A Theory of Rollover Risk, Sudden Stops, and Foreign Reserves

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Inter-American Development Bank

May 11th 2015

These views are those of the authors and not necessarily those of the Board of Governors or the Federal Reserve System.
Motivation

- Emerging economies hold large foreign reserves
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- Reserves are key for understanding global imbalances
  - Bernanke (2005 Global Savings Glut speech)
    Current account deficits in the U.S. is linked to global ‘savings glut’
  - Gourinchas and Jeanne (2011)
    The capital allocation puzzle is related to reserves accumulation patterns
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- Gourinchas and Jeanne (2011)
  The capital allocation puzzle is related to reserves accumulation patterns

However, reserves holdings remain a puzzle in the literature
Why reserves remain a puzzle?

- Existing literature
  Reserves as consumption smoothing against *exogenous* crises
  So, reserves are higher/lower when crises are more/less frequent

- Evidence
  Reserves are *negatively* associated with financial crises
  Reserves are all time high but not financial crises
Why reserves remain a puzzle?

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- Evidence
  Reserves are *negatively* associated with financial crises
  Reserves are all time high but not financial crises

- *Endogenous* default ...
  Reserves increase the value of autarky $\Rightarrow$ default more likely
  Puzzle worsens in models with default
Why did emerging economies accumulate so much reserves?
This paper

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- Foreign reserves endogenously reduce crises
This paper

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  - Reserves optimally rose following the late 90s’ crises

*sudden stop: large reversal of capital inflow accompanied by a recession (Calvo)*
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  - A ‘small’ rise in rollover risk can account for the temporary outburst of sudden stops* and the subsequent rise of reserves

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- Foreign reserves endogenously reduce crises
  - Reserves optimally rose following the late 90s’ crises
  - A ‘small’ rise in rollover risk can account for the temporary outburst of sudden stops* and the subsequent rise of reserves

- But, a policy of international pooling cuts reserves substantially
  - Pooling reserves reduces rollover risk through mutual insurance

* sudden stop: large reversal of capital inflow accompanied by a recession (Calvo)
facts
Facts on reserves and sudden stops

Fact 1: **Outburst of sudden stops** in emerging economies in 1997-2001
Fact 1: Sudden stop outbursts in late 1990s

Sudden stops

- Sudden stop: sudden slowdown or reversal of capital flows (year-on-year fall in capital flows of at least 1.65 standard deviations below the mean) and a recession

- Sudden stops:
Facts on reserves and sudden stops

- Fact 1: Outburst of sudden stops in emerging economies in 1997-2001
- Fact 2: Foreign reserves in emerging economies
  - are large
  - sharply *increased since the sudden stop outbursts*
Fact 2: Reserves are large and sharply increased.
<table>
<thead>
<tr>
<th></th>
<th>Average Foreign Reserves to GDP</th>
<th>Average Foreign Reserves to External Debt Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Emerging</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Argentina</td>
<td>4.9 13.5</td>
<td>14.3 21.4</td>
</tr>
<tr>
<td>Brazil</td>
<td>4.9 8.6</td>
<td>19.5 35.3</td>
</tr>
<tr>
<td>Chile</td>
<td>20.4 16.5</td>
<td>50.9 39.0</td>
</tr>
<tr>
<td>China</td>
<td>8.4 33.2</td>
<td>54.3 271.4</td>
</tr>
<tr>
<td>Colombia</td>
<td>9.9 10.8</td>
<td>35.6 35.1</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>17.4 25.3</td>
<td>57.2 77.5</td>
</tr>
<tr>
<td>Egypt</td>
<td>20.9 19.8</td>
<td>35.2 65.5</td>
</tr>
<tr>
<td>Hungary</td>
<td>15.5 16.6</td>
<td>26.6 26.2</td>
</tr>
<tr>
<td>India</td>
<td>3.5 18.4</td>
<td>11.8 101.0</td>
</tr>
<tr>
<td>Indonesia</td>
<td>6.5 12.4</td>
<td>11.7 25.2</td>
</tr>
<tr>
<td>Korea</td>
<td>5.4 24.6</td>
<td>28.0 97.4</td>
</tr>
<tr>
<td>Malaysia</td>
<td>28.5 47.1</td>
<td>77.0 125.6</td>
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<tr>
<td>Mexico</td>
<td>4.6 8.2</td>
<td>12.2 40.9</td>
</tr>
<tr>
<td>Morocco</td>
<td>10.4 28.6</td>
<td>15.9 99.1</td>
</tr>
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<td>Pakistan</td>
<td>1.8 10.4</td>
<td>4.3 28.2</td>
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<tr>
<td>Peru</td>
<td>11.2 18.4</td>
<td>16.7 49.1</td>
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<tr>
<td>Philippines</td>
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<tr>
<td>Poland</td>
<td>6.9 14.2</td>
<td>15.9 35.8</td>
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<tr>
<td>Romania</td>
<td>4.2 18.5</td>
<td>22.7 53.9</td>
</tr>
<tr>
<td>Russia</td>
<td>3.0 23.2</td>
<td>7.3 68.5</td>
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<td>South Africa</td>
<td>1.0 7.1</td>
<td>4.7 34.9</td>
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<tr>
<td>Thailand</td>
<td>19.3 30.6</td>
<td>41.8 112.1</td>
</tr>
<tr>
<td>Turkey</td>
<td>3.9 10.9</td>
<td>13.0 25.5</td>
</tr>
<tr>
<td><strong>Advanced</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>2.1 1.7</td>
<td>3.9 1.3</td>
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<td>Germany</td>
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<td>8.7 1.5</td>
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<td>2.4 0.7</td>
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<td>United States</td>
<td>1.0 0.5</td>
<td>3.2 0.8</td>
</tr>
</tbody>
</table>
Official sector reserves holdings

