272

DISCUSSION PAPER

ANTICIPATED AND UNANTICIPATED FISCAL SHOCKS IN AN ESTIMATED DSGE MODEL FOR THE BRAZILIAN ECONOMY

MARCO A. F. H. CAVALCANTI
LUCIANO VEREDA OLIVEIRA
VINICIUS DOS SANTOS CERQUEIRA
THAIS C. O. DA FONSECA

ipea

DISCUSSION PAPER

272

Brasilia, February 2023

ANTICIPATED AND UNANTICIPATED FISCAL SHOCKS IN AN ESTIMATED DSGE MODEL FOR THE BRAZILIAN ECONOMY

MARCO A. F. H. CAVALCANTI[1]
LUCIANO VEREDA OLIVEIRA[2]
VINICIUS DOS SANTOS CERQUEIRA[3]
THAIS C. O. DA FONSECA[4]

1. Researcher at the Department of Macroeconomic Studies and Policies of the Institute for Applied Economic Research (Dimac/Ipea). E-mail: <marco.cavalcanti@ipea.gov.br>.

2. Department of Economics of the Universidade Federal Fluminense (UFF). E-mail: <lvereda@gmail.com>.

3. Researcher at Dimac/Ipea. E-mail: <vinicius.cerqueira@ipea.gov.br>.

4. Department of Statistics of the Federal University of Rio de Janeiro (UFRJ). E-mail: <thais@dme.ufrj.br>.

Discussion Paper

CONTENTS

ABSTRACT

We estimate a DSGE model for Brazil that includes both anticipated and unanticipated fiscal shocks. The model contains a relatively detailed public sector, which allows us to investigate the effects of anticipation for a much wider array of fiscal instruments than previously considered in the literature – indeed, we also analyze important budget components such as public investment, employment, and transfers. Instead of fixing in advance the degree of anticipation of fiscal shocks (generally assuming that they are anticipated in several quarters), we estimate it through a selection scheme based on Bayes Factors. We confirm the literature's result that fiscal shocks are not the main drivers of business cycles. However, we find that anticipated shocks are less relevant in Brazil when compared to other countries, and that the degree of anticipation varies between only one and two quarters, depending on the fiscal instrument.

Keywords: fiscal policy; fiscal rules; anticipation; Bayesian estimation.

1 INTRODUCTION

There is great uncertainty on the macroeconomic effects of fiscal policy, both on theoretical and empirical grounds. Despite many recent studies on the issue, the statement by Perotti (2007) still rings true: "(P)erfectly reasonable economists can and do disagree on the basic theoretical effects of fiscal policy, and on the interpretation of the existing empirical evidence".

From an empirical perspective, the main difficulty in estimating the effects of fiscal policy stems from the obvious endogeneity of fiscal variables with respect to macroeconomic variables, which has led to the adoption of various methods aiming to isolate the exogenous or discretionary component of fiscal policy ("fiscal shocks") from its endogenous part. Some of these studies have used the "dummy variable approach" first introduced by Ramey and Shapiro (1998); others have adopted the "narrative approach" by Romer and Romer (2010); still others have relied upon structural vector autoregressive models (Blanchard and Perotti, 2002; Perotti, 2005; 2007; Mountford and Uhlig, 2009; Auerbach and Gorodnichenko, 2012; Ilzetsky et al., 2013). Another branch of the literature has solved the identification problem by construction, through the direct calibration or estimation of models in structural form – mainly, dynamic stochastic general equilibrium (DSGE) models (Cogan et al., 2010; Coenen et al., 2012; 2013; Forni, Monteforte and Sessa, 2009, Stähler and Thomas, 2012).

All of these studies have been useful in advancing our knowledge on the effects of fiscal policy, but in general they have suffered from the difficulty in dealing with the possibility of fiscal shocks being anticipated by agents in the economy. In fact, since most fiscal policy changes are usually discussed and announced some time before their actual implementation, it may be difficult to establish a relationship between the innovations estimated with econometric models, such as VAR models, and the underlying structural shocks (Yang, 2005; Ramey, 2011). Indeed, anticipated shocks make the information used by economic agents (which includes the future values of the referred shocks) different from the information available to the econometrician, hindering the task of linking structural shocks to innovations. It is worth mentioning that anticipation might introduce a non-invertible moving average (MA) component in the data generating process, thus making its representation by means of a VAR model unfeasible.

One way to deal with the possibility of anticipation of fiscal shocks is to insert forward-looking variables among the vector of endogenous variables in VAR models (Fisher and Peters, 2010; Ramey, 2011; Mertens and Ravn; 2011). Another approach is to allow for anticipated shocks within a DSGE framework (Khan and Tsoukalas, 2012; Schmitt-Grohé and Uribe, 2012; Born, Peter and Pfeifer, 2013; Hur and Rhee, 2020). In this paper, we follow the latter approach, by estimating a DSGE model for Brazil that includes both anticipated and unanticipated fiscal shocks. We intend

to contribute to the literature in three ways. First, we provide evidence on the relative importance of anticipated versus unanticipated fiscal shocks for a small open economy, which is a relatively unexplored theme – to our knowledge, only Hur and Rhee (2020) have done this within a DSGE model. Second, our model contains a relatively detailed public sector structure, which allows us to investigate the effects of anticipation for a much wider array of fiscal instruments than previously considered in the literature: whereas previous studies only allowed for the anticipation of shocks to government spending and/or capital and labor taxation, we also analyze important budget components such as public investment, employment, and transfers. Finally, we carefully assess the degree of fiscal shock anticipation that provides the best fit to our data – for all fiscal shocks taken together, as well as for each type of instrument individually –, through a selection scheme based on Bayes Factors. This is an important difference with respect to the previous literature, which relied upon degrees of anticipation that were fixed in advance, rather than being estimated.[1]

In general, our analysis confirms the main results found in the literature, which show that fiscal shocks (anticipated or not) have a limited role in explaining business cycles.[2] There are some interesting differences, however. First, the anticipated components seem to be less relevant in Brazil when compared to other countries. Furthermore, the estimated degree of anticipation, which varies between one and two quarters, depending on the fiscal instrument, is much smaller than the intervals of up to two years assumed in the literature.

The remainder of this paper is organized as follows. In section 2, we discuss how the public budget is prepared and executed in Brazil. In section 3 we present the DSGE model used in our econometric exercises, which is adapted to the operation of a small, open, and emerging economy such as Brazil. In section 4 we discuss the estimation procedures and our main empirical results. In section 5 we analyze the effects of anticipated and unanticipated fiscal policy shocks in our model, paying attention to their relative importance. Section 6 concludes the paper.

2 PREPARATION AND EXECUTION OF THE PUBLIC BUDGET IN BRAZIL

In order to assess the role that fiscal policy shocks may play in the economy, it is essential to understand how the public budget is prepared and executed. In particular, the degree to

---

1. Fujiwara, Hirose and Shintani (2011) also specify the degree of shock anticipation based on statistical criteria. However, these authors focus only on productivity shocks and adopt a different estimation strategy for the degree of anticipation from the one proposed here. We believe our statistical approach presents a few advantages over theirs, as discussed in section 4.

2. See, for example, Schmitt-Grohé and Uribe (2012).

which fiscal policy shocks may be anticipated, and the relative importance of anticipated versus unanticipated shocks, will crucially depend on the lags involved in the budget preparation process and on the level of rigidity in budget planning and execution.

In Brazil, the budget formulation process at all levels of the federation – federal government, states and municipalities – comprises three formal stages. The details of this process are established in the Federal Constitution and other legislation, especially the so-called Fiscal Responsibility Law, approved in 2000. The first stage of the process relates to the preparation and approval of the Multi-Year Plan (PPA – Plano Plurianual, in portuguese). In the first year of each administration, the executive branch must present the PPA to Congress, which will evaluate and approve the plan, subject to modifications. The PPA is a fixed four-year plan, covering the administrations's final three years and the next administration's first year, that describes the main public policy priorities and goals set by the government. It covers projects and programs in all government areas, including details on desired or expected expenditures. As Mendes (2008) notes, the PPA is akin to a "declaration of intent" that should, at least in theory, direct and restrict the annual budget laws in the subsequent stages of the process.

The second stage in the budget formulation process relates to the Budget Guidelines Law (LDO – Lei de Diretrizes Orçamentárias). Each year, the executive branch must submit to Congress a draft LDO by April 15th, and the final law must be approved by Congress until June 30th. The LDO aims to guide the formulation of the budget for the subsequent fiscal year (beginning on January 1st), in accordance with the general goals set by the multi-year plan (PPA). Based on expected revenues, the LDO sets the primary balance to be achieved and therefore defines the value of total expenditures to be considered in the annual budget law. It also specifies which expenditures are to be considered as "mandatory" – which means that those expenditures may not be cut during the budget implementation phase.

In the third and final stage of the budget formulation process, the executive branch must send to Congress a draft Annual Budget Law (LOA – Lei Orçamentária Anual) by August 31st, specifying resources to be allocated to each Ministry or Secretariat in accordance with the LDO guidelines. Congress must then discuss, evaluate and propose amendments to the budget, within the limits set in the legislation. Ideally, the budget should be approved by year's end, so that its execution could be implemented and supervised from January 1st. However, in recent years the final budget law has often been approved in January, after the beginning of the fiscal year.

In theory, this three-stage hierarchical process should provide a smooth transition from the government's strategic goals, as set in the PPA, to the more specific policy choices established by the LDO, and finally to the operational measures defined in the annual budget (LOA). In practice,

however, the political reality in Brazil confers greater importance to the annual budget, which is the main locus for political bargaining. Since the guidelines set in the PPA may be altered at any moment to be made compatible with the budget, this means that the rationale is actually inverted, so that the annual budget ends up determining the main outcomes of the whole budget formulation process. As Mendes (2008) points out, the tail (LOA) wags the dog (PPA).

When we consider the implications of the budget formulation process for the relevance of anticipated fiscal shocks in Brazil, we may therefore restrict attention to the yearly budget laws – LDO and LOA. In particular, the moments when each of these laws are either presented by the executive branch or approved by Congress may represent important "fiscal news" that anticipate changes to expenditures that will only occur months later. Given the laws' timetable, it is therefore possible that such fiscal news may precede actual changes to fiscal policy anywhere from one quarter (given that the LOA approval at year´s end may anticipate changes to fiscal policy at the beginning of the subsequent year) up to seven quarters (since the presentation of the draft LDO in April may anticipate expenditures to be made up to the end of the subsequent year). Since the annual budget law (LOA), presented by the executive branch at the end of August and usually approved by Congress in December or January, seems to be the main budget law in Brazil, it would seem natural to consider possible degrees of fiscal anticipation ranging from one to five quarters.

Budget formulation is not the end of the story, though. The budget must be executed, and there are many reasons to expect "fiscal surprises" (i.e., unanticipated fiscal shocks) to occur during budget implementation. Note that the budget defines the expected amount of mandatory expenditures (such as social security benefits, public employees salaries and unemployment benefits) and the maximum amount that ministries or secretariats may spend on non-mandatory items (which include public investments and a wide array of public programs). The actual amounts spent on both mandatory and non-mandatory expenditures may therefore differ from the budget figures, as fiscal needs may not coincide with the budget estimates.

We must also note that, depending on the evolution of total revenues and expenditures during the year, it may be necessary for the government to decrease the limit on non-mandatory expenditures in order to comply with the primary balance target set by the LDO or with other existing fiscal rules. Since these changes in fiscal policy are usually related to observed or expected changes in macroeconomic variables such as GDP and inflation – which affect the government's projection of revenues for the fiscal year –, it is arguable whether they might be characterized as "unanticipated shocks". However, if the government's forecasts of revenues and/or expenditures are subject to errors or manipulation, it may still be possible to characterize such changes to non-mandatory expenditures, at least in part, as "shocks".

3 A BRIEF DESCRIPTION OF THE MODEL

We model the Brazilian economy using a dynamic stochastic general equilibrium approach. This means that the main relationships between macroeconomic variables are derived from the optimal decisions of the various agents in the economy, who are subject to various constraints imposed by the environment. The model structure follows Smets and Wouters (2003; 2007) and Christiano, Eichenbaum and Evans (2005). It incorporates: i) rational agents; ii) firms/individuals with market power and the ability to set prices/wages; iii) price and wage rigidity; and iv) real frictions such as capital adjustment costs, variable capacity utilization and habit formation in consumption. The model has characteristics that are typical of an emerging economy like Brazil. The economy grows at a gross rate g due to a continuous rise in labor productivity.[3,4]

There are four types of agents: individuals, firms, the government, and the external sector. Individuals are classified as ricardians, who belong to a set of size 1, working non-ricardians, who belong to a set of size ζ^c, and non-working non-ricardians, who form a set of size ζ^a. The measure of the non-ricardian population is $\zeta = \zeta^c + \zeta^a$, therefore the share of ricardian (non-ricardian) individuals in the population is $\frac{1}{1+\zeta}$ ($\frac{\zeta}{1+\zeta}$). Ricardian individuals supply labor to firms or the government, receive dividends (since they are the ultimate shareholders of firms) and accumulate physical capital. They also have access to financial markets, so that they smooth consumption over time by borrowing and saving.

Non-ricardian individuals who work earn wages and government transfers. They are constrained to spend all income received in each period on consumption. Non-ricardian individuals who do not work depend on transfers paid by the government, which are their only source of income. Each ricardian individual provides a specific type of labor, which is combined with the other types

---

3. This section only offers an overview of the economy. We leave to three appendices the task of providing a more detailed analysis. Appendix I describes the optimization problems solved by individuals and firms. Appendix II shows the equations of the linearized model, which rely on a balanced growth path that exists in the nonstochastic steady state of the model. In appendix III we derive an expression showing how the production of the final good is absorbed by domestic residents. Interested readers may request the three appendices by sending a message to <lvereda@gmail.com> or <marco.cavalcanti@ipea.gov.br>.

4. In the absence of shocks, this trend brings about a balanced growth path in which most macroeconomic variables (especially those measuring quantities) grow at this gross rate g. Supposing that v_t is one of these variables and that it starts from the initial value $\bar{v}$, then its value at period t would be $g^t \bar{v}$. Variables like v_t should be detrended so that the system of equations describing the economy's equilibrium comprises only stationary variables. Detrending means that, if v_t grows at a gross rate g, then the transformed variable $\hat{v}_t \frac{v_t}{g^t}$ is always equal to $\bar{v}$. The shocks that disturb the economy make v_t rover around the balanced growth path, while $\hat{v}_t$ oscillates around $\bar{v}$.

to yield the aggregate used by intermediate goods producers. The fact that ricardian individuals are the only suppliers of a particular type of labor allows them to choose the wage they receive. Non-ricardian working individuals do not have this privilege and take the wage as given. Firms in charge of producing intermediate goods combine the aggregate of ricardian labor with homogeneous non-ricardian labor to yield a labor basket.

Firms are divided into three sectors. The first one comprises firms that produce a commodity, the second includes intermediate goods producers and the third final good manufacturers. Firms producing the final good operate under perfect competition and adopt a three-step production process. In the first step, they combine different intermediate goods into two distinct baskets, which are called manufactured tradable (*TM*) and non-tradable (*NT*). A fraction of the *TM* basket is exported before the second stage is performed. In the second stage, final good producers combine the commodity with a certain quantity of the *TM* basket. In the third stage, they combine the *NT* basket with the aggregate that comes from the second stage. The final good thus obtained is consumed or transformed in physical capital by the individuals and the government.

The commodity-producing sector is modeled as in Medina and Soto (2016) but allowing the commodity to be used by final good manufacturers. Commodity production does not require any input, being obtained from an exogenous endowment. According to Medina and Soto, "this endowment (...) can be interpreted as the value added by natural resources in the commodity gross production". The endowment grows at a rate g to match the balanced growth path. The domestic demand for the commodity depends on its domestic price, which equals an exogenous international price $P_{C,t}^*$ converted to the domestic currency using the nominal exchange rate e_t. The difference between the domestic demand and the endowment is exported.

Firms in the intermediate goods sector operate under monopolistic competition. They belong to two different sub-sectors. The first one includes firms whose production can be exported after being combined into a basket by firms of the final goods sector. The second one includes firms whose production will not be shipped abroad after manufacturing. This structure justifies the usage of the manufactured tradable and non-tradable terminology to identify each sub-sector, although the production of the first sub-sector (whose output is the *TM* basket) is not directly exported. Intermediate goods producers apply a Cobb-Douglas production function which combines capital, imported inputs, and a labor basket to yield differentiated intermediate goods. The labor aggregate comes from merging ricardian and non-ricardian labor. Capital can be public or private. Private capital comes from ricardian individuals, who receive the rental rate of capital in exchange of each unit supplied. Public capital is made available at zero cost to all firms. It affects

total factor productivity, but its impact depends on the ratio between the existing stock at period t and the stock that would prevail if the economy had operated in line with the balanced growth path up to t.[5]

The domestic economy is open to international trade and capital flows. Exports of tradable manufactured goods depend on the global economic activity (which is an exogenous variable) and the ratio of its price (denominated in the international currency) and the "average" price of similar products manufactured abroad (which are also exogenous). Intermediate goods producers use a basket of imported goods throughout the production process. Its price in domestic currency equals its international price (which is an exogenous variable) converted by the nominal exchange rate. The price effectively paid by these firms is increased by the application of a foreign trade tax.

Regarding the capital account, we let ricardian individuals buy and sell one period bonds issued by the local government and by foreigners. The market price of the domestic bond is given by P_t^b, while $e_t P_t^{b,*}$ gives the market price of the foreign bond converted to the local currency by means of the nominal exchange rate e_t. The price of the foreign bond in terms of the foreign currency ($P_t^{b,*}$) obeys $P_t^{b,*} = \frac{1}{\theta_t R_t^*}$, where R_t^* denotes the (exogenous) international one period gross interest rate and θ_t represents the risk premium required by foreign residents to invest in domestic bonds. This risk premium is subject to a shock reflecting exogenous changes in foreign investors' risk appetite. It also depends on the net foreign asset position, given by the ratio between the face value of one period bonds issued abroad and owned by domestic residents (which is expressed in terms of the domestic currency) and the nominal value of domestic output. In the linearized version of the model, the risk premium θ_t also depends on the public debt.[6] Finally, the balance of payments of the domestic economy must be in equilibrium at all periods (that is, its result is always zero).

The government manages the one-period gross nominal interest rate R_t and eleven fiscal policy instruments: lump-sum taxes paid by ricardian individuals (Tax_t^l); public investment (I_t^g); public employment (L_t^g); the wage paid to public servants (W_t^g); tax rates on consumption (τ_t^c), labor income (τ_t^w), capital income (τ_t^k), and imports of intermediate goods (τ_t^x); government consumption of goods and services (G_t) and transfers paid to non-ricardian individuals who work or not (TR_t^c and TR_i^a, respectively). Monetary authorities follow a rule in which the gap between

---

5. Under this setup, the TFP becomes "weak" when the stock of public capital stays behind its "normal" level.

6. Indeed, the explicit consideration of the effect of public debt on the risk premium in a DSGE model for Brazil is also an innovation of our work. This link is empirically important in emerging countries like Brazil. More details on this subject can be seen at the end of appendix I.

R_t and its value in the balanced growth path depends on the consumer inflation rate and the gap between output and its value in the balanced growth path. The rule incorporates an inertial component and is subject to an exogenous monetary policy shock $\hat{\varepsilon}_t^m$.

