

International Reserve Management under Rollover Crises

Mauricio Barbosa-Alves ^a Javier Bianchi ^b César Sosa-Padilla ^c

^aUniversity of Minnesota ^bMinneapolis Fed ^cUniversity of Notre Dame & NBER

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 be more effective

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 - Sunspot shocks, deterministic income
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 - **Borrowing to accumulate reserves helps exiting the crisis zone**
- **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

$$\kappa [1, (1 - \delta), (1 - \delta)^2, \dots]$$

- Risk-neutral deep pocket international investors:
 - 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

Government

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

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

- If the government repays:

$$c_t = y + a_t - \frac{a_{t+1}}{1+r} - \kappa b_t + q_t [b_{t+1} - (1-\delta)b_t]$$

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- If the government defaults:

$$c_t = y + a_t - \frac{a_{t+1}}{1+r}$$

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

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

If indifferent, assume repay

Value of Default

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

subject to

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

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- Given $\beta(1+r) = 1$, this is

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

Value of Repayment

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

subject to

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

Equilibrium Bond Price

$$q(a', b', s) = \begin{cases} \frac{1}{1+r} \mathbb{E} [(1 - d(s')) (\kappa + (1 - \delta) q(a'', b'', s'))] & \text{if } d(s) = 0 \\ 0 & \text{if } d(s) = 1 \end{cases}$$

where $a''(s')$ and $b''(s')$ are the future choice of reserves and debt

Multiplicity of Equilibria

- Coordination failure may lead to self-fulfilling crises (Cole-Kehoe)
- If lenders expect...
 - ... repayment, they lend, and the government repays
 - ... default, they don't lend, and the government defaults

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Next: incentives to default depending on initial portfolio and whether investors are willing to roll over or not

Repayment value when government can rollover

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

subject to

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

where $\tilde{q}(a', b')$ denotes fundamental bond price

Repayment Value in a Run

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

subject to

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

To pay debt, need to use reserves or cut consumption

Characterization

Safe zone, crisis zone and default zone

- Immediate: $V_R^+(a, b) \geq V_R^-(a, b)$

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$$\mathbf{S} = \{(a, b) : V_D(a) \leq V_R^-(a, b)\},$$

$$\mathbf{D} = \{(a, b) : V_D(a) > V_R^+(a, b)\},$$

$$\mathbf{C} = \{(a, b) : V_R^-(a, b) < V_D(a) \leq V_R^+(a, b)\}.$$

The Value in the Safe zone

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

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

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- **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}

The Crisis Zone

The Crisis Zone

- 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

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Continuation value:

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

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How to exit: raise a or lower b ?

The Crisis Zone (ctd)

Consider portfolio $(a, b) \in \mathbf{C}$. If government exits in $T(a, b)$ as long as $\{\zeta_t\}_{t=0}^{T-1} = 0$:

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

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Proposition 1 (Monotonically increasing consumption path)

Consider an initial portfolio $(a_0, b_0) \in \mathbf{C}$ such that the government exit time is T . Then, if $\zeta_t = 0$ for all $t \leq T-1$, we have $c_{t+1} \geq c_t$ for all $t \leq T$.

Debt Thresholds

$V_R(a, b)$ decreasing in $b \Rightarrow$ for every a , there \exists unique thresholds $b^-(a), b^+(a)$:

$$V_R^-(a, b^-(a)) = V_D(a)$$

$$V_R^+(a, b^+(a)) = V_D(a)$$

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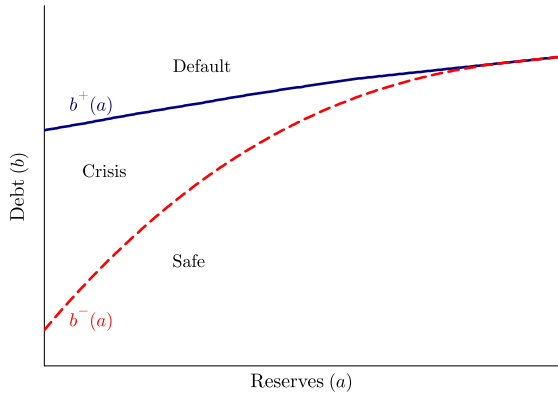
$$V_R^-(a, b^-(a)) = V_D(a)$$

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Thresholds are such that:

1. $(a, b) \in \mathbf{S}$ if and only if $b \leq b^-(a)$
2. $(a, b) \in \mathbf{C}$ if and only if $b^-(a) < b \leq b^+(a)$
3. $(a, b) \in \mathbf{D}$ if and only if $b > b^+(a)$

