Samba: Stochastic Analytical Model with a Bayesian Approach

DSGE Model Project for Brazil's economy

Working in Progress - Preliminary results

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Outline

- Introduction
- Model
- Estimation results
- Challenges and next steps

Purposes of the project

- Provide the Banco Central do Brasil with a Dynamic Stochastic General Equilibrium (DSGE) model to be used as a tool for:
  - policy analysis
    - framework for policy discussions; qualitative and quantitative assessment of shock effects, monetary policy decisions and different scenarios, etc.
  - medium-term forecast

- "All models are wrong! Some are useful" George Box

- Models and judgement are complements, not substitutes

Model features

- Microfounded model developed for the inflation targeting period (started in mid-1999)

- Small open economy model

- Aggregate demand (C + I + G + X - M):
  - Households -> private consumption and investment
  - Firms -> import demand
  - Government -> government consumption
  - Rest of the world -> export demand

Model features

- Supply side (Y)
  - Competitive firms -> assemble differentiated goods supplied by monopolistic competitive firms and sell them in
    - Local markets (domestic consumption and investment goods)
    - Abroad (export goods)
  - Monopolistic competitive firms -> production of differentiated goods
    - Inputs: labor, capital services, and imports
    - Price rigidity (à la Calvo) with forward- and backward-looking behavior (Galí and Gertler, 1999)

Model features

- Government:
  - Monetary policy: Taylor rule
  - Fiscal policy rule
- Rest-of-the-world variables: interest rate, inflation, world imports, and foreign investors' "risk aversion".

Main loglinear equations

- *Aggregate Demand:* Consumption
  - Optimizing households

$$c_t^o = \left(\frac{1}{1+h}\right) E_t\left(c_{t+1}^o\right) + \left(\frac{h}{1+h}\right) c_{t-1}^o - \frac{1}{\sigma}\left(\frac{1-h}{1+h}\right) E_t\left(r_t - \pi_{t+1}\right) +$$
$$... + \frac{1}{\sigma}\left(\frac{1-h}{1+h}\right)\left(1-\rho_c\right) z_t^c$$

  - Rule-of-thumb households

$$c_t^{rot} = w_t^r + n_t^{rot}$$

  - Aggregate consumption

$$c_t = \left(1-\varpi_c\right) c_t^o + \varpi_c c_t^{rot}$$

r_t - interest rate; π_t - inflation; z_t^c - shock to consumption;
w_t^r - real wages; n_t^{rot} - employment

- *Aggregate Demand:* Investment:

$$i_t = \frac{1}{\delta_s\left(1+\beta\right)} q_t^I + \frac{\beta}{1+\beta} E_t i_{t+1} + \frac{1}{1+\beta} i_{t-1} + \left(\frac{1-\rho_I \beta}{1+\beta}\right) z_t^I$$

Shadow price of capital

$$q_t^I = E_t\left\{\beta\left(1-\delta\right) q_{t+1}^I + \left(1-\beta(1-\delta)\right)\widehat{r}_{t+1}^k - \left(r_t - \pi_{t+1}\right)\right\}$$

- *Aggregate Demand:* Net Exports

  - Exports

$$x_t = m_t^* + \varkappa q_t$$

  - Imports

$$m_t = y_t - \varrho\left(q_t - mc_t\right)$$

$\widehat{r}_t^k$ - rental rate of capital; z_t^I - shock to investment; m_t^* - world imports; q_t - real exchange rate; y_t - (gross) output; mc_t - real marginal cost

- *Aggregate Supply*
  - Production function

$$y_t = f\left(k_t, u_t, n_t, m_t, a_t\right)$$

  - Labor market
    - Labor supply

$$n_t = \left(1 - \varpi_n\right) n_t^o + \varpi_n n_t^{rot}$$

    - Labor demand

$$\begin{aligned} n_t &= y_t - \left[(1-\varrho) + \varrho s_d\right] a_t - \left[\alpha + \varrho\left(1 + s_d\right)\left(1 - \alpha\right)\right] w_t^r + \\ &\quad + \alpha\left[1 - \varrho\left(1 - s_d\right)\right] r_t^k + \varrho(1 - s_d) q_t \end{aligned}$$

k_t - physical capital; u_t - rate of capital utilization; a_t - productivity shock