The government budget constraint states that:

$$SP_t = \frac{R_{t-1}}{\pi_t^\circ} \frac{D_{t-1}^l}{P_{t-1}} - \frac{D_t^l}{P_t},$$ (1)

in which SP_t represents the real primary surplus, D_t^l (D_{t-1}^l) is the nominal value of outstanding public debt at period t ($t-1$) and R_{t-1} is the gross nominal interest rate at period $t-1$. Recurring primary deficits raise the public debt and force fiscal authorities to take compensatory action. More specifically, fiscal policy instruments may react to the public debt following the rules (2) and (3), which are already in their linearized versions.[7]

$$ir_t = \rho ir_{t-1} + \alpha_i \hat{d}_{t-x} + \hat{\varepsilon}_t^{ir}$$ (2)

$$id_t = \rho id_{t-1} - \phi_i \hat{d}_{t-x} + \hat{\varepsilon}_t^{id},$$ (3)

in which ir_t and id_t denote the values of the fiscal instruments related to revenues and expenses, respectively, and $\hat{d}_t$ denotes the real value of the public debt. The three variables are measured as deviations from their values in the balanced growth path. The instruments that depend on $\hat{d}_{t-x}$ are public employment, wages paid to public employees, government consumption, public investment and taxes levied on consumption. The parameter ρ belongs to the interval $(0,1)$. Parameters ϕ_i and α_i are positive and vary with the fiscal instrument. The reaction to public debt fluctuations takes two periods, meaning that $x = 2$. This seems to be in accordance with the Brazilian budget process and guarantees the model's convergence.

---

7. It is usual in the literature to work with linearized equations, which are derived from their respective exact versions by calculating first-order approximations around a benchmark. If the economy is not disturbed by "huge" shocks, then the solution of the linearized system is a good approximation of the solution of its exact counterpart. The linearized equations embed variables that are written in the form of deviations. More specifically, a variable v_t that grows at a gross rate g is first transformed into $\hat{v}_t$, which oscillates around $\overline{v}$, and then into the deviation $\hat{v}_t \frac{\hat{v}_t - \overline{v}}{\overline{v}}$, which oscillates around zero. If the variable v_t remains constant at $\overline{v}$ in the balanced growth path, then the deviation is defined as $\hat{v}_t \frac{v_t - \overline{v}}{\overline{v}}$. Exceptions occur when $\overline{v}$ is negative or zero. In this case, the referred deviations are calculated relative to the benchmark value of another variable (detrended output, for example).

Fiscal instruments insensitive to the public debt evolve according to:

$$i_t = \rho i_{t-1} + \hat{\varepsilon}_t^i. \tag{4}$$

This rule is already written in linearized form. It is followed by lump-sum taxes, transfers paid to non-ricardian individuals, and the remaining tax rates (τ_t^w, τ_t^k and $\tau_t^\times$).

The terms $\hat{\varepsilon}_t^{ir}$, $\hat{\varepsilon}_t^{id}$ and $\hat{\varepsilon}_t^i$ represent the shocks that affect the dynamics of fiscal instruments. Allowing all these shocks to have both unanticipated and anticipated components would add too much complexity to the model and make it difficult to obtain convergence and sensible estimation results. We therefore opt to restrict some of the tax rate shocks to only have unanticipated components. Fiscal shocks that are subject to anticipated influences are written as:

$$\hat{\varepsilon}_t^{(...)} = \hat{\varepsilon}_t^{(...),0} + \hat{\varepsilon}_{t-j}^{(...),j}, \tag{5}$$

in which $(...) = ir, id, i$ and $\hat{\varepsilon}_{t-j}^{(...),j}$ for $j = 0, a$ is assumed to be an i.i.d. normal disturbance with mean zero and standard deviation $\sigma_{(...),j}$. The innovation $\hat{\varepsilon}_t^{(...),0}$ represents the unanticipated component of $\hat{\varepsilon}_t^{(...)}$, being $\hat{\varepsilon}_{t-j}^{(...),j}$ the notation used to represent a j-period anticipated change in $\hat{\varepsilon}_t^{(...)}$. For example, $\hat{\varepsilon}_{t-2}^{(...),2}$ is an innovation to the value of the fiscal instrument that materializes in period t, but that agents learn about in period $t-2$. Therefore, $\hat{\varepsilon}_{t-2}^{(...),2}$ is in the period $t-2$ information set of economic agents but results in an actual change in the value of the fiscal instrument only in period t. We thus say that $\hat{\varepsilon}_{t-2}^{(...),2}$ is a two-period anticipated innovation in the value of ir_t, id_t or i_t. We aim to use Bayesian methods not only to estimate the values of the standard deviations $\sigma_{(...),0}$ and $\sigma_{(...),j}$ (which are closely related to the relative importance of the two components), but also to determine the value of j, i.e. the degree of anticipation, that best fits the observed data.

4 ESTIMATION PROCEDURE AND RESULTS

The estimation strategy did not include the estimation of parameters related to the economy's long-run. In this respect, the approach used here distances itself from other DSGE models for Brazil such as Castro et al. (2015), Moura (2015) and Kanczuk (2015). Our decision not to estimate long-run parameters was based on three main reasons, as described in the following.

1) Skepticism as to the informative content of the available time series with respect to the balanced growth path of the Brazilian economy.

2) Availability of a sufficiently tested calibration for steady state parameters and ratios validated in the literature.[8]

3) The detailed specification of the public sector in the model, which is necessary to adequately investigate the effects of anticipated and unanticipated fiscal shocks, already resulted in a dynamic model with many parameters to be estimated (78 in total). The inclusion of additional long-run parameters would have increased the computational burden even further.

The focus of the estimation was therefore to obtain reasonable approximations to the a posteriori distributions of the parameters related to the monetary and fiscal policy rules, to the "deep" parameters measuring price and wage indexation, and to the standard deviation and persistence of each shock. In addition, measurement errors were included for some observed variables. In these cases, the variances of these errors were estimated together with the other parameters.

4.1 Data

The time series used in this study start in the first quarter of 1999 and end in the fourth quarter of 2017. In total there were 26 series for a total of 33 shocks, 7 of which representing anticipated fiscal shocks. Table 1 shows the transformations made in the series. The relationships between the time series and the model variables are analogous to those used by Smets and Wouters (2007). The same occurs in works with estimates using Brazilian data such as Castro et al. (2015), Kanczuk (2015) and Moura (2015).

---

8. See Cavalcanti et al. (2019) and Cavalcanti and Vereda (2015).

TABLE 1
Series and used transformations[1]

Observable variables	Source	Measurement equation
GDP – (seasonally adjusted – s.a.)	IBGE	$dpibobs = \widetilde{pib}_t - \widetilde{pib}_{t-1} + \eta$
Nominal interest rate (Selic)[2]	Central Bank of Brazil	$drobs = \hat{r}_t - \hat{r}_{t-1} + \bar{r}$
CPI Inflation: IPCA (s.a. – % per quarter)	IBGE	$dpiobs = \tilde{\pi}_t + \bar{\pi}$
Real wage index (s.a.)	Calculated by the authors[4]	$dwtil = \widehat{w}_t - \widehat{w}_{t-1} + \eta + e_t^{wtil}$
Tredables sector inflation (s.a. – % per quarter)	Calculated by the authors[4]	$dpi\_t\_tilobs = \tilde{\pi}_{T,t} + \bar{\pi}_T + e_t^{pi\_t\_til}$
Inflation in the non-tredables sector (s.a. – % per quarter)	Calculated by the authors[4]	$dpi\_nt\_tilobs = \tilde{\pi}_{NT,t} + \bar{\pi}_{NT} \quad e_t^{pi\_nt\_til}$
Ricardian individuals wage (s.a.)	Calculated by the authors[4]	$dwltilobs = \widehat{w}^l_t - \widehat{w}^l_{t-1} + \eta + e_t^{wlt}$
Non-ricardian individuals wage (s.a.)	Calculated by the authors[4]	$dwctilobs = \widehat{w}^c_t - \widehat{w}^c_{t-1} + \eta + e_t^{wctil}$
Real exchange rate	Calculated by the authors[4]	$drerobs = \hat{e}^r_t - \hat{e}^r_{t-1} + e_t^{rer}$
Country risk premium: EMBI Brazil (% per quarter)[3]	Calculated by the authors[4]	$dpremiumobs = \hat{\theta}_t - \hat{\theta}_{t-1}$
External debt stock (% GDP)	Central Bank of Brazil	$db\_starobs = \hat{b}^*_t - \hat{b}^*_{t-1} + e_t^{b\_star}$
G20 GDP (Index – s.a.)	Federal Reserve Bank of St Louis	$dy\_starobs = \hat{y}^{H,*}_t - \hat{y}^{H,*}_{t-1} + \bar{y}^{H,*} + e_t^{y\_star}$
G20 Inflation (Consumer Price Index – s.a.)	Federal Reserve Bank of St Louis	$dpi_{starobs} = \hat{\pi}^*_t - \hat{\pi}^*_{t-1} + \bar{\pi}^* + e_t^{pi\_sta}$
Government consumption (s.a.)	IBGE	$dgobs = \hat{g}^H_t - \hat{g}^H_{t-1} + \eta$
Government investment (s.a.)	Calculated by the authors[4]	$digobs = \hat{i}^{H,g}_t - \hat{i}^{H,g}_{t-1} + \eta$
Private investment (s.a)	IBGE	$dilobs = \hat{i}^{H,l}_t - \hat{i}^{H,l}_{t-1} + \eta$
Private consumption (s.a)	IBGE	$dcobs = \hat{c}^H_t - \hat{c}^H_{t-1} + \eta$
External interest rate – Fed Funds rate	Federal Reserve Bank of St Louis	$dr\_starobs = \hat{R}^*_t - \hat{R}^*_{t-1} + R^* + e_t^{r\_star}$
Number of employed people (s.a.)	Calculated by the authors[4]	$dlobs = \hat{l}_t - \hat{l}_{t-1} - \bar{l} + e_t^l$
Ricardian individual consumption (s.a.)	Calculated by the authors[4]	$dclobs = \hat{c}^{H,l}_t - \hat{c}^{H,l}_{t-1} + \eta + e_t^{cl}$
Primary surplus (% GDP)	Central Bank of Brazil	$dspobs = \widehat{sp}^H_t - \widehat{sp}^H_{t-1} + \overline{sp}$
Transfers (s.a.)	Calculated by the authors[4]	$dwmt\_obs = \hat{c}^{H,a}_t - \hat{c}^{H,a}_{t-1} + c^{H,a}$
Public sector salary (s.a)	Calculated by the authors[4]	$dwgtilobs = \widehat{w}^g_t - \widehat{w}^g_{t-1} + \eta$
Wage tax rate	Calculated by the authors[4]	$dtaowobs = \hat{\tau}^w_t - \hat{\tau}^w_{t-1} + \tau^w + e_t^{taow}$
Public employment (hours worked)	Calculated by the authors[4]	$dlgobs = \hat{l}^g_t - \hat{l}^g_{t-1} + \bar{l}^g$
Commodity price index	International Monetary Fund	$dcommstarobs = \hat{p}^*_{C,t} - \hat{p}^*_{C,t-1}$

Authors' elaboration.

Notes: [1] For a given series x(t), dx = ln(x(t)) - ln(x(t-1)).

[2] Difference in the natural logarithm of the gross interest rate accumulated in the quarter.

[3] In the case of the risk premium, the dpremuim series corresponds to the following expression: dpremium = ln(premium(t)) - ln(premium(t-1)), where premium(t) = (((embi+(t))/10.000+1)^(1/4).

[4] With information from the public finance coordination of the Dimac/Ipea.

For the model variables that are affected by the balanced growth path, the corresponding time series have this common trend removed, so that the log difference minus the growth rate is a zero-mean stationary time series. Some series that presented deterministic in the sample trends had such trends removed. In some cases, measurement errors were added to account for any discrepancies between the observable variable and the model variable. These errors were estimated together with the other parameters.

4.2 Estimation procedure

As in Smets and Wouters (2007), the estimation of parameters was performed through Bayesian techniques using Markov Chain Monte Carlo methods. In particular, the joint posterior distribution was obtained via the Metropolis-Hastings algorithm. Initially, the priori distributions were defined based on Smets and Wouters (2007) and Castro et al. (2015). For all parameters related to persistence, the Beta distribution was assumed a priori. For the standard deviation of each shock or measurement error, an Inverse-Gamma distribution was assumed. For the other positive parameters, a Gamma prior was used.

The precision of the proposal distributions was calibrated to improve the convergence of the Markov chains, an essential step to ensure convergence. For initialization of our algorithm, the first step was to obtain initial estimates for the posterior mode and Hessian matrix which were used as the parameters in the proposal distribution, resulting in an independent sampler. Due to the large number of parameters, several updates of the estimates mentioned were necessary.

In addition, to guarantee the independence of each element of the final sample composing the posterior distribution, chains of size 5 million were obtained and the first 80% being discarded as a burn-in period. The chains were often reinitialized to improve the performance of the sampler. The biggest challenge of the estimation process was to obtain reasonable convergence of the chains for the persistence parameters. The reinitialization solved this issue and the final chains resulted in reasonable posterior distributions for these parameters.

Another difficulty was the occurrence of posterior marginal distributions with bimodal behavior. In these cases, special care was necessary for the estimation of the mode used in the proposal distributions. Different specifications were tested, and the criteria for selecting the mode were the ones in the following.

1) Obtaining sensible results for the posterior distributions of the impulse response functions and for the historical decomposition of selected variables.

2) Obtaining an acceptance rate for the Metropolis-Hastings algorithm between 0.2 and 0.4.

3) The analysis of Brooks and Gelman's (1998) multivariate and univariate convergence diagnosis.

4.3 Determining the best-fitting degree of anticipation

In order to investigate the degree of fiscal shock anticipation that provided the best fit to our data, the model was estimated with different degrees of anticipation, i.e., with different values of j, ranging from zero (only unanticipated shocks) to 5 quarters. Note that all specifications allowed for unanticipated shocks; our interest here lied in determining whether an anticipated component was also present and, if so, what the degree of anticipation was. We followed Kass and Raftery (1995) and used the Bayes factor to determine the value of j most compatible with the observed data. The Bayes factor is defined as:

$$B_{12} = \frac{\Pr\left(\mathbf{D}|H_1\right)}{\Pr\left(\mathbf{D}|H_2\right)}, \tag{6}$$

in which $\mathbf{D}$ is the data assumed to have arisen under hypothesis $H_{(\ldots)}$ $((\ldots) = 1, 2)$ and according to a probability density $\Pr\left(\mathbf{D}|H_{(\ldots)}\right)$. The Bayes factor can be read as the ratio of the posterior odds of H_1 to its prior odds, regardless of the value of the prior odds. When there are unknown parameters under either or both of the hypothesis, the Bayes factor is still given by (6), but the densities $\Pr\left(\mathbf{D}|H_{(\ldots)}\right)$ are obtained by integrating over the parameter space. The results are sometimes called a marginal likelihood, or an integrated likelihood. In fact, B_{12} is closely related to the likelihood ratio statistic, in which parameters are eliminated by maximization rather than by integration. We also follow Kass and Raftery (1995) in interpreting the Bayes Factor to select the best specification, as shown in table 2.

TABLE 2

Guidance for the interpretation of B_{12}'s (Bayes factor), which is the evidence in favor of model m_1 versus model m_2
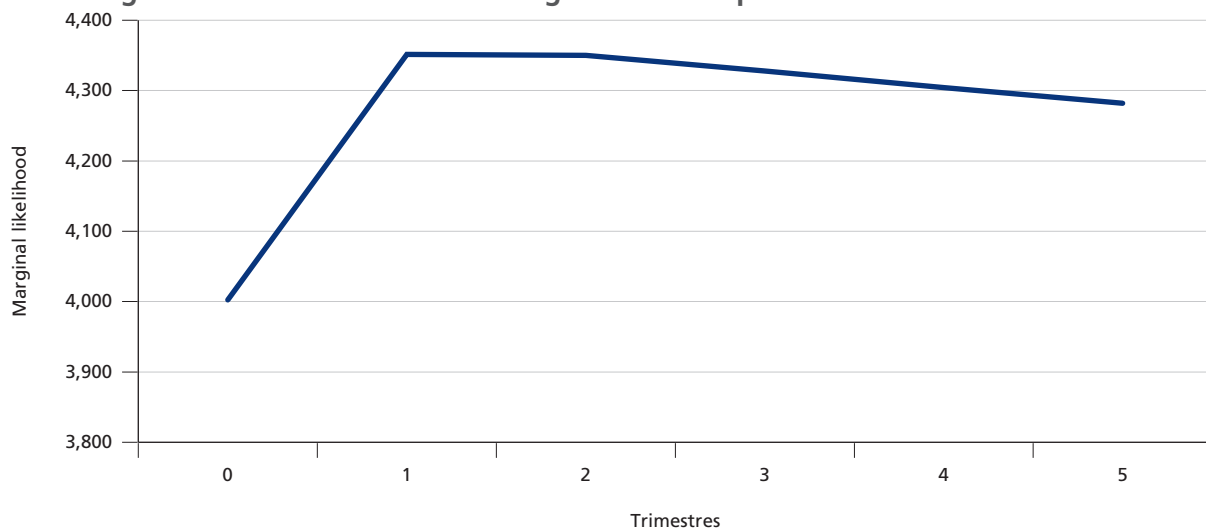
$2\ln(B_{12})$	B_{12}	Evidence against m_2
< 0	< 1	m_2 presents larger evidence than m_1
0 a 2	1 a 3	weak evidence against m_2
2 a 6	3 a 20	positive evidence against m_2
6 a 10	20 a 150	strong evidence against m_2
> 10	> 150	very strong evidence against m_2

Source: Kass and Raftery (1995).
Authors' elaboration.

It is useful to check twice the natural logarithm of the Bayes factor, which is on the same scale as the familiar deviance and likelihood ratio test statistics. In all cases, the procedures described in sub-section 4.2 were followed to ensure the convergence of the chains. Figure 1 shows the logarithm of the marginal likelihood for each degree of fiscal policy anticipation.

The maximum of the marginal likelihood occurred with the degree of anticipation equal to one quarter. Nonetheless, the differences between one-quarter anticipation and higher degrees of anticipation (especially two quarter-anticipation) seem quite small. To formally test whether these differences are significant, we rely on the Bayes Factor, as shown in table 3. The notation used in the table is such that $m(j)$ represents the model estimated for degree of anticipation j, with $j = 0, 1, \ldots, 5$.[9] According to the references established in table 2, the results do not deliver statistical evidence in favor of the model with one-quarter anticipation when compared to the specification with two-quarter anticipation. However, models with no anticipation or with anticipation greater than two quarters were rejected when compared to $m(1)$.

FIGURE 1

Marginal likelihood for different degrees of anticipation

Source: Results obtained in the estimation using the Dynare package.

9. If $j = 0$, then only the component $\hat{\varepsilon}_t^{(\ldots),0}$ is present in.

TABLE 3

Model selection test results

| Models	$2\ln(B_{1j})$	Evaluation
$m(0)$ *versus* $m(1)$	697	Very strong evidence against $m(0)$
$m(2)$ *versus* $m(1)$	2	The evidence against $m(1)$ is not relevant
$m(3)$ *versus* $m(1)$	47	Strong evidence against $m(3)$
$m(4)$ *versus* $m(1)$	94	Strong evidence against $m(4)$
$m(5)$ *versus* $m(1)$	138	Strong evidence against $m(5)$

Authors' elaboration.

