# On the macroeconomic effects of anticipated and unanticipated fiscal shocks: Evidence from Brazil


## 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, besides shocks to government spending and/or capital and labor taxation, 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.

JEL: E32, E62, H30.

## 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)**, **Coenen et al. (2013)**, **Forni et al. (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 (see, for example, **Schmitt-Grohé and Uribe (2012)**). 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 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, where it will be evaluated and approved, 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

[1] **Fujiwara et al (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.

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 Annual") 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 among macroeconomic variables are derived from the optimal decisions made by the 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.[2,3]

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 $\zeta^c$, and non-working non-ricardians, who form a set of size $\zeta^a$. 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 consume all income received in each period. 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 to yield the aggregate used by intermediate goods producers. The fact that ricardian individuals are the only

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[2] 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.

[3] 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 $\overline{v}$, then its value at period $t$ would be $g^t\overline{v}$. 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 $\hat{v}_t \equiv \frac{v_t}{g^t}$ is always equal to $\overline{v}$. The shocks that disturb the economy make $v_t$ rover around the balanced growth path, while $\hat{v}_t$ oscillates around $\overline{v}$.

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 $t$.[4]

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

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

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 $\theta_t$ 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 $\theta_t$ also depends on the public debt.[5] 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 ($\tau_t^c$), labor income ($\tau_t^w$), capital income ($\tau_t^k$), and imports of intermediate goods ($\tau_t^\times$); government consumption of goods and services ($G_t$) and transfers paid to non-ricardian individuals who work or not ($TR_t^c$ and $TR_t^a$, respectively). Monetary authorities follow a rule in which the gap between $R_t$ 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:

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

where $SP_t$ 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.

[5] 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.

More specifically, fiscal policy instruments may react to the public debt following the rules below, which are already in their linearized versions:[6]

$$ir_t = \rho ir_{t-1} + \alpha_i \hat{d}_{t-x} + \hat{\varepsilon}_t^{ir} \qquad (2) \qquad id_t = \rho id_{t-1} - \phi_i \hat{d}_{t-x} + \hat{\varepsilon}_t^{id} \qquad (3)$$

where $ir_t$ 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 $\rho$ belongs to the interval $(0,1)$. Parameters $\phi_i$ and $\alpha_i$ 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.

Fiscal instruments insensitive to the public debt evolve according to:

$$i_t = \rho i_{t-1} + \hat{\varepsilon}_t^{i} \qquad (4)$$

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 ($\tau_t^w$, $\tau_t^k$ 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:

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

where $(\ldots) = ir, id, i$ and $\hat{\varepsilon}_{t-j}^{(\ldots),j}$ for $j = 0, a$ is assumed to be an i.i.d. normal disturbance with mean zero and standard deviation $\sigma_{(\ldots),j}$. The innovation $\hat{\varepsilon}_t^{(\ldots),0}$ represents the unanticipated

[6]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 $\widehat{v}_t$, which oscillates around $\overline{v}$, and then into the deviation $\hat{v}_t \equiv \frac{\widehat{v}_t - \overline{v}}{\overline{v}}$, 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 $\hat{v}_t \equiv \frac{v_t - \overline{v}}{\overline{v}}$. 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).

component of $\hat{\varepsilon}_t^{(\ldots)}$, being $\hat{\varepsilon}_{t-j}^{(\ldots),j}$ the notation used to represent a $j$-period anticipated change in $\hat{\varepsilon}_t^{(\ldots)}$. For example, $\hat{\varepsilon}_{t-2}^{(\ldots),2}$ 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, $\hat{\varepsilon}_{t-2}^{(\ldots),2}$ 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 $\hat{\varepsilon}_{t-2}^{(\ldots),2}$ 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 $\sigma_{(\ldots),0}$ and $\sigma_{(\ldots),j}$ (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:

a) Skepticism as to the informative content of the available time series with respect to the balanced growth path of the Brazilian economy;
b) Availability of a sufficiently tested calibration for steady state parameters and ratios validated in the literature;[7]
c) 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 applied to 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)**.

[7] See **Cavalcanti, et al. (2019)** and **Cavalcanti e Vereda (2015)**.

**Table 1**. Series and used transformations (1)

| Observable Variables | Source | Measurement equation |
|---|---|---|
| GDP - (seasonally adjusted - s.a.) | IBGE | $dpibobs = \widehat{pib}_t - \widehat{pib}_{t-1} + \eta$ |
| 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 | $dpiobs = \hat{\pi}_t + \bar{\pi}$ |
| Real wage index (s.a.) | Calculated by the authors (4) | $dwtil = \hat{\tilde{w}}_t - \hat{\tilde{w}}_{t-1} + \eta + e_t^{wtil}$ |
| Tredables sector inflation (s.a. - % per quarter) | Calculated by the authors (4) | $dpi\_t\_tilobs = \hat{\pi}_{T,t} + \bar{\pi}_T + e_t^{pi\_t\_til}$ |
| Inflation in the non-tredables sector (s.a. - % per quarter) | Calculated by the authors (4) | $dpi\_nt\_tilobs = \hat{\pi}_{NT,t} + \bar{\pi}_{NT} \quad e_t^{pi\_nt\_til}$ |
| Ricardian individuals wage (s.a.) | Calculated by the authors (4) | $dwltilobs = \hat{\tilde{w}}^l{}_t - \hat{\tilde{w}}^l{}_{t-1} + \eta + e_t^{wltil}$ |
| Non-Ricardian individuals wage (s.a.) | Calculated by the authors (4) | $dwctilobs = \hat{\tilde{w}}^c{}_t - \hat{\tilde{w}}^c{}_{t-1} + \eta + e_t^{wctil}$ |
| 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 | $dpi_{starobs} = \hat{\pi}^*{}_t - \hat{\pi}^*{}_{t-1} + \bar{\pi}^* + e_t^{pi\_star}$ |
| 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 | $dr\_starobs = \hat{R}^*{}_t - \hat{R}^*{}_{t-1} + \bar{R}^* + e_t^{r\_star}$ |
| 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 | $dspobs = \hat{sp}^H{}_t - \hat{sp}^H{}_{t-1} + \overline{sp}$ |
| Transfers (s.a.) | Calculated by the authors (4) | $dwmt\_obs = \hat{c}^{H,a}{}_t - \hat{c}^{H,a}{}_{t-1} + \overline{c^{H,a}}$ |
| Public sector salary (s.a) | Calculated by the authors (4) | $dwgtilobs = \hat{\tilde{w}}^g{}_t - \hat{\tilde{w}}^g{}_{t-1} + \eta$ |
| Wage tax rate | Calculated by the authors (4) | $dtaowobs = \hat{\tau}^w{}_t - \hat{\tau}^w{}_{t-1} + \overline{\tau^w} + e_t^{taow}$ |
| Public employment (hours worked) | Calculated by the authors (4) | $dlgobs = \hat{l}^g{}_t - \hat{l}^g{}_{t-1} + \overline{l^g}$ |
| Commodity price index | International Monetary Fund | $dcommstarobs = \hat{p}^*{}_{C,t} - \hat{p}^*{}_{C,t-1}$ |

(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 macroeconomics directorate of the Institute of Applied Economic Research

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 in-sample deterministic 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: (i) obtaining sensible results for the posterior distributions of the impulse response functions and for the historical decomposition of selected variables; (ii) obtaining an acceptance rate for the Metropolis-Hastings algorithm between 0.2 and 0.4; and (iii) 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. We initially tested for the best-fitting "aggregate" degree of anticipation; i.e., we assumed that the degree of anticipation was identical for all fiscal instruments. 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:

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

where $\mathbf{D}$ is the data assumed to have arisen under hypothesis $H_{(\ldots)}$ ($(\ldots) = 1, 2$) and according to a probability density $\Pr\left(\mathbf{D} \middle| H_{(\ldots)}\right)$. 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 $\Pr\left(\mathbf{D} \middle| H_{(\ldots)}\right)$ 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** below.

**Table 2**. Guidance for the interpretation of $B_{12}$'s (Bayes Factor), which is the evidence in favor of model $m_1$ versus model $m_2$.

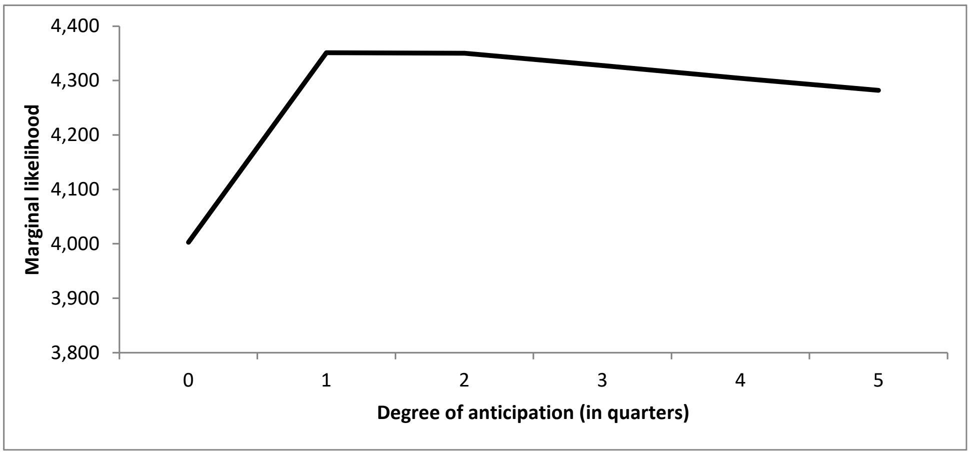
| $2\ln(B_{12})$ | $B_{12}$ | Evidence against $m_2$ |
|---|---|---|
| < 0 | < 1 | $m_2$ presents larger evidence than $m_1$ |
| 0 to 2 | 1 to 3 | weak evidence against $m_2$ |
| 2 to 6 | 3 to 20 | positive evidence against $m_2$ |
| 6 to 10 | 20 to 150 | strong evidence against $m_2$ |
| > 10 | > 150 | very strong evidence against $m_2$ |

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

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 "aggregate" 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 $j = 0,1,\ldots,5$.[8] According to the references 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 "Agrregate" Degrees of Anticipation (assuming the same degree of anticipation for all fiscal instruments).




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

[8] If $j = 0$, then only the component $\hat{\varepsilon}_t^{(\ldots),0}$ is present in (5).

**Table 3**. Model selection test results for the aggregate degree of anticipation

| 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 $m(2)$ 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 $m(5)$ |

Source: Authors' elaboration based on estimation results. The subindex $j$ can assume the values 0, 2, 3, 4 and 5. We choose $j = 1$ as the reference for comparisons. 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 one quarter in advance, all other shocks are anticipated two quarters in advance. 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 degrees of anticipation 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 |

Source: Authors' elaboration based on estimation results.

**Table 5**. Selection test results: "mixed" specification versus "aggregate" specification.

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

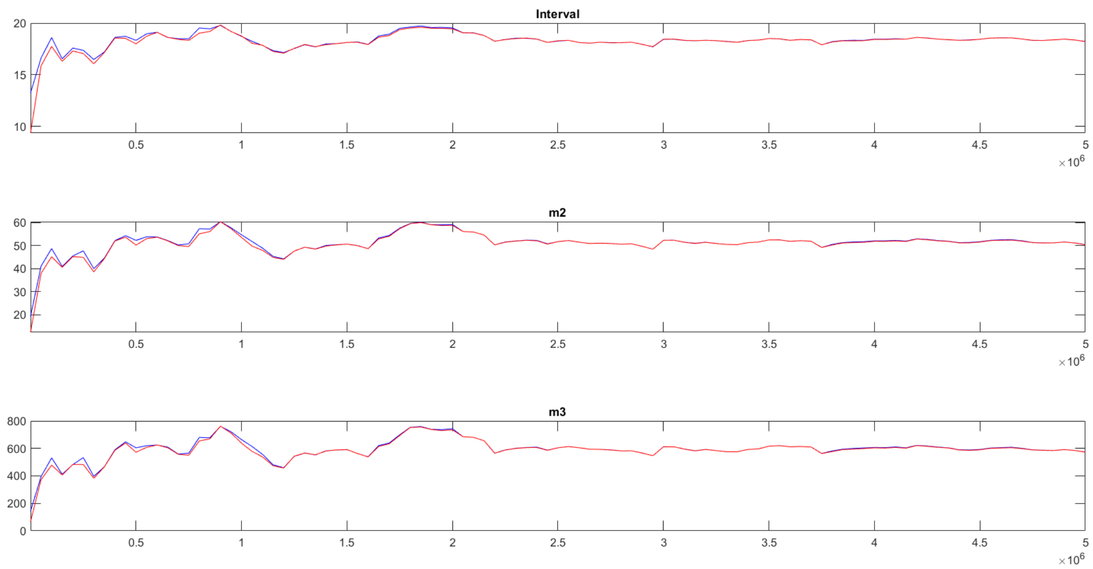
Source: Authors' elaboration based on estimation results. Regarding the "aggregate" specifications, the subindex $j$ can assume the values 0, 1, 2, 3, 4 and 5. We choose $m(1|2)\,(or\ \times = 1|2)$ as the reference or the null hypothesis. Table 2 is used to guide the judgements referring $2\ln(B_{xj})$.

