Analysis of the Monetary Policy Impact on Regional Gross Domestic Product: A Regional DSGE Model

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PPGDE-UFPR

Contents

Introduction

Introduction

- A modelagem macroeconômica é uma importante ferramenta para estudar as ligações entre a economia monetária e os resultados dos agregados de um país, Galí (2015).
- As regiões brasileiras possuem matrizes e setores econômicos heterogêneos que respondem de diferentes formas às decisões da autoridade monetária, Bertanha e Haddad (2008).

Introduction

- *Na realidade, a maior parte das tolices já escritas e que se continuam a escrever sobre economia poderia ter sido poupada se todo economista fosse obrigado a expor suas ideias construindo um modelo matemático* — Simonsen (1979, p.68).

Introduction

- Proposta: desenvolver um modelo estrutural com desdobramentos regionais, utilizando a metodologia DSGE (*Dynamic and Stochastic General Equilibrium*).
- Objetivo: verificar se existe correlação entre a taxa de juros nominal da economia (uma variável macroeconômica) e o nível de produção de uma região brasileira (uma variável regional). Existindo esta correlação, pretendemos quantificá-la.

O que é um modelo DSGE?

- Os modelos DSGE são ferramentas utilizadas em macroeconomia para avaliar a relação existente entre as variáveis selecionadas pelo pesquisador.
- Tem como principais características um horizonte de tempo infinito e choques aleatórios sobre algumas variáveis de interesse.

Real Business Cycles Theory

- Os modelos DSGE começaram a ser usados para estruturar a Teoria dos Ciclos Reais de Negócios (*Real Business Cycle Theory, RBC*), com os trabalhos seminais de Kydland e Prescott (1982) e Prescott (1986), Galí (2015).
- As principais características dos modelos RBC são: eficiência dos ciclos de negócios; importância dos choques de tecnologia como fontes de flutuações; papel limitado dos fatores monetários.

New Keynesian Theory

- Em paralelo aos modelos RBC, surgiram os modelos Novos Keynesianos (*New Keynesian Theory, NK*), que procuram dar microfundamentos aos conceitos Keynesianos, Galí e Gertler (2007, p.26).
- As características de destaque dos modelos NK são: competição monopolística; rigidez nominal de preços; não-neutralidade da moeda no curto prazo.

Literature Review

Macro modeling

- Costa Junior (2016): presents a RBC model and then adds NK elements in each chapter;
- Galí (2015): discuss monetary policy starting with a RBC model and also adds NK elements in each chapter;
- Bergholt (2012): presents a NK and the method of programming in `Dynare`;
- Solis-Garcia (2022): presents a RBC model and demonstrate the math tools necessary to solve a DSGE model;

Regional Modeling

- Rickman (2010): link between macro and regional modeling.
- Mora e Costa Junior (2019): efeitos do investimento estrangeiro direto (IED), levando em consideração onde ele é aplicado: modelo estrutural com duas regiões: Bogotá e o resto da Colômbia.
- Costa Junior et al. (2022): efeitos da política fiscal, considerando os entes federativos: modelo para o Estados de Goiás e o resto do país.

Modelagem Macroeconômica Regionalizada

- Osterno (2022): regionalização do SAMBA: SAMBA+REG (*Stochastic Analytical Model with Bayesian Approach* do Banco Central do Brasil).

Model

Characteristics

- four agents: households, intermediate and final-goods firms, monetary authority.
- no bonds.
- capital and investment.
- price stickiness of intermediate goods.

Agents

- the representative household maximizes utility;
- firms producing intermediate goods minimize costs and maximize profit flow;
- firms producing final goods maximize profit.
- the monetary authority determines the interest rate, aiming to control inflation and pursuing economic growth.

