Fiscal Policy Multipliers in a DSGE Model for Brazil*

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Abstract

This paper quantifies and compares the macroeconomic effects of shocks to different types of public expenditure – public investment, social transfers and public employees payroll – under various fiscal policy rules. The analysis is based on a medium-sized DSGE model developed and calibrated to represent the Brazilian economy. The model incorporates a realistic public sector capable of intervening in the economy through several channels; in particular, the model explicitly considers the existence of public employment. The main simulation results are:

- (i) shocks to social transfers spending increase output in the short run, but generate negative multipliers in the medium run under all fiscal rules considered;
- (ii) public investment multipliers may be negative in the short run but are always positive in the medium run;
- (iii) fiscal rules relying on distortionary taxation to balance the primary budget can lead to both lower output and higher inflation;
- (iv) policy rules based on a more protracted fiscal adjustment strategy may benefit economic activity in the short or medium run, but imply a higher adjustment cost in the long run.

Keywords: Fiscal policy, Fiscal multipliers, Disaggregation of taxes and expenditures, Public employment, DSGE modeling.

JEL Codes: E32, E62, H30.

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1. Introduction

The 2008 global crisis has renewed the interest of economists and policymakers in the use of fiscal policy instruments as a means to boost economic activity in the short and medium run. Under circumstances in which monetary policy had lost its effectiveness in compensating the adverse effects of the financial crisis on the real economy, countries affected by the global turmoil resorted to various kinds of fiscal stimulus to prevent further declines in real activity. According to OECD estimates, the sizes of the fiscal stimulus packages adopted to tackle the crisis in member countries reached an average of 2.5% of GDP in 2008-2009 (OECD, 2009). In Brazil, the countercyclical measures comprising tax cuts and increased public spending reached R\$ 43.4 billions (or about 1.4% of GDP) during the same period, according to Pires (2009).

Nevertheless, there is substantial uncertainty among economists on the effects of fiscal policy on economic activity – and, consequently, on the appropriateness and effectiveness of the fiscal stimulus measures adopted in reaction to the global crisis. Such uncertainty stems from the multiplicity of theoretical hypotheses on the possible macroeconomic effects of fiscal policy, as well as from the difficulties involved in the empirical estimation of such impacts.¹ As emphasized by Perotti (2007), “... perfectly reasonable economists can and do disagree on the basic theoretical effects of fiscal policies and on the interpretation of the existing empirical evidence”.

More recently, one issue that has received special attention in the literature is the analysis of the macroeconomic impacts of government spending. Such impacts have been investigated using mainly two approaches: structural vector autoregressive models (SVAR), as in Blanchard and Perotti (2002), Perotti (2005), Mountford and Uhlig (2009), Ilzetzky et al. (2010) and Mertens and Ravn (2010); and dynamic stochastic general equilibrium models (DSGE), as in Cogan et al. (2009), Forni et al. (2009), Leeper et al. (2010b,a), Stähler and Thomas (2012) and Woodford (2011), among others. In the context of DSGE models, recent studies of the macroeconomic impacts of public spending have built upon the pioneering works of Barro (1981), Aiyagari et al. (1992) and Baxter and King (1993) in several directions:

- (i) the introduction of nominal and real frictions, in line with medium-sized DSGE models developed a la Smets and Wouters (2007) (Cogan et al., 2009);
- (ii) the inclusion of non-ricardian agents in the economy (Galí et al., 2007);
- (iii) the introduction of lags in the implementation of public investment projects (Leeper et al., 2010b);

¹See, for instance, the surveys of Hemming et al. (2002), Spilimbergo et al. (2009) and Ramey (2011).

- (iv) the inclusion of different types of public spending and fiscal instruments (Forni et al., 2009, Stähler and Thomas, 2012);
- (v) the extension to the open economy case (Cardi and Muller, 2011);
- (vi) the analysis of the interactions between monetary and fiscal policy (Christiano et al., 2011, Davig and Leeper, 2011); and
- (vii) the investigation of different forms of financing fiscal deficits (Leeper et al., 2010a).

Various advancements in the study of fiscal multipliers have been achieved by DSGE models adapted to the Brazilian economy. The SAMBA model proposed by Castro et al. (2011) extends the theoretical framework found in Smets and Wouters (2007) and Christiano et al. (2005) to a small open economy that mirrors the Brazilian case; this goal is achieved by adding typical Brazilian characteristics such as the presence of regulated prices and agents with limited access to financial and credit markets. Carvalho and Valli (2011) and Monastier (2012) analyze the effects of different types of public spending (investment, consumption and social transfers) in models with non-ricardian agents and distortionary taxation. The work of Carvalho and Valli (2011), which introduces an extension of the NAWM model proposed by Christoffel et al. (2008), also investigates how to properly deal with public investment, in the context of a fiscal authority that pursues an explicit target for the primary surplus. Cavalcanti and Vereda (2011) adopt a government spending rule that reacts to the business cycle in a medium-sized DSGE model adapted to the Brazilian economy. Pro-cyclical fiscal rules are analyzed by Gadelha and Divino (2013) by means of an extension of the Galí et al. (2007) model. Mereb and Zilberman (2013) incorporate lags in the implementation of public investment to a simple RBC model. Barros and Lima (2013) follow Davig and Leeper (2011) and consider the occurrence of multiple fiscal and monetary policy regimes in a small new-Keynesian model.

These studies have allowed a better understanding of the macroeconomic impacts of public spending in Brazil, but there is still room for improvements. The aim of this study is to contribute to this literature in four basic directions. First, we present a calibrated DSGE model for the Brazilian economy that explicitly takes into account the presence of public employment, besides other forms of public spending already considered in previous studies. As noted by Stähler and Thomas (2012), the explicit consideration of public employment can significantly affect the analysis of fiscal multipliers, given that the civil servants' payroll usually accounts for an important share of government consumption as measured by national accounts. In the Brazilian case, this is likely to be an important concern, as the payroll of public servants amounted to about 60% of public consumption in the national accounts during the period 2007-2009. Second, our model incorporates a fairly detailed fiscal apparatus comprising several policy instruments both on the

taxation and spending sides; this allows the analysis of issues not addressed in previous studies for Brazil, based on models characterized by either simple fiscal structures or simple macroeconomic frameworks. Despite the difficulties inherent in using and interpreting more complex models, the greater level of detail of our model makes it more realistic and apt for the discussion of fiscal policy issues; furthermore, it allows analyzing sectoral and distributional implications of fiscal policy shocks, such as the different impacts of public investment and social transfers on the tradable and non-tradable sectors and the impacts of public employment shocks on the consumption levels of ricardian and non-ricardian households. Thirdly, the paper investigates government spending multipliers under different fiscal rules, amongst them rules requiring the maintenance of a balanced primary budget at all times – meaning that simulations performed under these rules reflect the fact that policymakers may have restricted ability or willingness to finance an increase in spending by issuing new debt. Such exercises illustrate the effects of reallocating resources among different types of expenditures and/or revenues; they also constitute an interesting benchmark for alternative ways of financing government expenditures. Finally, this study quantifies and compares fiscal multipliers pertaining to different types of public spending (public investment, social transfers and the payroll of public employees) for the Brazilian economy, both in the short and medium run.

Besides this introduction, the paper contains four sections. Section 2 describes the model and its calibration. In Section 3 we simulate the macroeconomic impacts of fiscal policy shocks under different policy rules. Section 4 analyzes the robustness of the simulation results to alternative model parameterizations. Section 5 concludes the paper and points to future research directions.

2. The Model

The model represents the main characteristics of the Brazilian economy by means of a dynamic general equilibrium model. In such models, the relationships among macroeconomic variables come from the solutions to utility and profit maximization problems faced by individuals and firms under technology and resource constraints. The basic theoretical framework is taken from Smets and Wouters (2003) and Christiano et al. (2005). Both papers have been highly influential in the development of medium-sized DSGE models worldwide. The SAMBA model, developed by the Central Bank of Brazil (BCB), is an outstanding example in the Brazilian scenario; its characteristics are described in Castro et al. (2011). Following the New Keynesian paradigm (see Woodford, 2003), the model displays the following main attributes:

- (i) agents that make decisions under the rational-expectations hypothesis;
- (ii) firms and individuals who are able to fix prices and wages due to the market power they possess;

- (iii) wage and price rigidity, which allow monetary policy to exert non-trivial effects over real variables; and
- (iv) real frictions (such as habit formation in consumption and adjustment costs of changing the capital stock and capacity utilization), which help to explain the various stylized facts on business cycle fluctuations. The extension to the open-economy case follows Dib (2011) and Medina and Soto (2006).