The Three Zones



The slopes of the two boundaries

Recall: $V_R^-(a, b^-(a)) = V_D(a)$ and $V_R^+(a, b^+(a)) = V_D(a)$

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Differentiating with respect to a

$$\frac{\partial b^-(a)}{\partial a} = \frac{\frac{\partial V_D(a)}{\partial a} - \frac{\partial V_R^-(a, b^-(a))}{\partial a}}{\frac{\partial V_R^-(a, b^-(a))}{\partial b}}$$

$$\frac{\partial b^+(a)}{\partial a} = \frac{\frac{\partial V_D(a)}{\partial a} - \frac{\partial V_R^+(a, b^+(a))}{\partial a}}{\frac{\partial V_R^+(a, b^+(a))}{\partial b}}$$

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Proposition 2 establishes: $\frac{\partial b^-(a)}{\partial a} \geq \frac{\partial b^+(a)}{\partial a} > 0$

Lowest-NFA safe portfolio

$$\begin{aligned}(a^*, b^*) &= \operatorname{argmin}_{a, b} a - b \\ \text{s.t. } & (a, b) \in \mathbf{S}\end{aligned}$$

Lowest-NFA safe portfolio

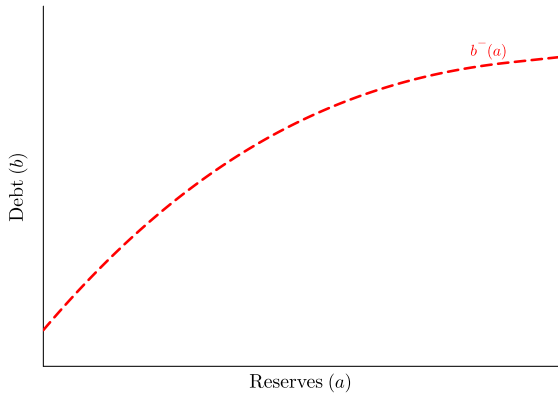
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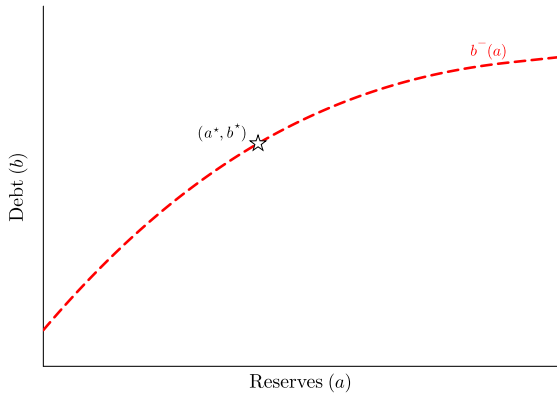
Using that $(a, b) \in \mathbf{S}$ if $b \leq b^-(a)$ and assuming a *strictly interior solution* for a^* , we obtain:

$$\frac{\partial b^-(a^*)}{\partial a} = 1$$

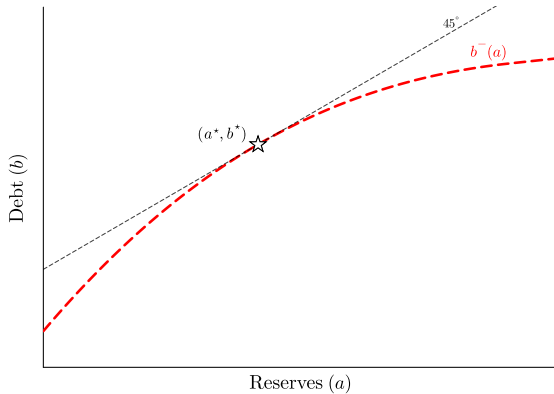
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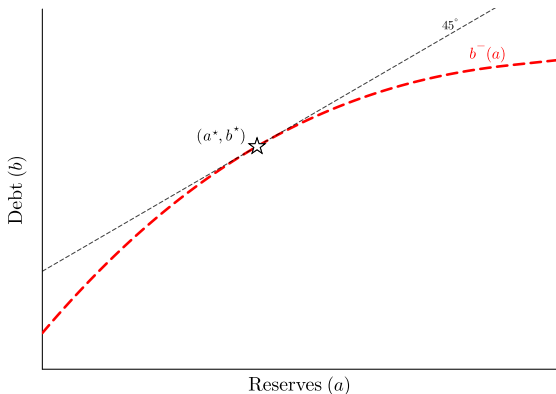
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Proposition 3 (Positive reserves)

