Crisis and Commitment: Inflation Credibility and the Vulnerability to Sovereign Debt Crises

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Introduction

Countries at record high levels of sovereign debt to GDP

- US, UK, Japan
- Eurozone: Greece, Spain, Portugal, Ireland, Italy
- Eurozone has experienced dramatic spikes in borrowing costs
- Key issue: their debt is in local currency
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Important factor

- Eurozone: Debt in “foreign currency”
  - Real debt: repay through fiscal surpluses
- US, UK, Japan: Debt in “home currency”
  - Nominal debt: repay through fiscal surpluses and/or inflate away
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Conjecture: additional instrument makes default and self-fulfilling crisis less likely

- We explore the validity of this conjecture
What we do

Develop a tractable continuous-time model of self-fulfilling debt crises

- Calvo (1988)
- Cole and Kehoe (2000)

Limited commitment

- Repay debt
- Inflation
What we do

Develop a tractable continuous-time model of self-fulfilling debt crises

▶ Calvo (1988)
▶ Cole and Kehoe (2000)

Limited commitment

▶ Repay debt
▶ Inflation

Currency denomination has an ambiguous impact on the possibility of self-fulfilling debt crises and on welfare
Inflation credibility and debt crisis

- The ability of nominal debt to reduce vulnerability depends on the government commitment to low inflation
  - A moderate commitment implies a small vulnerability area
    - Low inflation in tranquil periods and high inflation in response to a crisis
  - A very weak or a very strong commitment may both have a relatively large area of vulnerability
    - Weak commitment: High inflation all the time. Priced in.
    - Strong commitment: Low inflation all the time. Option never used.

- Option to partial default makes outright default more likely
A weak inflationary regime is best served by foreign currency debt
  - It reduces vulnerability to crises
  - And lowers temptation for inflation
  - Raises borrowing limit

“Original Sin” and “Debt Intolerance”
Road Map

- Model
- No-crisis equilibria
- Crisis equilibria
  - Inflation vulnerability and debt crises
- Conclude
The model

Environment

- Continuous time, $t$
- Open economy, world risk free rate, $r^*$
- One good: constant endowment, $y$
- Benevolent government that issues nominal bonds $B$
Nominal bonds $B_t$ pay interest rate $r_t$
Resource constraint:
\[
\dot{B}_t = P_t (c_t - y) + r_t B_t
\]
Real value of bonds $b = B/P$ evolves according to:
\[
\dot{b}_t = c_t - y + (r_t - \pi_t) b_t
\]
where $\pi_t$ is inflation rate
Real return of nominal bonds is $r_t - \pi_t$
Government preferences

- Utility:
  \[ \int_0^\infty e^{-\rho t} (u(c_t) - \psi(\pi_t)) \]

- \( \rho \) is discount rate

Assumption

Discount factor is such that:

\[ \rho = r^* \]

Assumption

\( \pi \in [0, \bar{\pi}] \) and inflation cost \( \psi(\pi) \) is:

\[ \psi(\pi) = \psi_0 \pi \]
Costs of Inflation

\[ \psi(\pi) \]

Slope = \( \psi_0 \)
Limited Commitment

- No commitment to inflation – cost $\psi_0$
Limited Commitment

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- No commitment to repayment of debt:
  - It can always choose outright default: $\checkmark$
Limited Commitment

- No commitment to inflation – cost $\psi_0$

- No commitment to repayment of debt:
  - It can always choose outright default: $V$
  - Full punishment of default can be avoided if principal and interest repaid within a grace period $\delta$
Limited Commitment

- No commitment to inflation – cost $\psi_0$

- No commitment to repayment of debt:
  - It can always choose outright default: $\forall$
  - Full punishment of default can be avoided if principal and interest repaid within a grace period $\delta$
    - Relevant if government cannot issue new debt (i.e. roll-over crisis)
Limited Commitment

- Costs of inflation differ from that of default
  - Inflation does not lead to renegotiation with creditors or loss of access to bond markets.

