this in mind, the first significant result —-consistent with the macroeconomic literature—- is the crowding-in effect; a 0,15% reduction in government consumption increases private investment by up to 0,025% in the fifth period. Regarding output, the

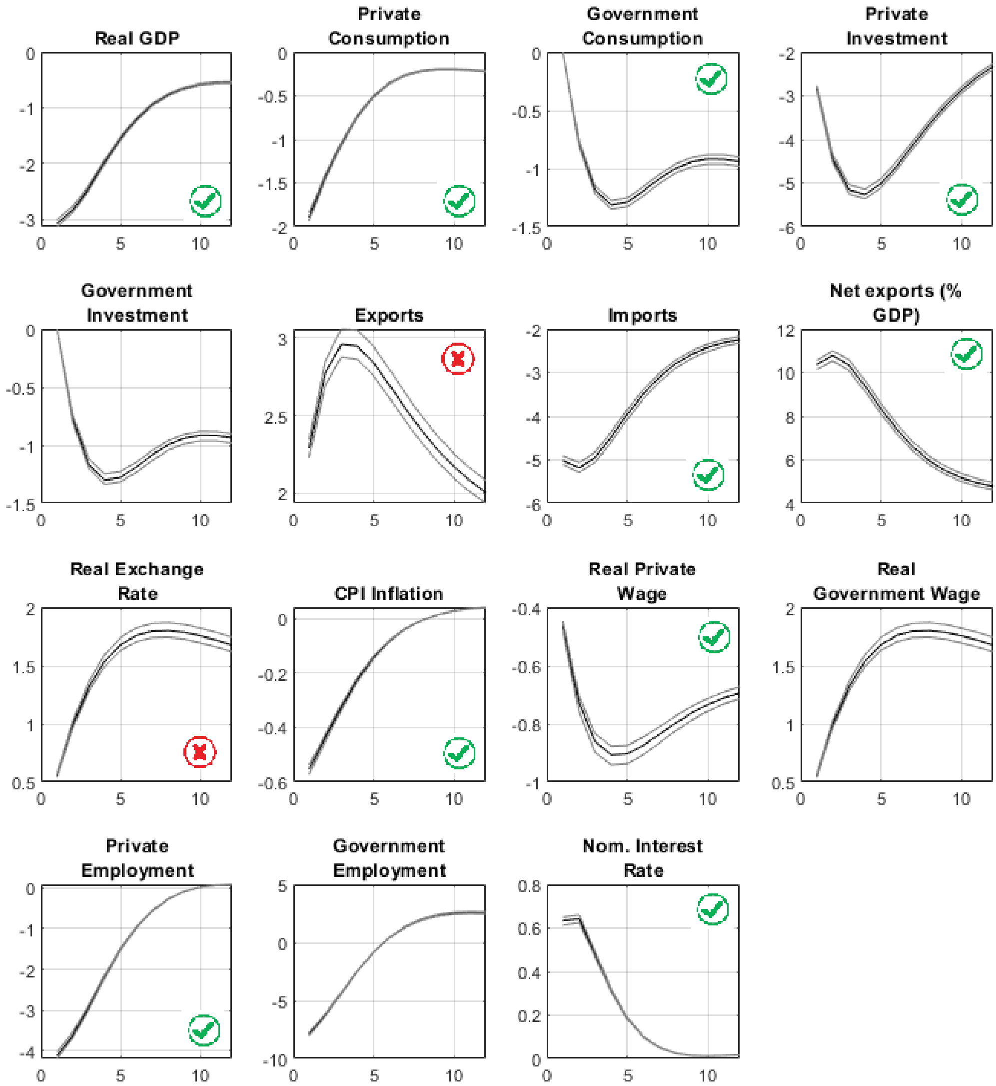

Figure 6: IRF of the monetary shock in the SNA-compliant model. Source: Authors' elaboration.

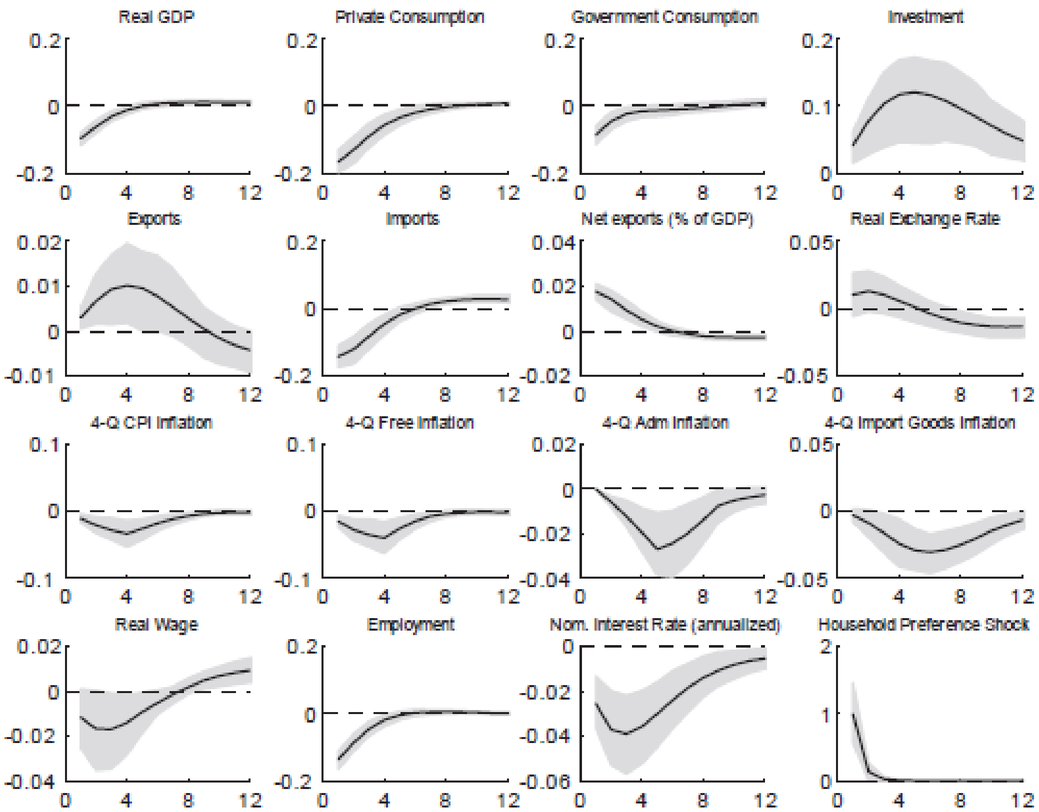

Figure 7: IRF of the preference shock in the SAMBA model. Source: Castro et al. (2015).

initial effect is a reduction of 0,02%, which returns to the steady state by the seventh period. This result is in line with the literature on fiscal multipliers, indicating a multiplier effect of less than 1.

The other fiscal spending shock analyzed in this subsection is a decrease of one standard deviation in public investment (figure 11). The initial output drops by 0,03%, but this effect is persistent, representing a negative aspect of this shock. Furthermore, the crowding-in effect observed in the government consumption shock does not appear in this scenario. On the fiscal side, revenue follows the output trend, and this decline in revenue initially hampers public debt sustainability, although with the abatement of these effects, the public debt-to-GDP ratio begins to decrease from the third period onward.

Moving on to the analysis of taxes, an increase of one standard deviation in the consumption tax rate (figure 12) initially affects output negatively by 0,02%, with the effect persisting for six periods. This result is primarily due to the decline in the consumption of goods and private investment. This weaker economic activity also reduces the demand for labor. On the fiscal side, the public debt-to-GDP ratio initially increases slightly —-given the weak economic activity—- but improves with economic recovery.

The tax on imported goods has a similar "foundation" to the previous tax but is directed at imported goods (figure 13). An increase of one percentage point in this tax rate yields mild economic results, such as a 0,002% reduction in output, with a quick return to the steady state. It is noteworthy that the weak performance of this fiscal instrument is due to the small proportion of imported goods in the household consumption basket.

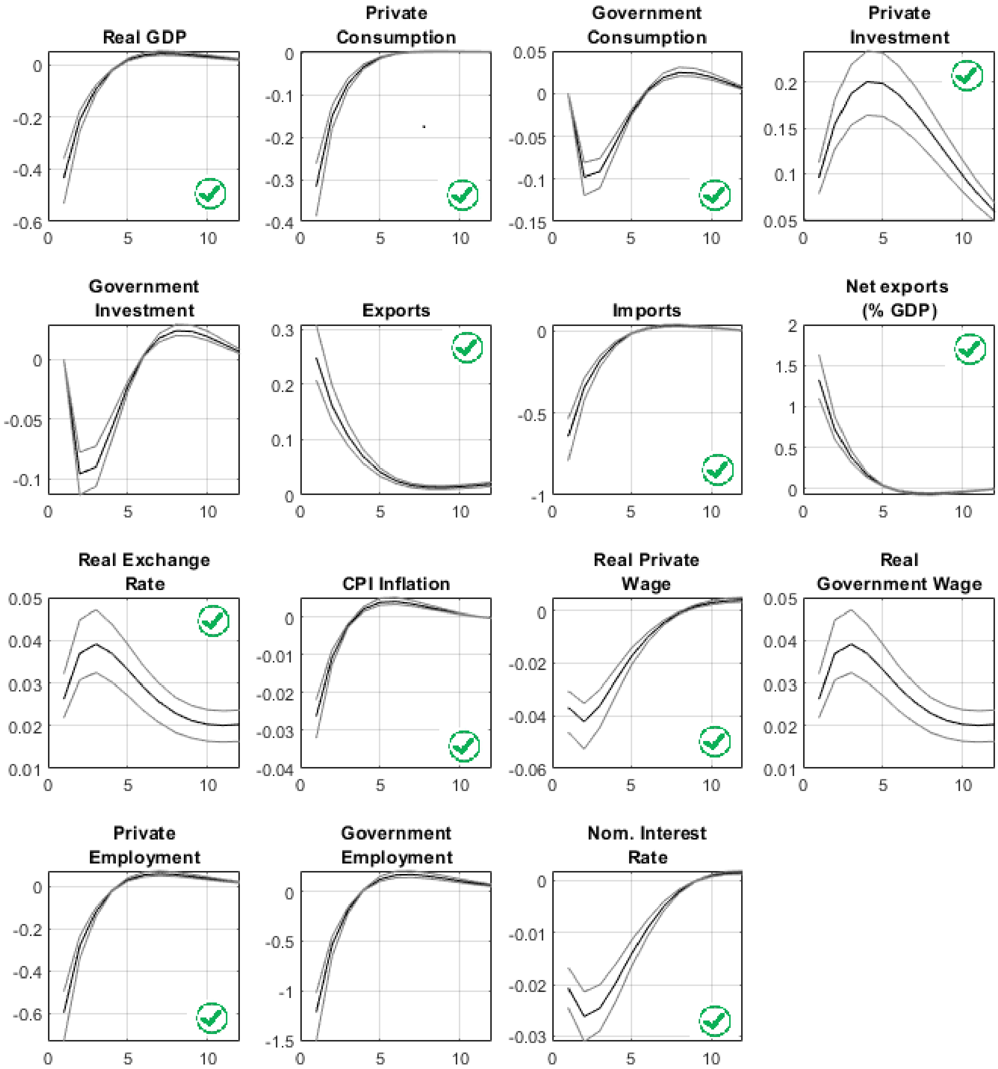

Figure 8: IRF of the preference shock in the SNA-compliant model. Source: Authors' elaboration.