**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. **Figure 2** below and **figure A1** 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.

### 4.4 Other estimation results

In the appendix, **tables A3 to A8** and **figure A2** 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 A8** (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 to the rate of depreciation of private capital, to the commodity price index, to the tax rate levied abroad on exports of the domestic economy and to the level of foreign economic activity. In terms of persistence, the highest values come from shocks to the risk premium, the international interest rate, the commodity price index and to the inflation rate prevailing in the rest of the world. In line with other studies in the DSGE literature (for example, **Castro et al (2015)**), we find that external shocks play a fundamental role in explaining Brazilian economic cycles.

The estimated standard deviations of fiscal shocks suggest that the shocks with the highest potential to affect cyclical fluctuations are those related to: (i) anticipated and unanticipated disturbances to public investment, (ii) anticipated disturbances to the taxation of wages paid to ricardian agents, and (iii) the anticipated component of the shock on the wage paid to public servants. Only in the case of the wages paid by the public sector can we 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 from the balanced growth path was higher for public consumption, relative to tax rates; and (ii) the reaction to changes in the debt/GDP ratio was greater for public employment and public investment, relative to other fiscal instruments.

## 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 A3 through A12**. The effects of unanticipated (anticipated) shocks are depicted in **figures A3, A5, A7, A9 and A11** (**A4, A6, A8, A10 and A12**). 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 to be important given their relatively high estimated standard deviations (see **sub-section 5.4**). The graphs show that an unanticipated positive shock to public investment 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 working agents 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 |
| Fiscal shocks \| expenses | 4.47 | 0.64 | 5.94 | 6.46 | 0.36 | 5.52 | 1.98 |
| Fiscal shocks \| receipts | 2.25 | 0.27 | 6.58 | 0.14 | 0.75 | 0.85 | 1.61 |
| Anticipated fiscal 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 |

**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 |

Regarding historical decompositions (see **Figures A13 to A18**), anticipated fiscal shocks had a positive impact on GDP growth between 2004 and 2010, but a mostly negative effect from 2011 onwards, 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

In this paper, we studied the effects of unanticipated and anticipated fiscal shocks in the context of a DSGE model for Brazil and found that: (i) fiscal policy shocks have a limited role in explaining business cycles; (ii) anticipated shocks account for a relatively small share of the total impact of fiscal policy shocks; (iii) the estimated degree of anticipation of fiscal shocks is relatively short, corresponding to one or two quarters, depending on the fiscal instrument. Our conclusion on the limited role of fiscal shocks as business cycles drivers is consistent with the previous literature, but the other two results differ from those found in previous studies, according to which anticipated shocks have a large weight in the total impact of fiscal policy shocks and the degree of anticipation of fiscal shocks could reach up to two years. These differences relative to previous studies may be due to two main reasons.

First, we assessed the degree of fiscal shock anticipation that provided the best fit to our data – for all fiscal shocks taken together, as well as for each type of instrument individually –, through an empirical selection scheme based on Bayes Factors, whereas the previous literature relied mainly upon degrees of anticipation that were fixed in advance, rather than being estimated. It is possible that the adoption of empirically-based criteria might have led to shorter degrees of anticipation in other studies as well.

Second, fiscal policy may work differently in Brazil than in other countries. More specifically, the legal and political process by which the public budget is negotiated and approved in Brazil may lead to relatively short time intervals between the announcement of “fiscal news” – changes to the fiscal guidelines initially proposed by the Executive branch – and their implementation, thus leading to relatively short degrees of anticipation of fiscal shocks.

We also investigated the effects of shock 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 analyzed important budget components such as public investment, employment, and transfers. According to our results, shocks to government consumption and lump-sum taxation are anticipated one quarter in advance, while all other shocks are anticipated two quarters in advance.

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Appendix

Table A1: Calibrated values for model parameters[9]

| Parameter | Description | Value |
|---|---|---|
| $\zeta$ | Size of the non-Ricardian population | 0,66 |
| $\sigma_C$ | Absolute value of the elasticity of the marginal utility of consumption with respect to consumption | 1,2 |
| $\sigma_L$ | Elasticity of the marginal disutility of labor with respect to labor | 2,0 |
| $\beta$ | Intertemporal discount factor | 0,9875 |
| $\theta$ | Sensitivity of the risk premium with respect to the debt/output ratio | 1,1 |
| $\delta$ | Depreciation rate of the private capital stock | 0,02 |
| $\tilde{\delta}$ | Depreciation rate of the public capital stock | 0,02 |
| $h$ | Degree of habit formation of individuals in the economy | 0,65 |
| $\nu = \left( \left. \frac{\partial^2 S}{\partial \left( \arg S \right)^2} \right\|_{SS} \right)^{-1}$ | Measure of the convexity of function *S*, which imposes costs to the adjustment of the capital stock | 0,15 |
| $\left. \frac{d^2 \Psi}{d\left( z_t^l \right)^2} \right\|_{SS} \Big/ \left. \frac{d\Psi}{dz_t^l} \right\|_{SS}$ | Parameter that characterizes function Ψ, which imposes a cost to the economy whenever the rate of utilization of private capital departs from its steady-state level | 5,92 |
| $\alpha_P^T$ | Proportion of firms in the tradable goods sector that are unable to choose optimal prices in a given period | 0,5 |
| $\alpha_P^{NT}$ | Proportion of firms in the non-tradable goods sector that are unable to choose optimal prices in a given period | 0,5 |
| $\alpha_W$ | Proportion of Ricardian individuals who are unable to choose optimal wages in a given period | 0,6 |

[9] The calibration was based on **Cavalcanti et al (2019)**.

Tabela A1 (continuação): Valores calibrados para os parâmetros do modelo

| Parâmetro | Descrição | Valor |
|---|---|---|
| $\eta_K^T$ | Exponent of capital in the Cobb-Douglas production function used by intermediate goods firms pertaining to the tradable sector of the economy | 0,425 |
| $\eta_L^T$ | Exponent of labor in the Cobb-Douglas production function used by intermediate goods firms pertaining to the tradable sector of the economy | 0,4 |
| $\eta_K^{NT}$ | Exponent of capital in the Cobb-Douglas production function used by intermediate goods firms pertaining to the non-tradable sector of the economy | 0,25 |
| $\eta_L^{NT}$ | Exponent of labor in the Cobb-Douglas production function used by intermediate goods firms pertaining to the non-tradable sector of the economy | 0,65 |
| $\mu_w$ | Parameter that measures the degree of substitution between the different kinds of labor supplied by Ricardian individuals | 0,5 |
| $\eta_g$ | Sensitivity of total factor productivity of intermediate goods firms with respect to public capital | 0,05 |
| $a$ | Parameter that measures the degree of substitution between the labor aggregates supplied by Ricardian and non-Ricardian individuals | 5,0 |
| $\gamma$ | Parameter that measures the importance of tradables goods in the production function used by firms manufacturing the final good | 0,32 |
| $\eta$ | Parameter that measures the degree of substitution between tradable and non-tradable aggregates in the production of the final good | 2,0 |
| $\varphi$ | Parameter that measures the importance of Ricardian labor in the labor aggregate used by intermediate goods firms | 0,65 |
| $\mu_T$ | Parameter that measures the degree of substitution between the various kinds of tradable goods used in the production of the tradable aggregate | 0,1 |
| $\mu_{NT}$ | Parameter that measures the degree of substitution between the various kinds of non-tradable goods used in the production of the non-tradable aggregate | 0,2 |
| $\tau^*$ | Sensitivity of the foreign demand for tradable goods manufactured in the domestic economy with respect to its relative price | 10 |

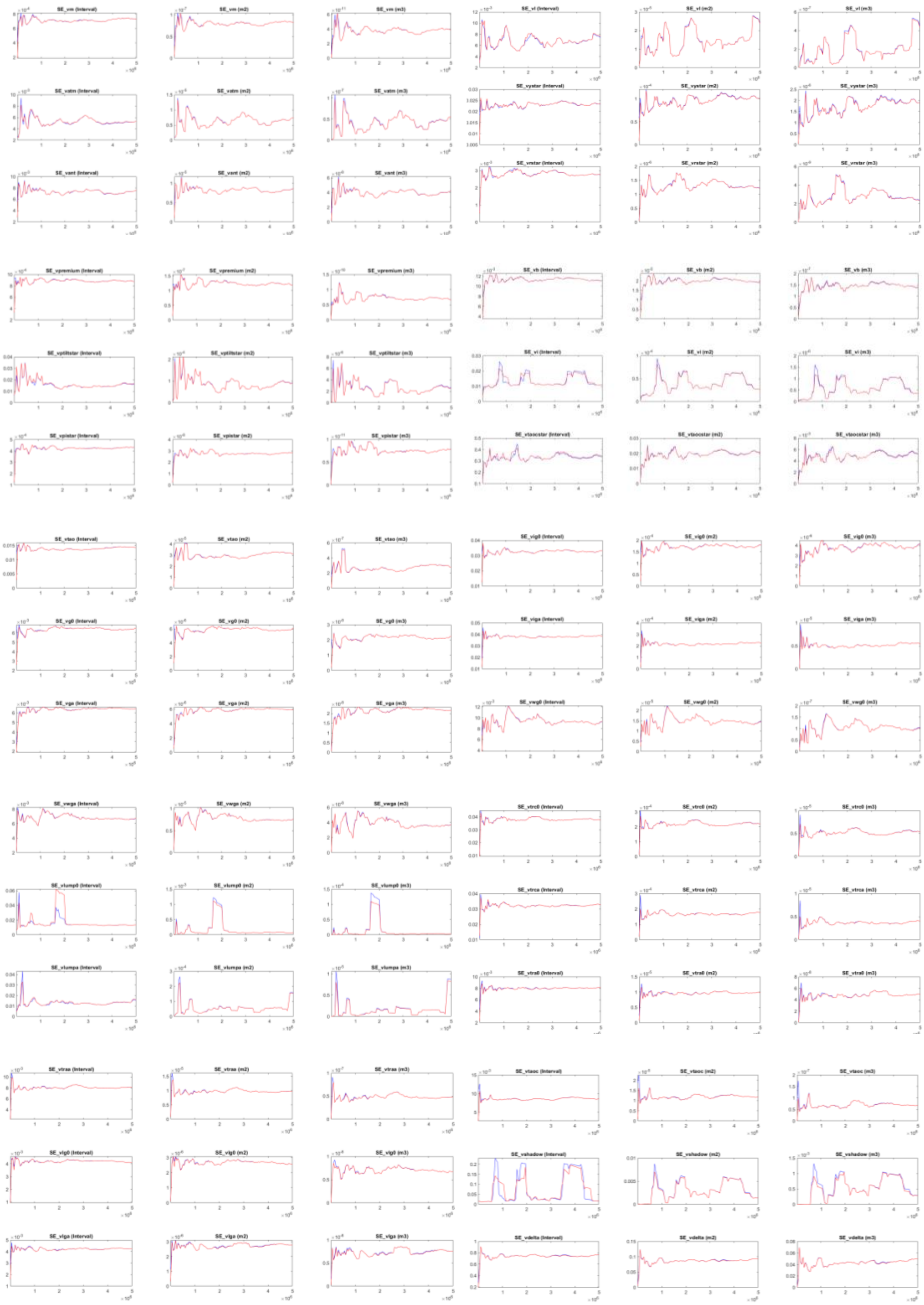
Tabela A2: Steady-state ratios for main macroeconomic aggregates[10]

