International Reserve Management under Rollover Crises

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

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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 $\left(\frac{\delta+r}{1+r}\right)\left[1, (1-\delta), (1-\delta)^2, ...\right]$
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  - Discount future flows at $1+r$, assume $\beta(1+r)=1$

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

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

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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

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

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

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

Value of Repayment

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

subject to

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

Equilibrium Bond Price

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

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

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

subject to

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

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

Repayment Value in a Run

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

subject to

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

To pay debt, need to use reserves or cut consumption

Characterization

Safe zone, crisis zone and default zone

- Immediate: $V_R^+(a,b) \geq V_R^-(a,b)$
- When $V_R^-(a,b) < V_D(a) \leq V_R^+(a,b)$, multiple equilibria

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$$
\begin{aligned}
\mathbf{S} &= \left\{(a,b) : V_D(a) \leq V_R^-(a,b)\right\}, \\
\mathbf{D} &= \left\{(a,b) : V_D(a) > V_R^+(a,b)\right\}, \\
\mathbf{C} &= \left\{(a,b) : V_R^-(a,b) < V_D(a) \leq V_R^+(a,b)\right\}.
\end{aligned}
$$

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, $a - b$

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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 $\{\zeta_t\}_{t=0}^{T-1}$:

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

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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 $b^-(a), b^+(a)$:

$$V_R^-\left(a, b^-(a)\right) = V_D(a)$$

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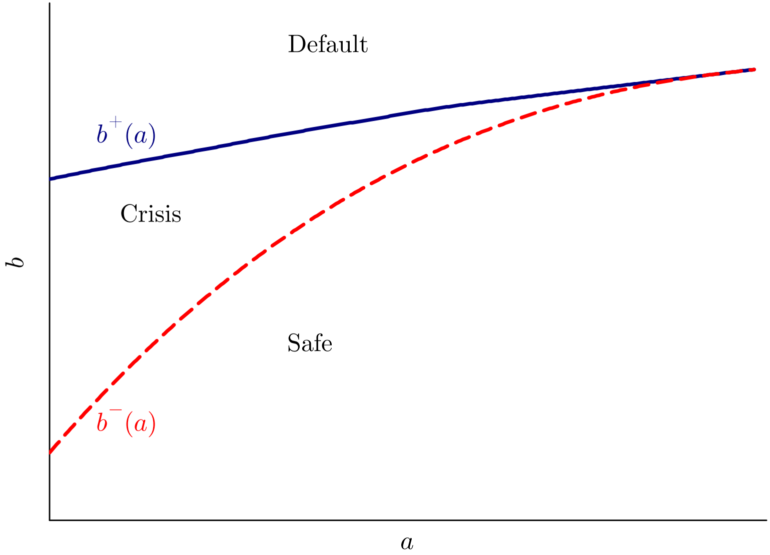
Thresholds are such that:

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 $b > b^+(a)$

Prelude

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

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

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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

$$(a^\star, b^\star) = \operatorname*{argmin}_{a,b}\, a - b$$
$$\text{s.t.} \quad (a, b) \in \mathbf{S}$$

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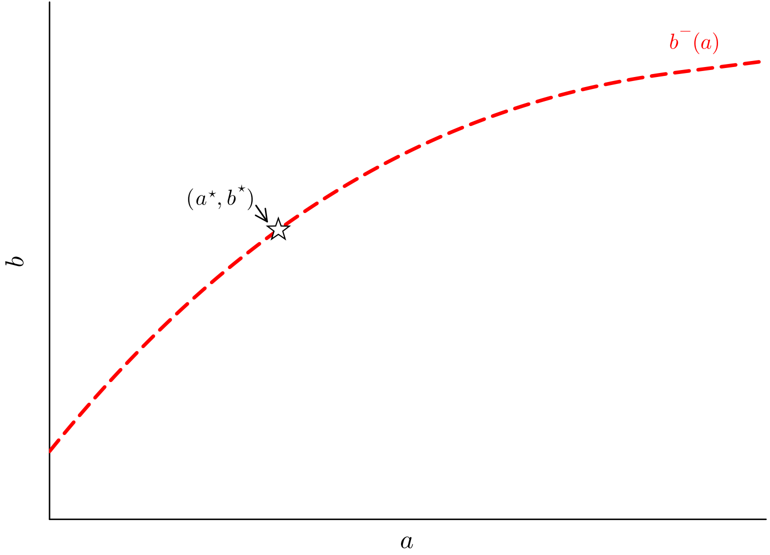
Using that $(a, b) \in \mathbf{S}$ if $b \leq b^-(a)$ and assuming a *strictly interior solution for* $a^\star$, we obtain:

