International Reserve Management under Rollover Crises

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The views expressed herein are those of the authors and not necessarily those of the Federal Reserve Bank of Minneapolis or the Federal Reserve System.

Motivation

To reduce the vulnerability to a debt crisis:

- Should the government reduce the debt or increase reserves?

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Answer unclear:

- Reserves provide liquidity

  ... but reducing debt may lower vulnerability more

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- Tractable model of rollover crises with long-duration bonds and reserves
  - Sunspot shocks, deterministic income
- How should the government exit the 'crisis zone'?

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- If heavily indebted, optimal to initially reduce debt and keep zero reserves
- Once debt is reduced sufficiently, optimal to increase debt and accumulate reserves

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- Once debt is reduced sufficiently, optimal to increase debt and accumulate reserves
- Borrowing to accumulate reserves can reduce spreads

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  - Reserves help avoid rolling over debt at high spreads
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- Hernandez (2019): numerical simulations w/ fundamental and sunspot shocks

Cole-Kehoe (2001); Corsetti-Dedola (2016); Aguiar-Amador (2020); Bianchi-Mondragon (2022); Bianchi and Sosa-Padilla (2023); Corsetti-Maeng (2023ab)

Model

Environment

- Discrete time, infinite horizon. Constant endowment: $y_t = y$
- Government trades two assets ...
  - short-term risk-free reserves, a
  - long-term defaultable debt, b

    a bond issued in t promises to pay

$$\kappa \left[1,\, (1-\delta),\, (1-\delta)^2,\, ...\right]$$

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  - Discount future flows at rate r, assume $\beta(1+r) = 1$

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- Risk-neutral deep pocket international investors:
  - Discount future flows at rate r, assume $\beta(1+r) = 1$
- Markov equilibrium w/ Cole-Kehoe (2000) timing:
  - Borrowing at the beginning of the period
  - Settlement (repay/default) at the end

Preferences and resource constraint

- Preferences:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t [u(c_t) - \phi d_t]$$

where $d_t = 0$ (1) denotes repayment (default)

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- If the government repays:

$$c_t = \underbrace{y + a_t - \kappa b_t}_{\text{resources avail.}} - \underbrace{\frac{a_{t+1}}{1+r}}_{\text{reserve purchases}} + \underbrace{q_t \left[b_{t+1} - (1-\delta) b_t\right]}_{\text{debt issuance}}$$

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- If the government defaults:

$$c_t = y + a_t - \frac{a_{t+1}}{1+r} \qquad \text{Gov. saves on bond payments}$$

and faces permanent exclusion and utility loss ϕ

Recursive Government Problem

- State is $s \equiv (a, b, \zeta)$

  ζ denotes an iid sunspot that coordinates the lenders

- The government chooses to repay or default

$$V(a, b, \zeta) = \max\{V_R(a, b, \zeta), V_D(a)\}$$

If indifferent, assume repay

Value of Default

$$V_D(a) = \max_{a' \geq 0} \left\{ u(c) - \phi + \beta V_D(a') \right\}$$

subject to

$$c \leq y + a - \frac{a'}{1+r}$$

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subject to

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- Given $\beta(1+r) = 1$, we have constant consumption

$$V_D(a) = \frac{u(y + (1-\beta)a) - \phi}{1-\beta}$$

Value of Repayment

Two cases, depending on whether the investors want to rollover the debt

If investors **want** to rollover:

$$V_R^{+}(a,b) = \max_{a' \geq 0, b'} \left\{ u(c) + \beta \mathbb{E} V(a', b', s') \right\}$$

subject to

$$c = y + a - \frac{a'}{1+r} - \kappa b + q(a', b') \left(b' - (1-\delta) b \right)$$

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Bond price depends on the portfolio and reflects default prob:

$$q(a', b') = \frac{1}{1+r} \mathbb{E} \left[\left(1 - d(s')\right) \left(\kappa + (1-\delta) q(a'', b'', s') \right) \right]$$

Value of Repayment

Two cases, depending on whether the investors want to rollover the debt

If investors **don't want** to rollover:

$$V_R^{-}(a, b) = \max_{a' \geq 0} \left\{ u(c) + \beta \mathbb{E} V(a', (1-\delta)b, s') \right\}$$

subject to

$$c = y + a - \frac{a'}{1+r} - \kappa b + \cancelto{0}{q(a', b') \left(b' - (1-\delta)b\right)}$$

To pay debt, need to use reserves or cut consumption

Multiplicity of Equilibria

- Coordination failure may lead to self-fulfilling crises (Cole-Kehoe)

- If lenders expect...