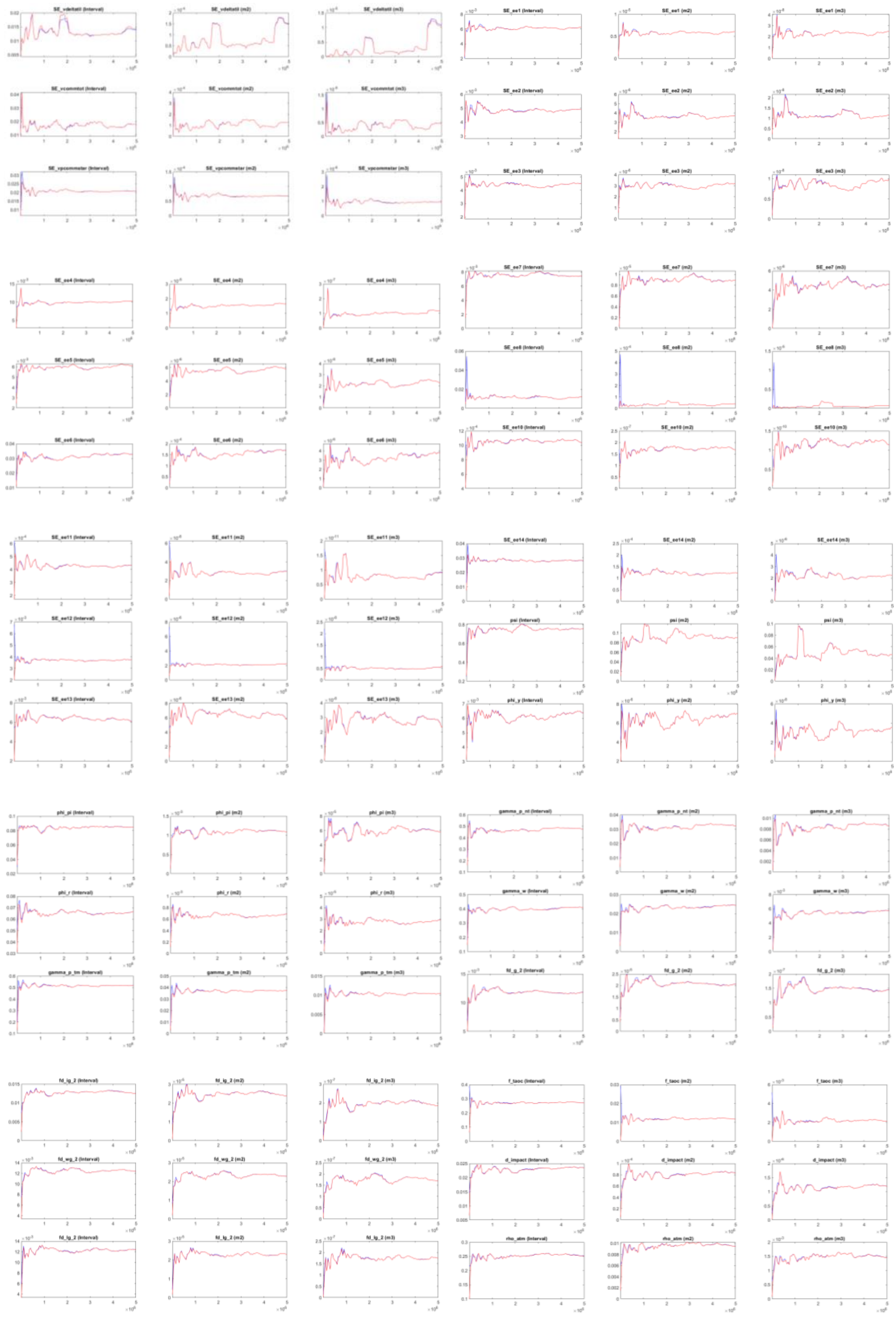
| Parameter | Description | Value |
|---|---|---|
| $\left(\bar{C}+\bar{G}\right)/\overline{PIB}$ | Ratio between total consumption and the gross domestic product (GDP) | 0,82 |
| $\bar{C}/\overline{PIB}$ | Ratio between total private consumption and GDP | 0,62 |
| $\bar{C}^{l}/\overline{PIB}$ | Ratio 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 |

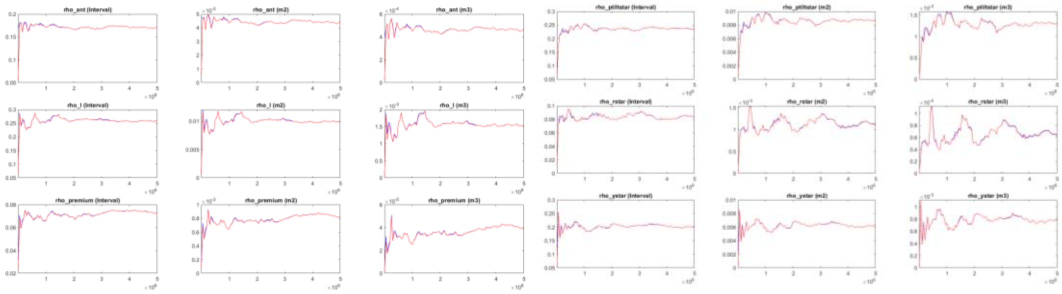
[10] See **Cavalcanti et al. (2019)**

| | | |
|---|---|---|
| $\left(\overline{w}^{l}\overline{L}^{l}+\overline{w}^{g}\overline{L}^{g}\right)\big/\overline{PIB}$ | Real labor income received by Ricardian workers as a proportion of GDP | 0,38 |
| $\left(\frac{\overline{Y}}{1+\overline{\tau}^{c}}-\overline{w}\overline{L}+\overline{BC}\right)\Big/\overline{PIB}$ | Real capital income as a proportion of GDP | 0,31 |
| $\frac{\overline{\tau}^{c}}{1+\overline{\tau}^{c}}\left(\overline{C}+\overline{G}\right)+\frac{\overline{\tau}^{\times}}{1+\overline{\tau}^{c,*}}\overline{e}^{r}\overline{\tilde{p}}_{T}^{*}\overline{Q}$ | Excise taxes + import taxes as a proportion of GDP | 0,16 |
| $\zeta\overline{w}^{m}\big/\overline{PIB}$ | Social transfers received by non-Ricardian individuals as a proportion of GDP | 0,16 |
| $\overline{\tau}_{w}\left(\overline{w}\overline{L}+\overline{w}^{c}\overline{L}^{c}\right)\big/\overline{PIB}$ | Taxes levied on labor income as a proportion of GDP | 0,12 |
| $\overline{\tau}^{k}\left(\frac{\overline{Y}}{1+\overline{\tau}^{c}}-\overline{w}\overline{L}+\overline{BC}\right)\Big/\overline{PIB}$ | 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 |

Figura A1. Univariate convergence diagnosis (**Brooks and Gelman (1998)**)



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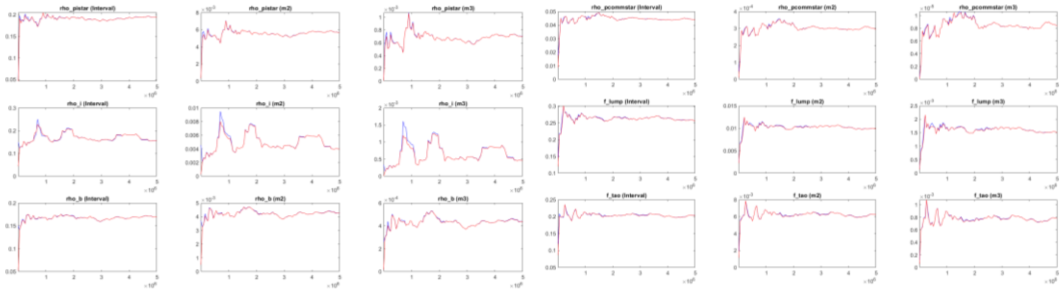
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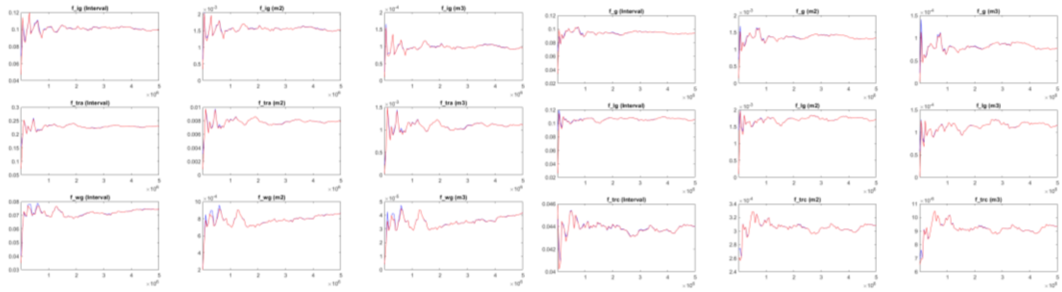
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f_wg (Interval)
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f_trc (m3)

# Table A3. Results of estimating the standard deviation of fiscal shocks

| Parameter | Description | Prior distribution | | | Posterior distribution | | |
|---|---|---|---|---|---|---|---|
| | | Distribution | Mean | Variance | Median | Cred. Interval (90%) | |
| $\sigma^{g}$ | Standard deviation of the unanticipated shock to government consumption | Invgamma | 0,2000 | inf | 0.0107 | 0.0066 | 0.0146 |
| $\sigma^{g1}$ | Standard deviation of the anticipated shock to government consumption | Invgamma | 0,2000 | inf | 0.0103 | 0.0061 | 0.0141 |
| $\sigma^{ig}$ | Standard deviation of the unanticipated shock to public investment | Invgamma | 0,1000 | inf | 0.0994 | 0.0781 | 0.1219 |
| $\sigma^{ig1}$ | Standard deviation of the anticipated shock to public investment | Invgamma | 0,1000 | inf | 0.0517 | 0.0265 | 0.0749 |
| $\sigma^{lg}$ | Standard deviation of the unanticipated shock to public sector employment | Invgamma | 0,0500 | inf | 0.0119 | 0.0092 | 0.0145 |
| $\sigma^{lg1}$ | Standard deviation of the anticipated shock to public sector employment | Invgamma | 0,0500 | inf | 0.0120 | 0.0093 | 0.0146 |
| $\sigma^{wg}$ | Standard deviation of the unanticipated public sector wage shock | Invgamma | 0,0100 | inf | 0.0078 | 0.0025 | 0.0145 |
| $\sigma^{wg1}$ | 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 |
| $\sigma^{\tau}$ | 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.

Table A4. 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 |
| $\sigma^{wtil}$ | Standard deviation of the wage index measurement error | Invgamma | 0.010 | inf | 0.0274 | 0.0234 | 0.0313 |
| $\sigma^{wctil}$ | 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 |
| $\sigma^{wltil}$ | Standard deviation of the error of measurement of the salary of ricardian individuals | Invgamma | 0.010 | inf | 0.0204 | 0.0175 | 0.0231 |
| $\sigma^{rer}$ | Standard deviation of the real exchange rate measurement error | Invgamma | 0.010 | inf | 0.0814 | 0.0604 | 0.1022 |
| $\sigma^{cl}$ | Standard deviation of consumption measurement error of ricardian individuals | Invgamma | 0.010 | inf | 0.0347 | 0.0297 | 0.0393 |
| $\sigma^{b\_star}$ | 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 |
| $\sigma^{y\_star}$ | Rest of the world production measurement error standard deviation | Invgamma | 0.010 | inf | 0.0050 | 0.0043 | 0.0057 |
| $\sigma^{pi\_star}$ | Standard deviation of the rest of the world's inflation measurement error | Invgamma | 0.010 | inf | 0.0015 | 0.0012 | 0.0018 |
| $\sigma^{l}$ | Standard deviation of the error in measuring the level of employment in the economy | Invgamma | 0.010 | inf | 0.0125 | 0.0101 | 0.0149 |
| $\sigma^{tr^a}$ | Standard deviation of the measurement error of consumption of non-ricardian individuals | Invgamma | 0.010 | inf | 0.0112 | 0.0074 | 0.0152 |
| $\sigma^{taow}$ | 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.

Table A5. 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%) | |
| $\sigma^{\varepsilon_B}$ | Standard deviation of preference shock | Invgamma | 0,0500 | inf | 0,0473 | 0,0397 | 0,0547 |
| $\sigma^{\varepsilon_L}$ | 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 |
| $\sigma^{\varepsilon_I}$ | Standard deviation of investment shock | Invgamma | 0,0500 | inf | 0,0440 | 0,0374 | 0,0520 |
| $\sigma^{\varepsilon_{a^T}}$ | Standard deviation of the tradables sector productivity shock | Invgamma | 0,0050 | inf | 0,0038 | 0,0012 | 0,0067 |
| $\sigma^{\varepsilon_{a^{NT}}}$ | Standard deviation of the non-tradables sector productivity shock | Invgamma | 0,0070 | inf | 0,0107 | 0,0061 | 0,0156 |
| $\sigma^{\varepsilon_m}$ | Standard deviation of the monetary shock | Invgamma | 0,0050 | inf | 0,0029 | 0,0024 | 0,0033 |
| $\sigma^{\Xi}$ | Standard deviation of the shadow price of capital | Invgamma | 0,0100 | inf | 0,0171 | 0,0021 | 0,0229 |
| $\sigma^{\hat{\delta}}$ | Standard deviation of the shock on the rate of depreciation of private capital | Invgamma | 0,0100 | inf | 3,5073 | 3,0315 | 3,9966 |
| $\sigma^{\hat{\hat{\delta}}}$ | 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.