- Can interpret inflation as a partial default technology
  - Debt contracts issued under domestic versus foreign law

- Reinhart and Rogoff (2009) identify historical episodes of overt default on domestic debt
No-Crisis Equilibria

- Creditors can commit to rolling over debt
- Limited commitment to debt repayment
  - Deterministic environment: Debt restricted to domain where never default
- Limited commitment to inflation (linear costs)
  - Threshold debt $b_\lambda$
    - $b > b_\lambda$, high inflation, high interest rates
    - $b \leq b_\lambda$, low inflation, low interest rates
  - Incentive to save to escape high inflation/high interest rates even though $r^* = \rho$ and $y$ is constant.
- Impact of inflation commitment ($\psi_0$) on $b_\lambda$, debt dynamics and welfare.
No-Crisis Equilibria

Let us first solve for equilibria without crisis
No-Crisis Equilibria

- $b$: state variable
- Look for recursive equilibria: interest rate a function of $b$
- $\tilde{\Omega} = [b_{\text{min}}, b_{\text{max}}]$: relevant domain for debt
- $r : \tilde{\Omega} \rightarrow \mathbb{R}_+$
No-Crisis Equilibria

- $b$: state variable
- Look for recursive equilibria: interest rate a function of $b$
- $\bar{\Omega} = [b_{\text{min}}, b_{\text{max}}]$: relevant domain for debt
- $r : \bar{\Omega} \to \mathbb{R}_+$
  - $r$ satisfies some regularity properties
Government’s problem:

\[ V(b) = \max_{\{c, \pi\} \in A} \left\{ \int_0^\infty e^{-\rho t} (u(c_t) - \psi_0 \pi_t)) \, dt \right\} \]

subject to:

\[ b_t \text{ solves } \dot{b}_t = c_t + (r(b_t) - \pi_t)b_t - y \text{ with } b_0 = b, \]

\[ b_t \in \overline{\Omega} \text{ for all } t \]
Government’s problem:

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\[ b_t \in \Omega \text{ for all } t \]

- Note: problem as if under commitment (choose full path of \( c, \pi \) at time 0)
  - \( r(b) \) is a primitive of the planning problem
\[ \rho V(b) = \max_{c, \pi \in [0, \bar{\pi}]} \left\{ u(c) - \psi_0 \pi + V'(b) \left( c + (r(b) - \pi) b - y \right) \right\} \]

- **Complications**
  - \( V(b) \) not differentiable at all \( b \)
  - \( r(b) \) not continuous at all \( b \)

- Use viscosity solution concept: Value function is the unique, bounded, continuous viscosity solution to \( HJB \)
Hamilton-Jacobi-Bellman Equation

$$\rho V(b) = \max_{c, \pi \in [0, \bar{\pi}]} \left\{ u(c) - \psi_0 \pi + V'(b) \left( c + (r(b) - \pi)b - y \right) \right\}$$

First Order Conditions

$$u'(c) = -V'(b)$$

$$\pi = \begin{cases} 
0 & \text{if } \psi_0 \geq -V'(b)b = u'(c)b \\
\bar{\pi} & \text{if } \psi_0 < u'(c)b 
\end{cases}$$
Heuristic

\[ u'(c) = -V'(b) \]
\[ \rho V'(b) = V'(b) [(r - \pi) + br'(b)] + V''(b) \dot{b} \]
\[ \frac{\dot{c}}{c} = \sigma (r - \pi - \rho) + br'(b) \]
No-Crises Equilibria

Recursive Equilibria

Recursive Equilibria:

- Interest rate $r(b)$, domain set $\Omega$, value function $V(b)$ and policies $C(b)$, $\Pi(b)$ such that:
  - $V(b), C(b), \Pi(b)$ solve government’s problem
  - $r(b) = r^* + \Pi(b)$
  - $V(b) \geq V$ for all $b \in \bar{\Omega}$

- All equilibria are monotone: $r(b)$ is non-decreasing
- Characterized by threshold $b_\pi$:

\[
r(b) = \begin{cases} 
  r^*, & \text{for } b \leq b_\pi \\
  r^* + \bar{\pi}, & \text{for } b > b_\pi 
\end{cases}
\]

- $b_\pi \in [\underline{b}_\pi, \bar{b}_\pi]$
No-Crises Equilibria

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\end{cases}
\]

- \( b_\pi \in [\underline{b}_\pi, \bar{b}_\pi] \)
  - \( \bar{b}_\pi \): Max debt below which choose low inflation when face \( r^* \)
  - \( \underline{b}_\pi \): Max debt below which choose low inflation when face \( r^* + \bar{\pi} \)
No-Crises Equilibria