The model adds to this basic structure some typical features of emerging economies such as Brazil:

- (i) the presence of individuals excluded from financial and credit markets, who are therefore unable to smooth their consumption over time;
- (ii) the inclusion of a risk premium paid by conventional fixed income securities issued by the Brazilian government, that depends on the country's net foreign debt and is subject to external factors such as fluctuations in the risk appetite of international investors; and
- (iii) the adoption of a rule of thumb by firms that are prevented to choose optimal prices in any given period; according to this rule of thumb, non-optimal prices are adjusted automatically by a weighted average of past inflation and the inflation target pursued by the Central Bank.

The fiscal policy apparatus embedded in the model is based on Forni et al. (2009), Stähler and Thomas (2012), Castro et al. (2011) and Carvalho and Valli (2011). In this framework, the government collects lump-sum and distortionary taxes to finance its expenses. Distortionary taxes are levied on consumer spending, wages, capital income and imports of intermediate goods. Expenses include pure or conventional public consumption, public investment (which is converted into public capital), social transfers to the non-ricardian share of the population and wages paid to public employees. Allowing for the existence of public employment is an important feature of the model, since payments made to public employees constitute a substantial part of public consumption in Brazil.

2.1 Individuals

There are two types of individuals, ricardians and non-ricardians. Ricardian individuals supply labor, receive dividends (since they are the ultimate shareholders of firms) and accumulate physical capital. They also have access to financial markets, so that they can smooth consumption over time by borrowing and saving. Non-ricardian individuals do not participate in financial markets, so that they are constrained to spend all of the income earned in each period. Some of the non-ricardian individuals have government transfers as their only source of income, while others are allowed to provide homogeneous labor in a competitive

market. The measure of the ricardian population is 1, while the measures of the working and non-working non-ricardian populations are ζ^c and ζ^a , respectively. The share of ricardian (non ricardian) individuals in the population is $\frac{1}{1+\zeta}$ ($\frac{\zeta}{1+\zeta}$), where $\zeta = \zeta^c + \zeta^a$.

Each non-ricardian individual who does not work just lives on a transfer $TR_{i,t}^a$ paid by the government. Since this individual does not have any other source of income and is excluded from financial markets, it is true that:

$$P_t C_{i,t}^a = TR_{i,t}^a \quad (1)$$

where P_t and $C_{i,t}^a$ denote the price of the final good and the quantity consumed by the non-ricardian individual who does not work, respectively.

Non-ricardian individuals who work receive a wage W_t^c , which is paid by firms in exchange for the labor they supply, and a transfer $TR_{i,t}^c$, which is paid by the government. They are also excluded from financial markets, so that:

$$P_t C_{i,t}^c = (1 - \tau_t^w) W_t^c L_{i,t}^c + TR_{i,t}^c \quad (2)$$

where $C_{i,t}^c$, $L_{i,t}^c$, W_t^c and τ_t^w denote the quantity of the final good consumed by the non-ricardian worker, the quantity of non-ricardian labor supplied, the wage received by non-ricardian workers in exchange for their labor supply and, finally, the tax rate on labor income, which is fixed by the government. Non-ricardian individuals supply labor services that are homogeneous.²

The preferences of non-ricardian individuals exhibit habit formation, that is, the utility derived from consumption depends on the difference between each individuals consumption and per capita consumption of non-ricardian individuals who take part in labor markets.³ The 1st order condition that characterizes the optimal choice of $L_{i,t}^c$ is given by:

$$\left((1 - \tau_t^w) w_t^c L_{i,t}^c + w_t^m - h \frac{C_{t-1}^c}{\zeta^c} \right)^{-\sigma^c} (1 - \tau_t^w) w_t^c - \varepsilon_t^L (L_{i,t}^c)^{\sigma^L} = 0 \quad (3)$$

where C_{t-1}^c / ζ^c represents per capita consumption of non-ricardian individuals who work as measured at $t - 1$, while w_t^c and w_t^m stand for real non-ricardian wages

²The superscript c comes from the fact that non-ricardian individuals who work are constrained to consume only from their current income. We use the superscript l for variables related to ricardian individuals because their consumption is determined by the income they receive throughout their lives (lifetime income). The superscript a is used for variables related to non-ricardian individuals who do not work because their consumption is sustained by public transfers or social assistance (hence the superscript a). We also assume that transfers paid to all non-ricardian individuals are the same, that is, $TR_{i,t}^c = TR_{i,t}^a = W_t^m$ for all i and t .

³The instantaneous utility function that characterizes the preferences of non-ricardian individuals who take part of labor markets is almost identical to the one that is embedded in ricardian preferences (which is presented below). The only difference is the fact that non-ricardian individuals do not supply labor to the public sector.

and transfers, respectively. Since equation (3) depends only on variables that are the same for all non-ricardian individuals who take part in labor markets (except for $L_{i,t}^c$, which is specific to each individual), it follows that all non-ricardian individuals in this group supply the same amount of labor.

At period 0, the representative ricardian individual makes his decisions trying to maximize the expected value of current and future utilities, which is given by:

$$E_0 \sum_{t=0}^{\infty} \beta^t \varepsilon_t^B \left[\frac{(C_{i,t}^l - hC_{i,t-1}^l)^{1-\sigma_C}}{1-\sigma_C} - \varepsilon_t^L \frac{(L_{i,t}^l + L_{i,t}^g)^{1+\sigma_L}}{1+\sigma_L} \right] \quad (4)$$

where σ_C and σ_L are positive constants and β is a parameter between 0 and 1. $C_{i,t}^l$ and $C_{i,t-1}^l$ represent the i -th individual's consumption level at t and per capita consumption of ricardian individuals at $t-1$, while $L_{i,t}^l$ and $L_{i,t}^g$ stand for the quantities of labor supplied to the private sector and the government at t . Each ricardian individual supplies a special kind of labor, which is combined with the varieties provided by the other individuals to yield a basket of ricardian labor. Ricardian preferences also exhibit habit formation and are affected by two shocks, ε_t^B and ε_t^L ; the first shock affects the general level of utility achieved by the individual, while the second one affects only his willingness to work.

Decisions taken by ricardian individuals must satisfy the following budget constraint:

$$\frac{P_t^b B_{i,t}^l}{P_t} + \frac{e_t P_t^{b,*} B_{i,t}^{l,*}}{P_t} = \frac{B_{i,t-1}^l}{P_t} + \frac{e_t B_{i,t-1}^{l,*}}{P_t} + Y_{i,t}^l - C_{i,t}^l - \frac{\tilde{P}_t I_{i,t}^l}{P_t} - Tax_{i,t}^l \quad (5)$$

The variable $B_{i,t}^l$ ($B_{i,t}^{l,*}$) represents the quantity of one period bonds issued by the local government (by foreigners) that the representative ricardian individual holds in his portfolio at t . 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 product $P_t^b B_{i,t}^l$ ($e_t P_t^{b,*} B_{i,t}^{l,*}$) measures the amount invested in domestic (foreign) bonds at t , while the sum $B_{i,t-1}^l + e_t B_{i,t-1}^{l,*}$ measures the amount redeemed by the investor at t , period in which the portfolio of one period bonds bought at $t-1$ come due. All terms in the budget constraint are expressed in real terms, that is, nominal figures are divided by the price of the final good P_t .

The model follows Dib (2011) in that 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. The risk premium is given by $\theta_t = \varepsilon_t^\theta \exp\left(-\theta \frac{e_t B_{i,t}^{l,*}}{P_t Y_t}\right)$, where ε_t^θ is a shock reflecting exogenous changes in foreign investors' risk appetite. The risk premium also depends on 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.

Since the government collects taxes on consumption, there is a wedge between the price of the final good P_t and the price that producers actually receive ($\tilde{P}_t$). Given the consumption tax rate τ_t^c , the relationship between the two is such that $P_t = (1 + \tau_t^c)\tilde{P}_t$. The term $\frac{\tilde{P}_t I_{i,t}^l}{P_t}$ (which can be written as $\frac{1}{1+\tau_t^c} I_{i,t}^l$) denotes the investment in physical capital made by the i -th ricardian individual; this figure is expressed in real terms and reflects the hypothesis that no indirect taxes are paid on purchases of investment goods, so that the price index of investment goods is the wholesale price $\tilde{P}_t$ (Forni et al., 2009). The variable $Tax_{i,t}^l$ denotes lump sum taxes paid by the i -th ricardian individual.

