Inflation Targeting with Sovereign Default Risk

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Motivation

Empirical:

- Emerging markets adopted *inflation targeting* in early 2000s
  - Low and stable inflation since: Mexico 4%, Brazil 7%
- History of recurring sovereign *debt crises*
  - Default risk important for EM fluctuations
- Business cycles in EM shaped by monetary policy *and* default risk

Theory:

- Monetary theory for EM largely abstracts from default risk
- Traditionally, quantitative work on default uses real models

What We Do

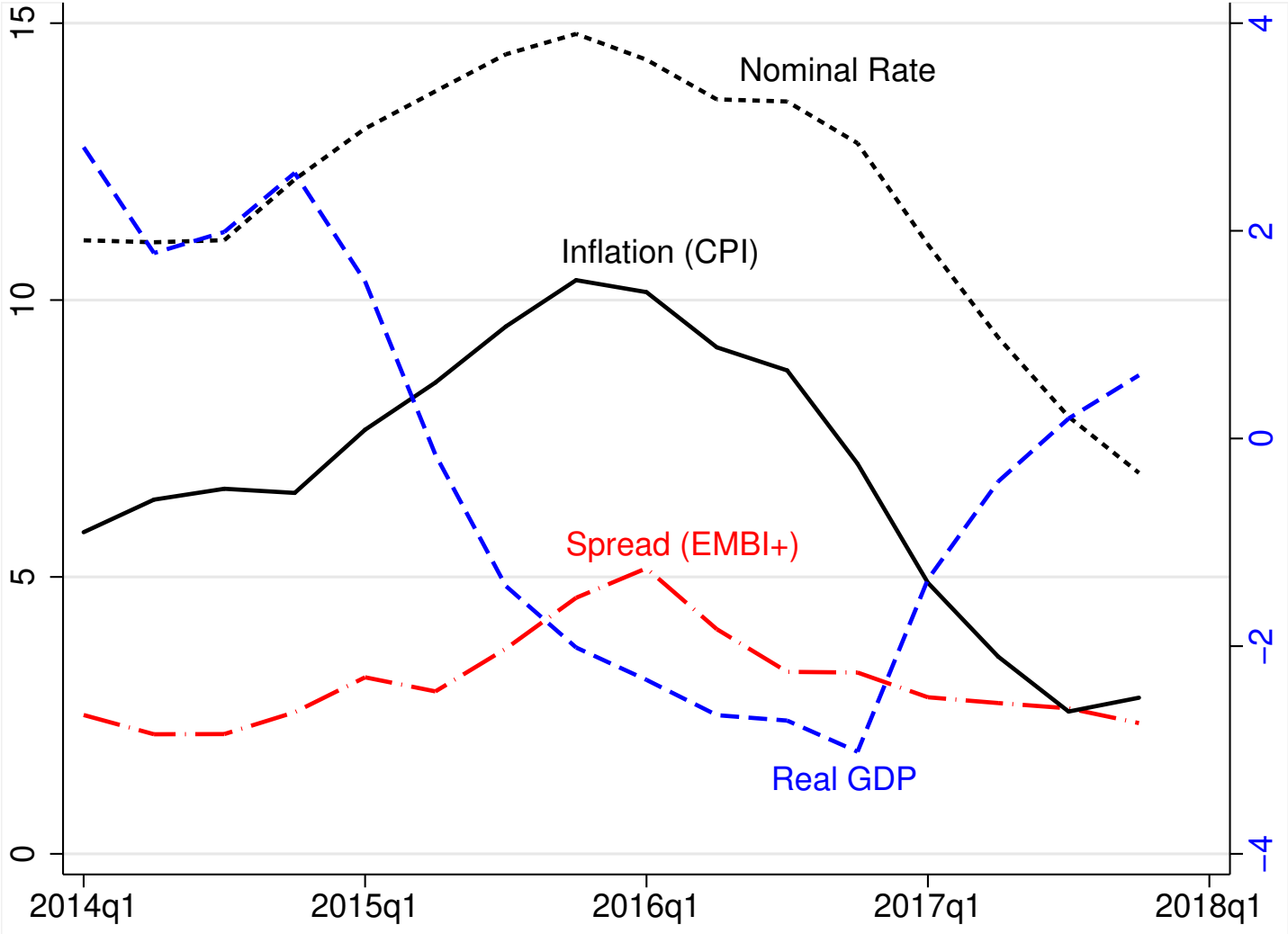
- Integrated framework for monetary policy and default risk
- Two-way interaction: MP alters and reacts to default risk

- Framework consistent with emerging market data
  - Positive co-movement of spreads, nominal rates, inflation
- Rationalize Brazilian experience with 2015 monetary tightening

- Counterfactual: effects of expansionary monetary policy

Brazil 2015

- Severe downturn with high inflation and high sovereign spreads



- Central bank raised interest rates to fight inflation

What We Find

- Monetary tightening alleviates sovereign debt crisis
  - And controls inflation
- With default risk more aggressive monetary policy required
  - Larger swings in nominal rates needed to hit inflation target
- Counterfactual expansionary policy for Brazil in 2015 event
  - Would have moderated the recession
  - At cost of large increases in inflation and sovereign spread

Key Takeaways

Monetary policy alters borrowing incentives of fiscal govt

- High nominal rates depress domestic consumption
- Govt *accommodates* with less borrowing ($\Rightarrow$ lower spreads)

Default risk leads to more aggressive monetary policy

- Default risk leads to more volatile consumption and inflation
- Nominal rates more volatile to target inflation

Literature (*work in progress*)

- Monetary policy in open economy: Gali and Monacelli (2005), Farhi and Werning (2012), Devereux et al. (2017)
- Quantitative sovereign default: Aguiar and Gopinath (2006), Arellano (2008), Chatterjee and Eyigungor (2012)
- Inflation, denomination and default:
  - **Nominal wage rigidity:** Uribe and Schmitt-Grohe (2016), Na et al. (2018)
  - **Self-fulfilling crises:** Calvo (1988), Aguiar et al. (2013), Corsetti and Dedola (2016), Bacchetta et al. (2018)
  - **Local currency defaultable debt:** Hur et al. (2018), Nuño and Thomas (2018), Sunder-Plassmann (2018)

Model

Open econ: private sector, monetary authority, and fiscal government

- **Private sector:**
  - Households: value domestic and imported goods, supply labor
  - Final good: consumed domestically and exported
  - Intermediate goods firms: produce with labor, subject to price-setting frictions (Rotemberg)
- **Monetary authority:**
  Follows interest rate rule, targets inflation
- **Government:**
  Borrows internationally, can default

Households

- Pref consumption of domestic and foreign goods, labor supply

$$\max \mathbf{E}_0 \sum_{t=0}^{\infty} \beta^t u(C_t, C_t^f, N_t)$$

$$\text{s.t.} \quad P_t^d C_t + P_t^f C_t^f + q_t^d B_{t+1}^d \leq W_t N_t + B_t^d + \Psi_t + T_t$$

- Domestic nominal bonds with price q_t^d, in zero net supply
- Receive profits from firms Ψ_t, and transfers from government T_t
- Optimality conditions:

$$\frac{u_{C^f,t}}{u_{C,t}} = e_t, \qquad -\frac{u_{N,t}}{u_{C,t}} = w_t, \qquad u_{C,t} = \beta i_t \mathbf{E}_t \left[\frac{u_{C,t+1}}{\pi_{t+1}} \right]$$