Model Structure

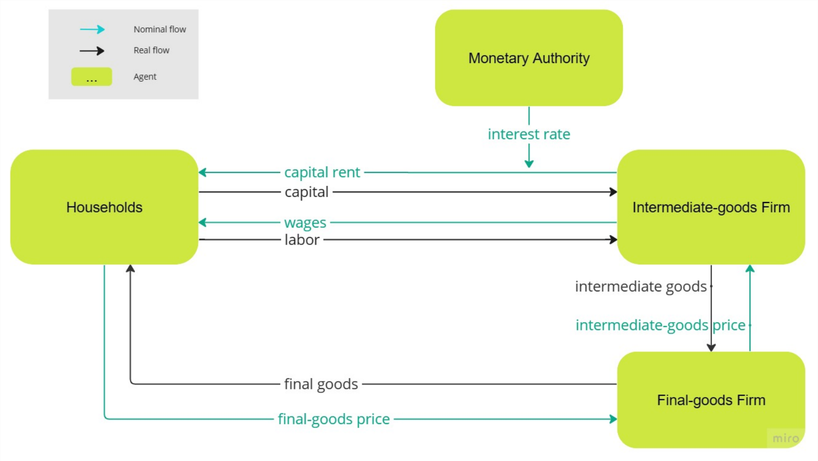


Figure 1: Model Diagram

Household Maximization Problem

$$
\begin{aligned}
\max_{C_t, L_t, K_{t+1}} \ : \quad & U(C_t, L_t) = \mathbb{E}_t \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\sigma}}{1-\sigma} - \phi \frac{L_t^{1+\varphi}}{1+\varphi} \right) && (1) \\
\text{s. t.} : \quad & P_t(C_t + I_t) = W_t L_t + R_t K_t + \Pi_t && (2) \\
& K_{t+1} = (1-\delta) K_t + I_t && (3) \\
& C_t, L_t, K_{t+1} \geq 0 \ ; K_0 \text{ given.}
\end{aligned}
$$

Final-goods Firm Maximization Problem

$$\max_{Y_{jt}} : \quad \Pi_t = P_t Y_t - \int_0^1 P_{jt} Y_{jt} \, \mathrm{d}\, j \tag{4}$$

$$\text{s. t.} : \quad Y_t = \left(\int_0^1 Y_{jt}^{\frac{\psi-1}{\psi}} \, \mathrm{d}\, j \right)^{\frac{\psi}{\psi-1}} \tag{5}$$

Intermediate-goods Firm Problems

Cost Minimization Problem:

$$\min_{K_{jt}, L_{jt}} : \quad R_t K_{jt} + W_t L_{jt} \tag{6}$$

$$\text{s. t.} : \quad Y_{jt} = Z_{At} K_{jt}^{\alpha} L_{jt}^{1-\alpha} \tag{7}$$

Intermediate-goods Firm Problems

Price Stickiness and Profit Flow, Calvo's Rule (CALVO, 1983):

$$\mathbb{P}(P_t = P_{t-1}) = \theta \tag{8}$$

$$\max_{P_{jt}} : \quad \mathbb{E}_t \sum_{s=0}^{\infty} \left\{ \frac{\theta^s \left[P_{jt} Y_{j,t+s} - TC_{j,t+s} \right]}{\prod_{k=0}^{s-1} (1 + R_{t+k})} \right\} \tag{9}$$

$$\text{s. t.} : \quad Y_{jt} = Y_t \left(\frac{P_t}{P_{jt}} \right)^{\psi} \tag{10}$$

Monetary Authority

Taylor's Rule (TAYLOR, 1993):

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\gamma_R} \left[\left(\frac{\pi_t}{\pi}\right)^{\gamma_\pi} \left(\frac{Y_t}{Y}\right)^{\gamma_Y}\right]^{1-\gamma_R} Z_{Mt} \tag{11}$$

Stochastic Shocks

Productivity Shock:

$$\ln Z_{At} = (1 - \rho_A) \ln Z_A + \rho_A \ln Z_{A,t-1} + \varepsilon_{At} \tag{12}$$

Monetary Policy Shock:

$$\ln Z_{Mt} = (1 - \rho_M) \ln Z_M + \rho_M \ln Z_{M,t-1} + \varepsilon_{Mt} \tag{13}$$

Model Structure i

Square system of 16 variables and 16 equations:

- from the household problem: C_t, L_t, K_{t+1};
- from the final-good firm problem: Y_{jt}, P_t;
- from the intermediate-good firm problems: K_{jt}, L_{jt}, P_t^*;
- from the market clearing condition: Y_t, I_t;
- prices: $W_t, R_t, \Lambda_t, \pi_t$;
- shocks: Z_{At}, Z_{Mt}.