The variable $Y_{i,t}^l$ denotes real income received by the i -th ricardian individual at period t . It is given by:

$$Y_{i,t}^l = (1 - \tau_t^w) (w_{i,t}^l L_{i,t}^l + w_t^g L_t^g) + (1 - \tau_t^k) (r_t^k z_{i,t}^l K_{i,t-1}^l - \Psi(z_{i,t}^l) K_{i,t-1}^l + Div_{i,t}^l) - \tau_t^k \Psi(z_{i,t}^l) K_{i,t-1}^l + A_{i,t}^l \quad (6)$$

The variable $A_{i,t}^l$ represents net income coming from an insurance contract that protects the individual against undesired fluctuations in total income. In practice, this contract makes all ricardian individuals face the same budget constraint, inducing them to make the same decisions regarding consumption, labor and investment. The term $(1 - \tau_t^w) (w_{i,t}^l L_{i,t}^l + w_t^g L_t^g)$ represents real after-tax labor income, which comes from labor supplied to the private sector and from public services absorbed by the government. The real wage $w_{i,t}^l = \frac{W_{i,t}^l}{P_t}$ is specific to each ricardian individual (hence the subscript i), since each of them provides a special kind of labor. The other real wage $w_t^g = \frac{W_t^g}{P_t}$ is fixed as a proportion of the general level of the real wage paid by the private sector to ricardian individuals, that is, $W_t^g = v^g W_t^l$, where $v^g > 1$. We assume that every ricardian individual supplies the same amount of labor to the public sector ($L_{i,t}^g = L_t^g$) and that the government freely decides the amount supplied by each ricardian individual. There is an implicit simplifying assumption that ricardian individuals prefer to work for the public sector, so that they are always willing to offer the amount of labor the government demands.

Income from investments in physical and financial capital is also taxed; the tax rate on capital income is given by τ_t^k . The variable $Div_{i,t}^l$ represents profits paid by firms; this variable does not really depend on i because ricardian individuals have the same stake in all firms. The term $r_t^k z_{i,t}^l K_{i,t-1}^l - \Psi(z_{i,t}^l) K_{i,t-1}^l$ denotes income received by the i -th ricardian individual when he rents physical capital. Ricardian individuals decide how much capital to accumulate, the extent to which the available stock is used ($z_{i,t}^l$) and the speed with which this stock grows (that

depends on $I_{i,t}^l$). The term $r_t^k z_{i,t}^l K_{i,t-1}^l$ represents revenues achieved by renting physical capital, which are equal to the product of the rate of return on capital (r_t^k) and the capital stock actually used by firms ($z_{i,t}^l K_{i,t-1}^l$). There is also a cost arising from an abnormal use of the capital stock, which is paid whenever $z_{i,t}^l$ is different from one; this cost is measured by $\Psi(z_{i,t}^l) K_{i,t-1}^l$. The evolution of the capital stock obeys the following equation:

$$K_{i,t}^l = K_{i,t-1}^l (1 - \delta) + I_{i,t}^l \left(1 - S \left(\varepsilon_t^I \frac{I_{i,t}^l}{I_{i,t-1}^l} \right) \right) \quad (7)$$

where δ is the depreciation rate. The function S establishes an adjustment cost, which is switched off in the absence of shocks that raise the cost of accumulating physical capital or when investment does not change over time. Investment shocks are captured by ε_t^I ; if there are no investment shocks, $\varepsilon_t^I = 1$. The ratio $\frac{I_{i,t}^l}{I_{i,t-1}^l}$ is also equal to one when investment in physical capital does not change over time. These circumstances make the value of S become zero (i.e. $S(1) = 0$), allowing investment to be fully converted into physical capital. There is also the assumption that the first derivative of S with respect to its argument is zero in steady-state, which makes the costs of adjusting physical capital depend only on the second derivative of S . Another assumption is that expenses coming from the sub (super) utilization of the stock of physical capital can not be deducted from the tax basis.

In summary, the representative ricardian individual must choose the paths of $\{B_{i,t}^l, B_{i,t}^{l,*}, C_{i,t}^l, W_{i,t}^l, z_{i,t}^l, I_{i,t}^l, K_{i,t}^l\}$ in order to maximize the value of (4) subject to (5), (6) and (7). The variable $W_{i,t}^l$ belongs to the set of variables chosen by the ricardian individual, since he is the only person providing labor of type i in the entire economy, and therefore has monopoly power over this labor type. When setting the value of the wage he wants to receive, the representative ricardian individual takes into account the fact that the demand for labor of type i is a decreasing function of $W_{i,t}^l$.

2.2 Firms

Firms can be divided into two sectors, wholesale and retail. Each firm of the wholesale sector produces a differentiated intermediate good that is subsequently used by firms of the retail sector to produce the final good. Firms of the final good (or retail) sector operate in a perfect competition environment. They apply a technology involving two stages of production: in the first stage, firms combine a continuum of intermediate goods to form two distinct baskets, which are called tradable (T) and non-tradable (NT); in the second stage, firms combine these two baskets to manufacture the final good. A fraction of tradable baskets are exported before the second stage is performed. The final good can be consumed by ricardian, non-ricardian individuals and the government; they can also be transformed into

physical capital by ricardian individuals or the government.

Firms in the intermediate goods (or wholesale) sector operate in a monopolistic competition environment. 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, while the second one includes firms whose production will not be shipped abroad after manufacturing. This structure justifies the usage of the tradable and non-tradable terminology to identify each sub-sector, although the production of the first sub-sector (which is the tradable one) is not directly exported.

Intermediate goods firms transform capital, imported inputs and a labor aggregate into intermediate goods. Each intermediate good is produced by a single firm. Capital may be public or private, with public capital being exogenously determined by the government. Public capital, which is made available at zero cost to all firms, is assumed to be productivity-enhancing (Baxter and King, 1993, Leeper et al., 2010b, Carvalho and Valli, 2011). The production function employed by intermediate goods firms is given by:

$$Y_{j,s,t} = A_t^s (v(L_t^g) K_{t-1}^g)^{\eta_g^s} \tilde{K}_{j,s,t}^{\eta_K^s} L_{j,s,t}^{\eta_L^s} Q_{j,s,t}^{1-\eta_K^s-\eta_L^s} \quad (8)$$

where $Y_{j,s,t}$ represents the quantity of the j -th intermediate good produced by the corresponding firm of sub-sector s ($s : T, NT$), A_t^s is a productivity shock that is common to all firms of sub-sector s , K_{t-1}^g is the public capital stock available at period t , $\tilde{K}_{j,s,t}$ is the stock of private capital employed by the j -th firm of sub-sector s at period t ($\tilde{K}_{j,s,t} = z_t^l K_{j,s,t-1}^l$), $L_{j,s,t}$ is the quantity of the labor aggregate employed by this firm at period t and $Q_{j,s,t}$ denotes the quantity of baskets of imported goods that the j -th firm of sub-sector s uses at period t . The parameter $\eta_g^s \in [0, 1)$ measures by how much public capital enhances the productivity of intermediate goods firms. Public capital can be interpreted as infrastructure provided by the government to firms; its quantity evolves according to the following law of movement:

$$K_t^g = (1 - \tilde{\delta}) K_{t-1}^g + \tilde{v}(L_t^g) I_{t-n}^g \quad (9)$$

Equation (9) implies that it takes n periods for public investment to turn into capital and become fully productive. This formulation is simpler than the time to build approach used, among others, by Leeper et al. (2010b) and Mereb and Zilberman (2013), although it yields similar results in the analysis of fiscal shocks.⁴ We also allow labor used by the public sector to affect the dynamics of K_t^g in (9), by exerting an amplifying effect on government investment, and to affect total factor productivity in (8) (see the terms $\tilde{v}(L_t^g)$ and $v(L_t^g)$).⁵

⁴See the sensitivity analysis in Section 4.

⁵These effects are hard to estimate or calibrate. In our simulation exercises in section 3, we therefore ignore such effects by adopting the simplifying assumption that $v(L_t^g) = \tilde{v}(L_t^g) = 1$.

An important feature of the model is the fact that labor is differentiated along two dimensions: first, ricardian labor is different from non-ricardian labor; second, each ricardian individual supplies a special variety of ricardian labor, which firms mix with other varieties in order to obtain the ricardian labor basket. It is therefore interesting to discuss in some detail how these different types of labor are combined to obtain the labor aggregate employed by intermediate goods firms.