Obs.: 1. The subindex j can assume the values 0, 2, 3, 4 and 5. We choose $j = 1$ as the reference for comparisons.

2. Table 2 is used to guide our judgements considering $2\ln(B_{1j})$.

Considering that the degree of anticipation may vary among fiscal instruments, we also considered "mixed" specifications that allowed for different degrees of anticipation for different instruments. Based on the results obtained above for the "aggregate" degree of anticipation, we restricted each expenditure item to be characterized either by one or two-quarter anticipation. We also tested for the best-fitting degree of anticipation for lump-sum taxes. Table 4 shows the "mixed" specification that provided the best fit to the data. Interestingly, while shocks to government consumption and lump-sum taxation are anticipated in one quarter, all other shocks are anticipated in two quarters. This result probably reflects the action of institutional factors that separate in time the announcement of the policy proposal from its impact on the economy.

TABLE 4

Best-fitting "mixed" specification (allowing for different anticipation degrees for each fiscal instrument)

Expenditure item	Anticipation degree (in quarters)
Public employment	2
Public wages	2
Transfers paid to working non-ricardians	2
Transfers paid to non-working non-ricardians	2
Government consumption	1
Public investiment	2
Lump-sum taxes	1

Authors' elaboration.

TABLE 5

Selection test results: "mixed" specification versus "aggregate" specification

Models	$2\ln(B_{xj})$	Evaluation
$m(0)$ versus $m(1\vert2)$	700	Very strong evidence against $m(0)$
$m(1)$ versus $m(1\vert2)$	3	Positive evidence against $m(1)$
$m(2)$ versus $m(1\vert2)$	5	Positive evidence against $m(2)$
$m(3)$ versus $m(1\vert2)$	50	Strong evidence against $m(3)$
$m(4)$ versus $m(1\vert2)$	97	Strong evidence against $m(4)$
$m(5)$ versus $m(1\vert2)$	141	Strong evidence against $m(5)$

Authors' elaboration.

Obs.: 1. Regarding the "aggregate" specifications, the subindex j can assume the values 0, 1, 2, 3, 4 and 5. We choose $m(1\vert2)\,(or\ \times=1\vert2)$ as the reference or the null hypothesis. Table 2 is used to guide the judgements referring $2\ln(B_{xj})$.

Table 5 compares the specification in table 4 with the "aggregate" specifications that allow for an unique degree of anticipation for all fiscal policy instruments, again using the Bayes Factor. There is evidence of better performance for the "mixed" specification relative to all "aggregate" specifications.

In general, the results point to a low degree of anticipation of fiscal shocks (one or two quarters). They also suggest that the degree of anticipation may depend on the policy instrument. The low degree of anticipation may be explained by the characteristics of the public budget process in Brazil, which demands the elaboration of the Budget Guidelines Law (LDO) and the Annual Budget Law (LOA). The two laws must be analyzed and approved by the National Congress, in a process characterized by intense political negotiations and significant changes in the guidelines initially proposed by Executive officers. Consequently, uncertainty about the outcomes hinders agents' ability to anticipate fiscal shocks many quarters in advance.

The last stage of the estimation procedure included the estimation of two chains, with 5 million generated values each, discarding the first 80% observations as the burn-in period. The acceptance rates for the "mixed" specification were 26.63% and 26.84%, suggesting that the generated chains have good properties. Figures 2 and A.1 (appendix A) show Brooks and Gelman's (1998) multivariate convergence diagnosis and univariate convergence diagnosis, respectively. In both cases the graphs indicate that convergence was achieved.

FIGURE 2

Multivariate convergence diagnosis
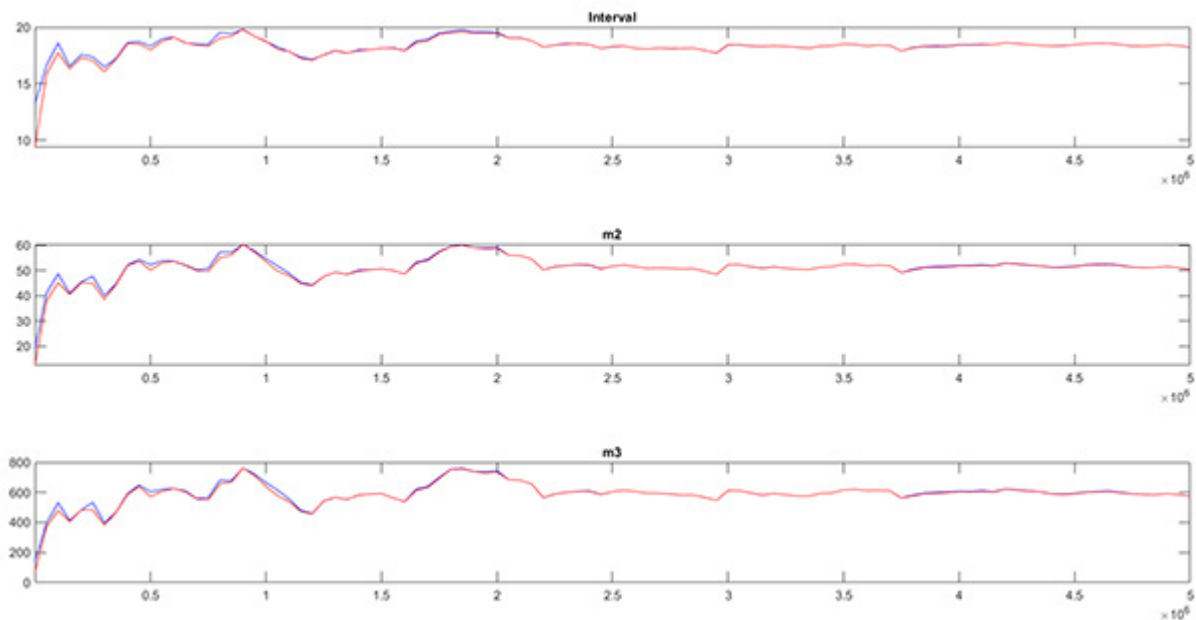
Source: Results obtained in the estimation using the Dynare package.

Publisher's note: Figure displayed in low resolution and whose layout and texts could not be formatted and proofread due to the technical characteristics of the original files.

4.4 Other estimation results

In the appendix A, tables A.3 to A.8 and figure A.2 show the posterior distributions for the parameters of the model with the best-fitting "mixed" anticipation scheme shown in table 4. In general, the posterior distributions are well behaved and provide plausible results. Regarding the results in table A.8 (estimation of selected parameters), they are in line with the estimates obtained in other works. For example, the estimated values for the parameters that measure the degrees of price and wage indexation (both around 0.5) are compatible with Castro et al. (2015), who estimate values between 0.33 and 0.65 for the five sectors that exist in their model. The estimated values of the parameter that measures monetary policy persistence (0.83) and the reaction to deviations of output from the balanced growth path (0.01) are also in line with previous findings, which also detected significant interest rate smoothing and a weak reaction to measures of economic activity (Minella et al., 2003; Silva and Portugal, 2010; Carvalho and Valli, 2011).

Regarding the shocks related to external variables and those whose effects have already been extensively studied in the literature, our results show that the largest standard deviations are associated with shocks in the rate of depreciation of private capital, in the commodity price

index, in the tax rate levied abroad on exports of the domestic economy and in the level of foreign economic activity. In terms of persistence, the highest values come from shocks in the risk premium, the international interest rate, the commodity price index and in the inflation prevailing in the rest of the world. In line with other works in the DSGE literature (for example, Castro et al., 2015), we can see that external shocks play a fundamental role in explaining Brazilian economic cycles.

Estimation of standard deviations of fiscal shocks suggests that anticipated and unanticipated disturbances in public investment, anticipated disturbances in the taxation of wages paid to ricardian agents and the anticipated component of the shock on the wage paid to public servants are the ones with the highest potential to cause cyclical fluctuations. Only in the case of the wages paid by the public sector we can say that the standard deviation of the anticipated component is greater than that of the unanticipated component with a 90% credibility. Regarding the fiscal rules, the main conclusions are: i) the persistence of deviations of public consumption from the values prevailing in the balanced growth path are greater than those of tax rates; and ii) the reaction to changes in the debt/GDP ratio was greater for public employment and public investment.

5 ANALYSIS OF FISCAL POLICY SHOCKS

The impulse response functions for some selected fiscal shocks (government consumption, public investment, public employment, wages paid by the public sector, and lump-sum taxes) are shown in figures A.3 through A.12. The effects of unanticipated (anticipated) shocks are depicted in figures A.3, A.5, A.7, A.9 and A.11 (A.4, A.6, A.8, A.10 and A.12). The y axis in each figure shows the deviations of a given macroeconomic variable from the values observed in the balanced growth path (measured in percentage terms). The x axis represents the timeline.

In the case of unanticipated shocks, the starting point of the x axis indicates the moment when the shocks hit the economy. In the case of anticipated shocks, the same point marks the period when agents become aware that such shocks will occur in the future (one or two quarters later).

Regarding the unanticipated fiscal shocks already investigated in the literature (for example, the government consumption shock), the impulse response functions are in line with previous results. The responses of inflation and the interest rate to the anticipated component of shocks on the various categories of public expenditure were significant, meaning that a shock that increases the amount spent on any of these items immediately increases inflation and the interest rate. A possible route would be the increase in inflation expectations due to the expected expansionary effect of fiscal policy. Another important point is that fiscal shocks (anticipated and unanticipated) significantly affect the risk premium.

It is also worth discussing the impulse response functions associated with anticipated and unanticipated shocks on public investment, which we know are important given the relatively high estimated values of their standard deviations (see sub-section 5.4). The graphs show that an unanticipated positive shock exerts a positive and immediate impact on output, inflation and the interest rate, and a negative and immediate effect on the primary surplus and private investment. In the anticipated case the responses change, since the immediate effect on output is negative and the maximum positive effect on inflation takes time to occur. A possible explanation for these differences is that agents anticipate that the increase in public investment will be offset by future decreases in government consumption, public employment, wages paid to public servants, and so on. The anticipation of these measures instantly inhibits the individuals' expenditure, forcing an anticipated fall of economic activity.

We also calculate the variance forecast error decomposition for the main macroeconomic variables. Table 6 presents the results for GDP, consumption, inflation, private investment, real exchange rates, the interest rate, and the risk premium. All calculations yield asymptotic (or long run) results.

For output, the bulk of the variance of forecast errors (almost 50%) is explained by the commodity price index shock. The second most important shock is the one that disturbs the depreciation of private capital, which accounts for half of the value under the heading "Others" (40.84%). Fiscal shocks are of limited importance, as they account for just over 10% of the variance of forecast errors. Anticipated components explain only a third of this amount.

In the case of inflation, the forecast error variance is dominated by the shock that affects the depreciation of private capital, which accounts for 21% of the total figure (63.34%). The shocks that affect individuals' preferences and private investment are also important and together account for almost 20% of the referred variance. Again, fiscal policy shocks are not very significant. Fiscal shocks account for almost 15% of the variance of forecast errors, but the anticipated components are responsible for only 2% of this amount.

Apparently, private investment is the macroeconomic variable most affected by anticipated fiscal shocks. In fact, fiscal shocks explain almost 11% of the forecast error variance, and 4 p.p. are explained by the anticipated components. The forecast error variances of the real exchange rate and the risk premium, on the other hand, are almost unaffected by anticipated fiscal shocks.

Table 7 helps to assess the importance of the different anticipated fiscal shocks that our model embeds. It shows that the shock affecting the transfers paid to non-ricardian agents who

work is the most important one, since it explains 1.74%, 1.65% and 3.42% of the variances in the projection errors of output, inflation, and private investment, respectively.

In summary, results suggest that fiscal shocks (anticipated or not) play a limited role in explaining the observed volatility of output and other real variables in Brazil. Furthermore, anticipated components do not appear to be particularly relevant. The first result is in line with Born, Peter and Pfeifer (2013), who estimate a New Keynesian business cycle model with anticipated and unanticipated tax and government spending shocks. They find that fiscal policy accounts for about 15% of output variance at business cycle frequencies in the U.S, but they also find that anticipated government spending shocks are important – which diverges from our second main result. Schmitt-Grohé and Uribe (2012) agree that fiscal shocks are not very important. They find that government spending shocks (which is the only fiscal impulse of their model) account for close to 10 percent of the variance of output growth. However, they show that two thirds of this fraction is attributable to anticipated innovations and one third to surprise movements in government spending.

TABLE 6

Forecast error variance decomposition

Shocks	GDP	Consumption	Inflation	Private_ investment	Real_ exchange_ rates	Interest_ rate	Risk_ premium
Others	40.84	86.11	63.34	51.28	57.85	66.07	79.62
Commodities	47.91	12.16	18.68	37.67	40.87	21.00	16.28
Tax shocks | expenditure	4.47	0.64	5.94	6.46	0.36	5.52	1.98
Tax shocks | taxation	2.25	0.27	6.58	0.14	0.75	0.85	1.61
Anticipated tax shocks	3.25	0.40	2.01	4.04	0.05	1.94	0.21
Monetary shocks	1.28	0.42	3.47	0.40	0.10	4.62	0.31

Authors' elaboration.
Obs.: Based on estimation results.

TABLE 7

Forecast error variance decomposition, results of anticipated fiscal shocks

Anticipated fiscal shocks	GDP	Consumption	Inflation	Private Investment	Real exchange rates	Interest rate	Risk premium
Transfers to non ricardian agents who do not work	0.02	0.02	0.01	0.00	0.00	0.01	0.00
Transfers to non ricardian agents who work	1.74	0.27	1.65	3.42	0.03	1.52	0.11
Public investiment	0.28	0.07	0.24	0.43	0.02	0.29	0.08
Public employment	0.11	0.01	0.02	0.05	0.00	0.05	0.00
Government consumption	0.05	0.01	0.05	0.07	0.00	0.06	0.02
Wages paid to public servants	1.05	0.02	0.04	0.07	0.00	0.01	0.00

Authors' elaboration.

Obs.: Based on estimation results.

Publisher's note: Table displayed in low resolution and whose layout and texts could not be formatted and proofread due to the technical characteristics of the original files.

Regarding historical decompositions (see figures A.13 to A.18), anticipated fiscal shocks were important to explain the growth of the Brazilian GDP between 2004 and 2010. On the other hand, from 2011 onwards, the contribution of these shocks started to be negative in most quarters, especially between 2014 and 2016. This result is consistent with the stylized facts about the dynamics of Brazilian fiscal policy and its impact on economic activity.

6 CONCLUSION

The main goal of this paper is to study the effects of unanticipated and anticipated fiscal shocks within a DSGE model that describes the workings of a small open economy such as Brazil. The model allows achieving some advances in relation to what has been done in the literature. First, we provide evidence on the relative importance of anticipated versus unanticipated fiscal shocks for a small open economy, which is a relatively unexplored theme. Second, our model contains a relatively detailed public sector structure, which allows investigating the effects of anticipation for a much wider array of fiscal instruments than previously considered in the literature. Indeed, whereas previous studies only allowed for the anticipation of shocks to government spending and/or capital and labor taxation, we also analyze important budget components such as public investment, employment, and transfers. Finally, we carefully assess the degree of fiscal shock anticipation that provides the best fit to our data – for all fiscal shocks taken together, as well as for each type of instrument individually –, through a selection scheme based on Bayes factors. This is an important difference with respect to the previous literature, which relied upon degrees of anticipation that were fixed in advance, rather than being estimated.

Regarding the results, we confirm the conclusions of previous works dedicated to other economies and show that fiscal shocks have a limited role in explaining business cycles in Brazil. In principle one could expect not only more pronounced effects, but also some anticipation. In fact, a preliminary analysis of the public budgeting process in Brazil suggests that the degree of anticipation of fiscal shocks could range from one to five quarters. Nonetheless, estimation results show that this degree varies between one and two quarters, depending on the fiscal instrument. These figures are smaller than those suggested by the analysis of the Brazilian public budgeting process. They are also much smaller than the intervals of up to two years generally assumed in the literature.

Some public budget items are more subject to the occurrence of anticipated fiscal shocks. The estimation of standard deviations of fiscal shocks suggests that anticipated and unanticipated disturbances in public investment, anticipated disturbances in the taxation of wages paid to ricardian agents and the anticipated component of the shock on the wage paid to public servants are those with the highest potential to cause cyclical fluctuations. The overall picture, however, shows that the anticipated portions are not relevant. This could be explained by the fact that the Brazilian political reality confers greater importance to the annual budget, which ends up determining the main outcomes of the whole budget formulation process and is very affected by political bargaining. Indeed, both the Budget Guidelines Law (LDO) and the Annual Budget Law (LOA) must be analyzed and approved by the National Congress, in a process characterized by intense political negotiations and significant changes in the guidelines initially proposed by Executive officers. Consequently, uncertainty about the outcomes hinders agents' ability to anticipate fiscal shocks many quarters in advance.

REFERENCES

BLANCHARD, O.; PEROTTI, R. An empirical characterization of the dynamic effects of changes in government spending and taxes on output. **Quarterly Journal of Economics**, v. 117, n. 4, p. 1329-1368, Nov. 2002.

BORN, B.; PETER, A.; PFEIFER, J. Fiscal news and macroeconomic volatility. **Journal of Economic Dynamics and Control**, v. 37, n. 12, p. 2582-2601, Dec. 2013.

BROOKS, S.; GELMAN, A. General methods for monitoring convergence of iterative simulations. **Journal of Computational and Graphical Statistics**, v. 7, n. 4, p. 434-455, 1998.

CARVALHO, F.; VALLI, M. **Fiscal policy in Brazil through the lens of an estimated DSGE model**. Brasilia: Banco Central do Brasil, Apr. 2011. (Texto para Discussão, n. 240).

CASTRO, M. et al. SAMBA: stochastic analytical model with a bayesian approach. **Brazilian Review of Econometrics**, v. 35, n. 2, p. 103-170, Nov. 2015.

CAVALCANTI, A. F. H. C.; VEREDA, L. Fiscal policy multipliers in a DSGE model for Brazil. **Brazilian Review of Econometrics**, v. 35, n. 1, p. 197-233, Nov. 2015.

CAVALCANTI, M. A. F. H. et al. Impactos macroeconômicos do choque fiscal de 2015: a regularização de despesas públicas não contabilizadas. **Revista Brasileira de Economia**, v. 73, n. 4, p. 489-527, out.-dez. 2019.

CHRISTIANO, L.; EICHENBAUM, M.; EVANS, C. Nominal rigidities and the dynamic effects to a shock of monetary policy. **Journal of Political Economy**, v. 113, n. 1, p. 1-45, Feb. 2005.

COGAN, J. F. et al. New Keynesian versus old keynesian government spending multipliers. **Journal of Economic Dynamics and Control**, v. 34, n. 3, p. 281-295, Mar. 2010.

FISHER, J. D. M.; PETERS, R. Using stock returns to identify government spending shocks. **The Economic Journal**, v. 120, n. 544, p. 414-436, May 2010.

