

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

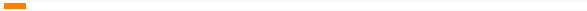
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from March 1st to Aug 31, 2023

PPGDE-UFPR

1. Introduction
2. Literature Review
3. Model
4. Regional Model
5. Expected Results
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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).

- *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).*

- 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.

- 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.

- 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

- 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;

- 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.

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

Model

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

- 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

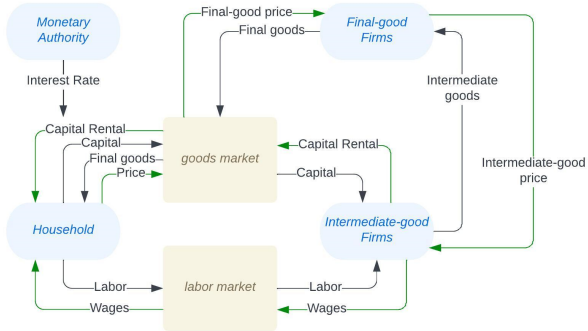


Figure 1: Model Diagram

Household Maximization Problem

$$\max_{C_t, L_t, K_{t+1}} : U(C_t, L_t) = \mathbb{E}_t \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\sigma}}{1-\sigma} - \phi \frac{L_t^{1+\varphi}}{1+\varphi} \right) \quad (1)$$

$$\text{s. t. : } P_t(C_t + I_t) = W_t L_t + R_t K_t + \Pi_t \quad (2)$$

$$K_{t+1} = (1 - \delta)K_t + I_t \quad (3)$$

$$C_t, L_t, K_{t+1} \geq 0 ; K_0 \text{ given.}$$

Final-goods Firm Maximization Problem

$$\max_{Y_{jt}} : \quad \Pi_t = P_t Y_t - \int_0^1 P_{jt} Y_{jt} dj \quad (4)$$

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

Cost Minimization Problem:

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

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

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

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

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

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

Taylor's Rule (TAYLOR, 1993):

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

Productivity Shock:

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

Monetary Policy Shock:

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

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} .

Equations:

1. Labor Supply:

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

2. Household Euler Equation:

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

3. Budget Constraint:

$$P_t(C_t + I_t) = W_t L_t + R_t K_t + \Pi_t \quad (16)$$

4. Law of Motion for Capital:

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

5. Bundle Technology:

$$Y_t = \left(\int_0^1 Y_{jt}^{\frac{\psi-1}{\psi}} dj \right)^{\frac{\psi}{\psi-1}} \quad (18)$$

6. General Price Level:

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

7. Capital Demand:

$$K_{jt} = \alpha Y_{jt} \frac{\Lambda_t}{R_t} \quad (20)$$

8. Labor Demand:

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

9. Marginal Cost:

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

10. Production Function:

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

11. Optimal Price:

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

12. Market Clearing Condition:

$$Y_t = C_t + I_t \quad (25)$$

13. Monetary Policy:

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

14. Gross Inflation Rate:

$$\pi_t = \frac{P_t}{P_{t-1}} \quad (27)$$

15. Productivity Shock:

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

16. Monetary Shock:

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

Steady State

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

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

Log-linearization

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

Square system of 12 variables and 12 equations:

Variables:

$$\left(\tilde{\pi} \quad \hat{P} \quad \hat{\lambda} \quad \hat{C} \quad \hat{L} \quad \hat{R} \quad \hat{K} \quad \hat{I} \quad \hat{W} \quad \hat{Z}_A \quad \hat{Y} \quad \hat{Z}_M \right) \quad (31)$$

Equations:

1. Gross Inflation Rate:

$$\tilde{\pi}_t = \hat{P}_t - \hat{P}_{t-1} \quad (32)$$

2. New Keynesian Phillips Curve:

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

3. Labor Supply:

$$\varphi \hat{L}_t + \sigma \hat{C}_t = \hat{W}_t + \hat{P}_t \quad (34)$$

4. Household Euler Equation:

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

5. Law of Motion for Capital:

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

6. Real Marginal Cost:

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

7. Production Function:

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

8. Marginal Rates of Substitution of Factors:

$$\hat{K}_t - \hat{L}_t = \hat{W}_t - \hat{R}_t \quad (39)$$

9. Market Clearing Condition:

$$\hat{Y}_t = \theta_C \hat{C}_t + \theta_I \hat{I}_t \quad (40)$$

10. Monetary Policy:

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

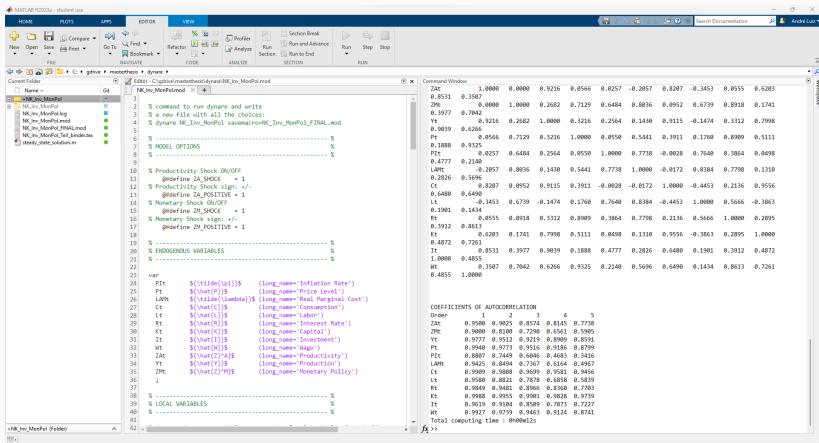
11. Productivity Shock:

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

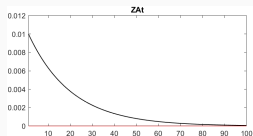
12. Monetary Shock:

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

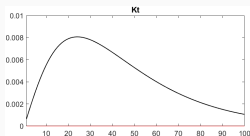
Matlab and Dynare



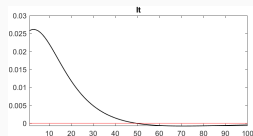
Productivity Shock



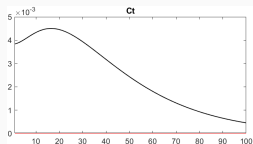
(a) Productivity Shock



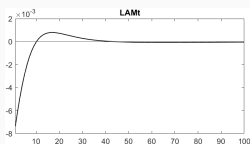
(b) Capital



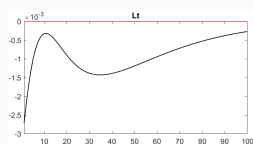
(c) Investment



(d) Consumption

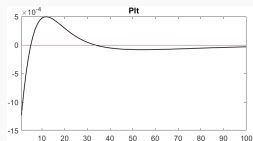


(e) Marginal Cost

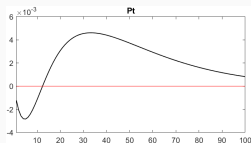


(f) Labor

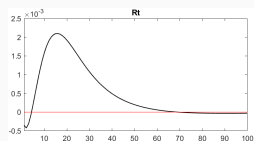
Productivity Shock



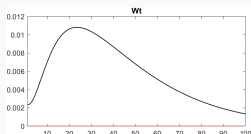
(a) Inflation



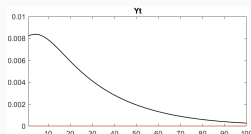
(b) Price Level



(c) Interest Rate

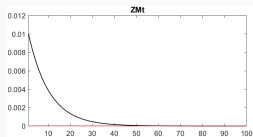


(d) Wage

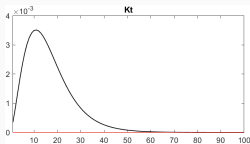


(e) Production

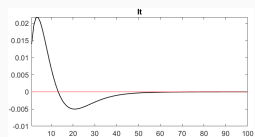
Monetary Shock



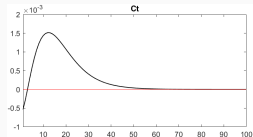
(a) Monetary Shock



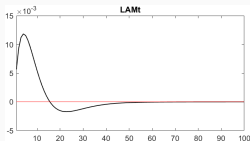
(b) Capital



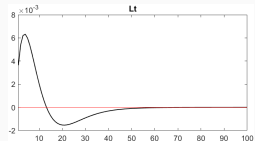
(c) Investment



(d) Consumption

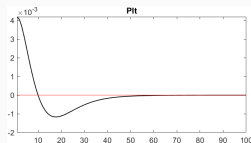


(e) Marginal Cost

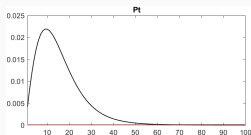


(f) Labor

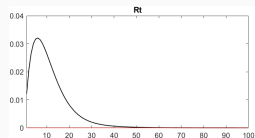
Monetary Shock



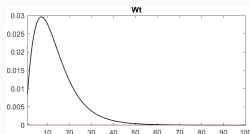
(a) Inflation



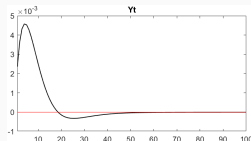
(b) Price Level



(c) Interest Rate



(d) Wage



(e) Production

Figure 6: Monetary Shock Impulse Response Functions

Regional Model

- two regions.
- mobility for final-goods.
- household and firm variables.
- regional inflation.

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Expected Results

- 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



Cronograma

Atividade	mar	abr	mai	jun	jul	ago	set	out	nov
Pesquisa Bibliográfica	x	x	x						
Projeto de Pesquisa			x						
Modelagem			x	x					
Programação no Dynare				x					
Seminário do Projeto				x					
Coleta dos dados					x				
Tratamento dos dados					x				
Cálculo dos Parâmetros						x			
Banca de Qualificação						x			
Análise dos Resultados							x		
Revisão e Edição								x	
Defesa da Dissertação									x
Reuniões de Orientação	x	x	x	x	x	x	x	x	x

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Dúvidas e Sugestões

Obrigado!
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