As previously discussed, non-ricardian individuals supply labor that is homogeneous, so that the quantity of labor provided by the i -th non-ricardian individual to the j -th firm of sub-sector s at period t is simply $L_{i,j,s,t}^c = L_{j,s,t}^c / \zeta^c$, where $L_{j,s,t}^c$ represents total demand for non-ricardian labor coming from the j -th firm. Ricardian individuals, in turn, supply different types of labor that are demanded by each firm j of sub-sector s according to the solution to the following optimization problem:

$$\begin{aligned} \min_{\{L_{i,j,s,t}\}} & \int_0^1 W_{i,t}^l L_{i,j,s,t}^l di \\ \text{st} & \left[\int_0^1 (L_{i,j,s,t}^l)^{\frac{1}{1+\mu_w}} di \right]^{1+\mu_w} = L_{j,s,t}^l \end{aligned} \quad (10)$$

where $W_{i,t}^l$ is the wage charged by the i -th ricardian individual at period t , $L_{i,j,s,t}^l$ is the quantity of labor supplied by this individual to the j -th firm of sub-sector s at period t and $L_{j,s,t}^l$ represents total demand for ricardian labor coming from this firm at the same time. The relative demands of ricardian and non-ricardian labor by firm j of sub-sector s at period t come from the solution to the following optimization problem:

$$\begin{aligned} \min_{\{L_{j,s,t}^l, L_{j,s,t}^c\}} & W_t^l L_{j,s,t}^l + W_t^c L_{j,s,t}^c \\ \text{st} & (L_{j,s,t}^l)^{\frac{1}{1+a}} = (\varphi)^{\frac{a}{1+a}} (L_{j,s,t}^l)^{\frac{1}{1+a}} + (1-\varphi)^{\frac{a}{1+a}} (L_{j,s,t}^c)^{\frac{1}{1+a}} \end{aligned} \quad (11)$$

where W_t^l is the average wage paid to ricardian individuals and W_t^c is the single wage paid to all non-ricardian individuals who engage in working activities. The combination of different types of ricardian labor results in the following demand function for the variety supplied by the i -th ricardian individual at period t :

$$L_{i,t}^l = \left(\frac{W_{i,t}^l}{W_t^l} \right)^{-\frac{1+\mu_w}{\mu_w}} L_t^l \quad (12)$$

According to (12), the quantity of labor supplied by the i -th ricardian individual ($L_{i,t}^l$) depends on the total amount of ricardian labor demanded by intermediate goods firms (L_t^l) and on the relative cost of labor of type i , which is measured by the ratio between the wage charged by the i -th ricardian individual ($W_{i,t}^l$) and

the average wage charged by ricardian individuals (W_t^l). Expressions analogous to (12) guide the choice between ricardian and non-ricardian labor:

$$L_t^l = \varphi \left(\frac{W_t^l}{W_t} \right)^{-\frac{1+a}{a}} L_t \quad (13)$$

$$L_t^c = (1 - \varphi) \left(\frac{W_t^c}{W_t} \right)^{-\frac{1+a}{a}} L_t \quad (14)$$

According to (13), the quantity of ricardian labor demanded by intermediate goods firms depends on the total amount of the labor aggregate they intend to use (L_t) and on the relative cost of ricardian labor, which is given by the ratio between the average ricardian wage (W_t^l) and the general wage level of the economy (W_t). The parameter φ measures the importance of ricardian labor in the production of the labor aggregate L_t used by intermediate goods firms, while the parameter a quantifies the degree of substitutability between ricardian and non-ricardian labor (recall the constraint of problem (11)). Equation (14) can be interpreted in the same way.

The price of one unit of the basket of imported goods in the domestic currency ($P_{T,t}^X$) is the product of the exogenous international price ($\tilde{P}_{T,t}^*$), the nominal exchange rate (e_t) and the gross tax rate on imports ($1 + \tau_t^X$):

$$P_{T,t}^X = (1 + \tau_t^X) e_t \tilde{P}_{T,t}^* \quad (15)$$

We also assume that foreign demand for the basket of tradable goods produced by domestic firms (denoted by $Y_{T,t}^*$) is given by the following equation:

$$Y_{T,t}^* = \left(\frac{\tilde{P}_{T,t}}{e_t \tilde{P}_t^*} \right)^{-\frac{1+\tau^*}{\tau^*}} Y_t^* \quad (16)$$

In the expression above, $\tilde{P}_{T,t}$ represents the price of the basket of tradable goods in the domestic currency, Y_t^* is a measure of international economic activity (taken as exogenous) and $e_t \tilde{P}_t^*$ is the foreign producer price level (also taken as exogenous) converted to the domestic currency by the nominal exchange rate e_t . This formulation, which follows Medina and Soto (2006) and Dib (2011), reflects the fact that domestic producers are unable to charge different prices at home and abroad.

2.3 Wage and price setting

Firms in the intermediate goods sector enjoy some degree of market power, so that they are able to choose prices. We suppose that price rigidity follows the Calvo (1983) hypothesis: at each period, a constant proportion of intermediate

goods firms (given by $1 - \alpha_P^s$; $s = T, NT$) is randomly selected to set new prices, while the other firms (a proportion α_P^s) simply follow a rule of thumb by which prices are adjusted according to past inflation, as follows:

$$\tilde{P}_{j,s,t} = \left(\frac{\tilde{P}_{t-1}}{\tilde{P}_{t-2}} \right)^{\gamma_P^s} \tilde{P}_{j,s,t-1} \quad (17)$$

where the ratio $\tilde{P}_{t-1}/\tilde{P}_{t-2}$ represents the gross producer inflation rate observed at $t-1$ and γ_P^s measures the degree of indexation to past inflation prevailing among intermediate goods firms of sub-sector s . The solution to the problem faced by intermediate goods firms who can choose optimal prices at period t is such that all firms choose the same price $\tilde{P}_{s,t}^{opt}$. As a result, the price level prevailing at sub-sector s evolves according to the following law of movement:

$$\tilde{P}_{s,t}^{-\frac{1}{\mu_s}} = (1 - \alpha_P^s) \left(\tilde{P}_{s,t}^{opt} \right)^{-\frac{1}{\mu_s}} + \alpha_P^s \tilde{P}_{s,t-1}^{-\frac{1}{\mu_s}} \left(\frac{\tilde{P}_{t-1}}{\tilde{P}_{t-2}} \right)^{-\frac{\gamma_P^s}{\mu_s}} \quad (18)$$

Linearizing this expression around a zero inflation steady state generates New-Keynesian Phillips curves that are valid for each sub-sector s .

Wage-setting by ricardian individuals follows the same lines. At each period, individuals may either be randomly selected to set new optimal wages, with probability α_W , or simply adjust their previous wages according to past inflation. The solution to the problem of choosing optimal wages generates a law of motion analogous to (18); this equation generates a wage Phillips Curve after linearization.

2.4 Resources constraint

At the macroeconomic level, the equality between resources and destinations can be derived from the budget constraints of individuals (ricardian and non-ricardian) and the government. This requirement generates the following equilibrium condition:

$$Y_t = C_t^l + C_t^c + C_t^a + I_t^l + I_t^g + G_t + \Psi(z_t^l) K_{t-1}^l \quad (19)$$

Equation (19) takes into account the fact that only ricardian individuals accumulate physical capital. The stock of public capital at period t comes from investments made by the government (I_t^g), which are taken as exogenous. Government spending G_t is also an exogenous variable. The last term of equation (19) takes into account the cost of moving away from full utilization of private capital. Equation (19) also reflects the fact that the balance of payments of the domestic economy must be in equilibrium at all periods (that is, its result is always zero).

2.5 Monetary policy

The linearized monetary policy rule is given by:

$$\hat{R}_t = \phi_R \hat{R}_{t-1} + (1 - \phi_R) \left(\phi_\pi (E_t (\pi_{t+p}) - \bar{\pi}_t) + \phi_Y E_t (\hat{Y}_{t+z}) \right) + \hat{\varepsilon}_t^m \quad (20)$$

This rule establishes that the one-period nominal interest rate depends on an inertial component, on the expected deviation of inflation from a target chosen by monetary authorities and on the expected deviation of output from its steady-state value. Besides an exogenous i.i.d. monetary policy shock $\hat{\varepsilon}_t^m$. Subscripts p and z are integer numbers that may assume any value. When $p = q = 0$, the one-period nominal interest rate reacts to the current deviation between the inflation rate and its target, and to the contemporaneous deviation between output and its steady-state level. If $p > 0$ and $q > 0$ ($p < 0$ and $q < 0$), then the monetary policy instrument depends on expected (past) deviations, thus being forward-looking (backward-looking).

2.6 Fiscal policy

The government controls nine fiscal policy instruments: lump-sum taxes paid by ricardian individuals (Tax_t^l); taxes on consumption, labor income, capital income, and imports of intermediate goods ($\tau_t^c, \tau_t^w, \tau_t^k$ and τ_t^X , respectively); government consumption of goods and services (G_t); public investment (I_t^g); transfers paid to non-ricardian individuals (w_t^m) and public sector employment (L_t^g).