  ... repayment, then they rollover, and the govt repays

  ... default, then they don't rollover, and the govt defaults

Characterization

Default thresholds

For a given level of reserves, two thresholds

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Safe | Default

$b^{-}(a)$ | $b^{+}(a)$ | $Debt(b)$

$V_R^{-}(a, b) \geq V^D(a)$

$V^D(a) > V_R^{+}(a, b)$

Default thresholds

For a given level of reserves, two thresholds

Safe | **Crisis** | Default

$b^{-}(a)$ $\qquad$ $b^{+}(a)$ $\qquad$ $Debt(b)$

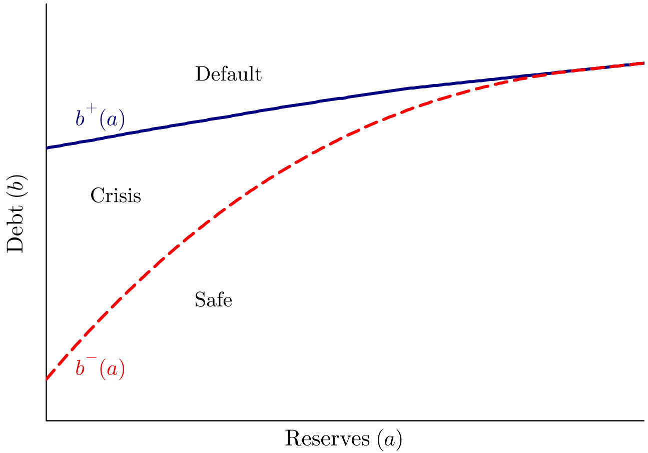
$$V_R^{-}(a, b) < V^D(a) \leq V_R^{+}(a, b)$$

Default thresholds

For a given level of reserves, two thresholds

Sunspot: assume government faces a run w/ prob π when initial portfolio (a, b) is in the crisis zone

The Three Zones



Given debt: higher reserves lower vulnerability

Escaping the Crisis Zone

How to Exit the Crisis Zone?

Remaining in the crisis zone is risky:

- in case of a run, the gov't defaults

But exiting is also costly:

- requires cutting consumption and improving NFA

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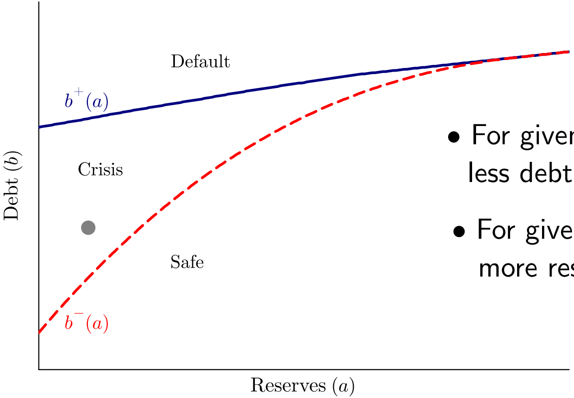
But exiting is also costly:

- requires cutting consumption and improving NFA

What's the best exit strategy for a country that is in the crisis zone (but didn't face a run today) ?

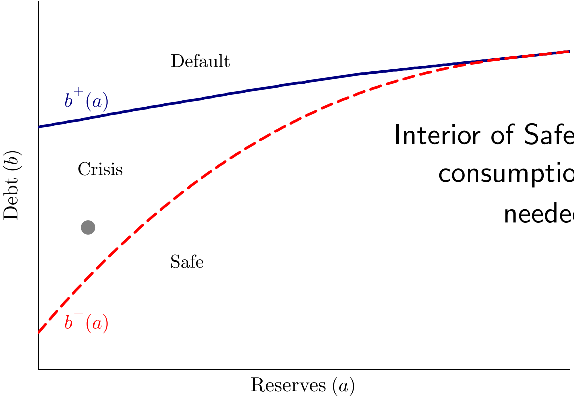
- Accumulate reserves ($a \uparrow$) or reduce debt ($b \downarrow$)?

Possible Exit Paths



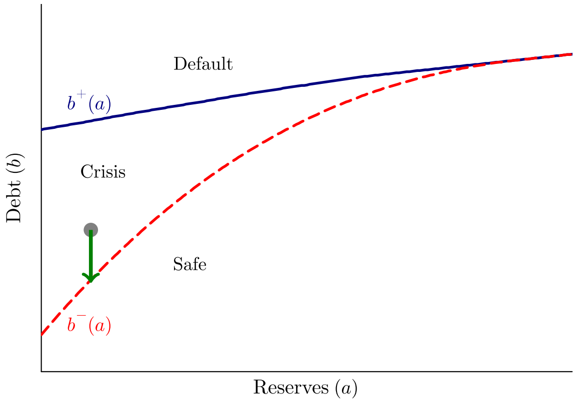
- For given reserves level: less debt lowers vulnerability
- For given debt level: more reserves lower vulnerability

Possible Exit Paths



Interior of Safe zone isn't optimal:
consumption cut larger than
needed to be safe

Possible Exit Paths



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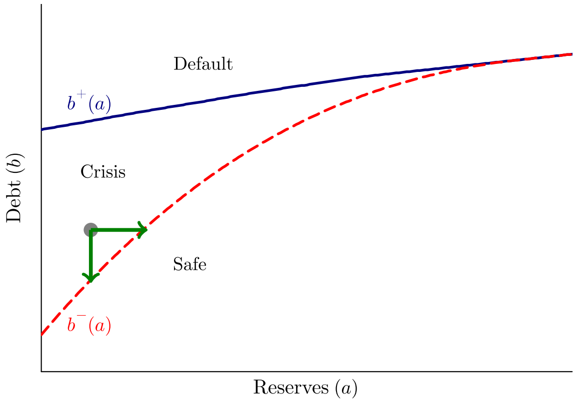