- Nominal rate $i_t = 1/q_t^d$, inflation $\pi_{t+1} = P_{t+1}^d / P_t^d$, terms of trade $e_t = P_t^f / P_t^d$ ($\uparrow$ depreciation)

Final Domestic Goods and Exports

- Y_t combines intermediates $y_t(i)$ with CES aggregator. Induced demand for intermediate goods

$$y_t(i) = \left(\frac{p_t(i)}{P_t^d} \right)^{-\eta} Y_t$$

- Final goods used for consumption and exports

$$Y_t = C_t + X_t + \langle \text{price-setting costs} \rangle$$

- Economy faces ct. elasticity demand for its export

$$X_t = e_t^{\rho} \xi$$

  Depreciations ($e \uparrow$) increase export demand

Intermediate Goods Firms

- Monopolistic competition
- Produce with labor n_{it} and face productivity shocks z_t

$$y_{it} = z_t \, n_{it}$$

- Costly to change prices relative to target inflation $\overline{\pi}$ (Rotemberg)
- Dynamic choice of n_{it} and prices p_{it} (NKPC)

$$\frac{\eta}{\eta - 1} \frac{w_t}{z_t} = 1 + \frac{1}{\eta - 1} \varphi \left(\pi_t - \overline{\pi} \right) \pi_t - \frac{1}{\eta - 1} \mathbf{E}_t \left[\beta \frac{u_{c,t+1}}{u_{c,t}} \frac{Y_{t+1}}{Y_t} \varphi \left(\pi_{t+1} - \overline{\pi} \right) \pi_{t+1} \right]$$

- Low z_t increases unit costs (LHS) $\implies$ π_t high

Policy

Monetary Authority: Interest rate rule

$$i_t = R\left(\frac{\pi_t}{\overline{\pi}}\right)^{\alpha_P} m_t$$

Targets inflation $\overline{\pi}$, subject to shocks m_t (later i_t smoothing)

Government:

- Issues foreign currency bonds B_{t+1}, at price q_t
- Transfers to households net proceeds from int'l bond sales
- Can default on its debt B_t
  - Benefit: Debt reduced to $\underline{B}$
  - Costs: Productivity reduced to $z_t^d \leq z_t$, utility cost ν_t

▸ Governent's Recursive Problem

Equilibrium

- *Private and Monetary Equilibrium:*
  - Optimality conditions, resource constraints, and interest rate rule
  - Given govt borrowing and default policies

- *Recursive Markov Equilibrium:*
  - Benevolent government
  - Understands how its borrowing and default impact economy
  - Time consistent policies

- State variables for govt: shocks $s = \{z, m, \nu\}$ and debt $\{B\}$

Private and Monetary Equilibrium

Resource Constraint: $$C + X = \left[1 - \frac{\varphi}{2}\left(\pi - \overline{\pi}\right)^2\right] zN$$

Balance of Payments: $$X = e^{\rho}\xi = e[C^f - (q(s, B')B' - B)]$$

Relative Consumption: $$u_{C^f} / u_C = e$$

Domestic Euler: $$u_C = \beta\, i\, M(s, B')$$

Interest Rate Rule: $$i = R\left(\frac{\pi}{\overline{\pi}}\right)^{\alpha_P} m$$

NKPC: $$\frac{1}{z}\frac{u_N}{u_C} = 1 + \frac{1}{\eta - 1}\varphi\left(\pi - \overline{\pi}\right)\pi - \frac{1}{u_C zN}F(s, B')$$

Given functions (Markov Eq.): $q(s, B')$ = bond price schedule,
$M(s, B')$ = expected marginal utility, $F(s, B')$ = expected inflation

- Lower B' increases e, raising C relative to C^f
- Lower B' increases q, lowers M and F

Borrowing and Monetary Policy: Reference

- Competitive borrowing, without default risk
  (cf. Gali and Monacelli (2005))

- Undistorted Euler. International borrowing smooths C^f

$$q\left[u_{C^f}\right] = \beta \mathbf{E}\left[u'_{C^f}\right]$$

Borrowing and Monetary Policy: With Default

- Optimal borrowing condition with wedges

$$q\left[u_{C_f}\right]\underbrace{(1-\tau_0)}_{\text{monetary}}-\underbrace{\tau_1}_{\text{monetary}}-\underbrace{\tau_2}_{\text{default}}=\beta\mathbf{E}\left[u'_{C_f}(1-\tau'_0)\right]$$

- Default wedge

$$\tau_2=-u_{C_f}\tau_0\frac{\partial q(s,B')}{\partial B'}B'+\langle\text{default discount}\rangle$$

  - Default next period more likely with high debt
  - Bond price falls with more borrowing
  - No repayment in some future states ("default discount")

Borrowing and Monetary Policy: With Default

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- Monetary wedge τ_0

$$\tau_0=\frac{\lambda}{u_C}$$

- λ multiplier on Relative Consumption Demand ($u_{C^f}/u_C=e$)
- $\lambda>0$ whenever C/C^f is low
- Lower B' increases C/C^f, lowering λ
- When monetary policy alters u_C, government responds via B'

Borrowing and Monetary Policy: With Default

- Optimal borrowing condition with wedges

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- Monetary wedge τ_1

$$\tau_1=\mu\frac{1}{M(z,B')}\frac{\partial M(z,B')}{\partial B'}+\gamma\frac{1}{u_C Y}\frac{\partial F(z,B')}{\partial B'}$$

- Govt alters expected marginal utility (μ Dom. Euler) and expected inflation (γ NKPC)
- Lower B' increases future C' and lowers expected u'_C

Borrowing and Monetary Policy: With Default

- *Contractionary MP*: increases i, lowers C: $[u_C] = i\beta\mathbf{E}\left[u'_C/\pi'\right]$
- Relative Consumption and Domestic Euler conditions bind:

$$q\left[u_{C_f}\right]\underbrace{(1-\tau_0)}_{\text{monetary}} - \underbrace{\tau_1}_{\text{monetary}} - \underbrace{\tau_2}_{\text{default}} = \beta\mathbf{E}\left[u'_{C_f}(1-\tau'_0)\right]$$

- Wedges τ_0 and τ_1 increase, lowering MB of borrowing
- Gov't borrows less, to accommodate low current consumption and increase future cons. (relax Relative Consumption and Euler)
- Less borrowing decreases government default risk and spreads

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Tight monetary policy decreases spreads

Quantitative Analysis

- Parameterize model to Brazil (output, inflation, spreads)
  ▸ Functional Forms ▸ Calibration
- IRFs to monetary and productivity shocks ▸ IRFs
  Compare to reference model, without default (cf. Gali and Monacelli (2005))
- Event analysis and MP counterfactual for 2015 recession

Business Cycle Moments

	Brazil	Benchmark	Reference
Means (%)			
Inflation	5.9	6.1	6.1
Nominal Rate	11.2	11.6	11.6
Spread	2.6	2.7	—
Standard Deviations (%)			
Output	1.9	2.0	1.9
Inflation	1.8	2.1	2.0
Nominal Rate	2.2	**2.1**	**1.4**
Spread	0.9	0.9	—
Correlations with Spread			
Output	-0.4	-0.5	—
Inflation	0.5	**0.7**	—
Nominal Rate	0.8	**0.4**	—

