An Estimated DSGE Model with Government Investment and Primary Surplus Rule: The Brazilian Case

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Abstract

This paper employs Bayesian techniques to estimate a DSGE model of an open economy where fiscal policy is implemented through rules for the primary surplus, public investment and distributional transfers. Fiscal policy interacts with a forward-looking monetary policy that targets inflation. There are Ricardian and non-Ricardian agents in the model, in addition to heterogeneity in labor skills which translates into differentiated labor productivity. This guarantees that, in steady state, distinct households will still work the same amount of daily hours, a feature that best describes a rigid labor market such as that of Brazil. We use Bayesian methods to estimate the parameters of the domestic economy using a sample of time series data from the inflation targeting regime in Brazil. The foreign economy is calibrated to the US and the Euro Zone following Coenen, McAdam and Straub (2008). The impulse responses to the primary fiscal surplus show stronger and longer-lasting reaction of output and private consumption than those obtained with exogenous rules for government purchases in Coenen, McAdam and Straub (2008) and Forni et. al. (2009). In addition, the fiscal multiplier of an expansionist primary surplus shock does not only stem from the reaction of non-Ricardian consumers. In fact, Ricardian agents also increase their consumption, although at a lower intensity and for a shorter duration of time. The estimated mode of the posterior distribution of the parameters shows important sectoral differences with respect to price rigidities. The exports sector shows more frequent price adjustments, and lower price indexation. Overall, prices are more frequently optimized in Brazil, yet the prices of domestic goods show a higher indexation to past inflation than in Europe, which could be an indication that there is still room for gains of credibility in the Brazilian monetary policy. Adjustment costs in Brazil are validated by the data, yet they are a little less important than in the Euro Zone. The paper also analyses the impulse responses of shocks to risk premia, investment efficiency, import bias, public transfers and investment, monetary policy, and wage and price markup.

Keywords: DSGE, fiscal policy, monetary policy, government investment, primary surplus, heterogeneous agents, market frictions; Bayesian estimation

JEL Classification: E32; E62; E63

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1. Introduction

A number of central banks and central banking institutes around the world have been resolutely putting forward a research agenda on the improvement of the theory and estimation of DSGE models. Tovar (2009) cites the Bank of Canada, Bank of England, Central Bank of Chile, Norges Bank and Sveriges Riksbank, as central banks where DSGE models have already been incorporated into the formal process of policy decision making. In spite of the fact that, for a great number of central banks, these models are still in the periphery of decision making\(^1\), the participants of international conferences worldwide have witnessed an ever-growing effort by central bank staff to improve these models in stances that suit the particular needs of policy making in their countries.

Such research agenda does not unanimously please the economics profession. Faust (2008) lists a number of critiques to DSGE models formulated by prominent academics. He classifies the criticism as an analog to that voiced toward the macroeconomic models of the 70s: lack of micro-foundation, incapacity to reproduce business cycles features of the data, or unreliable identifying assumptions.

Notwithstanding, as Faust himself notes, “even the existing DSGE models have an important role to play in the policy process”\(^2\). Indeed, for each of the mentioned critiques, new research agendas have been pursued, and as such the economic science evolves\(^3\).

\(^3\) Concerning identifiability, Canova and Sala (2006), for instance, argues that, in a model estimated from an objective function that measures the distance from impulse responses, the presence of weakly identified or under-identified parameters in the set of estimated parameters contaminates the estimates for the otherwise identifiable parameters, leading to biased estimates and problems in the significance ratios regardless of the sample size. He then advises to check the robustness of the estimations by loosening the prior distributions, by selecting priors based on strong evidence from alternative sources of information, by testing alternative optimization algorithms, among others. A few methods have been suggested in the literature to help identify estimated parameters (e.g., Iskrev, 2010, Komunjer and Ng, 2009). To our knowledge, they are still hardly implementable for large-scale models as they (restrictively) require too intense computational capacity. As to the lack of micro-foundation, the main criticism has been toward the inclusion of adjustment costs and \textit{adhoc} shocks. One such case is the \textit{adhoc} inclusion of risk premium shocks. There are, however, theoretical implications of the way risk premia are usually modeled in the
This paper belongs to the research agenda on DSGE models for policy analysis. In addition to bringing a state-of-the-art DGSE model to Brazilian data, we investigate the response to a number of shocks, including those from fiscal policy, in an estimated model of an economy with a high share of non-Ricardian agents and whose fiscal policy adjusts the primary surplus as the ultimate instrument to achieve a sustainable debt-to-GDP path and to influence business cycles. An additional important feature of our fiscal policy set-up is the concomitant introduction of government investment which endogenously affects the productivity of private firms.

The DSGE literature has already experimented with non-trivial state-dependent fiscal rules. In most cases, the preferred strategy has been to introduce rules for government purchases or government taxes with some type of response to output, debt and/or to some sort of fiscal target. Our strategy of directly emphasizing a primary surplus rule, instead of an expenditures or a tax rule, stems from the fact that the most important fiscal solvency indicator in Brazil and in many other countries that have theoretical literature. Log-linearization around a steady state in this setup eliminates the risk premia in the model, as highlighted by Rudebusch (2007). In the matter of micro-foundation, Faust (2008) argues that “we have little reason to suppose that, in the face of intractable problems, the best practical model will be some micro-founded model simplified to the point of tractability. It is manifestly false that ad hoc models outside the micro-founded class are of no practical value.” (p.p. 9-10). In addition, “(I)t is true that in the important search for the best micro-foundations-based model, it takes one to beat one. It is plainly false, however, that in the search for the best guide for practical policy, a micro-foundations-based model can only be beaten by another” (p.p. 11). The criticism toward the capacity of DSGE models to reproduce business cycles is also being called into question. The estimated NAWM in Christoffel, Coenen and Warne (2010) matches the first and second moments of the data reasonably well, in spite of not having financial or other important frictions that may better depict the fluctuations in the data. There is also an important research agenda currently being pursued on incorporating financial frictions in DSGE models, or modeling expectations away from rationality which could improve the ability of such models to reproduce the data.

4 Although the 59% of non-Ricardian agents calibrated for the domestic economy is high compared to European standards, it is lower than the 70% considered for Chile in Medina and Soto (2007).

5 Medina and Soto (2007) analyze three types of fiscal rules: one where government expenditures adjust to satisfy government’s budget constraint, another where government taxes do such as task, and the last one where government expenditures as a share of GDP adjust to meet a target for the “structural” balance, measured as the nominal fiscal result adjusted for cyclical revenues from government’s budget flow. Forni et al (2009) use tax rules that react to the debt-to-GDP ratio, and report that expenditure rules yield similar impact of the fiscal shocks to the economy. In CMS, lump-sum taxes are the chosen instrument to stabilize the debt-to-GDP ratio. Ratto et. al. (2009) introduce a rule for public investment that responds to the business cycle.
recently been under an IMF support agreement is actually the primary surplus\(^6\). In practice, a government with primary surplus targets makes concomitant decisions on expenditures, revenues, transfers, subsidies, tax recovery and exemptions, always keeping an eye on their impact on the primary balance. The identified shocks to the primary surplus rule are thus a clear-cut measure of changes in the preferences of the policymaker.

We let public investment endogenously affect the productivity of firms through their optimal choices of (public or private) capital allocation in the production line\(^7\). The optimal composition of capital services will depend on the elasticity of substitution between both types of capital goods and on a parameter that captures the economy’s “dependence” on public infrastructure. Households and the government have different investment agendas, and are faced with distinct efficiency in the transformation of investment to capital goods.

Apart from the modeling of the fiscal sector, this model follows the essence of ECB’s New Area Wide Model with both Ricardian and non-Ricardian agents presented in Coenen, McAdam and Straub (2008), hereinafter referred to as CMS, with some of the theoretical additions made in Christoffel, Coenen and Warne (2008), hereinafter referred to as CCW 2008, especially the inclusion of a trend growth and a greater number of shocks.

The estimated versions of the NAWM\(^8\) shut down important channels of fiscal policy transmission by only allowing for Ricardian agents. Moreover, they model the foreign sector with a simplifying VAR. On the other hand, they introduce new sectors

\(^6\) One critique towards targeting nominal balances is that inflation can mask structural imbalances in fiscal accounts.

\(^7\) Ratto et. al. (2009) are a recent attempt to account for the strategic role of public investment in policy decisions in a DSGE setup. They introduce a rule for public investment that responds to the business cycle and assume that public capital interferes in the productivity of private firms, but does not belong to factor decisions. It is more like an externality.

\(^8\) Christoffel, Coenen and Warne (2008 and 2010).
and new shocks to prepare the model for estimation. Christoffel, Coenen and Warne (2010), hereinafter referred to as CCW 2010, show that the point forecasts produced from the estimated NAWM perform quite well compared to the alternative forecasting techniques, which are VARs, BVARs and simple random walks. Quoting them, “the NAWM does well in forecasting real GDP growth, real export and import growth, import price deflator inflation, employment and the short-term nominal interest rate. The most difficult dimensions for the DSGE model concern nominal wage growth in particular, but also consumption deflator inflation at the shorter horizons”\textsuperscript{9}.

In our model, we maintain heterogeneity in agents’ investment choices, so as to have both Ricardian and non-Ricardian agents in the model. We introduce another source of heterogeneity, this time in labor skills. In Brazil, labor contracts are usually inflexible with regard to adjustments in (daily) worked hours. The most usual contracts set an 8-hour workday. Therefore, it seems reasonable to allow for a steady state where members of different social classes earn in average different wages for the same amount of hours worked.

