Endogenous Debt Crises

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Objectives

- Provide a simple theoretical framework accounting for:
  - the fact that some emerging countries prudently manage their external debt
  - while others periodically fall into the trap of debt crises

- Infer a typology of crises:
  - exogenously-driven: unanticipated shock on the fundamentals
  - endogenous crises:
    - self-enforcing (the country rationally adopts a risky behavior)
    - self-fulfilling (the markets trigger a crisis that was avoidable)

- Estimate their relative prevalence in historical data
Typology of self-fulfilling debt crises

- **Liquidity crises** (Cole and Kehoe, 1996, 2000)
  - Essentially a coordination problem
  - Analog to bank runs
  - Can be avoided with a simple coordination device (Chamon, 2007)

- **Snowball effect** (Calvo, 1988)
  - High interest rates $\Rightarrow$ more debt $\Rightarrow$ default
  - Low interest rates $\Rightarrow$ less debt $\Rightarrow$ no default
  - Can be avoided if negotiation occurs on the amount due tomorrow rather than the amount lent today (Chamon, 2007)
  - More generally, impossible when no social cost of default (generalization of Cohen and Portes, 2004)

$\Rightarrow$ Self-fulfilling crises characterized as the outcome of an endogenous destruction of fundamentals by the crisis
Self-enforcing (or Panglossian) effect

- Tendency to overborrow today when risk of default is high tomorrow
- Explanation: you don’t repay when you default, so why care?
- Similar to OLG models: risk premium $= \text{probability of death}$
  $\Rightarrow$ the two cancel out
- Technically: in the Euler equation, the derivative of expectation term w.r.t. debt is zero over the default set
Outline

1 The Model
   - Presentation
   - The two regimes
   - The risk of multiple equilibria
   - Generalization and reduced form

2 Empirical analysis
   - Dataset
   - Econometric model
   - Estimation technique and results

3 Conclusion
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Model features (1/2)

- In the spirit of Eaton and Gersovitz (1981), Arellano (2008)
- Discrete time
- Sovereign country (with representative agent) produces and consumes
- Production is an exogenous stochastic stream \((i.i.d. \text{ growth rate})\)
- Difference between production and consumption financed on international markets
  \(\Rightarrow\) accumulation of a stock of external debt
- Debt is short-term and needs to be refinanced every year
- Debt repayments not contingent to the state of nature
- Discount rate \(\delta\) supposed greater than \(r - \gamma \bar{g}\) (\(\gamma\) is inter-temporal elasticity of substitution)
  \(\Rightarrow\) the country has an inner tendency to borrow
The country can make the strategic decision to default

Default implies financial autarky and cost on output

Anticipating default, international markets may impose a (model-consistent) risk premium or ration the country

Two differences with standard models:

▶ negotiation occurs on the amount lent today rather than the amount due tomorrow
▶ output cost of default has two components: a social loss, and a fraction grabbed by investors
A two-period model (1/3)

Country perspective

- **Period 1:**
  - Output $Q_1$ known
  - Country borrows $L_1$, for a future repayment $D_2$ (interest rate is $D_2/L_1 - 1$)
  - It consumes $C_1 = Q_1 + L_1$

- **Period 2:**
  - Output can take two values: $Q_2^+ > Q_2^-$ (resp. with probability $1 - p$ and $p$)
  - If country repays: $C_2 = Q_2 - D_2$
  - If it defaults: $C_2 = (1 - \lambda) \mu Q_2$

- **Objective:**

$$\max_{C_1, C_2} u(C_1) + \beta E_1 u(C_2)$$
A two-period model (2/3)

Output cost of default

- In case of default:
  - Country gets \((1 - \lambda)\mu Q_2\)
  - Investors get \(\lambda\mu Q_2\)
  - Social loss is \((1 - \mu)Q_2\)

- The parameter \(\mu\) measures the negative externality associated to a default. If \(\mu = 1\), then default is efficient \textit{ex post}.
- The parameter \(\lambda\) measures the ability of creditors to seize country ressources. If \(\lambda = 0\), recovery for creditors is null.
Investors risk neutral, subject to zero-profit condition.