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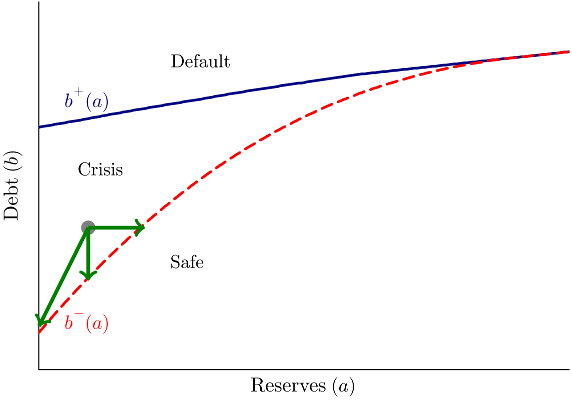

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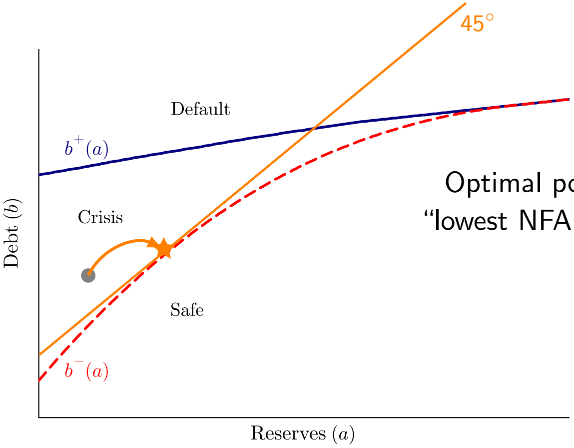
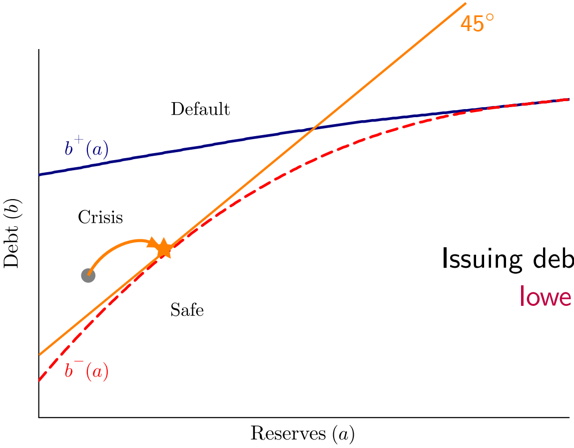


Optimal portfolio is the
"lowest NFA safe portfolio"

Possible Exit Paths



Issuing debt to buy reserves
lowers spreads!

Why do reserves help exit the crisis zone?

Getting to the safe zone requires $V_R^-(a, b) \geq V_D(a)$

- More reserves help sustain higher gross debt & net debt

  ... even though reserves increase default value $V_D(a)$.

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Intuition:

- Only a fraction κ of debt is due every period
- Reserves are liquid and can be used in a run:

$$c = y + \underbrace{a - \kappa b}_{\text{more resources}} - \frac{a'}{1+r}$$

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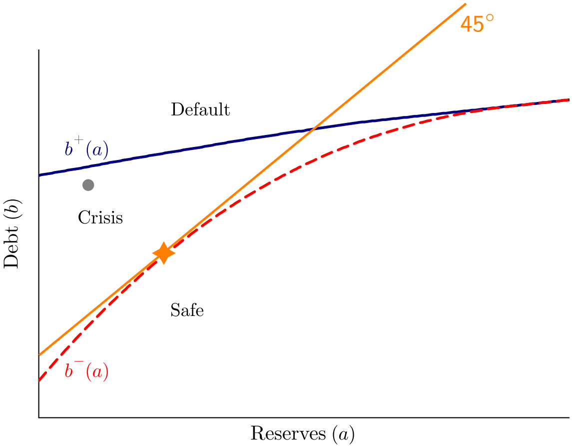
- Reserves also make default more attractive, but have lower marginal value:

$$c_D = y + a - \frac{a'}{1+r}$$

Deep in the Crisis Zone

Country has **higher** initial debt level: what to do?

Deep in the Crisis Zone



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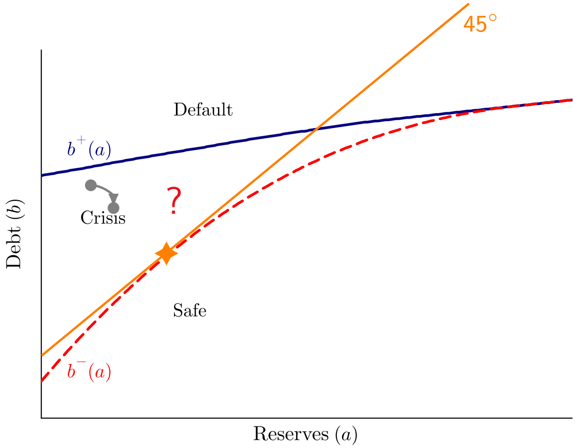

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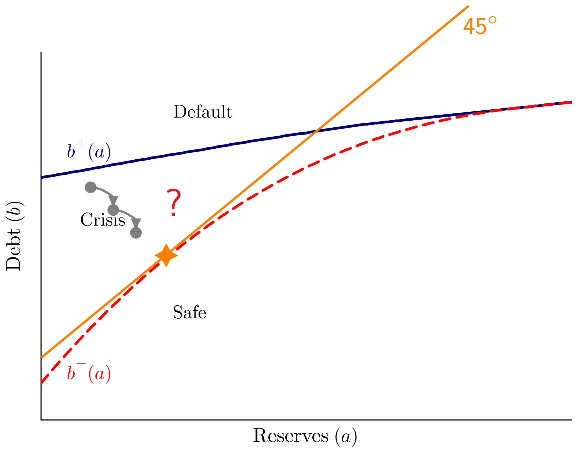