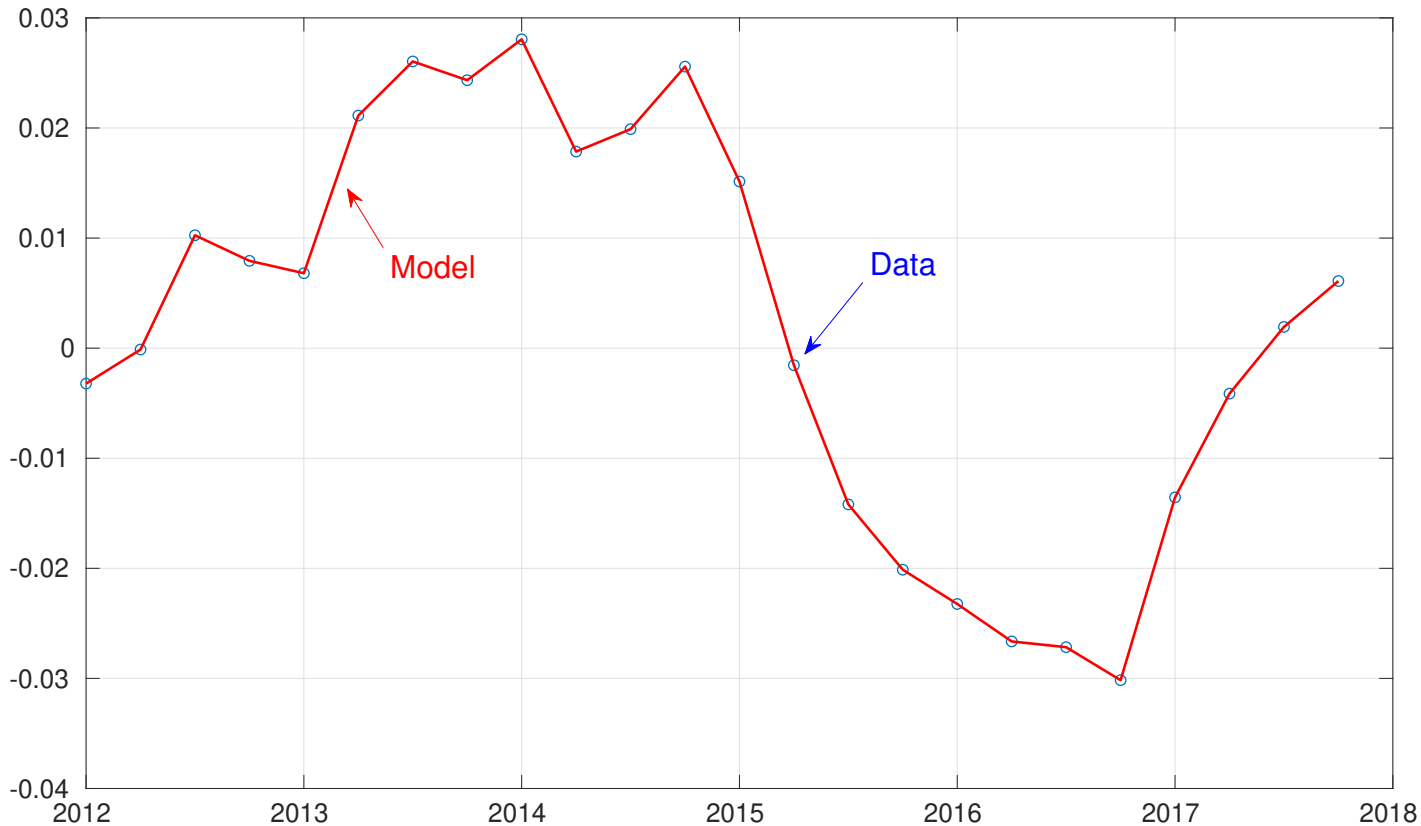
- Positive co-movement of inflation, nominal rates, and spreads
- Nominal rates much more volatile with default

▸ IRFs

Event Study

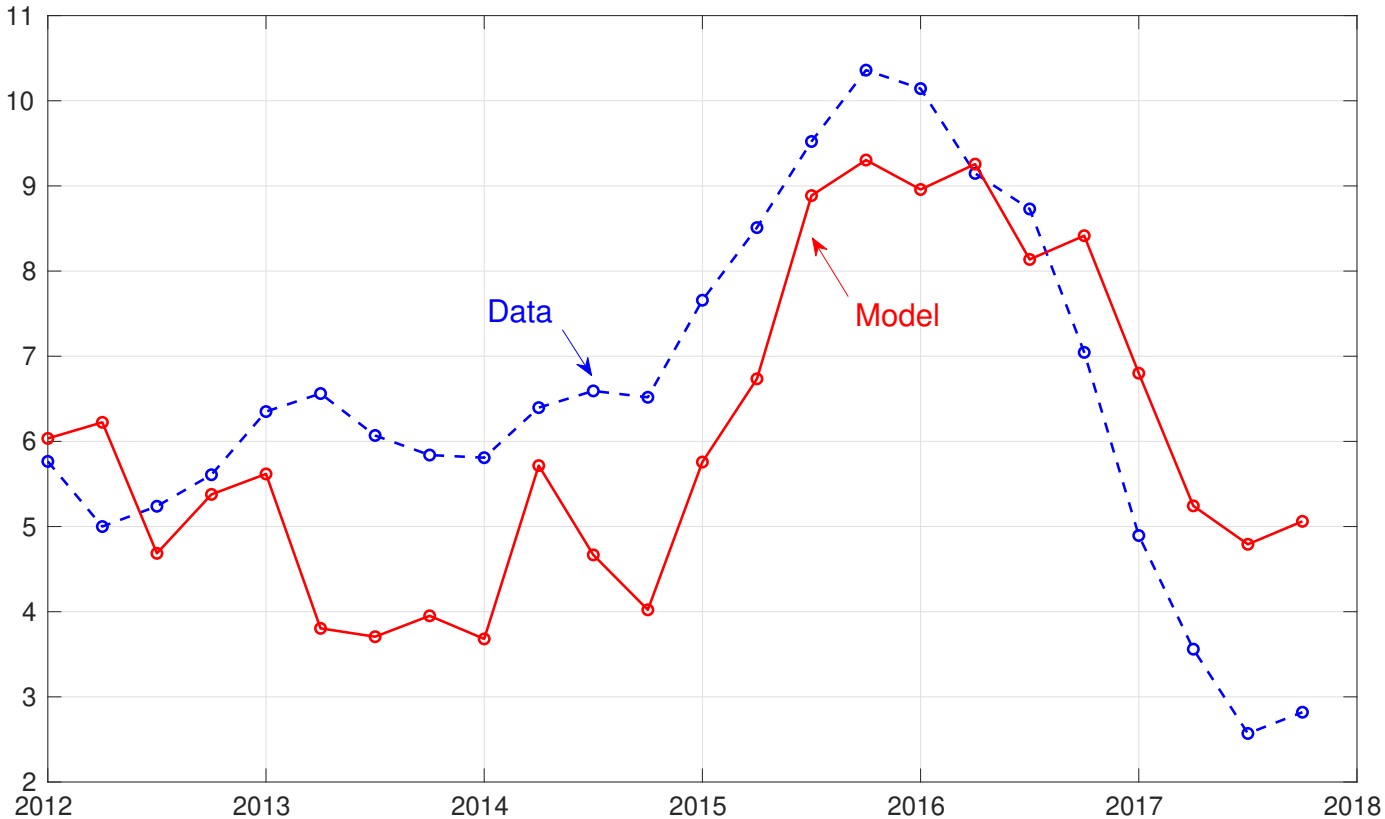
- Use Brazil data from 2012 to 2017
- Feed in a sequence of productivity shocks to replicate output path
- Model implications on inflation, spreads, and nominal rates
- Conduct counterfactual: Expansionary monetary policy