The presence of non-Ricardian agents has important implications for the responses of the model to fiscal policy shocks. Expansionist shocks to the primary surplus and to public transfers boost economic growth, and do not crowd out private consumption. Our modeling strategy for the fiscal sector has a qualitatively distinct impact on the crowding out effect of fiscal policy than those obtained in the literature. In Forni et al. (2009), for instance, where they incorporate a fraction of non-optimizing non-Ricardian agents to study the implications of expansionist government expenditures shocks, they find that these shocks have small and short-lived expansionary effects on

private consumption. In our model, the response of private consumption to a primary surplus shock is stronger and longer lasting. The difference might come from the higher share of non-Ricardian agents in our calibrated model, which helps sustain demand for the goods produced by the firms owned by Ricardians, and might also come from the reaction of the other fiscal variables in our model. After a shock to the primary surplus, it is not only government consumption that rises, increasing the demand for final consumption goods. In fact, public investment also rises, and that holds intricate relations with private decisions on capital accumulation and capital utilization. A greater shift in the demand for labor by firms increases the private income from labor, which also raises consumption of non-Ricardian agents, a feature that neither Forni et. al. nor CMS provide.

We analyze the impulse responses of the model, drawn from the posterior distribution, to shocks to monetary policy, primary fiscal surplus, public investment, public transfers, investment efficiency, import bias, UIP premium, and wage and price markups. Some of these shocks imply a distinct behavior compared to those of the Euro Zone reported in CCW 2008 likely due to the presence of non-Ricardian agents in our model. For others, the behavior is similar, yet with different intensity and duration, as the economies have different structural parameters.

The paper is organized as follows. Section 2 provides an overview of the model. Section 3 details the estimation procedure, reporting on the strategy for calibrating the steady state of the model, the reasons underlying the choices of priors, and also describing the data and the shocks. Section 4 analyses the impulse responses of the model. The last section concludes the paper.

They show that their results can also be obtained under a similar modeling strategy where non-Ricardian and Ricardian agents pool in a union that monopolistically sets wages. This may be a good approximation for Europe, but we believe it does not hold well for Brazil, as Brazilian unions are very decentralized and much less powerful in terms of wage bargaining.
2. The model

The model is exactly the same as in Valli and Carvalho (2010), which builds on ECB’s NAWM (CMS, 2008, CCW, 2008 and 2010). Figure 1 depicts the core structure of the model. Our theoretical contribution to ECB’s NAWM is highlighted in underlined italics.

The model has two economies of different sizes that interact in goods and financial markets. They are symmetric with respect to the equations that describe the dynamics of the modeled variables, with the exception of monetary and fiscal policy rules. The structural parameters of the model are allowed to differ between economies.

In each economy, there is a continuum of households, which can be categorized in two groups. The first, hereinafter referred to as group $I = [0, 1 - \omega]$, contains individuals with full access to savings technologies and with better labor skills. The other group, hereinafter referred to as $J = [1 - \omega, 1]$, can only smooth intertemporal consumption through holdings of non-interest bearing money balances, in addition to being less qualified to work. All households supply labor to intermediate goods firms in competitive monopolistic markets that are specific to their groups. There are group-specific Calvo-type wage rigidities and those not allowed to optimize will update their prices using a hybrid wage indexation rule.

The productive sector of the economy comprises firms that produce intermediate and final goods. The set of intermediate goods firms is composed of a continuum of firms that operate under monopolistic competition, facing Calvo-type price rigidities. Whenever they are unable to optimally adjust their prices, they will follow a hybrid price indexation rule to set prices. Their produced goods are sold either domestically or abroad.
Final goods firms operate under perfect competition. Each one of them assembles domestic and imported intermediate goods to produce one single type of final good: private consumption, public consumption, or investment goods.

The government comprises monetary and fiscal authorities. The monetary authority sets nominal interest rates and issues as much money as demanded by the public. The fiscal authority levies taxes on most economic activities and endogenously adjusts its consumption expenditures to comply with its investment, distributional transfers, and primary surplus rules.

In what follows, we provide a brief description of the model. A detailed derivation can be obtained in Valli and Carvalho (2010).

2.1. Wage setting

Household \( i \in I = [0,1 - \omega] \) chooses consumption \( C_{i,t} \) and labor services \( N_{i,t} \) to maximize the separable intertemporal utility with external habit formation

\[
E_t \sum_{k=0}^{\infty} \beta^k \left[ e_{t+k,C} \frac{1}{1 - \sigma} \left( \frac{C_{i,t+k} - \kappa C_{i,t+k-1}}{\kappa} \right)^{1-\sigma} - e_{t+k,N} \frac{1}{1 + \zeta} \left( N_{i,t+k} \right) \right] \tag{1}
\]

where \( e_{t+k,C} \) and \( e_{t+k,N} \) are shocks to consumption and labor preferences, the parameter \( \kappa \) is the external habit persistence, \( \beta \) is the intertemporal discount factor, \( \frac{1}{\sigma} \) is the intertemporal elasticity of consumption substitution, \( \frac{1}{\zeta} \) is the elasticity of labor effort relative to the real wage, and \( \delta \) is the depreciation of capital.

Consumer optimization is subject to the budget constraint

\[
\left(1 + \tau^F_t + \Gamma_v(v_{i,t})\right) P_C L_{i,t} C_{i,t} + P_L L_{i,t} R_{i,t} + (e_{t,Bp} R_t)^{-1} B_{i,t+1} \tag{2}
\]

\[
+ \left(1 - \Gamma^F_B(B^F_{i,t})\right) e_{t,RPP} R_{F,t} \right)^{-1} S_t B^F_{i,t+1} + M_t + \Xi_{i,t} + \Phi_{i,t} =
\]
\[
(1 - \tau^N_t - \tau^W_t) \ W_{i,t} N_{i,t} + (1 - \tau^K_t) [u_i R_{K,t} - \Gamma_u(u_i) P_{i,t}] K_{i,H,t} + \\
\tau^K_t \delta P_{i,t} K_{i,H,t} + (1 - \tau^D_t) D_{i,t} + TR_{i,t} - T_{i,t} + B_{i,t} + S_t B^F_{i,t} + M_{i,t-1}
\]

where, on the expenditure side, \( I_{i,t} \) is private investment in capital goods, \( B_{i,t+1} \) are domestic government bonds, \( B^F_{i,t+1} \) are foreign private bonds, \( R_t \) is the riskless free rate, \( R_F \) is the interest rate of the foreign bonds, \( e_{t,RP} \) and \( e_{t,RPF} \) are shocks to interest rate premia on domestic and international bonds, respectively, \( S_t \) is the nominal exchange rate, \( M_{i,t} \) are money holdings, \( \Xi_{i,t} \) is a lump sum rebate on the transactions cost \( (\Gamma_B B^F_{i,t}) \) introduced in the negotiation of international bonds, and \( \Phi_{i,t} \) is the stock of contingent securities negotiated within group \( I \), which act as an insurance against risks on labor income. In addition, \( \Gamma_y(v_{i,t}) \) is a transaction cost on consumption and \( v_{i,t} \) is the money-velocity of consumption. On the earnings side, \( W_{i,t} \) is the wage earned by household \( i \) for one unit of labor services, \( K_{i,H,t} \) is the private capital stock, \( u_{i,t} \) is capital utilization, \( \Gamma_u(u_{i,t}) \) is the cost of deviating from the steady state rate of capital utilization, \( R_{K,H,t} \) is the gross rate of the return on private capital, \( D_{i,t} \) are dividends, and \( TR_{i,t} \) are transfers from the government. Taxes are: \( \tau^C_t \) (consumption), \( \tau^N_t \) (labor income), \( \tau^W_t \) (social security), \( \tau^K_t \) (capital income), \( \tau^D_t \) (dividends) and \( T_{i,t} \) (lump sum, active only for the foreign economy). Price indices are \( P_{C,t} \) and \( P_{i,t} \), the prices of final consumption and investment goods, respectively. Cost functions are detailed in appendix A.

The accumulation of private capital follows the equation:

\[
K_{i,H,t+1} = (1 - \delta) K_{i,H,t} + e_{t,t} \left( 1 - \Gamma_t \left( I_{i,H,t}/I_{i,H,t-1} \right) \right) I_{i,H,t}
\]

where \( I_{i,H,t} \) is investment and \( e_{t,t} \) is a shock to its efficiency.

Households in group \( J \) maximize a utility function analogous to (1), but constrained on their investment choices, as they are only allowed to transfer wealth
from one period to another by holding non-interest bearing money balances. These are thus non-Ricardian agents.

Within each group, households compete in a monopolistic competitive labor market. By setting wage $W_{i,t}$, household $i$ commits to meeting any labor demand $N_{i,t}$. Wages are set à la Calvo, with a probability $(1 - \xi_t)$ of optimizing each period. Optimizing households in group $I$ choose the same wage $\tilde{W}_{i,t}$, which we denote $\tilde{W}_{i,t}$. Households that do not optimize readjust their wages based on a geometric average of realized and steady state inflation $\bar{W}_{i,t} := \left( \frac{P_{e,t-1}}{P_{e,t-2}} \right)^{\chi_t} \pi_c^{1 - e^{\chi_t}} W_{i,t-1}$. As the non-optimizing wage does not perfectly track the trend growth of the economy, there will be wage dispersion amongst households in the steady state.

Household $i$'s optimization with respect to the wage $\tilde{W}_{i,t}$ yields the first order condition, which is the same for every optimizing household:

$$E_i \left\{ \sum_{k=0}^{\infty} (\xi_t \beta)^k N_{i,\tau+k} \left[ \Lambda_{i,\tau+k} \left(1 - \tau_{i,\tau+k}^N - \tau_{i,\tau+k}^W \right) \tilde{W}_{i,t} \left( \frac{P_{C,t-k-1}}{P_{C,t-k}} \right)^{x_t} \pi_c^{(1-\xi_t)^k} \right] \right\} = 0 \quad (3)$$

where $\frac{\Lambda_{i,t}}{P_{C,t}}$ is the Lagrange multiplier for the budget constraint, and $e_{i,\tau+k,W}$ is, in the absence of staggering, a time varying markup of the real wage: $e_{t,W} = \rho_w e_{t-1,W} + (1 - \rho_w) \left( \frac{\eta_{t-1,W}}{\eta_{t-1}} \right) + \epsilon_{t,W}$.