Table A6. Results of estimating the parameters of the fiscal reaction function

| | | Prior distribution | | | Posterior distribution | | |
|---|---|---|---|---|---|---|---|
| Parameter | Description | Distribution | Mean | Variance | Median | Cred. Interval (90%) | |
| $\rho^{g}$ | Persistence of government consumption | Beta | 0,5000 | 0,1000 | 0,8293 | 0,7675 | 0,8914 |
| $\rho^{ig}$ | Persistence of public investment | Beta | 0,5000 | 0,1000 | 0,7941 | 0,7309 | 0,8621 |
| $\rho^{lg}$ | Persistence of employment in the public sector | Beta | 0,5000 | 0,1000 | 0,7902 | 0,7210 | 0,8602 |
| $\rho^{wg}$ | Persistence of public sector salary | Beta | 0,5000 | 0,2000 | 0,8629 | 0,8145 | 0,9106 |
| $\rho^{tr^{c}}$ | Persistence of transfers for working non-Ricardians | Beta | 0,5000 | 0,1000 | 0,9462 | 0,9188 | 0,9741 |
| $\rho^{tr^{a}}$ | 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 |
| $\rho^{\tau}$ | 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.

Table A7. 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 |
| $\rho^{Y*}$ | 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.

Table A8. Estimation results for selected parameters.

| Parameter | Description | Prior distribution | | | Posterior distribution | | |
|---|---|---|---|---|---|---|---|
| | | Distribution | Mean | Variance | Median | Cred. Interval (90%) | |
| $d^{\theta}$ | 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 |
| $\Psi$ | Parameter that measures the loss arising from variations in installed capacity | Gamm | 5,9200 | 5,0000 | 3,2124 | 2,7323 | 3,6893 |
| $\phi^{m}$ | Parameter that measures the persistence of monetary policy | Beta | 0,5000 | 0,1000 | 0,8319 | 0,7912 | 0,8736 |
| $\phi^{Y}$ | 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 |
| $\phi^{\pi}$ | 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 |
| $\gamma_P^T$ | Parameter that measures the degree of indexation of prices in the tradable sector | Beta | 0,5000 | 0,2000 | 0,5332 | 0,2255 | 0,8502 |
| $\gamma_P^{NT}$ | Parameter that measures the degree of price indexation in the non-tradables sector | Beta | 0,5000 | 0,2000 | 0,5819 | 0,3063 | 0,8850 |
| $\gamma_W$ | 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.

# Figure A2. Priors and posteriors

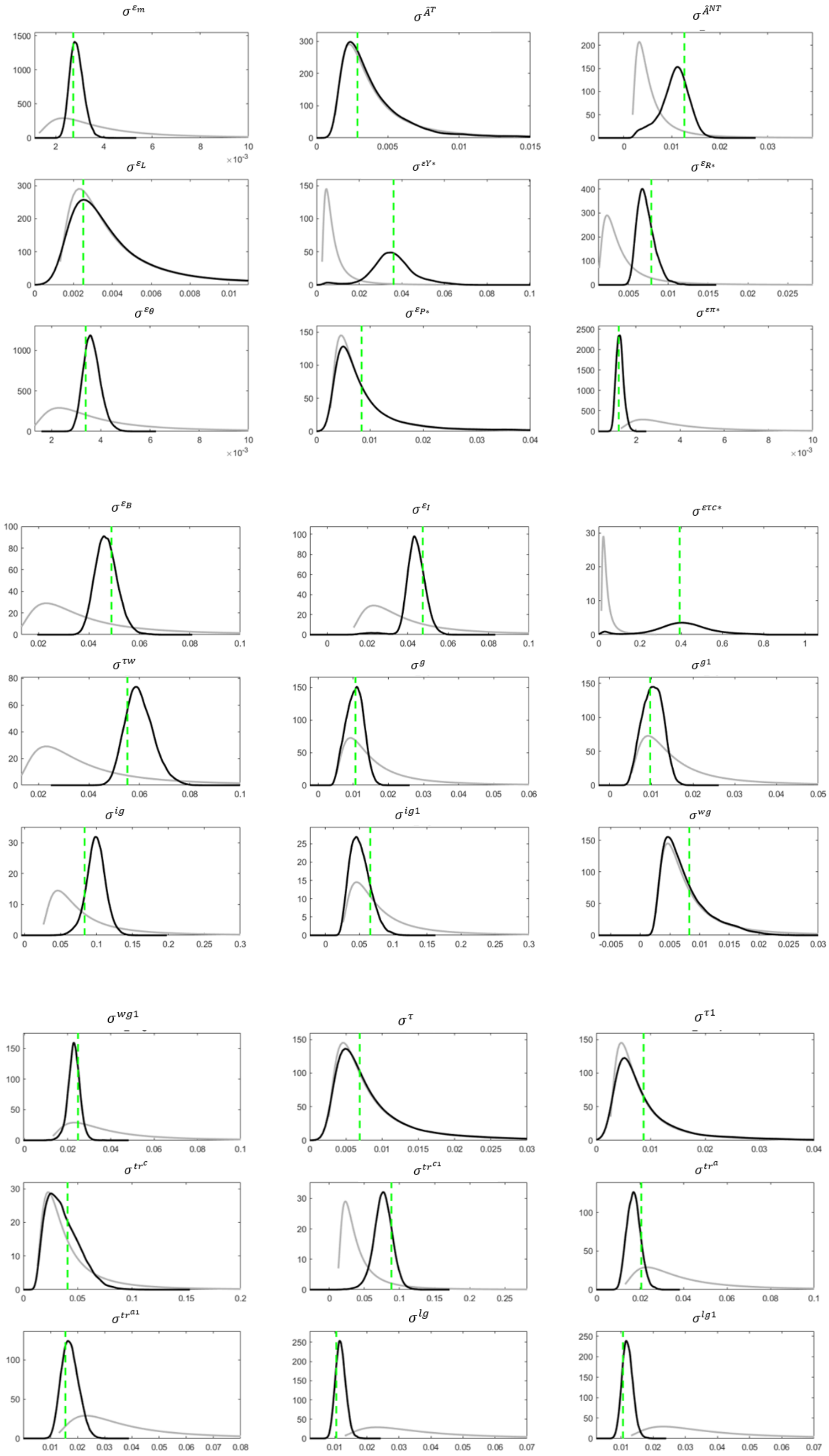
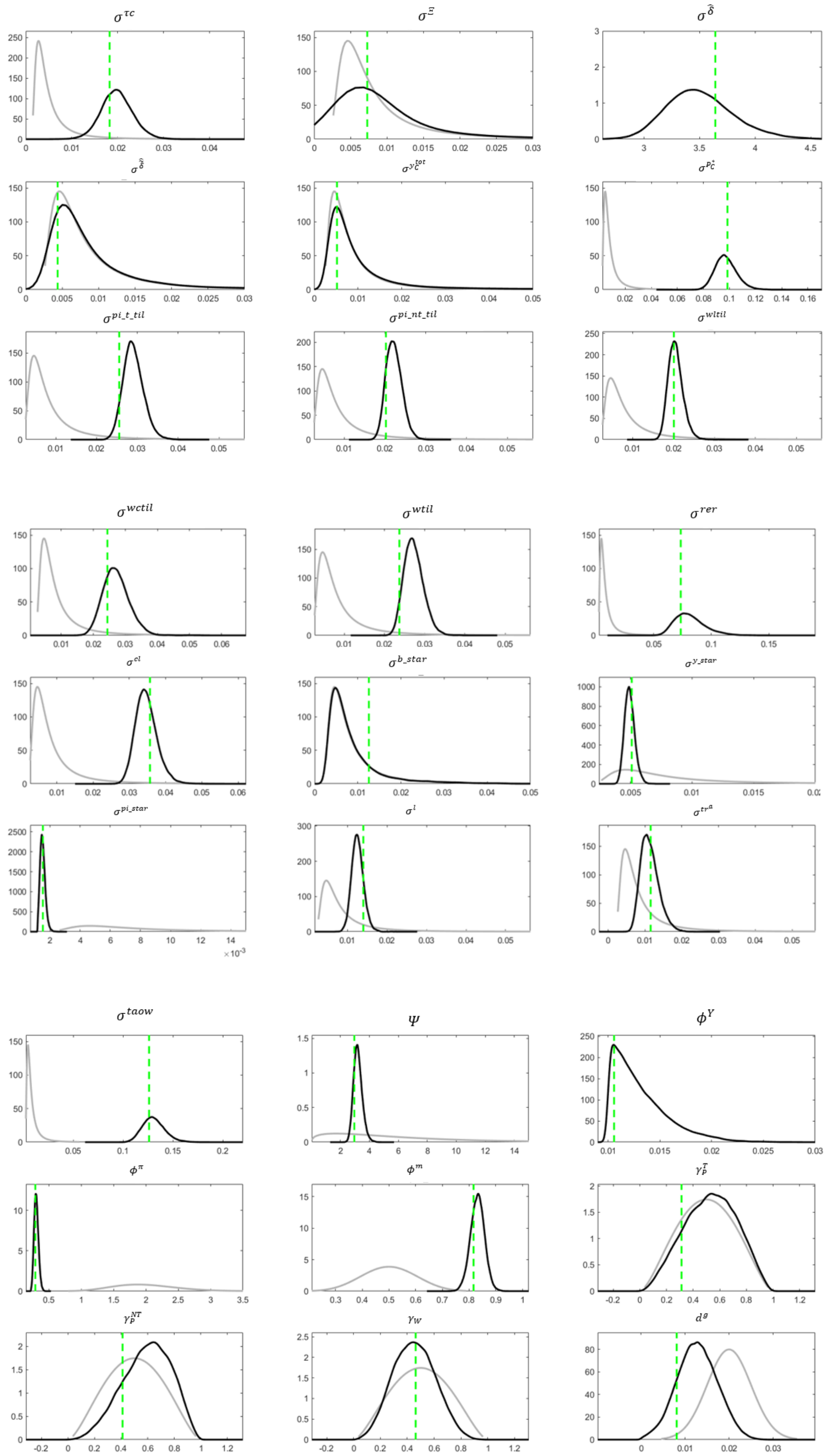
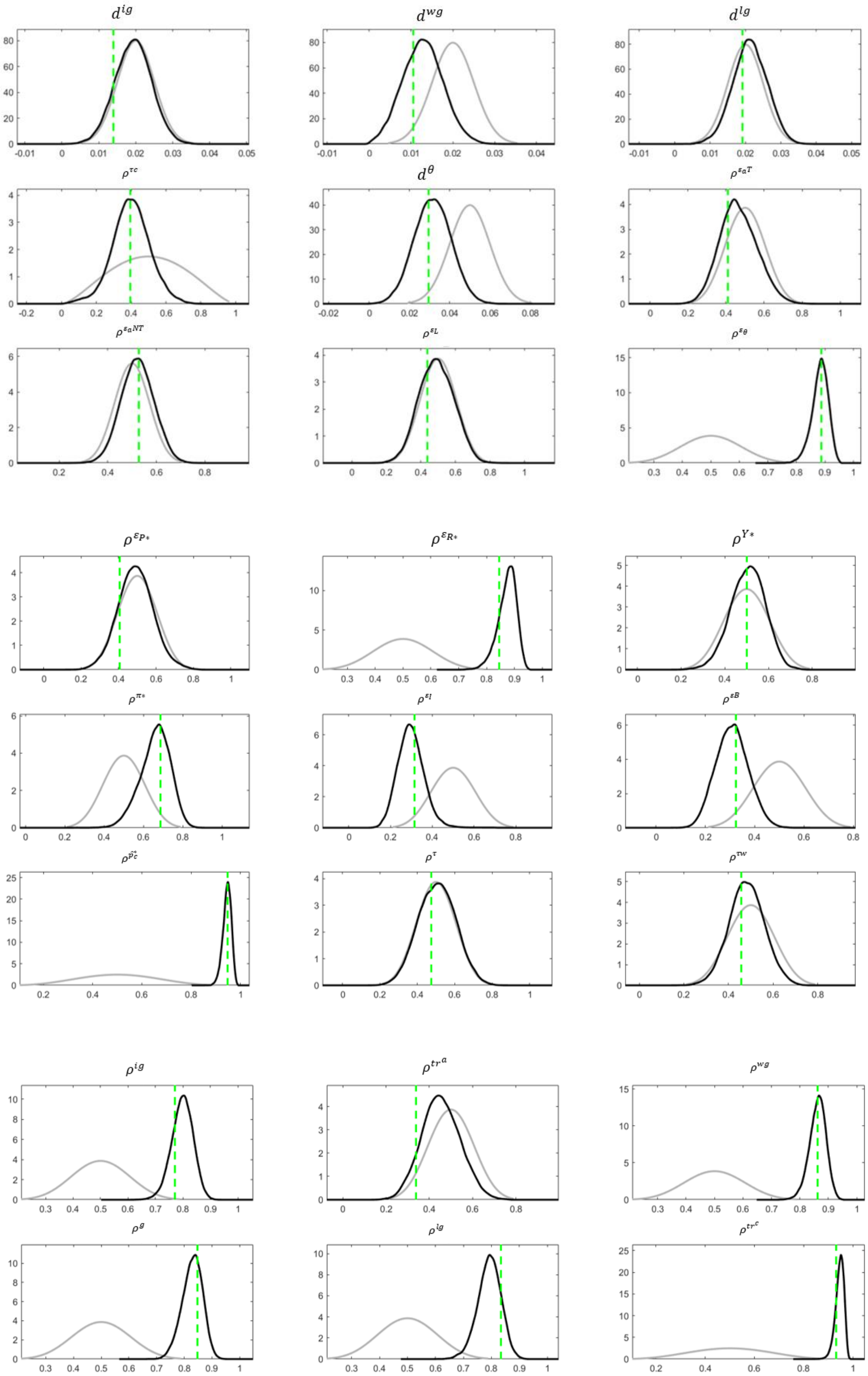


Figure A2. Priors and posteriors (continued)



## Figure A2. Priors and posteriors (continued)



Source: Results obtained with Dynare package.