Foreign Holdings of Outstanding US Treasuries

- Foreign official
- EMEs only
- Foreign private
Facts on reserves and sudden stops

- **Fact 1:** Outburst of sudden stops in emerging economies in 1997-2001
- **Fact 2:** Foreign reserves in emerging economies are large and sharply increased since the sudden stop outbursts.
- **Fact 3:** Foreign reserves in emerging economies are associated with lower probability of sudden stops.
### Table: Panel Logit Estimation across Emerging Economies

<table>
<thead>
<tr>
<th></th>
<th>1-2 years</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S.D.</td>
<td>$\delta p$</td>
<td>$\frac{\partial p}{\partial x}$</td>
</tr>
<tr>
<td><strong>Panel A: Sudden Stop Probabilities</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reserves over External Debt</td>
<td>20.16</td>
<td>-7.13***</td>
<td>-0.52***</td>
</tr>
<tr>
<td>Net Foreign Assets over GDP</td>
<td>10.07</td>
<td>-3.86*</td>
<td>0.46</td>
</tr>
<tr>
<td>Probability in percent ($p$)</td>
<td></td>
<td>11.76</td>
<td></td>
</tr>
</tbody>
</table>

Note: *, **, and *** denote significance at the 10, 5, and 1 percent level. $\frac{\partial p}{\partial x}$ is the marginal effect in percentage at “tranquil” sample mean. $s.d.(x)$ is the unconditional standard deviation of $x$ over “tranquil” times. Country fixed effects. See Gourinchas and Obstfeld (2012) for related exercise and methodology.
a theory of rollover risk, sudden stops, and reserves
Environment

First, a simple setup

- Small open economy
- Three stages $s = 0$ (initial), $1$ (interim), $2$ (final)
- Welfare maximizing government borrows short term at $s = 0$ to finance long term projects
- A continuum of foreign lenders who may choose or refuse to rollover the debt in the interim
- The fraction of lenders who can choose to rollover is random
Timeline

0 1 2

0. Govt. offers debt contract
1. Each lender chooses to lend or not
2. Each lender chooses to roll over or not

1. Govt. sets reserves and investments
2. Govt. pays the debt called with reserves or liquidation
3. Final output occurs
4. Govt. repays the rolled over debt
5. Domestic consumption

Liquidity shocks realized
Technologies à la Diamond-Dybvig

- Production and liquidation

<table>
<thead>
<tr>
<th>$s = 0$</th>
<th>$s = 1$</th>
<th>$s = 2$</th>
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<tbody>
<tr>
<td>$-K$ investment</td>
<td>$\lambda L$ liquidation</td>
<td>$A(K - L)$ final output</td>
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Technologies à la Diamond-Dybvig

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<tr>
<td>liquidation</td>
<td>liquidation</td>
<td>liquidation</td>
<td>liquidation</td>
</tr>
<tr>
<td>final output</td>
<td>final output</td>
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- Reserves

<table>
<thead>
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</thead>
<tbody>
<tr>
<td>initial reserves</td>
<td>$-R_1$</td>
<td>$R_1$</td>
<td>$-R_2$</td>
</tr>
<tr>
<td>interim reserves</td>
<td>$-R_1$</td>
<td>$R_1$</td>
<td>$R_2$</td>
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<tr>
<td>final output</td>
<td>final output</td>
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Interim liquidity shocks and rollover decision

- A random measure \( (1 - \varphi) \) of foreign lenders choose
  - whether to rollover the debt \( (\psi_i = 0) \)
  - or to call the loan \( (\psi_i = 1) \)

- The other \( \varphi \) foreign lenders must call the loan \( (\psi_i = 1) \)

- The aggregate shock \( \varphi \) has a c.d.f. \( F_\sigma(\varphi) \equiv 1 - (1 - \varphi)^{\frac{1}{\sigma}} \)
High and Low Aggregate uncertainty

\[ F_{\sigma_L} \quad F_{\sigma_H} \]

C.d.f.