The government budget constraint states that:

$$SP_t = R_{t-1} \frac{D_{t-1}^l}{P_t} - \frac{D_t^l}{P_t} \quad (21)$$

where SP_t represents the real primary surplus, D_t^l is the nominal value of outstanding public debt at period t and R_{t-1} is the gross nominal interest rate at period $t - 1$.⁶ The primary surplus is given by:

$$\begin{aligned} SP_t = & \frac{1}{1 + \tau_t^{c,*}} \tau_t^X e_t^r \tilde{p}_{T,t}^* Q_t + \tau_t^w (w_t L_t + w_t^g L_t^g) + \tau_t^k (r_t^k z_t^l K_{t-1}^l + Div_t^l) \\ & + Tax_t^l + \frac{\tau_t^c}{1 + \tau_t^c} (C_t^l + C_t^c + C_t^a) + \frac{\tau_t^c}{1 + \tau_t^c} G_t + \frac{\tau_t^c}{1 + \tau_t^c} \Psi(z_t^l) K_{t-1}^l \\ & - G_t - w_t^g L_t^g - \zeta w_t^m - \frac{1}{1 + \tau_t^c} I_t^g \end{aligned} \quad (22)$$

⁶The nominal value of outstanding public debt at period t is given by $D_t^l = P_t^b B_t^l$, where P_t^b is the price of a one-period bond issued by the government at period t ; such a bond promises to pay \$1 at its redemption date. The variable B_t^l is the quantity of one-period bonds purchased by ricardian individuals at period t . The nominal value of public debt at period $t - 1$ is given by D_{t-1}^l ; this value is given by \$1 $\times$ B_{t-1}^l , that is, the face value of a one-period bond (\$1) multiplied by the quantity of bonds issued by the government at period $t - 1$ (B_{t-1}^l).

In (22), terms with a negative sign denote government expenses. The sixth term represents taxes collected from the government itself, since it consumes a certain quantity of the final good. The seventh term comes from the costs paid by ricardian individuals when they depart from full utilization of the private capital stock.

Fiscal policy instruments evolve according to the general formulation below:

$$\hat{X}_t = \rho_X \hat{X}_{t-1} + \epsilon_t^X \quad (23)$$

where $\hat{X}_t = \{\hat{T}ax_t^l, \hat{I}_t^g, \hat{L}_t^g, \hat{\tau}_t^c, \hat{\tau}_t^w, \hat{\tau}_t^k, \hat{\tau}_t^\times, \hat{G}_t, \hat{w}_t^m\}$ and ϵ_t^X is an i.i.d. shock.

Ceteris paribus, given a positive shock to one of the expenditure items above, the primary surplus would decrease and this would lead to an increase in public debt. To prevent the public debt from exploding, the government must either reduce expenditures or increase taxation. There are many possible fiscal rules that ensure that the economy will return to its steady-state equilibrium. In this paper, we consider rules that vary along two dimensions. Firstly, given a shock that decreases the primary surplus, the government may either

- (i) increase the tax rates on capital and labor income (proportionately); or
- (ii) decrease spending on government consumption of goods and services.

Secondly, the fiscal instrument may be managed to either

- (i) guarantee a permanently balanced primary budget or
- (ii) make the primary surplus gradually converge back to its steady-state value. This results in four possible rules:⁷

- Fiscal rule I: permanently balanced primary budget; fiscal adjustment met by increasing distortionary taxation.
- Fiscal rule II: permanently balanced primary budget; fiscal adjustment met by reducing public consumption of goods and services.
- Fiscal rule III: partial adjustment of primary deficits; fiscal adjustment met by increasing distortionary taxation.
- Fiscal rule IV: partial adjustment of primary deficits; fiscal adjustment met by reducing public consumption of goods and services.

⁷In line with the current practice in the conduct of Brazilian fiscal policy, these rules have the primary surplus as their target. However, by themselves, such rules do not guarantee the stability of the public debt, since the public deficit measured in nominal terms also depends on interest payments – which vary with accumulated debt and interest rate changes. In order to ensure the stability of the model and, at the same time, be consistent with fiscal policymaking in Brazil, all fiscal rules include a direct reaction to deviations of the public debt from its steady-state value, with a sufficiently long lag (60 periods), so as not to affect the model's impulse response functions in the relevant time horizon (20 periods).

2.7 Model calibration and solution

As in Stähler and Thomas (2012), the model is calibrated so as to reproduce the main macroeconomic aggregates and ratios observed in Brazil in recent years, which supposedly reflect a steady-state equilibrium. Values for some of the model parameters are taken from the relevant national and international literature; for a review of this literature, see Cavalcanti and Vereda (2011).

Table 1 presents the basic parameterization used in our simulations. Table 2 shows the resulting macroeconomic ratios valid in steady-state.

Monetary policy is conducted by means of a Taylor rule in which the nominal interest rate reacts to its first lag, to the current deviation between the inflation rate and its target, and to the gap between observed output and its steady-state level (that is, in equation (20) we have $p = q = 0$).

For fiscal policy simulations, one of the most important parameters of the model is η_g , the weight of public capital in the Cobb-Douglas production function of intermediate goods firms. Leeper et al. (2010b) propose two alternative values for this parameter, 0.05 and 0.10; other authors adopt lower values – Stähler and Thomas (2012), for example, use $\eta_g = 0.015$. We fix the basic parameter value at 0.05, but also test two alternative values in the sensitivity analysis section, 0.02 and 0.08.

We assume $n = 6$ in equation (9), implying that public investment takes 6 periods to become fully productive; in other words, there is a six period lag between public investment and its conversion into public capital. Given the uncertainty about the shapes of $\tilde{v}(L_t^g)$ and $v(L_t^g)$, we assume that both functions are equal to 1 at all feasible values of L_t^g ; this means that public employment does not have direct impacts on either capital accumulation (see (9)) or total factor productivity (see (8)).

The parameter that measures the persistence of fiscal instruments (ρ_X , see (23)) is specified at 0.89, which implies that fiscal policy shocks have a half-life of 6 quarters. Given the nature of the shocks considered, which involve public sector measures with effects that usually last more than one year, this degree of persistence seems reasonable. For some types of spending, an even higher degree of persistence might seem appropriate; we therefore experiment with higher values of ρ_X in section 4.

Another parameter that may have a significant impact on the response of the economy to fiscal shocks is ζ , which controls the size of the non-ricardian population. Its value is set at 0.66, which implies that 40% of the population has limited access to credit markets; this is precisely the hypothesis adopted in the SAMBA model. In our model, we must additionally specify the relative sizes of the working and non-working fractions of the non-ricardian population. We set the proportion of the working fraction of the non-ricardian population at 60%, and in the sensitivity section test two alternative values: 40% and 80%.

The process of solving the model follows techniques described in Smets and

Table 1
Calibrated parameter values

Parameter	Description	Value
ζ_c	Size of non-ricardian working population	0,40
ζ_a	Size of non-ricardian non-working population	0,26
σ_C	Absolute value of the elasticity of the marginal utility of consumption with respect to consumption	1,2
σ_L	Elasticity of the marginal disutility of labor with respect to labor	2,0
β	Intertemporal discount factor	0,9875
θ	Sensitivity of the risk premium with respect to the debt/output ratio	1,1
δ	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
$\nu = \left(\frac{\partial^2 S}{\partial (\arg S)^2} \Big _{SS} \right)^{-1}$	Measure of the convexity of function S, which imposes costs to the adjustment of the capital stock	0,15
$\frac{d^2 \Psi}{d(z_t^l)^2} \Big _{SS} / \frac{d\Psi}{dz_t^l} \Big _{SS}$	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 ($\bar{z}^l = 1$)	5,92
α_P^T	Proportion of firms in the tradable goods sector that are unable to choose optimal prices in a given period	0,5
γ_P^T	Degree of price indexation prevailing at the tradable sector	0,47
α_P^{NT}	Proportion of firms in the non-tradable goods sector that are unable to choose optimal prices in a given period	0,5
γ_P^{NT}	Degree of price indexation prevailing at the non-tradable sector	0,47
α_W	Proportion of ricardian individuals who are unable to choose optimal wages in a given period	0,6
γ_W	Degree of wage indexation prevailing among ricardian individuals	0,7

Table 1
Calibrated parameter values (cont'd)

Parameter	Description	Value
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	0,425
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	0,4
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	0,25
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	0,65
μ_w	Parameter that measures the degree of substitution between the different kinds of labor supplied by ricardian individuals	0,5
η_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
γ	Parameter that measures the importance of tradables goods in the production function used by firms manufacturing the final good	0,32
η	Parameter that measures the degree of substitution between tradable and non-tradable aggregates in the production of the final good	2,0
φ	Parameter that measures the importance of ricardian labor in the labor aggregate used by intermediate goods firms	0,65
μ_T	Parameter that measures the degree of substitution between the various kinds of tradable goods used in the production of the tradable aggregate	0,1
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	0,2
τ^*	Sensitivity of the foreign demand for tradable goods manufactured in the domestic economy with respect to its relative price	10
ρ_X	Degree of persistence of fiscal policy instruments	0,89