FORNI, L.; MONTEFORTE, L.; SESSA, L. The general equilibrium effects of fiscal policy: estimates for the Euro area. **Journal of Public Economics**, v. 93, n. 3-4, p. 559-585, Apr. 2009.

FUJIWARA, I.; HIROSE, Y.; SHINTANI, M. Can news be a major source of aggregate fluctuations? A Bayesian DSGE approach. **Journal of Money, Credit and Banking**, v. 43, n. 1, p. 1-29, Feb. 2011.

HUR, J.; RHEE, W. Multipliers of expected vs. unexpected fiscal shocks: the case of Korea. **Economic Modelling**, v. 85, p. 244-254, Feb. 2020.

KANCZUK, F. Brazil through the eyes of CHORINHO. **Brazilian Review of Econometrics**, v. 35, n. 2, p. 171-195, Nov. 2015.

KASS, R.; RAFTERY, A. E. Bayes factor. **Journal of the American Statistical Association**, v. 90, n. 430, p. 773-795, June 1995.

KHAN, H.; TSOUKALAS, J. The quantitative importance of news shocks in estimated DSGE models. **Journal of Money, Credit and Banking**, v. 44, n. 8, p. 1535-1561, Dec. 2012.

MEDINA, J. P.; SOTO, C. Commodity prices and fiscal policy in a commodity exporting economy. **Economic Modelling**, v. 59, p. 335-351, Dec. 2016.

MENDES, M. **Sistema Orçamentário Brasileiro**: planejamento, equilíbrio fiscal e qualidade do gasto público. Brasília: Consultoria Legislativa do Senado Federal, fev. 2008. (Texto para Discussão, n. 39).

MERTENS, K.; RAVN, M. O. Understanding the aggregate effects of anticipated and unanticipated tax policy shocks. **Review of Economic Dynamics**, v. 14, n. 1, p. 27-54, Jan. 2011.

MOUNTFORD, A.; UHLIG, H. What are the effects of fiscal policy shocks? **Journal of Applied Economics**, v. 24, p. 960-992, 2009.

MOURA, G. V. Multiplicadores fiscais e investimento em infraestrutura. **Revista Brasileira de Economia**, v. 69, n. 1, p. 75-104, jan.-mar. 2015.

PEROTTI, R. **Estimating the effects of fiscal policy in OECD countries**. [s.l.]: CEPR, Jan. 2005. (Discussion Paper, n. 4842).

_____. **In search of the transmission mechanism of fiscal policy**. Cambridge, United States: NBER, June 2007. (Working Paper, n. 13143).

RAMEY, V. A. Identifying government spending shocks: it's all in the timing. **The Quarterly Journal of Economics**, v. 126, n. 1, p. 1-50, Feb. 2011.

RAMEY, V. A.; SHAPIRO, M. Costly capital reallocation and the effects of government spending. **Carnegie-Rochester Conference Series on Public Policy**, v. 48, p. 145-194, June 1998.

ROMER, C. D.; ROMER, D. H. The macroeconomic effects of tax changes: estimates based on a new measure of fiscal shocks. **American Economic Review**, v. 100, n. 3, p. 763-801, June 2010.

SCHMITT-GROHÉ, S.; URIBE, M. What's news in business cycles, **Econometrica**, v. 80, n. 6, p. 2733-2764, Nov. 2012.

SMETS, F.; WOUTERS, R. An estimated dynamic stochastic general equilibrium model of the Euro Area. **Journal of the European Economic Association**, v. 1, n. 5, p. 1123-1175, Sept. 2003.

_____. Shocks and frictions in US business cycles: a Bayesian DSGE approach. **American Economic Review**, v. 97, n. 3, p. 586-606, Jun. 2007.

STÄHLER, N.; THOMAS, C. FiMod – a DSGE model for fiscal policy simulations. **Economic Modelling**, v. 29, n. 2, p. 239-261, Mar. 2012.

YANG, S.-C. S. Quantifying tax effects under policy foresight. **Journal of Monetary Economics**, v. 52, n. 8, p. 1557-1568, Nov. 2005.

COMPLEMENTARY BIBLIOGRAPHY

GAMERMAN, D.; LOPES, H. F. (Ed.). **Markov Chain Monte Carlo**: stochastic simulation for Bayesian inference. 2nd ed. London: Chapman & Hall, 2006.

KRIWOLUZKY, A. Pre-announcement and timing: the effects of a government expenditure shock. **European Economic Review**, v. 56, n. 3, p. 373-388, Apr. 2012.

LEEPER, E. M.; TRAUM, N.; WALKER, T. B. Clearing up the fiscal multiplier morass. **American Economic Review**, v. 107, n. 8, p. 2409-2454, Aug. 2017.

LIU, P.; THEODORIDIS, K. DSGE model restrictions for structural VAR identification. **International Journal of Central Banking**, v. 8, n. 4, p. 61-95, Dec. 2012.

MERTENS, K.; RAVN, M. O. Measuring the impact of fiscal policy in the face of anticipation: a structural VAR approach. **The Economic Journal**, v. 120, n. 544, p. 393-413, May 2010.

SILVA, F.; PORTUGAL, M. **O impacto de choques fiscais na economia brasileira**: uma abordagem DSGE. Porto Alegre: Ed. UFRGS, 2011. (Texto para Discussão, n. 2011/01).

UHLIG, H. What are the effects of monetary policy on output? Results from an agnostic identification procedure. **Journal of Monetary Economics**, v. 52, n. 2, p. 381-419, Mar. 2005.

DISCUSSION PAPER

APPENDIX A

TABLE A.1
Calibrated values for model parameters[1]

Parameter	Description	Value
ζ	Size of the non-ricardian population	0.6600
σ_C	Absolute value of the elasticity of the marginal utility of consumption with respect to consumption	1.2000
σ_L	Elasticity of the marginal disutility of labor with respect to labor	2.0000
β	Intertemporal discount factor	0.9875
θ	Sensitivity of the risk premium with respect to the debt/output ratio	1.1000
δ	Depreciation rate of the private capital stock	0.0200
$\tilde{\delta}$	Depreciation rate of the public capital stock	0.0200
h	Degree of habit formation of individuals in the economy	0.6500
$\nu = \left(\left. \dfrac{\partial^2 S}{\partial \left(\arg S \right)^2} \right|_{SS} \right)^{-1}$	Measure of the convexity of function S, which imposes costs to the adjustment of the capital stock	0.1500
$\left. \dfrac{d^2 \Psi}{d \left(z_t^I \right)^2} \right|_{SS} \bigg/ \left. \dfrac{d\Psi}{dz_t^I} \right|_{SS}$	Parameter that characterizes function , which imposes a cost to the economy whenever the rate of utilization of private capital departs from its steady-state level	5.9200
α_P^T	Proportion of firms in the tradable goods sector that are unable to choose optimal prices in a given period	0.5000
α_P^{NT}	Proportion of firms in the non-tradable goods sector that are unable to choose optimal prices in a given period	0.5000
α_W	Proportion of ricardian individuals who are unable to choose optimal wages in a given period	0.6000
η_K^T	Exponent of capital in the Cobb-Douglas production function used by intermediate goods firms pertaining to the tradable sector of the economy	0.4250
η_L^T	Exponent of labor in the Cobb-Douglas production function used by intermediate goods firms pertaining to the tradable sector of the economy	0.4000
η_K^{NT}	Exponent of capital in the Cobb-Douglas production function used by intermediate goods firms pertaining to the non-tradable sector of the economy	0.2500
η_L^{NT}	Exponent of labor in the Cobb-Douglas production function used by intermediate goods firms pertaining to the non-tradable sector of the economy	0.6500

(Continues)

(Continued)

Parameter	Description	Value
μ_w	Parameter that measures the degree of substitution between the different kinds of labor supplied by ricardian individuals	0.5000
η_g	Sensitivity of total factor productivity of intermediate goods firms with respect to public capital	0.0500
a	Parameter that measures the degree of substitution between the labor aggregates supplied by ricardian and non-ricardian individuals	5.0000
γ	Parameter that measures the importance of tradables goods in the production function used by firms manufacturing the final good	0.3200
η	Parameter that measures the degree of substitution between tradable and non-tradable aggregates in the production of the final good	2.0000
φ	Parameter that measures the importance of ricardian labor in the labor aggregate used by intermediate goods firms	0.6500
μ_T	Parameter that measures the degree of substitution between the various kinds of tradable goods used in the production of the tradable aggregate	0.1000
μ_{NT}	Parameter that measures the degree of substitution between the various kinds of non-tradable goods used in the production of the non-tradable aggregate	0.2000
τ^*	Sensitivity of the foreign demand for tradable goods manufactured in the domestic economy with respect to its relative price	10

Authors' elaboration.

Note: [1] The calibration was based on Cavalcanti et al. (2019).

TABLE A.2

Steady-state ratios for main macroeconomic aggregates[1]

Parameter	Description	Value
$\left(\bar{C}+\bar{G}\right)/\overline{PIB}$	Ratio between total consumption and the gross domestic product (GDP)	0.82
$\bar{C}/\overline{PIB}$	Ratio between total private consumption and GDP	0.62
$\bar{C}^l/\overline{PIB}$	Ratio between total ricardian consumption and GDP	0.35
$\zeta\bar{C}^c/\overline{PIB}$	Ratio between total non-ricardian consumption and GDP	0.27
$\left(\bar{G}+\bar{w}^g\bar{L}^g\right)/\overline{PIB}$	Ratio between total government consumption and GDP	0.21
$\bar{G}/\overline{PIB}$	Ratio between pure government spending (purchases of goods and services) and GDP	0.07
$\bar{w}^g\bar{L}^g/\overline{PIB}$	Ratio between the real value of the payroll of public servants and GDP	0.13
$\bar{I}/\overline{PIB}$	Ratio between aggregate investment and GDP	0.18
$\bar{I}^l/\overline{PIB}$	Ratio between private investment and GDP	0.16
$\bar{I}^g/\overline{PIB}$	Ratio between public investment and GDP	0.02
$\left(\bar{Y}+\bar{w}^g\bar{L}^g\right)/\overline{PIB}$	Ration between total domestic absorption and GDP	1.00
$\bar{\tilde{p}}_T\bar{Y}_T^*/\overline{PIB}$	Ratio between the real value of exports and GDP	0.10
$\bar{p}_T^{\times}\bar{Q}/\overline{PIB}$	Ratio between the real value of imports and GDP	0.10
$\left(\bar{w}\bar{L}+\bar{w}^g\bar{L}^g\right)/\overline{PIB}$	Real labor income as a proportion of GDP	0.53
$\bar{w}\bar{L}/\overline{PIB}$	Real labor income paid by the private sector as a proportion of GDP	0.40
$\bar{w}^g\bar{L}^g/\overline{PIB}$	Real labor income paid by the public sector as a proportion of GDP	0.13
$\bar{w}^c\bar{L}^c/\overline{PIB}$	Real labor income received by non-ricardian workers as a proportion of GDP	0.15
$\left(\bar{w}^l\bar{L}^l+\bar{w}^g\bar{L}^g\right)/\overline{PIB}$	Real labor income received by ricardian workers as a proportion of GDP	0.38
$\left(\dfrac{\bar{Y}}{1+\bar{\tau}^c}-\bar{w}\bar{L}+\overline{BC}\right)/\overline{PIB}$	Real capital income as a proportion of GDP	0.31
$\dfrac{\bar{\tau}^c}{1+\bar{\tau}^c}\left(\bar{C}+\bar{G}\right)+\dfrac{\bar{\tau}^{\times}}{1+\bar{\tau}^{c,*}}\bar{e}^r\bar{\tilde{p}}_T^*\bar{Q}$	Excise taxes + import taxes as a proportion of GDP	0.16
$\zeta\bar{w}^m/\overline{PIB}$	Social transfers received by non-ricardian individuals as a proportion of GDP	0.16

(Continues)

(Continued)

Parameter	Description	Value
$\overline{\tau}_w\left(\overline{w}\overline{L}+\overline{w}^c\overline{L}^c\right)\Big/\overline{PIB}$	Taxes levied on labor income as a proportion of GDP	0.12
$\overline{\tau}^k\left(\dfrac{\overline{Y}}{1+\overline{\tau}^c}-\overline{w}\overline{L}+\overline{BC}\right)\Big/\overline{PIB}$	Taxes levied on capital income as a proportion of GDP	0.07
$\overline{T}\big/\overline{PIB}$	Lump-sum taxes as a proportion of GDP	0.01
$\overline{Y}^T\big/\overline{Y}^{NT}$	Ratio between the outputs of the tradable and non-tradable sectors	0.78
$\overline{K}\big/\overline{PIB}$	Capital stock as a proportion of GDP	2.28

Source: Cavalcanti et al. (2019).
Authors' elaboration.

FIGURE A.1
Univariate convergence diagnosis
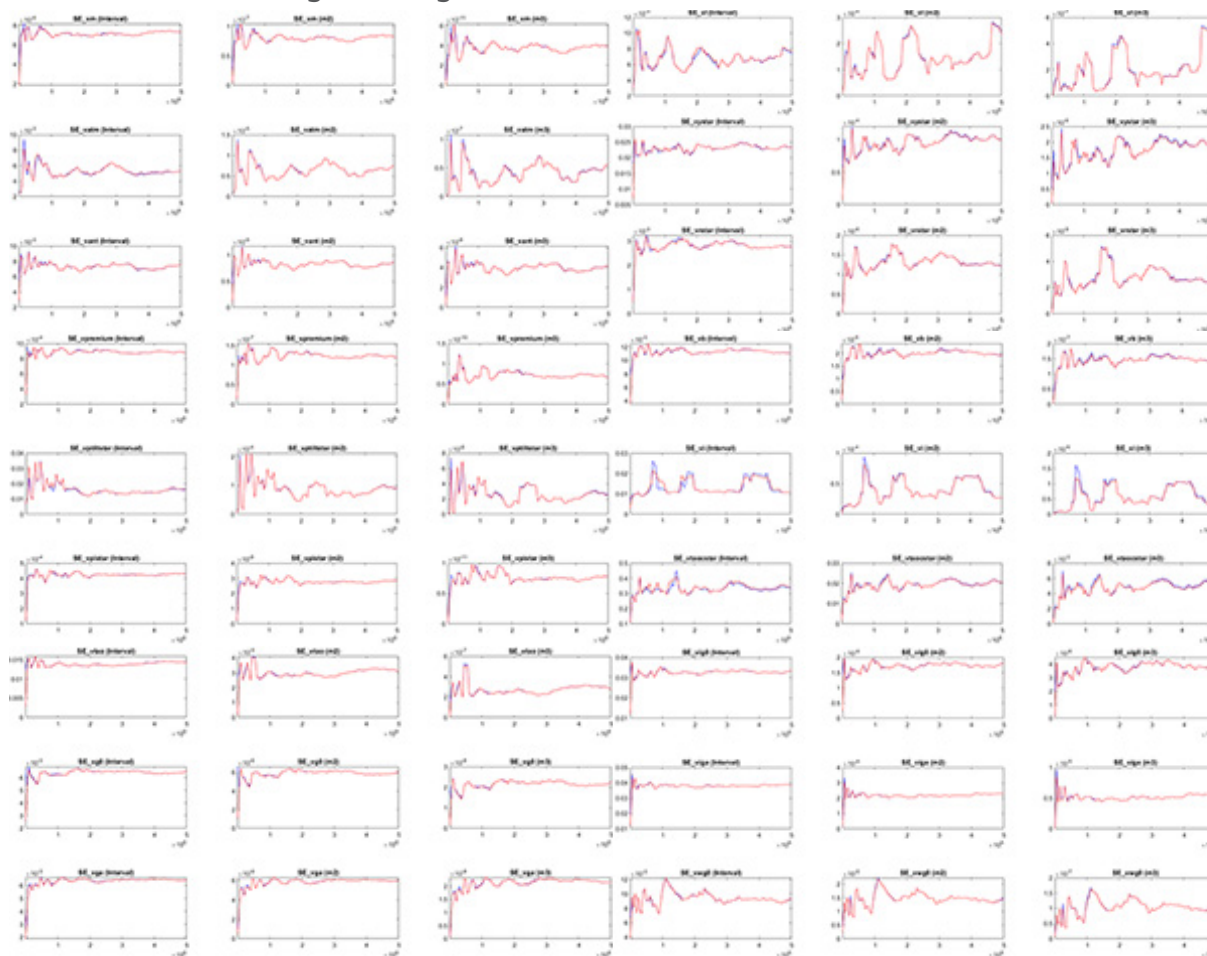
(Continued)
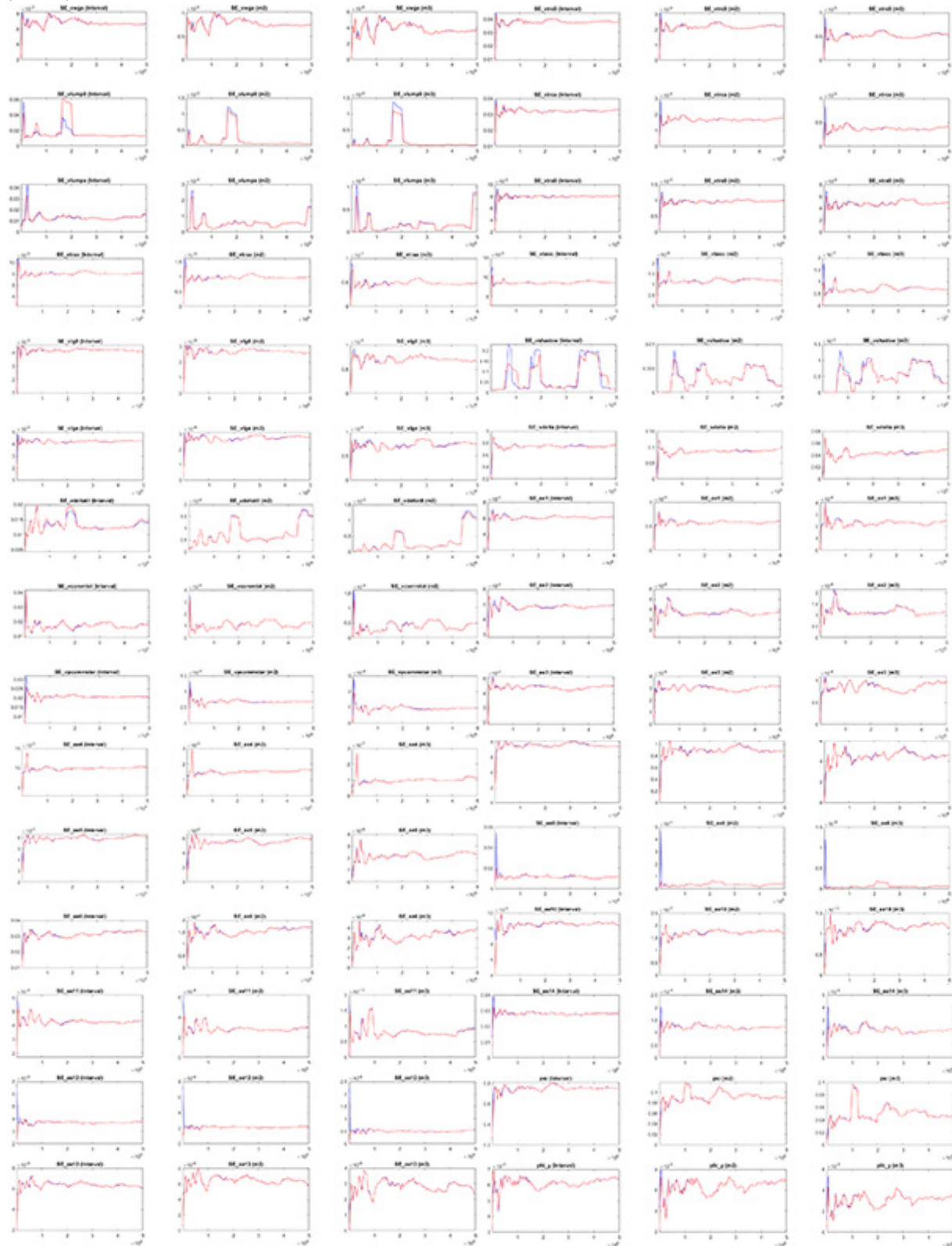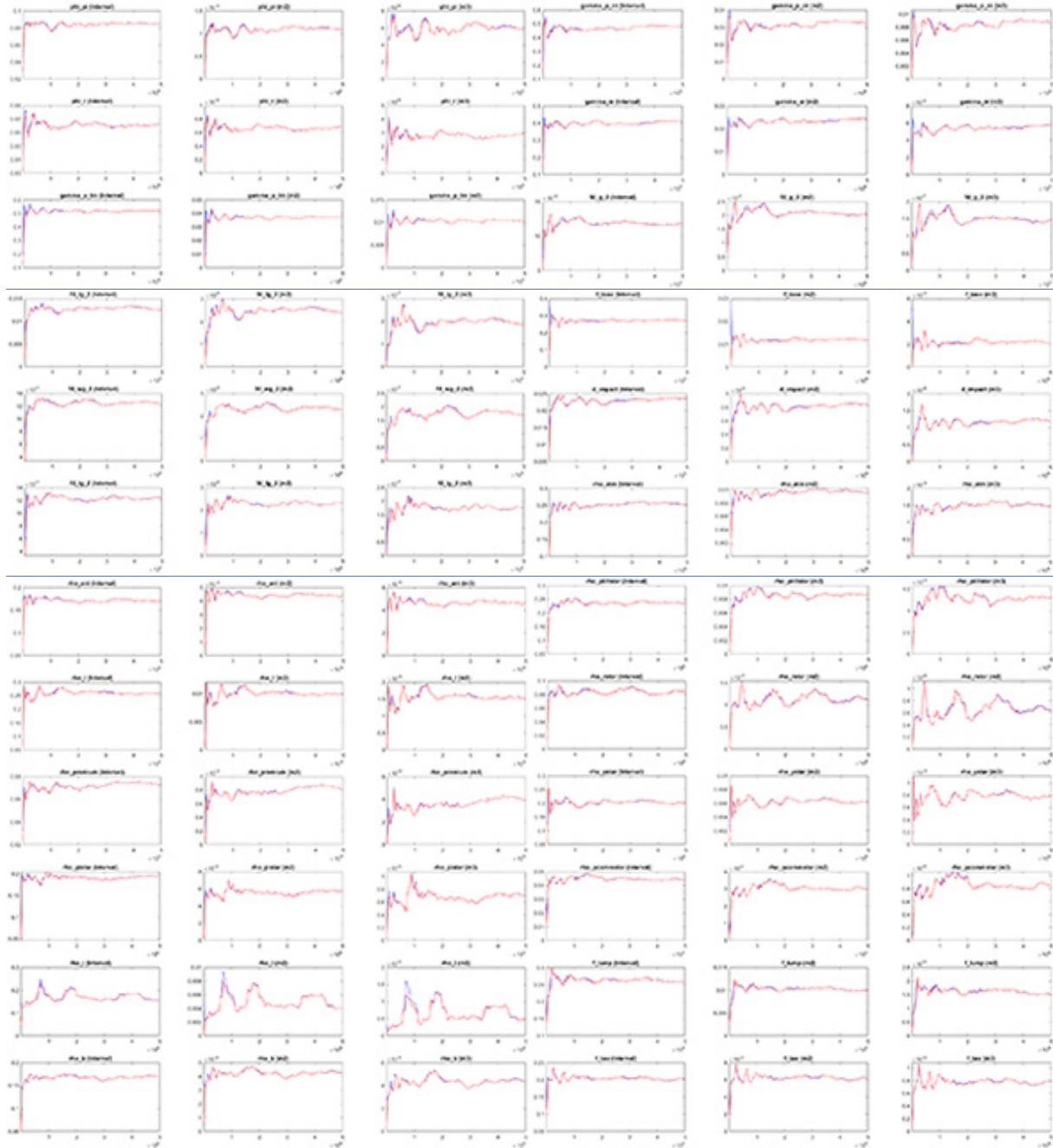
(Continues)