Equation (3) can be expressed in the following recursive form:

$$(1 - \omega)^{\xi_t} \left( \frac{\tilde{W}_{i,t}}{P_{C,t}} \right)^{1+\eta_{i,W}} = e_{t,W} e_{t,N} \frac{F_{i,t}}{G_{i,t}} \quad (4)$$

where
\[ F_{t,j} = \left( \frac{W_{t,j}}{P_{C,i}} \right)^{\eta_{t}} N^{1+\zeta}_{t} + \xi_{t} \beta_{t} E_{t} \left( \frac{\pi_{C,t+1}}{\pi_{C,t}^{1+\zeta}} \right)^{\eta_{t}(1+\zeta)} . F_{t,j+1} \]

\[ G_{t,j} := A_{t,j} \left( 1 - \tau_{i}^{n} - \tau_{w}^{w} \right) \left( \frac{W_{t,j}}{P_{C,i}} \right)^{\eta_{t}} N^{1}_{t} + \xi_{t} \beta_{t} E_{t} \left( \frac{\pi_{C,t+1}}{\pi_{C,t}^{1+\zeta}} \right)^{\eta_{t}^{-1}} . G_{t,j+1} \]

and \( N^{1}_{t} \) is households group I aggregate labor demanded by firms, and \( W_{t,j} \) is household group I's aggregate wage index. Superscripts in the labor variable represent demand. Subscripts represent supply.

2.2. Production

There are two types of firms in the model: producers of tradable intermediate goods and producers of non-tradable final goods.

2.2.1 Intermediate goods firms

A continuum of firms, indexed by \( f \in [0,1] \), produce tradable intermediate goods \( Y_{f,j} \) under monopolistic competition. In our model, the production technology also takes public capital as input. We assume that firms competitively rent capital services from the government, \( K_{G,f,j}^{S} \), and from households in group I, \( K_{H,f,j}^{S} \), and transform them into the total capital input \( K_{f,j}^{S} \) through the following CES technology:

\[ K_{f,j}^{S} = \left( 1 - \omega_{g} \right)^{-\eta_{t}} \left( K_{H,f,j}^{S} \right)^{\eta_{t}^{-1}} + \left( \omega_{g} \right)^{-\eta_{t}} \left( K_{G,f,j}^{S} \right)^{\eta_{t}^{-1}} \]

where \( \omega_{g} \) is the economy’s degree of dependence on government investment, and \( \eta_{t} \) stands for the elasticity of substitution between private and public goods, and also relates to the sensitivity of demand to the cost variation in each type of capital.

Government’s capital accumulation follows the equation
\[
K_{G,t+1} = (1 - \delta)K_{G,t} + e_{t,t}\left(1 - \Gamma_1\left(l_{G,t}/l_{G,t-1}\right)\right)l_{G,t}
\]

where \(l_{G,t}\) is public investment and \(e_{t,t}\) is the same shock to the efficiency of investment that affects private capital accumulation.

In addition to renting capital services, intermediate goods firms hire labor \(N^D_{f,t}\) from all groups of households to produce the intermediate good \(Y_t\) using the technology:

\[
Y_{f,t} = z_t\left(K^s_{f,t}\right)^{\alpha} \left(z_{n_t} N^D_{f,t}\right)^{1-\alpha} - \psi z_{n_t}
\]

where \(\psi z_{n_t}\) is a cost, which in steady state is constant relative to the output. The constant \(\psi\) is chosen to ensure zero profit in the steady state, and \(z_t\) and \(z_{n_t}\) are respectively (temporary) neutral and (permanent) labor-augmenting productivity shocks.

In equilibrium, \(K^s_{f,t} = u_{f,t} K_{f,t}\), where \(K_{f,t}\) is the stock of capital used by firm \(f\).

For a given total demand for capital services, the intermediate firm minimizes the total cost of private and public capital services, solving:

\[
\min_{K^H_{H,t}, K^G_{G,t}} R^H_{K,t} K^H_{H,t} + R^G_{K,t} K^G_{G,t}
\]

subject to (5).

The rental rate on private capital services results from the equilibrium conditions in the private capital market. The rental rate on government capital services also results from equilibrium conditions, this time in the market for government capital goods, but, in steady state, we calibrate \(\omega_g\) in order to have the rental rate of public capital goods exclusively covering expenses with capital depreciation, so as to reproduce the fact that public capital is usually subsidized.

First order conditions to this problem yield the average rate of return on capital and the aggregate demand functions for each type of capital goods services:
All firms are identical since they solve the same optimization problem. The aggregate composition of capital services rented by intermediate goods firms can be restated by suppressing the subscript “$f$” from (5), using (8), and aggregating the different types of capital services across firms:

$$K_{G,j}^S = \omega \left( \frac{R_{G,j}}{R_{K,j}} \right)^{-\eta_g} K_i^S$$

$$K_{H,j}^S = \left( 1 - \omega \right) \left( \frac{R_{H,j}}{R_{K,j}} \right)^{-\eta_g} K_i^S$$

$$K_i^S = \left( 1 - \omega \right) \left( \frac{R_{G,j}}{R_{K,j}} \right)^{-\eta_g} K_i^S$$

In our model, we introduce differentiated labor skills. We reason that individuals with a lower degree of formal education are usually more constrained on their ability to analyze more sophisticated investment possibilities. In addition, it also seems reasonable to hypothesize that individuals with a lower degree of education will also have lower levels of labor skills. Therefore, we make the assumption that the group of households that is investment-constrained in our model also has lower labor skills. This modeling strategy allows for a steady state where skillful workers can earn more yet working the same amount of hours as the less skilled.

The labor input used by firm $f$ in the production of intermediate goods is a composite of labor demanded to both groups of households. In addition to a population-size adjustment ($\omega$) to the firm’s labor demand, we add the parameter $\nu_o \in [0, 1/\omega]$ to introduce a bias in favor of more skilled workers. The resulting labor composite obtains from the following transformation technology
\[ N_{f,s}^D := \left(1 - v_{\omega} \omega \right)^{\frac{1}{\eta}} \left(N_{f,s}^I \right)^{-\frac{1}{\eta}} \right)^{\eta^{-1}} + \left(v_{\omega} \omega \right)^{\frac{1}{\eta}} \left(N_{f,s}^J \right)^{-\frac{1}{\eta}} \left(1 \right)^{\frac{1}{\eta} - 1} \] (12)

where
\[ N_{f,s}^I := \left( \frac{1}{1 - \omega} \right)^{\frac{1}{\eta} \left( 1 - \omega \right)} \left[ \int_0^{N_{f,s}} (N_{f,s}^I)^{\frac{1}{\eta} - 1} \, di \right] \eta^{1/\eta} \] (13)
\[ N_{f,s}^J := \left( \frac{1}{\omega} \right)^{\frac{1}{\eta} \left( 1 - \omega \right)} \left[ \int_{1 - \omega}^{N_{f,s}} (N_{f,s}^J)^{\frac{1}{\eta} - 1} \, dj \right] \eta^{1/\eta} \] (14)

and where \( \eta \) is the price-elasticity to demand for specific labor bundles, \( \eta_i \) and \( \eta_j \) are the price-elasticities for specific labor varieties. The special case when \( v_{\omega} = 1 \) corresponds to the equally skilled workers assumption.

Taking average wages (\( W_{f,s}^I \) and \( W_{f,s}^J \)) in both groups as given, firms choose how much to hire from both groups of households by minimizing total labor cost \( W_{f,s}^I N_{f,s}^I + W_{f,s}^J N_{f,s}^J \) subject to (12). It follows from first order conditions that the aggregate wage is:
\[ W_t = \left(1 - v_{\omega} \cdot \omega \right) W_{f,s}^I W_{f,s}^J \] (15)

and the aggregate demand functions for each group of households are:
\[ N_{f,s}^I = (1 - v_{\omega} \cdot \omega) \left( \frac{W_{f,s}^I}{W_t} \right)^{-\eta} \cdot N_{f,s}^D \] (16)
\[ N_{f,s}^J = v_{\omega} \cdot \omega \left( \frac{W_{f,s}^J}{W_t} \right)^{-\eta} \cdot N_{f,s}^D \] (17)

Prices are set under monopolistic competition, with Calvo-type price rigidities. We assume local currency pricing. Let \( P_{H,f,s}^I \) and \( P_{X,f,s}^I \) be the prices for goods sold by firm \( f \) in the domestic and foreign markets, with \( \xi_H \) and \( \xi_X \) denoting the probability that the firm will not optimize prices in each of these markets. Non-optimizing domestic and foreign firms mechanically adjust their prices according to the rules.
\( \bar{P}_{H,f,t} = \left( \frac{P_{H,t-1}}{P_{H,t-2}} \right)^{x_H} (\pi_H)^{1-x_H} P_{H,f,t-1} \)  

(18)

\( \bar{P}_{X,f,t} = \left( \frac{P_{X,t-1}}{P_{X,t-2}} \right)^{x_X} (\pi_X)^{1-x_X} P_{X,f,t-1} \)  

(19)

where \( \pi_H \) and \( \pi_X \) are domestic and foreign intermediate goods’ steady state inflation rates.

Optimizing firms choose the prices \( \bar{P}_{H,f,t} \) and \( \bar{P}_{X,f,t} \) to maximize the expected discounted sum of nominal profits:

\[
E \left[ \sum_{k=0}^{\infty} \Lambda_{I,t+1+k} (\xi_H)^k D_{H,f,t+1+k} + (\xi_X)^k D_{X,f,t+1+k} \right]
\]

(20)

where \( \Lambda_{I,t+1+k} \) is household \( I \)'s average discount factor, given by

\[
\Lambda_{I,t+1+k} = \frac{1}{1-\omega} \int_0^\omega \frac{\Lambda_{I,t+k} P_{C,t}}{\Lambda_{I,t} P_{C,t+k}} di
\]

(21)

and nominal profits, net of fixed costs, are defined as

\[
D_{H,f,t} = (P_{H,f,t} - MC_f) H_{f,t}
\]

(22)

\[
D_{X,f,t} = (P_{X,f,t} - MC_f) X_{f,t}
\]

(23)

Optimization is subject to the price indexation rule, to domestic and foreign demand for firm \( f \)'s goods, \( H_{f,t} \) and \( X_{f,t} \), taking as given the marginal cost, the exchange rate and aggregate demand.