Model Structure i

Equations:

1. Labor Supply:

$$\frac{\phi L_t^{\varphi}}{C_t^{-\sigma}} = \frac{W_t}{P_t} \tag{14}$$

2. Household Euler Equation:

$$\left(\frac{\mathbb{E}_t C_{t+1}}{C_t}\right)^{\sigma} = \beta \left[(1-\delta) + \mathbb{E}_t \left(\frac{R_{t+1}}{P_{t+1}}\right)\right] \tag{15}$$

3. Budget Constraint:

$$P_t(C_t + I_t) = W_t L_t + R_t K_t + \Pi_t \tag{16}$$

Model Structure ii

4. Law of Motion for Capital:

$$K_{t+1} = (1 - \delta)K_t + I_t \tag{17}$$

5. Bundle Technology:

$$Y_t = \left(\int_0^1 Y_{jt}^{\frac{\psi - 1}{\psi}} \, \mathrm{d}\, j \right)^{\frac{\psi}{\psi - 1}} \tag{18}$$

6. General Price Level:

$$P_t = \left[\theta P_{t-1}^{1-\psi} + (1 - \theta) P_t^{*1-\psi} \right]^{\frac{1}{1-\psi}} \tag{19}$$

Model Structure iii

7. Capital Demand:

$$K_{jt} = \alpha Y_{jt} \frac{\Lambda_t}{R_t} \tag{20}$$

8. Labor Demand:

$$L_{jt} = (1-\alpha) Y_{jt} \frac{\Lambda_t}{W_t} \tag{21}$$

9. Marginal Cost:

$$\Lambda_t = \frac{1}{Z_{At}} \left(\frac{R_t}{\alpha}\right)^{\alpha} \left(\frac{W_t}{1-\alpha}\right)^{1-\alpha} \tag{22}$$

Model Structure iv

10. Production Function:

$$Y_{jt} = Z_{At} K_{jt}^{\alpha} L_{jt}^{1-\alpha} \tag{23}$$

11. Optimal Price:

$$P_t^* = \frac{\psi}{\psi - 1} \cdot \frac{\mathbb{E}_t \sum_{s=0}^{\infty} \left\{ \theta^s Y_{j,t+s} \Lambda_{t+s} / \prod_{k=0}^{s-1} (1 + R_{t+k}) \right\}}{\mathbb{E}_t \sum_{s=0}^{\infty} \left\{ \theta^s Y_{j,t+s} / \prod_{k=0}^{s-1} (1 + R_{t+k}) \right\}} \tag{24}$$

12. Market Clearing Condition:

$$Y_t = C_t + I_t \tag{25}$$

Model Structure v

13. Monetary Policy:

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\gamma_R} \left[\left(\frac{\pi_t}{\pi}\right)^{\gamma_\pi} \left(\frac{Y_t}{Y}\right)^{\gamma_Y}\right]^{1-\gamma_R} Z_{Mt} \tag{26}$$

14. Gross Inflation Rate:

$$\pi_t = \frac{P_t}{P_{t-1}} \tag{27}$$

15. Productivity Shock:

$$\ln Z_{At} = (1-\rho_A)\ln Z_A + \rho_A \ln Z_{A,t-1} + \varepsilon_{At} \tag{28}$$

Model Structure vi

16. Monetary Shock:

$$\ln Z_{Mt} = (1 - \rho_M) \ln Z_M + \rho_M \ln Z_{M,t-1} + \varepsilon_{Mt} \tag{29}$$

Steady State

Steady State

Steady state solution (COSTA JUNIOR, 2016, p.41):

$$\mathbb{E}_t X_{t+1} = X_t = X_{t-1} = X_{ss} \tag{30}$$

Log-linearization

Log-linearization

Uhlig's rules for log-linearization (UHLIG, 1999).