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

Lowest-NFA safe portfolio



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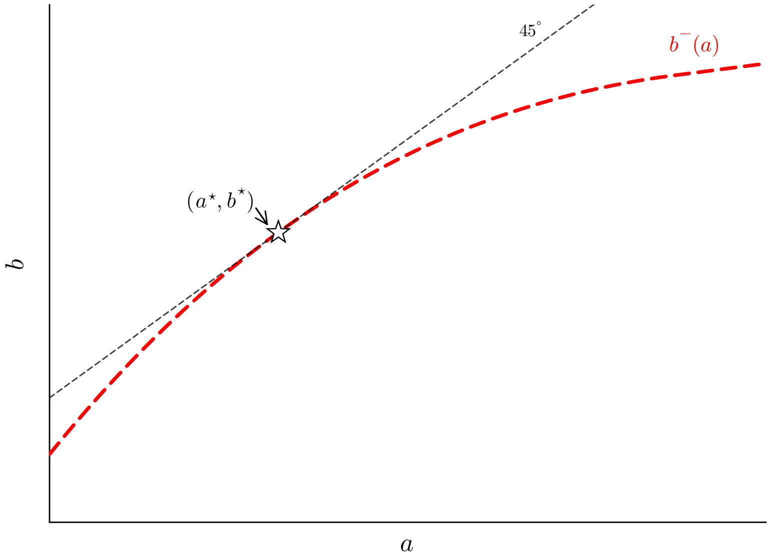

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Proposition 3 (Positive reserves)

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

$$\beta(1-\delta)\left[u'\left(y-\left(\frac{\delta+r}{1+r}\right)b^-(0)\right)-u'\left(y-(1-\beta)(1-\delta)b^-(0)\right)\right] > u'(y).$$

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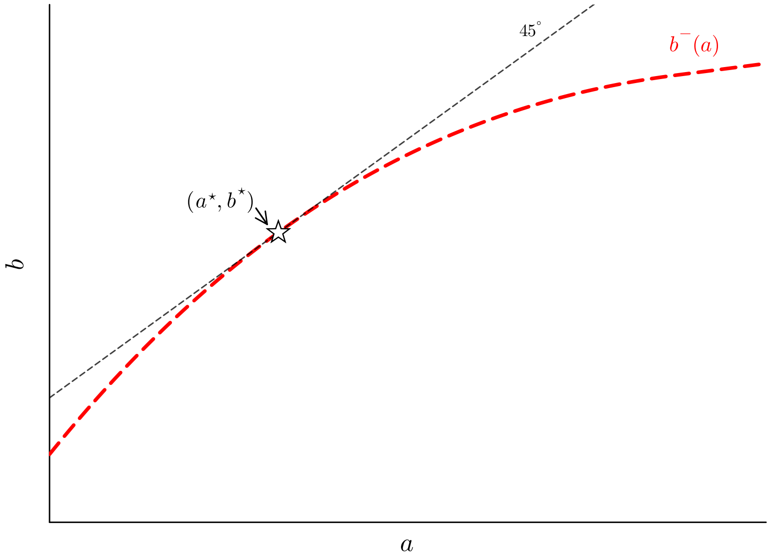
- Proposition implies $\left.\frac{\partial b^-(a)}{\partial a}\right|_{a=0} > 1$
- When does it fail? (i) low risk-aversion , (ii) one-period debt ($\delta = 1$) [**Prop. 4**]

Lowest-NFA safe portfolio



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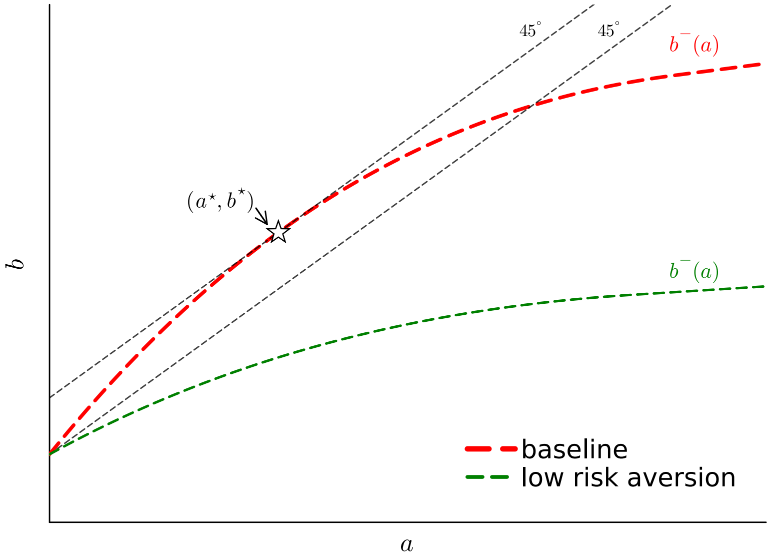


Simulations: Exiting the Crisis Zone

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
$1/\delta$	7	Maturity of debt	Italian Debt
$\underline{c}$	0.70	Consumption floor	Bocola-Dovis (2019)
β	$(1+r)^{-1}$	Discount factor	$\beta(1+r) = 1$
λ	0.5%	Sunspot probability	Baseline
ϕ	0.34	Default Cost	Debt-to-income =90%

Optimal Exit Strategy

Q1: How many periods until exiting?