First order conditions for the pricing decisions yield

\[
E_i \left[ \sum_{k=0}^{\infty} (\xi_H)^k \Lambda_{I,f,t+k} \left( \bar{P}_{H,i} \left( \frac{P_{H,t+k-1}}{P_{H,t-1}} \right)^{x_H} (\pi_H)^{1-x_H} k - e_{r_t,k} P_{MC_{t+k}} \right) H_{f,t+k} \right] = 0
\]

(24)

and

\[
E_i \left[ \sum_{k=0}^{\infty} (\xi_X)^k \Lambda_{I,f,t+k} \left( S_{r_t,k} \bar{P}_{X,i} \left( \frac{P_{X,t+k-1}}{P_{X,t-1}} \right)^{x_X} (\pi_X)^{1-x_X} k - e_{r_t,k} P_{MC_{t+k}} \right) X_{f,t+k} \right] = 0
\]

(25)
where $e_{t+1,p}$ represents the time-varying markup of prices in the absence of staggering,

$$e_{t,p} = \rho_w e_{t-1,p} + \left(1 - \rho_w\right) \left(\theta \frac{\theta}{\theta - 1}\right) + \varepsilon_{t,p},$$

where $\varepsilon_{t,p}$ is white noise. For simplicity we assume that the markup for both domestic and exported goods is the same.

As firms are identical, they face the same optimization problem, choosing the same optimal price $\tilde{P}_{H,t} = \tilde{P}_{H,t}$ and $\tilde{P}_{X,t} = \tilde{P}_{X,t}$.

Pricing equations (24) and (25) can be restated recursively as

$$(26)$$

$$\frac{\tilde{P}_{H,t}}{P_{H,t}} = e_{t,p} \frac{F_{H,t}}{G_{H,t}}$$

$$(27)$$

$$\frac{\tilde{P}_{X,t}}{P_{X,t}} = e_{t,p} \frac{F_{X,t}}{G_{X,t}}$$

where

$$F_{H,t} := MC_{H,t} + \xi_H \beta E_t \left\{ \frac{\pi_{H,t+1}}{\pi_{H,t} \pi_{X,t}} \right\} F_{H,t+1}$$

$$G_{H,t} := P_{H,t} + \xi_H \beta E_t \left\{ \frac{\pi_{H,t+1}}{\pi_{H,t} \pi_{X,t}} \right\} G_{H,t+1}$$

$$F_{X,t} = MC_{X,t} + \xi_X \beta E_t \left\{ \frac{\pi_{X,t+1}}{\pi_{X,t}} \right\} F_{X,t+1}$$

$$G_{X,t} = S_t P_{X,t} + \xi_X \beta E_t \left\{ \frac{\pi_{X,t+1}}{\pi_{X,t}} \right\} G_{X,t+1}$$

Aggregating over firms, domestic and export intermediate goods prices are

$$(28)$$

$$P_{H,t} = \left(1 - \xi_H \right) \left(\tilde{P}_{H,t}\right)^{1-\theta} + \xi_H \left(\tilde{P}_{H,t}\right)^{-\theta} \left[1^{(1-\theta)}\right]$$

$$(29)$$

$$P_{X,t} = \left(1 - \xi_X \right) \left(\tilde{P}_{X,t}\right)^{1-\theta} + \xi_X \left(\tilde{P}_{X,t}\right)^{-\theta} \left[1^{(1-\theta)}\right]$$

2.2.2 Final goods firms

There are three firms producing non-tradable final goods. One specializes in the production of private consumption goods, another in public consumption goods, and the third in investment goods. Except for the firm that produces public consumption goods,
all final goods’ producers combine domestic and imported intermediate goods in their production. The differentiation in the assumption regarding public consumption goods stems from the evidence that usually the greatest share of government consumption is composed of services, which are heavily based on domestic human resources.

To produce private consumption goods, \( Q_t^c \), the firm purchases bundles of domestic \( H_t^c \) and foreign \( IM_t^c \) intermediate goods. To adjust its imported share of inputs, the firm faces the cost

\[
\Gamma_{IM} \left( \frac{IM_t^c}{Q_t^c} \right) = \frac{\gamma_{IM}^c}{2} \left( \frac{e_{t,IM}}{\gamma_{IM}^c} \frac{IM_t^c}{IM_{t-1}^c} Q_t^c Q_{t-1}^c - 1 \right)^2,
\]

where \( e_{t,IM} \) is an import demand shock.

Letting \( \nu_c \) denote the bias towards domestic intermediate goods, the technology to produce private consumption goods is

\[
\begin{align*}
Q_t^c := & \left( (\nu_c)^{\frac{1}{\mu_c}} H_t^c \right)^{-\frac{1}{\mu_c}} + \\
& \left( (1-\nu_c)^{\frac{1}{\mu_c}} \left( [1-\Gamma_{IM}^c (IM_t^c / Q_t^c)] IM_t^c \right)^{-\frac{1}{\mu_c}} \right) \text{,}
\end{align*}
\]

where

\[
\begin{align*}
H_t^c := & \left( \int (H_{f,t}^c)^{-1+\theta} d\theta \right)^{\theta / (\theta-1)} \\
IM_t^c := & \left( \int (IM_{f,t}^c)^{-1+\theta'} d\theta' \right)^{\theta' / (\theta'-1)}
\end{align*}
\]

The firm will minimize total input costs

\[
\min_{H_t^c, IM_t^c} P_{H_t^c} H_t^c + P_{IM_t^c} IM_t^c
\]

subject to the technology constraint (30) taking intermediate goods prices as given.

The existence of an adjustment cost to the share of imported goods in the production of final goods invalidates the standard result that the Lagrange multiplier of the technology constraint equals the price index of final goods. The price index of
private consumption goods that ensures that the producing firm operates under perfect
competition is:\(^{11}\):

\[
P_{C,t} = (\Omega_t^C)^{-\mu_C} (\lambda_t^C)^{\mu_C} \tag{32}\]

where

\[
\lambda_t^C = \left[ v_C P_{H,t}^{-\mu_C} + (1 - v_C) \left( P_{IM,t} / \Gamma^C_{IM,t} (IM_t^C / Q_t^C) \right)^{-\mu_C} \right]^{-1} \tag{33}\]

\[
\Omega_t^C = \left\{ v_C \left( P_{H,t} \right)^{-\mu_C} + (1 - v_C) \left( \frac{\Gamma^3_{IM,t} (IM_t^C / Q_t^C)}{1 - \Gamma^3_{IM,t} (IM_t^C / Q_t^C)} \right) \right\}^{-1} \tag{34}\]

\[
\times \left( P_{IM,t} / \Gamma^C_{IM,t} (IM_t^C / Q_t^C) \right)^{-\mu_C} \]

In general, first order conditions and equation (32) can be combined to yield the
following demand equations:

\[
H_t^C = v_C \left( \frac{P_{H,t}}{\Omega_t^C} \right)^{-\mu_C} \left( \frac{P_{H,t}}{P_{C,t}} \right)^{-\mu_C} Q_t^C \tag{35}\]

\[
IM_t^C = (1 - v_C) \left( \frac{P_{C,t}}{\Omega_t^C} \right)^{-\mu_C} \left( \frac{P_{IM,t} / \Gamma^3_{IM,t} (IM_t^C / Q_t^C)}{P_{C,t}} \right)^{-\mu_C} \frac{Q_t^C}{1 - \Gamma^3_{IM,t} (IM_t^C / Q_t^C)} \tag{36}\]

The description of the model for investment goods is analogous, and the import
demand shock that affects the cost to adjust the import basket is exactly the same.

2.3 Fiscal authorities

The domestic fiscal authority pursues a primary surplus target \((sp)\), levies taxes
on consumption, labor, capital and dividends, makes biased transfers, and adjusts
expenditures and budget financing accordingly.

The primary surplus \(SP_t\) is defined as:

---

\(^{11}\) Details of the derivation of (32) are shown in Valli and Carvalho (2010).
\[ SP_t = \tau_t^c P_{G,t} + \tau_t^w w_t + \tau_t^r r_t, W_t, N_t^D \]
\[ + \tau_t^K \left( R_{H,t} u_{t,t} - \left( \Gamma_a (u_{t,t}) + \delta \right) P_{t,t} \right) K_{H,t} + \tau_t^b D_t \]
\[ + u_{t,t} R_{G,t} G_{G,t} - P_{t,t} G_{t} - TR_t - P_{t,t} I_{G,t} \]

where \( \tau_t^c, \tau_t^w, \tau_t^K, \tau_t^b \) are rates of taxes levied on consumption, labor income, social security from workers, social security from firms, capital and dividends.

\( P_{G,t} G_{t} \) stands for aggregate expenditures with government consumption, \( TR_t \) stands for government transfers, and \( P_{t,t} I_{G,t} \) stands for aggregate expenditures with government investment.

The realization of the primary surplus is affected by deviations of the public debt and economic growth from their steady-states \( (B_y \text{ and } g_y, \text{ respectively}) \):

\[ sp_t = \rho_{1,sp} sp_{t-1} + \]
\[ (1 - \rho_{1,sp}) \left[ \{ sp + \phi_{b_y} (b_{y,t} - b_y) \} + \phi_{g_y} (g_{y,t-1} - g_y) + \epsilon_{sp,t} \right] \]

where \( sp_t = \frac{SP_t}{Y_t} \), \( b_{y,t} = \frac{B_y}{P_{Y,t-1} Y_{t-1}} \), \( g_{y,t} = \frac{Y_t}{Y_{t-1}} \), the unindexed counterparts are steady-state ratios, and \( \epsilon_{sp,t} \) is a white noise shock to the primary surplus.