(Continued)

(Continues)

(Continued)
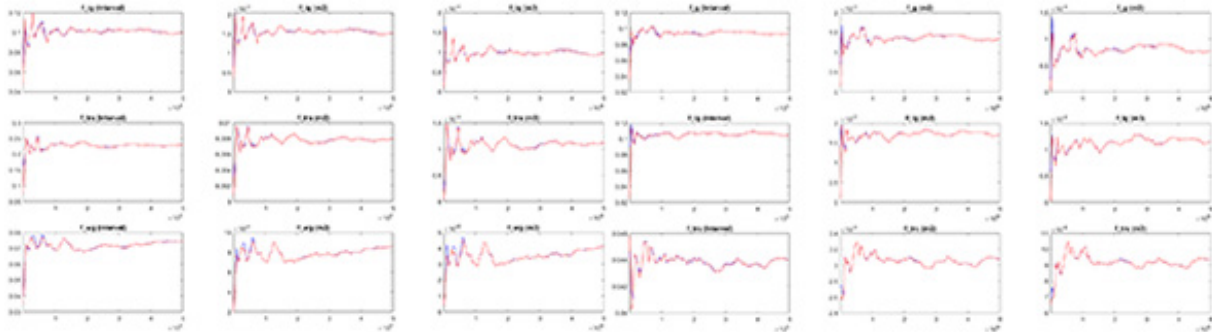
Source: Brooks and Gelman (1998).
Authors' elaboration.
Publisher's note: Figure displayed in low resolution and whose layout and texts could not be formatted and proofread due to the technical characteristics of the original files.

TABLE A.3
Results of estimating the standard deviation of fiscal shocks

Parameter	Description	Prior distribution			Posterior distribution		
		Distribution	Mean	Variance	Median	Cred. interval (90%)	
σ^g	Standard deviation of the unanticipated shock to government consumption	Invgamma	0.2000	inf	0.0107	0.0066	0.0146
σ^{g1}	Standard deviation of the anticipated shock to government consumption	Invgamma	0.2000	inf	0.0103	0.0061	0.0141
σ^{ig}	Standard deviation of the unanticipated shock to public investment	Invgamma	0.1000	inf	0.0994	0.0781	0.1219
σ^{ig1}	Standard deviation of the anticipated shock to public investment	Invgamma	0.1000	inf	0.0517	0.0265	0.0749
σ^{lg}	Standard deviation of the unanticipated shock to public sector employment	Invgamma	0.0500	inf	0.0119	0.0092	0.0145
σ^{lg1}	Standard deviation of the anticipated shock to public sector employment	Invgamma	0.0500	inf	0.0120	0.0093	0.0146
σ^{wg}	Standard deviation of the unanticipated public sector wage shock	Invgamma	0.0100	inf	0.0078	0.0025	0.0145
σ^{wg1}	Standard deviation of the anticipated public sector wage shock	Invgamma	0.0500	inf	0.0225	0.0178	0.0275
$\sigma^{\tau c}$	Standard deviation of the unanticipated shock of consumption taxation	Invgamma	0.0060	inf	0.0196	0.0143	0.0251
$\sigma^{\tau w}$	Standard deviation of the unanticipated shock of taxation of the salary of the ricardian agent	Invgamma	0.0500	inf	0.0601	0.0511	0.0691
$\sigma^{tr a}$	Standard deviation of the unanticipated shock of transfers to non-ricardians	Invgamma	0.0500	inf	0.0172	0.0122	0.0221
$\sigma^{tr a 1}$	Standard deviation of the anticipated shock of transfers to non-ricardians	Invgamma	0.0500	inf	0.0171	0.0119	0.0223
$\sigma^{tr c}$	Standard deviation of the anticipated shock of transfers to working non-ricardians	Invgamma	0.0500	inf	0.0047	0.0017	0.0080
$\sigma^{tr c 1}$	Standard deviation of the anticipated shock of transfers to working non-ricardians	Invgamma	0.0500	inf	0.0036	0.0012	0.0062
σ^{τ}	Standard deviation of the unanticipated lump-sum taxation shock	Invgamma	0.0100	inf	0.0092	0.0023	0.0172
$\sigma^{\tau 1}$	Standard deviation of the anticipated lump-sum taxation shock	Invgamma	0.0100	inf	0.0085	0.0024	0.0157

Source: Results obtained with Dynare package.
Authors' elaboration.

TABLE A.4
Results of estimating the standard deviation of measurement errors

Parameter	Description	Prior distribution			Posterior distribution		
		Distribution	Mean	Variance	Median	Cred. Interval (90%)	
$\sigma^{pi\_t\_til}$	Standard deviation of the inflation measurement error of the tredables sector	Invgamma	0.010	inf	0.0290	0.0251	0.0329
$\sigma^{pi\_nt\_til}$	Standard deviation of the inflation measurement error in the non tredables sector	Invgamma	0.010	inf	0.0222	0.0191	0.0253
σ^{wtil}	Standard deviation of the wage index measurement error	Invgamma	0.010	inf	0.0274	0.0234	0.0313
σ^{wctil}	Standard deviation of the measurement error of the salary of non-ricardian individuals who work	Invgamma	0.010	inf	0.0268	0.0202	0.0329
σ^{wltil}	Standard deviation of the error of measurement of the salary of ricardian individuals	Invgamma	0.010	inf	0.0204	0.0175	0.0231
σ^{rer}	Standard deviation of the real exchange rate measurement error	Invgamma	0.010	inf	0.0814	0.0604	0.1022
σ^{cl}	Standard deviation of consumption measurement error of ricardian individuals	Invgamma	0.010	inf	0.0347	0.0297	0.0393
σ^{b_star}	Standard deviation of the measurement error of the stock of external securities in the portfolio of ricardian individuals	Invgamma	0.010	inf	0.0081	0.0024	0.0146
σ^{y_star}	Rest of the world production measurement error standard deviation	Invgamma	0.010	inf	0.0050	0.0043	0.0057
σ^{pi_star}	Standard deviation of the rest of the world's inflation measurement error	Invgamma	0.010	inf	0.0015	0.0012	0.0018
σ^{l}	Standard deviation of the error in measuring the level of employment in the economy	Invgamma	0.010	inf	0.0125	0.0101	0.0149
σ^{tr^a}	Standard deviation of the measurement error of consumption of non-ricardian individuals	Invgamma	0.010	inf	0.0112	0.0074	0.0152
σ^{taow}	Standard deviation of the wage tax rate measurement error	Invgamma	0,0050	inf	0.1295	0.1113	0.1470

Source: Results obtained with Dynare package.
Authors' elaboration.

TABLE A.5
Results of estimating the standard deviation of "structural" shocks and shocks on external variables

Parameter	Description	Prior distribution			Posterior distribution		
		Distribution	Mean	Variance	Median	Cred. Interval (90%)	
σ^{ε_B}	Standard deviation of preference shock	Invgamma	0.0500	inf	0.0473	0.0397	0.0547
σ^{ε_L}	Shock standard deviation in leisure preference	Invgamma	0.0050	inf	0.0046	0.0011	0.0089
$\sigma^{\varepsilon_\theta}$	Standard deviation of the risk premium shock	Invgamma	0.0050	inf	0.0037	0.0031	0.0042
σ^{ε_I}	Standard deviation of investment shock	Invgamma	0.0500	inf	0.0440	0.0374	0.0520
$\sigma^{\varepsilon_{aT}}$	Standard deviation of the tradables sector productivity shock	Invgamma	0.0050	inf	0.0038	0.0012	0.0067
$\sigma^{\varepsilon_{aNT}}$	Standard deviation of the non-tradables sector productivity shock	Invgamma	0.0070	inf	0.0107	0.0061	0.0156
σ^{ε_m}	Standard deviation of the monetary shock	Invgamma	0.0050	inf	0.0029	0.0024	0.0033
σ^{Ξ}	Standard deviation of the shadow price of capital	Invgamma	0.0100	inf	0.0171	0.0021	0.0229
$\sigma^{\widehat{\delta}}$	Standard deviation of the shock on the rate of depreciation of private capital	Invgamma	0.0100	inf	3.5073	3.0315	3.9966
$\sigma^{\widehat{\widehat{\delta}}}$	Standard deviation of the shock in the rate of depreciation of public capital	Invgamma	0.0100	inf	0.0095	0.0023	0.0173
$\sigma^{y_C^{tot}}$	Standard deviation of the shock in commodity production	Invgamma	0.0100	inf	0.0108	0.0022	0.0209
$\sigma^{P_C^*}$	Standard deviation of the shock in the international commodity price index	Invgamma	0.0100	inf	0.0976	0.0839	0.1108
$\sigma^{\varepsilon_{R*}}$	Standard deviation of the external interest rate shock	Invgamma	0.0050	inf	0.0072	0.0054	0.0090
$\sigma^{\varepsilon_{P*}}$	Standard deviation of the shock on G20 CPI	Invgamma	0.0100	inf	0.0092	0.0023	0.0175
$\sigma^{\varepsilon_{\pi*}}$	Standard deviation of the inflation shock in the rest of the world	Invgamma	0.0050	inf	0.0013	0.0010	0.0015
$\sigma^{\varepsilon_{\tau c*}}$	Standard deviation of the shock on the tax rate levied abroad on exports	Invgamma	0.0500	inf	0.4000	0.1992	0.6633
$\sigma^{\varepsilon_{Y*}}$	Standard deviation of the shock of the level of international economic activity	Invgamma	0.0100	inf	0.2675	0.2268	0.3062

Source: Results obtained with Dynare package.
Authors' elaboration.

DISCUSSION PAPER

TABLE A.6
Results of estimating the parameters of the fiscal reaction function

Parameter	Description	Prior distribution			Posterior distribution		
		Distribution	Mean	Variance	Median	Cred. Interval (90%)	
ρ^g	Persistence of government consumption	Beta	0.5000	0.1000	0.8293	0.7675	0.8914
ρ^{ig}	Persistence of public investment	Beta	0.5000	0.1000	0.7941	0.7309	0.8621
ρ^{lg}	Persistence of employment in the public sector	Beta	0.5000	0.1000	0.7902	0.7210	0.8602
ρ^{wg}	Persistence of public sector salary	Beta	0.5000	0.2000	0.8629	0.8145	0.9106
ρ^{tr^c}	Persistence of transfers for working non-ricardians	Beta	0.5000	0.1000	0.9462	0.9188	0.9741
ρ^{tr^a}	Persistence of transfers to non-ricardians	Beta	0.5000	0.1500	0.4479	0.3051	0.5897
$\rho^{\tau c}$	Persistence of the consumption tax rate	Beta	0.5000	2.0000	0.4047	0.2289	0.5815
$\rho^{\tau w}$	Persistence of the tax rate levied on the wages of ricardians	Beta	0.5000	0.1000	0.4819	0.3514	0.6129
ρ^{τ}	lump sum tax persistence	Beta	0.5000	0.1000	0.5010	0.3278	0.6632
d^g	Sensitivity of government consumption to changes in the debt/GDP ratio	Norm	0.2000	0.0500	0.0125	0.0052	0.0196
d^{ig}	Sensitivity of public investment to changes in the debt/GDP ratio	Norm	0.2000	0.0500	0.0197	0.0117	0.0278
d^{lg}	Sensitivity of public sector employment to changes in the debt/GDP ratio	Norm	0.2000	0.0500	0.0212	0.0132	0.0293
d^{wg}	Sensitivity of public sector wages to changes in the debt/GDP ratio	Norm	0.2000	0.0500	0.0131	0.0049	0.0213

Source: Results obtained with Dynare package.
Authors' elaboration.

TABLE A.7

Results of estimating the parameters of persistence of "structural" shocks

Parameter	Description	Prior distribution			Posterior distribution		
		Distribution	Mean	Variance	Median	Cred. Interval (90%)	
$\rho^{\varepsilon B}$	Parameter that measures the persistence of the ricardian preference shock	Beta	0.5000	0.1000	0.3085	0.1975	0.4122
$\rho^{\varepsilon L}$	Parameter that measures the persistence of the shock in leisure preference	Beta	0.5000	0.1000	0.4888	0.3311	0.6516
$\rho^{\varepsilon \theta}$	Parameter that measures the persistence of the risk premium shock	Beta	0.5000	0.1000	0.8844	0.8406	0.9294
$\rho^{\varepsilon I}$	Parameter that measures the persistence of the shock in the adjustment cost of the capital stock	Beta	0.5000	0.2000	0.3003	0.1891	0.3958
$\rho^{\varepsilon_a T}$	Parameter that measures the persistence of the productivity shock in the tradables sector	Beta	0.5000	0.1000	0.4625	0.3025	0.6249
$\rho^{\varepsilon_a NT}$	Parameter that measures the persistence of the productivity shock of the non-tradables sector	Beta	0.5000	0.0700	0.5211	0.4114	0.6325
$\rho^{\varepsilon R*}$	Parameter that measures the persistence of the shock in the external interest rate	Beta	0.5000	0.1000	0.8729	0.8190	0.9261
$\rho^{\varepsilon P*}$	Parameter that measures the persistence of the shock in the general price index for products from the "rest of the world"	Beta	0.5000	0.1000	0.4851	0.3326	0.6323
$\rho^{\pi*}$	Parameter that measures the persistence of the inflation shock in G20	Beta	0.5000	0.1000	0.6538	0.5295	0.7792
ρ^{Y*}	Parameter that measures the persistence of the shock in G20 GDP	Beta	0.5000	0.1000	0.5045	0.3777	0.6331
$\rho^{\hat{p}_c^*}$	Parameter that measures the persistence of the shock in the international commodity price index	Beta	0.5000	0.2000	0.9442	0.9176	0.9722

Source: Results obtained with Dynare package.

Authors' elaboration.

DISCUSSION PAPER

TABLE A.8
Estimation results for selected parameters

Parameter	Description	Prior distribution			Posterior distribution		
		Distribution	Mean	Variance	Median	Cred. Interval (90%)	
d^θ	Parameter that measures the sensitivity of the risk premium to changes in the debt/GDP ratio	Norm	0.0500	0.0100	0.0315	0.0162	0.0462
Ψ	Parameter that measures the loss arising from variations in installed capacity	Gamm	5.9200	5.0000	3.2124	2.7323	3.6893
ϕ^m	Parameter that measures the persistence of monetary policy	Beta	0.5000	0.1000	0.8319	0.7912	0.8736
ϕ^Y	Parameter that measures the monetary policy response to deviations in output from the balanced growth path	Gamm	0.5000	0.2000	0.0133	0.0100	0.0172
ϕ^π	Parameter that measures the monetary policy response to inflation deviations from the established target	Gamm	2.0000	0.5000	0.3056	0.2501	0.3568
Y_P^T	Parameter that measures the degree of indexation of prices in the tradable sector	Beta	0.5000	0.2000	0.5332	0.2255	0.8502
Y_P^{NT}	Parameter that measures the degree of price indexation in the non-tradables sector	Beta	0.5000	0.2000	0.5819	0.3063	0.8850
γ_W	Parameter that measures the degree of indexation of the wages of ricardians	Beta	0.5000	0.2000	0.4467	0.1932	0.6940

Source: Results obtained with Dynare package.
Authors' elaboration.