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

Optimal Exit Strategy

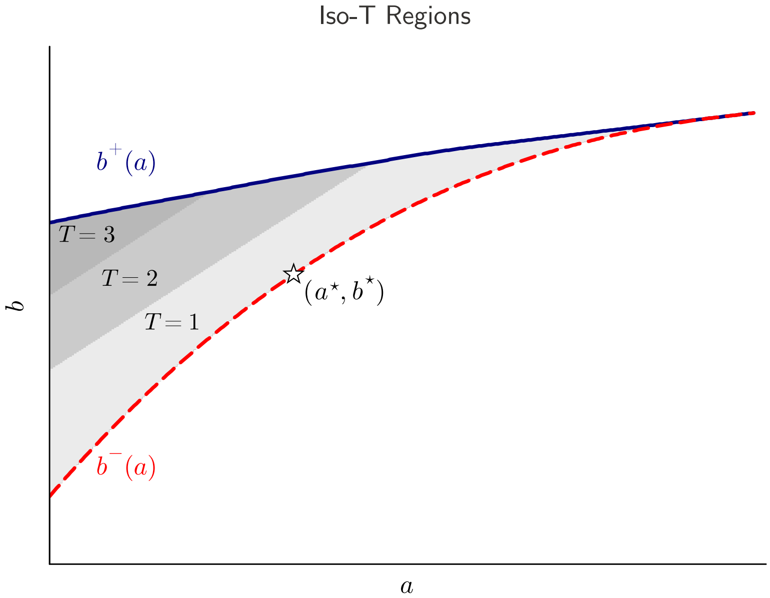
Q1: How many periods until exiting?

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

Q2: What's the best strategy to exit the crisis zone?

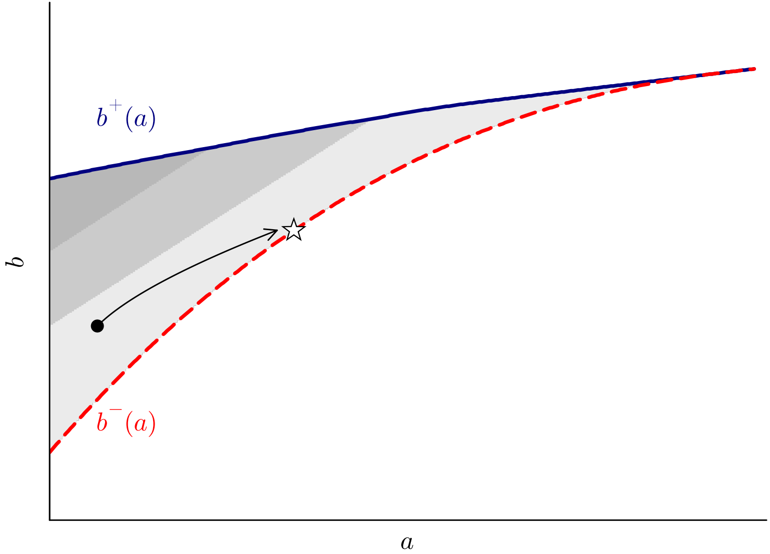
- Should the government reduce its debt or increase reserves?
- If reserves are optimal, should gov. slowly build up its stock of reserves?