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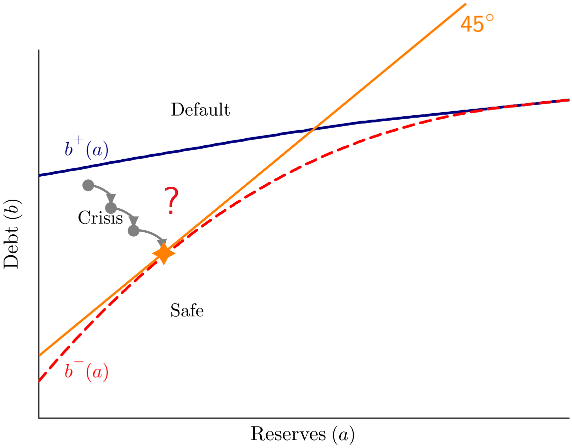

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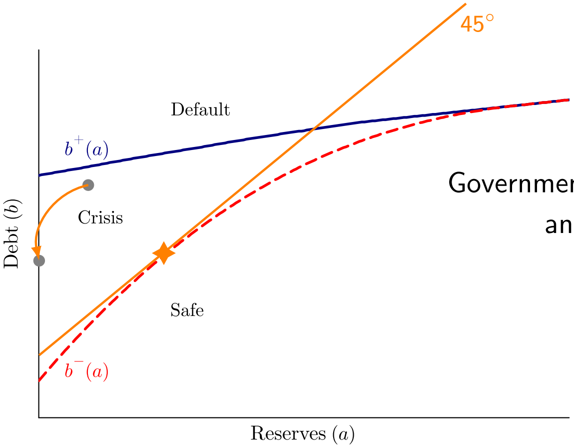
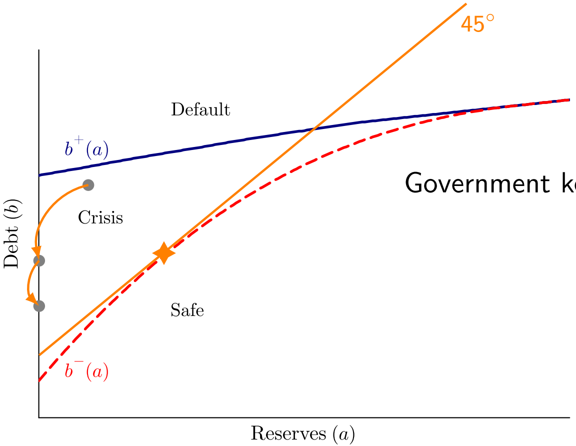


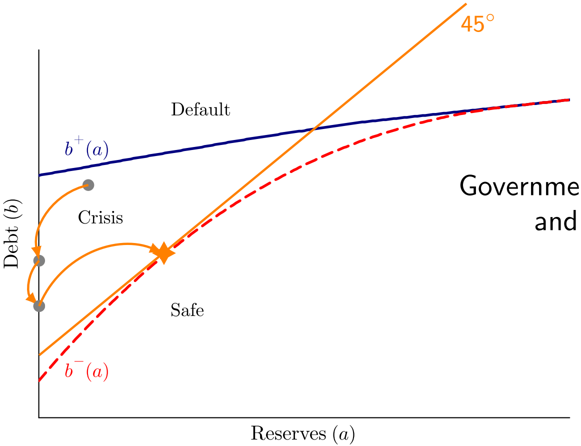
Government <u>sells</u> reserves and lowers debt

Deep in the Crisis Zone



Government keeps reducing debt

Deep in the Crisis Zone



Government issues debt
and buys reserves

Why selling reserves (initially)?

- When the government is ‘deep’ in the Crisis Zone, on the margin reserves do not change the probability of a run

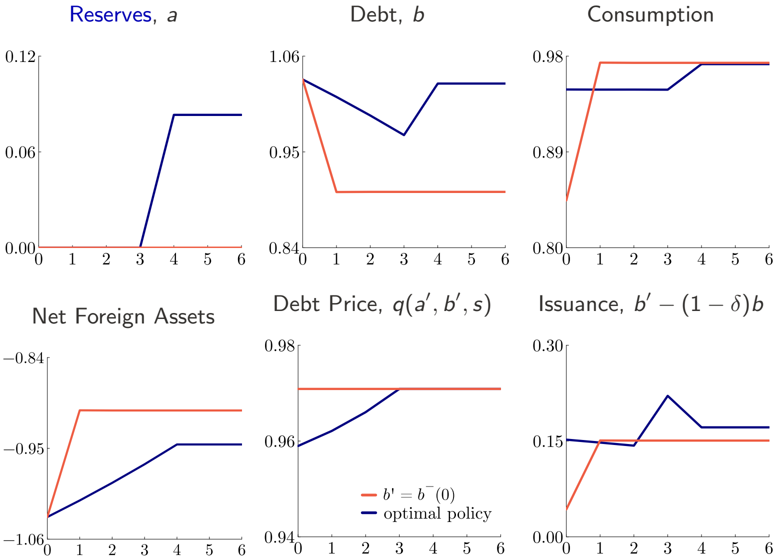
- Using the reserves to lower debt allows the govt to save on interest payments and helps deleveraging