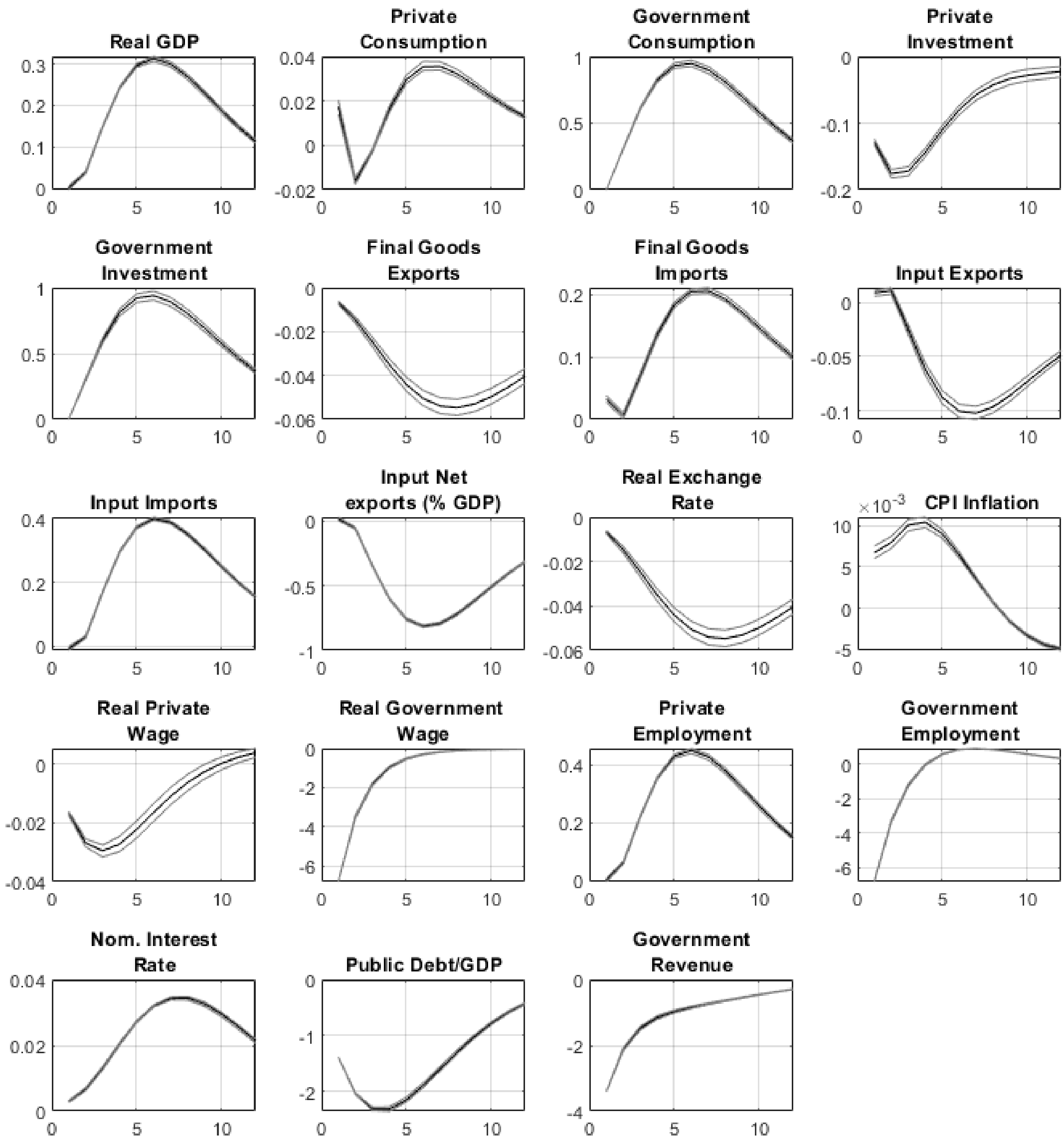

Figure 9: Shock to public wages. Source: Author's elaboration.

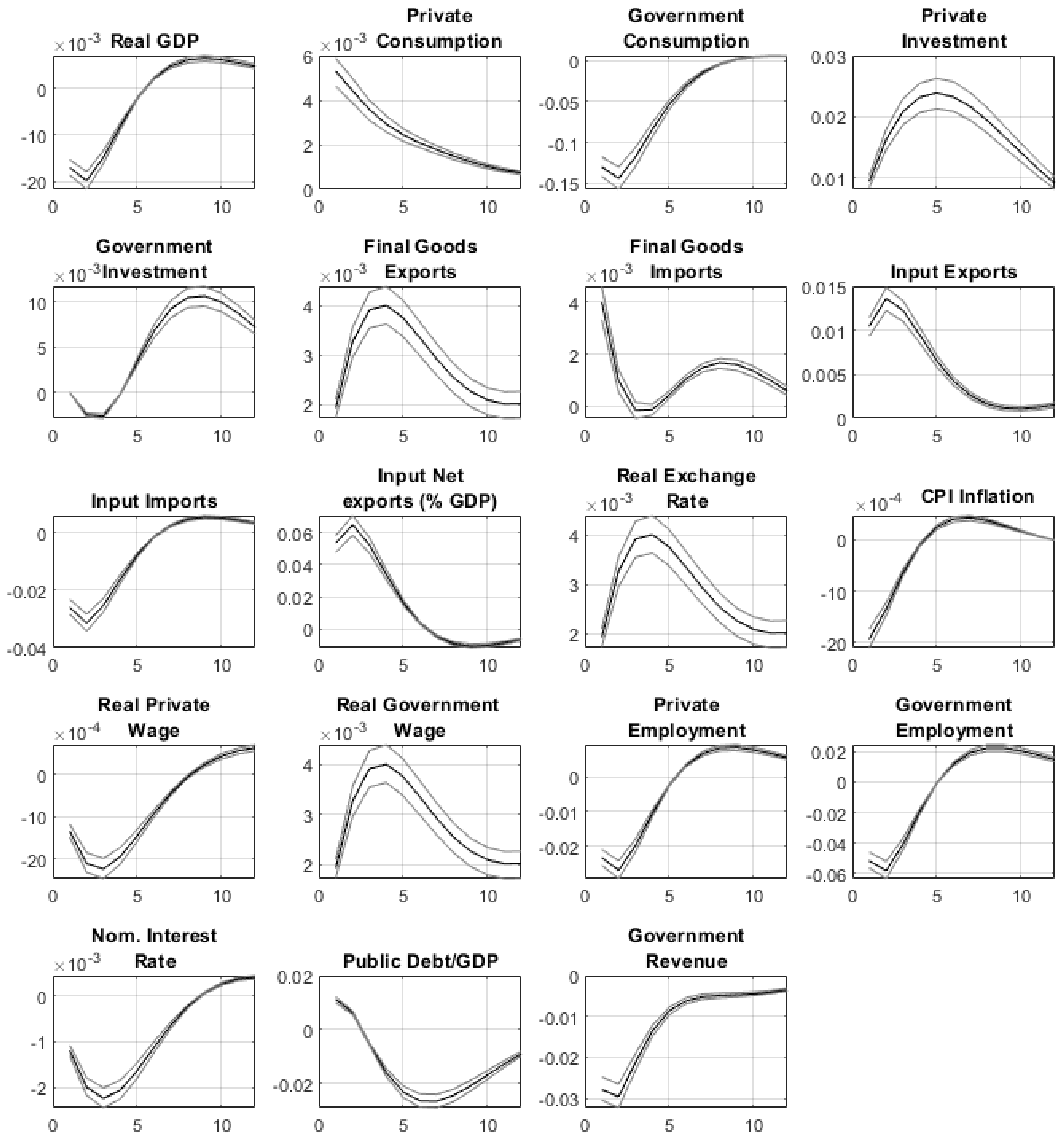

Figure 10: Shock to government consumption. Source: Author's elaboration.

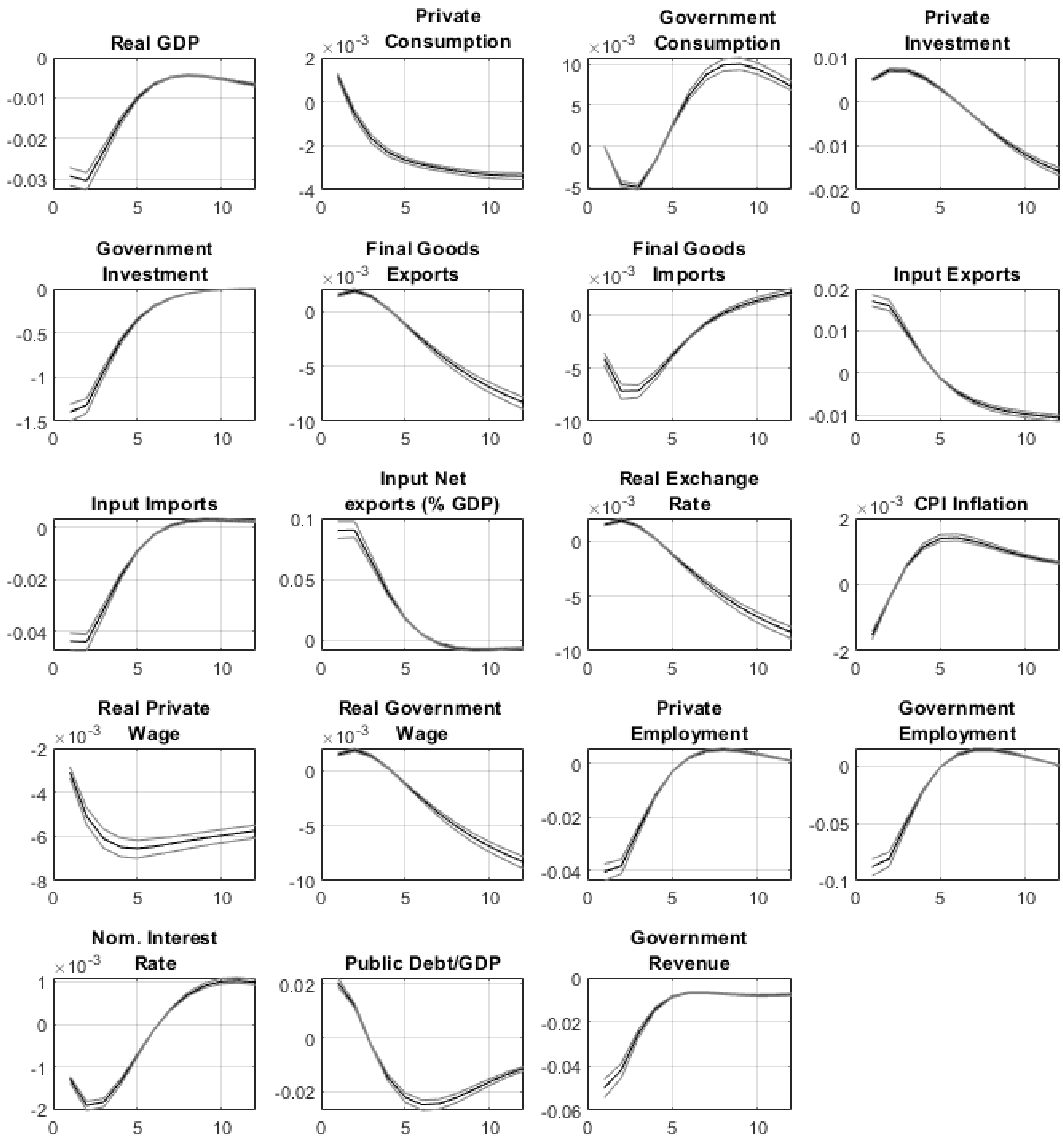

Figure 11: Shock to government investment. Source: Author's elaboration.