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

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

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

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1. low risk-aversion,

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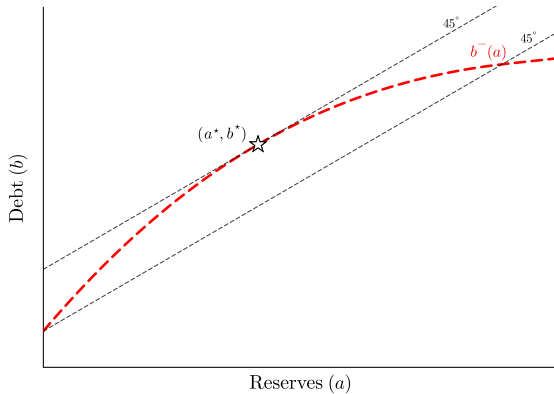
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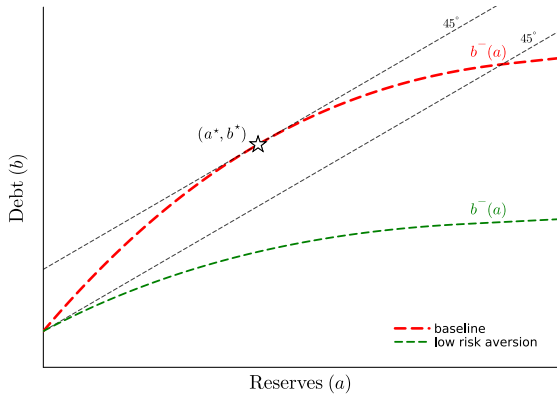
When does it fail?

1. low risk-aversion,
2. one-period debt ($\delta = 1$) [**Prop. 4**]

Lowest-NFA safe portfolio



Lowest-NFA safe portfolio



Simulations: Exiting the Crisis Zone

Parametrization

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

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

Optimal Exit Strategy

Q1: How many periods until exiting?

- Inside the Crisis Zone we can define Iso-T regions

Optimal Exit Strategy

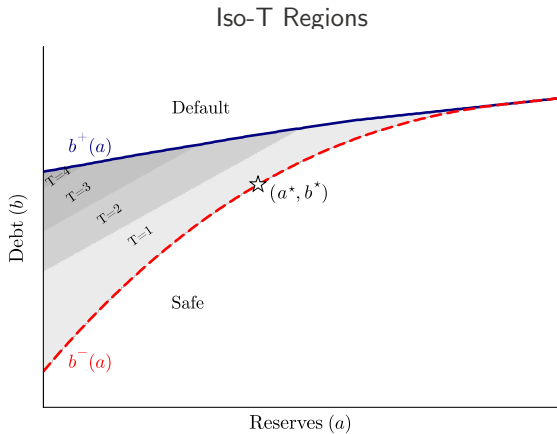
Q1: How many periods until exiting?

- Inside the Crisis Zone we can define Iso-T regions

Q2: How to manage the portfolio in the transition?

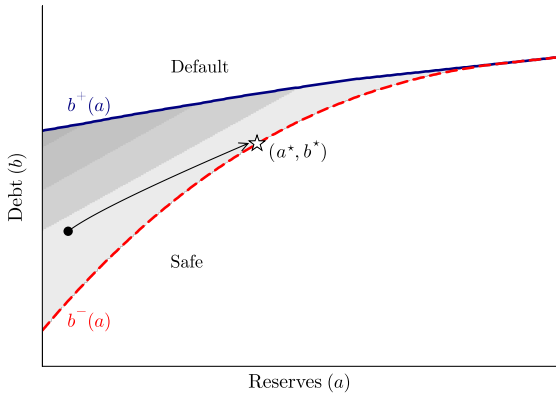
- Should the government reduce its debt or increase reserves?
- If reserves are optimal, should gov. slowly build up its stock of reserves?