If repayment is expected (safe case):

\[ L_1(1 + r) = D_2^s \]

If default is expected (unsafe case):

\[ L_1(1 + r) = (1 - p)D_2^u + p\lambda\mu Q_2 \]
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The safe case

- Repayment in period 2 occurs when:
  \[ D_2 \leq \kappa \ Q_2 \]

  where \( \kappa = 1 - (1 - \lambda) \mu \)

- In that case, the FOC is:
  \[ u'(Q_1 + L_1) = \beta (1+r) \{ (1-p)u' (Q_2^+ - L_1(1+r)) + p \ u' (Q_2^- - L_1(1+r)) \} \]

- \( C_1 \) is increasing in \( Q_2^- \) \( \Rightarrow \) prudent behavior
The unsafe case

- Occurs when $D_2 > \kappa Q_2$
- The FOC becomes:

\[ u'(C_1) = \beta (1 + r) u'(C_2^+) \]

- The risk premium and the probability of the bad state cancel each other
- If $\lambda > 0$, $Q^-_2$ only plays a role in the supply curve for lending; if $\lambda = 0$, no role at all
- Panglossian/self-enforcing effect: country indifferent to the bad state of nature; tendency to rationally overborrow
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Characterization of multiple equilibria (1/2)

- Usually, the risk determines the interest rate
- But the reverse causation can also be at work (snowball effect)
- Possible when $D_2^s \leq \kappa Q^-_2$ and $D_2^u > \kappa Q_2$, i.e.

$$\kappa Q^-_2 - p(1 - \mu)Q^-_2 < L_1(1 + r) \leq \kappa Q^-_2$$

- Range of multiple equilibria smaller as $\mu$ get bigger; nil when $\mu = 1$
  $\Rightarrow$ multiple equilibria disappear when fundamentals are immune to the crisis
Characterization of multiple equilibria (2/2)

Efficient case ($\mu = 1$)

Unsafe
Safe

Inefficient case ($\mu < 1$)

Unsafe
Safe
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Generalization to infinite horizon

- Insights of the two-period model still hold.
- The impossibility of multiple equilibria needs a slightly stronger condition than $\mu = 1$ (we name it a *smooth default*).
- Panglossian effect now written as:

$$u'(C_t) = \beta (1 + r)(1 + \xi_{t+1|t}) \mathbb{E}_t \left[ u'(C_{t+1}) | \mathcal{R}(D_{t+1}, Q_t) \right]$$

where $\xi_{t+1|t} > 0$ reduces the propensity to borrow (nil for the *smooth default* case).
- The recovery of investors $\lambda$ is supposed stochastic.
Reduced form of debt dynamics

\[ \hat{D}_{t+1} = a_1 + a_2 \hat{D}_t - a_3 g_{t+1} \hat{D}_t + a_4 (g_{t+1|t} - \bar{g}) + \varepsilon_{t+1} \]

where

- \( \varepsilon_{t+1} \) is deviation from “desired” debt (Alesina and Tabllini 1990; Beetsma and Mavromatis 2014)
- \( g_{t+1|t} - \bar{g} \) is the Panglossian effect: growth differential between repayment states and average state

The Panglossian term can be rewritten as \( \pi_{t+1|t} (g_{t+1|t} - g_{t+1|t}^-) \), with \( \pi_{t+1|t} \) the probability of default and \( g_{t+1|t}^+ - g_{t+1|t}^- \) the growth differential between repayment states and default states
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Debt crises
Definition of Kraay & Nehru (2004)

For a given year, a country is considered to be in debt crisis if at least one of the following 3 conditions holds:

- it receives debt relief from the Paris Club (rescheduling and/or debt reduction)
- the sum of its principal and interest arrears is above 5% of outstanding debt stock
- it receives substantial balance of payments support from the IMF through a non-concessionnal Standby Arrangement (SBA) or Extended Fund Facility (EFF)

Threshold: amount of support > 50% of IMF quota
Episodes

- Having defined *years* of crisis (or no-crisis), we define *episodes* made of several consecutive years.

- *Distress episodes*: at least 3 consecutive years of crisis, preceded by at least 3 years without crisis.

- *Normal times episodes*: 5 consecutive years without crisis.