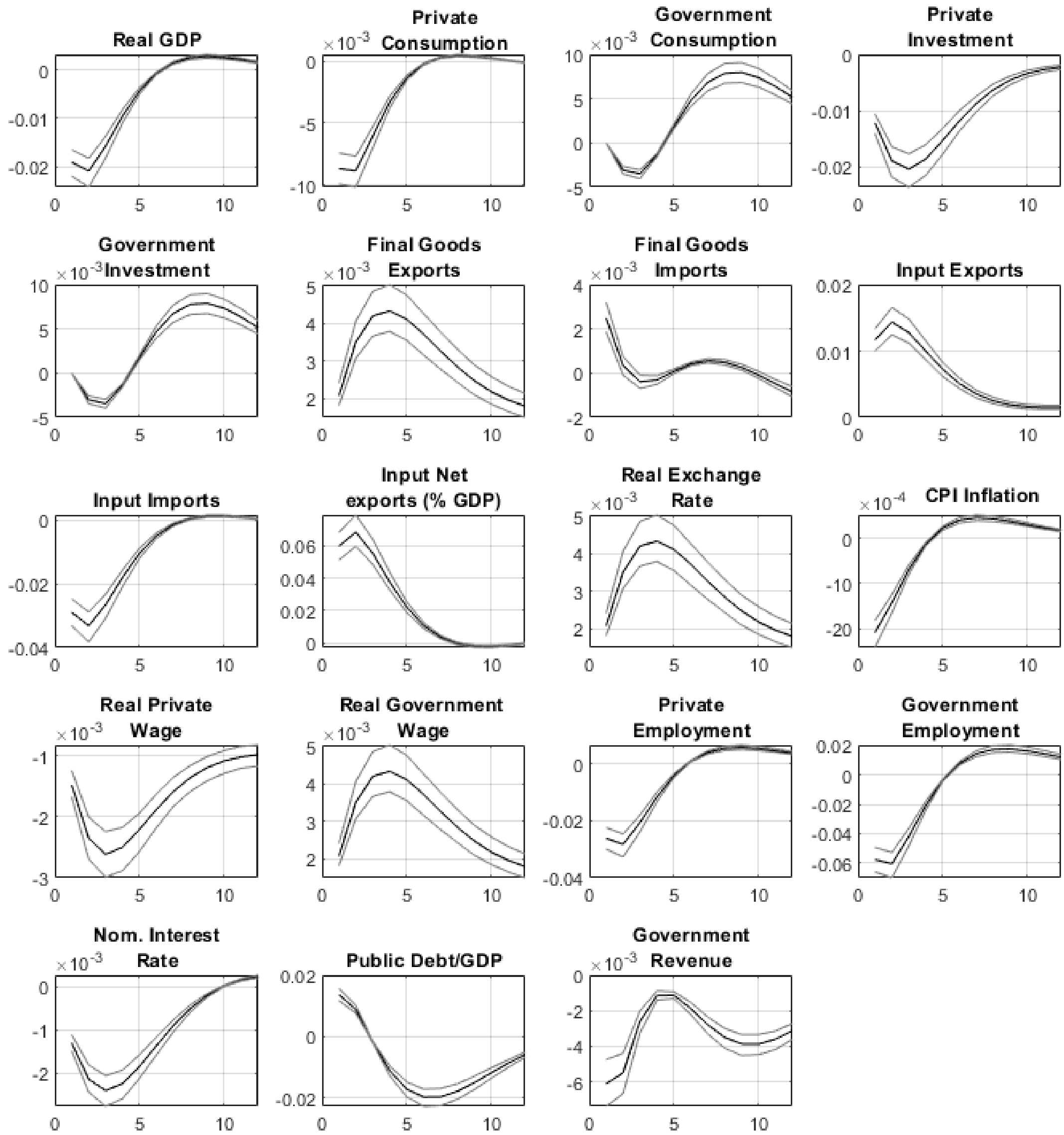

Figure 12: Shock to the consumption tax. Source: Author's elaboration.

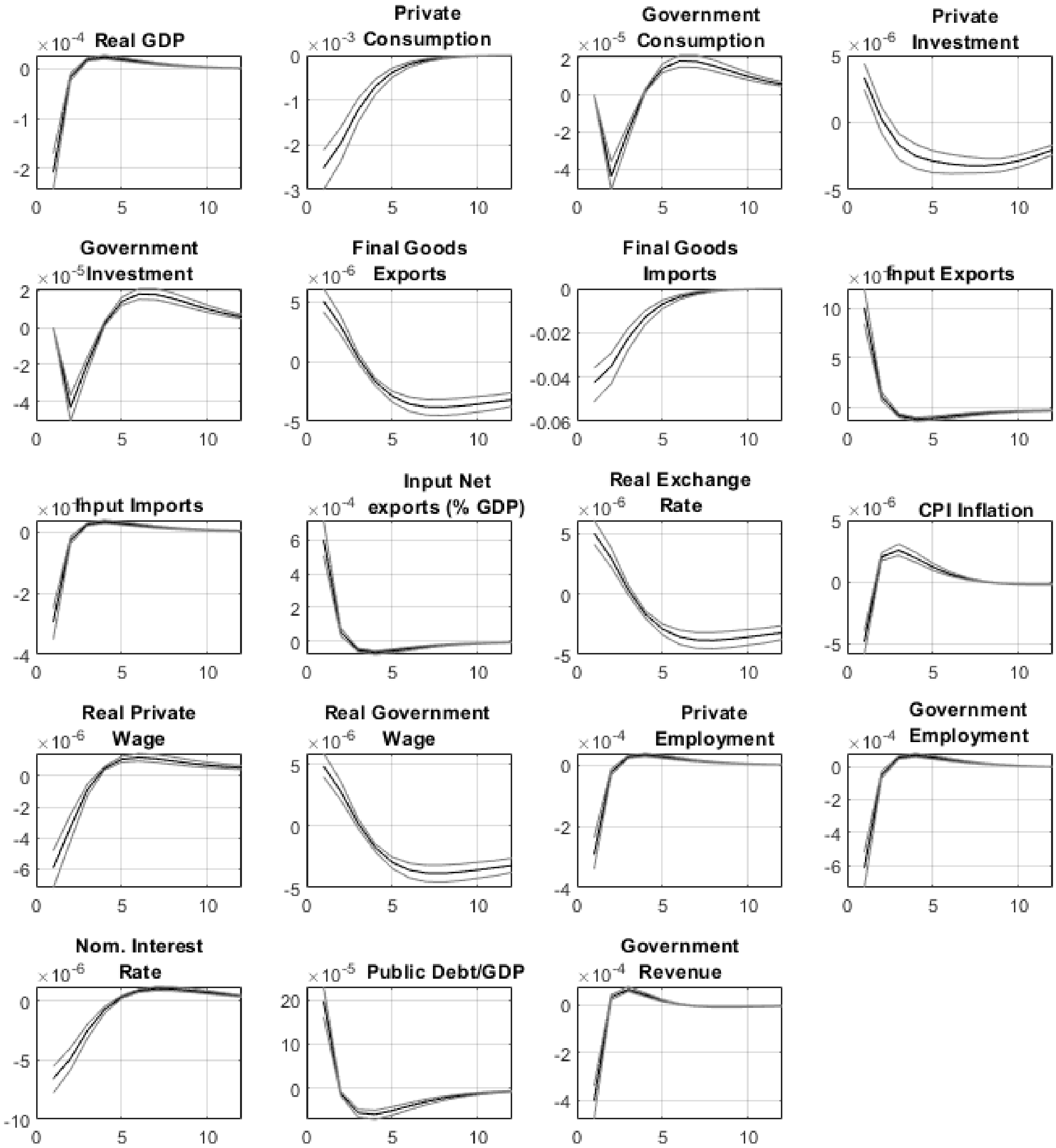

Figure 13: Shock to the tax on imported goods. Source: Author's elaboration.

Another form of taxation in the model relates to income. First, we examine the effects of a one percentage point shock to the labor income tax rate (figure 14). This tax rate increase reduces the labor supply by 0,08% and 0,2% in the private and public sectors, respectively. This lower willingness to work initially negatively impacts output by 0,06%. On the fiscal side, there is a substitution of public labor for the government's acquisition of goods and services. Tax revenue increases by 0,4%, but the highlight is the sustained decrease in the public debt-to-GDP ratio.

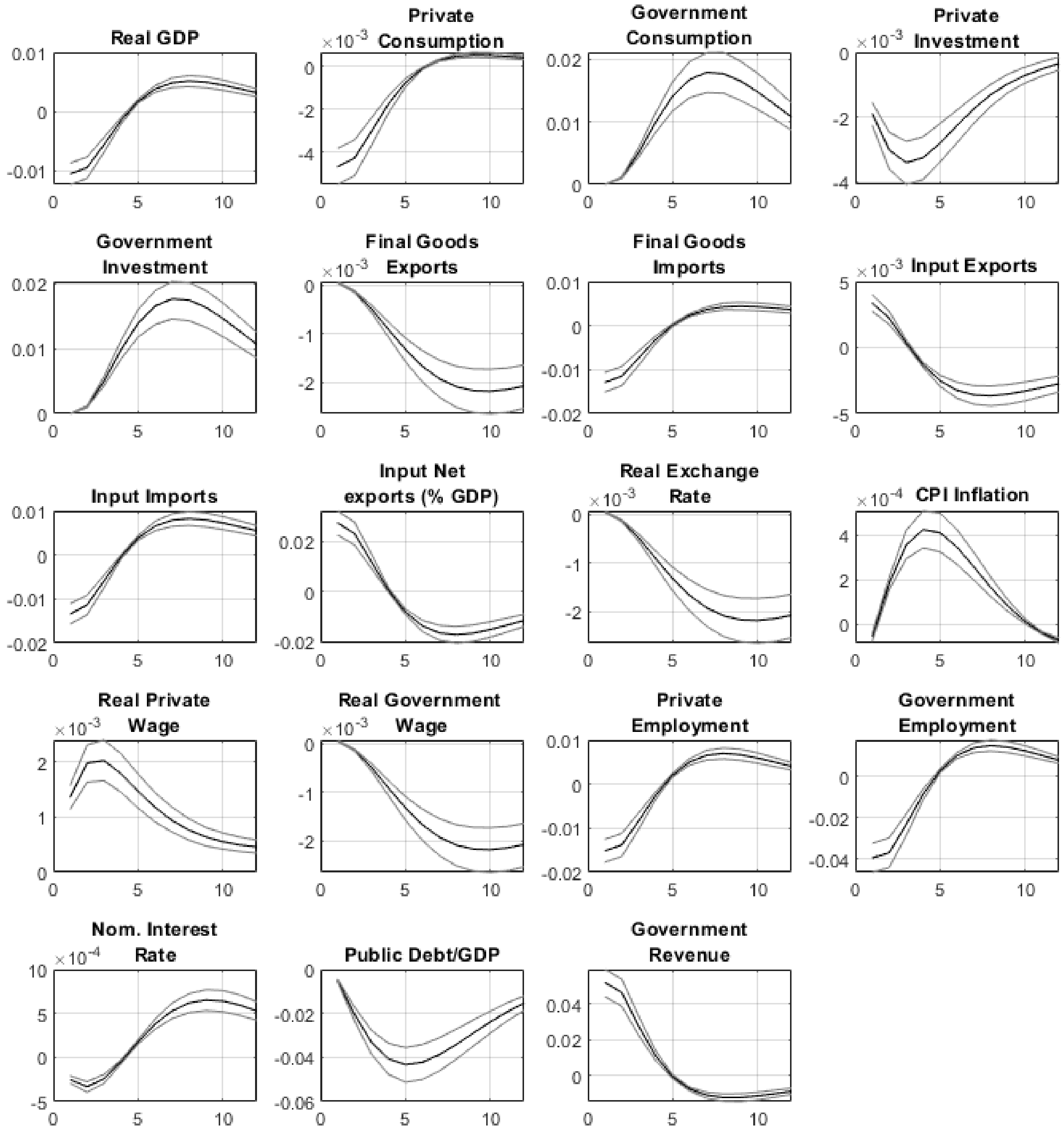

Figure 14: Shock to the labor income tax. Source: Author's elaboration.

Similar to the previous shock, the one percentage point increase in the capital income tax rate (figure 15) affects the availability of resources used in the production of domestic inputs. Consequently, there is a persistent decline in private investment, initially negatively impacting output. Additionally, as with the previous shock, the highlight is the sustained decrease in the public debt-to-GDP ratio.

In the model, there are two contributions related to labor, one paid by households[11] and the other paid by firms. An increase of one percentage point in the firms' labor contribution rate (fig-

[11] As this result is very similar to the shock given to the labor income tax rate, it will not be presented here.

