Inflation Targeting with Sovereign Default Risk

Cristina Arellano
FRB Minneapolis and NBER

Yan Bai
University of Rochester and NBER

Gabriel Mihalache
Stony Brook University

Oct 2018

The views expressed here are those of the authors and not necessarily those of the Federal Reserve Bank of Minneapolis or the Federal Reserve System.
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 (⇒ 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)


- **Inflation, denomination and default:**
  - **Nominal wage rigidity**: Uribe and Schmitt-Grohe (2016), Na 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
  
  \[
  \max E_0 \sum_{t=0}^{\infty} \beta^t u(C_t, C^f_t, N_t)
  \]

  s.t.  
  \[
  P^d_t C_t + P^f_t C^f_t + q^d_i B^d_{t+1} \leq W_t N_t + B^d_t + \Psi_t + T_t
  \]

- Domestic nominal bonds with price \(q^d_i\), in zero net supply

- Receive profits from firms \(\Psi_t\), and transfers from government \(T_t\)

- Optimality conditions:
  
  \[
  \frac{u_{C^f,t}}{u_{C,t}} = e_t, \quad -\frac{u_{N,t}}{u_{C,t}} = w_t, \quad u_{C,t} = \beta_i t E_t \left[ \frac{u_{C,t+1}}{\pi_{t+1}} \right]
  \]

- Nominal rate \(i_t = 1/q^d_i\), inflation \(\pi_{t+1} = P^d_{t+1}/P^d_t\),
  
  terms of trade \(e_t = P^f_t/P^d_t\) (↑ depreciation)
Final Domestic Goods and Exports

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

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

- 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

$$X_t = e^0_t \zeta$$

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 $\bar{\pi}$ (Rotemberg)
- Dynamic choice of $n_{it}$ and prices $p_{it}$ (NKPC)
  \[ \frac{\eta}{\eta - 1} \frac{w_t}{z_t} = 1 + \frac{1}{\eta - 1} \varphi \left( \pi_t - \bar{\pi} \right) \pi_t \]
  \[ - \frac{1}{\eta - 1} E_t \left[ \beta \frac{u_{c,t+1}}{u_{c,t}} \frac{Y_{t+1}}{Y_t} \varphi \left( \pi_{t+1} - \bar{\pi} \right) \pi_{t+1} \right] \]
- Low $z_t$ increases unit costs (LHS) $\implies \pi_t$ high
Policy

Monetary Authority: Interest rate rule

\[ i_t = R \left( \frac{\pi_t}{\pi} \right)^{\alpha_p} m_t \]

Targets inflation \( \pi \), 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 \( B \)
  - Costs: Productivity reduced to \( z_t^d \leq z_t \), utility cost \( \nu_t \)
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: \[ C + X = \left[ 1 - \frac{\varphi}{2} (\pi - \bar{\pi})^2 \right] zN \]

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

Relative Consumption: \[ u_{Cf}/u_C = e \]

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

Interest Rate Rule: \[ i = R \left( \frac{\pi}{\bar{\pi}} \right)^{\alpha p} \]

NKPC: \[ \frac{1}{z} \frac{u_N}{u_C} = 1 + \frac{1}{\eta - 1} \varphi \left( \pi - \bar{\pi} \right) \pi - \frac{1}{u_C z N} F(s, B') \]

Given functions (Markov Eq.): \[ q(s, B') = \text{bond price schedule}, \]
\[ M(s, B') = \text{expected marginal utility}, F(s, B') = \text{expected inflation} \]

- 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 $C_f$

$$ q [u_{Cf}] = \beta E [u'_{Cf}] $$
Borrowing and Monetary Policy: With Default

- Optimal borrowing condition with wedges

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

- 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

- Optimal borrowing condition with wedges

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

- Monetary wedge \( \tau_0 \)

\[ \tau_0 = \frac{\lambda}{u_C} \]

- \( \lambda \) 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 \( \lambda \)

- When monetary policy alters \( u_C \), government responds via \( B' \)
Borrowing and Monetary Policy: With Default

- Optimal borrowing condition with wedges

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

- Monetary wedge \( \tau_1 \)

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

- Govt alters expected marginal utility (\( \mu \) Dom. Euler) and expected inflation (\( \gamma \) NKPC)

- Lower \( B' \) increases future \( C' \) and lowers expected \( u'_C \)
Borrowing and Monetary Policy: With Default

- **Contractionary MP**: increases $i$, lowers $C$: $[u_C] = i \beta E [u'_C / \pi']$

- Relative Consumption and Domestic Euler conditions bind:

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

- Wedges $\tau_0$ and $\tau_1$ 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
Borrowing and Monetary Policy: With Default

- **Contractionary MP**: increases $i$, lowers $C$: $[u_C] = i \beta E [u'_C / \pi']$

- Relative Consumption and Domestic Euler conditions bind:

$$q \left[ u_{Cf} \right] (1 - \tau_0) - \tau_1 - \tau_2 = \beta E \left[ u'_C f (1 - \tau'_0) \right]$$