How many periods until exit



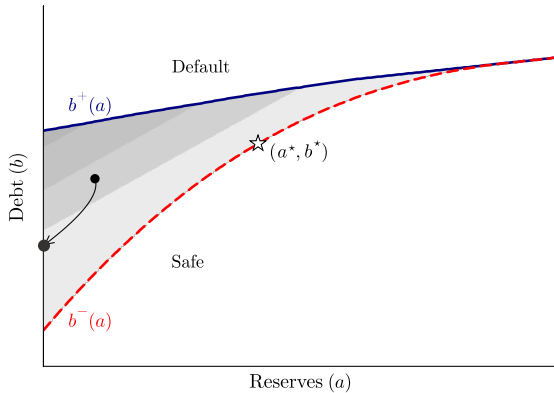
Deleveraging Path

Safety in One Period $\rightarrow (a^*, b^*)$



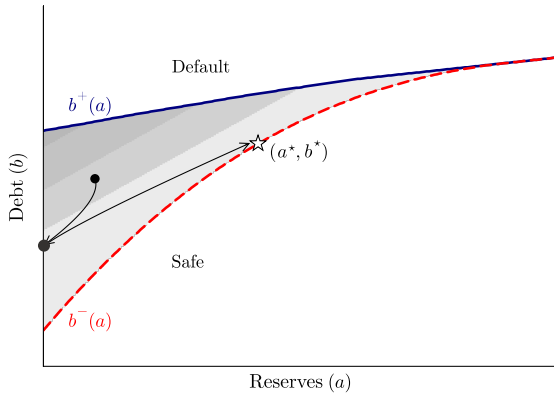
Deleveraging Path

Safety in Two Periods $\rightarrow (a^*, b^*)$



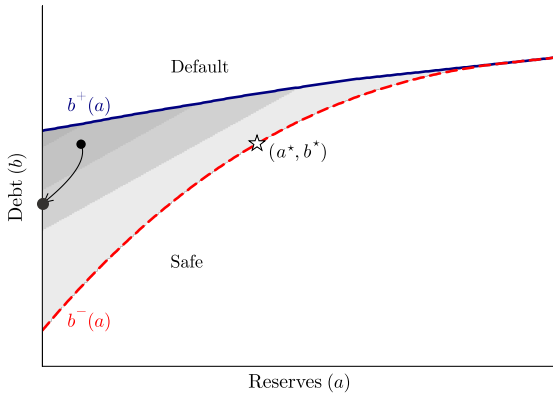
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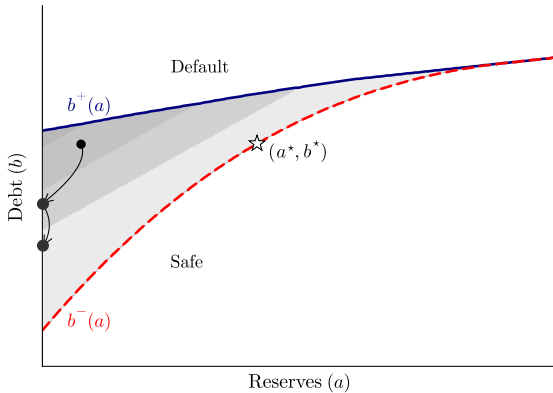
Deleveraging Path

Safety in Three Periods $\rightarrow (a^*, b^*)$



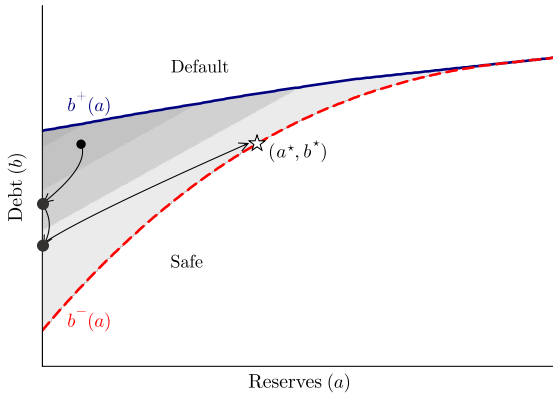
Deleveraging Path

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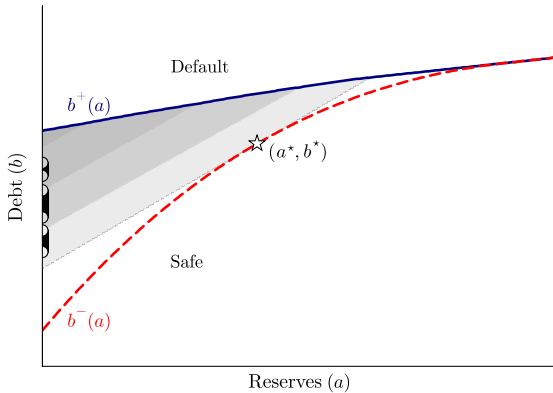
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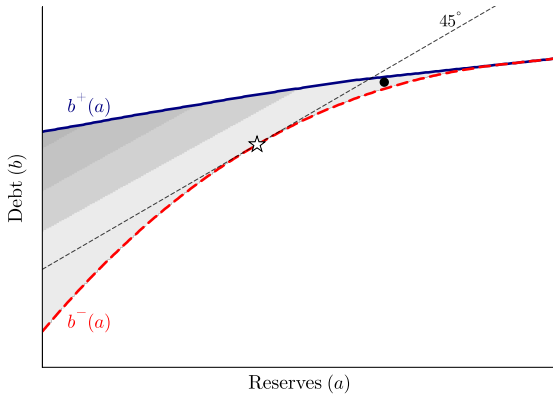
Deleveraging Path