Log-linear Model i

Square system of 12 variables and 12 equations:

Variables:

$$\begin{pmatrix} \tilde{\pi} & \hat{P} & \hat{\lambda} & \hat{C} & \hat{L} & \hat{R} & \hat{K} & \hat{I} & \hat{W} & \hat{Z}_A & \hat{Y} & \hat{Z}_M \end{pmatrix} \tag{31}$$

Equations:

1. Gross Inflation Rate:

$$\widetilde{\pi}_t = \hat{P}_t - \hat{P}_{t-1} \tag{32}$$

2. New Keynesian Phillips Curve:

$$\widetilde{\pi}_t = \varrho \mathbb{E}_t \widetilde{\pi}_{t+1} + \frac{(1-\theta)(1-\theta\varrho)}{\theta} \hat{\lambda}_t \tag{33}$$

3. Labor Supply:

$$\varphi \hat{L}_t + \sigma \hat{C}_t = \hat{W}_t + \hat{P}_t \tag{34}$$

Log-linear Model ii

4. Household Euler Equation:

$$\mathbb{E}_t \hat{C}_{t+1} - \hat{C}_t = \frac{\beta R}{\sigma P} \mathbb{E}_t(\hat{R}_{t+1} - \hat{P}_{t+1}) \tag{35}$$

5. Law of Motion for Capital:

$$\hat{K}_{t+1} = (1-\delta)\hat{K}_t + \delta \hat{I}_t \tag{36}$$

6. Real Marginal Cost:

$$\hat{\lambda}_t = \alpha \hat{R}_t + (1-\alpha)\hat{W}_t - \hat{Z}_{At} - \hat{P}_t \tag{37}$$

Log-linear Model iii

7. Production Function:

$$\hat{Y}_t = \hat{Z}_{At} + \alpha \hat{K}_t + (1 - \alpha)\hat{L}_t \tag{38}$$

8. Marginal Rates of Substitution of Factors:

$$\hat{K}_t - \hat{L}_t = \hat{W}_t - \hat{R}_t \tag{39}$$

9. Market Clearing Condition:

$$\hat{Y}_t = \theta_C \hat{C}_t + \theta_I \hat{I}_t \tag{40}$$

Log-linear Model iv

10. Monetary Policy:

$$\hat{R}_t = \gamma_R \hat{R}_{t-1} + (1 - \gamma_R)(\gamma_\pi \widetilde{\pi}_t + \gamma_Y \hat{Y}_t) + \hat{Z}_{Mt} \tag{41}$$

11. Productivity Shock:

$$\hat{Z}_{At} = \rho_A \hat{Z}_{A,t-1} + \varepsilon_A \tag{42}$$

12. Monetary Shock:

$$\hat{Z}_{Mt} = \rho_M \hat{Z}_{M,t-1} + \varepsilon_M \tag{43}$$

Matlab and Dynare

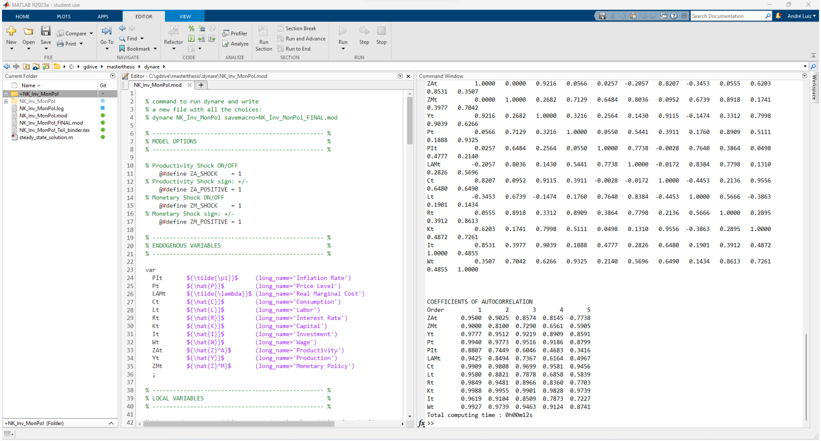
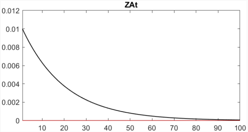
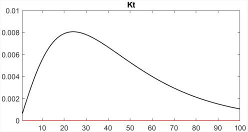