Deleveraging Dynamics

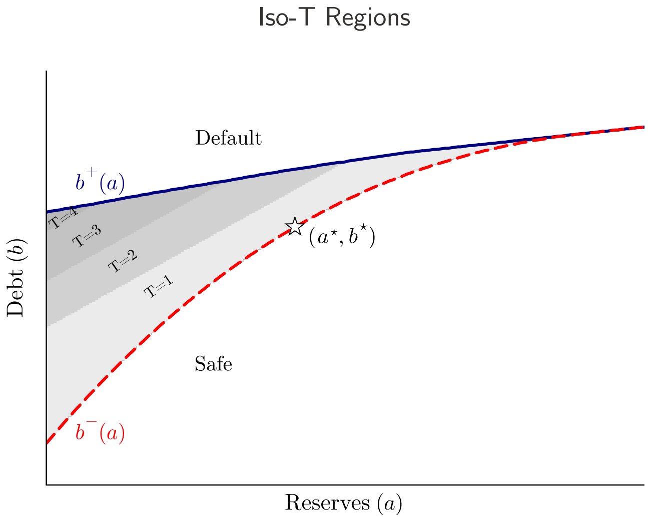
More

Deleveraging Dynamics

More



How many periods until exit?



Formalizing the Results

Formalizing the Results: (a^*, b^*) portfolio

$(a^\star, b^\star)$ is a focal point – we call it **Lowest-NFA safe portfolio**

When do we have $a^\star > 0$?

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Answer: when $\left.\frac{\partial b^-(a)}{\partial a}\right|_{a=0} > 1$

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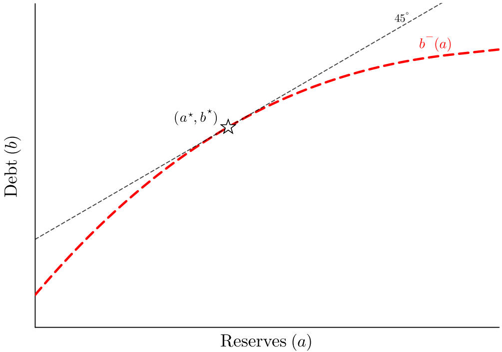

Lowest-NFA safe portfolio, $(a^\star, b^\star)$

$(a^\star, b^\star)$ is a focal point. When do we have $a^\star > 0$?

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Proposition 3 (Positive reserves)

Suppose that the boundary of the crisis region at zero reserves $b^-(0)$ satisfies

$$\beta(1-\delta)\left[u'\left(y-\kappa b^-(0)\right)-u'\left(y-(1-\beta)(1-\delta)b^-(0)\right)\right] > u'(y)$$

Then, the lowest-NFA safe portfolio has strictly positive reserves, $a^\star > 0$

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When does it fail?

1. low curvature in $u(c)$,

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1. low curvature in $u(c)$, ▸ figure
2. one-period debt ($\delta = 1$) **[Prop. 4]** ▸ sensitivity

Formalizing the Results: Optimal portfolio

To exit crisis zone, first deleverage, then raise debt and reserves

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Proposition 5 (Optimal portfolio)

Consider an initial portfolio $(a, b) \in \mathbf{C}$. The optimal portfolio satisfies:

- If (a, b) is such that $a - b < a^\star - b^\star$ and $(a', b') \in \mathbf{S}$. Then we have $T = 1$ and $a' = a^\star$, $b' = b^\star$
- If (a, b) is such that $a - b \geq a^\star - b^\star$. Then, we have $T = 1$ and any portfolio $(a', b') \in \mathbf{S}$ and $a - b = a' - b'$ is optimal.
  If $a = 0, b = b^\star - a^\star$, then $a' = a^\star, b = b^\star$.
- If (a, b) is such that $(a', b') \in \mathbf{C}$. Then, the optimal solution features $a' = 0$.

Connecting with the data

Theory predicts that borrowing to accum. reserves lowers spreads

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$$\Delta \log(\text{Spread})_{it} = \Delta\text{Reserves}_{it} + \Delta\text{Debt}_{it} + \text{Controls}_{it} + \varepsilon_{it}$$

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	Full Sample
Δ Reserves	-2.14***
	(0.74)
Δ Debt	0.46*
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Num.Obs.	4,468
R2 Adj.	0.352

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Theory also predicts **stronger** effect for low Debt or high NFA

Connecting with the data

Stronger effect in **low debt** periods ...

	Full Sample	Low Debt	High Debt
Δ Reserves	-2.14***	-3.72*	-1.23***
	(0.74)	(1.73)	(0.46)
Δ Debt	0.46*	1.24***	0.19
	(0.24)	(0.32)	(0.28)
Num.Obs.	4,468	2,559	1,909
R2 Adj.	0.352	0.424	0.263

All specs. include year dummies and additional macro controls (as in Sosa-Padilla and Sturzenegger, 2023).

Robust standard errors in parentheses. * $p<0.1$; ** $p<0.05$; *** $p<0.01$.

Connecting with the data

levels

... also stronger effect in **high NFA** periods

	Full Sample	Low NFA	High NFA
Δ Reserves	-2.14***	-1.32***	-3.27**
	(0.74)	(0.51)	(1.56)
Δ Debt	0.46*	0.34	1.19**
	(0.24)	(0.25)	(0.49)
Num.Obs.	4,468	2, 226	2,242
R2 Adj.	0.352	0. 282	0.416

All specs. include year dummies and additional macro controls (as in Sosa-Padilla and Sturzenegger, 2023).