Possible chosen portfolios for $a - b < a^* - b^*$



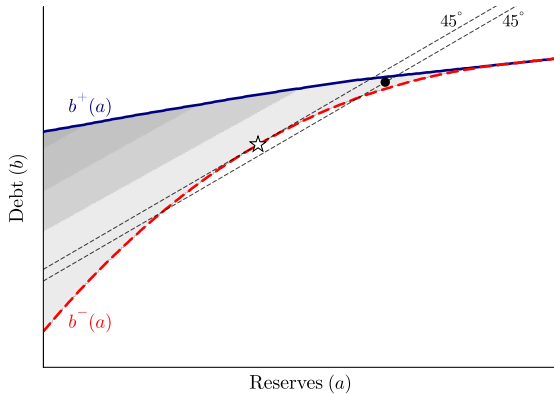
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Safety in One Period $\rightarrow (a - b > a^* - b^*)$



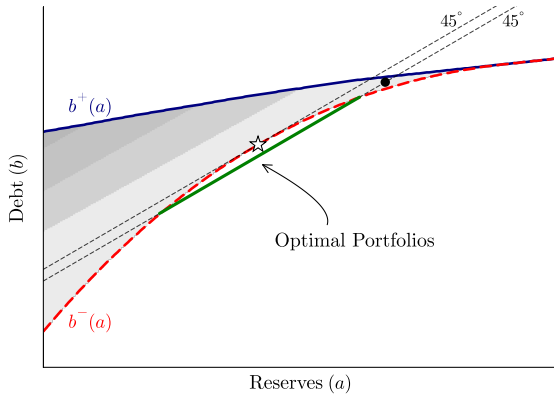
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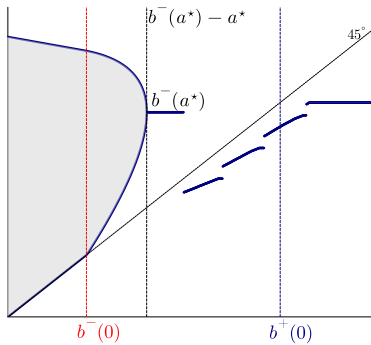
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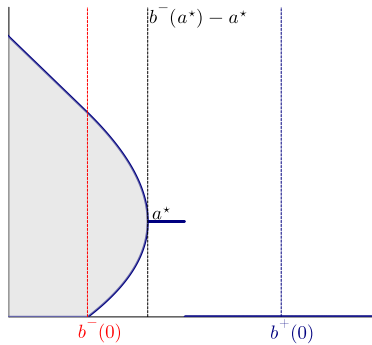


Policies

Debt, b'

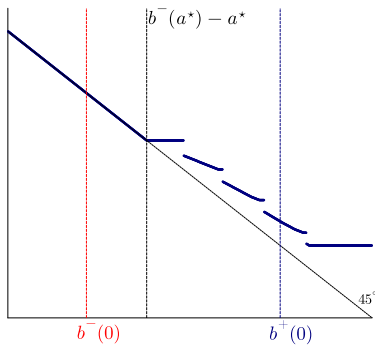


Reserves, a'

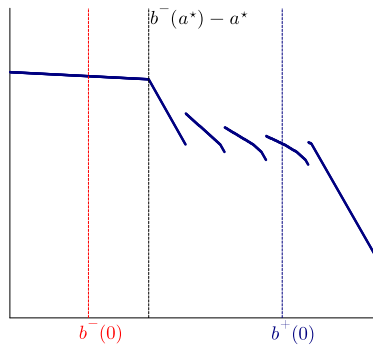


Policies

Net Foreign Assets, $a' - b'$

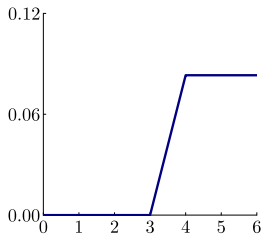


Consumption

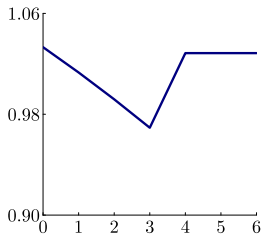


Deleveraging Dynamics

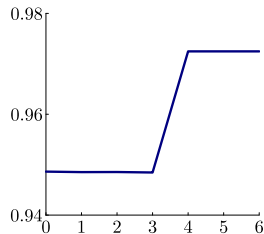
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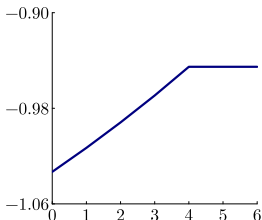
Debt, b