How many periods until exit



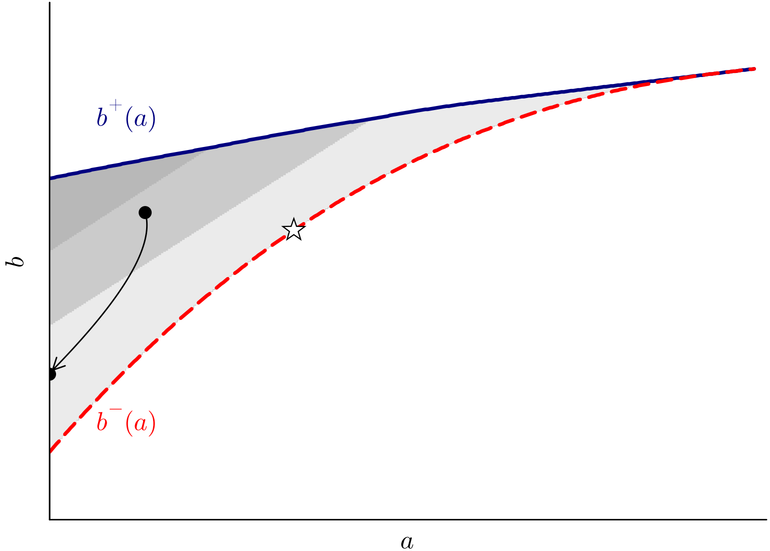
Deleveraging Path

Safety in One Period → $(a^\star, b^\star)$



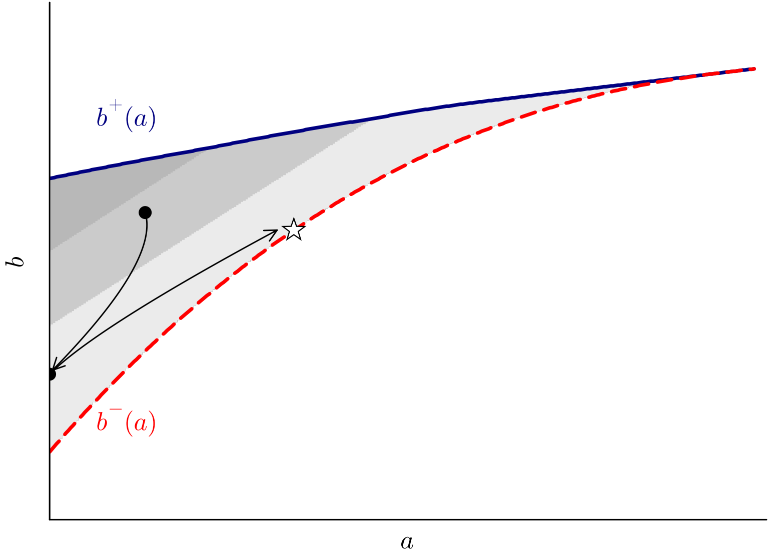
Deleveraging Path

Safety in Two Periods → $(a^\star, b^\star)$



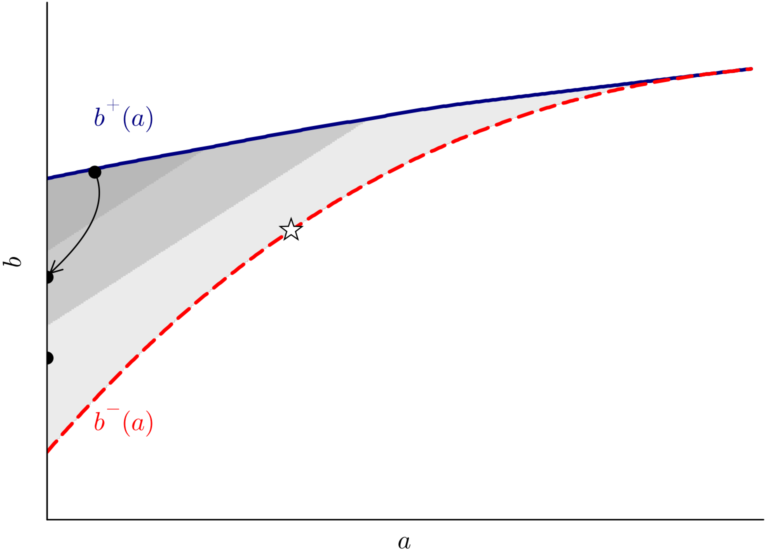
Deleveraging Path

Safety in Two Periods $\rightarrow$ $(a^{\star}, b^{\star})$



Deleveraging Path

Safety in Three Periods $\rightarrow (a^{\star}, b^{\star})$



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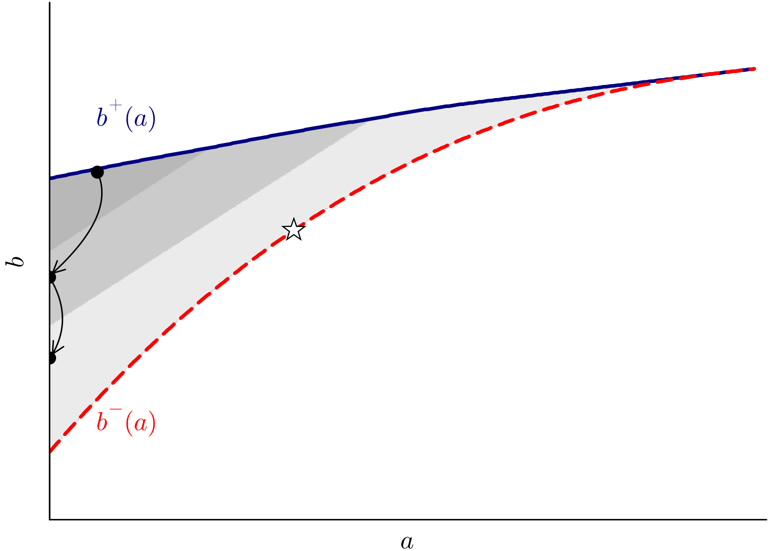