FIGURE A.2
Priors and posteriors

(Continues)

(Continued)

(Continues)

(Continued)

(Continued)

(Continues)

(Continued)
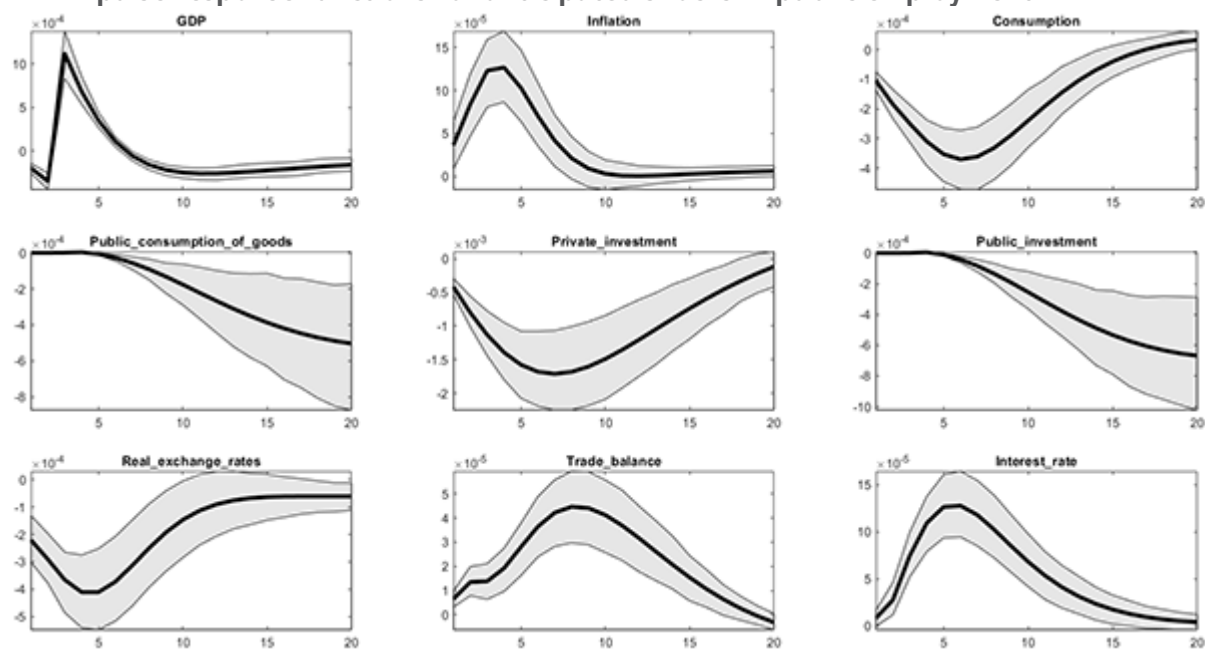

Source: Results obtained with Dynare package.
Authors' elaboration.
Publisher's note: Figure displayed in low resolution and whose layout and texts could not be formatted and proofread due to the technical characteristics of the original files.
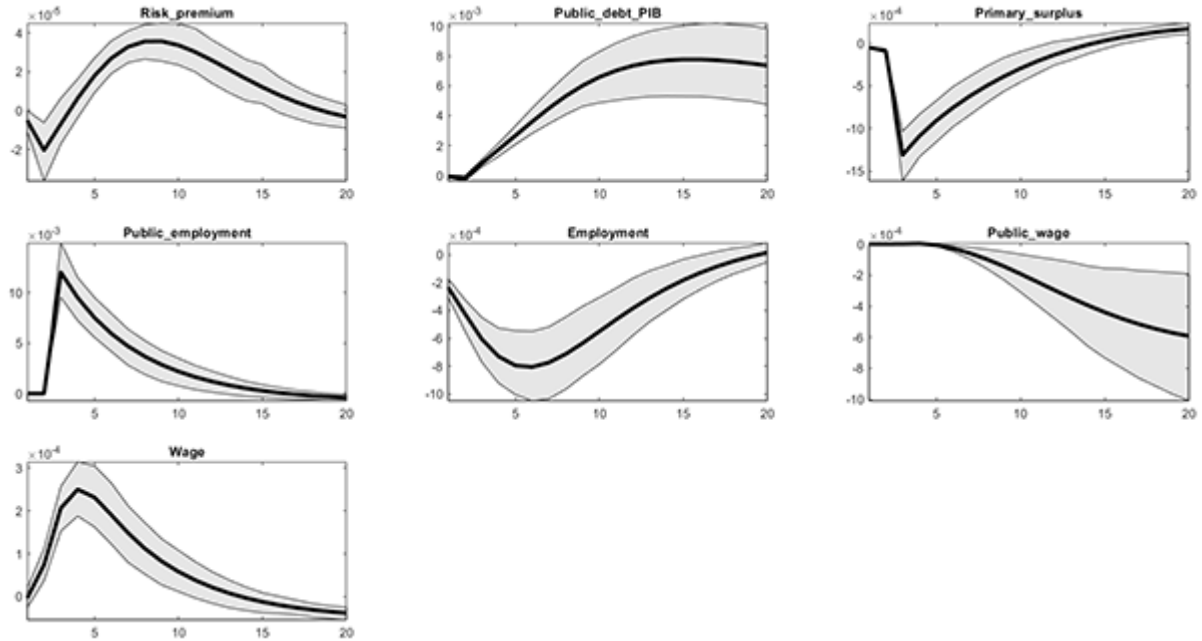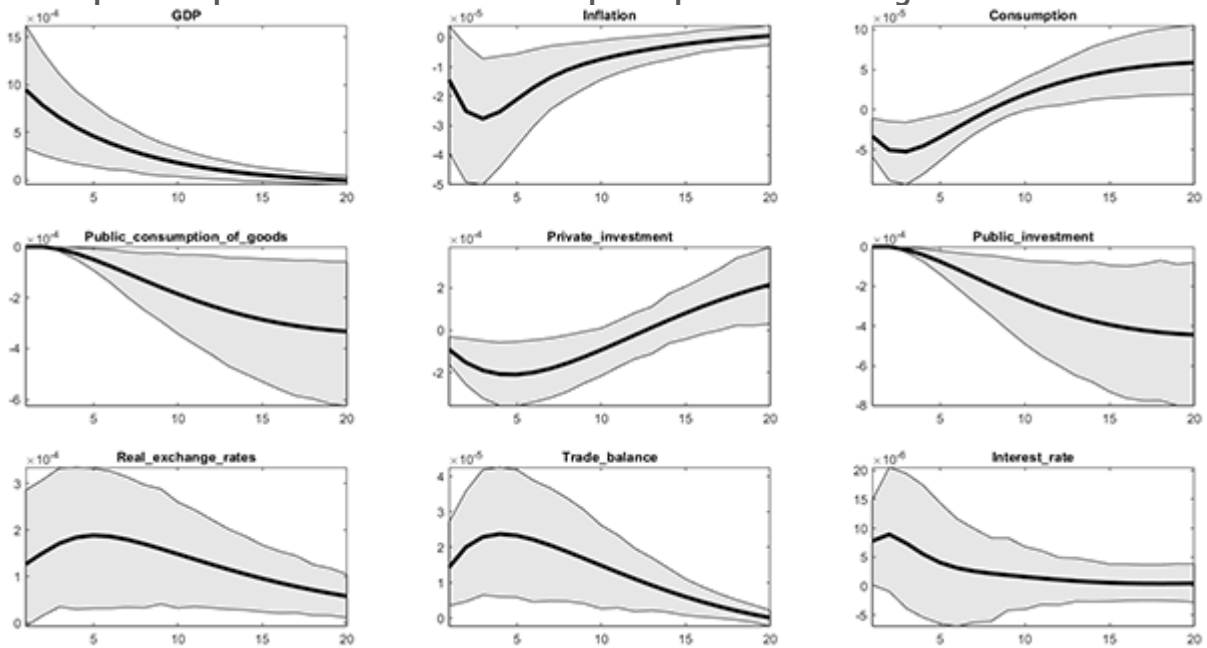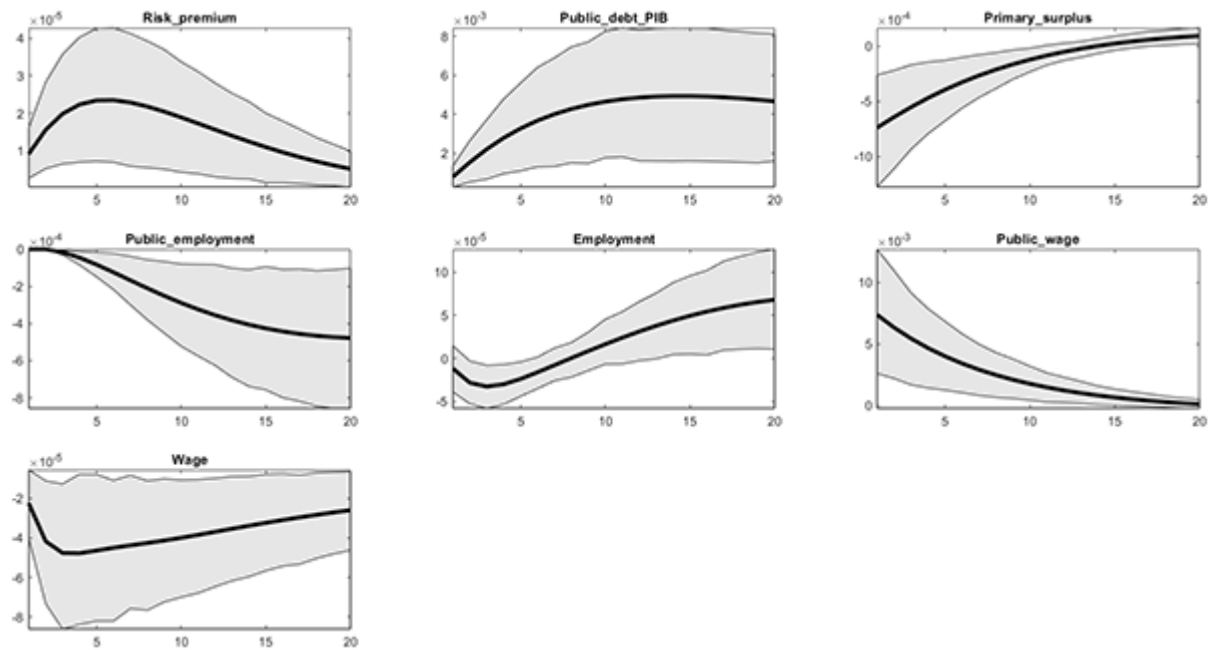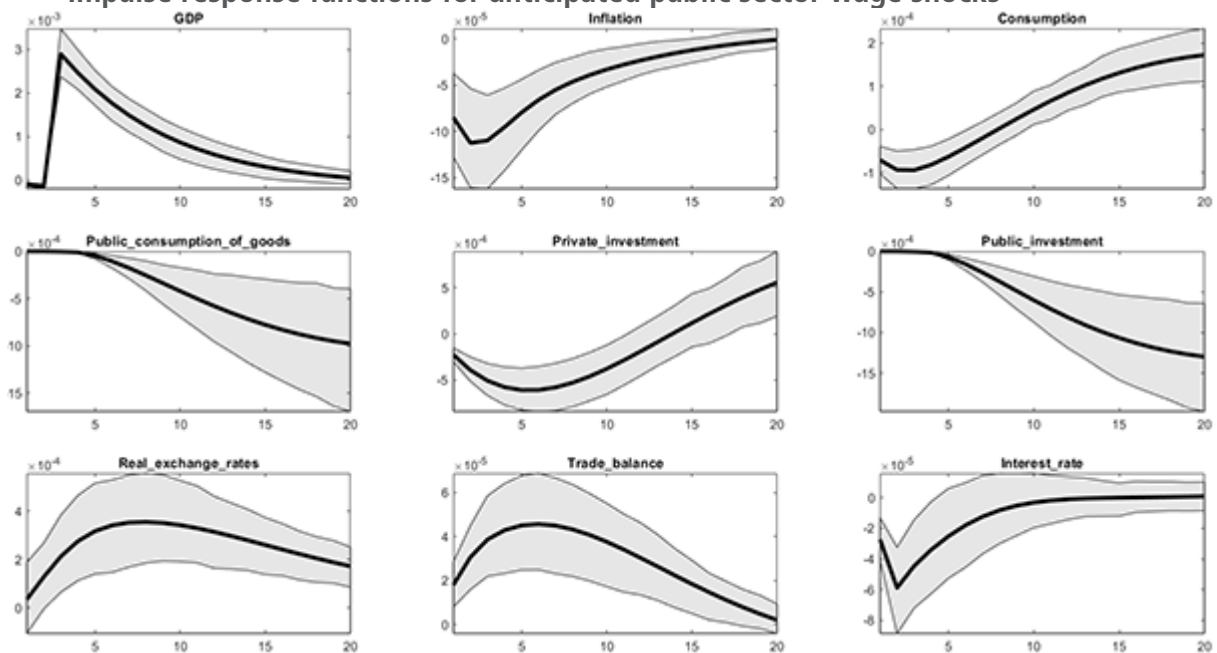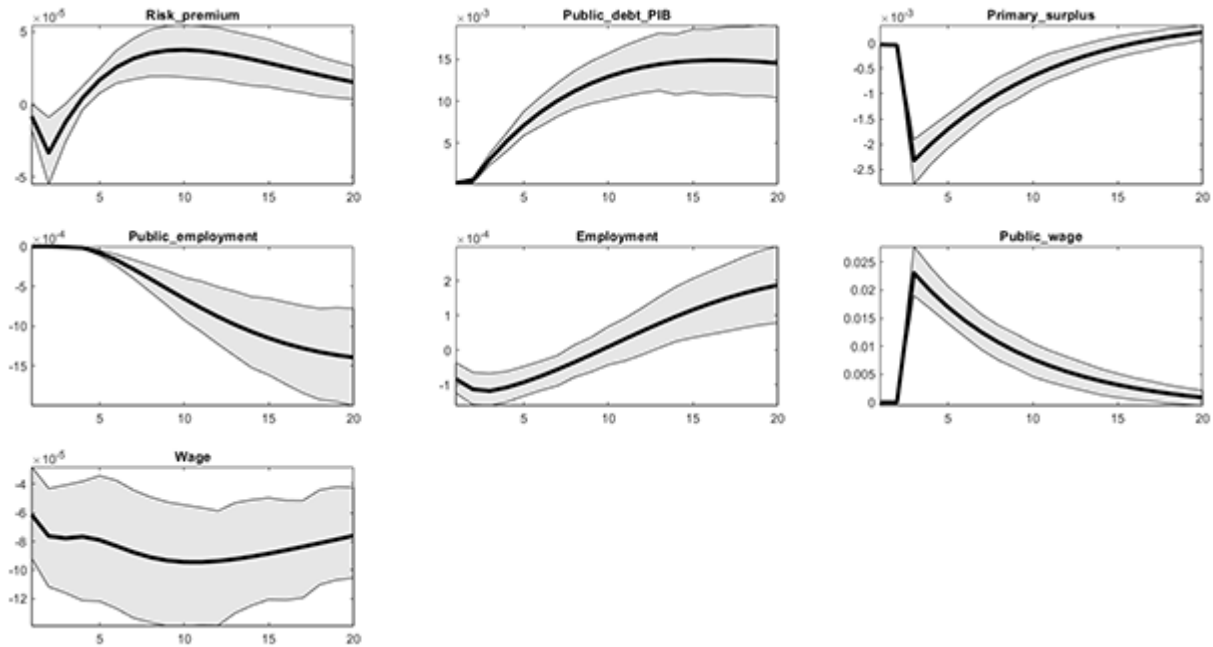
FIGURE A.3
Impulse response functions for unanticipated shocks in government consumption
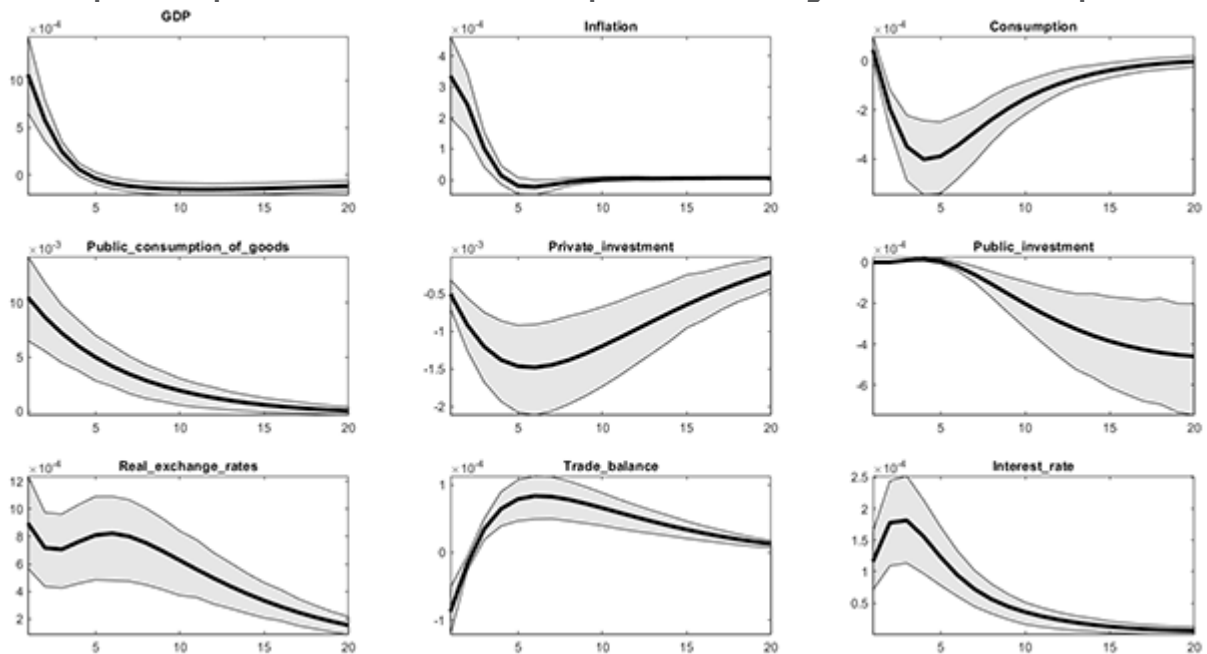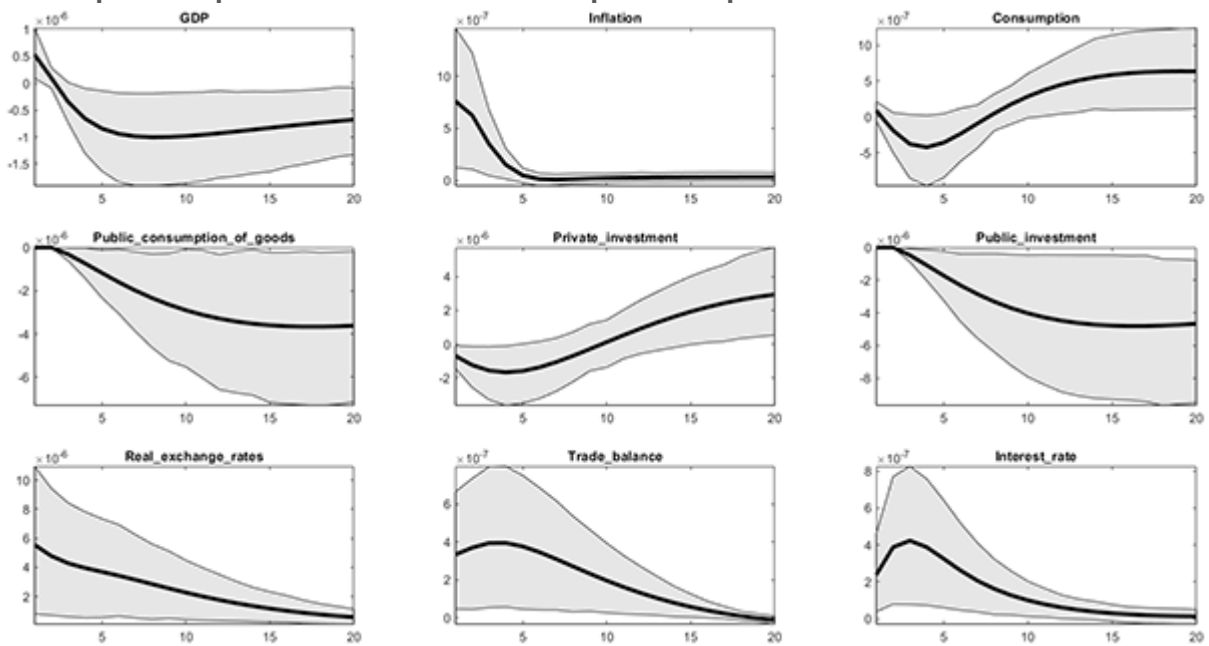
(Continued)

Authors' elaboration.
Publisher's note: Figure displayed in low resolution and whose layout and texts could not be formatted and proofread due to the technical characteristics of the original files.