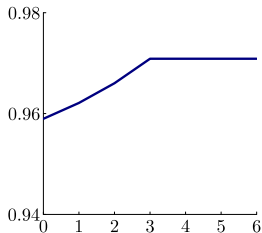
Consumption



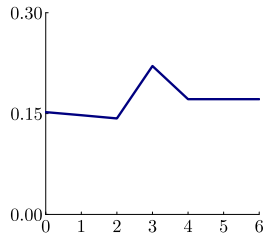
Net Foreign Assets



Debt Price, $q(a', b', s)$

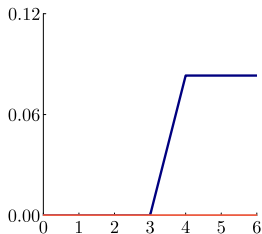


Issuance, $b' - (1 - \delta)b$

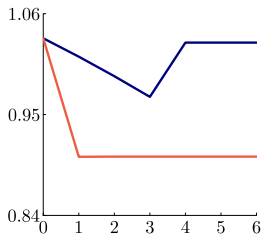


Deleveraging Dynamics

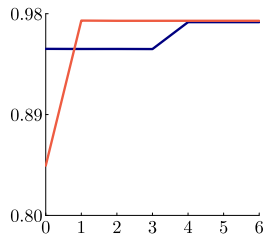
Reserves, a



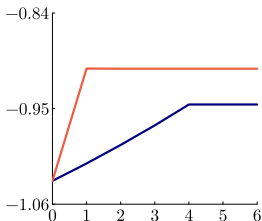
Debt, b



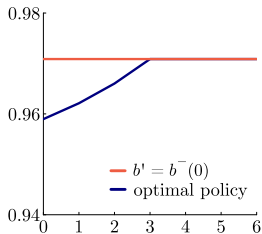
Consumption



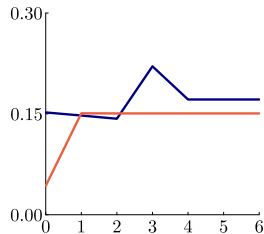
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Taking Stock

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

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- If initial portfolio (a, b) is such that $a - b < a^* - b^*$ and $(a', b') \in \mathbf{S}$. Then we have $a' = a^*, b' = b^*$
- If initial portfolio (a, b) is such that $(a', b') \in \mathbf{C}$. Then, the optimal solution features $a' = 0$.

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Remark on maturity:

- With one-period debt, $\delta = 1$: V_R^- and V_R^+ are unaffected by equal increases in debt and reserves \Rightarrow issuing debt to accumulate reserves increases spreads
 - Zero reserves are optimal

Experiment – How reserves help exit crisis zone

- Assume gov. starts w/ portfolio (a, b) , **but** from $t+1$ onward, $a' = 0$

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- Exiting takes longer to exit and cuts more consumption

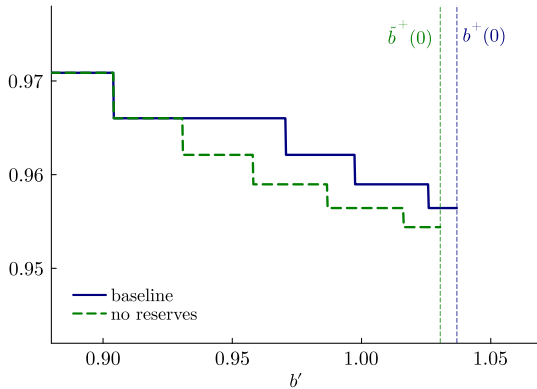
Experiment – How reserves help exit crisis zone

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

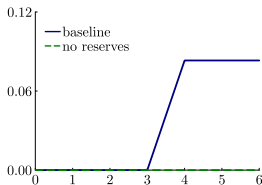
► Default zone expands

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

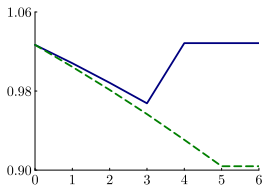


Lower consumption without reserves

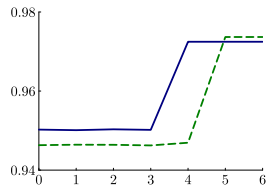
Reserves, a



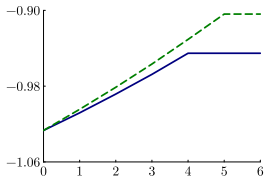
Debt, b



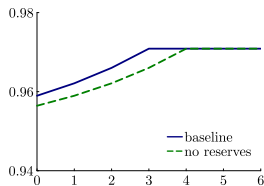
Consumption



Net Foreign Assets



Debt Price, $q(a', b', s)$



Conclusions

- Simple theory of optimal foreign reserve management under rollover risk
- Optimal to accumulate reserves to reduce vulnerability
 - However, only after debt has been reduced towards safe zone
- Issuing debt to accumulate reserves can reduce spreads