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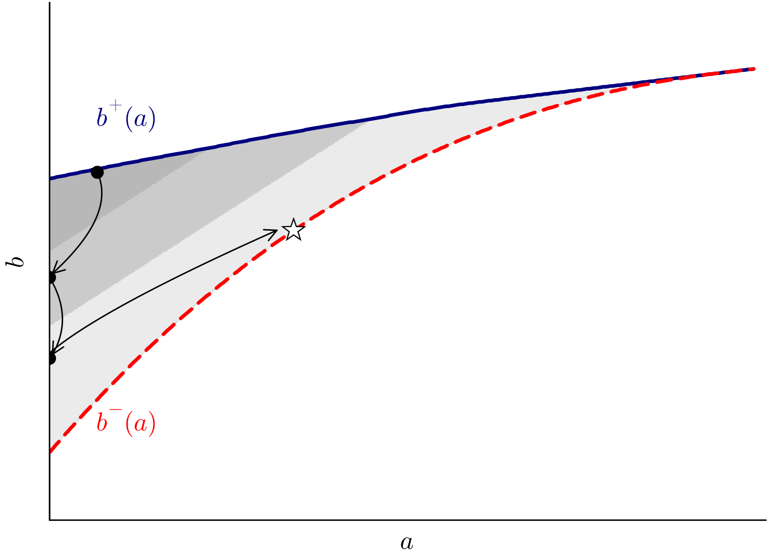
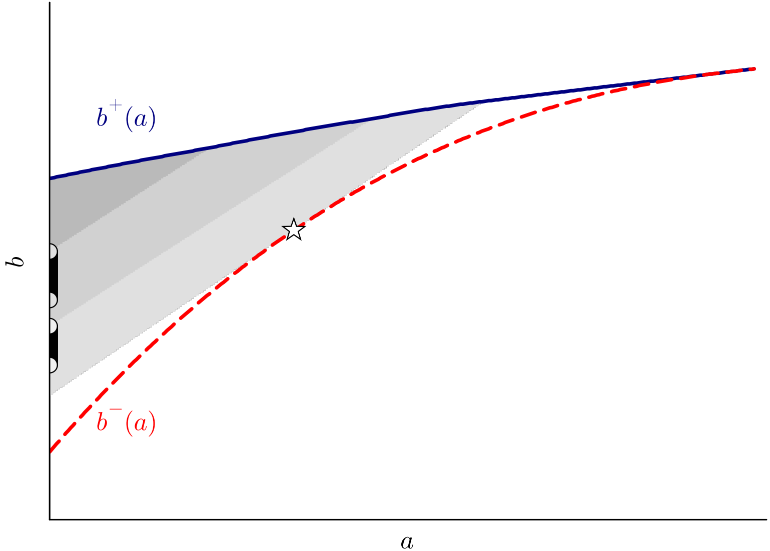
Safety in Three Periods $\rightarrow (a^\star, b^\star)$