- Capital services
  - Demand

$$\begin{aligned} k_t + u_t &= y_t - [(1 - \varrho\,(1 - s_d)]\,a_t - [(1 - \alpha) + \alpha\varrho\,(1 - s_d)]\,\widehat{r}_t^k + \\ &\quad \ldots + (1 - \alpha)\,[(1 - \varrho\,(1 - s_d)]\,w_t^r + \varrho(1 - s_d)q_t \end{aligned}$$

  - Supply

$$u_t = \frac{1}{\delta_a}\widehat{r}_t^k$$

  - Law of motion for capital

$$k_{t+1} = (1 - \delta)k_t + \left(\frac{I}{K}\right) i_t$$

– Phillips curve

$$\pi_t = \lambda mc_t + \lambda_b \pi_{t-1} + \lambda_f E_t \pi_{t+1}$$

where:

$$mc_t = s_d \left[\alpha \widehat{r}_t^k + (1-\alpha) w_t^r - a_t \right] + (1 - s_d) q_t$$

$$\left(\lambda, \lambda_b, \lambda_f \right) = f\left(\theta, \varpi_b, \beta \right)$$

- *Financial variables*
  - Real exchange rate (UIP)

$$q_t = E_t q_{t+1} - \left[\left(r_t - E_t \pi_{t+1}\right) - \left(r_t^* + \phi_t - E_t \pi_{t+1}^*\right)\right]$$

  - Country-risk premium

$$\phi_t = -\psi b_{t+1}^{y*} + \nu z_t^{\phi^*} + z_t^{\phi}$$

r_t^* - world interest rate; π_t^* - world inflation;
$z_t^{\phi^*}$ - international investors' risk averstion; z_t^{ϕ} - shock to country-risk premium

- *Government*
  - Monetary policy (Taylor rule)

$$r_t = \gamma_r r_{t-1} + (1-\gamma_r)\left[\gamma_\pi E_t\left(\pi_{t+1} - \overline{\pi}_{t+1}\right) + \overline{\pi}_t + \gamma_y y_t^{VA}\right] + z_t^r$$

  - Fiscal policy rule

$$g_t^y = \gamma_g g_{t-1}^y + \left(1-\gamma_g\right)\left(\gamma_s \widehat{s}_{t-1}^y - \gamma_b b_t^y\right) + z_t^g$$

$\overline{\pi}_t$ - inflation target; z_t^r - shock to monetary policy;
g_t^y - government consumption-to-GDP ratio; $\overline{s}_t^y$ - primary fiscal surplus target;
z_t^g - shock to fiscal policy; $\widehat{s}_{t-1}^y$ - primary fiscal surplus deviation from the target

- *Shocks and rest-of-the-world variables:*

$$z_t = \rho z_{t-1} + \varepsilon_t$$

- *Value added (GDP) - Equilibrium:*

$$y_t^{VA} = s_c c_t + s_i i_t + s_g g_t + s_x x_t - s_m m_t$$

Estimation technique

- Bayesian estimation:

Estimated parameter distribution = prior distribution + likelihood information from the data

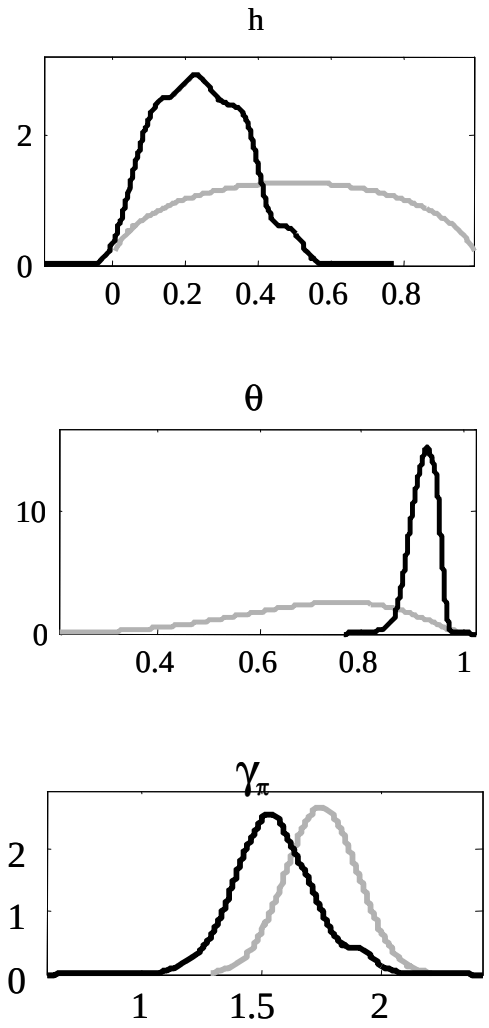
It is a bridge between calibration and maximum likelihood