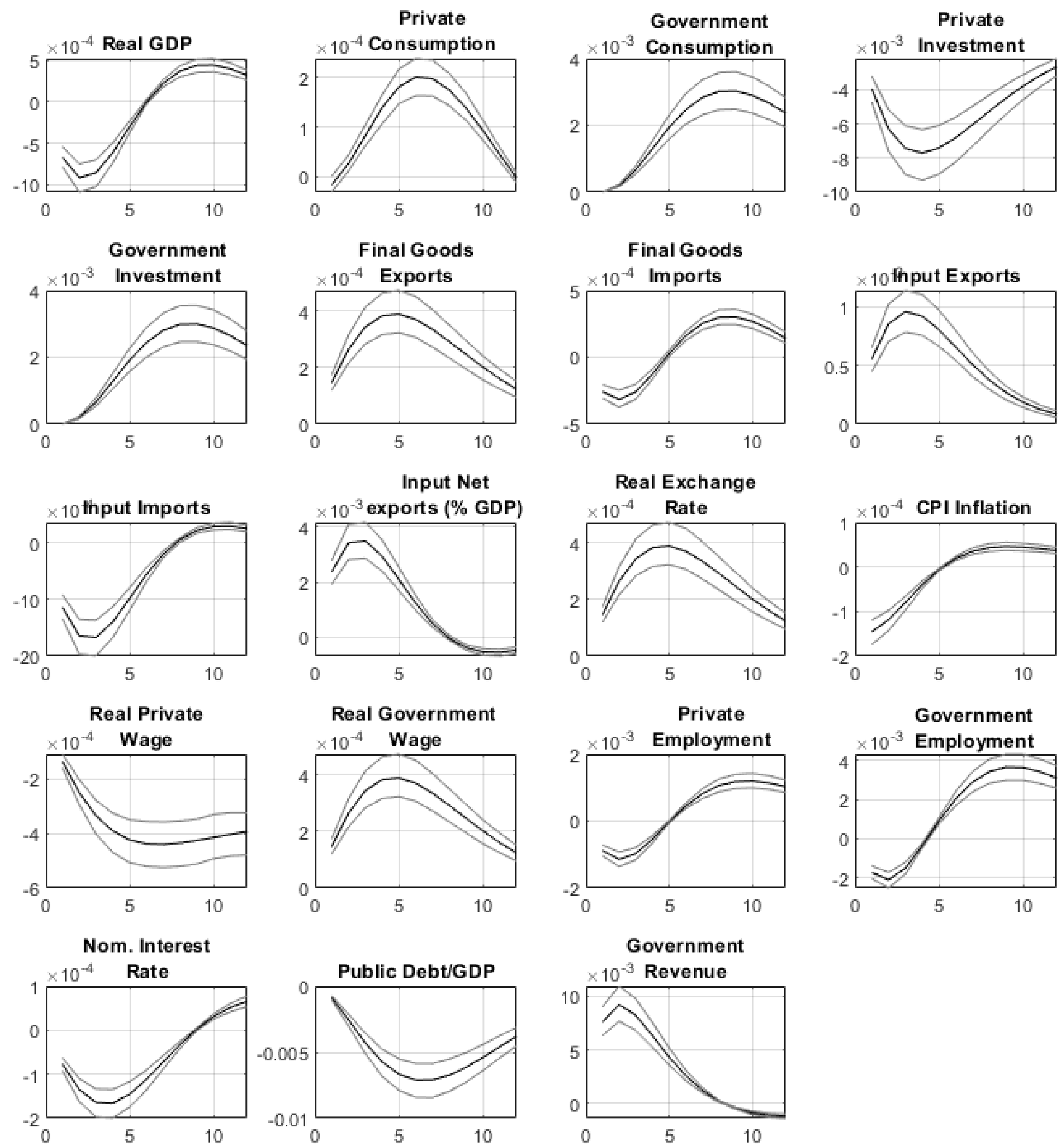

Figure 15: Shock to the capital income tax. Source: Author's elaboration.

ure 16) presents moderate results for the economy, with output initially decreasing by 0,018%. The improvement in revenue by 0,02% facilitates a reduction in the public debt-to-GDP ratio, reaching -0,04% by the sixth period. Furthermore, the higher revenue allows for increases in public investment and government consumption by up to 0,02% and 0,01%, respectively.

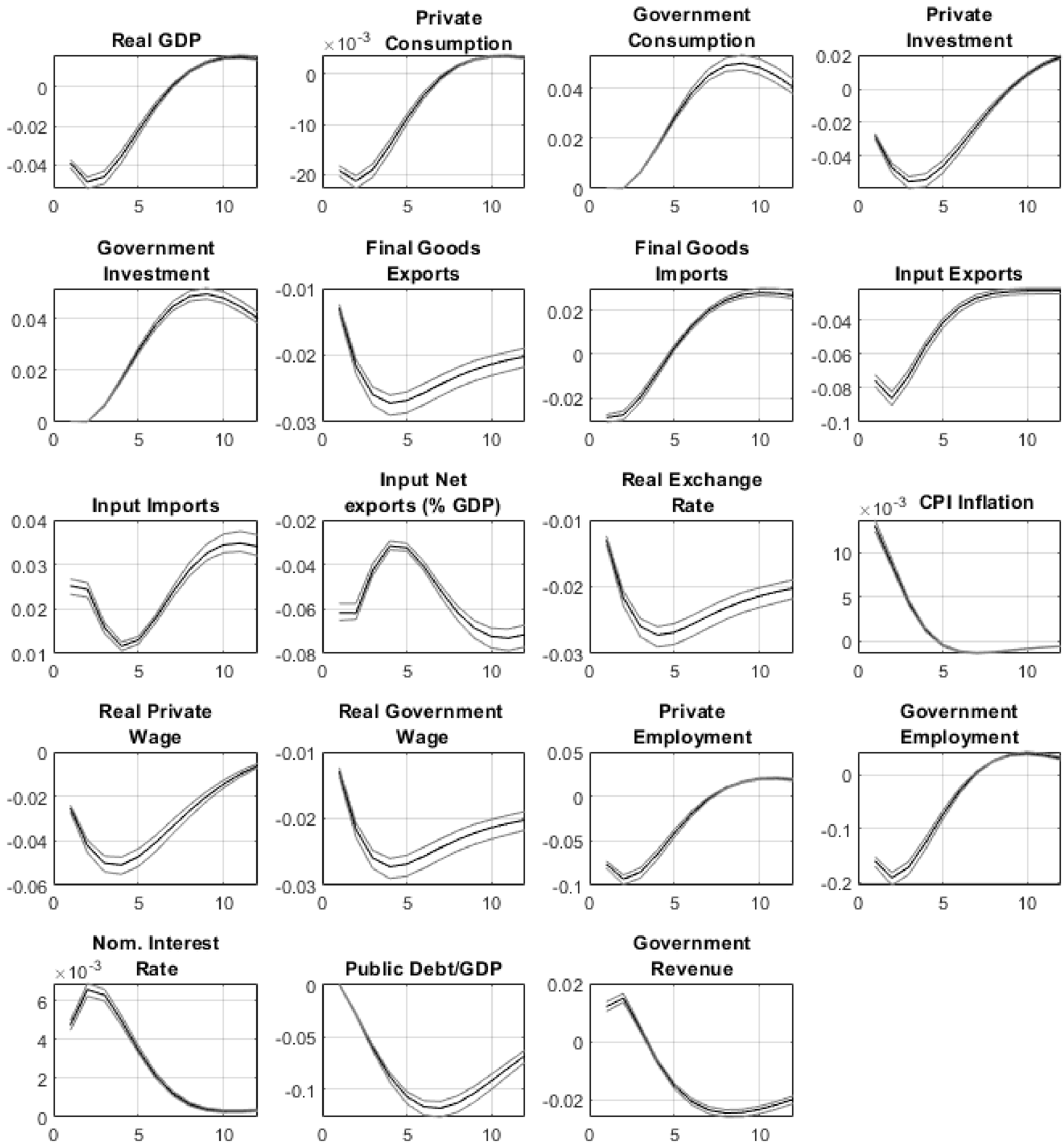

Figure 16: Shock to firms' labor contribution. Source: Author's elaboration.

4.2 Decomposition of shocks to GDP

Figure 17 illustrates the decomposition of shocks to Brazil's observable GDP. The black line represents real Gross Domestic Product (GDP) growth, while the colored bars denote different types of economic shocks modeled to influence this growth. Each color corresponds to a distinct type of shock, such as supply shocks, demand shocks, fiscal policy shocks, monetary policy shocks, among others.

From 2002 to 2008, Brazil experienced robust economic growth, as evidenced by the rising black line. This growth can be attributed to a combination of positive shocks, including rising commodity prices and strong domestic demand (Cavalcanti *et al.*, 2015), along with expansionary fiscal and monetary policies (Carvalho and Garcia, 2008). The global financial crisis (2008-2009) had a significant negative impact on Brazilian economic growth. The shock decomposition shows a decline in demand for Brazilian exports, negatively affecting the economy. Literature highlights that emerging economies are particularly vulnerable to external shocks due to their reliance on exports (De Gregorio, 2013). The global crisis also resulted in reduced investor confidence and credit constraints, exacerbating the economic slowdown (Didier *et al.*, 2012).

Subsequently, there was a period of recovery and stagnation until 2014. The shock decomposition suggests that expansionary fiscal policies, such as increased public spending, initially aided recovery. However, as discussed by Carvalho and Garcia (2014), the sustainability of these policies became a growing concern, leading to rising fiscal deficits and public debt. Furthermore, a series of adverse shocks, including energy sector issues and political crises, contributed to economic stagnation. These problems worsened from 2014 onwards. The political crisis, including corruption scandals and institutional uncertainty, had a devastating impact on economic confidence and investment (Almeida *et al.*, 2017). In response to rising deficits, the government implemented more restrictive fiscal policies, which, combined with the political crisis, exacerbated the recession (Bastos, 2017). From 2017, Brazil began showing signs of recovery. However, the pandemic brought significant negative shocks, such as reduced demand, supply chain disruptions, and increased unemployment, leading to a new recession (Bonacini *et al.*, 2021).

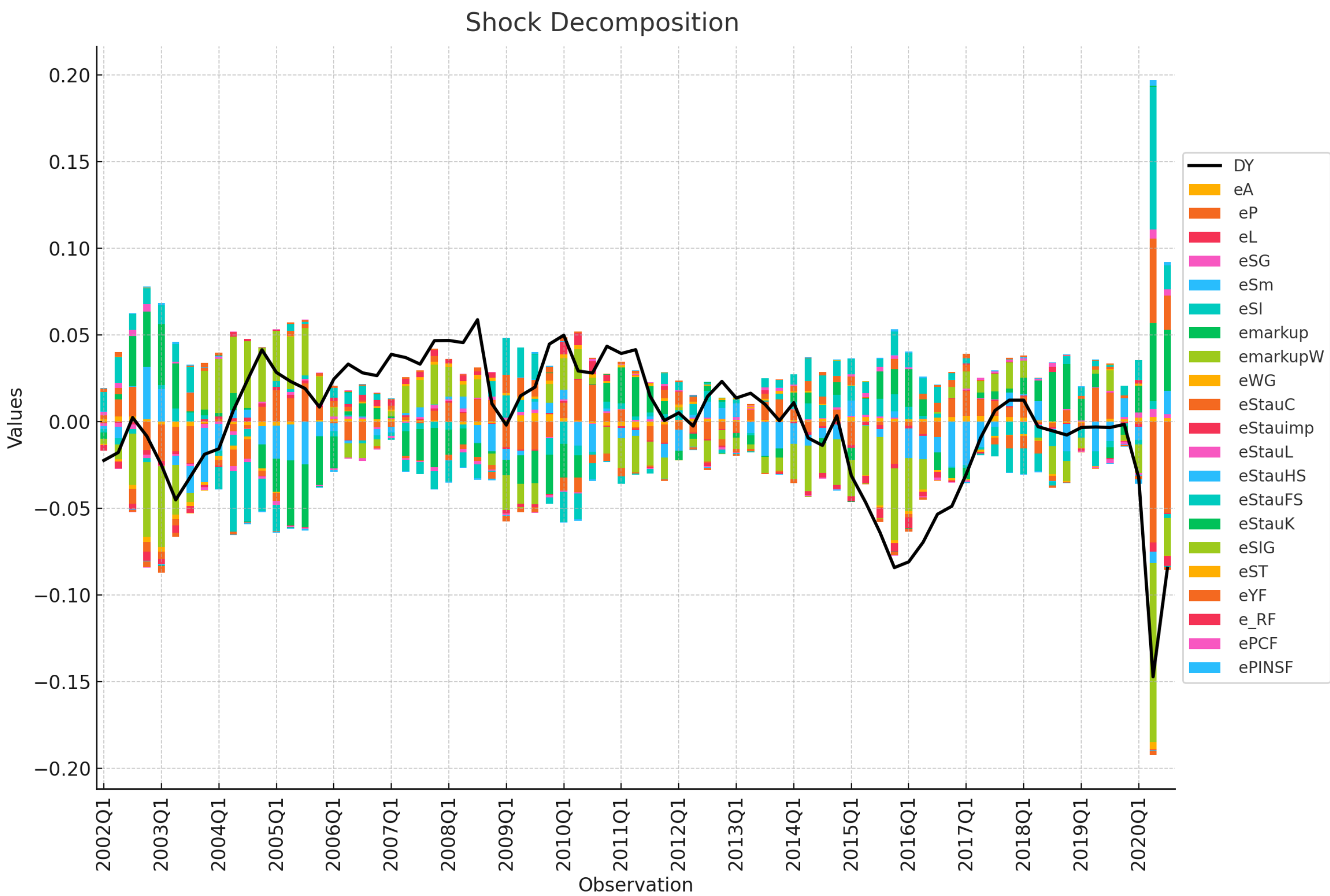

Figure 17: Decomposition of shocks to observable GDP. Source: Authors' elaboration.

