Reserve Accumulation, Macroeconomic Stabilization and Sovereign Risk

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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

Data: large holdings of int'l reserves, particularly for countries w/ currency pegs

Traditional argument (Krugman, 79; Flood and Garber, 84):

- Peg $\rightarrow$ cannot use seigniorage as source of revenue
- Reserves allow to sustain peg (even w/ primary deficits)
- Reseves are **needed**

Our paper:

- Theory based on the **desirability** to hold reserves to manage macroeconomic stability under sovereign risk concerns

This Paper

A theory of reserve accum. based on **macro stabilization** and **sovereign risk**

- Model of sovereign default and reserve accumulation w/ nominal rigidities

Intuition:

- Consider a negative shock that worsens the borrowing terms faced by a gov
- Optimal response: reduction in borrowing and consumption
- Under "fixed" and w/ nominal wage rigidity: $\downarrow c \rightarrow$ recession $\rightarrow$ further $\downarrow c$
- Having reserves: gov. can smooth the $\downarrow c$ and mitigate the recession

- Why not just borrow? These are precisely the states in which spreads $\uparrow$
- Reserves give a "hedge" against having to roll-over the debt in bad times and free up resources to mitigate the recession

This Paper – Take away

▸ related lit.

Key insight: when output is partly demand determined, larger gross positions help smooth aggregate demand, reduce severity of recessions and facilitate repayment

Quantitatively: Macro-stabilization is essential to account for observed reserve levels

- Fixers hold 16% of GDP, floaters 7%

Policy: simple and implementable rules for res. accum. can deliver significant gains

Main Elements of the Model

- Small open economy (SOE) with $T - NT$ goods:
  - Stochastic endowment for tradables: y^T
  - Non-tradables produced with labor: $y^N = F(h)$
- Wages are downward rigid in domestic currency (SGU, 2016)
  - With fixed exchange rate, $\pi^\star = 0$ and L.O.P. $\Rightarrow$ wages are rigid in tradable goods

$$W_t \geq \overline{W} \quad \Rightarrow \quad w_t \geq \overline{w}$$

- Government issues non-contingent long-duration bonds (b) and saves in one-period risk free assets (a), all in units of T
- Default entails one-period exclusion and utility loss $\psi_d(y^T)$
- Risk averse foreign lenders $\rightarrow$ "risk-premium shocks"

Households

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \{u(c_t)\}$$

$$c = C(c^T, c^N) = [\omega(c^T)^{-\mu} + (1-\omega)(c^N)^{-\mu}]^{-1/\mu}$$

- Budget constraint in units of tradables

$$c_t^T + p_t^N c_t^N = y_t^T + \phi_t^N + w_t h_t^s - \tau_t$$

- ϕ_t^N: firms' profits; τ_t: taxes. No direct access to external credit.
- Endowment of hours $\overline{h}$, but $h_t^s < \overline{h}$ when $w_t \geq \overline{w}$ binds.
- Optimality

$$p_t^N = \frac{1-\omega}{\omega} \left(\frac{c_t^T}{c_t^N} \right)^{1+\mu}$$

Firms

- Hire labor to produce y^N
- Maximize profits given by

$$\phi_t^N = \max_{h_t} \; p_t^N F(h_t) - w_t h_t$$

- p_t^N, w_t: price of non-tradables and wages, in units of tradables
- Firms' optimality condition is

$$p_t^N F'(h_t) \;\; = \;\; w_t$$

Equilibrium in the Labor Market

Assume: $F(h) = h^{\alpha}$ with $\alpha \in (0, 1]$.

Optimality conditions imply:

$$\mathcal{H}(c^T, w) = \left[\frac{1-\omega}{\omega}\,\frac{\alpha}{w}\right]^{1/(1+\alpha\mu)} (c^T)^{\frac{1+\mu}{1+\alpha\mu}}$$

Note: $\frac{\partial \mathcal{H}}{\partial c^T} > 0$

$$\text{Equilib. employment} = \begin{cases} \mathcal{H}(c^T, \overline{w}) & \text{for } w = \overline{w} \\ \bar{h} & \text{for } w > \overline{w} \end{cases}$$

plot

Asset/Debt Structure

- Long-term bond:
  - Bond pays $\delta\left[1, (1-\delta), (1-\delta)^2, (1-\delta)^3, ...\right]$
  - Law of motion for bonds $b_{t+1} = b_t(1-\delta) + i_t$
  - price is q
- Risk-free one-period asset which pays one unit of trad. consumption $\rightarrow$ reserves
  - price is q_a
- Government's budget constraint if **repay:**

$$q_a a_{t+1} + b_t\delta = \tau_t + a_t + q_t \underbrace{\left(b_{t+1} - (1-\delta)b_t\right)}_{i_t \text{ : debt issuance}}$$