Figure 2: Matlab and Dynare

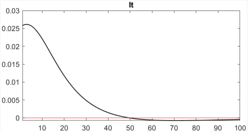
Productivity Shock



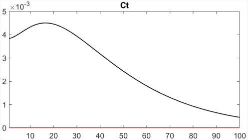
(a) Productivity Shock



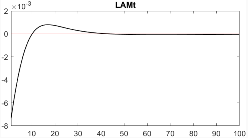
(b) Capital



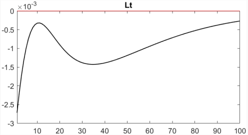
(c) Investment



(d) Consumption

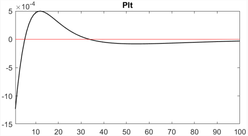


(e) Marginal Cost

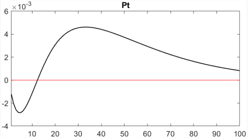


(f) Labor

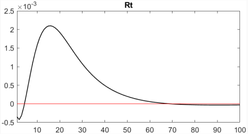
Productivity Shock



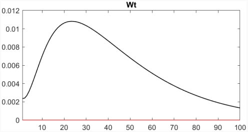
(a) Inflation



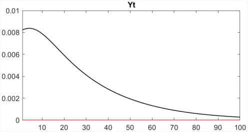
(b) Price Level



(c) Interest Rate

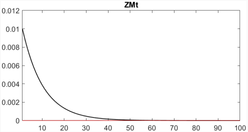


(d) Wage

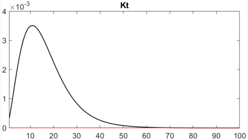


(e) Production

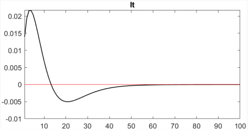
Monetary Shock



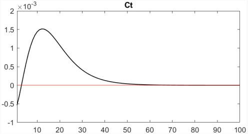
(a) Monetary Shock



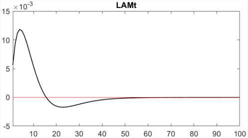
(b) Capital



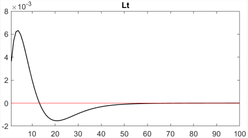
(c) Investment



(d) Consumption

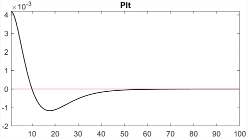


(e) Marginal Cost

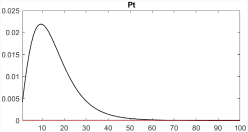


(f) Labor

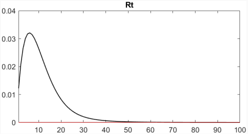
Monetary Shock



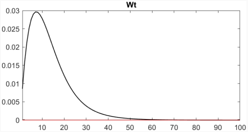
(a) Inflation



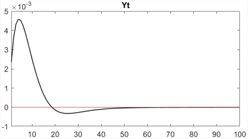
(b) Price Level



(c) Interest Rate



(d) Wage



(e) Production

Figure 6: Monetary Shock Impulse Response Functions

Regional Model

Characteristics

- two regions.
- mobility for final-goods.
- household η and firm ν indexes.
- regional inflation π_ν.