Results: Model + Data + Priors

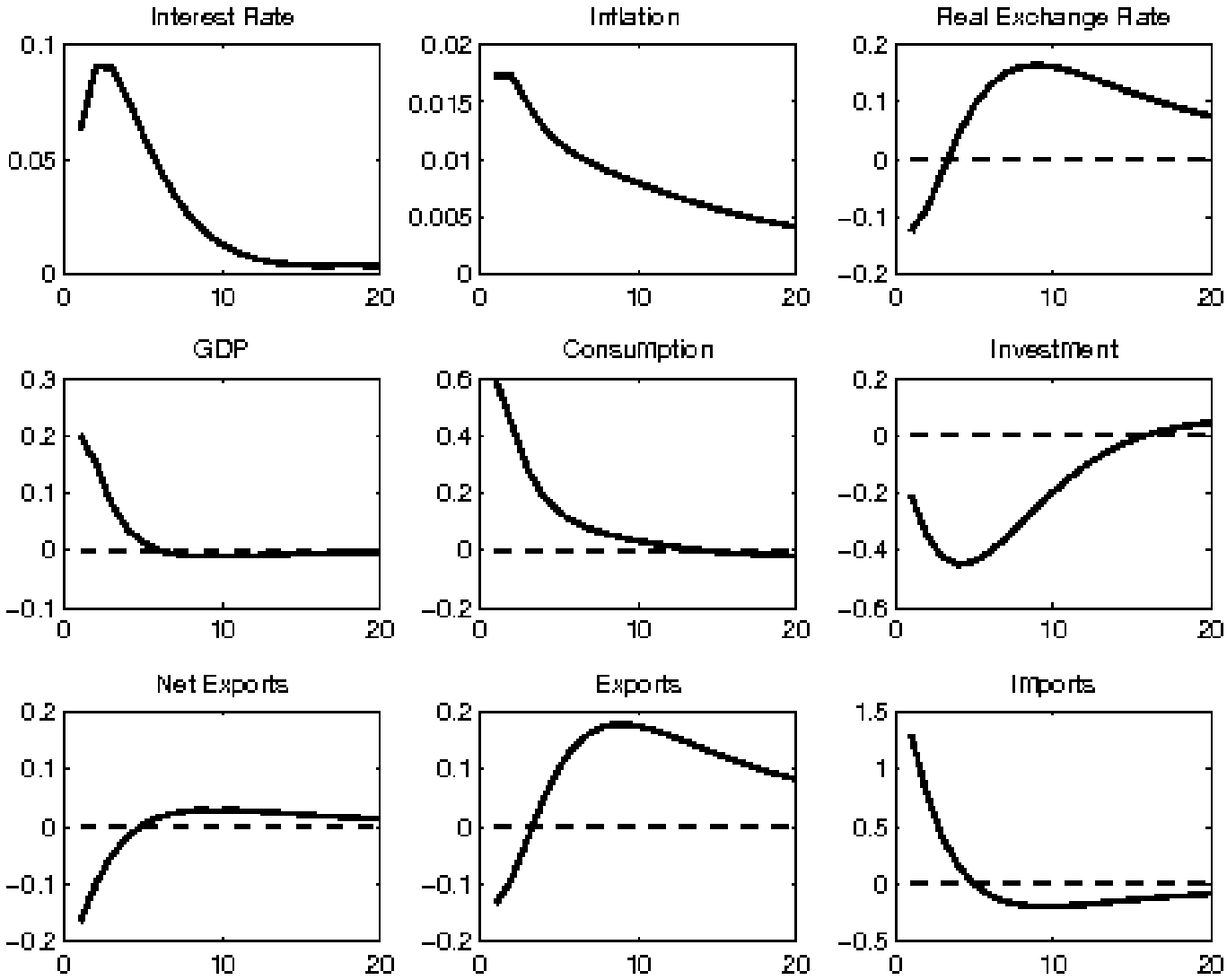
Estimation

- Sample period: 1999Q2 to 2008Q1 (36 obs)
- Data: 25 series:
- Data treatment: HP filter
- Number of model parameters: 58
  - 41 estimated: 17 structural parameters and 24 shock parameters
  - 17 calibrated: 3 structural parameters and 14 steady-state relationships