- Government's budget constraint in **default:**

$$q_a a_{t+1} = \tau_t + a_t$$

Foreign Investors

more

- Competitive, deep-pocketed foreign lenders, subject to “risk-premium” shocks:
  - SDF: $m(s, s')$ with $s = \{y^T, \nu\}$
- Not essential for the analysis, but helps to capture **global factors** and match **spread dynamics**
- Formulation follows Vasicek (77), constant r:

$$q_a = \mathbb{E}_{s'|s} m(s, s') = e^{-r}$$

- Bond price given by: $q = \mathbb{E}_{s'|s} \{m(s, s')(1 - d') [\delta + (1 - \delta) q']\}$

$$d' = \hat{d}(a', b', s'), \quad q' = q(a'', b'', s')$$

Recursive Problem

$$V(b,a,s) = \max_{d\in\{0,1\}} \left\{(1-d)V^R(b,a,s) + d\,V^D(a,s)\right\}$$

Value of repayment:

$$V^R(b,a,s) = \max_{b',a',h\le\overline{h},c^T} \left\{u(c^T,F(h)) + \beta\mathbb{E}_{s'|s}\left[V\left(b',a',s'\right)\right]\right\}$$

$$\text{subject to}$$

$$c^T + q_a a' + \delta b = a + y^T + q\left(b',a',s\right)\left(b' - (1-\delta)b\right)$$

$$h \le \mathcal{H}(c^T,\overline{w}) \qquad [\xi]$$

$\mathcal{H}(c^T,\overline{w}) \rightarrow$ summarizes implementability const. from labor mkt & wage rigidity

Value of default

- Total repudiation, utility cost of default, 1-period exclusion
- Keep a and choose a'

$$V^D(a,s) = \max_{c^T, h \leq \overline{h}, a'} \left\{ u\left(c^T, F(h)\right) - \psi_d\left(y^T\right) + \beta \mathbb{E}_{s'|s}\left[V\left(0, a', s'\right)\right] \right\}$$

subject to

$$c^T + q_a a' = y^T + a$$

$$h \leq \mathcal{H}(c^T, \overline{w}) \qquad [\xi]$$

Optimal Portfolio: gains from borrowing to buy reserves

Perturbation: issue additional unit of debt to buy reserves. Keep $\overline{c}$. From tomorrow onward, optimal policy.

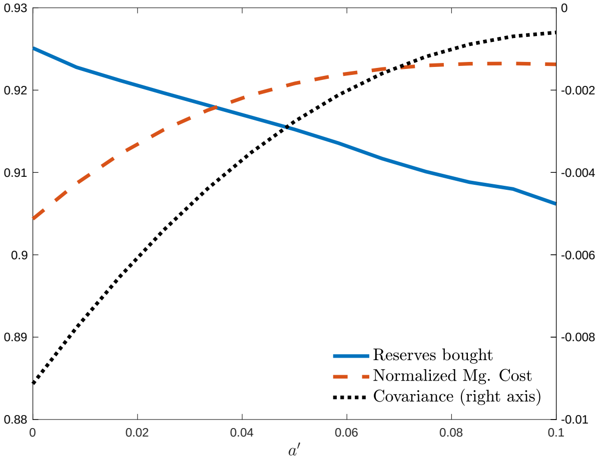
$$\overbrace{\underbrace{\left(\frac{q + \frac{\partial q}{\partial b'} i}{q_a - \frac{\partial q}{\partial a'} i}\right)}_{\text{Reserves bought}} \mathbb{E}_{s'|s}\left[u'_T + \xi' \mathcal{H}'_T\right]}^{\text{MU. benefit of borrowing to buy reserves}} = \mathbb{E}_{s'|s}[1-d'] \Big\{ \mathbb{E}_{s'|s,d'=0}\left[\delta + (1-\delta) q'\right] \mathbb{E}_{s'|s,d'=0}\left[u'_T + \xi' \mathcal{H}'_T\right]$$

$$+ \underbrace{\mathbb{COV}_{s'|s,d'=0}\left(\delta + (1-\delta) q', u'_T + \xi' \mathcal{H}'_T\right)}_{\text{Macro-stabilization hedging}} \Big\}$$

Costs are lower in bad times: low q', high $u'_T + \xi' \mathcal{H}'_T \rightarrow$ hedging benefit

With 1-period debt ($\delta = 1$): $\mathbb{COV}_{s'|s,d'=0}\left(\delta + (1-\delta) q', u'_T + \xi' \mathcal{H}'_T\right) = 0$

Optimal Portfolio: gains from borrowing to buy reserves



Covariance: negative (macro-stabilitization hedging) and upward sloping

Benefits of reserve accumulation

We want to highlight <u>two</u> benefits of “borrowing to save:”

i. Help reduce future unemployment.