Figure A3. Impulse response functions for unanticipated shocks in government consumption.

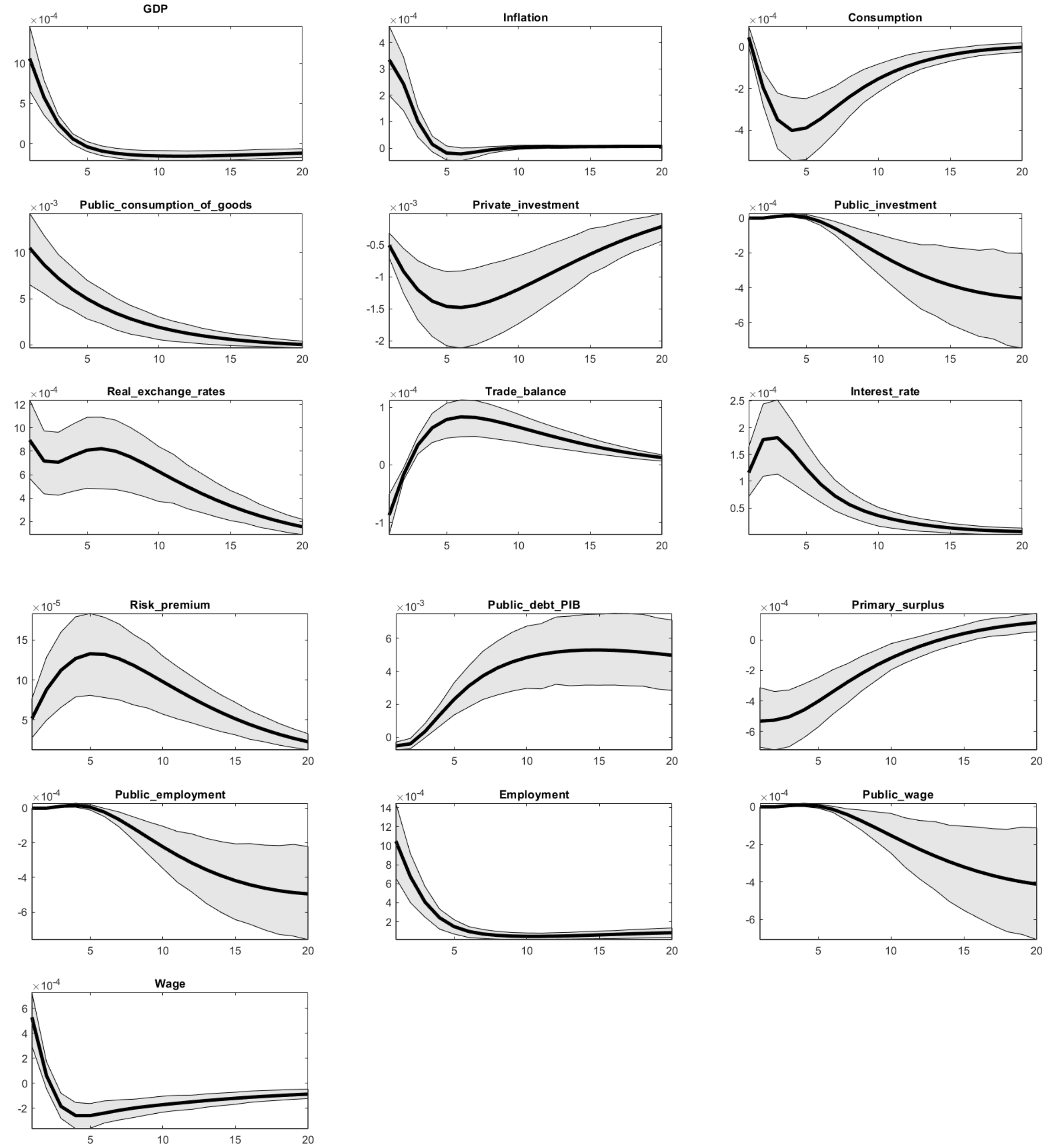


Figure A4. Impulse response functions for anticipated shocks in government consumption.

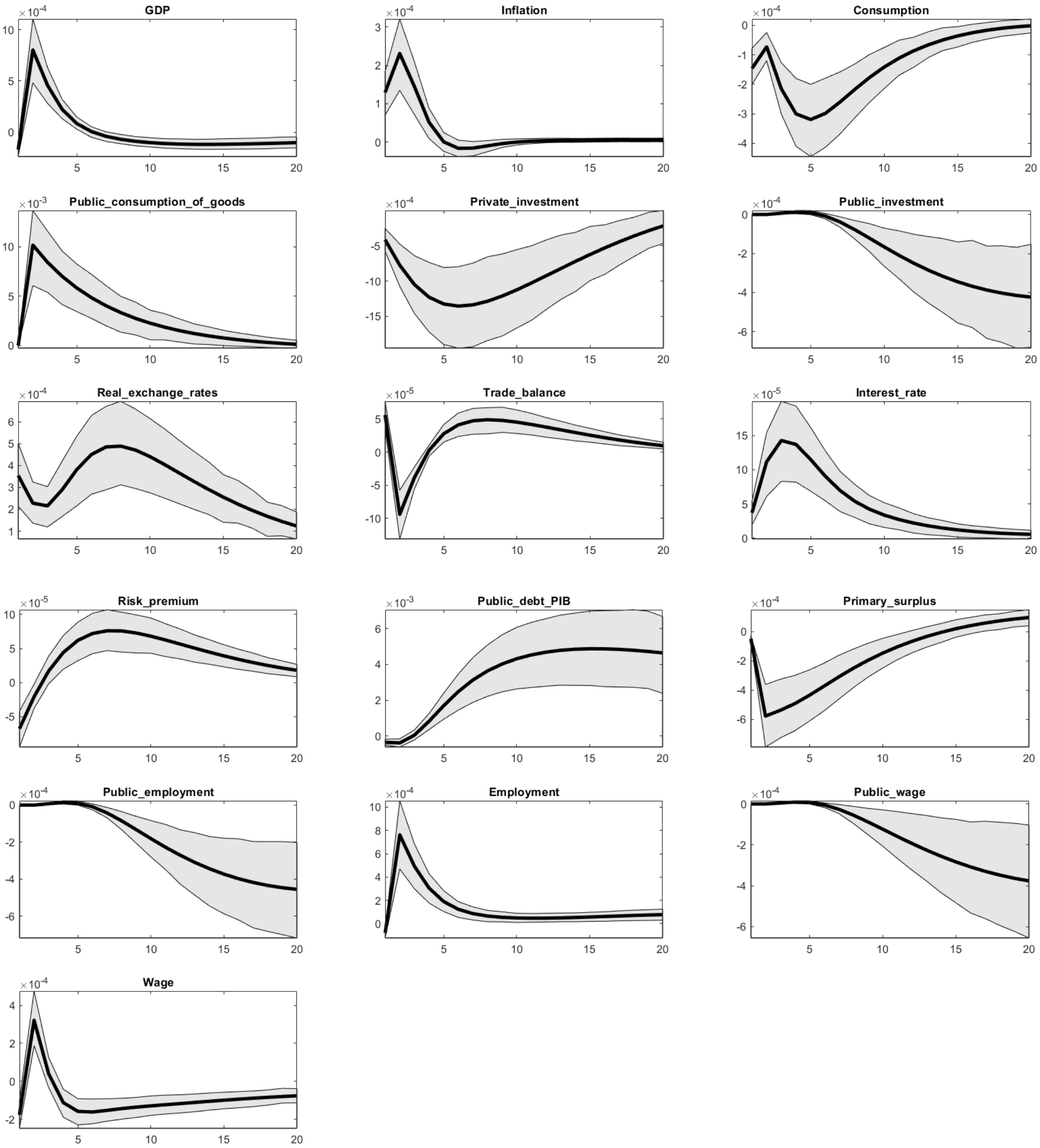


Figure A5. Impulse response functions for unanticipated shocks in public investment.

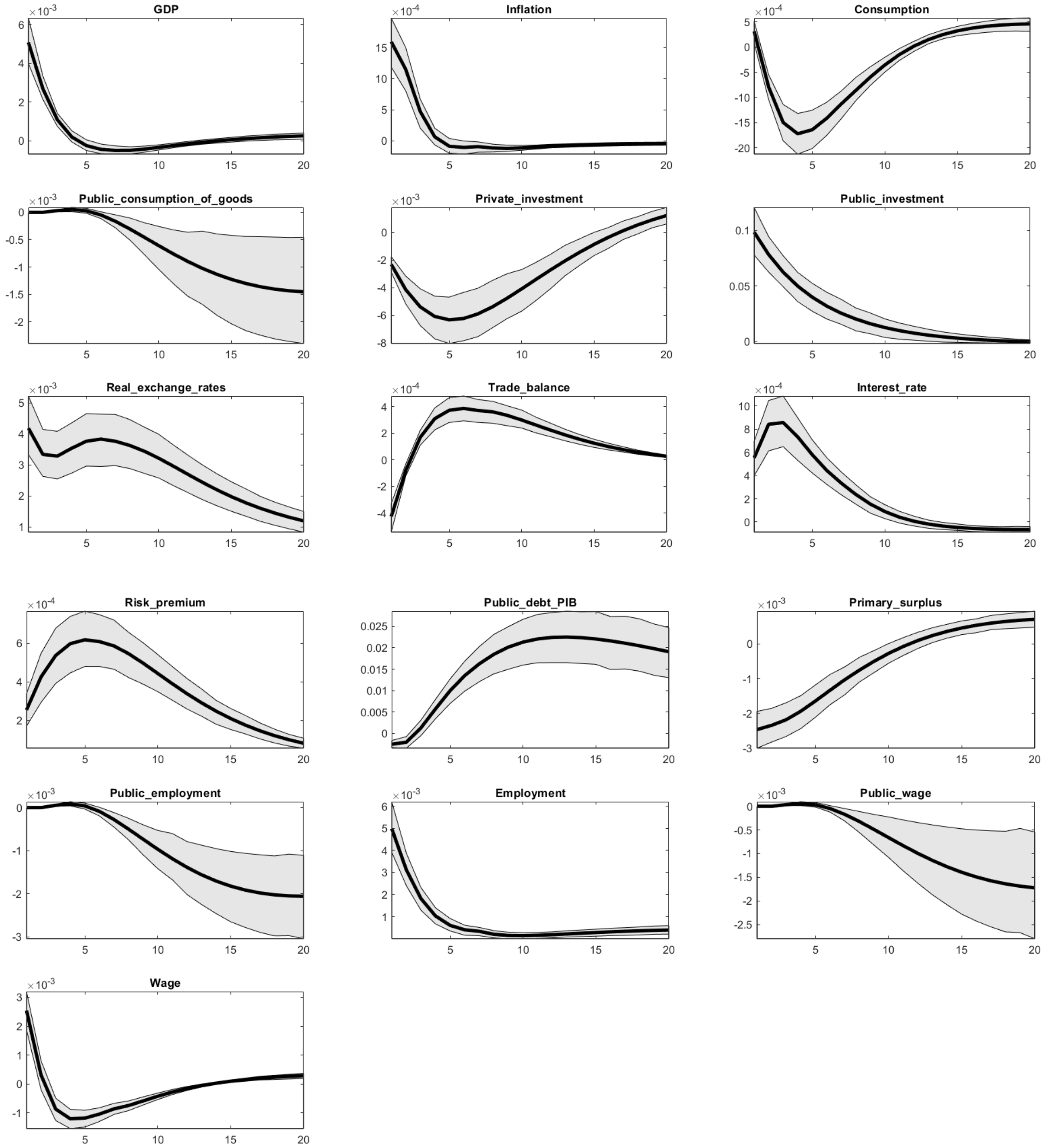


Figure A6. Impulse response functions for anticipated shocks in public investment.