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Conclusions

- Simple theory of optimal res. management w/ rollover crises
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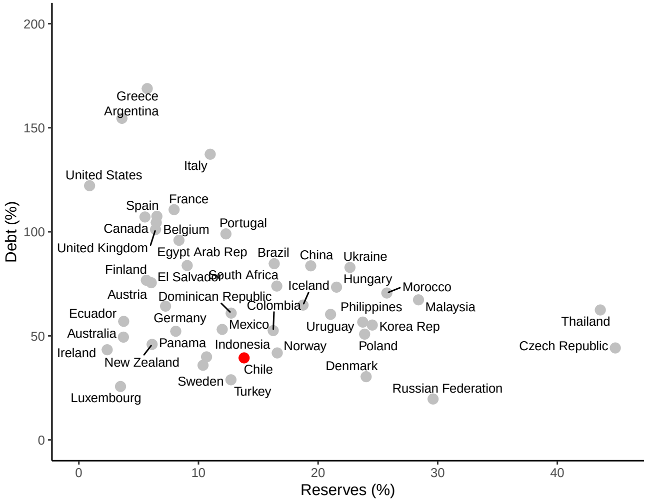
  - Not using them doesn't mean they're unnecessary
- Issuing debt to accumulate reserves can reduce spreads
- Findings speak to policy discussions on appropriate level of FX reserves (e.g. IMF)
  - Following a debt crisis, IMF often prescribes increasing reserves
  - However, we find holding reserves <u>not optimal</u> at beginning of deleveraging process

Scan to find the paper!

THANKS!

Data: Government Debt and International Reserves

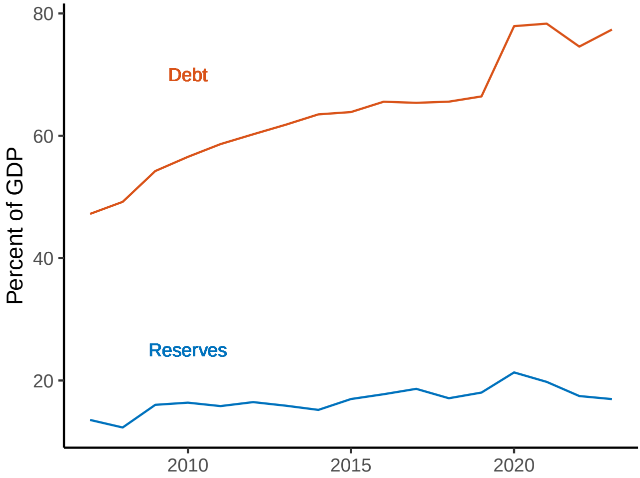
back



Government debt and reserves (as % of GDP), 2023

Evolution of Debt and Reserves

▸ back



Avg. Government debt and reserves (as % of GDP)

Characterization: Value in the Safe zone

back

- If $(a, b) \in \mathbf{S}$: we assume gov. stays in safe zone

$$V^S(a-b) = \frac{u(y + (1-\beta)(a-b))}{1-\beta}$$

- **Note:** relevant state variable is the NFA, $a - b$

For a high enough δ: can establish that gov. finds it optimal to stay in $\mathbf{S}$

Characterization: Crisis zone

back

- If $(a, b) \in \mathbf{C}$, govt. seeks to exit in finite time (may default along the way if bad sunspot hits)
  - Staying in the crisis zone implies eventually costly default
  - Speed of exit depends on curvature of $u(\cdot)$ and probability of bad sunspot

Continuation value:

$$\mathbb{E}V(a', b', \zeta') = \begin{cases} V^S(a' - b') & \text{if } (a', b') \in \mathbf{S} \\ (1-\lambda)V_R^+(a', b') + \lambda V_D(a') & \text{if } (a', b') \in \mathbf{C} \\ V_D(a') & \text{if } (a', b') \in \mathbf{D} \end{cases}$$

Characterization: Fundamental Bond Price

▸ back

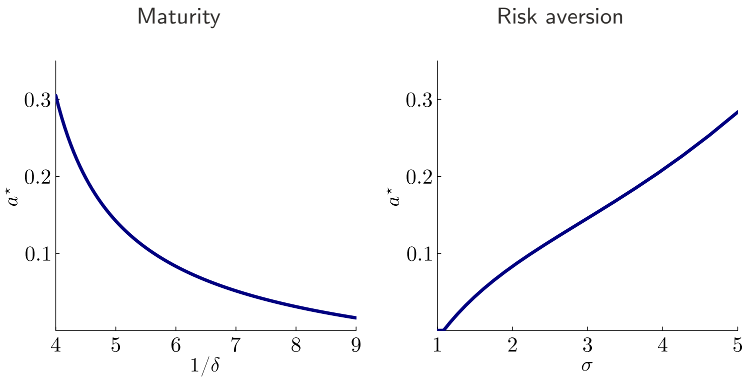
We have that for any $T > 0$ the bond price is given by

$$q(a', b') = \frac{\delta + r}{1 + r} \sum_{t=1}^{T-1} \left(\frac{1 - \lambda}{1 + r}\right)^t (1-\delta)^{t-1} + \left[\frac{(1 - \lambda)(1 - \delta)}{1 + r}\right]^{T-1} \frac{1}{1 + r}$$