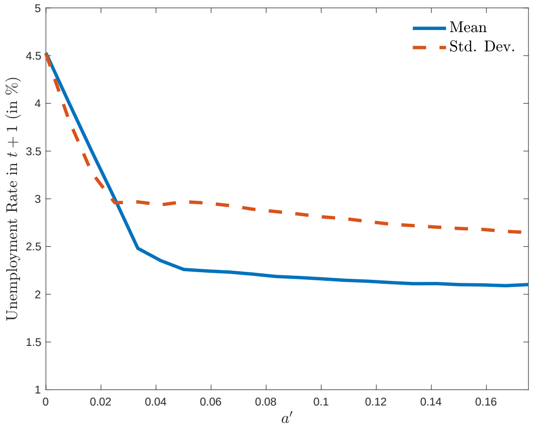
ii. May improve bond prices.

Exercise:

- Fix a point in the s.s. and a given level of consumption $\overline{c}$.
- Look at alternative a', and find b' that ensures $c = \overline{c}$.

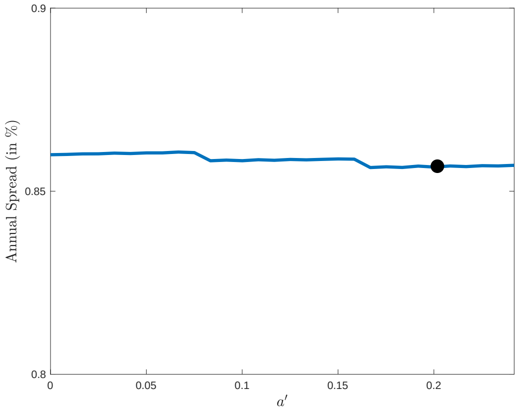
Next-period unemployment for given (a', b'): mean and std. dev.

▸ densities



Note: higher reserves **reduce** future unemployment

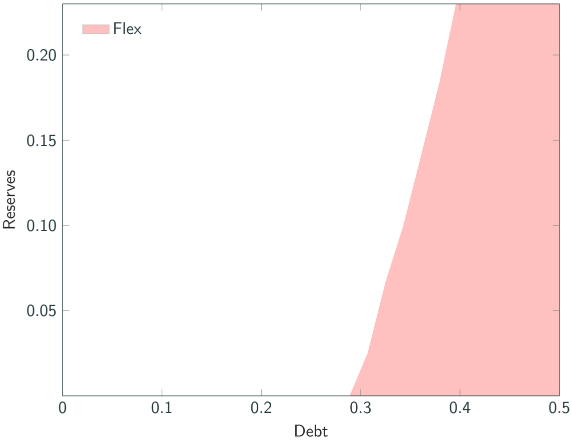
Borrowing to save may improve bond prices



Intuition: Reserves increase V^R and V^D. If gov. is borrowing constrained (high unemployment), effect on V^R may dominate effect on V^D.

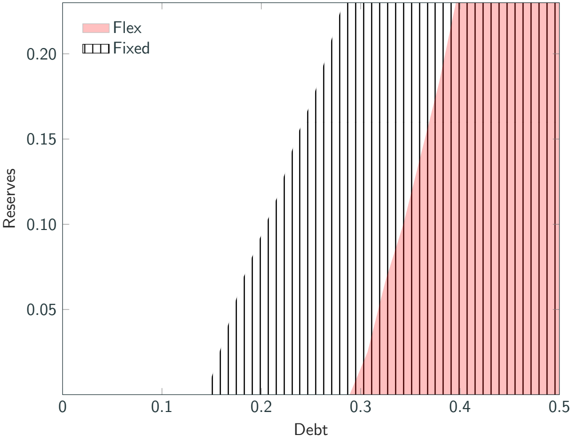
Results: default regions

spread plots



Results: default regions

spread plots



- Nominal rigidities **increase** default incentives
- Gross positions matter for default incentives

Quantitative Analysis – Functional forms

- Calibrate to the average of a panel of 22 EMEs (1990–2015).
- Benchmark = economy with nominal rigidities.
- 1 model period = 1 year.