FIGURE A.4
Impulse response functions for anticipated shocks in government consumption
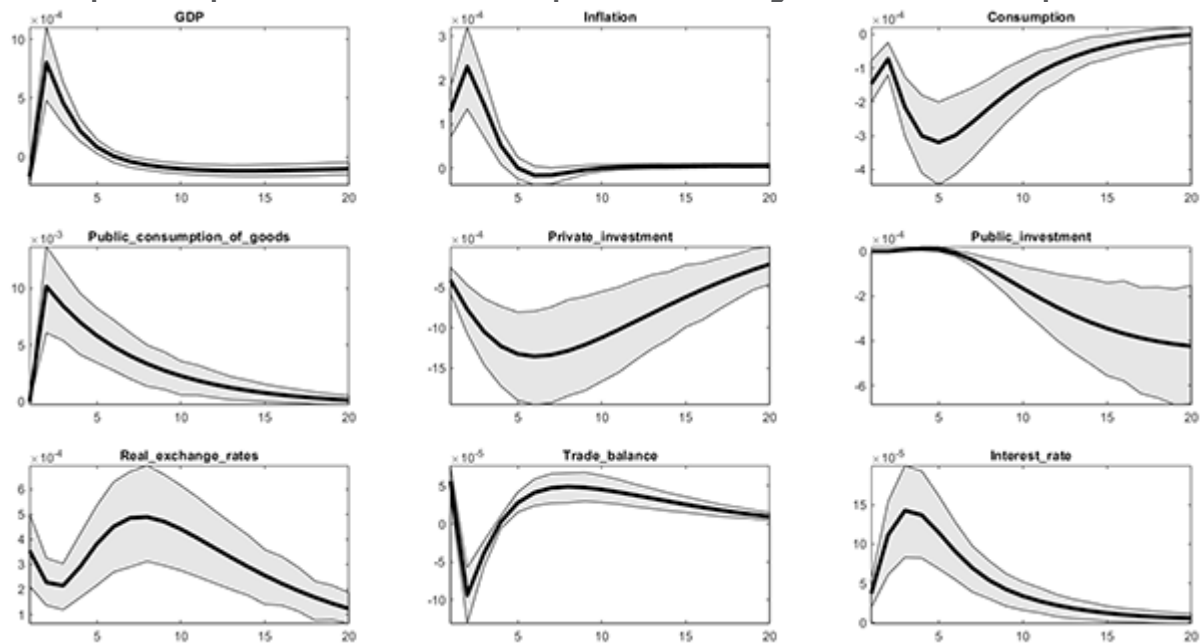
(Continues)

(Continued)
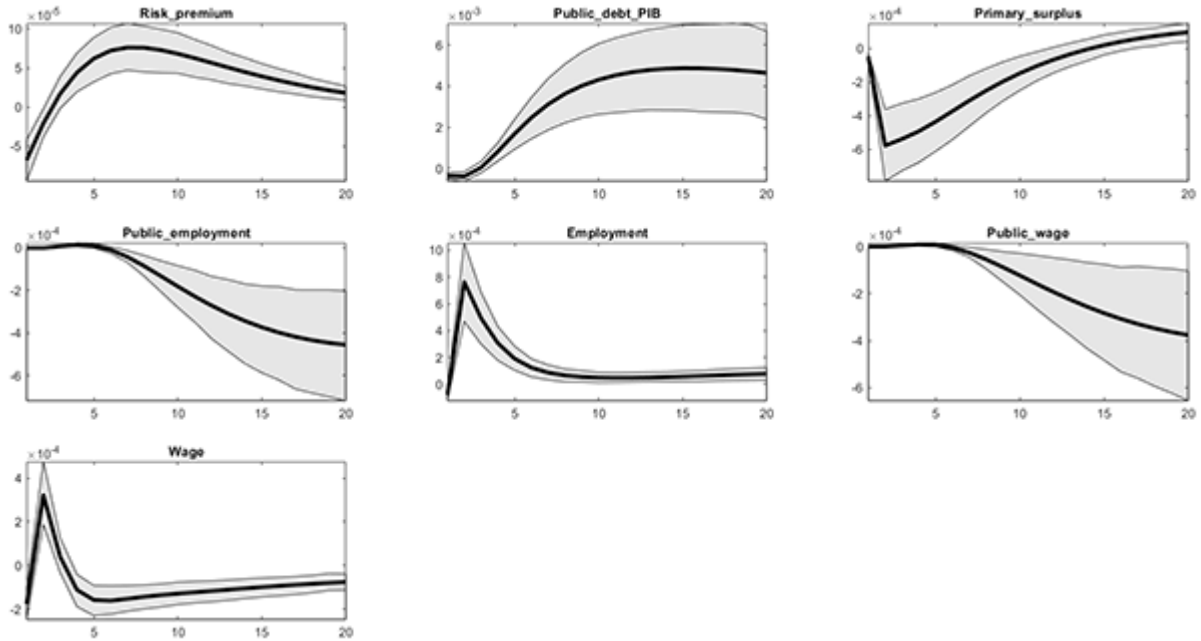
Authors' elaboration.

Publisher's note: Figure displayed in low resolution and whose layout and texts could not be formatted and proofread due to the technical characteristics of the original files.
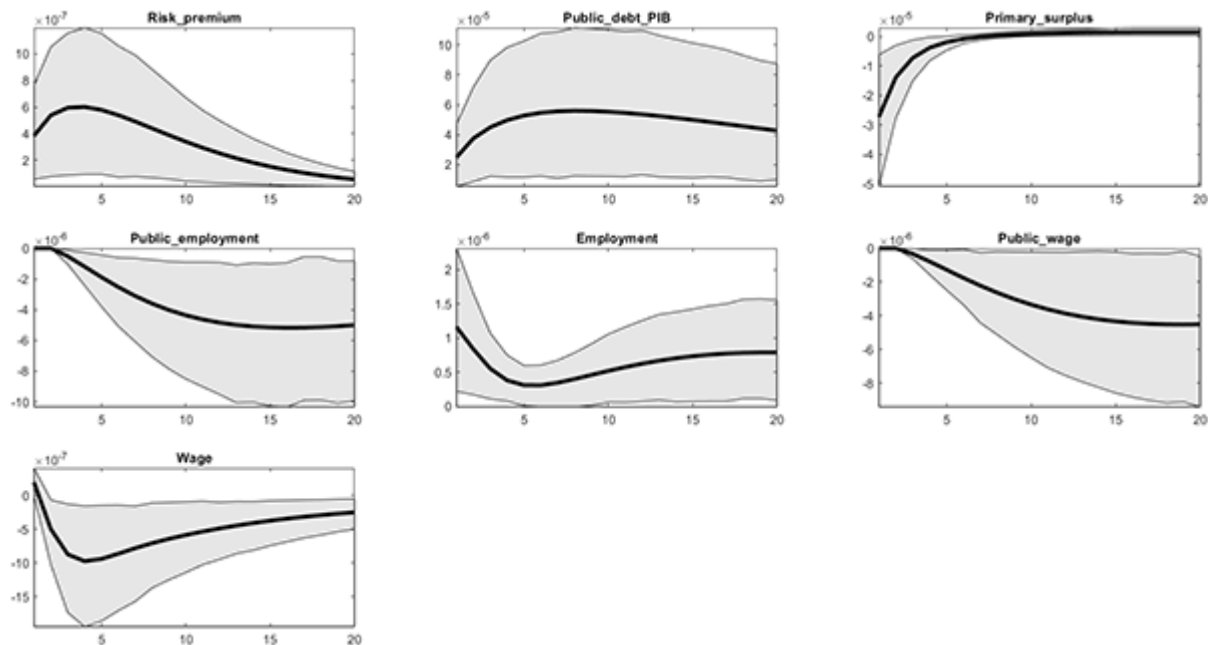
FIGURE A.5

Impulse response functions for unanticipated shocks in public investment
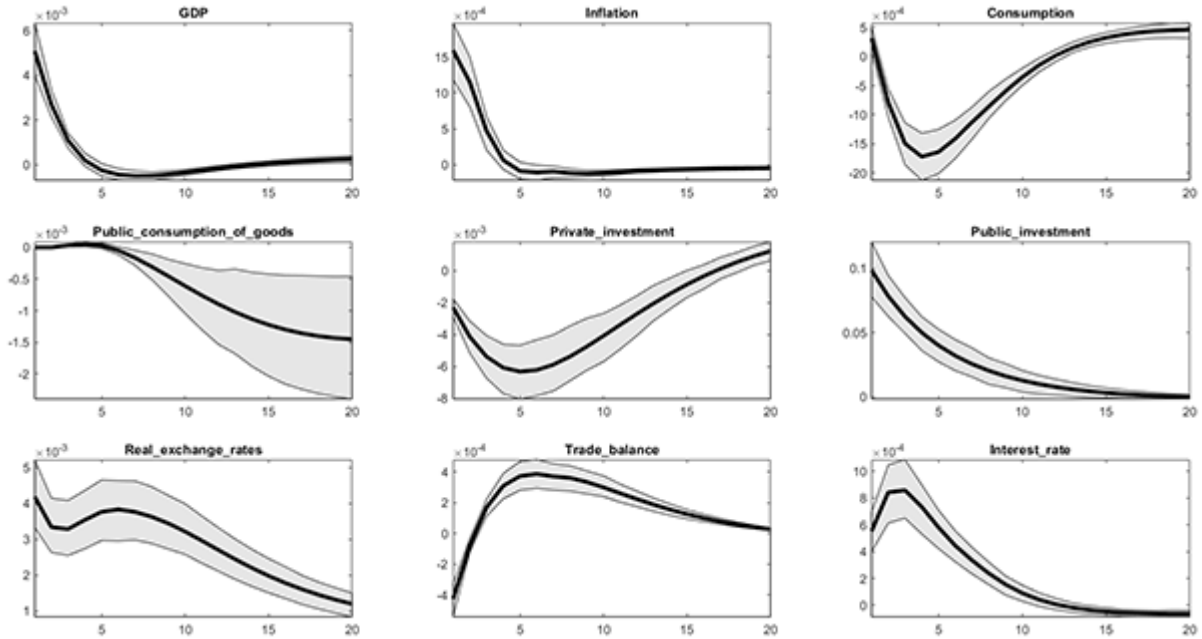
(Continues)
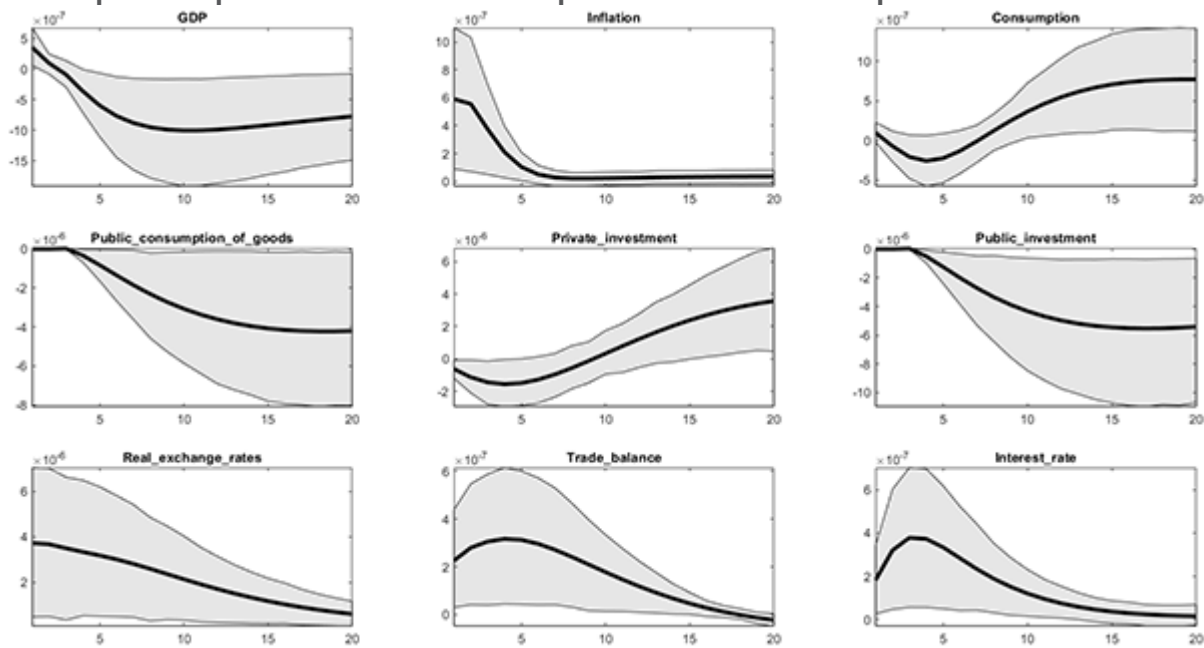
DISCUSSION PAPER

(Continued)
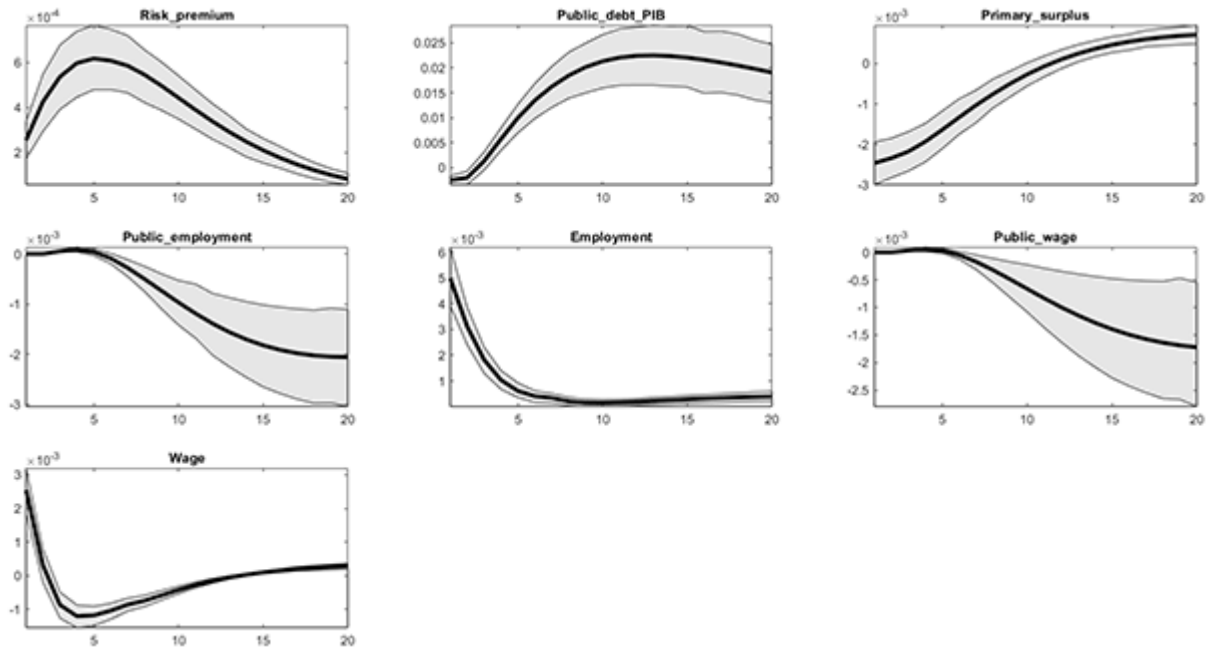
Authors' elaboration.

Publisher's note: Figure displayed in low resolution and whose layout and texts could not be formatted and proofread due to the technical characteristics of the original files.