- An episode is characterized by 4 informations:
  1. type: distress or normal
  2. country
  3. year of beginning
  4. length (in years)
Data sources

- World Bank’s *Global Development Finance* for data on debt levels and payment arrears
- Paris Club website for information on debt reliefs
- IMF’s *International Financial Statistics* for data on SBA/EFF commitments
- World Bank’s *World Development Indicators* for general macroeconomic variables
- *Penn Word Tables* for data on Purchasing Power Parity (PPP) variables
Country set:

- 135 developing countries (World Bank definition)
- 38 with no access to private financial markets
- 97 countries in the sample

Time span: 1970-2004

Number of episodes obtained:
- 70 distress episodes
- 223 normal times episodes

Average default episode length: 13.3 years
Average GDP loss peak to through: 1.9%
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Core equations

\[ d_{it} = X_{i,t-1}^{d} \eta^{d} + g_{it} X_{i,t-1}^{d,g} \eta^{d,g} + \varepsilon^{d}_{it} \]

\[ g_{it} = X_{i,t-1}^{g} \eta^{g} + \delta_{it} X_{i,t-1}^{g,\delta} \eta^{g,\delta} + \varepsilon^{g}_{it} \]

\[ \delta_{it} = 1_{\{X_{i,t-1}^{\delta} + d_{it} X_{i,t-1}^{\delta,d} + \varepsilon^{\delta}_{it} > 0\}} \]

where:

- \( i \) country concerned by the episode
- \( t \) beginning year of the episode
- \( d_{it} \) debt-to-GDP ratio
- \( g_{it} \) growth rate
- \( \delta_{it} \) dummy for debt crisis
- \( X \) vectors of exogenous variables
- \( \eta \) parameters
- \( \varepsilon \) exogenous shocks
Possibility of multiple equilibria

- Crisis explained by a probit equation where debt/GDP appears
- Debt/GDP explained by two linear predictors, the second of which is growth
- Growth itself gets a malus in case of crisis
  ⇒ endogeneity of the fundamentals to the crisis
- Model not well-specified at this stage: circular dependency of the three endogenous variables
- For a given set of exogenous and a given draw of random shocks, one could have a crisis equilibrium and a no-crisis equilibrium
  ⇒ possibility of self-fulfilling crises
Completion of the model specification

- **Solution**: add a *sunspot*, which determines the equilibrium when both are possible.

- The sunspot is “on” with probability $p$.

- For a given set of exogenous and a given draw of random shocks, three cases are possible:
  1. Only the no-crisis equilibrium is possible.
  2. Only the crisis equilibrium is possible ⇒ crisis driven by an exogenous shock.
  3. Both crisis and no-crisis equilibrium are possible. The crisis occurs if sunspot is “on” ⇒ self-fulfilling crisis.

- *A posteriori*, for a given observed crisis, it is possible to compute the probability that it was self-fulfilling rather than exogenously driven.
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Estimation technique

- Maximum likelihood estimation, with randomization algorithm to deal with the non-global concavity of likelihood function
- Exogenous variables taken two years before beginning of episode
- Concerning parameter $p$ (the probability of sunspot being “on”):
  - It is never statistically significant
  - Therefore we calibrate with sensible values
    - $p = 1$: markets panic-prone
    - $p = 0.5$: markets lose confidence half of the time
Measuring the Panglossian effect

- Constructed variable: \( \pi_{t+1|t} (g_{t+1|t}^+ - g_{t+1|t}^-) \)
- Probability of default computed with a first-stage Probit
- Growth gap approximated by the mean growth rate (across the whole sample) above and below quantile \( \pi_{it} \)
- Generated regressor \( \Rightarrow \) standard errors corrected by the Murphy and Topel (1985) method
### Estimation results

#### Debt/GDP ratio dynamics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\eta^d$: Debt/GDP $(t - 2)$</td>
<td>1.204***</td>
<td>0.023</td>
<td>0.000</td>
</tr>
<tr>
<td>$\eta^d$: Crisis prob $\times$ Growth gap $\hat{g}$ $(t/t - 2)$</td>
<td>1.205***</td>
<td>0.023</td>
<td>0.000</td>
</tr>
<tr>
<td>$\eta^{d,g}$: Debt/GDP $(t - 2) \times$ Growth $(t)$</td>
<td>1.104***</td>
<td>0.075</td>
<td>0.000</td>
</tr>
</tbody>
</table>