5 Concluding remarks

The objective of this work was to develop a DSGE model with blocks detailing the fiscal accounts. In presenting the results, we initially aimed to test the reliability of the model by comparing it with the most popular medium-sized model in Brazil, SAMBA. Despite structural differences between the models —-SAMBA develops an advanced price structure and simplifies fiscal issues, while the SNA-compliant DSGE model emphasizes the fiscal side with basic price and wage frictions—-, the comparability between the models exceeded all expectations.

Appendix

5.1 Empirical analysis

5.1.1 Data processing

The dataset utilized in the model comprises quarterly data from the first quarter of 2002 to the third quarter of 2020, as detailed in Table 1. The data were processed to remove seasonal effects and trends using the X12-ARIMA algorithm and log differences, respectively. The global GDP series is composed of the GDPs of the USA, China, and the Eurozone, weighted according to their respective proportions.

Table 1: Observable variables in the model.

Series	Source
GDP pm - real quarterly var. - (%)	IBGE/SCN
Final consumption - households - real quarterly var. - (%)	IBGE/SCN
Final consumption - APU - real quarterly var. - (%)	IBGE/SCN
Gross fixed capital formation - real quarterly var. - (%)	IBGE/SCN
Exports - goods and services - real quarterly var. - (%)	IBGE/SCN
Imports - goods and services - real quarterly var. - (%)	IBGE/SCN
Exchange rate - R$/US$	Bacen/Boletim/ BP
Interest rate - Over/Selic - (% p.m.)	Bacen/Boletim/M. Finan.
IPCA - general - (% p.m.)	IBGE/SNIPC
CPI - USA - (% p.q.)	FRED, Federal Reserve Bank of St. Louis
10-year bond yield - USA - (% p.m.)	FRED, Federal Reserve Bank of St. Louis
GDP - USA - real quarterly var. - (%)	FRED, Federal Reserve Bank of St. Louis
GDP - Eurozone - real quarterly var. - (%)	FRED, Federal Reserve Bank of St. Louis
GDP - China - real quarterly var. - (%)	FRED, Federal Reserve Bank of St. Louis
Industry hours worked (2006 = 100)	CNI
Cofins - gross revenue - R$ (millions)	Min. Fazenda/SRF
EMBI - Brazil risk	JP Morgan
Financial account - balance (Captures - Concessions) - US$ (millions)	BCB/BP
Government personnel expenses	Fiscal Sub-secretariat/SPE/ME
Gross general government debt	Fiscal Sub-secretariat/SPE/ME
Commodity index (IC-BR)	DEPEC/BCB
τ^C	Fiscal Sub-secretariat/SPE/ME[a]
$\tau^{H,S}$	Fiscal Sub-secretariat/SPE/ME[a]
τ^L	Fiscal Sub-secretariat/SPE/ME[a]
τ^K	Fiscal Sub-secretariat/SPE/ME[a]

[a] The procedure of Mendoza, Razin, and Tesar (1994) was used to calculate the average effective tax rates on consumption, household contributions on wages, labor income tax, and capital income tax.

Source: Authors' elaboration.

The calibrated data for this study were obtained from various sources, including national accounts, academic literature, and financial institution reports. Long-term equilibrium values for output (Y_{ss}), consumption (C_{ss}), government spending (G_{ss}), government (I^G_{ss}) and private investment (I^P_{ss}), and financial expenditure consumption (CDF_{ss}) were all derived from national accounts. Specifically, C_{ss} was set at 65% of Y_{ss}, G_{ss} at 18% of Y_{ss}, I^G_{ss} at 2% of Y_{ss}, I^P_{ss} at 15% of Y_{ss},

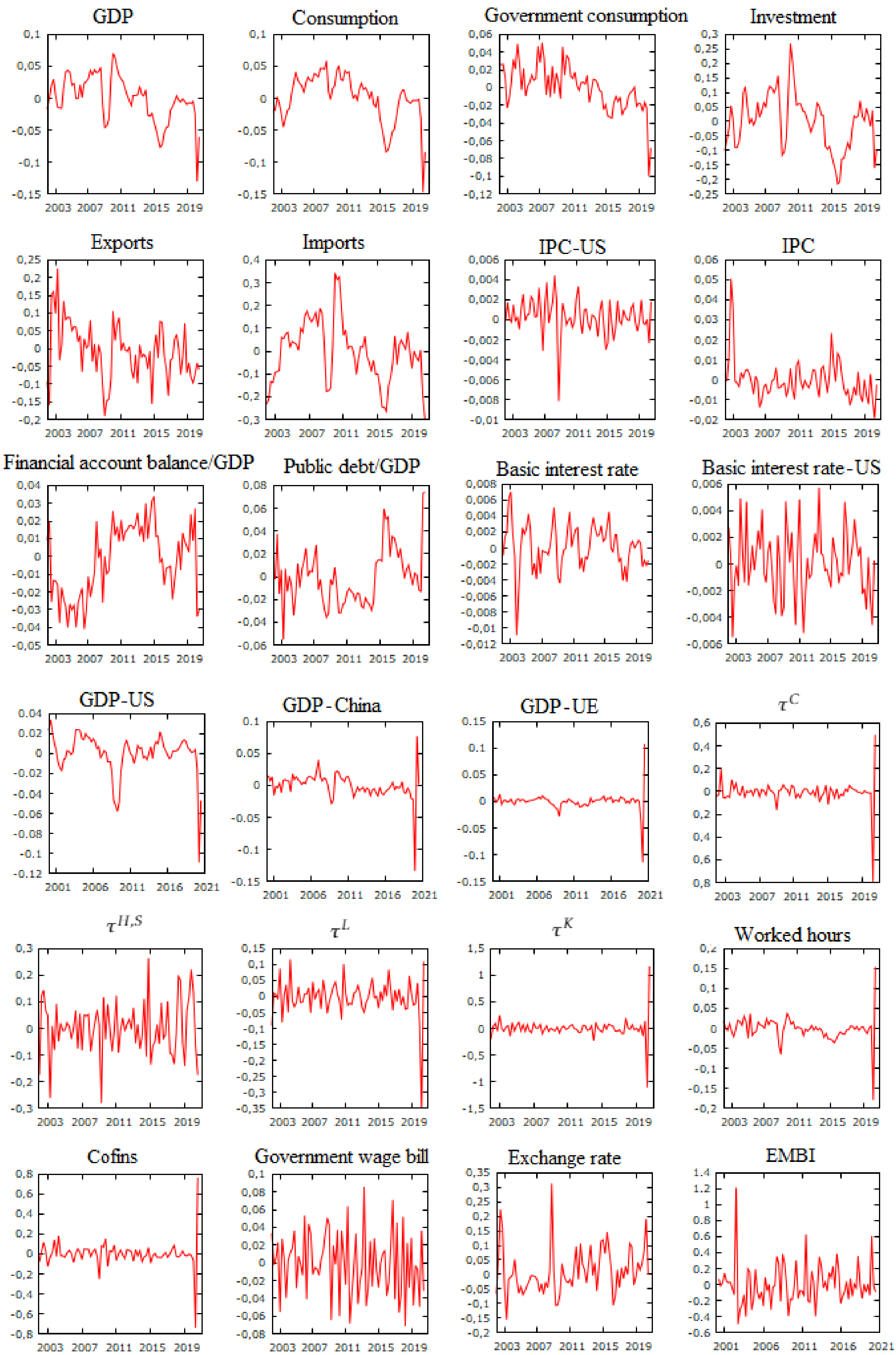

Figure 18: Processed data used in Bayesian estimation. The series are in variations and detrended. Source: Authors' elaboration.

and CDF_{ss} at 10% of Y_{ss}.

The steady-state capital (K_{ss}) was calculated as 2,7 times the annual GDP (2,7*4 for quarterly GDP, Y_{ss}), as described by Morandi and Reis (2004). The production parameters α_1, α_2, and α_3 were obtained from Mussolini (2011), where α_1 was set at 0,3, α_2 at 0,6, and $\alpha 3$ at 0,1. The steady-state interest rate (R^B_{ss}) was based on the Selic rate, with a value of $1,02^{0,25}$, and the discount rate (β) was set as its inverse, $1/1,02^{0,25}$.

The capital depreciation rate (δ) was calculated as the ratio of total investment to total capital (I_{ss}/K_{ss}). The efficiency of government spending (Ξ_G) was calibrated at 1,2, according to Cavalcanti and Santos (2020). The tax rates on consumption (τ^C_{ss}), health and safety ($\tau^{HS}ss$), capital ($\tau^K ss$), and labor (τ^L_{ss}) were obtained using data from the Secretariat of Economic Policy (SPE) following Mendoza *et al.* (1994), with values of 0,21, 0,021, 0,19, and 0,3, respectively. Public debt (B^F_{ss}) was derived from the Balance of Payments (BP) data from the Central Bank of Brazil (BCB), with a value of 0,016. The parameter θ was based on Castro *et al.* (2015), set at 0,75. Parameters σ and φ_G were obtained from Galí (2008), both set at 1.

This calibration was performed to ensure that the model accurately reflects the characteristics and behaviors observed in the Brazilian economy, relying on credible sources and methodologies established in economic literature.

Table 2 reports the calibrated parameter values.

Table 2: Parameter Calibration.

Parameter	Value	Source
Y_{ss}	1,923	National accounts
C_{ss}	0,65*Y_{ss}	National accounts
G_{ss}	0,18*Y_{ss}	National accounts
I^G_{ss}	0,02*Y_{ss}	National accounts
I^P_{ss}	0,15*Y_{ss}	National accounts
CDF_{ss}	0,1*Y_{ss}	National accounts
K_{ss}	2,7*4*Y_{ss}	Morandi and Reis (2004)
α_1	0,3	Mussolini (2011)
α_2	0,6	Mussolini (2011)
$\alpha 3$	0,1	Mussolini (2011)
R^B_{ss}	$1,02^{0,25}$	Selic rate
β	$1/1,02^{0,25}$	1/selic
δ	I_{ss}/K_{ss}	–
Ξ_G	1,2	Cavalcanti and Santos (2020)
τ^C_{ss}	0,21	SPE
$\tau^{HS}ss$	0,021	SPE
$\tau^K ss$	0,19	SPE
τ^L_{ss}	0,3	SPE
B^F_{ss}	0,016	BCB/BP
θ	0,75	Castro et al. (2015)
σ	1	Galí (2008)
φ_G	1	Galí (2008)
φ_p	$\Xi_G{}^*\varphi_G$	–

Source: Author's elaboration.

5.1.2 Estimation

Given the *prior* distribution of the parameters, the *posterior* distribution was estimated using a Markov chain process through the Metropolis-Hastings algorithm with 100,000 iterations, a scale factor of 0,1, and 2 parallel chains. Table 3 presents the *prior* and *posterior* distributions of each estimated parameter.