Conclusions

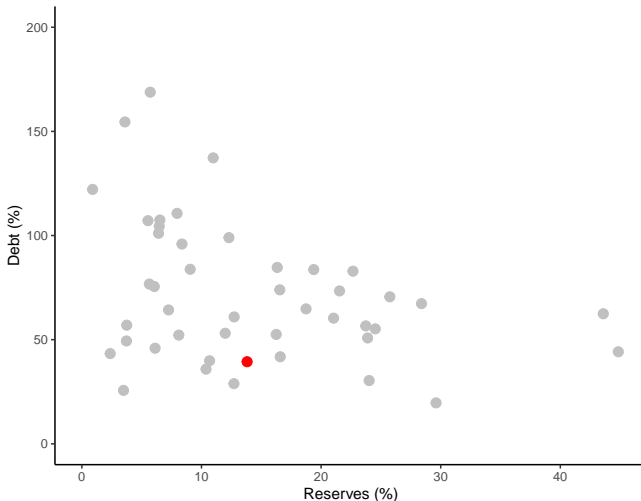
- Simple theory of optimal foreign reserve management under rollover risk
- Optimal to accumulate reserves to reduce vulnerability
 - However, only after debt has been reduced towards safe zone
- Issuing debt to accumulate reserves can reduce spreads
- Findings speak to policy discussions on appropriate level of FX reserves (e.g. IMF)
 - Following a debt crisis, IMF often prescribes increasing reserves
 - However, we find holding reserves not optimal at beginning of deleveraging process



Scan to find the paper!

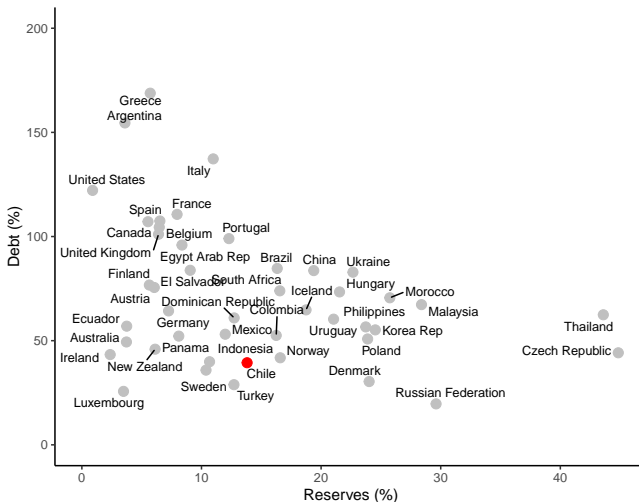
THANKS!

Data: Government Debt and International Reserves

[▶ back](#)

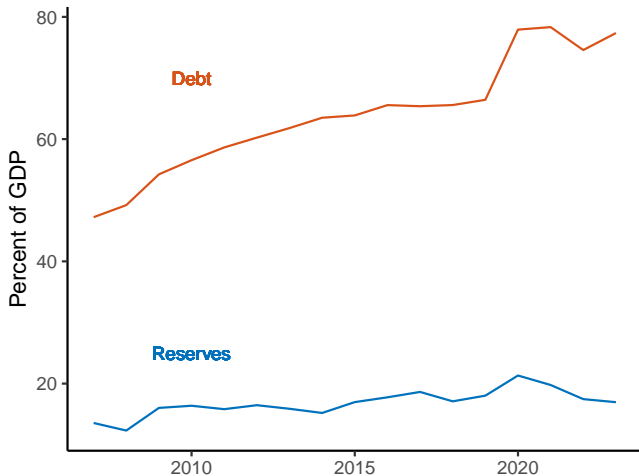
Government debt and reserves (as % of GDP), 2023

Data: Government Debt and International Reserves

[▶ back](#)