FIGURE A.6
Impulse response functions for anticipated shocks in public investment
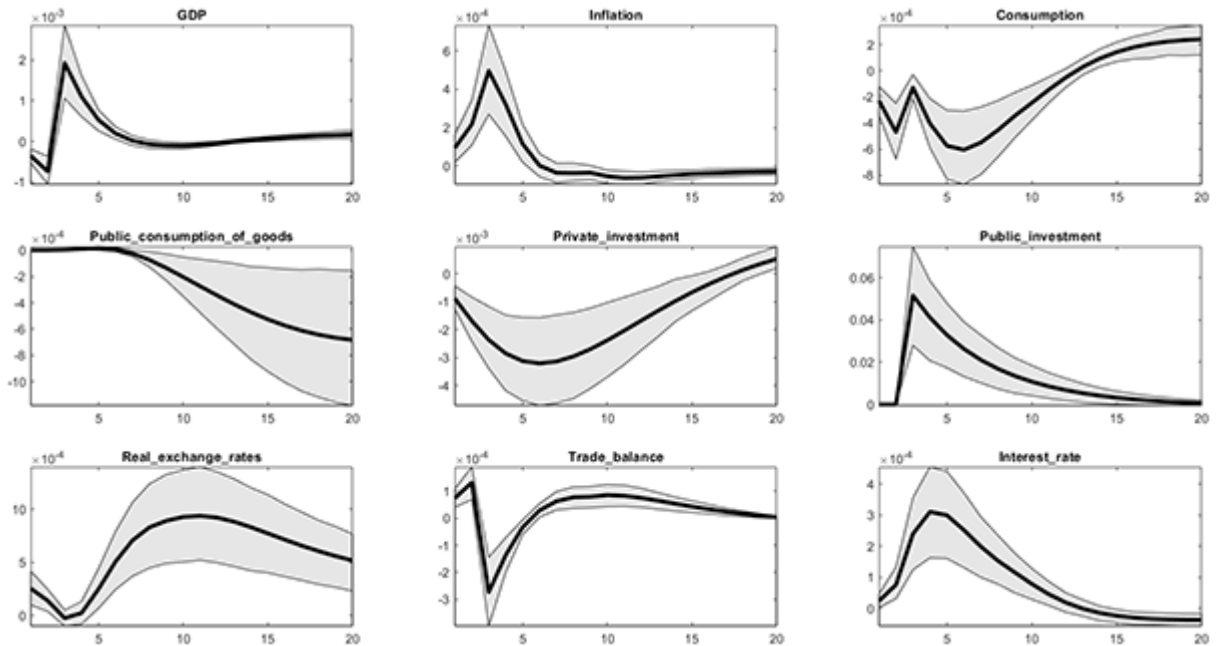
(Continues)

(Continued)
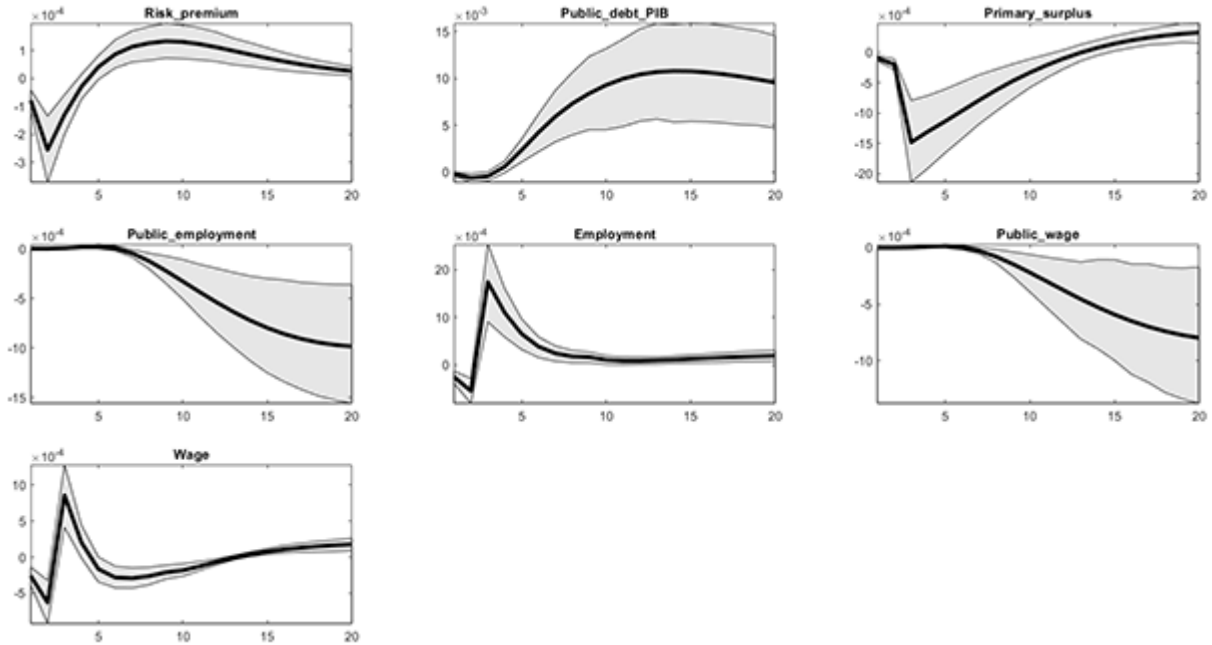
Authors' elaboration.

Publisher's note: Figure displayed in low resolution and whose layout and texts could not be formatted and proofread due to the technical characteristics of the original files.
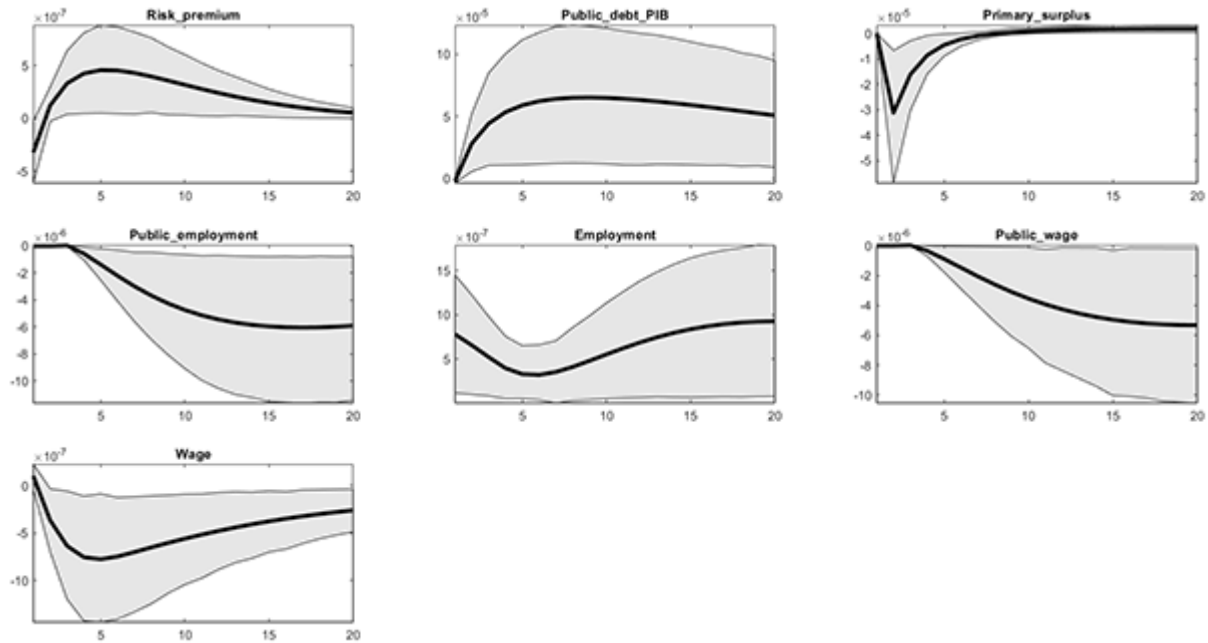
FIGURE A.7

Impulse response functions for unanticipated shocks in public employment
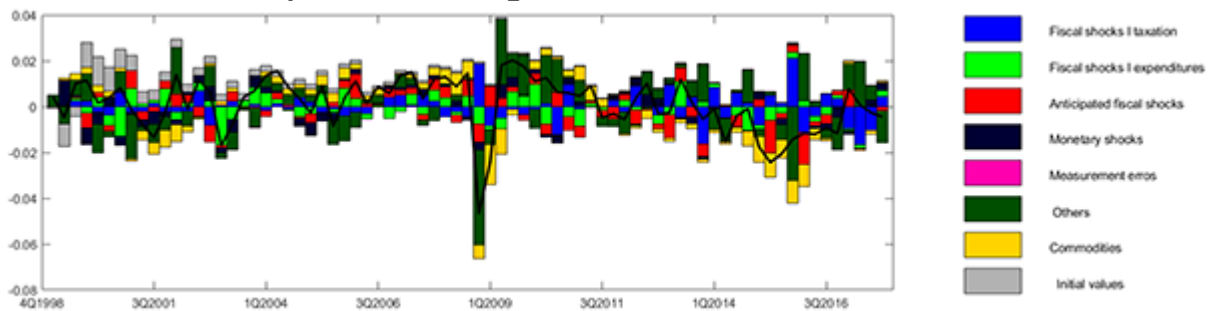

(Continues)

(Continued)

Authors' elaboration.

Publisher's note: Figure displayed in low resolution and whose layout and texts could not be formatted and proofread due to the technical characteristics of the original files.

FIGURE A.8

Impulse response functions for anticipated shocks in public employment

(Continued)

Authors' elaboration.

Publisher's note: Figure displayed in low resolution and whose layout and texts could not be formatted and proofread due to the technical characteristics of the original files.

FIGURE A.9

Impulse response functions for unanticipated public sector wage shocks

(Continues)

(Continued)

Authors' elaboration.

Publisher's note: Figure displayed in low resolution and whose layout and texts could not be formatted and proofread due to the technical characteristics of the original files.

FIGURE A.10

Impulse response functions for anticipated public sector wage shocks

(Continues)

(Continued)

Authors' elaboration.

Publisher's note: Figure displayed in low resolution and whose layout and texts could not be formatted and proofread due to the technical characteristics of the original files.

FIGURE A.11
Impulse response functions for unanticipated lump-sum tax shocks

(Continues)

(Continued)

Authors' elaboration.

Publisher's note: Figure displayed in low resolution and whose layout and texts could not be formatted and proofread due to the technical characteristics of the original files.

FIGURE A.12

Impulse response functions for anticipated shocks in the lump-sum tax

(Continues)

(Continued)

Authors' elaboration.

Publisher's note: Figure displayed in low resolution and whose layout and texts could not be formatted and proofread due to the technical characteristics of the original files.

FIGURE A.13
Historical decomposition of GDP growth[1]

Source: Results obtained with Dynare package.

Authors' elaboration.

Note: [1] In this case, the growth rate is defined as $\ln(GDP_t) - \ln(GDP_{t-1})$, being 0.005 the quarterly growth rate throughout the balanced growth path. Analogous definitions are valid for the figures that show the decompositions for aggregate consumption and private investment.

Publisher's note: Figure displayed in low resolution and whose layout and texts could not be formatted and proofread due to the technical characteristics of the original files.

FIGURE A.14

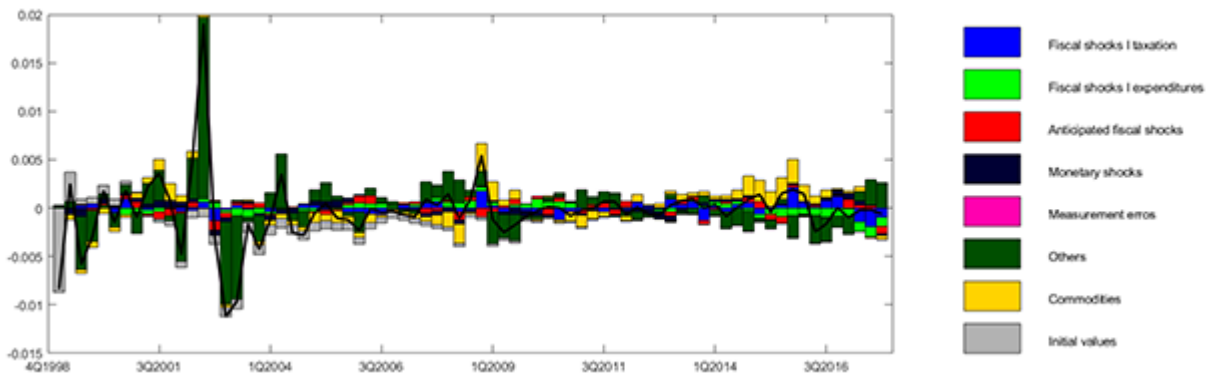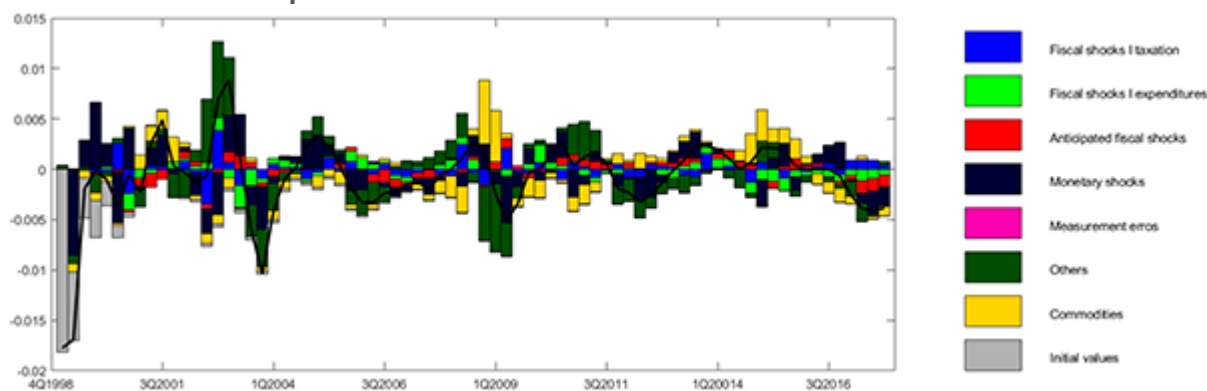**Historical decomposition of the aggregate consumption growth rate**
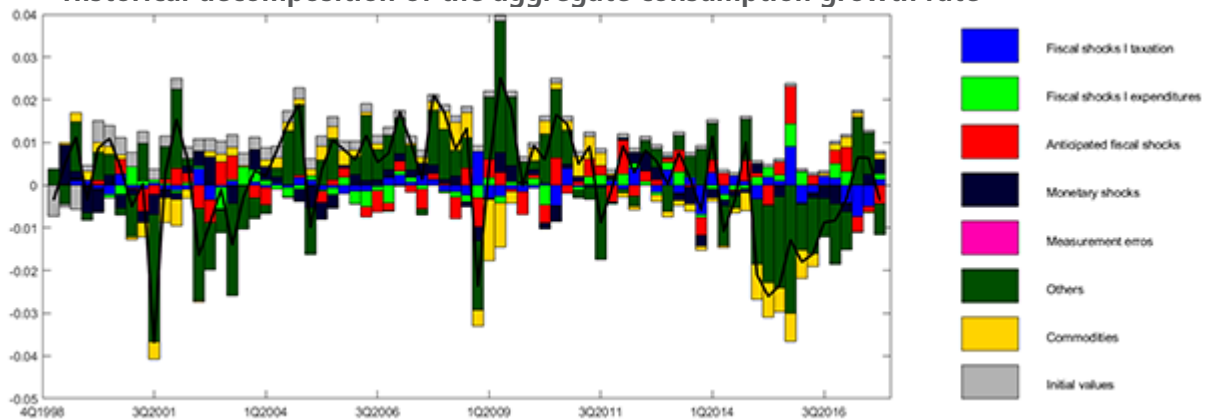
Source: Results obtained with Dynare package.

Authors' elaboration.

Publisher's note: Figure displayed in low resolution and whose layout and texts could not be formatted and proofread due to the technical characteristics of the original files.

FIGURE A.15

Historical decomposition of private investment growth
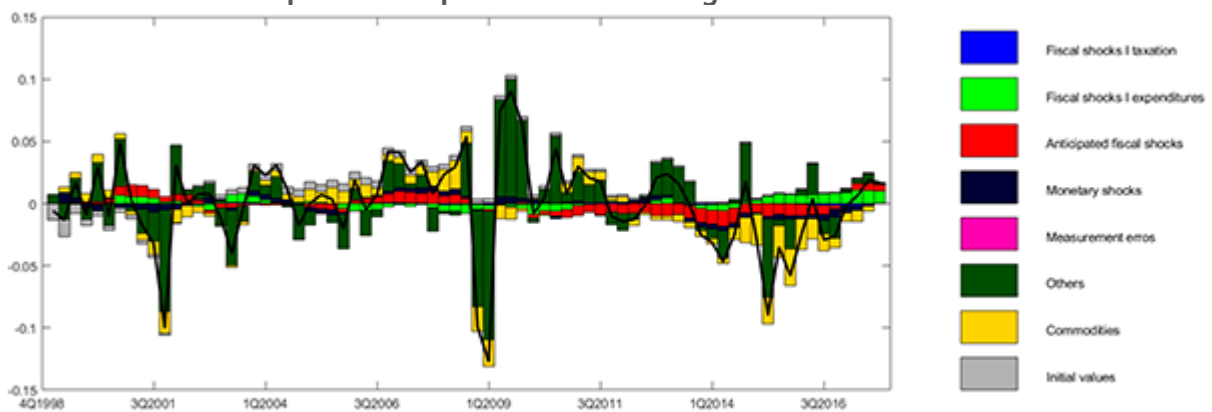
Source: Results obtained with Dynare package.

Authors' elaboration.

Publisher's note: Figure displayed in low resolution and whose layout and texts could not be formatted and proofread due to the technical characteristics of the original files.

FIGURE A.16

Historical decomposition of inflation
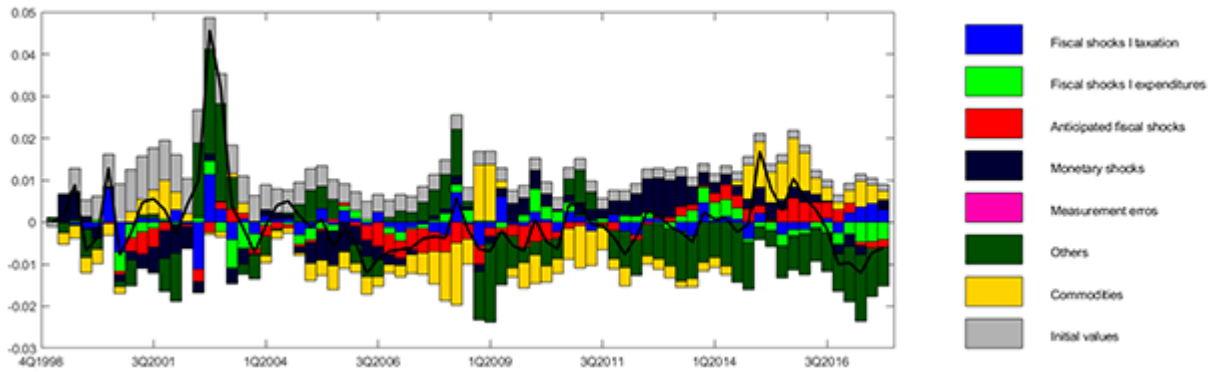
Source: Results obtained with Dynare package.

Authors' elaboration.

Publisher's note: Figure displayed in low resolution and whose layout and texts could not be formatted and proofread due to the technical characteristics of the original files.

FIGURE A.17

Historical decomposition of the risk premium variation rate

Source: Results obtained with Dynare package.

Authors' elaboration.

Publisher's note: Figure displayed in low resolution and whose layout and texts could not be formatted and proofread due to the technical characteristics of the original files.

FIGURE A.18

Historical decomposition of interest rate variation

Source: Results obtained with Dynare package.

Authors' elaboration.

Publisher's note: Figure displayed in low resolution and whose layout and texts could not be formatted and proofread due to the technical characteristics of the original files.

REFERENCES

BROOKS, S.; GELMAN, A. General methods for monitoring convergence of iterative simulations. **Journal of Computational and Graphical Statistics**, v. 7, n. 4, p. 434-455, 1998.

CAVALCANTI, M. A. F. H. et al. Impactos macroeconômicos do choque fiscal de 2015: a regularização de despesas públicas não contabilizadas. **Revista Brasileira de Economia**, v. 73, n. 4, p. 489-527, out.-dez. 2019.

ipea Instituto de Pesquisa
Econômica Aplicada

MINISTÉRIO DO
**PLANEJAMENTO
E ORÇAMENTO**

GOVERNO FEDERAL
BRASIL
UNIÃO E RECONSTRUÇÃO