A Macroprudential Theory of Foreign Reserve Accumulation

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Fact 1: Private External Debt & Foreign Reserves over time

GDP weighted average reserves to GDP & private external debt to GDP in middle income countries (excluding China) for 1980-2015.

Fact 2: Private External Debt & Foreign Reserves in cross-section

Average private external debt to GDP & average reserves to GDP (1980-2015).

Source: World Bank, Lane and Milesi-Ferretti (2007)
Fact 3: Private Debt & Foreign Reserves are procyclical

Correlation between the annual growth rates of private debt and reserves and real GDP (2000-2015).

Fact 4: Financial Openness & Foreign Reserves

Average Chinn-Ito financial openness index & average reserves to GDP (1980-2015).

Source: Lane and Milesi-Ferretti (2007) and Chinn and Ito (2006)
• Existing theories of foreign reserve accumulation: insurance against income shocks or government credit market access
  • Heller, 1966, Bianchi, Hatchondo and Martinez, 2018

• Data suggests link between private capital flows and official reserve accumulation

• **This paper:** A theory of reserve accumulation as a macroprudential policy
• Model of emerging market crises with pecuniary externalities expanded with reserve accumulation

• Theory: Show that reserve accumulation can implement constrained efficiency
  • Alternative to borrowing taxes/capital controls

• Quantitative analysis consistent with three facts presented:
  • Sizable average levels of reserve and private debt
  • Positive association between gross private debt and foreign reserves
  • Procyclical feature of optimal reserve accumulation policy
Main elements of the model

- Small-open endowment economy with 2 goods: tradables ($T$) and nontradables ($N$)

- Debt denominated in units of tradables

- Occasionally binding credit constraint depending on current income, and thus on real exchange rate (Mendoza, 2002)

- Government accumulates foreign reserves, in units of tradables
Choose $b_{t+1}, c^T_t, c^N_t$ to maximize

$$E_0 \sum_{t=0}^{\infty} \beta^t u(c_t),$$

where $u(c(c^T, c^N)) = \frac{c(c^T, c^N)^{1-\sigma}}{1-\sigma},$

$c(c^T, c^N) = [\omega(c^T)^{-\eta} + (1 - \omega)(c^N)^{-\eta}]^{-\frac{1}{\eta}} \eta > -1, \omega \in (0, 1),$

subject to budget constraint

$$\frac{b_{t+1}}{R} + c^T_t + p^N_t c^N_t = b_t + y^T_t + p^N_t y^N - T_t,$$

and credit constraint

$$-\frac{b_{t+1}}{R} \leq \kappa_t \left(y^T_t + p^N_t y^N\right).$$
Government accumulates reserves $A \geq 0$ subject to budget constraint

$$\frac{A_{t+1}}{R} = T_t + A_t.$$
Equilibrium conditions

Household optimization

\[ p_t^N = \frac{1 - \omega}{\omega} \left( \frac{c_T}{c^N_T} \right)^{\eta+1} \]

\[ u_T(t) = \beta R E_t u_T(t + 1) + \mu_t \]

Market clearing for non-tradables

\[ c^N_t = y^N \]

Resource constraint for tradables

\[ c_T^t + \frac{A_{t+1} + b_{t+1}}{R} = y_T^t + A_t + b_t \]
Competitive equilibrium

Sequence of policies and prices such that:

(i) Households optimize
(ii) Market for non-tradable clears
(iii) Government budget constraint holds
Constrained-efficient planner (Bianchi, 2011)

Planner solves

\[
\max_{b_{t+1}, c_t^T} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t u(c_t),
\]

subject to

\[
b_{t+1} \frac{R}{R} + c_t^T = b_t + y_t^T \\
c_t^N = y^N,
\]

\[
-\frac{b_{t+1}}{R} \leq \kappa_t \left( y_t^T + \frac{1 - \omega}{\omega} \left( \frac{c_t^T}{y^N} \right)^{\eta+1} y^N \right)
\]
Constrained-efficient planner (Bianchi, 2011)

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\]
\[
c_t^N = y^N,
\]

\[
- \frac{b_{t+1}}{R} \leq \kappa_t \left( y_t^T + \frac{1 - \omega}{\omega} \left( \frac{c_t^T}{y^N} \right)^{\eta+1} y^N \right)
\]
When credit constraint does not bind

- Intertemporal Euler equation for households

\[ u_T(t) = \beta R^E_t u_T(t + 1) \]

- Intertemporal Euler equation for planner

\[ u_T(t) = \beta R^E_t [u_T(t + 1) + \mu_{t+1}\Psi_{t+1}] \]

with \( \Psi_t \equiv \kappa_t(p^N_t c^N_t)/(c^T_t)(1 + \eta) \).
Proposition 1

Constrained efficiency is achieved if government follows reserve policy

\[ A^R_{t+1} = b^*_{t+1} + R \left[ A^R_t + b_t - b^*_t + \kappa \left( y^T_t + p^*_N y^N_t \right) \right], \]

in all periods, where \( \star \) refer to variables in constrained-efficient allocation.