Event: GDP



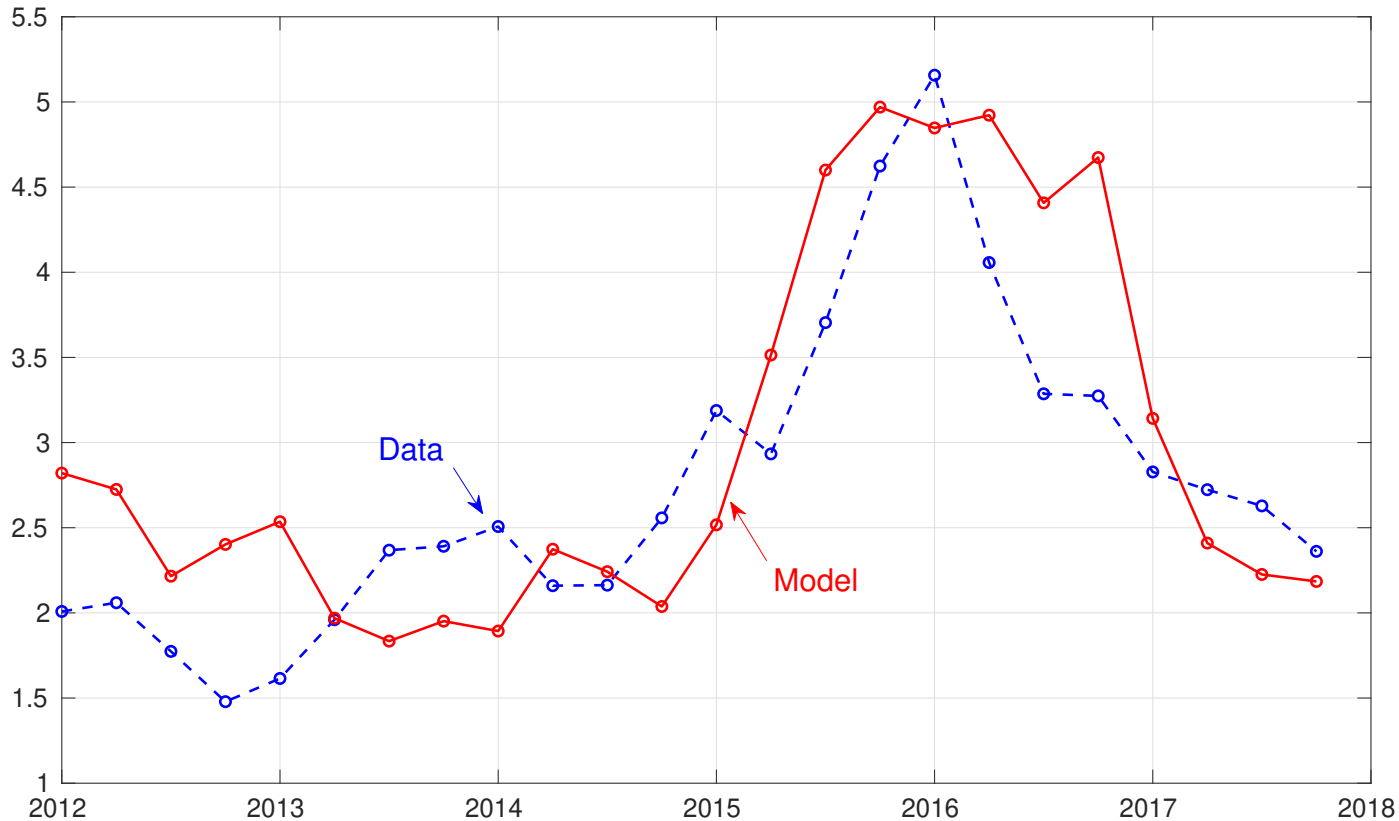
- Sequence of TFP shocks such that model matches output

Event: Inflation



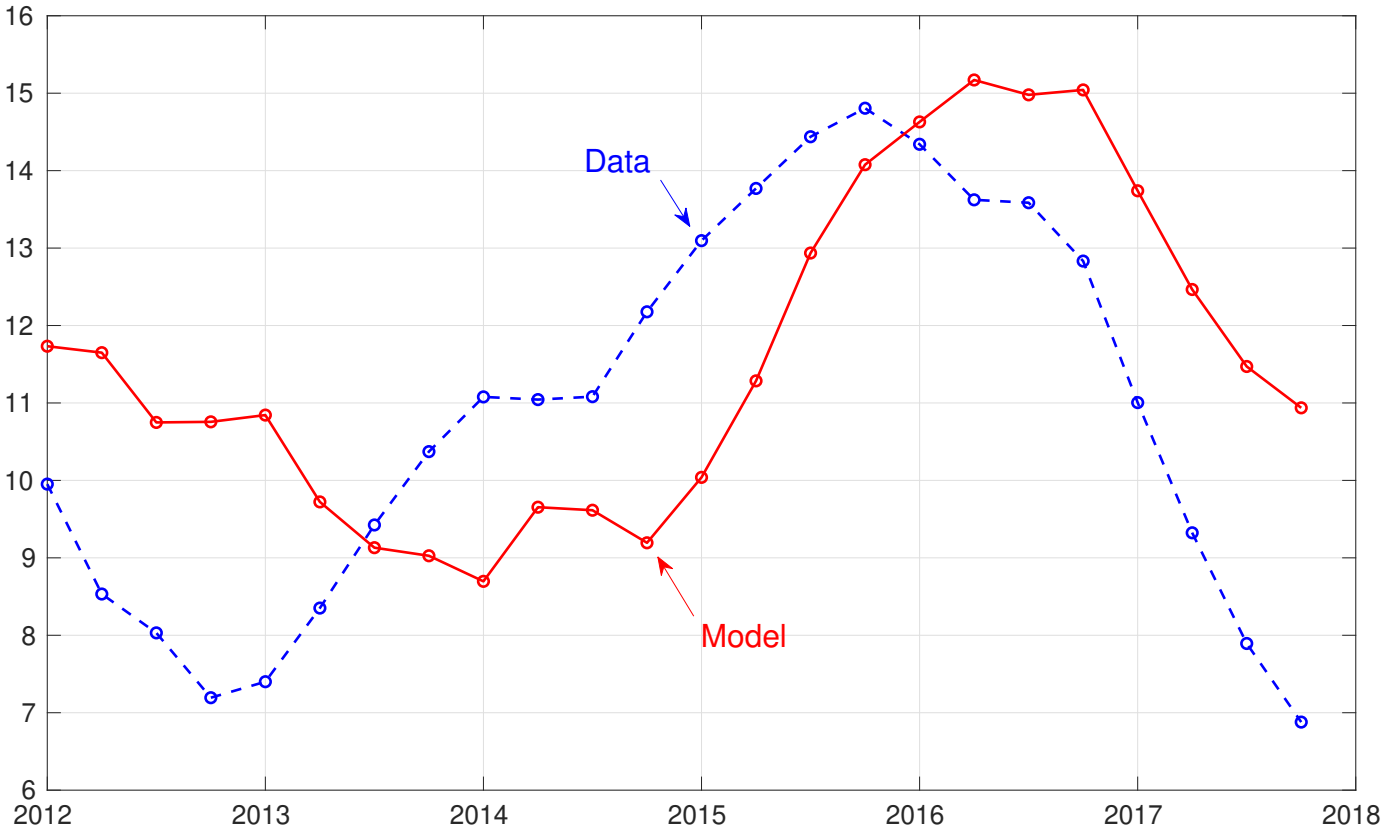
- Model generates similar increase in inflation as in the data