Utility function:

$$u(c) = \frac{c^{1-\gamma} - 1}{1-\gamma}, \text{ with } \gamma \neq 1$$

Utility cost of defaulting:

$$\psi_d(y^T) = \psi_0 + \psi_1 log(y^T)$$

Tradable income process:

$$\log(y_t^T) = (1-\rho)\mu_y + \rho log(y_{t-1}^T) + \epsilon_t$$

with $|\rho| < 1$ and $\epsilon_t \sim N(0, \sigma_\epsilon^2)$

Quantitative Analysis – Calibration

Parameter	Description	Value
r	Risk-free rate	0.04
α	Labor share in the non-tradable sector	0.75
β	Domestic discount factor	0.90
π_{LH}	Prob. of transitioning to high risk premium	0.15
π_{HL}	Prob. of transitioning to low risk premium	0.8
σ_ε	Std. dev. of innovation to $log(y^T)$	0.045
ρ	Autocorrelation of $log(y^T)$	0.84
μ_y	Mean of $log(y^T)$	$-\frac{1}{2}\sigma_\varepsilon^2$
δ	Coupon decaying rate	0.2845
$1/(1+\mu)$	Intratemporal elast. of subs.	.44
γ	Coefficient of relative risk aversion	2.273
$\overline{h}$	Time endowment	1
	Parameters set by simulation	
ω	Share of tradables	0.4
ψ_0	Default cost parameter	3.6
ψ_1	Default cost parameter	22
κ_H	Pricing kernel parameter	15
$\overline{w}$	Lower bound on wages	0.98

Results – road map

1. Simulations moments.
2. Welfare exercises.
3. Simple, implementable reserve accumulation rules.
4. Robustness to alternative monetary regimes.

Results: data and simulation moments

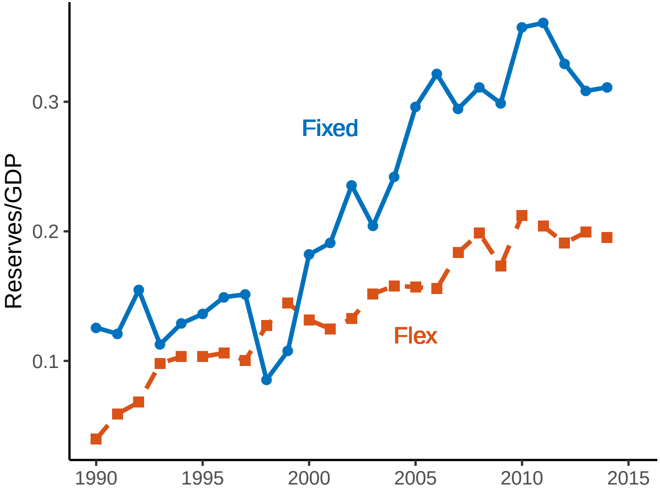
	Data	Model Benchmark
Targeted		
Mean debt (b/y)	45	44
Mean r_s	2.9	2.9
Δr_s w/ risk-prem. shock	2.0	2.0
Δ UR around crises	2.0	2.0
Mean y^T/y	41	41
Non-Targeted		
$\sigma(c)/\sigma(y)$	1.1	1.0
$\sigma(r_s)$ (in %)	1.6	3.1
$\rho(r_s, y)$	-0.3	-0.6
$\rho(c, y)$	0.6	1.0
Mean Reserves (a/y)	16	16
Mean Reserves/Debt (a/b)	35	35

Results: data and simulation moments

	Data	Model Benchmark	Model Flexible
Targeted			
Mean debt (b/y)	45	44	46
Mean r_s	2.9	2.9	3.0
Δr_s w/ risk-prem. shock	2.0	2.0	1.9
Δ UR around crises	2.0	2.0	0.0
Mean y^T/y	41	41	41
Non-Targeted			
$\sigma(c)/\sigma(y)$	1.1	1.0	1.1
$\sigma(r_s)$ (in %)	1.6	3.1	2.9
$\rho(r_s, y)$	-0.3	-0.6	-0.8
$\rho(c, y)$	0.6	1.0	1.0
Mean Reserves (a/y)	16	16	7
Mean Reserves/Debt (a/b)	35	35	15

Reserves in the data: fixed vs. flex

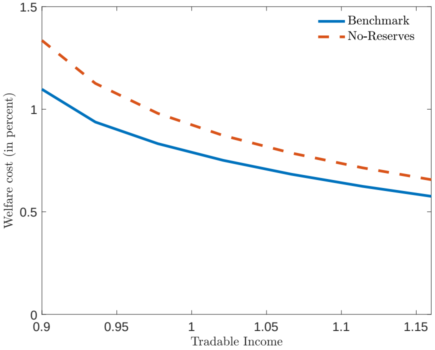
more



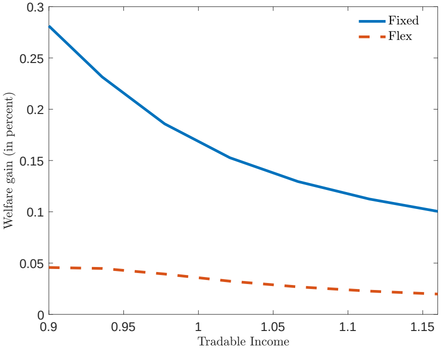
Welfare implications

▸ more

Welfare costs of rigidities



Welfare gain of reserves



- Nominal rigidities decrease welfare by around 0.9% and are costlier if cannot accumulate reserves
- Having access to reserves is welfare improving, especially w/ nominal rigidities