Table 3: Results from Metropolis-Hastings (parameters)

	Prior			Posterior			
	Dist.	Mean	Stdev.	Mean	Stdev.	HPD inf	HPD sup
χ_{BF}	unif	3.000	1.1547	3.230	0.0223	3.1939	3.2622
θ^W	unif	0.850	0.0289	0.855	0.0008	0.8538	0.8563
ψ_f	unif	1.105	0.0548	1.093	0.0017	1.0905	1.0955
γ^C	unif	0.800	0.0289	0.802	0.0006	0.8011	0.8031
χ	unif	3.000	1.1547	2.843	0.0240	2.8035	2.8812
P_{ss}^{INSF}	unif	1.050	0.5485	0.962	0.0154	0.9408	0.9846
P_{ss}^{CD}	unif	1.100	0.0577	1.121	0.0019	1.1186	1.1238
P_{ss}^{CF}	unif	1.050	0.5485	0.782	0.0116	0.7632	0.8016
γ_R	unif	0.800	0.0577	0.824	0.0031	0.8203	0.8278
γ_π	unif	2.500	0.2887	2.456	0.0064	2.4460	2.4638
γ_Y	unif	0.115	0.0202	0.123	0.0006	0.1219	0.1238
ω_R	unif	0.650	0.0866	0.674	0.0034	0.6697	0.6784
γ_G	unif	0.130	0.0693	0.115	0.0020	0.1123	0.1183
α_G	unif	0.200	0.0289	0.201	0.0009	0.2002	0.2027
τ_{ss}^{FS}	gamm	0.080	0.0040	0.078	0.0001	0.0782	0.0786
τ_{ss}^{imp}	gamm	0.250	0.0300	0.258	0.0009	0.2561	0.2589
γ_{WG}	beta	0.500	0.2500	0.515	0.0084	0.5031	0.5268
γ_{τ^C}	beta	0.500	0.2500	0.457	0.0028	0.4529	0.4618
ϕ_{τ^C}	unif	0.750	0.1443	0.732	0.0023	0.7277	0.7355
$\gamma_{\tau^{imp}}$	beta	0.500	0.2500	0.513	0.0115	0.4986	0.5286
$\phi_{\tau^{imp}}$	unif	0.500	0.2887	0.579	0.0066	0.5669	0.5891
γ_{τ^L}	beta	0.500	0.2500	0.474	0.0100	0.4602	0.4881
ϕ_{τ^L}	unif	0.750	0.1443	0.773	0.0024	0.7693	0.7765
$\gamma_{\tau^{HS}}$	beta	0.500	0.2500	0.569	0.0068	0.5583	0.5785
$\phi_{\tau^{HS}}$	unif	0.500	0.2887	0.560	0.0057	0.5518	0.5710
$\gamma_{\tau^{FS}}$	beta	0.500	0.2500	0.624	0.0087	0.6125	0.6350
$\phi_{\tau^{FS}}S$	unif	0.500	0.2887	0.509	0.0067	0.4993	0.5203
γ_{τ^K}	unif	0.725	0.0144	0.719	0.0003	0.7190	0.7198
ϕ_{τ^K}	unif	0.325	0.0144	0.332	0.0009	0.3309	0.3331
γ_T	beta	0.500	0.2500	0.587	0.0039	0.5803	0.5931
ϕ_T	unif	0.750	0.1443	0.720	0.0082	0.7088	0.7295
γ_{IG}	beta	0.500	0.2500	0.507	0.0041	0.5015	0.5142
ϕ_{IG}	unif	-0.500	0.2887	-0.446	0.0080	-0.4569	-0.4329
γ_G	beta	0.500	0.2500	0.502	0.0038	0.4954	0.5076
ϕ_G	unif	-0.500	0.2887	-0.450	0.0039	-0.4561	-0.4433
$\rho_{S\tau^C}$	beta	0.500	0.2500	0.527	0.0070	0.5174	0.5368

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Table 3: (continued)

		Prior		Posterior			
	Dist.	Mean	Stdev.	Mean	Stdev.	HPD inf	HPD sup
$\rho_{S\tau^{imp}}$	beta	0.500	0.2500	0.315	0.0076	0.3002	0.3241
$\rho_{S\tau^{L}}$	beta	0.500	0.2500	0.442	0.0097	0.4308	0.4591
$\rho_{S\tau^{HS}}$	beta	0.500	0.2500	0.466	0.0146	0.4461	0.4838
$\rho_{S\tau^{FS}}$	beta	0.500	0.2500	0.589	0.0043	0.5810	0.5951
$\rho_{S\tau^{K}}$	beta	0.500	0.2500	0.541	0.0058	0.5307	0.5493
ρ_{ST}	beta	0.500	0.2500	0.441	0.0030	0.4355	0.4451
ρ_{SIG}	beta	0.500	0.2500	0.435	0.0068	0.4256	0.4440
ρ_{YF}	beta	0.500	0.2500	0.487	0.0020	0.4840	0.4905
ρ_{RF}	beta	0.500	0.2500	0.553	0.0040	0.5479	0.5601
ρ_{PCF}	beta	0.500	0.2500	0.703	0.0036	0.6984	0.7101
ρ_{PINSF}	beta	0.500	0.2500	0.493	0.0100	0.4787	0.5057
ρ_{A}	beta	0.500	0.2500	0.450	0.0101	0.4352	0.4631
ρ_{L}	beta	0.500	0.2500	0.419	0.0051	0.4107	0.4268
ρ_{P}	beta	0.500	0.2500	0.536	0.0066	0.5280	0.5454
ρ_{SG}	beta	0.500	0.2500	0.585	0.0047	0.5775	0.5914
ρ_{Sm}	beta	0.500	0.2500	0.393	0.0038	0.3864	0.3987
ρ_{SI}	beta	0.500	0.2500	0.569	0.0037	0.5633	0.5756
ρ_{markup}	beta	0.500	0.2500	0.471	0.0052	0.4632	0.4796
$\rho_{markupW}$	beta	0.500	0.2500	0.634	0.0050	0.6265	0.6428
θ_1	beta	0.500	0.2500	0.466	0.0076	0.4542	0.4768
θ_2	beta	0.500	0.2500	0.594	0.0036	0.5885	0.6002
θ_3	beta	0.500	0.2500	0.413	0.0045	0.4073	0.4219
θ_4	beta	0.500	0.2500	0.543	0.0061	0.5350	0.5531
θ_5	beta	0.500	0.2500	0.476	0.0087	0.4645	0.4892
θ_6	beta	0.500	0.2500	0.555	0.0165	0.5337	0.5761
θ_7	beta	0.500	0.2500	0.571	0.0020	0.5675	0.5738
θ_8	beta	0.500	0.2500	0.543	0.0037	0.5380	0.5494
θ_9	beta	0.500	0.2500	0.466	0.0071	0.4553	0.4771
θ_{10}	beta	0.500	0.2500	0.472	0.0107	0.4552	0.4863
θ_{11}	beta	0.500	0.2500	0.562	0.0070	0.5507	0.5715
θ_{12}	beta	0.500	0.2500	0.495	0.0123	0.4803	0.5111
θ_{13}	beta	0.500	0.2500	0.484	0.0033	0.4791	0.4899
θ_{14}	beta	0.500	0.2500	0.518	0.0076	0.5078	0.5300
θ_{15}	beta	0.500	0.2500	0.558	0.0028	0.5528	0.5623
ε_{A}	invg	1.000	Inf	0.129	0.0076	0.1176	0.1396
ε_{P}	invg	1.000	Inf	0.717	0.0919	0.5976	0.8747
ε_{L}	invg	1.000	Inf	0.279	0.0475	0.2023	0.3555
ε_{SG}	invg	1.000	Inf	0.130	0.0086	0.1176	0.1412
ε_{Sm}	invg	1.000	Inf	0.939	0.0174	0.9067	0.9627
ε_{StauC}	invg	1.000	Inf	0.152	0.0135	0.1317	0.1748
$\varepsilon_{Stauimp}$	invg	1.000	Inf	0.207	0.0225	0.1708	0.2438
ε_{StauL}	invg	1.000	Inf	0.147	0.0140	0.1234	0.1697
ε_{StauHS}	invg	1.000	Inf	0.148	0.0159	0.1211	0.1724
ε_{StauFS}	invg	1.000	Inf	1.538	0.0442	1.4751	1.6144
ε_{StauK}	invg	1.000	Inf	0.214	0.0240	0.1743	0.2524
ε_{SIG}	invg	1.000	Inf	1.403	0.0625	1.3166	1.5161

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Table 3: (continued)

		Prior		Posterior			
	Dist.	Mean	Stdev.	Mean	Stdev.	HPD inf	HPD sup
ε_{YF}	invg	1.000	Inf	0.123	0.0048	0.1176	0.1287
ε_{RF}	invg	1.000	Inf	0.121	0.0035	0.1176	0.1258
ε_{PCF}	invg	1.000	Inf	1.189	0.0630	1.1121	1.2721
ε_{PINSF}	invg	1.000	Inf	1.051	0.0685	0.9321	1.1440
ε_{ST}	invg	1.000	Inf	0.321	0.0551	0.2426	0.4190
ε_{SI}	invg	1.000	Inf	0.151	0.0161	0.1239	0.1754
ε_{markup}	invg	1.000	Inf	0.646	0.0187	0.6196	0.6726
$\varepsilon_{markupW}$	invg	1.000	Inf	0.127	0.0069	0.1176	0.1365
ε_1	invg	1.000	Inf	0.727	0.0364	0.6775	0.7888
ε_2	invg	1.000	Inf	0.121	0.0034	0.1176	0.1261
ε_3	invg	1.000	Inf	0.141	0.0122	0.1208	0.1591
ε_4	invg	1.000	Inf	0.141	0.0134	0.1177	0.1587
ε_5	invg	1.000	Inf	1.475	0.0367	1.4272	1.5247
ε_6	invg	1.000	Inf	0.180	0.0245	0.1388	0.2172
ε_7	invg	1.000	Inf	0.125	0.0060	0.1176	0.1334
ε_8	invg	1.000	Inf	0.365	0.0397	0.2977	0.4206
ε_9	invg	1.000	Inf	0.152	0.0161	0.1257	0.1781
ε_{10}	invg	1.000	Inf	0.138	0.0126	0.1176	0.1567
ε_{11}	invg	1.000	Inf	0.218	0.0303	0.1678	0.2692
ε_{12}	invg	1.000	Inf	0.225	0.0316	0.1730	0.2740
ε_{13}	invg	1.000	Inf	0.795	0.0401	0.7292	0.8503
ε_{14}	invg	1.000	Inf	0.199	0.0248	0.1596	0.2382
ε_{15}	invg	1.000	Inf	0.136	0.0131	0.1176	0.1549

5.2 Model reliability test (continued)

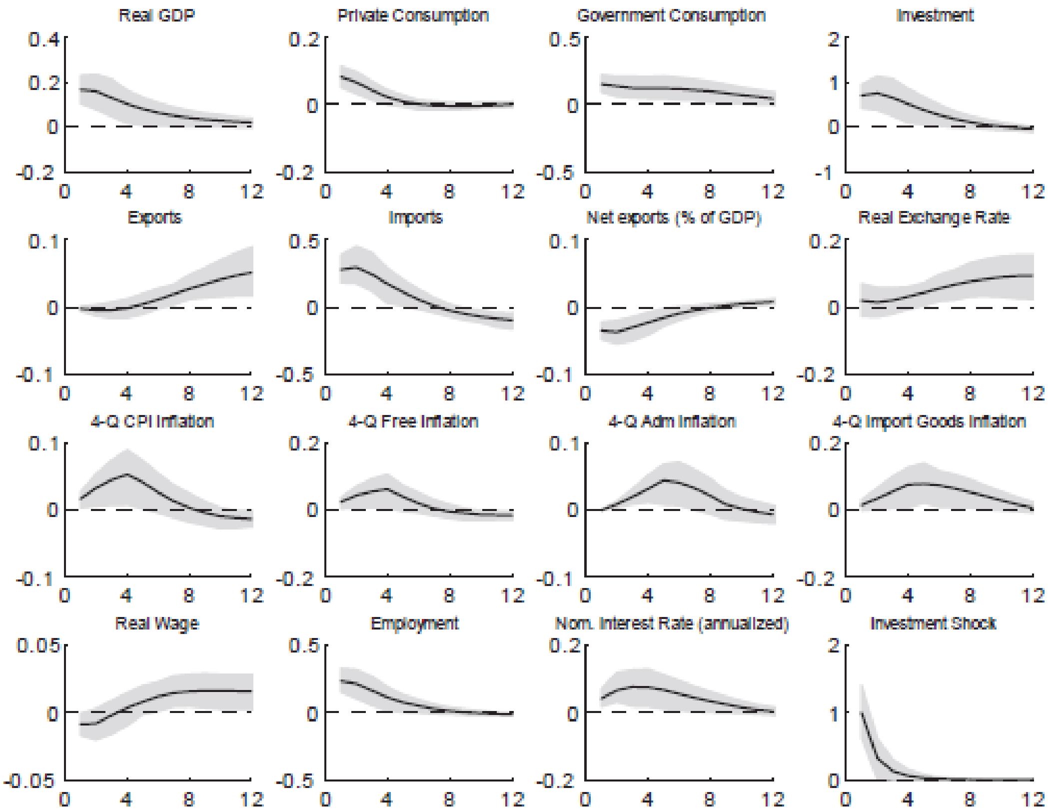

Figure 19: IRF of productivity shock in investment in SAMBA. Source: Authors' elaboration.