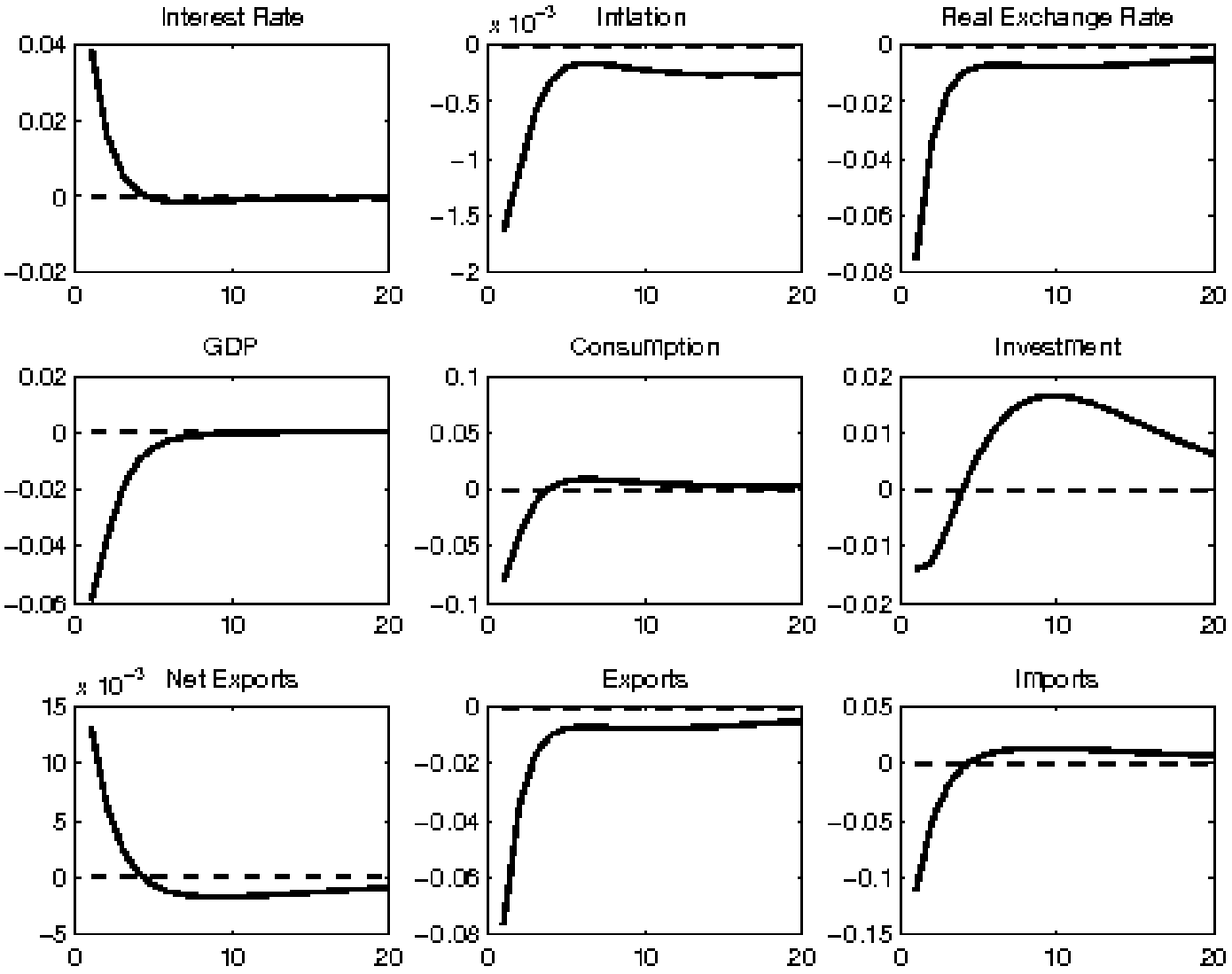
Posteriors distributions for selected parameters