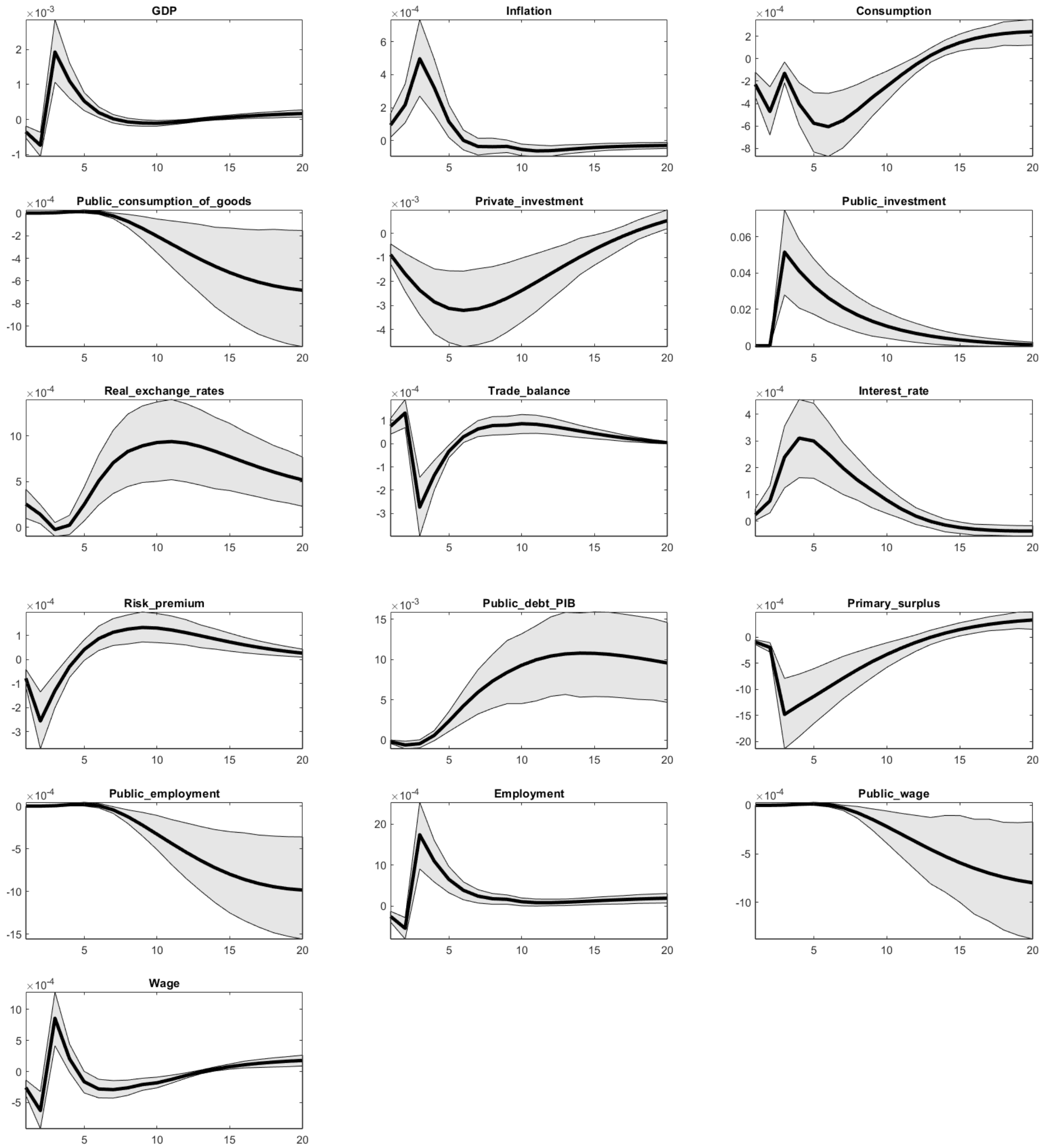


Figure A7. Impulse response functions for unanticipated shocks in public employment.

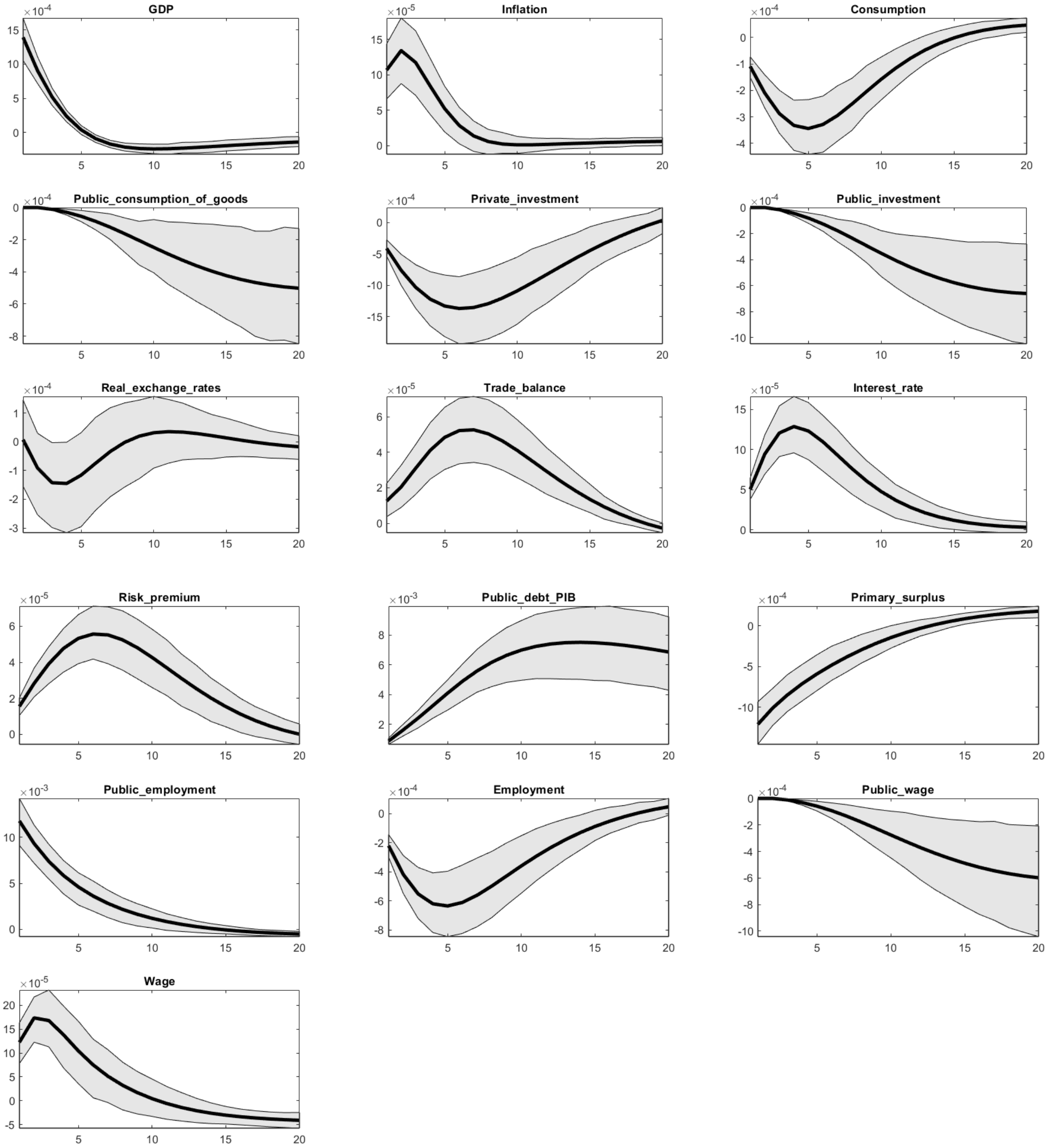


Figure A8. Impulse response functions for anticipated shocks in public employment.

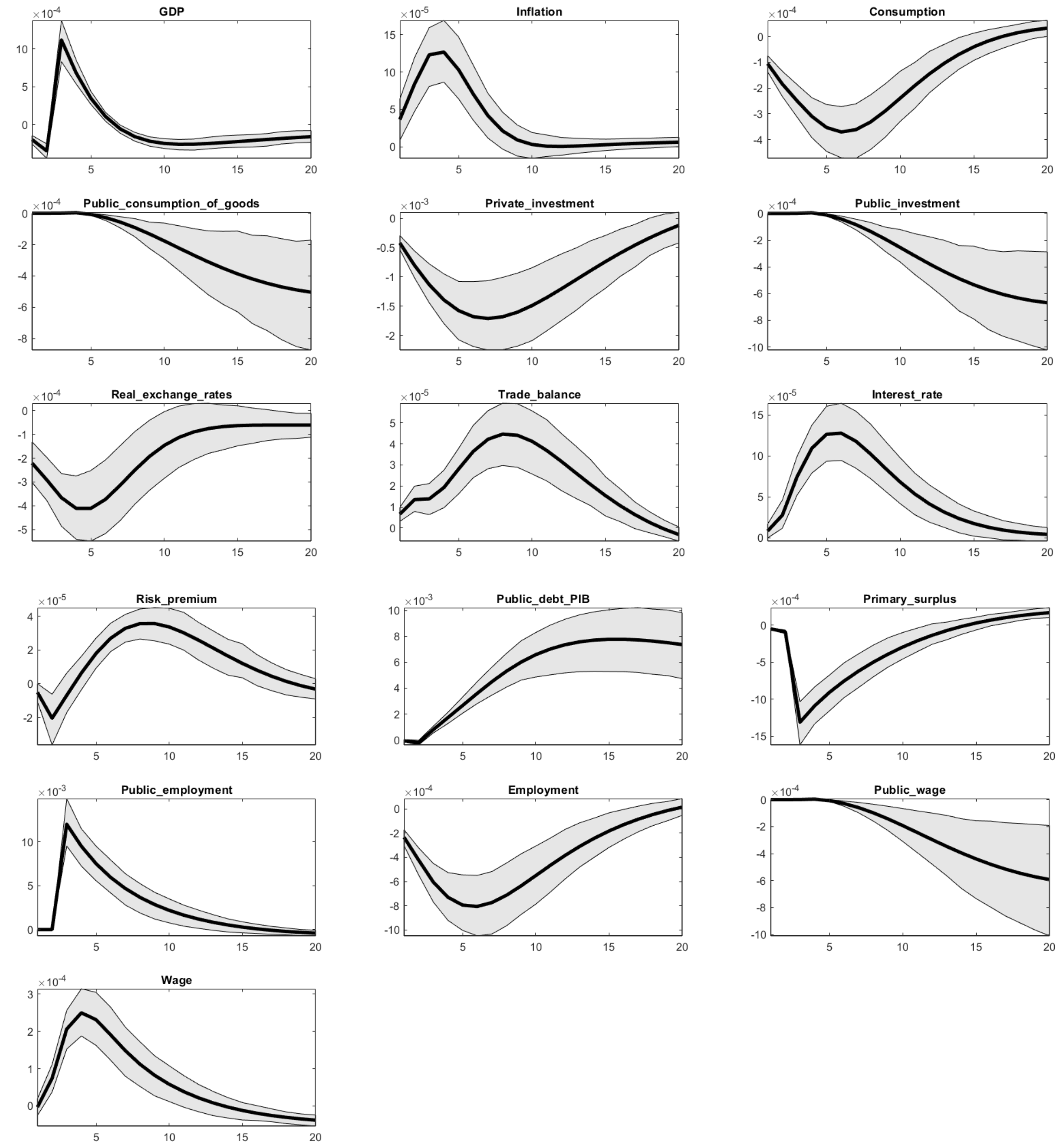


Figure A9. Impulse response functions for unanticipated public sector wage shocks.