- Wedges $\tau_0$ and $\tau_1$ 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

  *Tight monetary policy decreases spreads*
Quantitative Analysis

- Parameterize model to Brazil (output, inflation, spreads)
  - Functional Forms
  - Calibration

- IRFs to monetary and productivity shocks
  Compare to reference model, without default (cf. Gali and Monacelli (2005))

- Event analysis and MP counterfactual for 2015 recession
## Business Cycle Moments

<table>
<thead>
<tr>
<th></th>
<th>Brazil (%)</th>
<th>Benchmark (%)</th>
<th>Reference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Means (%)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inflation</td>
<td>5.9</td>
<td>6.1</td>
<td>6.1</td>
</tr>
<tr>
<td>Nominal Rate</td>
<td>11.2</td>
<td>11.6</td>
<td>11.6</td>
</tr>
<tr>
<td>Spread</td>
<td>2.6</td>
<td>2.7</td>
<td>—</td>
</tr>
</tbody>
</table>

|                      |            |               |               |
| **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
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
Model generates similar increase in spreads
Event: Nominal Rate

Nominal rate increases to fight inflation
- Feed in same productivity sequence
- Feed in substantial expansionary money shocks from start of recession
Output falls by less with expansionary monetary policy
Inflation increases by more with expansionary monetary policy.
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
  \[ V(s, B) = \max \left\{ W(s, B), W(s^d, B) - \nu \right\} \]

- And borrowing \( B' \)
  \[ W(s, B) = \max_{B'} \left\{ u(C, C^f, N) + \beta E_s V(s', B') \right\} \]

subject to private and monetary eqm and three functions

- Bond price schedule reflects default and recovery
  \[ q(s, B') = \frac{1}{1 + r^*} E \left[ 1 - D(s', B') + D(s', B') B / B' \right] \]
Functional Forms and Definitions

- Rule with interest rate smoothing

\[ i = \left[ R \left( \frac{\pi}{\bar{\pi}} \right)^{\alpha P} \right]^{1-\kappa} (i_-)^\kappa m \]

- 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

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

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


\[ z^d(z) = z - \max\{0, \lambda_0 z + \lambda_1 z^2\} \]
## Parameter Values

**Assigned Parameters**

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

**Parameters from Moment Matching**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount factor</td>
<td>$\beta = 0.99$</td>
<td>Debt service to GDP = 6%</td>
</tr>
<tr>
<td>Inflation target</td>
<td>$\pi = 1.018$</td>
<td>Mean inflation = 5.9%</td>
</tr>
<tr>
<td>Inflation weight in rule</td>
<td>$\alpha_P = 1.125$</td>
<td>Inflation volatility = 1.8%</td>
</tr>
<tr>
<td>Rotemberg adjustment cost</td>
<td>$\varphi = 12$</td>
<td>Mean nominal rate = 11.2%</td>
</tr>
<tr>
<td>Std of TFP shock</td>
<td>$\sigma_z = 0.55%$</td>
<td>GDP volatility = 1.9%</td>
</tr>
<tr>
<td>Std. of money shock</td>
<td>$\sigma_m = 0.31%$</td>
<td>Nominal rate volatility = 2.2%</td>
</tr>
<tr>
<td>Productivity loss parameter</td>
<td>$\lambda_0 = -0.275$</td>
<td>Mean govt spread = 2.6%</td>
</tr>
<tr>
<td>Productivity loss parameter</td>
<td>$\lambda_1 = 0.3$</td>
<td>Govt spread volatility = 1%</td>
</tr>
<tr>
<td>Std. of default cost</td>
<td>$\sigma_v = 0.675%$</td>
<td>corr(GDP, spread) = −0.40</td>
</tr>
<tr>
<td>Recovery</td>
<td>$B = 0.2$</td>
<td>Brazil mean recovery = 86%</td>
</tr>
</tbody>
</table>

**Brazilian Data**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Debt service to GDP</td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td>Mean inflation</td>
<td>5.9%</td>
<td></td>
</tr>
<tr>
<td>Inflation volatility</td>
<td>1.8%</td>
<td></td>
</tr>
<tr>
<td>Mean nominal rate</td>
<td>11.2%</td>
<td></td>
</tr>
<tr>
<td>GDP volatility</td>
<td>1.9%</td>
<td></td>
</tr>
<tr>
<td>Nominal rate volatility</td>
<td>2.2%</td>
<td></td>
</tr>
<tr>
<td>Mean govt spread</td>
<td>2.6%</td>
<td></td>
</tr>
<tr>
<td>Govt spread volatility</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>corr(GDP, spread)</td>
<td>−0.40</td>
<td></td>
</tr>
<tr>
<td>Brazil mean recovery</td>
<td>86%</td>
<td></td>
</tr>
</tbody>
</table>
Impulse Responses to Money Shock

Nominal Interest Rate

Inflation

- Standard: high nominal rates depress consumption and lower inflation
- New: high nominal rates lowers govt spreads
Impulse Responses to Productivity Shock

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