In our calibrations, the foreign economy is represented by the USA and the Euro area. Therefore, for the foreign economy, we adopt CMS’s assumption that the fiscal authority does not follow a primary surplus target, and government expenditures with consumption, \( g_t = \left( P_{G,t} \right) \left( \frac{G_t}{Y_t} \right) \), follow an autoregressive process:

\[ g_t = (1 - \rho_g) g + \rho_g g_{t-1} + \epsilon_{g,t} \]

where \( g \) is the steady state value of government expenditures as a share of GDP and \( \epsilon_{g,t} \) is a white noise shock to government expenditures. Specifically for the foreign economy, we assume that lump sum taxes exist and follow an autoregressive process of the type:
where $B_Y$ is the steady state value of government bonds.

For both economies, government transfers follow the autoregressive process:

$$\left( \frac{TR_t}{P_{Y,j}Y_t} \right) = (1 - \rho_{tr}) tr + \rho_{tr} \left( \frac{TR_t}{P_{Y,j}Y_t} \right) + \epsilon_{tr,t}$$

(41)

where $tr$ is the steady state value of government transfers, and $\epsilon_{tr,t}$ represents a white noise shock to government transfers.

Total transfers are distributed to each household group according to:

$$TR_{t,j} := \left( \frac{1 - \omega \nu_{\tau_j}}{1 - \omega} \right) TR_t$$

(42)

$$TR_{t,j} := \nu_{\tau_j} TR_t$$

(43)

where $\nu_{\tau_j}$ is the bias in transfers towards group $J$.

Government investment follows an autoregressive rule of the form

$$ig_t = (1 - \rho_{ig}) ig + \rho_{ig} ig_{t-1} + \epsilon_{ig,t}$$

(44)

The government budget constraint is thus

$$\tau_t^C P_{C,j} C_t + (\tau_t^N + \tau_t^W + \tau_t^R) W_t N_t^D + \tau_t^K (R_{k,j} u_{k,j} - (\Gamma_u(u_{k,j}) + \delta) R_{k,j}) K_t + \tau_t^D D_t + T_t + (\epsilon_{\tau_t} R_t)^{-1} B_{t+1} + M_t + u_{t,j} R_{G,j} K_{G,j} - P_{G,j} G_t - TR_t - B_t - M_{t-1} - P_{t,j} I_{G,j} = 0$$

(45)

with $T_t = 0$ for the domestic economy, which, using the primary surplus definition, can be stated as:

$$SP_t = (B_t - (\epsilon_{\tau_t} R_t)^{-1} B_{t+1}) - (M_t - M_{t-1})$$

(46)

This equation makes clear that, in this model, money not only has an effective role in real decisions, but also matters for the adjustment of fiscal accounts. Increased
money supply can alleviate the financial burden from public debt, a feature that approximates the theoretical model to the real conduct of economic policy.

2.4. Monetary authorities

The domestic monetary authority follows a forward-looking interest rate rule that is compatible with an inflation targeting regime

\[ R_t^4 = \phi_{R1} R^4_{t-1} + (1 - \phi_{R1}) \left[ R^4 + \phi_{\Pi} \left( \frac{P_{C,j+3}}{P_{C,j-1}} - \Pi \right) \right] + \phi_{\varepsilon_y} (g_{Y,t-1} - g_Y) + \varepsilon_{R,t} \]

where \( \Pi \) is the annual inflation target, \( R^4 \) is the annualized quarterly nominal equilibrium interest rate, which satisfies \( R^4 = \beta^{-4} \Pi \), \( g_Y \) is the steady state output growth rate, and \( \varepsilon_{R,t} \) is a white noise shock to the interest rate rule.

For the foreign economy we adopt the representation in CMS:

\[ R_t^f = \phi_R R^4_{t-1} + (1 - \phi_R) \left[ R^4 + \phi_{\Pi} \left( \frac{P_{C,j}}{P_{C,j-3}} - \Pi \right) \right] + \phi_{\varepsilon_y} \left( \frac{Y_t}{Y_{t-1}} - g_Y \right) + \varepsilon_{R,t} \]

3. Bayesian Estimation

We estimate the NAWM through Bayesian inference methods\(^{12}\). Below are the procedures we adopted to this end.

3.1. Calibration

First we stationarize the variables in the model as shown in Valli and Carvalho (2010). Except for hours worked, we transform real variables to real GDP ratios to handle the unit root that arises from the permanent labor productivity shock. Nominal variables are

\(^{12}\) We use Dynare to conduct the log-linear approximation of the model to the calibrated steady state and to perform all estimation routines.
transformed to shares of nominal GDP as they also share the trend that arises from the non-zero inflation target.

The foreign economy is entirely calibrated, following the parameterization presented in CMS.

To calibrate the domestic economy, we adopt the following strategy. Price levels and capital utilization are normalized to 1, while profits and adjustment costs are set to zero. Some endogenous variables are calibrated so as to reproduce Brazilian historical averages during the inflation targeting regime (Table 1), and they consequently pin down the steady state values for the remaining endogenous variables of the model.

The parameters that affect the steady state of the model were also calibrated. Their values are shown in Table 2. Some of them were set at the same value as in CMS. A few others were calibrated to ensure that some desired relations hold in the steady state. The labor demand bias, \( \nu_w \), for instance, was calibrated to ensure that households’ groups \( I \) and \( J \) work the same amount of hours. The home biases \( \nu_c \) and \( \nu_I \) were obtained from the demand equations of imported goods using the steady state value of consumption and investment goods, in addition to the quantum of imports.

With the exception of consumption taxes, \( \tau^C \), which were calibrated following Siqueira et. al. (2001), Brazilian tax rates were set based on broad terms of current tax laws. These laws usually differentiate tax rates according to taxable bases, in addition to allowing for a great variety of exemptions. As such, they are not concise references for calibration. However, to our knowledge there is no aggregate data we could refer to for such a purpose, and so we chose the tax rates that are most commonly applied, yet, again, we cannot argue how good portraits of reality they are.

We calibrated the price-elasticity to demand of government investment goods, \( \eta_g \), to a value that is close to 1, arbitrarily approximating it to a Cobb-Douglas
technology. This enabled us to calibrate \( \nu_q \) from the rental rate on government capital, which we assumed to be just enough to cover expenditures with depreciation.

3.2. The data

We used the following time series to estimate the parameters of the domestic economy:

- Consumer price inflation \( \pi_{C,t} \): quarterly inflation of the IPCA (Índice de Preços ao Consumidor Amplo – IBGE)
- Nominal interest rate \( R_t \): quarterly effective nominal base rate (Selic)
- Total investment \( \frac{P_{I,t}I_t}{P_{Y,t}Y_t} \): seasonally adjusted quarterly flows of gross fixed capital formation and inventory change in the national accounts as a share of quarterly GDP
- Exports \( \frac{P_{X,t}X_t}{P_{Y,t}Y_t} \): seasonally adjusted quarterly flows of exports in the national accounts as a share of quarterly GDP
- Exports inflation \( \pi_{X,t} \): quarterly inflation rate of Brazilian export prices calculated in USD by Funcex
- Exports \( \frac{P_{IM,t}IM_t}{P_{Y,t}Y_t} \): seasonally adjusted quarterly flows of imports in the national accounts as a share of quarterly GDP
- Private consumption \( \frac{P_{C,t}C_t}{P_{Y,t}Y_t} \): seasonally adjusted quarterly flows of household consumption in the national accounts as a share of quarterly GDP
• Government consumption \( \frac{P_{G,t}G_t}{P_{Y,t}Y_t} \): seasonally adjusted quarterly flows of government expenditures in the national accounts as a share of quarterly GDP

• Installed capacity utilization \( u_{i,t} \): quarterly capacity utilization published by FGV, normalized using the average of the series

• Exchange rate variation \( \frac{S_t}{S_{t-1}} \): quarterly nominal BRL/USD exchange rate variation

• Primary surplus \( sp_t \): seasonally adjusted primary surplus of the consolidated government (methodology that includes Petrobrás in the public sector) as a share of GDP

At this stage, we did not incorporate measurement errors in the estimation, as the ones we tested proved to be important sources of non-invertibility of the hessian matrix at the estimated mode.

As Guerron-Quintana (2007) pointed out, the data set chosen for the estimation does matter for parameter identification. In our attempt to include the most number of series available, we noticed that the inclusion of monetary aggregates destabilized the estimations, and maximization algorithms could generally not find any optimum. We thus chose to exclude them from our data sample.

3.3. Shocks

We estimate the model with the following shocks:

• Total factor productivity, \( z \)
• Labor productivity, \( zn \)
• Consumption preferences, \( e_C \)
• Labor preferences, \( e_N \)
• Foreign risk premium, \( e_{RPF} \)
• Domestic risk premium, \( e_{RP} \)
• Import bias, \( e_{IM} \)
• Monetary policy, \( \varepsilon_R \)
• Primary surplus, $\varepsilon_{SP}$
• Public transfers, $e_{tr}$
• Government investment, $e_{ig}$
• Investment efficiency, $e_l$
• Wage markup, $e_W$
• Price markup, $e_p$

Except for monetary policy and primary surplus shocks, which are white noise, all other shocks follow AR processes that converge to a steady state. The process that governs the labor productivity shock is allowed to trend, following the equation:

$$\frac{zn_t}{zn_{t-1}} = (1 - \rho_{z_n}) \cdot g_y + \rho_{z_n} \cdot \frac{zn_{t-1}}{zn_{t-2}} + \varepsilon_{z_n, t}$$

(8)

where $g_y$ is the steady state growth rate of labor productivity, and $\varepsilon_{z_n, t}$ is an exogenous white noise process.

The steady state of the shocks to the wage and price markups are respectively $\frac{\eta}{\eta - 1}$ and $\frac{\theta}{\theta - 1}$.

3.3. Estimation

The parameters were estimated after the model was log-linearized around the calibrated steady state. Table 3 shows the priors and the estimated moments of the posterior distribution.