Constructing the equilibria

▶ Recall \( \rho = r^* \)

Stationary low inflation equilibrium

▶ \( c(b) = y - r^* b \)
▶ \( v_1(b) = \frac{u(y - r^* b)}{\rho} \)
▶ \( u'(c(b))b \leq \psi_0 \)
  ▶ need \( b_\pi \leq \bar{b}_\pi \) where \( u'(y - r^* \bar{b}_\pi)\bar{b}_\pi = \psi_0 \)
No-Crises Equilibria

Constructing the equilibria

- Recall $\rho = r^*$

Stationary low inflation equilibrium

- $c(b) = y - r^*b$
- $v_1(b) = \frac{u(y - r^*b)}{\rho}$
- $u'(c(b))b \leq \psi_0$
  - need $b_\pi \leq \bar{b}_\pi$ where $u'(y - r^*\bar{b}_\pi)\bar{b}_\pi = \psi_0$

Stationary high inflation equilibrium

- $c(b) = y - r^*b$
- $v_3(b) = \frac{u(y - r^*b) - \psi_0\bar{\pi}}{\rho}$
- $u'(c(b))b > \psi_0$
Construction of Value Function

\[ V(b) \]

\[ V_1 \]

\[ b_\pi \]

\[ V_3 \]
\( v_1 \) and \( v_3 \) satisfy \( HJB \) locally, but together are not continuous
- $v_1$ and $v_3$ satisfy HJB locally, but together are not continuous
- HJB at $b_\pi$:
  - From the left: $\rho v_1(b_\pi) = u(y - r^* b_\pi)$
  - From the right: $c_\pi \in (0, y - r^* b_\pi)$ that solves
    \[
    \rho v_1(b_\pi) = u(c_\pi) - \psi_0 \bar{\pi} - u'(c_\pi)(c_\pi + r^* b_\pi - y)
    \]
\( \nu_1 \) and \( \nu_3 \) satisfy \( HJB \) locally, but together are not continuous.

**HJB at \( b_\pi \):**
- From the left: \( \rho \nu_1(b_\pi) = u(y - r^*b_\pi) \)
- From the right: \( c_\pi \in (0, y - r^*b_\pi) \) that solves
  \[
  \rho \nu_1(b_\pi) = u(c_\pi) - \psi_0 \bar{\pi} - u'(c_\pi)(c_\pi + r^*b_\pi - y)
  \]

In neighborhood above \( b_\pi \), optimal to save \( (c_\pi < y - r^*b_\pi) \) to obtain inflation credibility.

As \( \rho = r^* \), no need to vary consumption while saving: \( C(b) = c_\pi \) for \( b \) such that \( c_\pi < y - r^*b \)

From envelope condition, \( V'(b) = -u'(c_\pi) \) is constant over this range (\( V \) is linear).

Note: For \( \bar{\pi} \) to be optimal, require \( u'(c_\pi)b_\pi > \psi_0 \rightarrow b_\pi \geq b_\pi \)
Recall $v_1(b) = u(y - r^\star b)$ and $v_3(b) = u(y - r^\star b) - \psi_0 \bar{\pi}$. If $b_\pi \in [b_\pi, \bar{b}_\pi]$, then the proposed $v_1, v_2, v_3$ is a viscosity solution of the HJB with an inflation policy equal to the equilibrium conjecture. Hence, we have found an equilibrium.
No-Crises Equilibria
Putting everything together

(a) Value Function
(b) Interest Rate
(c) Consumption Policy
(d) Inflation Policy
Low-inflation Region

- Temptation to inflate provides incentive to save
- Borrowing limit greatest with commitment to low inflation (foreign currency bonds)
- As in Calvo (1988), many equilibria can be supported:
  \[ b_{\pi} \in [b_{\pi}, \bar{b}_{\pi}] \]
- Best case scenario is \( b_{\pi} = \bar{b}_{\pi} \) where
  \[ u'(y - r^*\bar{b}_{\pi})\bar{b}_{\pi} = \psi_0 \]