Simple and implementable reserve accumulation rules

- Policy discussion: what constitutes an "adequate" amount of reserves?
- Explore the performance of a simple rule that is linear in the state variables
- Compare it against:
  - fully optimizing model
  - other reserve accumulation rules (Greenspan-Guidotti)

$$a_{t+1} = \beta_0 + \beta_{debt}\, b_t + \beta_{spr}\, spread_t + \beta_{res}\, a_t + \beta_y\, y_t^T$$

$$\beta_0 = 0.336,\ \beta_{debt} = 2.535,\ \beta_{spread} = -1.69, \beta_{res} = 0.422,\ \beta_y = 0.418.$$

1 p.p. increase in spreads, controlling for other factors, should lead to reserves declining 1.69% of mean (tradable) output (roughly 0.70% of GDP)

Simple and implementable reserve accumulation rules

	Benchmark	Rules	
		Best Rule	Greenspan-Guidotti
Targeted			
Mean debt (b/y)	44	42	19
Mean r_s	2.9	2.8	2.4
Δr_s w/ risk-prem. shock	2.0	1.9	1.7
Δ UR around crises	2.0	2.0	1.8
Mean y^T/y	41	41	40
Non-Targeted			
$\sigma(c)/\sigma(y)$	1.0	1.0	1.0
$\sigma(r_s)$ (in %)	3.1	3.0	2.7
$\rho(r_s, y)$	-0.6	-0.6	-0.7
$\rho(c, y)$	1.0	1.0	1.0
Mean Reserves (a/y)	16	15	6
Mean Reserves/Debt (a/b)	35	38	31
Reserves/S.T. liabilities	112	139	100
Welfare gain (vs. No-Reserves)	0.18	0.07	-0.22

Robustness: other monetary regimes

1. Inflation Targeting
   - Instead of fixing e, the gov. commits to delivering constant (zero) inflation
   - Now the nominal exchange rate (e) can move.
   - Finding: still optimal to sustain large amounts of reserves ($\approx 12\%$)

2. Costly Depreciations
   - Allow for costly depreciations in the model.
     - Today: one-time depreciations
     - Revision: available all the time – joint decision $\{b', a', e\}$
   - Finding: the more the country depreciates, the less it uses reserves to cope w/ negative shocks $\rightarrow$ in line w/ data.

Takeaway: importance of the macro-stabilization role of reserves under MP constraints

Costly one-time depreciations

- Implication of the model: countries with a **lower degree of exchange rate flexibility** find it optimal to use a **larger portion of the reserves** to deal w/ shocks.

- **Suitable episode:** GFC. Notable decline in the accumulation of reserves and a large dispersion in depreciation rates across countries.

- Ask whether in the cross-section, the larger drop in reserves was associated with a lower depreciation in the exchange rate. Answer: yes.

- Does the model predict something similar?

Costly one-time depreciations

Consider a variant of the model w/ flexible e but costly depreciations

$$u(c^T, F(h)) - \kappa(y^T) - \Phi\left(\frac{e-\bar{e}}{\bar{e}}\right), \qquad \Phi(0) = 0 \text{ and } \Phi'(0) = 0$$

Exercise:

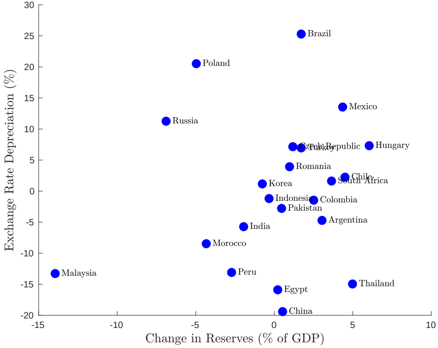
- Focus on the response to a negative income shock and consider a one-time adjustment cost.
- Economy under fix, avg. (b, a) and hit by $\downarrow y$ such that spreads $\uparrow$ 300 bps.
- How much reserves are used as a functions of Φ ?