A technical condition that guarantees this result is that a unitary elasticity of substitution between T-NT and \( \kappa (1 - \omega) < 1 \), but logic applies more broadly.
Implementation when private households are unconstrained in the absence of reserve accumulation.
Illustration of Implementation (when constraint binds)

Implementation when private households are constrained in the absence of reserve accumulation.

\[-b_{t+1} = -b^*_t = -b^R_t\]
Quantitative Analysis: Calibration


<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Source/Targets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest rate</td>
<td>$r = 0.04$</td>
<td>Standard value</td>
</tr>
<tr>
<td>Risk aversion</td>
<td>$\sigma = 2$</td>
<td>Standard value</td>
</tr>
<tr>
<td>Elasticity of substitution</td>
<td>$1/(1 + \eta) = 0.83$</td>
<td>Standard value</td>
</tr>
<tr>
<td>Weight tradables in CES</td>
<td>$\omega = 0.45$</td>
<td>Share of tradable output=45%</td>
</tr>
<tr>
<td>Discount factor</td>
<td>$\beta = 0.93$</td>
<td>Average NFA-GDP ratio = $-32.0%$</td>
</tr>
<tr>
<td>Financial shock mean</td>
<td>$\bar{\kappa} = 0.35$</td>
<td>Frequency of crises = $5.1%$</td>
</tr>
<tr>
<td>Financial shock variance</td>
<td>$\sigma_\kappa = 0.033$</td>
<td>Std dev of CA/GDP = $2.3%$</td>
</tr>
</tbody>
</table>
Government optimally accumulates more reserves

- the higher income,
- the laxer the financing conditions,
- the lower current debt.

(a) Wrt income.

(b) Wrt financing conditions.
Quantitative Analysis: Reserve & Overborrowing

Private external debt choice as function of current external debt.
Quantitative Analysis: Reserve & Overborrowing

Private external debt choice as function of current external debt.
Private external debt choice as function of current external debt.
In simulations, long-run mean of reserves (to GDP) is 4.8%, vs 10.3% in 2001-2015 Mexican data.
Experiment: suppose Mexico in laissez-faire until 2000, feed observed income shocks, financial shocks to replicate private debt path for 2001-2015, what does reserve path look like?

(a) Path of reserves.

(b) Path of private debt.
Quantitative Analysis: Cross-sectional Implications

Experiment: simulate large number (30,000) of samples of 30 years each, compute average debt, average reserves and average output for each sample

(a) Reserves and private debt.  
(b) Reserves and output.
Correlations between log changes in output, debt, and reserves

(a) Private debt and output

(b) Reserves and output

Fact 4: Reserves vs Taxes on debt
Conclusion

- Propose new theory of reserve accumulation based on a macroprudential motive

- Theory can account for
  - sizable reserve holding,
  - increasing reserves post EM crisis episodes of the 1990s,
  - positive association between reserves and private external debt,
  - positive correlation between accumulation of reserves and private external debt and real GDP growth
• Data source: International Debt Statistics from the World Bank.

• Private external debt is non-publicly guaranteed external debt.

• Country list (26): Argentina, Brazil, Cameroon, Colombia, Costa Rica, Dominican Republic, Ecuador, Egypt, El Salvador, Ghana, Guatemala, Honduras, India, Kenya, Malaysia, Mexico, Morocco, Nigeria, Pakistan, Peru, Philippines, South Africa, Sri Lanka, Thailand, Tunisia and Turkey.
### Table 1: Panel regressions of Reserves to GDP on Private External Debt to GDP (in logs)