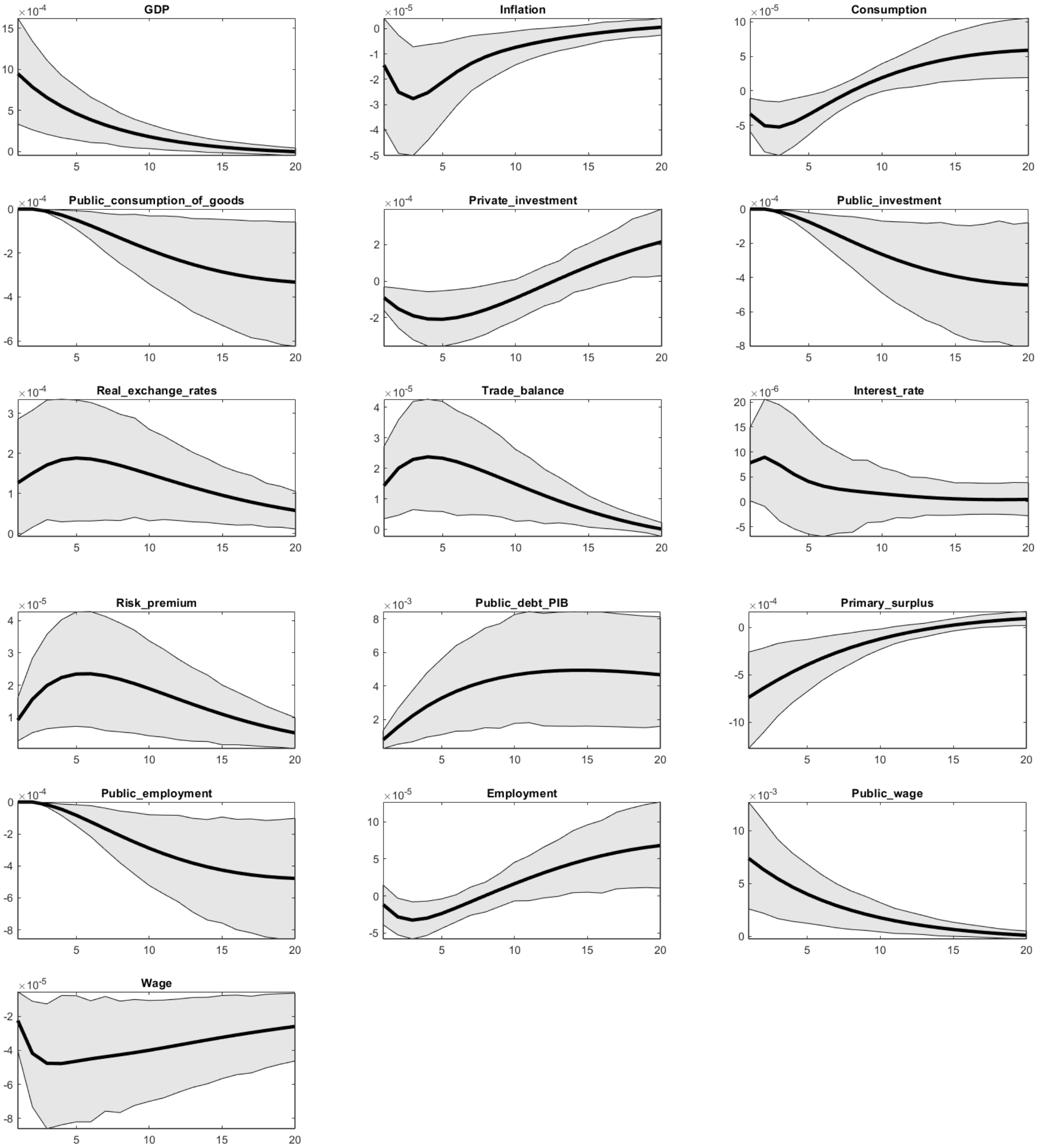


Figure A10. Impulse response functions for anticipated public sector wage shocks.

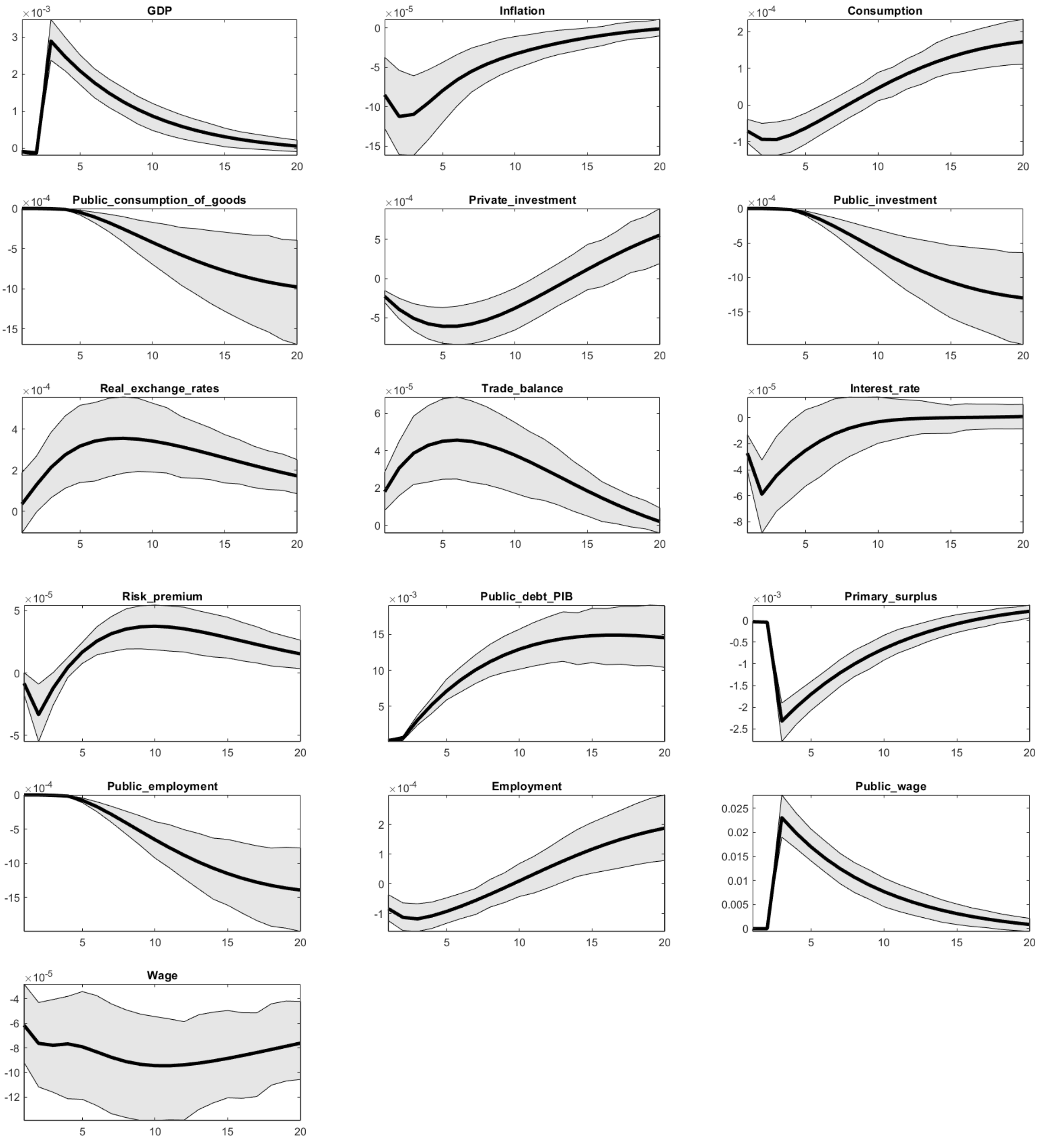


Figure A11. Impulse response functions for unanticipated lump-sum tax shocks.

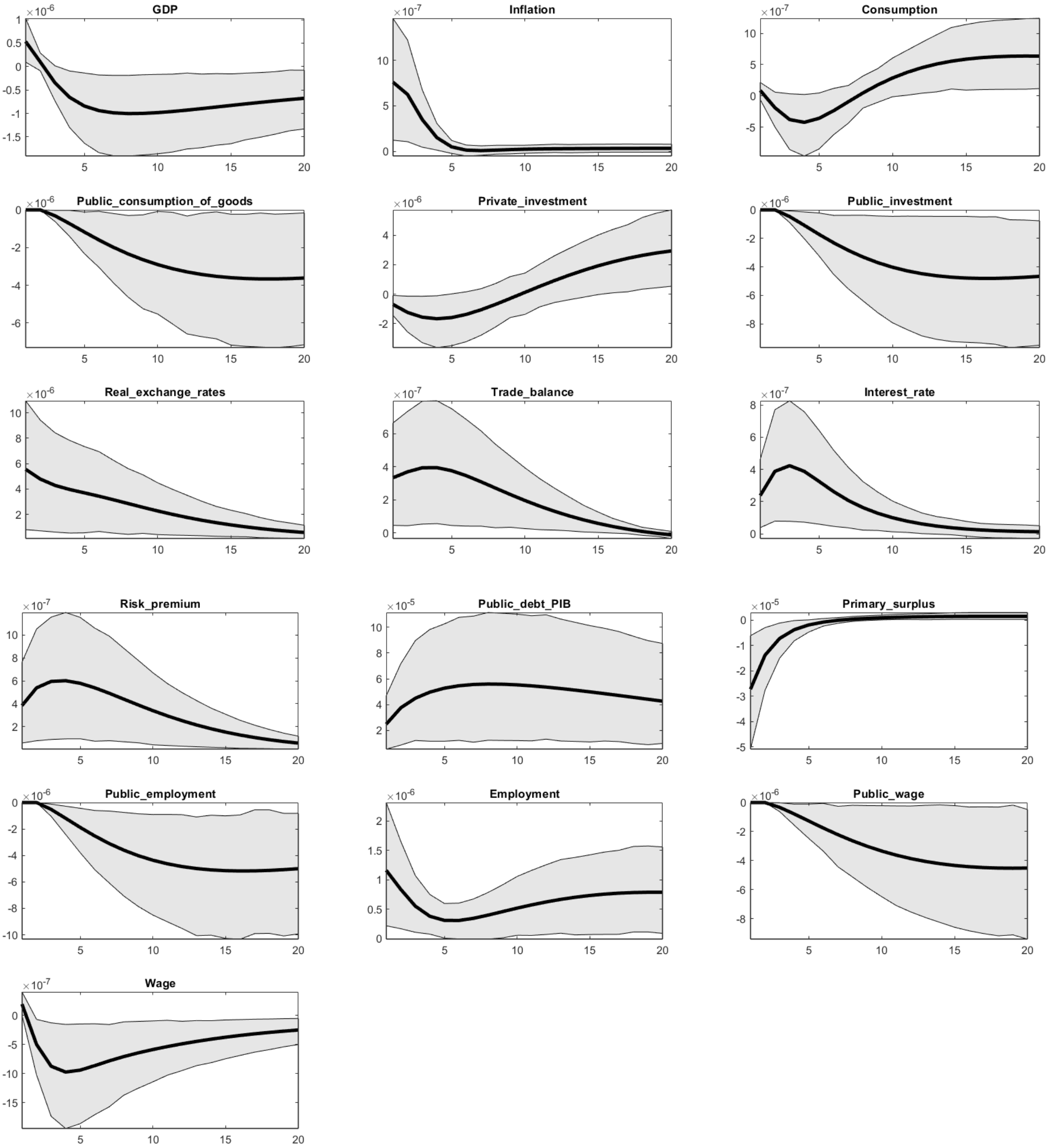


Figure A12. Impulse response functions for anticipated shocks in the lump-sum tax.