Table 2
Steady-state ratios for main macroeconomic aggregates

$(\bar{C} + \bar{G})/\bar{PIB}$	Ratio between total consumption and output	0,82
$\bar{C}/\bar{PIB}$	Ratio between total private consumption and output	0,62
$\bar{C}^l/\bar{PIB}$	Ratio between total ricardian consumption and output	0,35
$\zeta\bar{C}^c/\bar{PIB}$	Ratio between total non-ricardian consumption and output	0,27
$(\bar{G} + \bar{w}^g\bar{L}^g)/\bar{PIB}$	Ratio between total government consumption and output	0,21
$\bar{G}/\bar{PIB}$	Ratio between pure government spending (purchases of goods and services) and output	0,07
$\bar{w}^g\bar{L}^g/\bar{PIB}$	Ratio between the real value of the payroll of public servants and output	0,13
$\bar{I}/\bar{PIB}$	Ratio between aggregate investment and output	0,18
$\bar{I}^l/\bar{PIB}$	Ratio between private investment and output	0,16
$\bar{I}^g/\bar{PIB}$	Ratio between public investment and output	0,02
$(\bar{Y} + \bar{w}^g\bar{L}^g)/\bar{PIB}$	Ratio between total domestic absorption and output	1,00
$\bar{p}_T\bar{Y}_T^*/\bar{PIB}$	Ratio between the real value of exports and output	0,10
$\bar{p}_T^x\bar{Q}/\bar{PIB}$	Ratio between the real value of imports and output	0,10
$(\bar{w}\bar{L} + \bar{w}^g\bar{L}^g)/\bar{PIB}$	Real labor income as a proportion of output	0,53
$\bar{w}\bar{L}/\bar{PIB}$	Real labor income paid by the private sector as a proportion of output	0,40
$\bar{w}^g\bar{L}^g/\bar{PIB}$	Real labor income paid by the public sector as a proportion of output	0,13
$\bar{w}^c\bar{L}^c/\bar{PIB}$	Real labor income received by non-ricardian workers as a proportion of output	0,15
$(\bar{w}^l\bar{L}^l + \bar{w}^g\bar{L}^g)/\bar{PIB}$	Real labor income received by ricardian workers as a proportion of output	0,38

Table 2
Steady-state ratios for main macroeconomic aggregates (cont'd)

$\left(\frac{\bar{Y}}{1+\bar{\tau}^c} - \bar{w}\bar{L} + \bar{B}\bar{C}\right)/\bar{P}\bar{I}\bar{B}$	Real capital income as a proportion of output	0,31
$\frac{\bar{\tau}^c}{1+\bar{\tau}^c}(\bar{C} + \bar{G}) + \frac{\bar{\tau}^x}{1+\bar{\tau}^{c,*}}\bar{e}^r\bar{p}_T^*\bar{Q}$	Excise taxes + import taxes as a proportion of output	0,16
$\zeta\bar{w}^m/\bar{P}\bar{I}\bar{B}$	Social transfers received by non-ricardian individuals as a proportion of output	0,16
$\bar{\tau}_w(\bar{w}\bar{L} + \bar{w}^c\bar{L}^c)/\bar{P}\bar{I}\bar{B}$	Taxes levied on labor income as a proportion of output	0,12
$\bar{\tau}^k\left(\frac{\bar{Y}}{1+\bar{\tau}^c} - \bar{w}\bar{L} + \bar{B}\bar{C}\right)/\bar{P}\bar{I}\bar{B}$	Taxes levied on capital income as a proportion of output	0,07
$\bar{T}/\bar{P}\bar{I}\bar{B}$	Lump-sum taxes as a proportion of output	0,01
$\bar{Y}^T/\bar{Y}^{NT}$	Ratio between total productions of the tradable and non-tradable sectors	0,78
$\bar{K}/\bar{P}\bar{I}\bar{B}$	Capital stock as a proportion of output	2,28

Wouters (2003), Christiano et al. (2005) and Medina and Soto (2006), among others. These techniques are implemented by the DYNARE software, which embeds a set of routines developed by researchers from CEPREMAP (Centre pour la Recherche Economique et ses Applications); they are all executed by the MATLAB software.

3. Simulating the Effects of Fiscal Policy Shocks

In this section we analyze the effects of shocks to three types of public spending: public sector employment (LG), transfers to non-ricardian individuals (WM) and public investment (IG). All shocks are standardized so that their magnitude amounts to 1% of steady-state GDP. All figures presented below depict the effects of these shocks upon 12 macroeconomic variables: GDP (y), total private consumption (c), private investment (i), total labor supplied to the private sector (l), consumer inflation (p), nominal interest rate (r), average private sector real wage (w), ratio between average wages paid to ricardian and non-ricardian individuals (wr), consumption of ricardian individuals (cl), consumption of non-ricardian individuals (cc), the ratio between the labor supply of ricardian and non-ricardian individuals to the private sector (lr) and the ratio between the output levels of the tradable and non-tradable sectors (yr).

Figure 1 shows impulse responses under fiscal policy rule I, according to which

the government maintains a permanently balanced primary budget by managing distortionary taxation (tax rates on capital and labor income).

Figure 1

Responses to shocks in public expenditures under fiscal policy rule I (permanently balanced primary budget; fiscal adjustment met by increasing distortionary taxation).

WM/blue line: shock to social transfers; IG/green line: shock to public investment;

LG/red line: shock to public employment.

A WM shock leads to an instantaneous 0,85% increase in GDP, with a corresponding impact multiplier slightly below 1. This positive effect is partly explained by the higher income that accrues to non-ricardians, who increase consumption and therefore drive up demand for goods; as a result, production by firms also goes up. Given the positive wealth effect from increased social transfers, non-ricardian labor supply decreases, which drives up their real wage and increases the relative demand for ricardian labor. The higher labor demand by firms is accommodated by an increase in labor supply by ricardian individuals, who try to compensate for expected higher taxation in the future (and thus smooth their consumption path). Note that the higher contemporaneous level of economic activity automatically expands the tax base and generates higher tax revenues for the government, so that there is no immediate need to raise tax rates. However, as production expands and the average real wage rises, marginal costs and inflation go up, which leads to an increase in interest rates by the central bank. The higher production and capital costs drive investment down, and therefore also future capital stock levels. This means that the initial increase in production (and in the tax base) is not sustainable, and that the higher level of government expenditure will have

to be met by higher tax rates in the future. In the subsequent quarters, as the interest rate is kept high and the government raises tax rates on capital and labor income, investment moves further down, and so does labor supply by ricardians; non-ricardian consumption also gradually decreases, as a result of lower transfers and higher labor taxation. Consequently, GDP falls and soon finds itself below its steady-state level (from the 3rd quarter after the shock onwards). After one year, the cumulative multiplier of total spending (cumulative deviation of GDP from steady-state divided by the cumulative deviation of total public spending from steady-state)⁸ is only 0,47; after three years, it becomes negative (see Table 3, line 1).

The WM shock has clear distributional consequences, as it implies resources transfers from ricardians to non-ricardians. The former must bear most of the costs of fiscal adjustment, which falls upon both labor and capital income, and see their average real wage decline relative to non-ricardian wage (see the *wr* graph in Figure 1). The responses of ricardian and non-ricardian consumption levels (*cl* and *cc*, respectively) clearly reflect this redistribution of income. Private investment falls heavily because the increase in interest rates and distortionary taxation hurts ricardian individuals, who are the ultimate owners of private capital and decide how to accumulate it. As for sectoral consequences, the *yr* graph in Figure 1 shows that the tradables sector is more adversely affected than the non-tradables one, the basic reason being that higher interest rates and higher tax rates on capital impose a heavy burden on the cost of capital, and thus penalize the more capital-intensive tradables sector.

Conversely, an LG shock may be interpreted as a transfer of income in favor of the ricardian population, who are the only individuals who supply labor to the public sector. The increase in LG induces ricardian agents to cut their labor supply to the private sector, pushing their wages upwards – not only wages paid by private firms but also wages paid by the public sector, which by assumption move proportionately. Differently from the case of a WM shock, there is no instantaneous boost to demand, and therefore no automatic increase in the tax base, which means that tax rates must be increased from the outset to finance the higher public spending level and keep a balanced primary budget. Higher taxes lead to higher production costs for private sector firms, and consequently higher inflation; as a response, the interest rate rises, in accordance with the central bank's reaction function. Higher taxation decreases available income for both ricardians and non-ricardians and causes consumption to fall; in this case, however, non-ricardians are more adversely affected, as they do not benefit from higher public sector em-

⁸The multiplier of total spending takes into account the fact that other government expenditures, besides the specific item being shocked, vary in response to the shock. For instance, the value of public employees' payroll changes as the real wage changes. We therefore consider this multiplier a more accurate indicator than the specific multiplier that only takes into consideration expenditures related to the specific item being shocked. Table 3 presents both estimates for each shock.