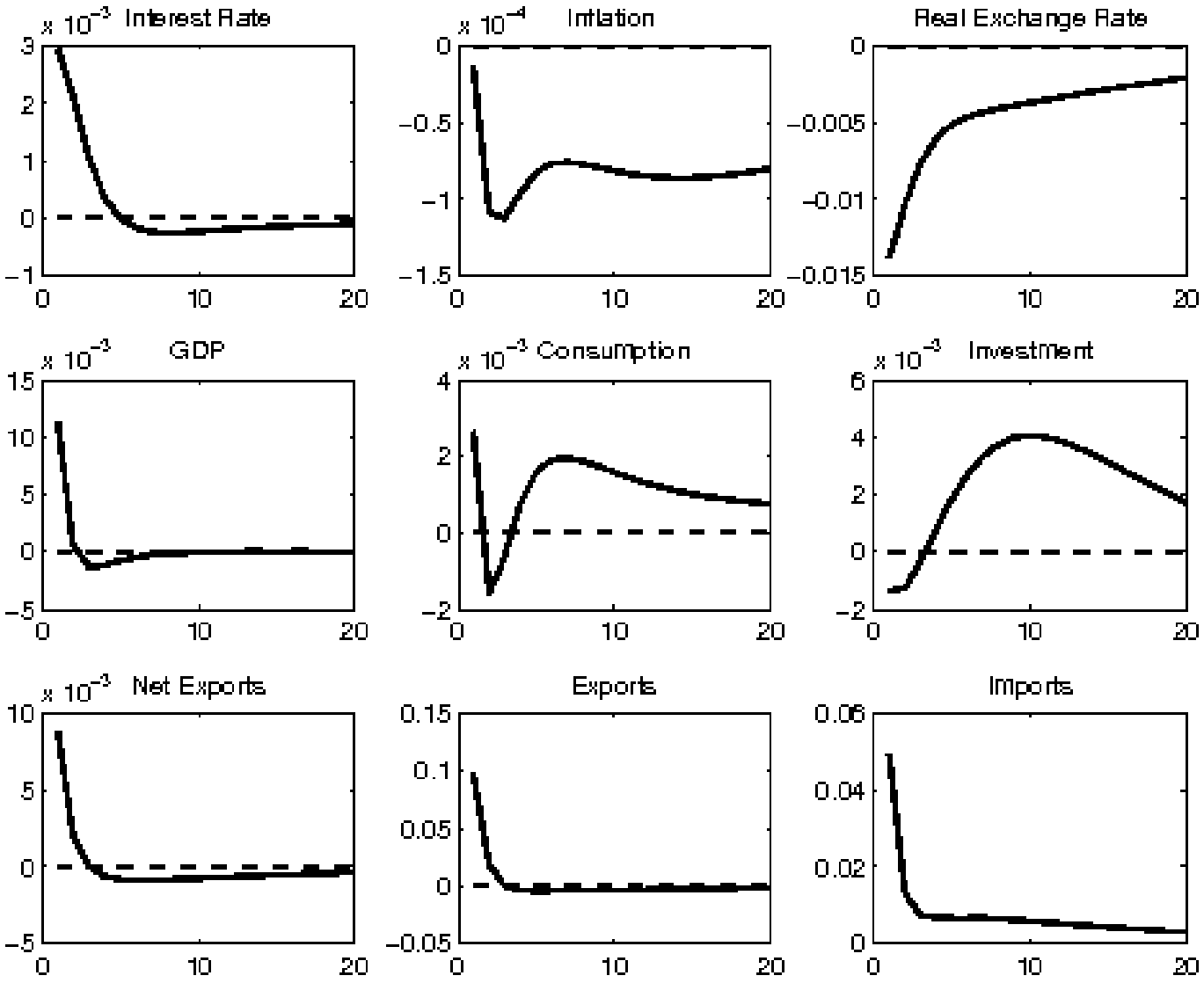
Impulse responses to a consumption shock



Impulse responses to a monetary policy shock



Impulse responses to a world GDP shock



Challenges

- Common to DSGE models and their estimation:
  - Generation of slower and more persistent dynamics (enough propagation mechanisms, lags in the transmission mechanisms, etc.)
  - Identification of the main model channels in place
  - Large number of parameters to be estimated – calibration versus estimation

Challenges

- Brazilian economic features:
  - Small sample size
  - Specific features: administered prices
  - Large changes in some ratios over the sample (ex.: net external debt-to-GDP ratio)

Next steps

- Refining model setup:
  - Add nominal and real rigidities: wage rigidity, price rigidity in the import and export sectors, firm-specific capital
  - Disaggregate CPI inflation into administered and non-administered prices
- New estimation and model implementation

Thank you for your attention!