<table>
<thead>
<tr>
<th></th>
<th>Reserves</th>
<th>Reserves</th>
<th>Reserves</th>
<th>Reserves</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Private External Debt</strong></td>
<td>0.183***</td>
<td>0.176***</td>
<td>0.0526***</td>
<td>0.0553***</td>
</tr>
<tr>
<td></td>
<td>(0.0237)</td>
<td>(0.0227)</td>
<td>(0.0203)</td>
<td>(0.0207)</td>
</tr>
<tr>
<td><strong>Publicly Guaranteed Debt</strong></td>
<td>-0.450***</td>
<td>-0.0379</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0480)</td>
<td>(0.0541)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>GDP Growth Rate</strong></td>
<td>0.00254</td>
<td>-0.000146</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.00194)</td>
<td>(0.00175)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Constant</strong></td>
<td>1.691***</td>
<td>3.118***</td>
<td>1.027***</td>
<td>1.139***</td>
</tr>
<tr>
<td></td>
<td>(0.117)</td>
<td>(0.193)</td>
<td>(0.138)</td>
<td>(0.210)</td>
</tr>
<tr>
<td><strong>Observations</strong></td>
<td>874</td>
<td>874</td>
<td>874</td>
<td>874</td>
</tr>
<tr>
<td><strong>Countries</strong></td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td><strong>Pooled OLS/ Fixed Effects</strong></td>
<td>Pooled</td>
<td>Pooled</td>
<td>FE</td>
<td>FE</td>
</tr>
</tbody>
</table>

*Note: Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$*
Recursive decentralized problem

Given exogenous state $s = (y^T, \kappa)$, household solves:

$$V^R(b, B, A, s) = \max_{b', c^T, c^N} \frac{c(c^T, c^N)^{1-\sigma}}{1-\sigma} + \beta \mathbb{E}_{s'|s} V^R(b', B', A', s')$$

Subject to:

$$b' + c^T + p^N(B, A, s)c^N = y^T + p^N(B, A, s)y^N + Rb + T(B, A, s)$$

$$b' \geq -\kappa(y^T + p^N(B, A, s)y^N)$$

$$B' = \Gamma(B, A, s); \quad A' = \Lambda(B, A, s)$$

Government chooses $A'$ to maximize household’s welfare taking its policy functions as given
Recursive constrained efficient problem

Given exogenous state $s = (y^T, \kappa)$, the planner solves:

$$V^*(b, s) = \max_{b', c^T} \frac{c(c^T, y^N)^{1-\sigma}}{1-\sigma} + \beta \mathbb{E}_{s'|s} V^*(b', s)$$

Subject to:

$$c(c^T, y^N) = [\omega(c^T)^{-\eta} + (1 - \omega)(y^N)^{-\eta}]^{-\frac{1}{\eta}}$$

$$b' + c^T = y^T + Rb$$

$$b' \geq -\kappa(y^T + \frac{(1-\omega)}{\omega} (\frac{c^T}{y^N})^{\eta+1} y^N)$$
A decentralized Recursive Decentralized Equilibrium is a list of:

1. A pricing function $p^N(B, A, s)$
2. A perceived law of motion $\Gamma(B, A, s)$
3. A law of motion of $\Lambda(B, A, s)$
4. Decision rules:
   
   $\hat{b}'(b, B, A, s), \hat{c}^N(b, B, A, s), \hat{c}^T(b, B, A, s), \hat{A}'(B, A, s)$

5. A value function $\hat{V}^R(b, B, A, s)$
Recursive Decentralized Equilibrium

Such that:

1. Given \( p, \Gamma, A \), the value and policy functions, \( V^R, \hat{b}', \hat{c}^N \) and \( \hat{c}^T \), solve the household’s problem

2. The households policy function \( \hat{b}' \) is consistent with \( \Gamma \)

3. The government policy function \( \hat{A}' \) is consistent with \( \Lambda \)

4. Markets clear:

\[
y^N = \hat{c}^N(b, B, A, s)
\]

\[
y^T + RB + RA = \hat{c}^T(b, B, A, s) + \Gamma(B, A, s) + \Lambda(B, A, s)
\]
Recursive Constrained Efficient Equilibrium

A Recursive Constrained Efficient Equilibrium is a list of:

1. Decision rules: \( \tilde{b}'(b, s), \tilde{c}^N(b, s), \tilde{c}^T(b, s) \)

2. A value function \( \tilde{V}^*(b, s) \)

Such that:

1. The value and policy functions, \( \tilde{V}^*, \tilde{b}', \tilde{c}^N \) and \( \tilde{c}^T \), solve the planner’s problem

2. Markets clear:

\[
y^N = \tilde{c}^N(b, s) \\
y^T + Rb = \tilde{c}^T(b, s) + \tilde{b}'(b, s)
\]
Quantitative Analysis: Long rung simulations and equivalent tax on debt

Long run distribution of reserves and output. Reserves are procyclical, taxes are counter cyclical

(a) Reserves and output

(b) Tax on debt and output.