Table 3
Effects of expenditure shocks on output

Public expenditure item	Fiscal rule	Average cumulative % deviation of output from steady-state level				Specific cumulative multiplier of public spending				Total cumulative multiplier of public spending			
		Year 1	Year 3	Year 5		Year 1	Year 3	Year 5		Year 1	Year 3	Year 5	
Social transfers	I	0.21	-0.07	-0.09		0.25	-0.12	-0.21		0.47	-0.22	-0.39	
	II	0.32	0.02	-0.02		0.38	0.03	-0.06		0.76	0.07	-0.13	
	III	0.27	-0.02	-0.06		0.32	-0.03	-0.14		0.57	-0.05	-0.25	
	IV	0.28	0.01	-0.03		0.33	0.02	-0.08		0.60	0.04	-0.15	
Public investment	I	-0.12	-0.17	0.02		-0.14	-0.30	0.04		-0.20	-0.43	0.05	
	II	-0.01	0.08	0.20		-0.01	0.14	0.49		1.96(*)	5.46(*)	4.80(*)	
	III	0.32	0.10	0.17		0.38	0.18	0.42		0.51	0.24	0.53	
	IV	0.47	0.23	0.26		0.55	0.40	0.63		0.76	0.55	0.83	
Public employment	I	-0.28	-0.38	-0.30		-0.33	-0.66	-0.72		-0.33	-0.66	-0.71	
	II	-0.17	-0.02	0.00		-0.20	-0.03	0.00		14.22(*)	-5.38(*)	-0.21(*)	
	III	0.33	0.02	-0.05		0.39	0.04	-0.11		0.37	0.04	-0.10	
	IV	0.53	0.20	0.09		0.63	0.35	0.22		0.62	0.35	0.21	

(*) These results refer to cases in which cumulative changes in total public spending are either negative or very close to zero, which tends to distort the values of calculated multipliers. Special care is therefore needed to interpret these values and compare them to the other entries in the table.

ployment and wages. Higher taxes and interest rates also penalize investment, but not dramatically so; in fact, the rise in public employment partially preserves the income of ricardian individuals, who are the owners of the economy's private capital stock, and therefore attenuates the fall in private investment. Lower labor supply, higher production costs and lower consumption and investment levels translate into lower GDP, so that cumulative multipliers of public spending are always negative, for any time horizon (Table 3, line 9).

The LG shock adversely affects the tradables sector even more than the WM shock and the ratio between the output levels of the tradable and non-tradable sectors falls substantially. The reason is that marginal costs in the tradables sector rise relatively more in the case of an LG shock, given that the cost of capital rises more than the cost of labor, thus penalizing the more capital-intensive sector. In fact, in the absence of an automatic expansion of the tax base, tax rates need to be raised significantly, which leads to a substantial increase in the cost of capital. Besides, despite ricardian agents supplying less labor, total labor supplied to the private sector does not decrease by much, since the working fraction of the non-ricardian population increases their own labor supply, seeking to compensate for the fall in their available income. Coupled with a weaker demand for goods, this means that the real wage actually falls, thus helping firms in the non-tradable sector, which are labor intensive.

Finally, the IG shock has a slightly positive effect on GDP on impact, which becomes negative for the next 9 quarters, before turning back to positive values. As in the WM shock case, the initial positive effect on GDP is due to a boost in demand, given the higher demand for investment goods by the government. However, the increase in demand is not enough to guarantee a sufficiently large expansion of the tax base, so that tax rates must be immediately raised to balance the budget, as in the LG shock case. Consequently, we again observe a significant increase in taxation, higher production and capital costs – especially for the more capital-intensive tradables sector firms –, higher inflation and interest rates, lower levels of available income and consumption (for both ricardians and non-ricardians) and lower investment. The main difference from the previous cases is that in the medium run, as public capital becomes productive and enhances the total factor productivity of intermediate goods firms, many of the above effects are reversed. First, lower marginal costs allow firms to expand production and earn more profits, which are distributed as dividends to ricardian individuals and increase resources available for private investment. Second, the downward pressure on costs also reduces inflation, so that interest rates go down. As a result, investment increases, leading to higher output and consumption levels. The cumulative multiplier of public investment, which is negative after one and three years, becomes slightly positive after 5 years (Table 3, line 5).

One interesting point to note is that all three types of shocks lead to higher inflation rates, even when demand and output are falling. The main reason for

this is that the higher taxation on capital and labor income required to balance the public budget generates an upward pressure on production costs.

Figure 2 shows impulse responses under fiscal policy rule II, according to which, after a shock to either WM, LG or IG, the government adjusts its expenditures with the consumption of goods and services in order to maintain a permanently balanced primary budget. This rule therefore prescribes a reallocation of public expenditures, from the consumption of goods and services to one of the three items being shocked (social transfers, public employment or public investment).

Figure 2

Responses to shocks in public expenditures under fiscal policy rule II (permanently balanced primary budget; fiscal adjustment met by reducing public consumption of goods and services). WM/blue line: shock to social transfers; IG/green line: shock to public investment; LG/red line: shock to public employment.

In the case of a WM shock, impulse responses are similar to those observed under fiscal policy rule I. In fact, some of the main mechanisms seen earlier are still at work: the positive wealth effect from higher transfers leads to less labor supply from non-ricardians and more labor supply from ricardians, resulting in higher average real wages; higher costs of production cause inflation and interest rates to rise, pushing up the cost of capital and driving investment down; less investment translates into lower capital stock levels and output in the future. Differently from before, there is no change in tax rates, which partly alleviates the burden on ricardians and explains a slightly less adverse evolution of investment and output; as Table 3 (line 2) shows, cumulative multipliers of public spending are slightly larger than under rule I.

In the cases of shocks to IG and LG, the short run effects are different under policy rules I and II. For an IG shock, differently from the case in Figure 1, under rule II there is now no significant short run effect on GDP or any of the variables considered. This is due to the fact that we are simply shifting the composition of government spending from the consumption of goods and services to public investment. The increase in public investment is expected to affect the stock of public capital in the future, enhancing total factor productivity and boosting output in the medium term; in the short run, however, government spending in consumption and in investment are indistinguishable, so that the net effect on the economy is zero. In the medium run, as public investment becomes productive, the economy behaves similarly under both rules.

In the case of a shock to LG, policy rule II yields an immediate fall in GDP, which quickly rebounds to slightly above-steady-state levels before converging back to equilibrium. Recall that the LG shock is tantamount to an income transfer in favor of ricardian individuals. The increase in LG induces ricardian agents to cut their labor supply to the private sector, and non-ricardian agents are called upon to reestablish labor supply. The net effect is an increase in the relative wage of ricardians and a fall in total labor supply. The fall in labor supply is consistent with the reduced demand for labor by firms. In fact, total domestic demand diminishes for two main reasons. First, as non-ricardian income falls, so does their consumption. Second, as the government reduces its consumption of goods and services to make room for the higher expenditure with public employees, the total demand for goods falls. As a result, GDP falls on impact. The low demand for labor causes the average real wage to fall, which pushes marginal costs and inflation down.

In the subsequent quarters, economic activity quickly recovers. This is explained by the fact that the higher income of ricardian individuals, coupled with the lower interest rate afforded by low inflation rates, boost private investment. Consumption by ricardians increase, while the initial fall in non-ricardian consumption is partly attenuated, so that total consumption rises.

For all three shocks, it is worth noting that under policy rule II both the average private sector real wage and inflation are positively correlated with GDP. This is in contrast with the case of policy rule I, under which it was possible to observe high inflation even though GDP was falling. Another point to note is that, under this policy, shocks that favor ricardians and investment always cause the ratio between the output levels of the tradable and non-tradable sectors to increase.

Figures 3 and 4 show impulse responses under fiscal policy rules III and IV, according to which, after a shock to WM, LG or IG, the government either increases taxation or adjusts consumption expenditures in order to gradually reestablish the primary budget balance. We assume a fiscal response such that it takes 6 quarters to halve the fiscal deficit observed immediately after the shock. We can see that many responses are similar to the ones depicted in Figures 1 and 2; there are, how-

ever, important differences. First, all shocks cause GDP to increase in the short run, in contrast with some of the cases previously discussed. As there is no need for large immediate increases in taxation or reductions in public consumption, some of the effects previously discussed are attenuated; the more flexible rules preserve total domestic demand and prevent GDP from falling. Second, private investment falls even more strongly than under permanently balanced primary budget rules. This is due to the fact that a more protracted fiscal adjustment strategy may benefit economic activity in the short or medium run, but implies a higher adjustment cost in the long run. In fact, as primary deficits accumulate, so does the public debt; therefore, the longer it takes for the government to counteract the initial deterioration in its finances, the larger will be the size of the fiscal adjustment required to push the debt back to equilibrium. As an example, we may note that 20 periods after an LG shock, the public debt to GDP ratio is close to its steady-state level under policy rule I, but finds itself 8.8% above steady-state under policy rule III. Similar results apply to the other shocks.

Figure 3

Responses to shocks in public expenditures under fiscal policy rule III (partial adjustment of primary deficits; fiscal adjustment met by increasing distortionary taxation). WM/blue line: shock to social transfers; IG/green line: shock to public investment; LG/red line: shock to public employment.