Result:

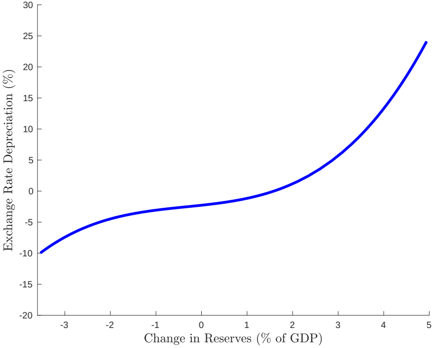
- As $\Phi \searrow$ we see a higher depreciation rate and a lower decline in reserves.
- In line w/ data: a gov. that depreciates more doesn't use as many reserves when hit by a negative shock.

Costly one-time depreciations

(a) Data



(b) Model



In line w/ data: a gov. that depreciates more doesn't use as many reserves when hit by a negative shock.

Things we are exploring ...

- Costly depreciations: joint decision of $\{b', a', e\}$
    - capture the empirical regularity that default risk and depreciation go together (Na et. al. 2018; Galli 2020)

- Alternative nominal rigidities:
    - $W_t \geq \gamma W_{t-1}$
    - Symmetric rigidity: $\underline{W} \leq W_t \leq \overline{W}$
    - Price/wage rigidity *a la* Rotemberg.

- Trend in reserve accumulation

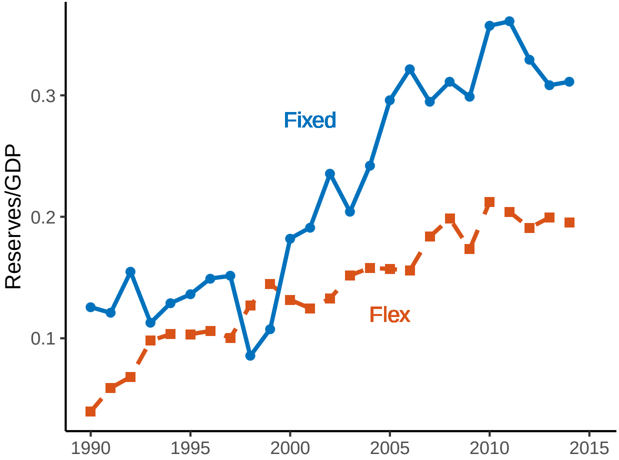
Conclusions

- Provided a theory of reserve accum. for macro-stabilization and sovereign risk
- Reserves help reduce future unemployment risk and may improve bond prices
- Aggregate demand effects essential to account for observed reserves in the data
- Simple and implementable rules for res. accum. can deliver significant gains
- Agenda:
  - Temptation to abandon pegs—how reserves can help
  - Equilibrium Multiplicity

THANKS !

Reserves in the data: fixed vs. flex

▸ (back)

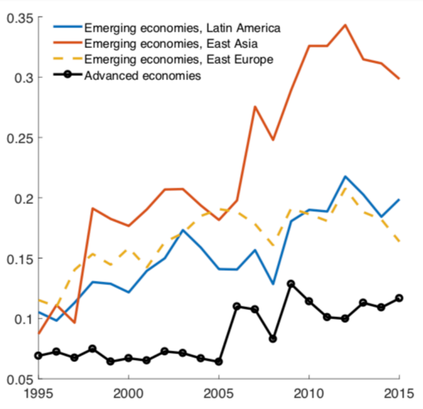


Massive holdings of international reserves, particularly for countries with fixed exchange rates

Reserves around the world

(back)

Over the past 20 years massive increase in reserves around the world, specially EMEs.



(from Amador, Bianchi, Bocola and Perri, 2018)

Reserve accumulation – Regressions

(back to motivation) (back to simulations)

	Dependent variable: log(*Reserves*/*y*)				
	(1)	(2)	(3)	(4)	(5)
ERV	**−0.647***	**−0.656****	**−0.662****	**−0.281***	**−0.206***
	(0.367)	(0.332)	(0.334)	(0.152)	(0.121)
log(*Debt*/*y*)		0.245	0.250	0.349	0.324
		(0.214)	(0.244)	(0.240)	(0.203)
$\hat{y}$			−0.069	1.158	1.389
			(1.227)	(1.326)	(1.007)
log(*Spread*)				−0.155	−0.063
				(0.095)	(0.093)
r^{world}					−0.119***
					(0.038)
Number of countries	22	22	22	22	22
Observations	459	459	458	314	314
R^2	0.02	0.04	0.04	0.12	0.24
F Statistic	7.28***	8.97***	6.53***	9.43***	18.24***

Note: All explanatory variables are lagged one period. $\hat{y}$ is the cyclical component of GDP. All specifications include country fixed effects. Robust standard errors (clustered at the country level) are reported in parentheses. $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$.