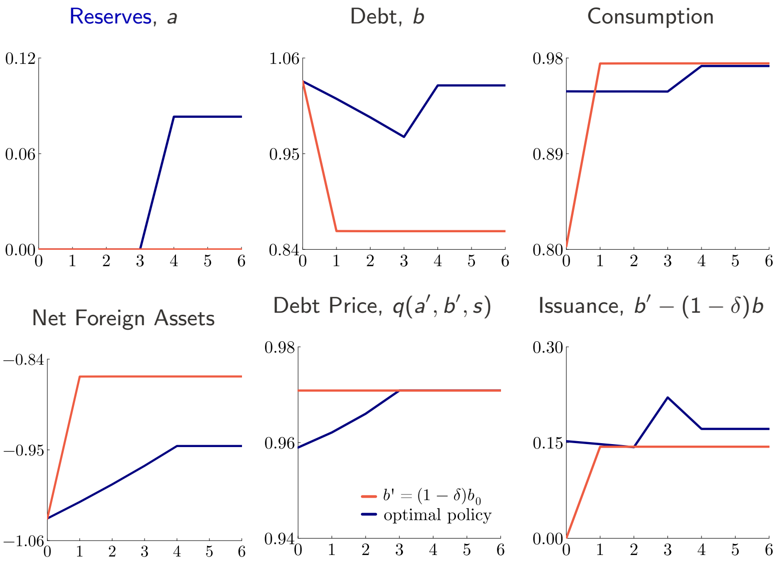
- First term: bond coupon payments investors expect to receive
- Second term: risk-free price of the bond once the government exits the crisis zone

Sensitivity: effect of maturity and risk-aversion on $a^\star$

▸ back



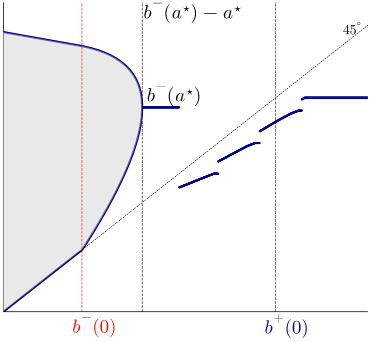
Deleveraging Dynamics: $b' = (1-\delta)b_0$



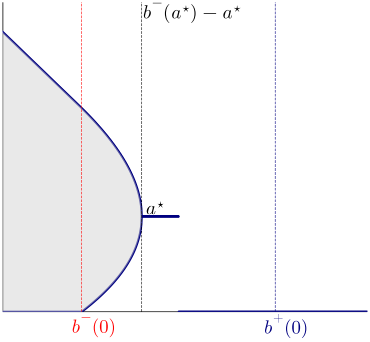
Policies

Back

Debt, b'



Reserves, a'



Policies

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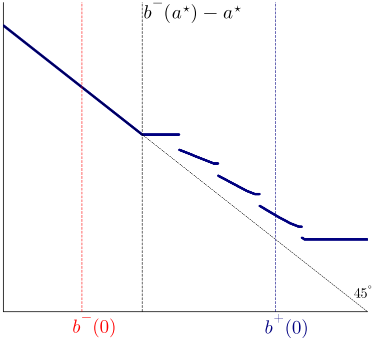
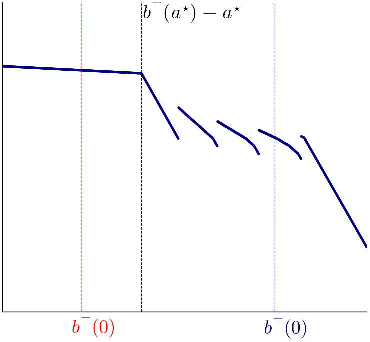
Net Foreign Assets, $a' - b'$

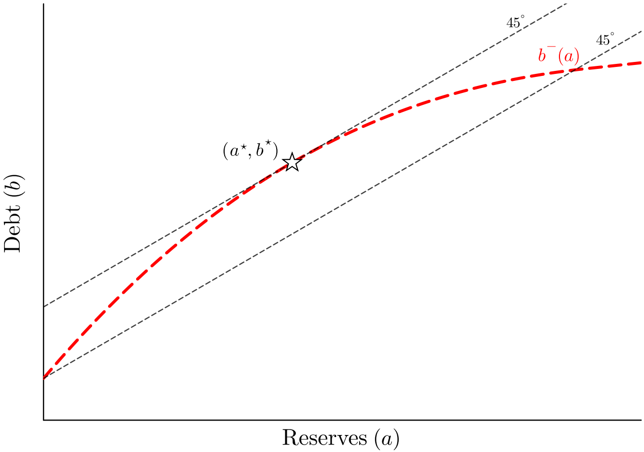


Consumption



Lowest-NFA safe portfolio, $(a^\star, b^\star)$

back



Lowest-NFA safe portfolio, $(a^\star, b^\star)$

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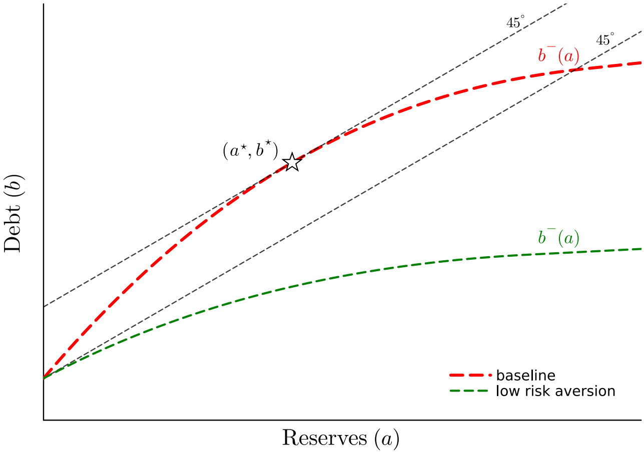