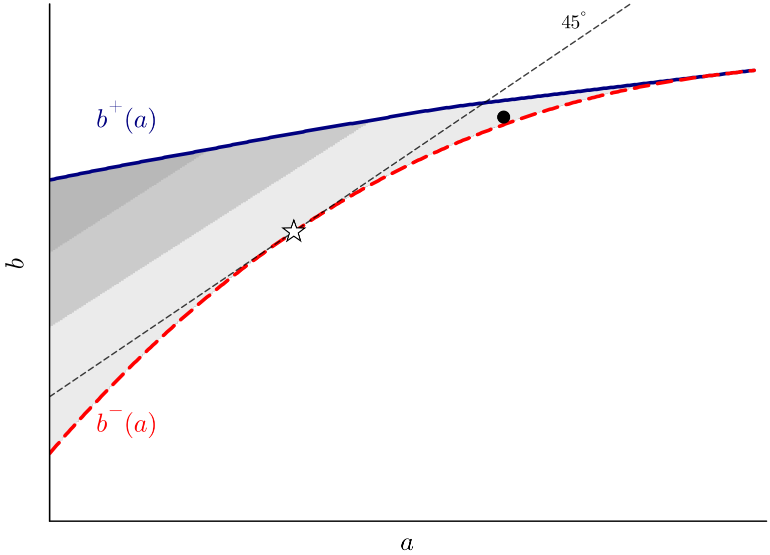
Deleveraging Path

Possible chosen portfolios for $a - b < a^\star - b^\star$



Deleveraging Path

Safety in One Period → $(a - b > a^\star - b^\star)$



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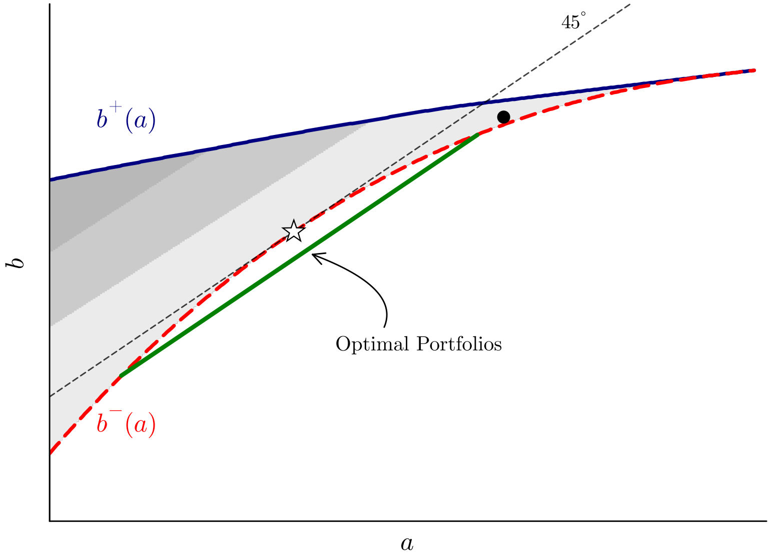
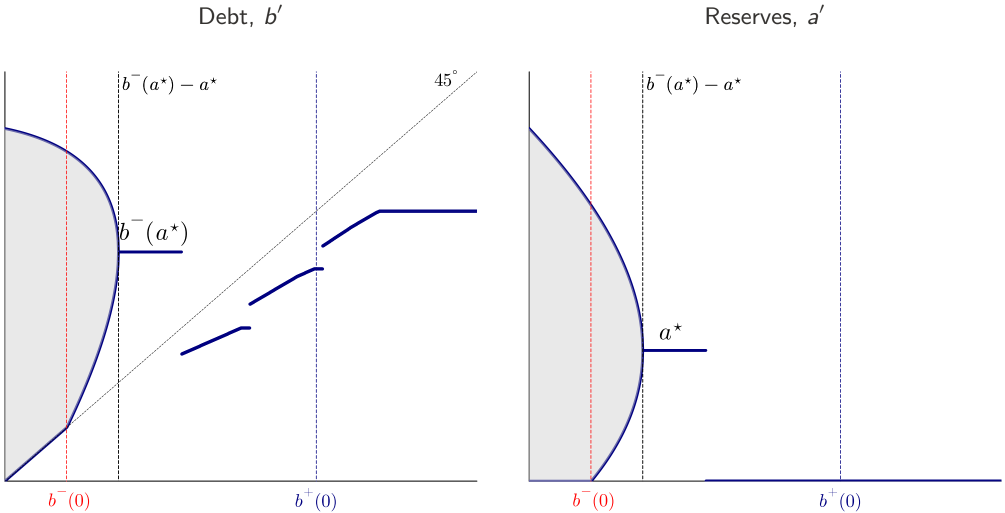


Policies


Debt, b'
Reserves, a'
$b^-(a^\star) - a^\star$
45°
$b^-(a^\star)$
$a^\star$
$b^-(0)$
$b^+(0)$
$b^-(a^\star) - a^\star$
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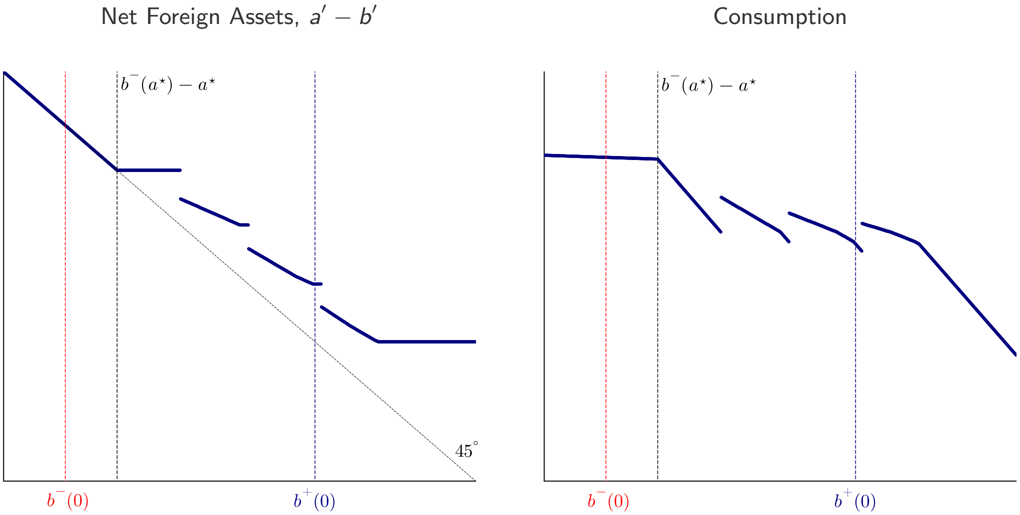
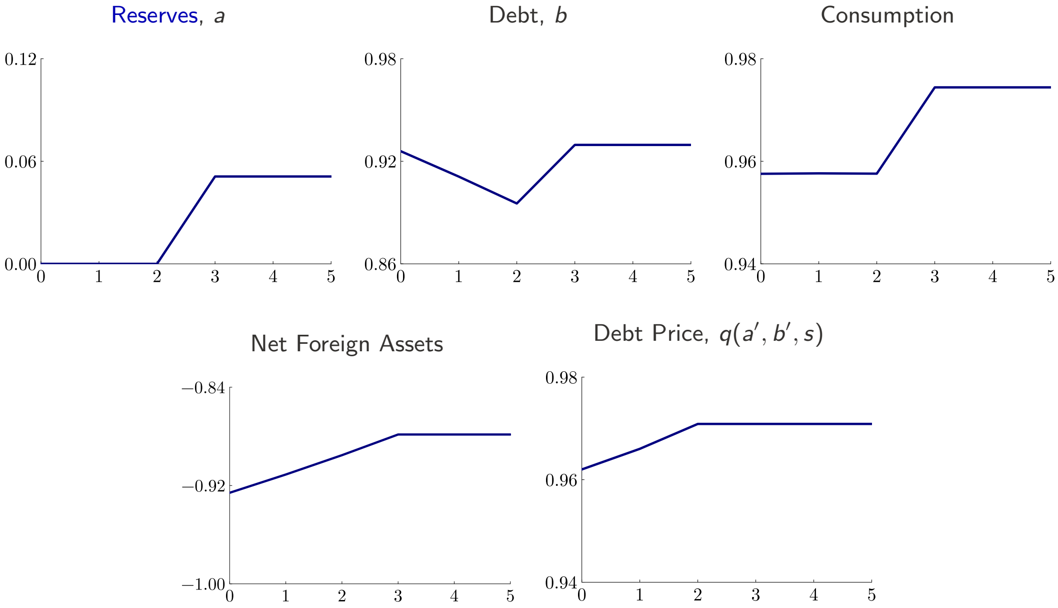
$b^+(0)$