Event: Spread



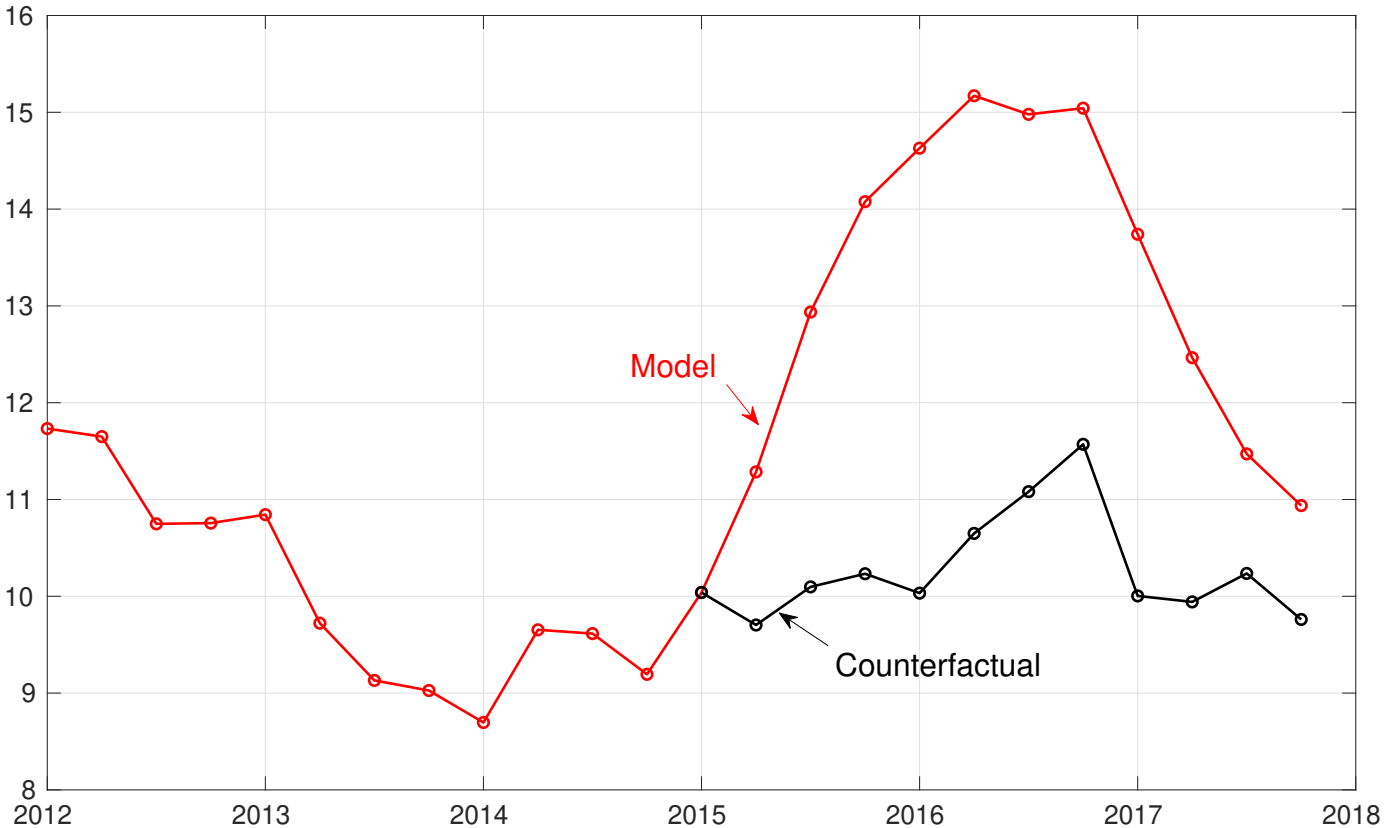
- Model generates similar increase in spreads

Event: Nominal Rate



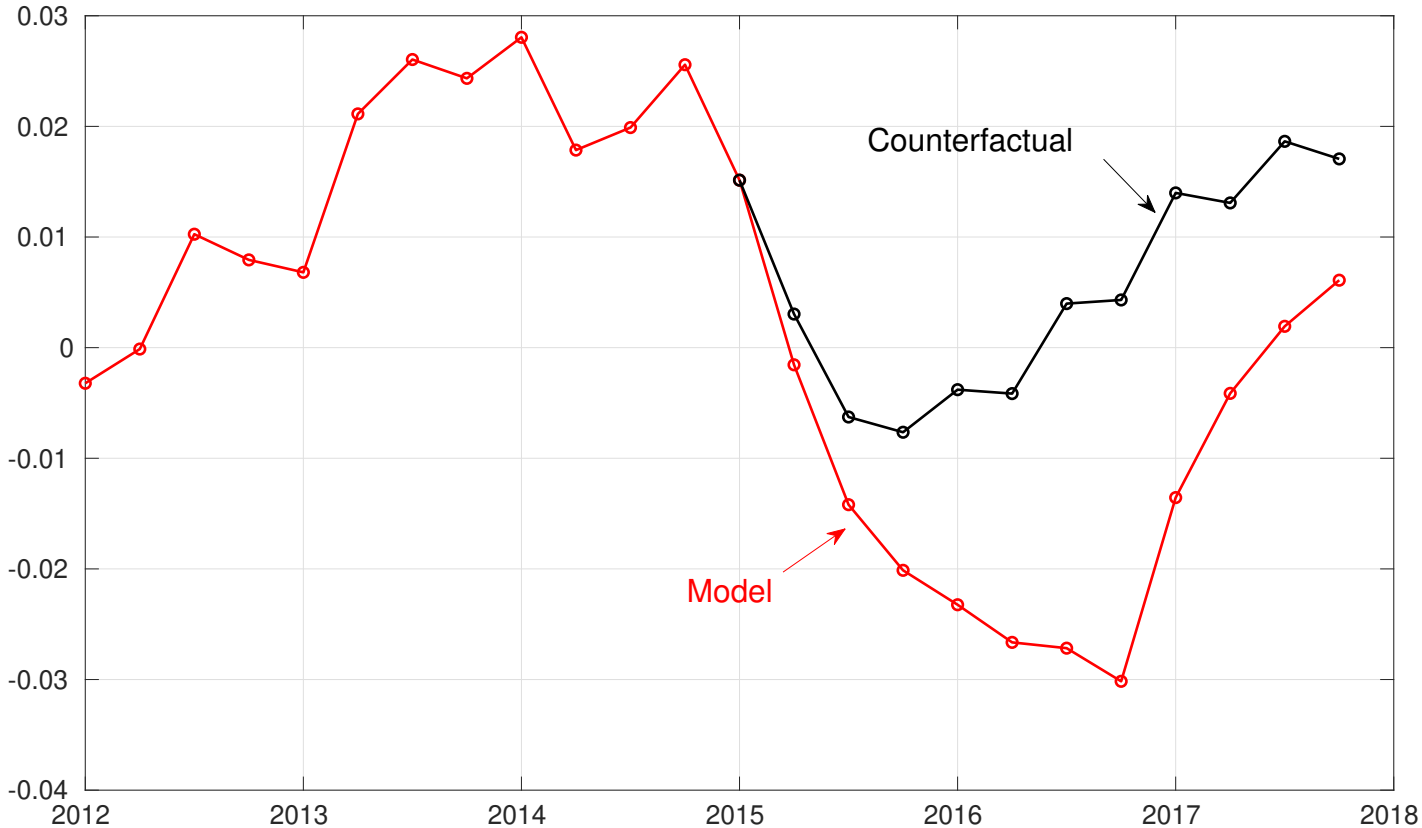
- Nominal rate increases to fight inflation