- As \( \psi_0 \uparrow \), the low-inflation zone increases (\( \bar{b}_{\pi} \uparrow \)) \( \Rightarrow \) the government would like to have commitment to low inflation
Low-inflation Region

- Temptation to inflate provides incentive to save
- Borrowing limit greatest with commitment to low inflation (foreign currency bonds)
- As in Calvo (1988), many equilibria can be supported: \( b_\pi \in [b_\pi, \bar{b}_\pi] \)
- Best case scenario is \( b_\pi = \bar{b}_\pi \) where

\[
    u'(y - r^* \bar{b}_\pi) \bar{b}_\pi = \psi_0
\]

- As \( \psi_0 \uparrow \), the low-inflation zone increases (\( \bar{b}_\pi \uparrow \)) \( \Rightarrow \) the government would like to have commitment to low inflation
- In what follows: focus on the best monetary outcome
Debt dynamics and inflation regime

- $\psi_0 \uparrow$
  - Gains from reaching low-inflation region increase
  - Incentive to increase savings increase
  - Reduces the low inflation region, reducing the need to save
  - Effect is ambiguous

- Government would like to commit to low inflation
Debt dynamics and inflation regime

Figure 2: The Role of Inflation Commitment Absent a Crisis: Increase in $\psi b\pi b$

(a) No Change in $b\pi$

(b) Change in $b\pi$

is not. This reflects that inflation rate is higher in this region for the low-$\psi$ economy, and savings is the method to regain commitment to a low inflation rate. As we let $\psi_0$ go to infinity, the low inflation zone covers the entire space, and savings is zero everywhere. In this limiting case, a strong commitment to low inflation is consistent with weakly higher steady state debt levels and a higher maximal debt limit.

4 Equilibria with Rollover Crises

The preceding analysis constructed equilibria in which bonds were risk free. We now consider equilibria in which investors refuse to roll over outstanding bonds, and the government defaults in equilibrium. This links the preceding analysis of nominal bonds with Cole and Kehoe (2000)'s real-bond analysis of self-fulfilling crises and allows us to explore the role of inflation credibility in the vulnerability to debt crises.

Recall that bonds mature at every instant. If investors refuse to roll over outstanding bonds, the government will be unable to repay the debt immediately. However, the government has the option to repay within the grace period $\delta$ to avoid the full punishment of default. We first characterize the sub-problem of a government that enters the default state but repays the debt within the grace period. We then characterize the government's full problem and characterize equilibria with rollover crises.
Rollover Crises

- Investors may refuse to roll-over debt
  - Government defaults in equilibrium

- Second threshold $b_\lambda$: Above this threshold government defaults if cannot roll-over.
  - “crisis zone”: $b \in (b_\lambda, b_{\text{max}}]$
  - “safe zone”: $b \in [b_{\text{min}}, b_\lambda]$

- Crisis zone: additional incentive to save so as to escape self-fulfilling debt crisis and the associated higher interest rates.

- Evaluate impact of inflation credibility on the vulnerability to debt crises
  - how $b_\lambda$ is impacted by changes in $\psi_0$. 
Rollover Crises

Grace period problem

- Suppose that the government cannot roll over its debts

Pay \( r_t B_t \) and issue \( \dot{B}_t \)

\( (B_t, r_t) \)

- Default
  - Use Grace Period \( \rightarrow W(b_t, r_t) \)
  - Never Repay \( \rightarrow V \)

- Grace period: Tractable continuous time representation
  - Feasible to repay, partly inflate
  - \( \delta \) proxies for debt maturity
Grace period problem:

Repay $b$ at nominal rate $r_0$ within $\delta$

\[ W(b, r_0) = \max \left\{ \{c, \pi\} \right\} \int_0^\delta e^{-\rho t} (u(c_t) - \psi_0 \pi_t) \, dt + e^{-\rho \delta} V(0), \]

subject to:

\[ \dot{b}_t = c_t + (r_0 - \pi_t) b_t - y \]

\[ \dot{b}_t \leq -\pi_t b_t \]

\[ b_0 = b \text{ and } b_\delta = 0. \]
Rollover Crises

Properties:

- $W(b, r_0)$ is decreasing in both arguments.
Rollover Crises

Properties:

- $W(b, r_0)$ is decreasing in both arguments.
- Given $b$ and $r_0$, $W$ is decreasing in $\psi_0$: more costly to inflate away debt when called.
Rollover Crises

Properties:

- $W(b, r_0)$ is decreasing in both arguments.
- Given $b$ and $r_0$, $W$ is decreasing in $\psi_0$: more costly to inflate away debt when called.
- If $W(b, r_0) < V$, government will default if it cannot roll over outstanding debt.