In the choice of priors, we either set the prior mean at the posterior modes obtained in CCW 2008 or used information from Brazilian-specific empirical evidence. In general our priors were more diffuse than those in CCW 2008. Below are more detailed descriptions of the priors we set based on Brazilian data:

• The prior means for $\chi_{H}$ and $\chi_{X}$, which govern the indexation of domestic and export intermediate prices, were set at a 0.30, a value that closely reflects the
average price rigidity in Brazilian CPI-micro-data, which is of about 1.3 quarters (Gouvea, 2007).

• The priors for the coefficients in the primary surplus rule were set at the point estimates of the regression shown in Valli and Carvalho (2010), run on a sample from 1996 to 2009.

• For the monetary policy rule, our prior means were set at the point estimates of the Taylor rule presented in Minella and Sobrinho-Souza (2009).

• However, our policy rules were estimated with only one lag in the policy instrument, as the maximization algorithm showed special difficulties finding the optimum when we allowed for two-lag policy rules. The prior mean for the autoregressive components were thus set as the sum of the point estimates of the two lags in the individual regressions we just mentioned.

• The prior means for the autoregressive components of the rules for transfers and public investment were set according to the point estimates obtained in isolated regressions of federal transfers to households and investment using disaggregated monthly data available from 2006 to 2009.

The posterior modes\(^{13}\) present important differences compared to those of the Euro Zone shown in CCW 2008:

• Uncertainty in the estimation of wage rigidities in Brazil is more pronounced in Brazil (wider confidence interval). Although wage rigidities in the non-Ricardian group are somewhat greater in the estimations for Brazil, for the Ricardian group, they are a little lower.

• The prices of intermediate goods produced for the domestic market are more frequently optimized in Brazil. However, the degree to which they are indexed

\(^{13}\) We used 10 blocks of 100,000 replications of the Metropolis Hastings algorithm.
to past inflation is almost twice as much in Brazil. Such an evidence could be an indication that there is still room for the Central Bank of Brazil to build on its credibility.

- Price rigidities in the export sector are much lower in Brazil than in Europe, with the Calvo coefficient estimated at a point very close to micro-data evidence. This might be due to the greater share of commodity products in our export portfolio, as compared to Europe.
- In CCW 2008 they also found that the export sector was less backward-looking than the domestic sector in its pricing decisions.
- Adjustment costs are statistically significant in Brazil. Nonetheless, they are smaller in magnitude than in the Euro Zone. The exception is the parameter that governs adjustment costs to holding foreign debt away from steady state levels, which was not estimated in CCW 2008. Its prior was set according to the calibrated version of the NAWM in CMS.
- The persistence of shocks that were also estimated in the Euro Zone was in general smaller in Brazil. The exception was the shock to price markup, which was almost twice as much in Brazil, with a tighter distribution.
- In spite of the fact that the theoretical model presented in CCW 2008 did introduce shocks to consumer and labor preferences, for some unreported reason, the parameters that govern their dynamics were not included in the reported results of the Bayesian estimation. In our estimations, the variances of these shocks were not statistically significant (t-stats of 0.24). In fact, the only shocks that had significant t-ratios were the shocks to monetary policy and primary surplus rule. However, as we will report below, impulse responses of one standard deviation of such shocks have important and significant economic
impact. Even if they are unlikely to occur, should they occur, their transmission is non-trivial and worth analyzing\textsuperscript{14}.

Figure 2 plots the prior and posterior distributions.

4 – Impulse Responses

Figure 3 shows impulse responses to the shocks in the model. The median responses are shown in bold lines, within the 90\% confidence interval plotted with thinner lines, drawn from the posterior distribution. The shocks are in the magnitude of a 1 standard deviation from the steady state of the variables they directly affect.

4.4.1. A contractionist shock to monetary policy

As mentioned earlier, the steady state of our domestic economy was calibrated using data from the entire inflation targeting period in Brazil. The average nominal interest rate in this period was very high (17.4\% p.y.), and, thus a one standard-deviation shock to monetary policy increases interest rates to 20\% p.y.. Since 2006, and except for a halt in 2008, benign economic conditions have allowed the central bank to systematically cut the base rate. From 2009 to June 2010, it was kept at one-digit. Any sample choice in this scenario would be arbitrary, and pros and cons could be raised for each one of them. Our choice for the longer period was primarily based on the need for a reasonable amount of data to obtain reliable estimates of the structural parameters. We actually attempted to proceed with the estimations using the 2006-2009 sample, but the optimization routines failed to find an optimum.

\textsuperscript{14} Canova and Sala (2006), estimating a standard DSGE model with an objective function that measures the distance of impulse responses, suggests that the $t$-ratios in maximum likelihood estimations should not be trusted indistinctly. We are unaware of such a type of analysis for the Bayesian set-up, but as the source of problems seems to be almost as likely in Bayesian estimations, we suspect that the advice extends to Bayesian estimations as well.
An interest rate shock curtails domestic demand. The shock immediately impacts output, with a real GDP decline of about 1% already in the first quarter. The trough in the shock transmission to real GDP is reached at over a year (5 to 6 quarters). As compared to the Euro Zone, the interest rate shock in Brazil has stronger effects on output (also due to its higher magnitude), and the transmission is also more sluggish, but as in the Euro Zone, by the fourth year, the shock has practically taken full effect on output.

Underlying the real GDP behavior is a strong and sluggish reduction in investment, mostly in the private sector, which, as in the estimated NAWM, falls more sharply than private consumption. The decline in aggregate demand leads firms to cut their demand for capital services and labor, and, thus households’ real income from labor and capital rents fall. These forces are enough to drive private consumption down.

As the exchange rate appreciates shortly after the shock, the prices of imported goods drop noticeably, and more pronouncedly than the prices of intermediate domestic goods. The fall in domestic prices transmit to consumer prices. The trough in consumer inflation is reached still within the first year, at about the third quarter after the shock hits. The transmission of the shock to inflation is a little faster than in the Euro Area, the latter reaching its peak after the first year.

As the demand for investment goods falls, government investment initially drops by about 1%, and due to its high estimated autoregressive coefficient (0.93), it takes very long (10 quarters) to start reverting back to the steady state.

In our estimated fiscal rule, a one p.p. drop in (lagged) output growth triggers a modest 0.04 p.p. cut in the fiscal primary surplus. As output growth remains below the steady state for over a year, such is the time length that the primary surplus (slightly) remains below target. Debt servicing increases with interest rate hikes, as the public
debt pays the base rate\textsuperscript{15}. This source of income pushes households towards the public debt market. As households also hold less money balances, and tax collection falls with the drop in economic activity, public debt rises.

A depressed output base in the debt-to-GDP ratio drives this fiscal indicator up to a new level for a very long time. After the first year, the ratio peaks at 50\% of GDP.

4.4.2. Expansionist shock to the primary surplus

A one-standard-deviation shock to the primary surplus as a share of GDP implies a stronger and more persistent effect in private consumption than that obtained with a shock to government consumption in Forni et. al. (2009). It is true that the policy rule adopted there is different from ours, but the fact that the median expansionist effect in private consumption in our model takes over two years to fade is noteworthy. Importantly, a shock to the primary surplus translates into not only government purchases of consumption goods, but also into increased public investment. The transmission of each of these fiscal instruments to the economy implies more complex interactions that result in a longer-lasting incentive to the economy.

The shock has an expansionist effect over the productive sector of the economy. The rise in public expenditures with consumption and investment implies a higher demand for intermediate goods, to produce both consumption and investment goods. Capital utilization thus rises, as does the demand for labor. Output grows steadily, peaking a few quarters after the shock, and remains above steady state for almost 3 years.

The shock puts pressure on the prices of both domestic and imported intermediated goods. The depreciation of the exchange rate puts further pressure on

\textsuperscript{15} Plus a risk premium shock, if it is active.
imported prices, which peak higher than the domestic. These cost-push pressures translate into higher consumer prices. Consumer price inflation thus rises, and interest rates rise only enough to drive inflation back to its steady state after four quarters, the horizon that is actually targeted by the monetary policy.

The expanded output base drives the debt-to-GDP ratio to below the steady state during the first year. Later on, however, as the highly autoregressive rules for government expenditures keep on exerting pressures on the fiscal results, the debt-to-GDP ratio rises up to about 50% of GDP.

The shock to the primary surplus implies a stronger expansion in the consumption of non-Ricardian agents, likely due to the fact that the rise in real income cannot be saved up for the event of a gloomier future. What is striking in the responses we obtain is the very response of private consumption by Ricardian agents. Unlike in the heterogeneous-agents models in CMS and in Forni et. al., where a shock to government expenditures reduces the consumption of Ricardian agents, here the shock to the primary surplus ends up having a positive impact in their consumption, although much quicker and lower in magnitude than that for non-Ricardian agents. Underlying this behavior is the fact that investment prices rise, implying a cut down in private investment. Ricardian households decide to increase the utilization of existing capital instead of augmenting on their capital stock. As government capital is cheaper, Ricardian households improve on their dividends.

The shock does crowd out private investment, as public investment, which strongly increases as part of the fiscal policy, is cheaper and is just enough to supply firms with their additional demand for capital services.
4.4.3. Shock to government transfers

The response of a one-standard-deviation shock to government transfers as a share of GDP implies a much stronger, yet shorter, expansion of private consumption than that obtained in Forni et al. (2009). Also different is the reaction of Ricardian agents to the shock. While in Forni et al. Ricardian consumption falls, here it remains practically unaffected.

Non-Ricardian agents in our model receive the highest stake of government transfers, to account for the fact that in Brazil government programs are usually oriented to lower-income population. From the second quarter on, this infusion of income into non-Ricardian households’ budgets translates into higher demand for consumer goods, which is met by firms by increasing their demand for labor and capital services. There is mild pressure on the prices of domestic goods, but, as the currency depreciates in the medium run, the prices of imported goods rise, putting pressure on final consumer prices. At about the second year after the shock, this effect reverts: currency appreciates, and the drop in prices of imported goods put downward pressure on consumer prices.