Counterfactual: Nominal Rate



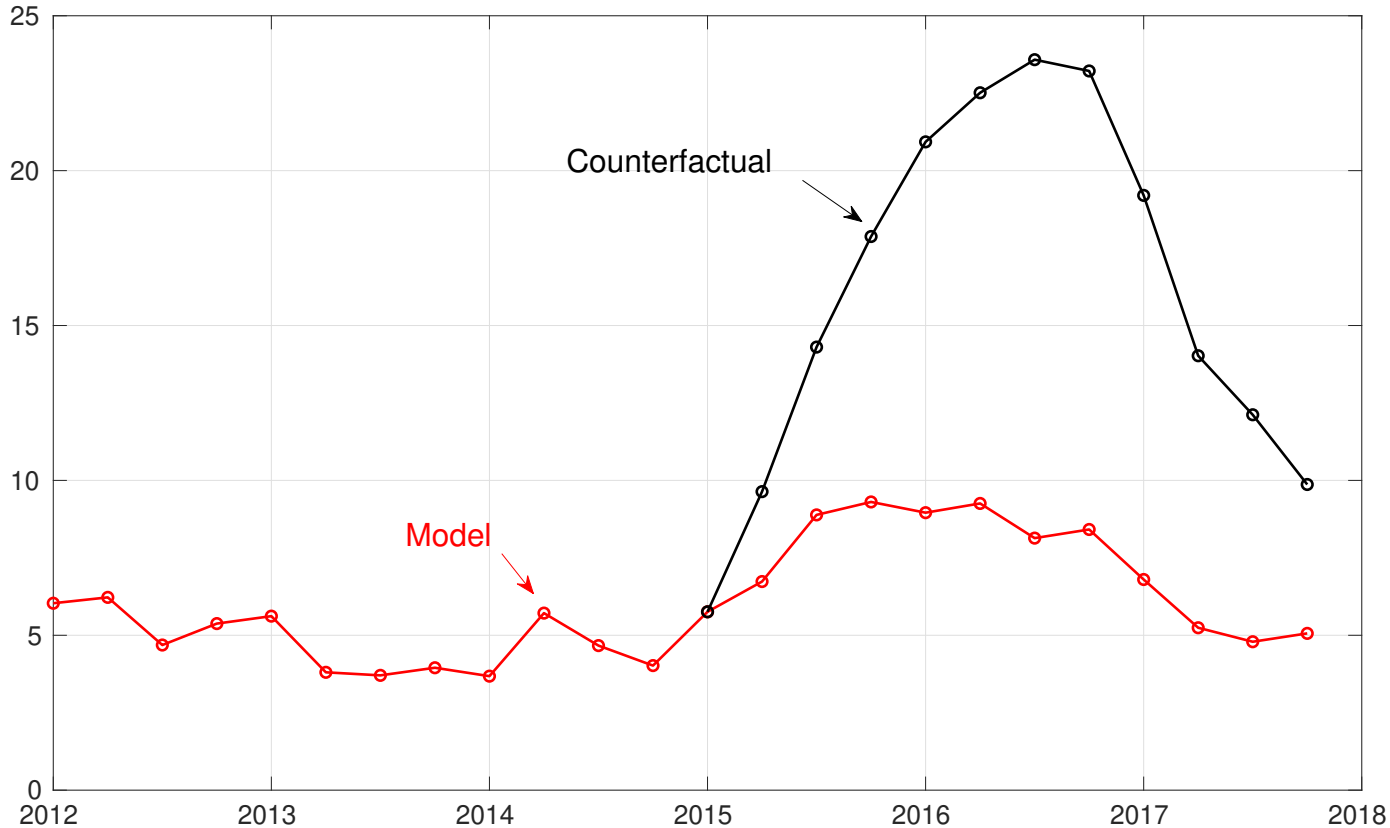
- Feed in same productivity sequence
- Feed in substantial expansionary money shocks from start of recession