Parametrization

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$$u(c) = \frac{(c - \underline{c})^{1-\sigma}}{1-\sigma}$$

Parameter	Value	Description	Source
y	1	Endowment	Normalization
σ	2	Risk-aversion	Standard
r	3%	Risk-free rate	Standard
$1/\delta$	6	Maturity of debt	Italian Debt
$\underline{c}$	0.68	Consumption floor	Bocola-Dovis (2019)
β	0.97	Discount factor	$\beta(1+r) = 1$
λ	0.5%	Sunspot probability	Baseline
ϕ	0.33	Default Cost	Debt-to-income =100%
κ	$\frac{\delta+r}{1+r}$	Coupon	Normalization

Experiment – How reserves help exit crisis zone

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Without reserves: $\downarrow b^{+}$. More costly to deleverage $\Rightarrow$ lower debt-carrying capacity

Default zone expands

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Price Schedule, $q(0, b')$

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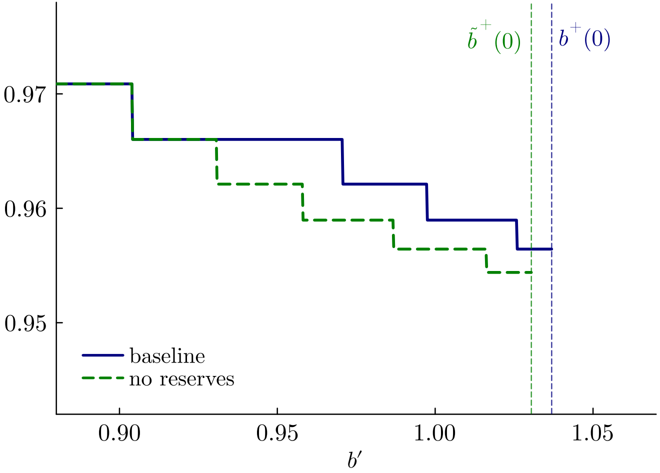

Lower consumption without reserves

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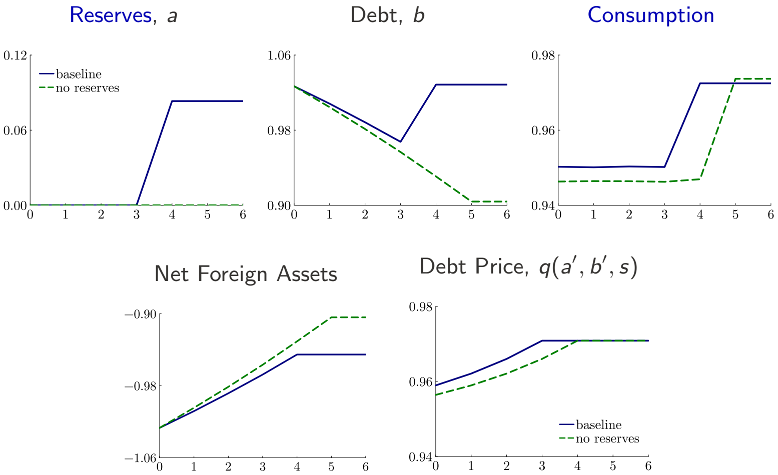
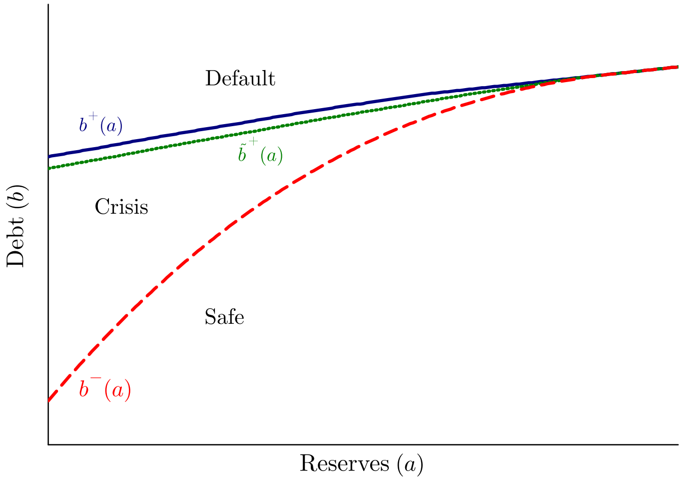


Default zone expands

▸ back



Increasing reserves and debt lowers spreads (levels)

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Dep. Variable:	log(Spread)		
	(0)	(1)	(2)
Reserves	−2.39***		
	(0.11)		
Sov.Debt	1.25***	−1.13***	1.58***
	(0.10)	(0.14)	(0.20)
NFA_public		−2.39***	−2.69 ***
		(0.11)	(0.11)
$(\text{Sov.Debt})^2$			−5.48***
			(0.31)
Num.Obs.	4497	4497	4497
R2	0.791	0.791	0.997

+ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

All specs. include country FEs, year dummies and additional macro controls (as in Sosa-Padilla and Sturzenegger, 2023).