Policies


Net Foreign Assets, $a' - b'$
Consumption
$b^-(a^\star) - a^\star$
$b^-(a^\star) - a^\star$
45°
$b^-(0)$
$b^+(0)$
$b^-(0)$
$b^+(0)$

Deleveraging Dynamics



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 $(a, b) \in \mathbf{C}$ and $a - b > a^\star - b^\star$. Then optimal to exit in one period and choose $a' = a^\star$
- 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

Sensitivity

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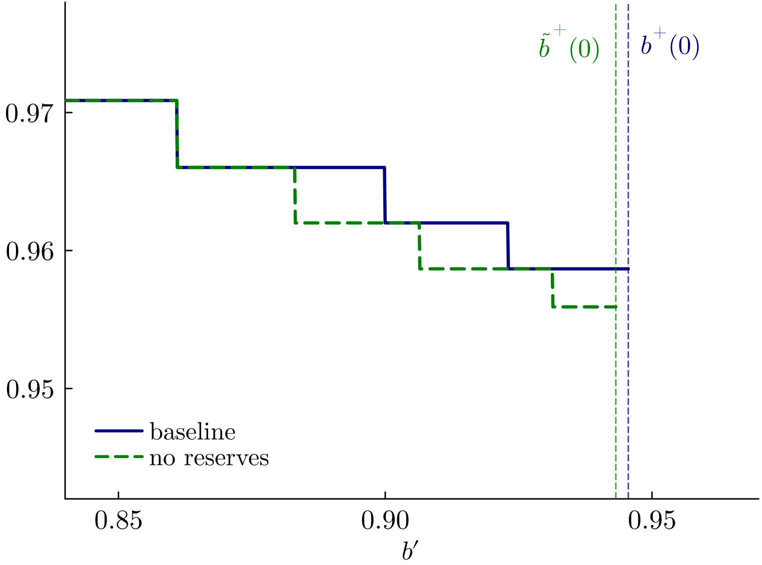
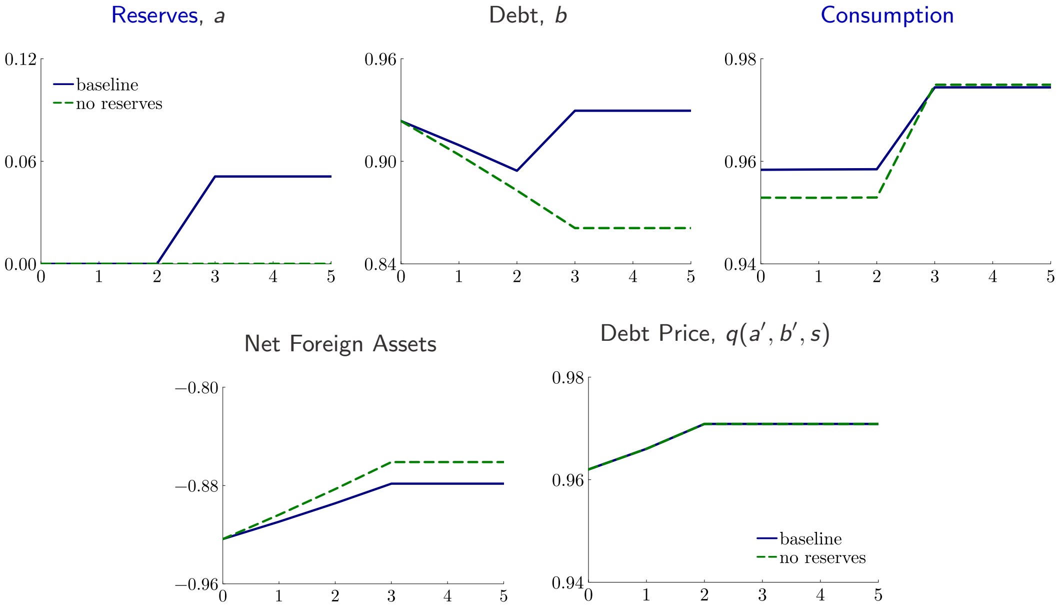
<u>Without reserves:</u> $\downarrow b^{+}$. More costly to deleverage $\Rightarrow$ lower debt-carrying capacity