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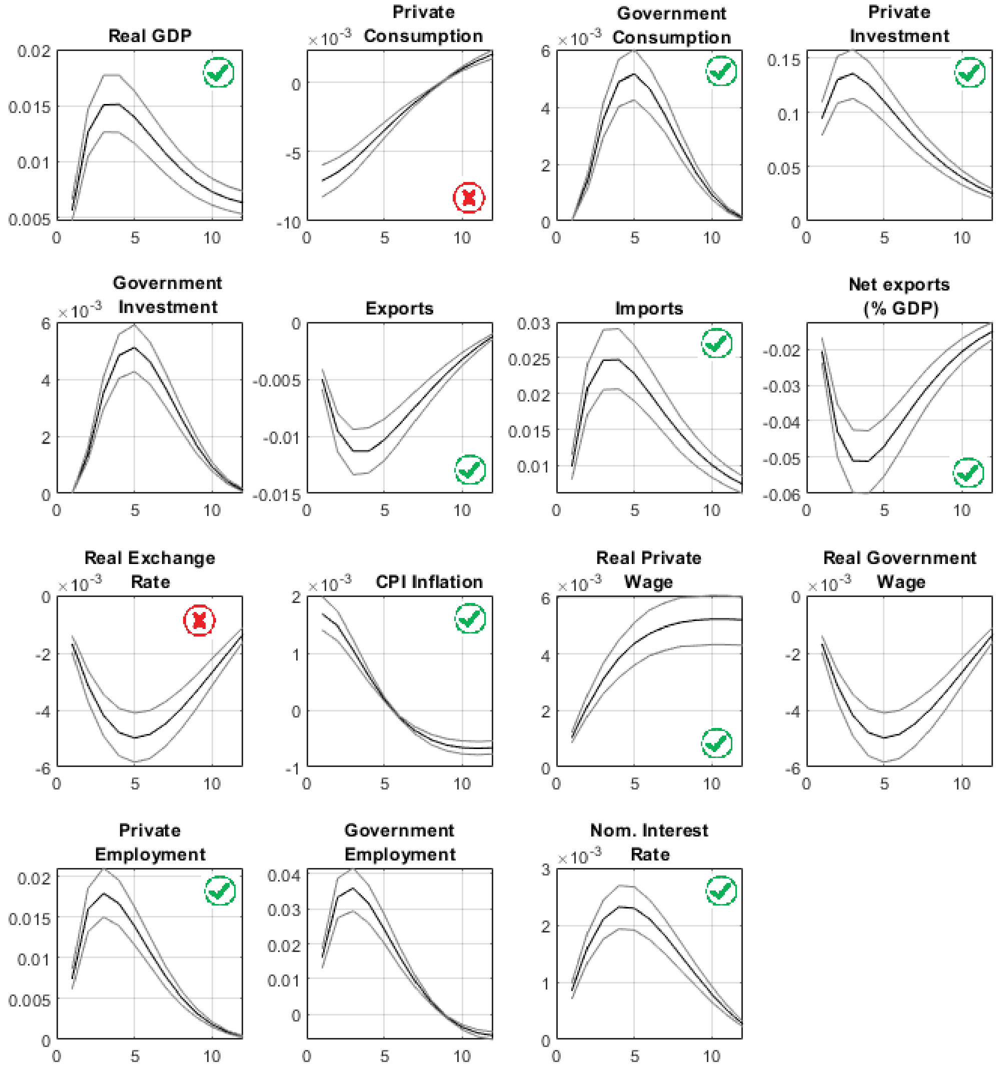

Figure 20: IRF of productivity shock in investment in the SNA-compliant DSGE model. Source: Authors' elaboration.

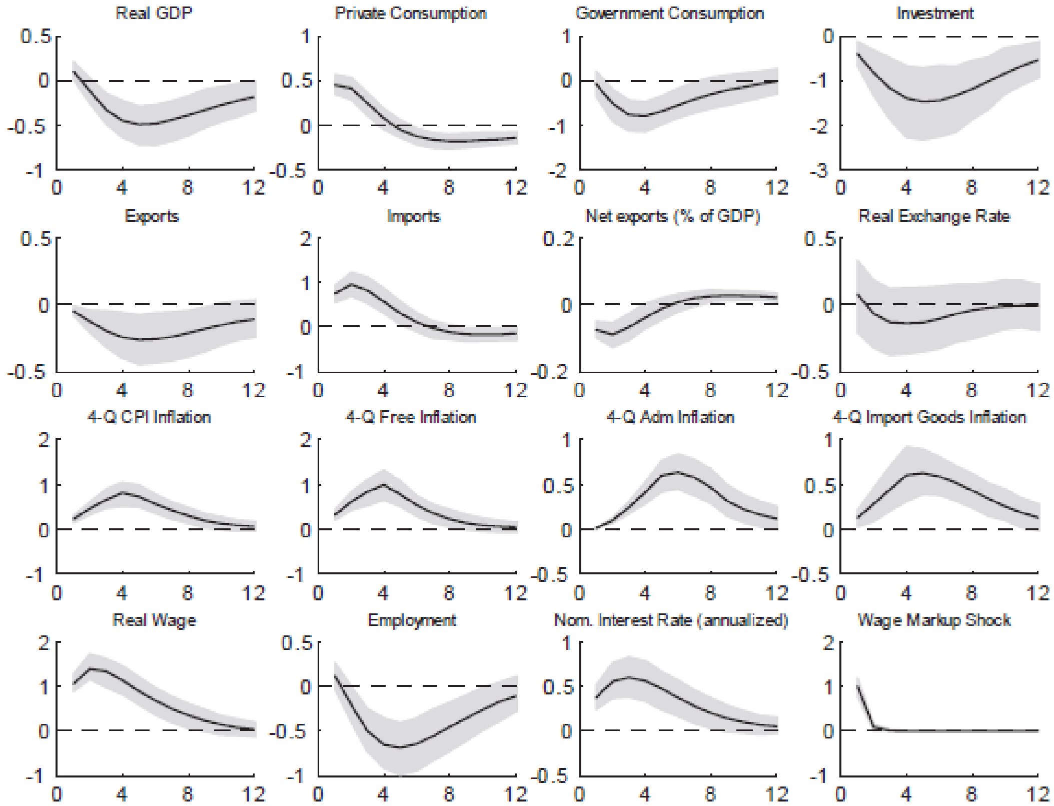

Figure 21: IRF of wage markup shock in SAMBA. Source: Authors' elaboration.

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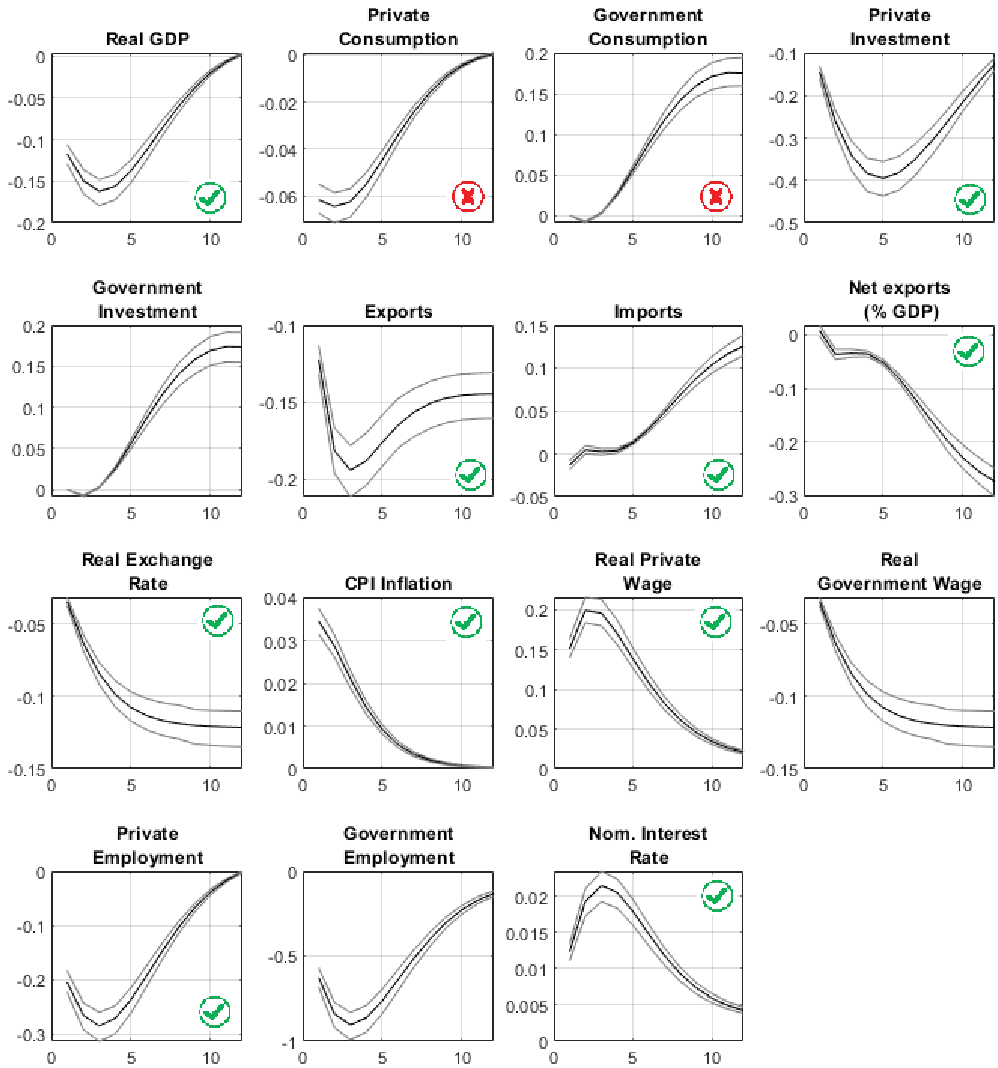

Figure 22: IRF of wage markup shock in the SNA-compliant DSGE model. Source: Authors' elaboration.