#### Growth dynamics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\eta^g$: Log per capita PPP real GDP $(t - 2)$</td>
<td>-0.023**</td>
<td>0.008</td>
<td>0.001</td>
</tr>
<tr>
<td>$\eta^g$: Growth $(t - 2)$</td>
<td>0.281**</td>
<td>0.101</td>
<td>0.001</td>
</tr>
<tr>
<td>$\eta^{g,d}$: Debt crisis dummy $(t)$</td>
<td>-0.059***</td>
<td>0.015</td>
<td>0.000</td>
</tr>
</tbody>
</table>

#### Debt crisis determinants

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\eta^\delta$: Log per capita PPP real GDP $(t-2)$</td>
<td>-0.365**</td>
<td>0.132</td>
<td>0.001</td>
</tr>
<tr>
<td>$\eta^\delta$: US$ GDP / PPP GDP $(t-2)$</td>
<td>1.477**</td>
<td>0.535</td>
<td>0.001</td>
</tr>
<tr>
<td>$\eta^{\delta,d}$: Debt/GDP $(t)$</td>
<td>2.883***</td>
<td>0.456</td>
<td>0.000</td>
</tr>
</tbody>
</table>

#### Additional parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Coefficient</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$p$: Sunspot Bernoulli parameter</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Self-fulfilling probability</td>
<td>0.111</td>
<td></td>
</tr>
<tr>
<td>Self-enforcing probability</td>
<td>0.124</td>
<td></td>
</tr>
</tbody>
</table>
Robustness checks

- The Panglossian effect is not simply a proxy for the risk premium effect
- It is not either a proxy for “bad news,” which trigger an debt increase in a model of inter-temporal consumption smoothing (tested by introducing a measure of the business cycle)
- The following possible missing variables in growth equation (Moral-Benito, 2012) have been tested:
  - price of investment goods
  - distance to major world cities
  - political rights
For each crisis, probability that it was self-fulfilling
i.e., probability that it would have been avoided if confidence had been maintained

<table>
<thead>
<tr>
<th>Country</th>
<th>Year</th>
<th>Crisis length</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jordan</td>
<td>1989</td>
<td>16</td>
<td>0.2%</td>
</tr>
<tr>
<td>Somalia</td>
<td>1981</td>
<td>24</td>
<td>1.4%</td>
</tr>
<tr>
<td>Rwanda</td>
<td>1994</td>
<td>11</td>
<td>1.4%</td>
</tr>
<tr>
<td>Congo, Rep.</td>
<td>1985</td>
<td>20</td>
<td>1.6%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Venezuela</td>
<td>1989</td>
<td>4</td>
<td>19.3%</td>
</tr>
<tr>
<td>Indonesia</td>
<td>1997</td>
<td>8</td>
<td>19.6%</td>
</tr>
<tr>
<td>El Salvador</td>
<td>1990</td>
<td>3</td>
<td>19.9%</td>
</tr>
<tr>
<td>Argentina</td>
<td>1983</td>
<td>13</td>
<td>20.3%</td>
</tr>
</tbody>
</table>

Computed for $p = 1$
## Model simulation

### Contribution of each shock to crises

<table>
<thead>
<tr>
<th>Effect</th>
<th>Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market shock ($\varepsilon_{it}^\delta$)</td>
<td>55.8%</td>
</tr>
<tr>
<td>Debt shock ($\varepsilon_{it}^d$)</td>
<td>15.2%</td>
</tr>
<tr>
<td>Panglossian effect</td>
<td>12.0%</td>
</tr>
<tr>
<td>Growth shock ($\varepsilon_{it}^g$)</td>
<td>11.0%</td>
</tr>
<tr>
<td>Self-fulfilling effect ($\zeta_{it}$)</td>
<td>6.1%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>

Monte-Carlo simulations of the benchmark estimated model. Results computed over 2,500 simulations of a 10-year duration and starting from a debt-to-GDP ratio of 60%.
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- Two endogenous forces at work in debt crises:
  - self-enforcing / Panglossian effect
  - self-fulfilling effect

- Categories that are empirically relevant: taken together, they explain between 1/4 and 1/5 of crises

- However, the majority of crises are of an exogenous nature (earthquake model)

- Policy implications:
  - Promote the usage of state contingent debt (solution to the exogenously driven case)
  - Debate about debt restructuring (solution to the self-fulfilling case) less important than finding more innovative sources of financing