Table 3 summarizes the estimates of public spending multipliers for all the cases considered. The table shows, for each shock and time horizon, two types of multipliers: the specific multiplier of public spending, which is the ratio between the cumulative change in GDP and the cumulative change in the public expenditure item being shocked; and the total multiplier of public spending, which is

Figure 4

Responses to shocks in public expenditures under fiscal policy rule IV (partial adjustment of primary deficits; fiscal adjustment met by reducing public consumption of goods and services). WM/blue line: shock to social transfers; IG/green line: shock to public investment; LG/red line: shock to public employment.

the ratio between the cumulative change in GDP and the cumulative change in total public expenditures. From the point of view of economic policy, the most relevant concept is the latter, which measures the output gains (or losses) for a given expansion in total government expenditure. The main results are:

- (i) in the short run and under rules I and II, multipliers are positive only in the case of an increase in social transfers;
- (ii) in the long run and under rules I and II, multipliers are (slightly) positive only in the case of an increase in public investment;
- (iii) in the short run and under rules III and IV, multipliers are positive in all three cases;
- (iv) in the long run and under rules III and IV, multipliers remain positive only in the case of an increase in public investment; and
- (v) there are almost no cases in which multipliers are near or above 1, the exception being a public investment shock counterbalanced by government consumption spending cuts.

4. Sensitivity Analysis

In this section we analyze the sensitivity of our results to alternative model parameterizations. The first exercise is to assign a higher value to the parameter that measures the persistence of fiscal instruments; we set $\rho_X=0.944$, which implies that fiscal policy shocks have a half-life of 12 quarters. Impulse responses to shocks in WM, IG and LG under rules I, II, III and IV are qualitatively similar to the ones depicted in Figures 1-4, so that our basic conclusions remain valid. The main difference refers to the sizes of responses, which in all cases point to relatively smaller positive effects (or larger negative effects) of fiscal shocks on economic activity under higher shock persistence. Table 4 shows the values of multipliers under this parameterization.

As a second exercise, we vary the ratio of the working/non-working non-ricardian population (ζ_c^*). The benchmark case in the previous simulations is $\zeta_c^* = 0.6$; we additionally test $\zeta_c^* = 0.4$ and $\zeta_c^* = 0.8$. We note that impulse responses to shocks to IG and LG are relatively unaffected. In the case of a WM shock, a higher proportion of working non-ricardians leads to slightly sharper reductions in GDP, investment and the ratio between the output levels of the tradable and non-tradable sectors, as shown in Figure 5 (under fiscal rule I). This result is not surprising; as the number of working non-ricardians increases, so does the reduction in labor supply arising from the social transfers positive wealth effect, which sets in motion the output-reducing mechanisms previously discussed. It is interesting to note, however, that the basic conclusions from our simulations are unaffected.

5. Conclusions

In this paper we derived and calibrated a medium-sized DSGE model to represent the main characteristics of the Brazilian economy. The fiscal policy block is rich enough to investigate the macroeconomic impacts of different types of public spending – purchases of goods and services, investment, social transfers and wages paid to public employees – under different fiscal rules that ensure that the economy will return to its steady-state equilibrium. Our main simulation results were:

- (i) shocks to social transfers spending increase output in the short run, but generate negative multipliers in the medium run under all fiscal rules considered;
- (ii) public investment multipliers may be negative in the short run, especially under permanently balanced primary budget fiscal rules, but are always positive in the medium run, as public capital becomes productive;
- (iii) under permanently balanced budgets, multipliers relative to public employment expenditures are negative or close to zero, whereas under partial fiscal adjustment rules they are initially positive but gradually decline towards or below zero;

Table 4
Effects of expenditure shocks on output under higher shock persistence ($\rho_X = 0.944$)

Public expenditure item	Fiscal rule	Average cumulative % deviation of output from steady-state level					Specific cumulative multiplier of public spending					Total cumulative multiplier of public spending				
		Year 1	Year 3	Year 5	Year 1	Year 3	Year 5	Year 1	Year 3	Year 5	Year 1	Year 3	Year 5	Year 1	Year 3	Year 5
Social transfers	I	0.14	-0.15	-0.18	0.15	-0.20	-0.29	0.15	-0.20	-0.29	0.28	-0.38	-0.54	0.28	-0.38	-0.54
	II	0.26	-0.04	-0.08	0.28	-0.05	-0.14	0.28	-0.05	-0.14	0.59	-0.13	-0.33	0.59	-0.13	-0.33
	III	0.21	-0.08	-0.12	0.22	-0.10	-0.21	0.22	-0.10	-0.21	0.41	-0.19	-0.38	0.41	-0.19	-0.38
	IV	0.23	-0.04	-0.09	0.25	-0.05	-0.15	0.25	-0.05	-0.15	0.45	-0.09	-0.28	0.45	-0.09	-0.28
Public investment	I	-0.19	-0.28	-0.07	-0.20	-0.38	-0.12	-0.20	-0.38	-0.12	-0.29	-0.53	-0.16	-0.29	-0.53	-0.16
	II	-0.01	0.09	0.25	-0.01	0.12	0.41	-0.01	0.12	0.41	1.75(*)	5.83(*)	4.89(*)	1.75(*)	5.83(*)	4.89(*)
	III	0.30	0.08	0.17	0.32	0.11	0.28	0.32	0.11	0.28	0.43	0.14	0.36	0.43	0.14	0.36
	IV	0.46	0.25	0.31	0.50	0.33	0.50	0.50	0.33	0.50	0.68	0.46	0.67	0.68	0.46	0.67
Public employment	I	-0.37	-0.56	-0.51	-0.40	-0.75	-0.83	-0.40	-0.75	-0.83	-0.40	-0.64	-0.82	-0.40	-0.64	-0.82
	II	-0.16	-0.02	-0.00	-0.17	-0.02	-0.03	-0.17	-0.02	-0.03	19.3(*)	-14.3(*)	0.21(*)	19.3(*)	-14.3(*)	0.21(*)
	III	0.30	-0.03	-0.12	0.33	-0.04	-0.20	0.33	-0.04	-0.20	0.31	-0.04	-0.18	0.31	-0.04	-0.18
	IV	0.52	0.21	0.09	0.57	0.29	0.15	0.57	0.29	0.15	0.56	0.28	0.15	0.56	0.28	0.15

(*) These results refer to cases in which cumulative changes in total public spending are either negative or very close to zero, which tends to distort the values of calculated multipliers. Special care is therefore needed to interpret these values and compare them to the other entries in the table.

Figure 5

Responses to shock to social transfers under fiscal policy rule I (permanently balanced primary budget; fiscal adjustment met by increasing distortionary taxation) and different values for the ratio of the working/non-working non-ricardian population.

Blue line: $\zeta_c^* = 0.4$; green line: $\zeta_c^* = 0.6$; red line: $\zeta_c^* = 0.8$

- (iv) substituting public investment for public consumption of goods and services can be relatively neutral in the short run, but in the medium run, as public capital becomes productive, leads to higher output, investment and consumption and lower inflation;
- (v) fiscal rules relying on distortionary taxation to balance the primary budget can lead to both lower output and higher inflation, due to the impact of higher taxes on the cost of capital and production costs;
- (vi) policy rules based on a more protracted fiscal adjustment strategy may benefit economic activity in the short or medium run, but imply a higher adjustment cost in the long run.

Under fiscal adjustment rules committed to a permanently balanced primary budget, fiscal shocks are equivalent to mere reallocations among different budget items. If this is the case, then fiscal policy should yield positive effects on output only when it succeeds in transferring resources from less productive activities to more productive ones – as in the case of a public investment shock financed by a reduction in government consumption. The negative effects of a more expansionist stance on social transfers are explained by the fact that such policies favor the non-ricardian population relative to ricardian individuals; since the latter are the

Figure 6

Responses to shock to public investment under fiscal policy rule I (permanently balanced primary budget; fiscal adjustment met by increasing distortionary taxation) and different values of the sensitivity of TFP to public capital. Blue line: $\eta_g = 0.02$; green line: $\eta_g = 0.05$; red line: $\eta_g = 0.08$

ultimate owners of private capital and decide how its stock evolves, their falling income restrains private investment and production, especially in the medium term. Another explanation comes from the fact that non-ricardian agents reduce their labor supply, which is a result of the positive wealth effect engendered by increasing transfers; this factor reinforces the fall in production. The crucial role played by the substitution between labor and leisure by both ricardian and non-ricardian agents calls attention to the need for more empirical studies quantifying these relationships.

It is worth noting that some results depend on the importance assigned to public capital in the production function used by intermediate goods firms. Given the uncertainty about the appropriate value of this parameter for the Brazilian economy, one must therefore interpret with caution our conclusions on public investment shocks. This result also highlights the importance of further studies aiming to estimate the impact of public capital on the productivity of the Brazilian economy.

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