To enforce this rise in public transfers, the government chooses to reduce purchases of consumer goods, but does not cut down on its investment expenditures. The latter actually increase and remain above the steady state for over two years, as the rule that public investment follows concerns its ratio to GDP, with a target. The rise in output helps alleviate the debt-to-GDP ratio.

4.4.4. Shock to government investment

The investment base in Brazil where this shock first hits is small in magnitude. As such, the percentage increase that it yields on public investment as a share of GDP is
quite large: 100%. The crowding out of private sector investment is mild (less than 1%), also due to the base effect.

The shock first translates into a greater stock of capital, which thus implies a lower capital utilization rate. As public consumption drops to meet the primary surplus target, so does the demand for intermediate goods. The share of government consumption in the demand for intermediate goods by far outweighs that of public investment. As such, the overall economic impact is an initial mild drop in economic activity, which only reverts after the first year. As long as the economy is slightly depressed, so is private consumption of non-Ricardian agents. Ricardian agents are not so much affected because they benefit from cheaper public capital, which increases with the rise in government investment. As the economy peaks up, so does private consumption.

The inflationary pressure of this shock stems primarily from the prices of investment goods, which, in addition to responding to the increased demand, also responds to cost-push pressure that comes from imported inputs with the depreciation of the exchange rate. Consumer price inflation rises, as do monetary policy responses to the inflation outlook.

4.4.5. Shock to the demand for imports

A shock that makes the domestic economy more dependent on imports has an overall recessionary impact, as it demobilizes the productive sector of the economy.

The increased demand for imports reduces production of domestic intermediate goods. As such, capital utilization and firms’ demand for labor falls. The reduction in income leads households to cut down on their consumption. Output thus falls.
As the exchange rate depreciates, imported prices rise, which exerts high pressure on the prices of final goods. Consumer price inflation rises initially to 9% p.y. and the monetary policy reacts accordingly, increasing the interest rate, which exerts more downward pressure on the economy.

The reduced demand for capital services affect investment decisions, and both private and public investment falls. To attain the primary surplus target, the government has to reduce not only investment but also consumption, as the output base is weak.

4.4.6. Shock to the efficiency of investment

The model does not distinguish the efficiency of public investment from private investment, except for the impact of the quarter-by-quarter change in each of the stocks. As such, a shock that increases the efficiency of investment affects the accumulation of both public and private capital, yet private investment, which is greater in magnitude, expands much more as a response to the shock than public investment.

In addition to an expansion in the stock of capital available to firms, capital utilization also increases in the initial quarters. Firms’ demand for labor also increase, which results in important gains in real labor income. Together with improvements in the income of capital, private consumption rises.

As tax revenues increase, the government consumes more, and even so, with an expanded output base, the primary surplus-to-GDP rises. Consumer price inflation steadily rises over the first year, mostly due to cost pressures stemming from imported goods in the production of intermediate goods. This enacts a response of the monetary policy.
4.4.7. Shock to the UIP risk premium

This shock differs from a monetary policy shock inasmuch as the central bank only focuses on the net effect of the shock to inflation and reacts accordingly. The direct impact of the risk premium shock is indeed on the government’s budget, as the debt becomes costlier. The primary surplus falls by about half a percentage point of GDP after the shock, showing that the anti-cyclic component of the primary surplus rule dominates that of the public debt stabilization. The public debt strongly and persistently rises. The strong reduction in government expenditures with consumption and investment drives down economic growth, and thus private consumption.

4.4.8 - Wage markup shock

Here the distributive aspect of the model enacts very distinct responses compared to CCW. A shock to wage markup represents greater a burden on firms hiring Ricardian agents, as their wages are substantially higher than non-Ricardians’. The technology that aggregates optimized and non-optimized wages also exacerbates this effect as the weight on optimizing wages increases with the shock. All of that implies a strong shift in the demand of firms for the (cheaper) labor of non-Ricardian agents, with important impact on the aggregate economy.

The shift in labor demand towards non-Ricardian agents allow firms to cut down on their real marginal costs. Labor demand in terms of hours worked surge, which allows non-Ricardian consumers to increase their money holdings for future consumption and to also raise their consumption. Aggregate consumption follows, and so does output. In spite of the surge in demand, prices are subdued due to depressed marginal costs and to an appreciated exchange rate, the latter only in the initial quarters. As the exchange rate depreciates from the end of the first year to the end of the second
year, imported prices exert some upward pressure in consumer price inflation, but that is short-lived.

4.4.9 - Price markup

A shock to the markup of prices of domestic intermediate goods is a cost-push shock to the economy that translates into higher final goods prices. The monetary policy reacts to inflation prospects, driving down real GDP and GDP growth. This entails firms’ cutting down on labor and capital services. As the demand for capital services reduces, so does investment. The reduction in real income from labor and from capital rented to firms results in a reduction of private consumption. The loss in economic dynamism prompts the primary surplus to operate countercyclically, by means of an increase in government expenditures with consumption.

5. Conclusion

In this paper, we employ Bayesian methods to estimate an open-economy model of two economies where the fiscal policy is implemented through primary surplus, investment, and transfer rules. There are both Ricardian and non-Ricardian agents, rendering the fiscal policy an important driver of business cycles.

In its essence, the model follows the ECB NAWM presented in CMS, with some theoretical additions made in CCW 2008. In addition to a different modeling of the fiscal sector, we also incorporate labor heterogeneity to allow for a steady state where both Ricardian and non-Ricardian agents can work the same amount of hours, yet earning different wages.
We estimate the essential parameters of the domestic economy using Brazilian data from the inflation targeting regime. The estimated mode of the posterior distribution of the parameters shows important sectoral differences with respect to price rigidities. The export sector in Brazil shows more frequent price adjustments, and lower price indexation. Overall, prices are more frequently optimized in Brazil than in the Euro Zone (CMS’ estimation), yet the prices of domestic goods show a higher indexation to past inflation than in Europe, which could be an indication that there is still room for gains of credibility in the Brazilian monetary policy. Adjustment costs in Brazil are validated by the data, yet they are a little less important than in the Euro Zone.

The shock to the primary surplus has qualitatively distinct responses compared to the public expenditures shocks in Forni et. al. (2009) and CMS, where non-Ricardian agents are also introduced. In addition to having a stronger expansion in output and private consumption, the primary surplus shocks imply an increase in the consumption of Ricardian agents as well. We believe this result bears strong relation with the higher share of non-Ricardian agents in our model, which represents a broader base for demand after the expansionist fiscal shock, but we also understand that the type of fiscal rule we model has implications for such an outcome. This point will be further investigated in future work.

After a shock to monetary policy in Brazil, real GDP falls and reaches a trough at over a year (5 to 6 quarters). As compared to the Euro Zone, the interest rate shock in Brazil has stronger effects on output (also due to its higher magnitude), and the transmission is more sluggish, but, as in the Euro Zone, by the fourth year, the shock has practically taken full effect on output. As to consumer price inflation, the trough
after the interest rate shock is estimated to occur still within the first year (3\textsuperscript{rd} to 4\textsuperscript{th} quarter). The transmission to inflation is a little faster than in the Euro Area.

The paper also analyses the impulse responses of shocks to risk premia, investment efficiency, import bias, public transfers and investment, monetary policy, and wage and price markup. Some hold qualitatively distinct implications for the dynamics of the model as compared to the estimated version of ECB’s NAWM presented in CCW 2008. The reason seems to be highly associated with their simplification to exclude non-Ricardian agents.
APPENDIX

A. Cost functions

We describe below the functional form for each of the cost functions in the paper.

Consumption transactions cost:

\[ \Gamma_v(v_h) := \gamma_v \cdot v_h + \gamma_v \cdot v_h^1 - 2 \sqrt{\gamma_v \cdot \gamma_v^1} \]  
(A.1)

Cost on the transaction with international bonds:

\[ \Gamma_{B^F}(B_{t,t+1}^F) := \gamma_{B^F} \left( \exp \left( \frac{(1-\omega)S_r R_{F,t}^{-1} B_{t,t+1}^F}{P_{t,t} Y_t} \right) - \exp(B_F) \right) \]  
(A.2)

where \( B_F \) is the steady state ratio of international bonds as a share of GDP.

Cost on the utilization of capital:

\[ \Gamma_u(u_{t,t}) := \gamma_u \cdot (u_{t,t} - 1) + \frac{\gamma_u}{2} (u_{t,t} - 1)^2 \]  
(A.3)

Cost on the adjustment of the level of investment:

\[ \Gamma_I \left( \frac{I_{t,t}}{I_{t,t-1}} \right) := \gamma_I \left( \frac{I_{t,t}}{2} - g_Y \right)^2 \]  
(A.4)

where \( g_Y \) is the trend growth rate of the economy.