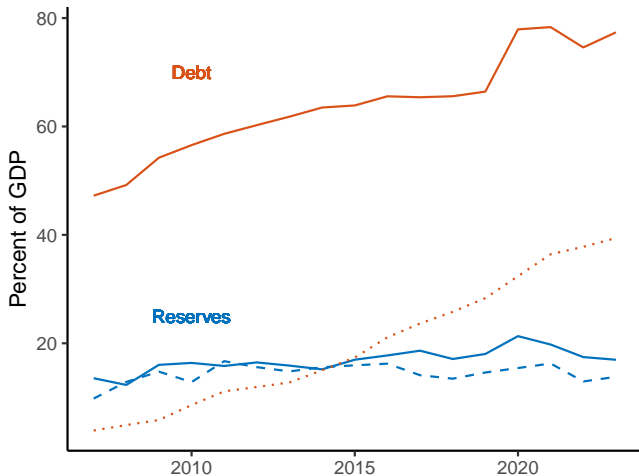
Government debt and reserves (as % of GDP), 2023

Evolution of Debt and Reserves

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

Evolution of Debt and Reserves

[▶ back](#)

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

If government not vulnerable tomorrow after repaying in a run:

$$\max_{a'} u \left(y - a - \frac{a'}{1+r} \right) + \beta V^S(a' - (1-\delta)b)$$

- **Solution:** $a'(a, b) = \max[0, a - \delta b]$.
 - With low initial reserves, government constrained
 $\Rightarrow a' = 0$

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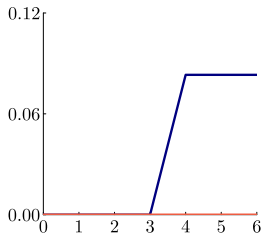
$$\max_{a'} u \left(y - \frac{a'}{1+r} \right) + \beta V^S(a' - (1-\delta)b)$$

- Solution: $a'(a, b) = \max[0, a - \delta b]$.
 - With low initial reserves, government constrained
 $\Rightarrow a' = 0$
- If $a \geq \delta b$ and $(a - \delta b, (1 - \delta)b) \in \mathcal{S}$, then
 $V_R^-(a, b) = V_R^+(a, b)$.
 - If high reserves, govt. can achieve unconstrained consumption even in a run
 - Note reserves enough to pay all coupons not needed!

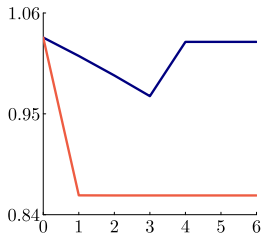
Deleveraging Dynamics: $b' = (1 - \delta)b_0$

► Back

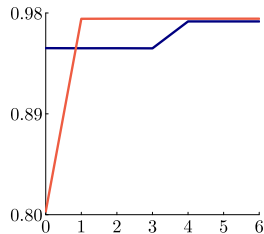
Reserves, a



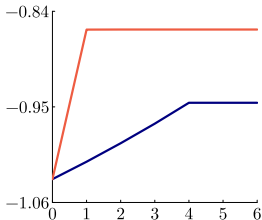
Debt, b



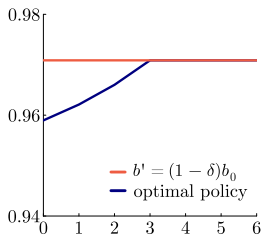
Consumption



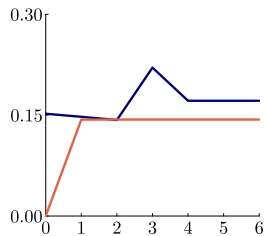
Net Foreign Assets



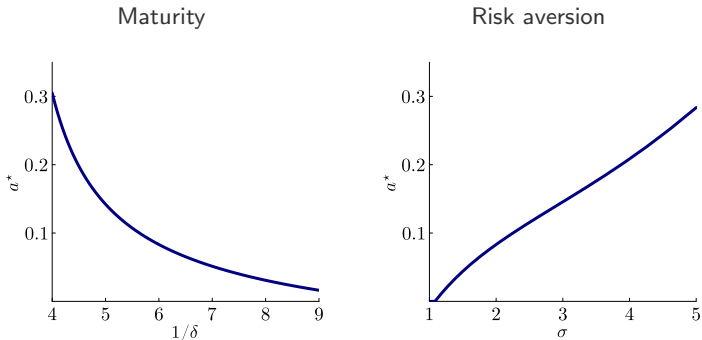
Debt Price, $q(a', b', s)$



Issuance, $b' - (1 - \delta)b$



Sensitivity: effect of maturity and risk-aversion on a^*

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Panels show the level of a^* for different values for δ and σ . The value of ϕ is recalibrated to match the same debt level $b^-(0)$ as in baseline.

Default zone expands

► back