Note: $W(b, r_0) \leq V(b, r_0)$, so never utilize grace period absent a rollover crisis.
Rollover Crises

Properties:

- \( W(b, r_0) \) is decreasing in both arguments.
- Given \( b \) and \( r_0 \), \( W \) is decreasing in \( \psi_0 \): more costly to inflate away debt when called.
- If \( W(b, r_0) < \underline{V} \), government will default if it cannot roll over outstanding debt.
- Note: \( W(b, r(b)) \leq V(b; r(b)) \), so never utilize grace period absent a rollover crisis.
Rollover Crises

Properties:

- \( W(b, r_0) \) is decreasing in both arguments.
- Given \( b \) and \( r_0 \), \( W \) is decreasing in \( \psi_0 \): more costly to inflate away debt when called
- If \( W(b, r_0) < V \), government will default if it cannot roll over outstanding debt
- Note: \( W(b, r(b)) \leq V(b; r(b)) \), so never utilize grace period absent a rollover crisis

Crisis indicator

\[
I(b, r_0) = \begin{cases} 
1 & \text{if } W(b, r_0) < V \\
0 & \text{otherwise}
\end{cases}
\]
Equilibrium Selection

- Look for equilibria where roll-over crisis occurs with probability

\[ \lambda I(b, r(b)) \]

for some \( \lambda > 0 \).
Government’s Problem

\[
V(b) = \max_{\{c, \pi\} \in A} \left\{ \int_0^\infty e^{-\rho t - \lambda \int_0^t I_s ds}(u(c_t) - \psi_0 \pi_t)dt + \frac{V}{\rho} \int_0^\infty \lambda e^{-\lambda \int_0^t I_s ds} \right\}
\]

subject to:

\( b_t \) solves: \( \dot{b}_t = c_t + (r(b_t) - \pi_t)b_t - y \) with \( b_0 = b \),

\( b_t \in \overline{\Omega} \) for all \( t \).
Government’s Problem

\[(\rho + \lambda l_b)V(b) = \max_{c, \pi} \left\{ u(c) - \psi_0 \pi + V'(b) (c + (r(b) - \pi)b - y) + \lambda l_b V \right\} \].

- Inflate if \( u'(c)b > \psi_0 \). Do not inflate otherwise.

- Equilibrium condition: \( r(b) \in \{r^*, r^* + \bar{\pi}, r^* + \lambda, r^* + \bar{\pi} + \lambda\} \)
Monotone equilibria

Two thresholds $b_\pi$ and $b_\lambda$ such that:
- $\pi = 0$ for $b \leq b_\pi$ and $\pi = \bar{\pi}$ otherwise.
- $I = 0$ for $b \leq b_\lambda$ and $I = 1$ otherwise.
Rollover Crises

“Crisis” thresholds

Crisis thresholds

Define $b_\lambda$ and $\bar{b}_\lambda$:

\[ W(b_\lambda, r^* + \bar{\pi}) = V \]
\[ W(\bar{b}_\lambda, r^*) = V \]

$\Rightarrow b_\lambda \in [b_\lambda, \bar{b}_\lambda]$
Repay or Default?

$W(b, r)$

$V$

$W(b, r^*)$

$W(b, r^* + \bar{\pi})$

$b_\lambda$  $\bar{b}_\lambda$  $b$
Repay or Default?

\[ W(b, r) \]

\[ V \]

\[ W(b, r^*) \]

\[ W(b, r^* + \bar{\pi}) \]

\[ b_\lambda \quad \bar{b}_\lambda \]

As \( \psi_0 \uparrow \Rightarrow W \downarrow \Rightarrow b_\lambda, \bar{b}_\lambda \downarrow \]
Inflation thresholds

- \( \bar{b}_{\pi} \): max debt consistent with zero inflation when the government is offered an interest rate of \( r^* \).

- \( \tilde{b}_{\pi} \): max debt when there is the possibility of a crisis, \( r = r^* + \lambda \), and yet the government opts for low inflation.