Cost on the adjustment of the import share in the production of final consumption goods:

\[ \Gamma_{IM} \left( \frac{IM^C}{Q_t^C} \right) := \gamma_{IM} \left( \frac{IM^C}{2} \right) \left( \frac{IM^C}{IM^C_{t-1}} \frac{Q_t^C}{Q_t^C} \right)^2 \]  
(A.5)

Cost on the adjustment of the import share in the production of investment goods:
\[
\Gamma_{im}^i \left( \frac{IM_i^i}{Q_i^i} \right) = \frac{\gamma_{im}^i}{2} \left( e_{im} \right)^{\gamma_{im}^i} \frac{IM_i^i}{Q_i^i} \left( \frac{IM_i^i}{Q_i^i} - 1 \right)^2 
\]

(A.6)

\[
\Gamma_{im}^c (IM_i^c / Q_i^c) = 1 - \Gamma_{im}^{c^c} (IM_i^c / Q_i^c) - \Gamma_{im}^{c^c} (IM_i^c / Q_i^c) (IM_i^c / Q_i^c)
\]

(A.7)

\[
\Gamma_{im}^c (IM_i^c / Q_i^c) = 1 - \Gamma_{im}^{c^c} (IM_i^c / Q_i^c) - \Gamma_{im}^{c^c} (IM_i^c / Q_i^c) (IM_i^c / Q_i^c)
\]

(A.8)
References


### Table 1: Steady State Ratios

<table>
<thead>
<tr>
<th>Model variable</th>
<th>Description</th>
<th>Calibrated value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\pi, \bar{\pi}$</td>
<td>Consumer price inflation, inflation target</td>
<td>4.92% p.y.</td>
</tr>
<tr>
<td>$g_Y$</td>
<td>Output growth</td>
<td>3% p.y.</td>
</tr>
<tr>
<td>$P_I G / P_Y Y$</td>
<td>Government investment</td>
<td>1.86% of GDP</td>
</tr>
<tr>
<td>$B / P_Y Y$</td>
<td>Domestic net public debt</td>
<td>185% of quarterly GDP</td>
</tr>
<tr>
<td>$SP / P_Y Y$</td>
<td>Primary surplus</td>
<td>3.6% of GDP</td>
</tr>
<tr>
<td>$P_G G / P_Y Y$</td>
<td>Government consumption expenditures</td>
<td>19.93% of GDP</td>
</tr>
<tr>
<td>$SR_F^{-1} B / P_Y Y$</td>
<td>Net foreign debt</td>
<td>-16.33% of quarterly GDP</td>
</tr>
<tr>
<td>$R / \pi$</td>
<td>Real interest rate</td>
<td>9% p.y.</td>
</tr>
</tbody>
</table>
### Table 2: Calibrated parameters for Brazil

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
<th>Source of calibration</th>
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</thead>
<tbody>
<tr>
<td>A. Households</td>
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<td></td>
</tr>
<tr>
<td>$s$</td>
<td>0.03</td>
<td>Population size</td>
<td>World Bank 2008</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>1.0</td>
<td>Inverse of the intertemporal elasticity of substitution</td>
<td>Log-linear utility</td>
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<tr>
<td>$\kappa$</td>
<td>0.60</td>
<td>Degree of habit persistence</td>
<td>ECB NAWM (CMS)</td>
</tr>
<tr>
<td>$\zeta$</td>
<td>2.0</td>
<td>Inverse of the Frisch elasticity of labor supply</td>
<td>ECB NAWM (CMS)</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.025</td>
<td>Depreciation rate</td>
<td>ECB NAWM (CMS)</td>
</tr>
<tr>
<td>$\omega$</td>
<td>0.59260</td>
<td>Size of household $J$</td>
<td>Brazil’s PNAD survey 2007</td>
</tr>
<tr>
<td>$\xi_I, \xi_J$</td>
<td>0.765</td>
<td>Fraction of households not setting wages optimally each quarter</td>
<td>Posterior mode of NAWM (CCW 2008)</td>
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<tr>
<td>B. Intermediate-good firms</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\alpha$</td>
<td>0.3</td>
<td>Share of capital income in value added</td>
<td>ECB NAWM (CMS)</td>
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<tr>
<td>$z$</td>
<td>1.0</td>
<td>Stationary total productivity level</td>
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<tr>
<td>$\eta$</td>
<td>6.0</td>
<td>Price elasticity of demand for labor bundles</td>
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<td>$\eta_I$</td>
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<td>Price elasticity of demand for labor of household $I$</td>
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<td>$\nu_\omega$</td>
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<tr>
<td>$v_c$</td>
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<td>Home bias in the production of consumption final goods</td>
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<td>$v_l$</td>
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<tr>
<td>$\theta$</td>
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<td>Price elasticity of demand for the intermediate-good variety</td>
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<tr>
<td>$\tau^c$</td>
<td>0.162</td>
<td>Consumption tax rate</td>
<td>Siqueira, Nogueira, Souza (2001)</td>
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<td>$\tau^d$</td>
<td>0.15</td>
<td>Dividend tax rate</td>
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<td>$\tau^k$</td>
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<td>Capital income tax rate</td>
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<td>$\tau^n$</td>
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<td>Labor income tax rate</td>
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<td>$\tau^{wh}$</td>
<td>0.11</td>
<td>Rate of social security contributions by households</td>
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<tr>
<td>$\tau^{wf}$</td>
<td>0.20</td>
<td>Rate of social security contributions by firms</td>
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<tr>
<td>$\nu_{tp}$</td>
<td>1.0</td>
<td>Household J lump-sum tax bias (1 = no bias)</td>
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<td>$\eta_g$</td>
<td>1.001</td>
<td>Elasticity of substitution between private and public investment goods</td>
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### E. Adjustment and transaction costs

<table>
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<th>Parameter</th>
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<td>Subst. Elast: inv. $\mu_I$ gamm</td>
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<td>5.169</td>
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<td>Transfers: autoregr. $\rho_{tr}$ beta</td>
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<td>Autoregressive coefficients</td>
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<td>Consumer preference $\rho_{c}$ beta</td>
<td>0.650</td>
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<td>0.660</td>
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<tr>
<td>Risk premium: foreign debt $\rho_{rp}$ beta</td>
<td>0.880</td>
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<td>0.600</td>
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<td>Import demand $\rho_{im}$ beta</td>
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<td>Labor preference $\rho_{N}$ beta</td>
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<td>Wage markup $\rho_{W}$ beta</td>
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<td>Price markup $\rho_{P}$ beta</td>
<td>0.396</td>
<td>0.083</td>
<td>0.636</td>
</tr>
<tr>
<td>Standard deviations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monetary policy $\varepsilon_R$ invg</td>
<td>0.100</td>
<td>0.000</td>
<td>0.025</td>
</tr>
<tr>
<td>Neutral technology $\varepsilon_{1}$ invg</td>
<td>0.100</td>
<td>0.118</td>
<td>0.073</td>
</tr>
<tr>
<td>Permanent technology $\varepsilon_{zn}$ invg</td>
<td>0.100</td>
<td>0.034</td>
<td>0.023</td>
</tr>
<tr>
<td>Public transfers $\varepsilon_{tr}$ invg</td>
<td>0.100</td>
<td>0.022</td>
<td>0.196</td>
</tr>
<tr>
<td>Primary surplus $\varepsilon_{sp}$ invg</td>
<td>0.100</td>
<td>0.009</td>
<td>0.016</td>
</tr>
<tr>
<td>Public investment $\varepsilon_{ig}$ invg</td>
<td>0.100</td>
<td>0.012</td>
<td>0.016</td>
</tr>
<tr>
<td>Consumer preference $\varepsilon_{C}$ invg</td>
<td>0.100</td>
<td>0.180</td>
<td>0.044</td>
</tr>
<tr>
<td>Risk premium: foreign debt $\varepsilon_{rp}$ invg</td>
<td>0.100</td>
<td>0.113</td>
<td>0.146</td>
</tr>
<tr>
<td>Import demand $\varepsilon_{im}$ invg</td>
<td>0.100</td>
<td>0.183</td>
<td>0.171</td>
</tr>
<tr>
<td>Investment specific $\varepsilon_{i}$ invg</td>
<td>0.100</td>
<td>0.253</td>
<td>0.289</td>
</tr>
<tr>
<td>Risk premium: domestic $\varepsilon_{rp}$ invg</td>
<td>0.100</td>
<td>0.020</td>
<td>0.019</td>
</tr>
</tbody>
</table>
Figure 1: The map of the core structure of the model

<table>
<thead>
<tr>
<th>Households</th>
<th>Government</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type I</strong></td>
<td><strong>consume (maximize utility)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>hold money</strong></td>
</tr>
<tr>
<td></td>
<td><strong>invest: government bonds, international bonds and capital</strong></td>
</tr>
<tr>
<td></td>
<td>* more specialized labor services *</td>
</tr>
<tr>
<td><strong>Type J</strong></td>
<td><strong>consume (maximize utility)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>hold money</strong></td>
</tr>
<tr>
<td></td>
<td>* less specialized labor services *</td>
</tr>
</tbody>
</table>

**Labor services market**: monopolistic competition with wage rigidities

**Capital market**: perfect competition

**Intermediate goods firms**
- combine labor and capital (private + public) inputs

<table>
<thead>
<tr>
<th>Domestic market</th>
<th>Exports</th>
</tr>
</thead>
</table>

**Intermediate goods market**: monopolistic competition with price rigidities

**Final goods firms**
- combine domestic and imported intermediate goods

<table>
<thead>
<tr>
<th>Private Consumption</th>
<th>Government Consumption</th>
<th>Private and Government Investment</th>
</tr>
</thead>
</table>

**Final goods market**: perfect competition *(zero profit/price index)*

**Government**
- consumes final goods
- *invests (buy final investment goods)*
- issues domestic bonds
- levies distortive taxes: consumption, labor income and payroll
- transfers to households *(biased to type J households)*

**Monetary Policy**
- Interest rate rule *(Forward Looking)*

**Fiscal Policy**
- Primary surplus rule *(Debt Stabilization Commitment and Countercyclical Components)*

**Domestic bonds market**: households are interest rate takers

**Rest of the world**
- modeled symmetrically, except for:
  - monetary rule: backward looking
  - fiscal rules: government consumption rule and lump-sum taxes
  - steady state

**International markets**: international bonds: *sovereign risk spread*
- intermediate goods: local currency pricing
Figure 2: Prior and Posterior Distributions
Figure 3: Impulse responses
Price of capital
% of stationary level

Price of investment good
% of stationary level

Profit
% of stationary level

steady state
1 std shock to the primary surplus/GDP (median)
10% percentil
90% percentil
Price of investment good
% of stationary level

Price of capital
% of stationary level

Profit
% of stationary level

steady state

1 std shock in government transfers/GDP (median)

10% percentil

90% percentil
Price of capital
% of stationary level

Price of investment good
% of stationary level

Profit
% of stationary level

- steady state
- 1 std shock in government investment (median)
- 10% percentil
- 90% percentil