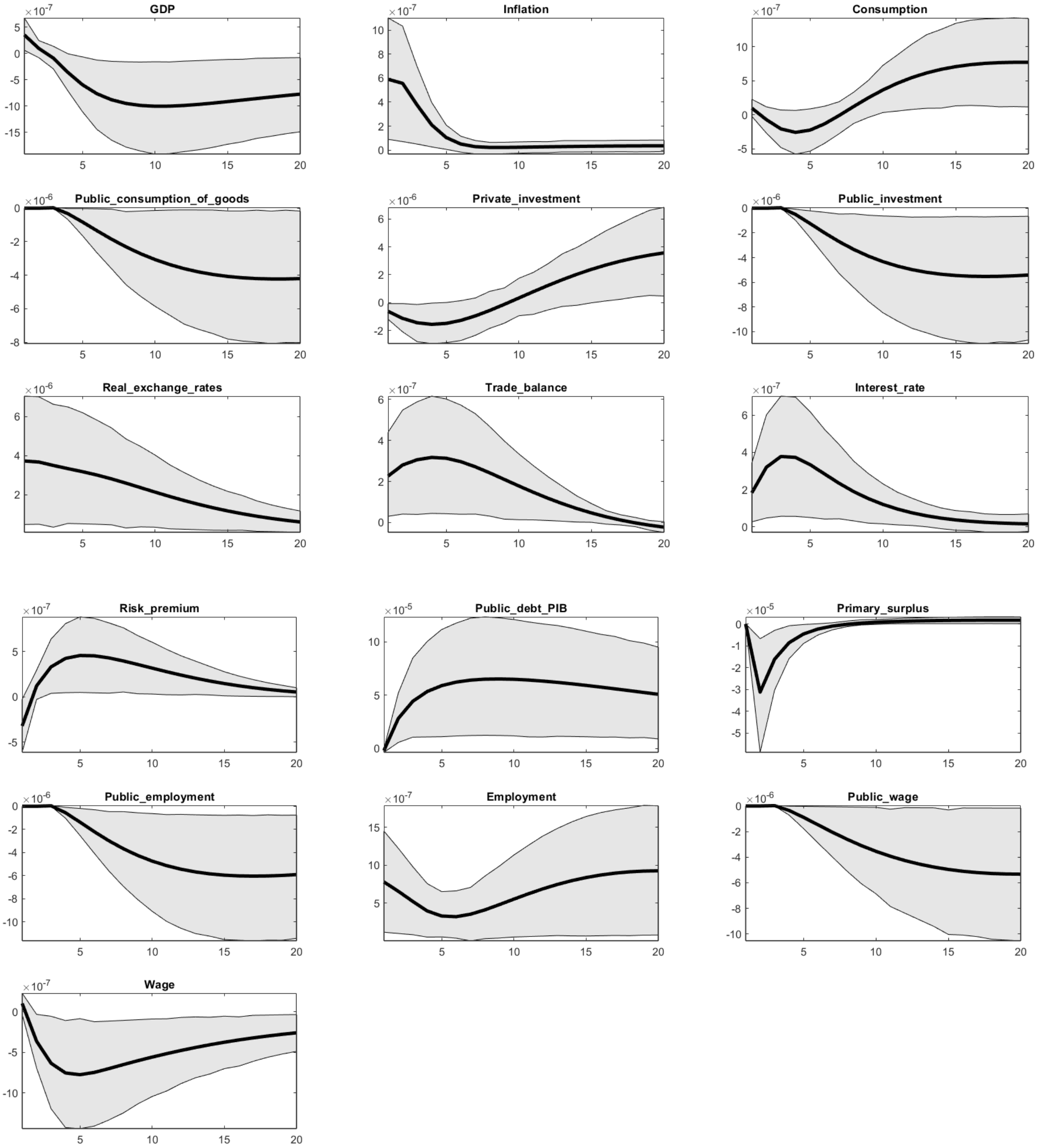
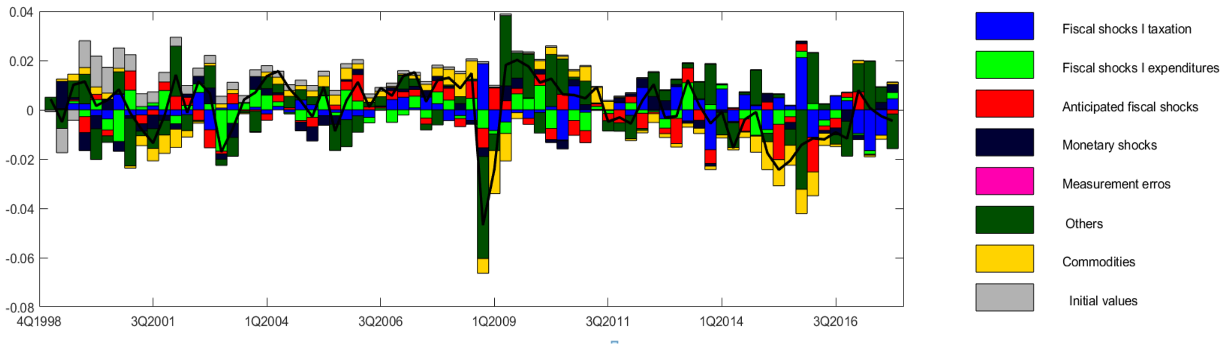
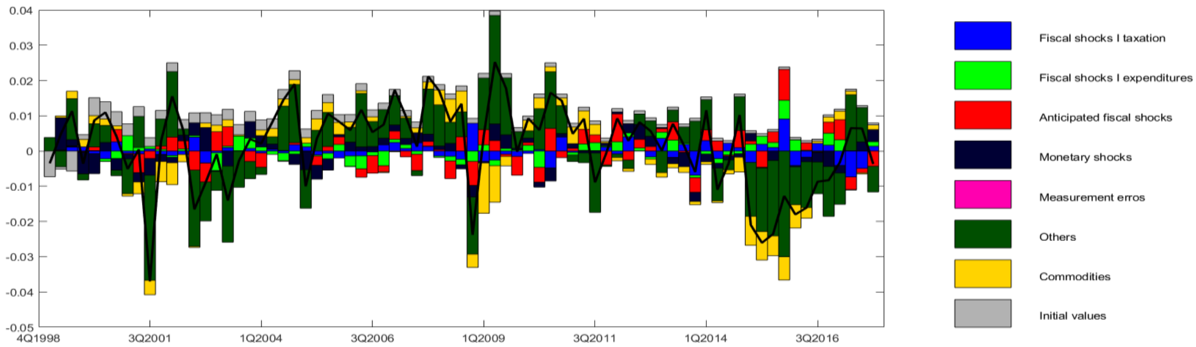


Figure A13. Historical decomposition of GDP growth [11]



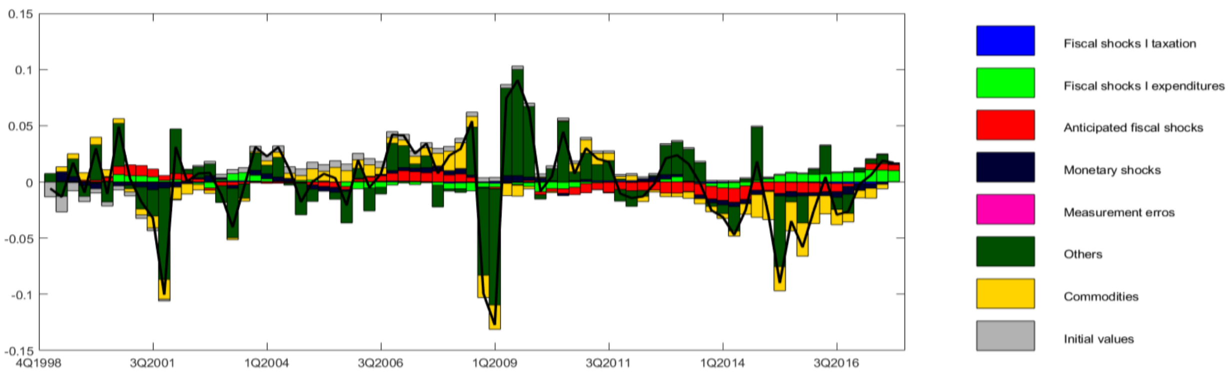

Source: Results obtained with Dynare package.

Figure A14. Historical decomposition of the aggregate consumption growth rate




Source: Results obtained with Dynare package.

Figure A15. Historical decomposition of private investment growth




Source: Results obtained with Dynare package.

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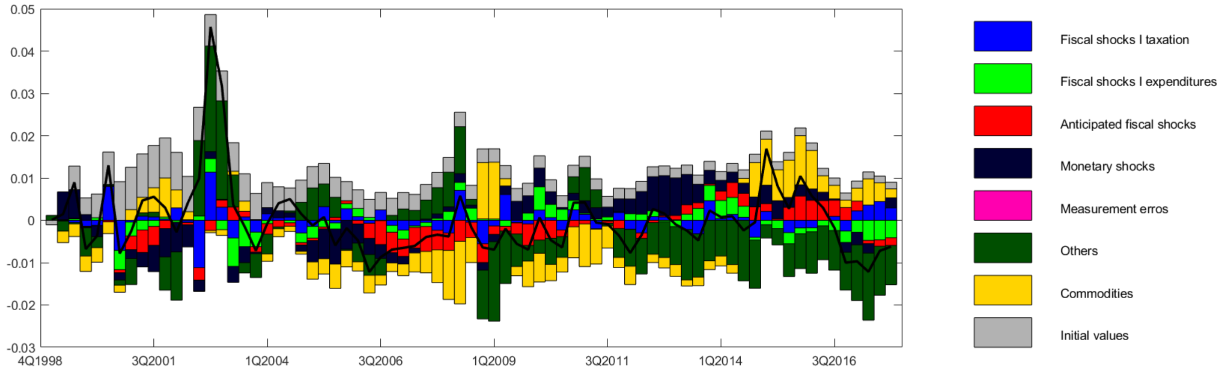
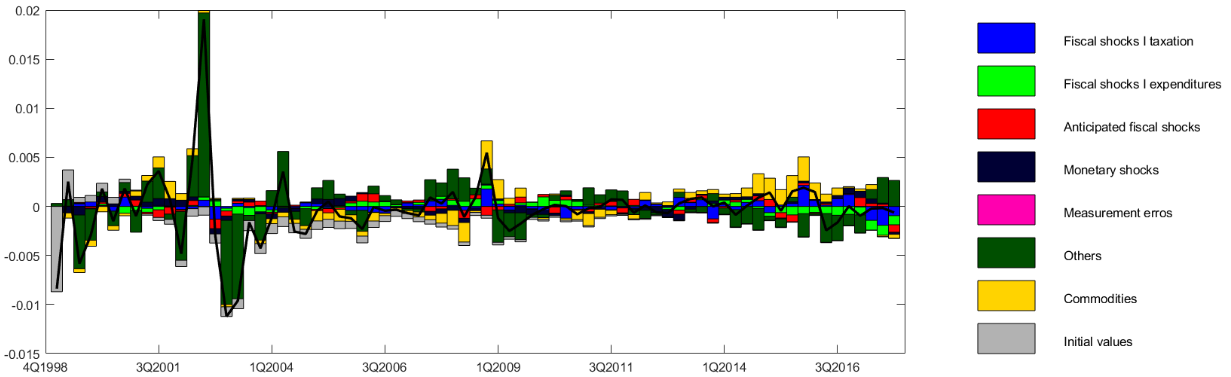
11 In this case, the growth rate is defined as $\ln(GDP_t) - \ln(GDP_{t-1})$, being 0,005 the quarterly growth rate throughout the balanced growth path. Analogous definitions are valid for the figures that show the decompositions for aggregate consumption and private investment.

Figure A16. Historical decomposition of inflation.



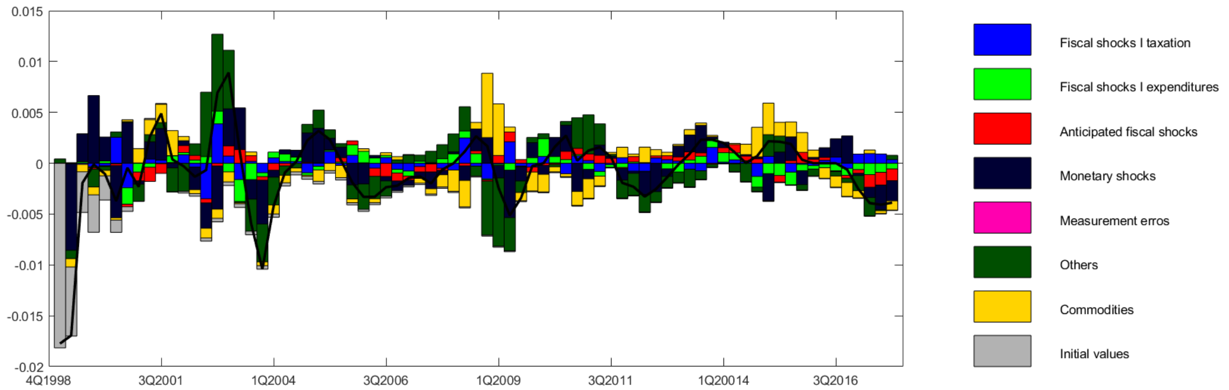

Source: Results obtained with Dynare package.

Figure A17. Historical decomposition of the risk premium variation rate




Source: Results obtained with Dynare package.

Figure A18. Historical decomposition of interest rate variation




Source: Results obtained with Dynare package.