Countries in our dataset

(back to motivation) (back to simulations)

We use the IMF Classif. of Exch. Rate Arrangements (fixed $= 1$ and 2)

We follow Kondo and Hur (2016) and focus on 22 EMEs:

Argentina	India	Poland
Brazil	Indonesia	Romania
Chile	Malaysia	Russia
China	Mexico	South Africa
Colombia	Morocco	South Korea
Czech Republic	Pakistan	Thailand
Egypt	Peru	Turkey
Hungary		

Related Literature

back

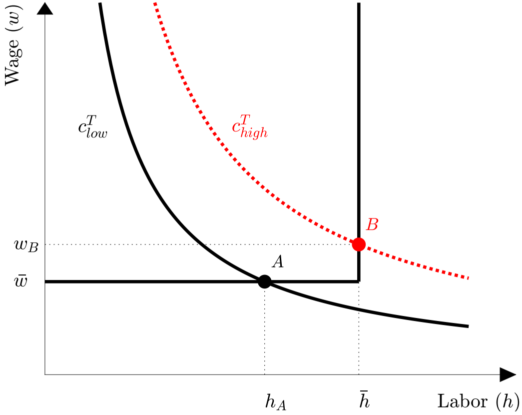
Two main related branches of the literature:

Reserve accumulation: Aizenmann and Lee (2005); Jeanne and Ranciere (2011) ; Durdu, Mendoza and Terrones (2009); Alfaro and Kanczuk (2009), Bianchi, Hatchondo and Martinez (2018); Hur and Kondo (2016); Amador et al. (2018); Arce, Bengui and Bianchi (2019); Bocola and Lorenzoni (2018); Cespedes and Chang (2019)

Sovereign default models with nominal rigidities: Na, Schmitt-Grohe, Uribe and Yue (2018); Bianchi, Ottonello and Presno (2021); Arellano, Bai and Mihalache (2020); Bianchi and Mondragon (2021)

Plot of the Labor Market Equilibrium

(back)



Foreign Investors' SDF – details

back

- Pricing kernel: a function of innovation to domestic income (ε) and a global factor $\nu = \{0, 1\}$ (assumed to be independent of ε)

$$m_{t,t+1} = e^{-r-\nu_t(\kappa\varepsilon_{t+1}+0.5\kappa^2\sigma_\varepsilon^2)}, \quad \text{with} \quad \kappa \geq 0,$$

- Functional form + normality of $\varepsilon \rightarrow$ constant short-term rate:

$$\mathbb{E}_{s'|s} m(s, s') = e^{-r} = q_a, \qquad \text{with} \quad s = \{y^T, \nu\}$$

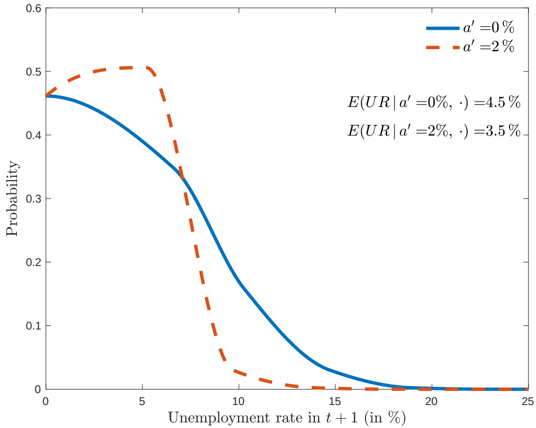
- Bond price given by: $q = \mathbb{E}_{s'|s} \{m(s, s')(1 - d') [\delta + (1 - \delta) q']\}$

- Bond becomes a worse hedge if $\nu = 1$ and gov. tends to default with low ε

$\implies$ positive risk premium

Distribution of next-period unemployment for given (a', b')

back

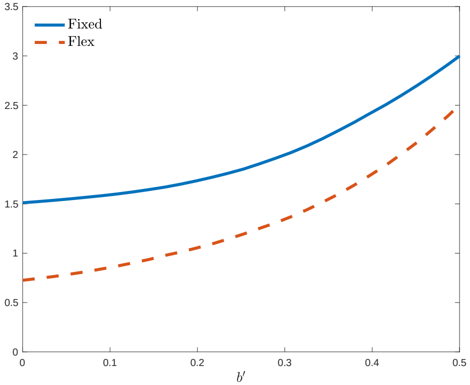


Note: higher reserves **reduce** future unemployment

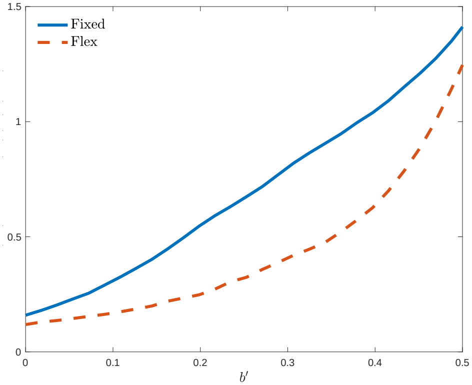
Results: spreads, reserves and nominal rigidities

(back)

Spread schedule (avg. reserves)



$\uparrow r_s$ if zero reserves



- Nominal rigidities **increase** spreads.
- Reserves **decrease** spreads, and **more** with nominal rigidities.