- \( b_{\pi} \in [\tilde{b}_{\pi}, \bar{b}_{\pi}] \)
Inflation credibility and default region
Inflation credibility and default region

\[ r_0 \]

\[ \bar{b}_\pi \]

\[ r^* + \bar{\pi} \]

\[ r^* \]

\[ \bar{b}'_{\lambda} \quad \bar{b}'_{\lambda} \quad \bar{b}'_\pi \quad \bar{b}_\pi \]

\[ b_0 \]
Inflation credibility and default region
Inflation cutoffs are strictly increasing in $\psi_0$.

Crisis thresholds are strictly decreasing in $\psi_0$ (as long as inflation is optimal in the grace-period problem, which will be the case for low $\psi_0$.)

Define $\psi_1$ as the cost of inflation such that $\bar{b}_\pi = b_\lambda$; define $\psi_2$ as the cost of inflation such that $\bar{b}_\pi = \bar{b}_\lambda$; and define $\psi_3$ as the cost of inflation such that $\tilde{b}_\pi = \bar{b}_\lambda$.

$\psi_1 < \psi_2 < \psi_3$. 
Inflation cutoffs are strictly increasing in $\psi_0$. 

Crisis thresholds are strictly decreasing in $\psi_0$ (as long as inflation is optimal in the grace-period problem, which will be the case for low $\psi_0$.)

Define $\psi_1$ as the cost of inflation such that $\bar{b}_\pi = b_\lambda$; define $\psi_2$ as the cost of inflation such that $\bar{b}_\pi = \bar{b}_\lambda$; and define $\psi_3$ as the cost of inflation such that $\tilde{b}_\pi = \bar{b}_\lambda$.

$\psi_1 < \psi_2 < \psi_3$. 
Thresholds as Functions of $\psi_0$
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Thresholds as Functions of $\psi_0$

![Diagram showing thresholds as functions of $\psi_0$. The graph has axes labeled $b_\lambda$ and $\psi_0$, with thresholds $b_\pi$, $\tilde{b}_\pi$, $\bar{b}_\lambda$, and $\bar{b}_\pi$ indicated. There is a note for Low $\psi_0$ and $\psi_1$.]}
Thresholds as Functions of $\psi_0$

\[ b_\lambda \quad \bar{b}_\pi \quad \tilde{b}_\pi \quad \bar{b}_\lambda \]

0 \quad \psi_1 \quad \psi_2 \quad \psi_0
Comparative Statics

\[ b_\lambda \]

\[ \bar{b}_\pi \]

\[ \tilde{b}_\pi \]

\[ b_\lambda \]

\[ 0 \]

\[ \psi_1 \]

\[ \psi_2 \]

\[ \psi_0 \]
Case 1: Low Inflation Cost

(a) Value Function

(b) Interest Rate

(c) Consumption Policy

(d) Inflation Policy
Thresholds as a Function of Inflation Commitment

Figure 4: Thresholds as a Function of Inflation Commitment

- $\bar{b}_\lambda$
- $\tilde{b}_\pi$
- $b_\lambda$
- $\psi^*$

(a) $b$ as a Function of $\psi_0$

(b) $b_\pi$ as a Function of $\psi_0$
Thresholds as a Function of Inflation Commitment
Welfare and borrowing limits

- Domestic currency debt (black line) vs. Foreign currency (blue line)
- Weak commitment (left) vs. Intermediate commitment (right)
Conclusion

Inflation Commitment

\( \psi_0 = \infty \): foreign currency debt or monetary union

- Weak inflation credibility (low \( \psi_0 \)), with domestic currency debt:
  - Crisis zone is larger
  - Inflation is higher
  - Conventional wisdom fails
Conclusion
Inflation Commitment

\[ \psi_0 = \infty: \text{foreign currency debt or monetary union} \]

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- Weak inflation credibility (low \( \psi_0 \)), with domestic currency debt:
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- Intermediate inflation credibility, with domestic currency debt
  - Crisis zone is smaller
  - Can credibly deliver low inflation
  - ... and inflate in a crisis
Currently working

- Multiple countries + one monetary authority
  - Fiscal externality
  - Heterogeneous debt levels and exposure to crisis