Counterfactual: GDP



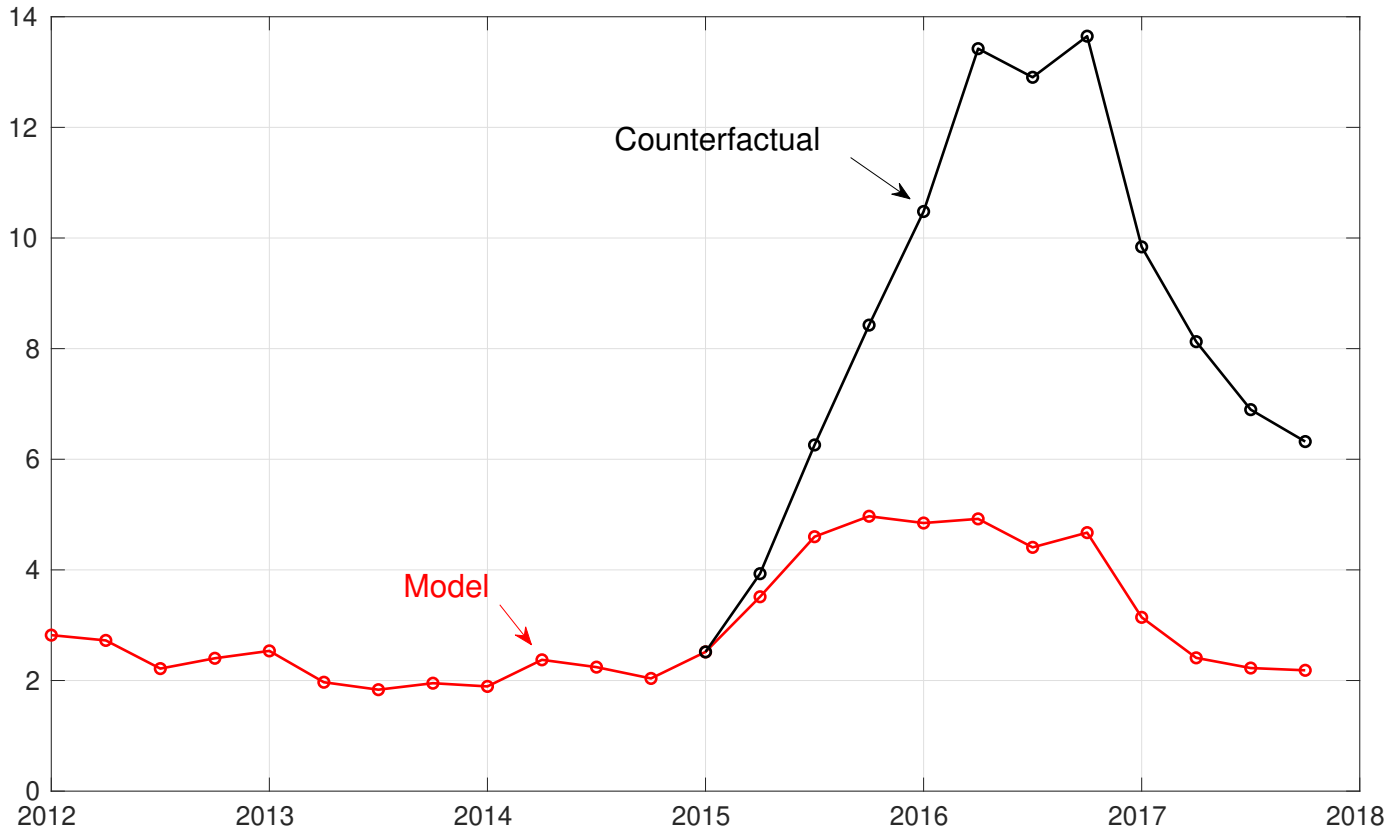
- Output falls by less with expansionary monetary policy

Counterfactual: Inflation



- Inflation increases by more with expansionary monetary policy

Counterfactual: Spread



- Expansionary monetary policy worsens the debt crisis
- Brazil's inflation target helped with inflation *and* debt crisis

Conclusion

- Integrated framework: monetary policy and sovereign debt crises
- Tight monetary policy lowers inflation and sovereign spreads
- With default risk, inflation targeting requires stronger responses by the nominal rate

Appendix

Government Recursive Problem

- Chooses whether to default

$$V(s,B) = \max\left\{W(s,B),\ W(s^d,\underline{B}) - \nu\right\}$$

- And borrowing B'

$$W(s,B) = \max_{B'}\left\{u(C,C^f,N) + \beta \mathbf{E}_{s'} V(s',B')\right\}$$

subject to private and monetary eqm and three functions

- Bond price schedule reflects default and recovery

$$q(s,B') = \frac{1}{1+r^*}\mathbf{E}\left[1 - D(s',B') + D(s',B')\underline{B}/B'\right]$$

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Functional Forms and Definitions

- Rule with interest rate smoothing

$$i = \left[R \left(\frac{\pi}{\overline{\pi}} \right)^{\alpha_P} \right]^{1-\kappa} (i_-)^{\kappa} m$$

- Preferences

$$u(C,\ C^f, N) = \theta \log C + (1-\theta) \log C^f - \frac{N^{1+\zeta}}{1+\zeta}$$

- Consumer price index: domestic prices and terms of trade

$$P^{\text{CPI}} \propto \left(P^d \right)^{\theta} e^{1-\theta}$$

$$\pi^{\text{CPI}} = \pi^{\theta} \left(\frac{e}{e_{-1}} \right)^{1-\theta}$$

- Default Productivity loss cf. Chatterjee and Eyigungor (2012)

$$z^d(z) = z - \max\{0, \lambda_0 z + \lambda_1 z^2\}$$

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Parameter Values

Assigned Parameters		
Share of import in consumption	$\theta = 0.85$	Import share of Brazil
Export demand elasticity	$\rho = 5$	Literature: Devereux et al. (2018)
International rate	$r^* = 2\%$	US Treasury yields
Goods elasticity	$\eta = 6$	Literature: 20% markup
Frisch elasticity	$\zeta = 1/0.7$	Literature: Heathcote et al. (2010)
Persistence of TFP shock	$\rho_z = 0.95$	Literature
Interest rate smoothing	$\kappa = 0.6$	Literature

Parameters from Moment Matching		*Brazilian Data*
Discount factor	$\beta = 0.99$	Debt service to GDP $= 6\%$
Inflation target	$\overline{\pi} = 1.018$	Mean inflation $= 5.9\%$
Inflation weight in rule	$\alpha_P = 1.125$	Inflation volatility $= 1.8\%$
Rotemberg adjustment cost	$\varphi = 12$	Mean nominal rate $= 11.2\%$
Std of TFP shock	$\sigma_z = 0.55\%$	GDP volatility $= 1.9\%$
Std. of money shock	$\sigma_m = 0.31\%$	Nominal rate volatility $= 2.2\%$
Productivity loss parameter	$\lambda_0 = -0.275$	Mean govt spread$= 2.6\%$
Productivity loss parameter	$\lambda_1 = 0.3$	Govt spread volatility $= 1\%$
Std. of default cost	$\sigma_\nu = 0.675\%$	corr(GDP, spread) $= -0.40$
Recovery	$\underline{B} = 0.2$	Brazil mean recovery $= 86\%$