Appendix – Welfare

(back)

We'll compute **welfare costs** of 'moving' from a **baseline** economy to an **alternative** economy:

$$\text{Welfare gain} = 100 \times \left[\left(\frac{(1-\gamma)(1-\beta)V_{baseline} + 1}{(1-\gamma)(1-\beta)V_{alternative} + 1} \right)^{1/(1-\gamma)} - 1 \right]$$

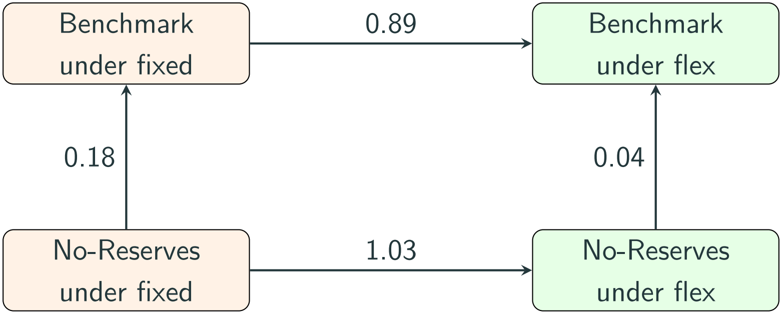
We're interested in studying:

- Costs of nominal rigidities
- Costs of not having access to reserves

To do this: define a "No-Reserves" economy (which can be under "fixed" or "flex").

Appendix – Welfare

(back)

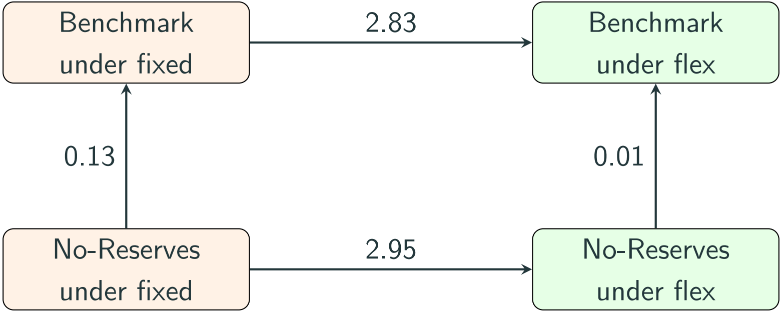


- Eliminating nominal rigidities is **welfare enhancing**, and more so when **reserve accumulation is not possible**.
- Being able to accumulate reserves is **welfare enhancing**, and more so under **fixed**.

Appendix – Welfare

(back)

Initial debt = Avg. in simulations. Initial reserves= zero.



Appendix – Inflation Targeting

(back)

	Data	Model	
		Fixed Exchange Rate	Inflation Targeting
Targeted			
Mean debt (b/y)	45	44	51
Mean r_s	2.9	2.9	2.8
Δr_s w/ risk-prem. shock	2.0	2.0	2.1
Δ UR around crises	2.0	2.0	0.5
Mean y^T/y	41	41	42
Non-Targeted			
$\sigma(c)/\sigma(y)$	1.1	1.0	1.1
$\sigma(r_s)$ (in %)	1.6	3.1	3.0
$\rho(r_s, y)$	-0.3	-0.6	-0.7
$\rho(c, y)$	0.6	1.0	1.0
Mean Reserves (a/y)	16	16	12
Mean Reserves/Debt (a/b)	35	35	23

Key: some form of monetary inflexibility is enough to create demand for reserves

Appendix – Inflation Targeting

(back)

- Define price aggregator as

$$P\left(P^T, P^N\right) \equiv \left(\omega^{\frac{1}{1+\mu}}\left(P^T\right)^{\frac{\mu}{1+\mu}} + (1-\omega)^{\frac{1}{1+\mu}}\left(P^N\right)^{\frac{\mu}{1+\mu}}\right)^{\frac{1+\mu}{\mu}}.$$

- Instead of fixing $e = 1$, gov. targets $P = \overline{P} > 0$

- All this yields an exchange rate policy

$$e = \overline{P}/\mathcal{P}\left(c^T, h\right) \tag{1}$$

- Replace fixed e for (1).