Household Maximization Problem

$$\max_{C_{1\eta t}, C_{2\eta t}, L_{\eta t}, K_{\eta,t+1}} : \quad U_\eta(C_{\eta t}, L_{\eta t}) = \mathbb{E}_t \sum_{t=0}^{\infty} \beta^t \left(\frac{C_{\eta t}^{1-\sigma}}{1-\sigma} - \phi \frac{L_{\eta t}^{1+\varphi}}{1+\varphi} \right) \tag{44}$$

$$\text{s. t.} : \quad P_{C1t} C_{1\eta t} + P_{C2t} C_{2\eta t} + P_{C\eta t} I_{\eta t} = W_t L_{\eta t} + R_t K_{\eta t} + \Pi_{\nu t} \tag{45}$$

$$K_{\eta,t+1} = (1-\delta) K_{\eta t} + I_{\eta t} \tag{46}$$

$$C_{\eta t} = C_{1\eta t}^{\omega_\eta} C_{2\eta t}^{1-\omega_\eta} \tag{47}$$

$$C_{\nu\eta t}, L_{\eta t}, K_{\eta,t+1} > 0 \text{ ; } K_0 \text{ given.}$$

Final-goods Firm Maximization Problem

$$\max_{Y_{\nu jt}} : \quad \Pi_{\nu t} = P_{C\nu t} Y_{\nu t} - \int_0^1 P_{C\nu jt} Y_{\nu jt} \, \mathrm{d}\, j \tag{48}$$

$$\text{s. t.} : \quad Y_{\nu t} = \left(\int_0^1 Y_{\nu jt}^{\frac{\psi - 1}{\psi}} \, \mathrm{d}\, j \right)^{\frac{\psi}{\psi - 1}} \tag{49}$$

Intermediate-goods Firm Problems

Cost Minimization Problem:

$$\min_{K_{\eta jt}, L_{\eta jt}} : \quad R_t K_{\eta jt} + W_t L_{\eta jt} \tag{50}$$

$$\text{s.t.} : \quad Y_{\nu jt} = Z_{A\nu t} K_{\eta jt}^{\alpha_\nu} L_{\eta jt}^{1-\alpha_\nu} \tag{51}$$

Intermediate-goods Firm Problems

Price Stickiness and Profit Flow, Calvo's Rule (CALVO, 1983):

$$
\begin{aligned}
& \mathbb{P}(P_t = P_{t-1}) = \theta && (52) \\
\max_{P_{C\nu jt}} : \quad & \mathbb{E}_t \sum_{s=0}^{\infty} \left\{ \frac{\theta^s \left[P_{C\nu jt} Y_{\nu j,t+s} - TC_{\nu j,t+s} \right]}{\prod_{k=0}^{s-1} (1 + R_{t+k})} \right\} && (53) \\
\text{s. t.} : \quad & Y_{\nu jt} = Y_{\nu t} \left(\frac{P_{C\nu t}}{P_{C\nu jt}} \right)^{\psi} && (54)
\end{aligned}
$$

Monetary Authority

Taylor's Rule (TAYLOR, 1993):

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\gamma_R} \left[\left(\frac{\pi_t}{\pi}\right)^{\gamma_\pi} \left(\frac{Y_t}{Y}\right)^{\gamma_Y}\right]^{1-\gamma_R} Z_{Mt} \tag{55}$$

Regional Price Level and Inflation

Regional price level $P_{C\nu t}$ and regional inflation rate:

$$\pi_{\nu t} = \frac{P_{C\nu t}}{P_{C\nu,t-1}} \tag{56}$$

National price level:

$$P_t = \vartheta_1 P_{C1t} + (1 - \vartheta_1) P_{C2t} \tag{57}$$

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Expected Results

Resultados Esperados

- Esperamos que o modelo demonstre que uma região brasileira responde um choque de política monetária, gerando uma variação no produto regional.
- Por exemplo, um choque de 1% na taxa de juros gera uma diminuição de x% do produto de um Estado brasileiro.

Project Timeline

Project Timeline

Activity	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Literature Review	x	x								
Project & Seminar			x	x						
Modeling			x	x	x					
LaTeX			x	x	x					
`Dynare`					x	x				
Qualification						x				
Regional Model						x	☐			
Data Treatment							☐			
Parametrization								☐		
Results								☐		
Systematic Review									☐	
Revision & Edition									☐	
Thesis Defense										☐

Referências Iniciais

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Dúvidas e Sugestões

Obrigado!

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