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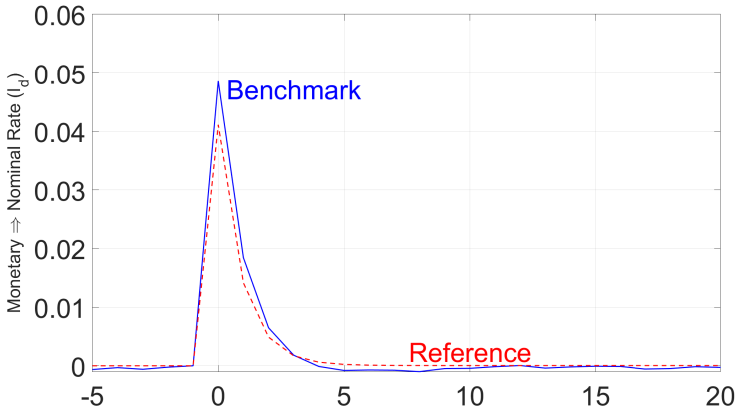
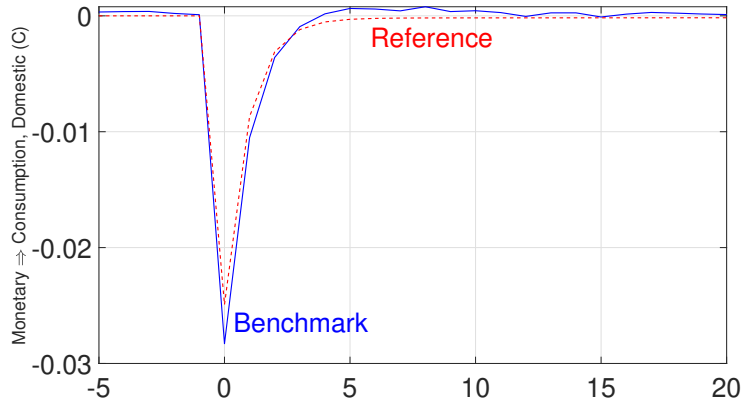
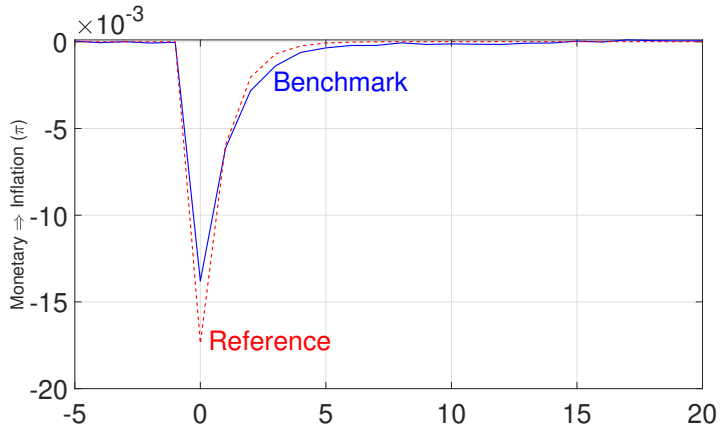
Impulse Responses to Money Shock



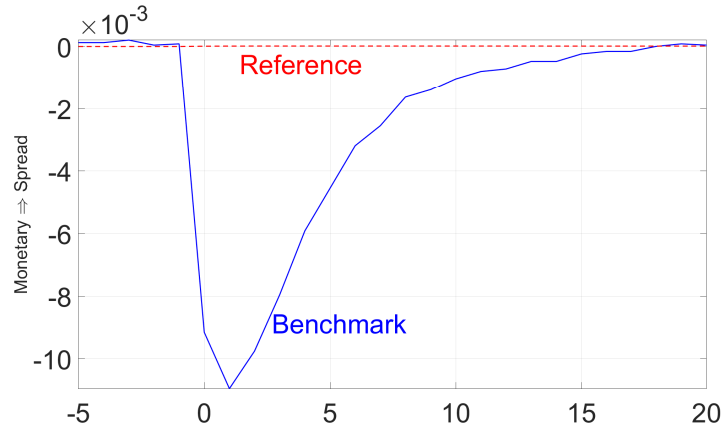
Nominal Interest Rate



Domestic Consumption



Inflation



Spread

- Standard: high nominal rates depress consumption and lower inflation
- New: high nominal rates lowers govt spreads

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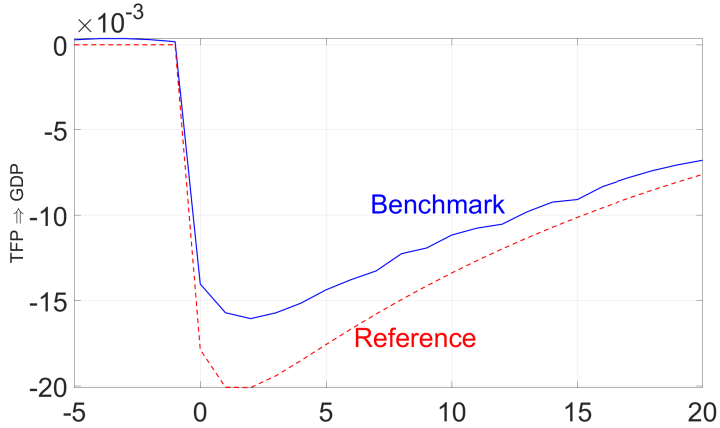
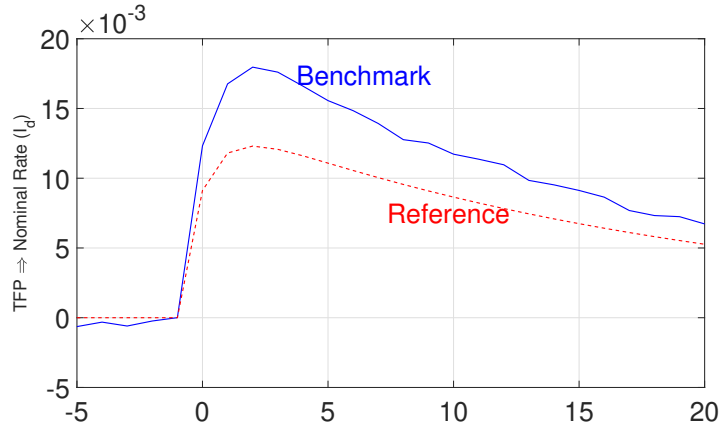
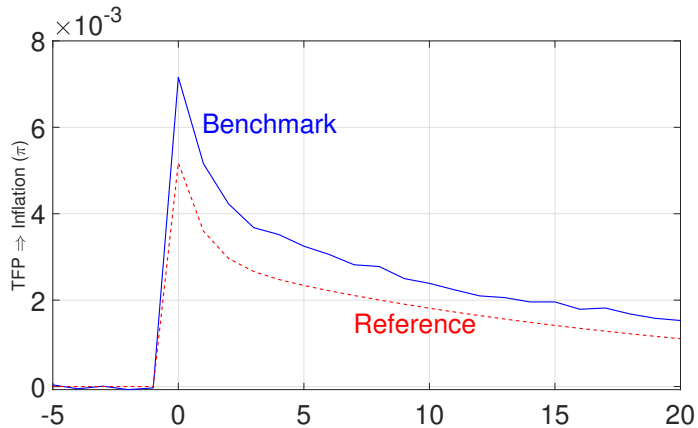
Impulse Responses to Productivity Shock



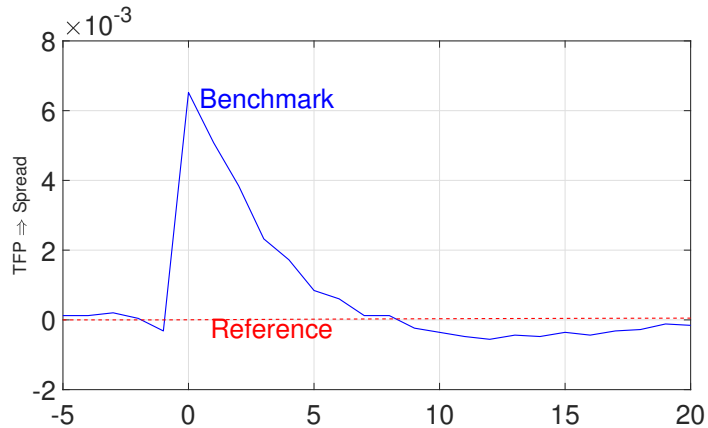
Output



Nominal Interest Rate



Inflation



Spread

- Recession associated with high nominal rates, inflation, and spreads
- Nominal rates respond more forcefully with default risk

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