▸ Default zone expands

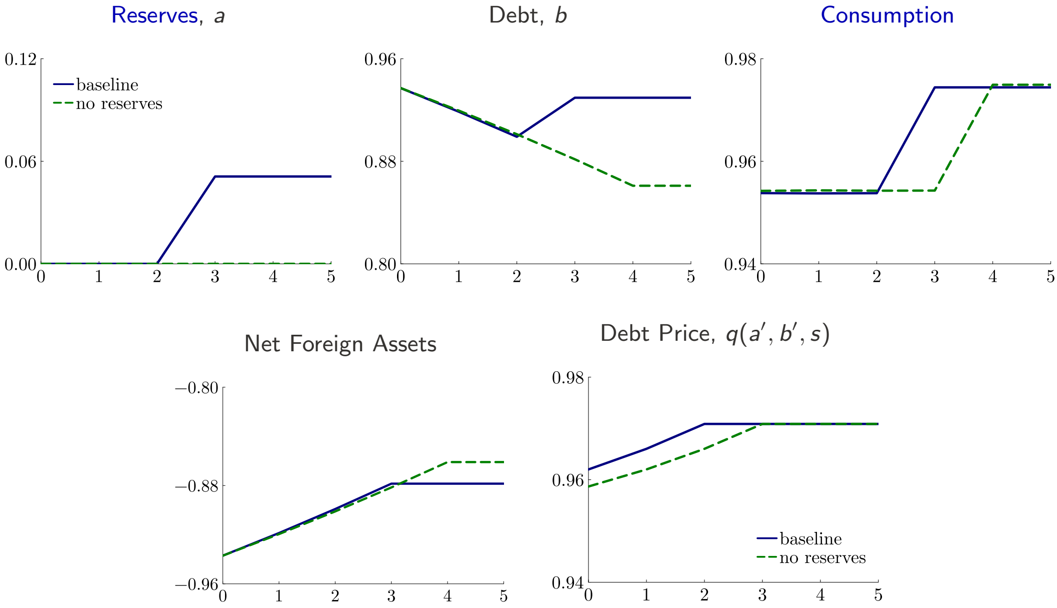
Price Schedule, $q(0, b')$



Lower consumption without reserves



Longer to exit without reserves



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
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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 <u>not optimal</u> at beginning of deleveraging process

Scan to find the paper!

THANKS!

Prelude

back

If government not vulnerable tomorrow after repaying in a run:

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

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

Prelude

▸ back

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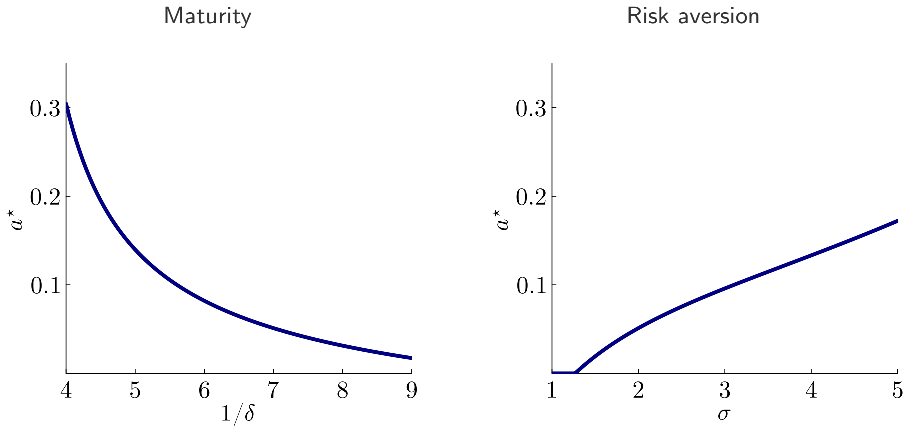
- Solution: $a'(a,b) = \max[0, a - \delta b]$.
  - With low initial reserves, government constrained $\Rightarrow a' = 0$
- If $a \geq \delta b$ and $(a - \delta b, (1-\delta)b) \in \mathcal{S}$, then $V_R^-(a,b) = V_R^+(a,b)$.
  - If high reserves, govt. can achieve unconstrained consumption even in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

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

back



Panels show the level of $a^\star$ 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