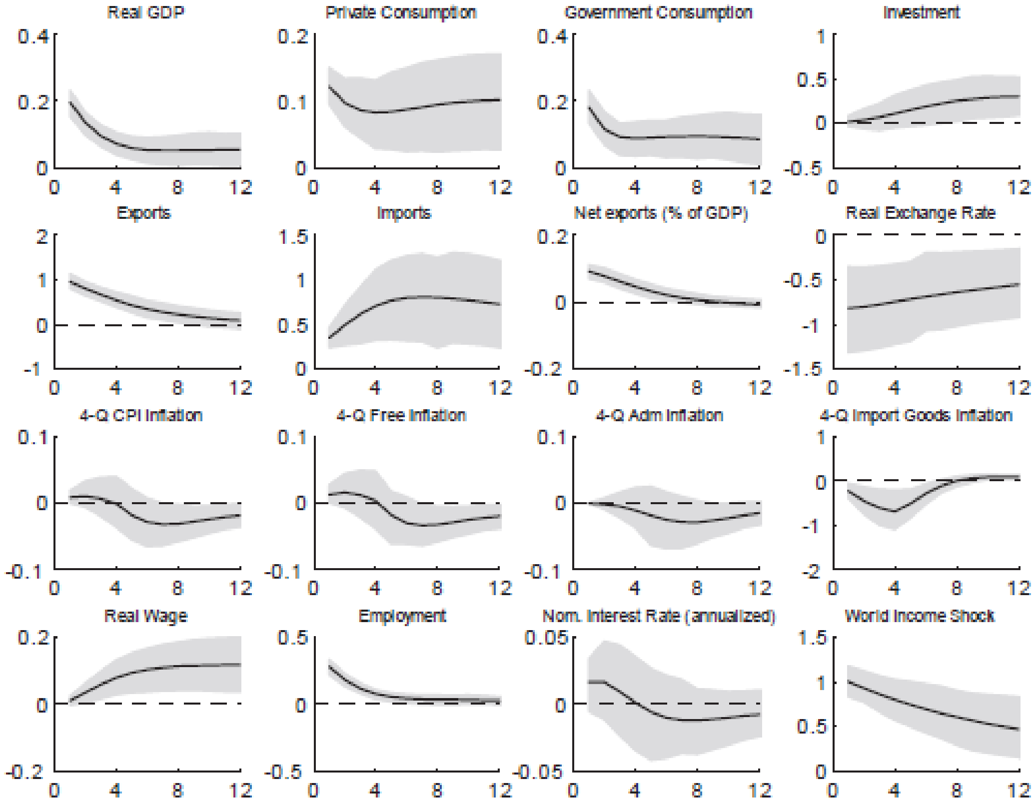

Figure 23: IRF of foreign income shock in SAMBA. Source: Authors' elaboration.

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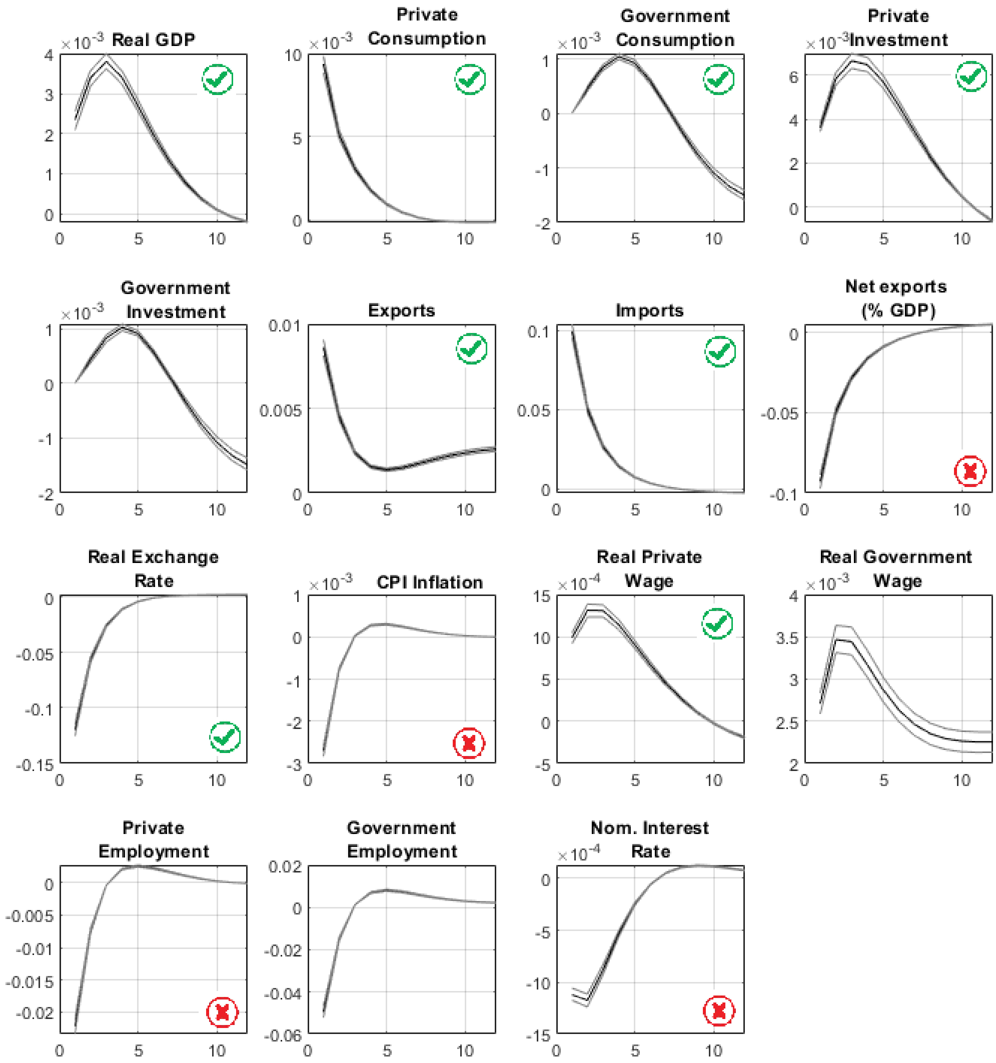

Figure 24: IRF of foreign income shock in the SNA-compliant DSGE model. Source: Authors' elaboration.

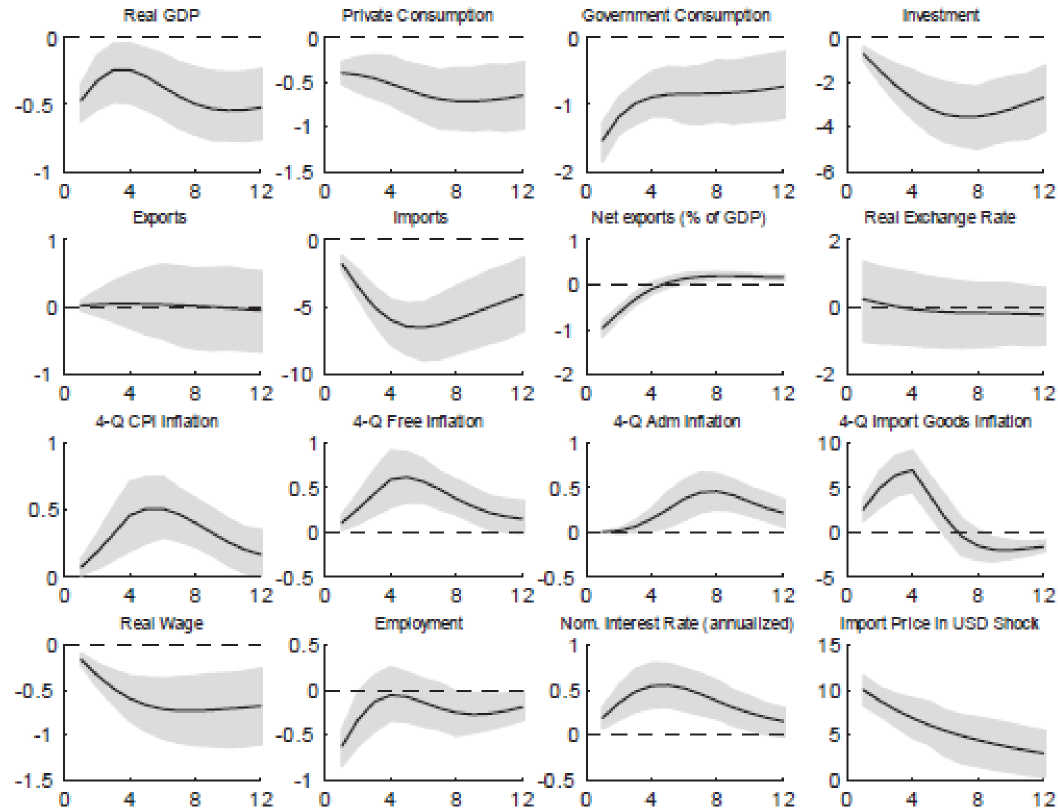

Figure 25: IRF of imported input price shock in SAMBA. Source: Authors' elaboration.

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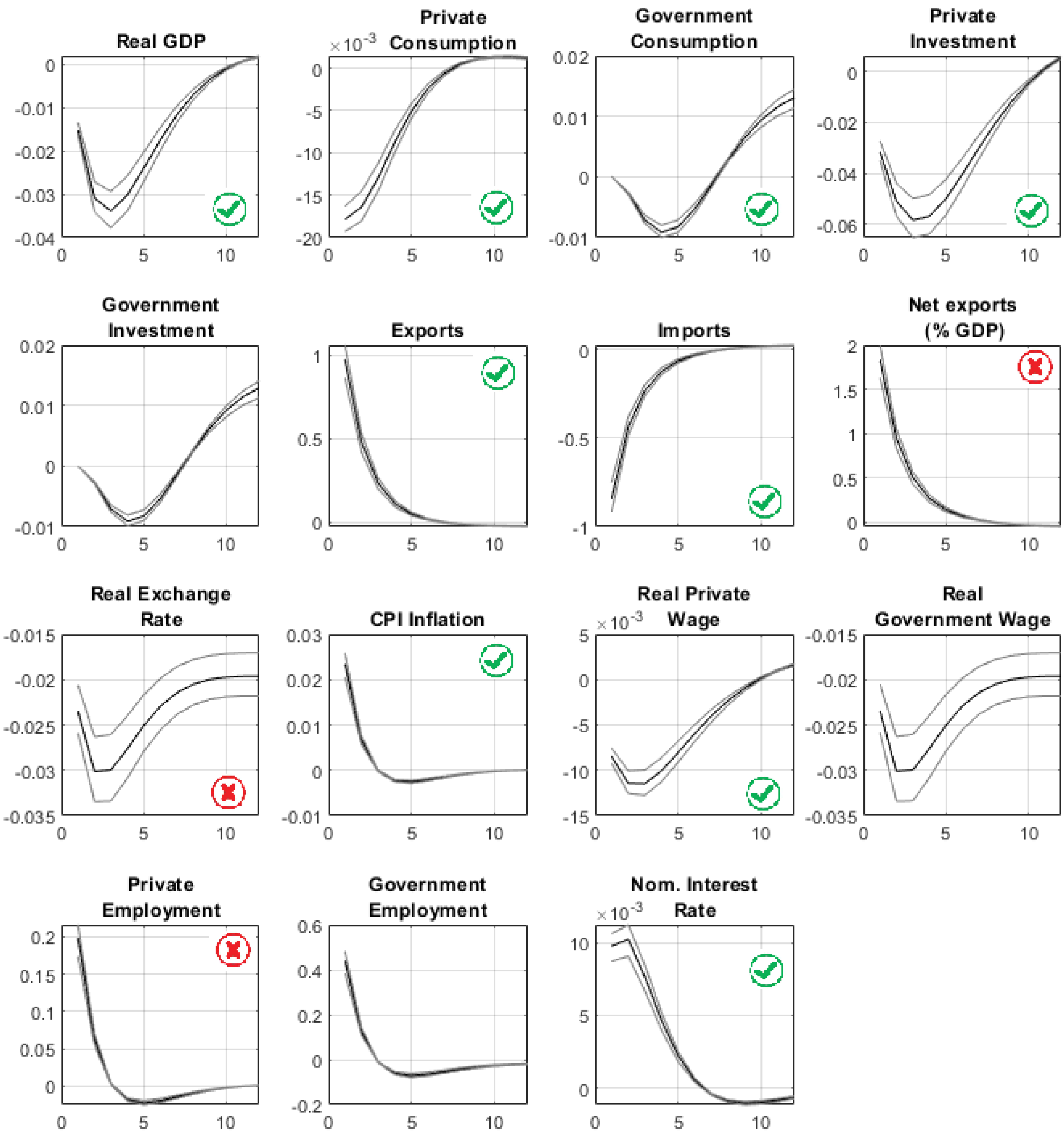

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