0 \quad 1 \quad \varphi

Hur and Kondo (Pitt and FRB)
A random measure \((1 - \varphi)\) of foreign lenders choose
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\(\Rightarrow\) This creates a debt rollover risk
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⇒ This creates a debt rollover risk

- The total fraction of lenders calling the debt is \(\psi \equiv \int \psi_i di\)
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\[\Rightarrow\] This creates a debt rollover risk

- The total fraction of lenders calling the debt is \(\psi \equiv \int \psi_i \, di\)

- We call sudden stops when all lenders refuse to roll over: \(\psi = 1\)
Debt repayment schedule

- Debt contract can be contingent on sudden stop

<table>
<thead>
<tr>
<th>Normal times ($\psi &lt; 1$)</th>
<th>Interim payment</th>
<th>Final payment</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>$P_1$</td>
<td>$P_2$</td>
</tr>
<tr>
<td>$D$</td>
<td>$(1 + r_N)D$</td>
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Hur and Kondo (Pitt and FRB) Rollover Risk, Sudden Stops, and Reserves IADB - May 2015 17 / 31
Debt repayment schedule

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<tr>
<td>Sudden stop ($\psi = 1$)</td>
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Debt repayment schedule

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<tr>
<td>Sudden stop ($\psi = 1$)</td>
<td>$(1 + r_S)D$</td>
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- Lenders collectively have bargaining power $\theta$ during sudden stops

\[(1 + r_S)D \geq \min \left\{ (1 + r_N)D, \theta(R_1 + \lambda K) \right\}\]
An optimal debt contract is

\[ B^* = \{ R_1^*, K^*, r_N^*, r_S^*, C^*(\varphi), R_2^*(\varphi), L^*(\varphi), \psi_i^*(\varphi, \varphi_i) \} \]

which solves

\[
\max_{B} \mathbb{E}_\varphi [C(\varphi)] \\
\text{s.t. } [RF], [IR], [PC], [RP]
\]
An optimal debt contract is

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which solves

$$\max_B \mathbb{E}_\varphi [C(\varphi)]$$

s.t. $[RF]$ , $[IR]$ , $[PC]$ , $[RP]$ allocations are resource feasible

$$[RF]: \begin{cases} 
R_1 + K & \leq D \\
R_2(\varphi) + \psi(\varphi)P_1(\psi(\varphi)) & \leq R_1 + \lambda L(\varphi) \\
C(\varphi) + (1 - \psi(\varphi))P_2(\psi(\varphi)) & \leq R_2(\varphi) + A(K - L(\varphi)) \\
L(\varphi) & \in \{0, K\}
\end{cases}$$
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\]

s.t. \[ RF \], \[ IR \], \[ PC \], \[ RP \]

rollover policy is individually rational

\[ IR : V(\psi_i|\varphi, \varphi_i) \geq V(1 - \psi_i|\varphi, \varphi_i) \ \forall \varphi, \varphi_i \]

where

\[
V(\psi_i|\varphi, \varphi_i) = \begin{cases} 
P_1(\psi(\varphi)) & \text{if } \psi_i = 1 \\
1_{\varphi_i=0}P_2(\psi(\varphi)) & \text{if } \psi_i = 0
\end{cases}
\]
An optimal debt contract is

$$B^* = \{R_1^*, K^*, r_N^*, r_S^*, C^*(\varphi), R_2^*(\varphi), L^*(\varphi), \psi_i^*(\varphi, \varphi_i)\}$$

which solves

$$\max_B \mathbb{E}_\varphi [C(\varphi)]$$

s.t. $[RF], [IR], [PC], [RP]$

each lender rationally agrees to participate ex ante

$$[PC]: \mathbb{E}_\varphi [V(\psi_i|\varphi, \varphi_i)] \geq (1 + r_w)D$$
An optimal debt contract is

\[ B^* = \{ R_1^*, K^*, r_N^*, r_S^*, C^*(\varphi), R_2^*(\varphi), L^*(\varphi), \psi_i^*(\varphi, \varphi_i) \} \]

which solves

\[
\max_B \mathbb{E}_\varphi [C(\varphi)] \\
\text{s.t. } [RF], [IR], [PC], [RP]
\]

the contract is consistent with sudden stop bargaining

\[
[RP] : (1 + r_S)D \geq \min \left\{ (1 + r_N)D, \theta(R_1 + \lambda K) \right\}
\]
Proposition (1)

(i) Interim payments are made with reserves until they are depleted: 
\[ \exists \varphi_R^* \in [0, 1] \text{ s.t. } R_2^*(\varphi) > 0 \iff L^*(\varphi) = 0 \iff \varphi < \varphi_R^* \]
Proposition (1)

(i) Interim payments are made with reserves until they are depleted:
\[ \exists \varphi^*_R \in [0, 1] \text{ s.t. } R^*_2(\varphi) > 0 \iff L^*(\varphi) = 0 \iff \varphi < \varphi^*_R \]

(ii) All lenders call their loans whenever reserves are depleted:
\[ \psi(\varphi) = \begin{cases} \varphi & \forall \varphi < \varphi^*_R \\ 1 & \forall \varphi \geq \varphi^*_R \end{cases} \]
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\[\psi(\varphi) = \begin{cases} \varphi & \forall \varphi < \varphi^*_R \\ 1 & \forall \varphi \geq \varphi^*_R \end{cases}\]

(iii) Furthermore,
\[\varphi^*_R = \frac{R_1}{D} = 1 - \left[\frac{A - 1}{A - \lambda} \left(\frac{\sigma}{\sigma + 1}\right)\right]^\sigma\]
Optimal reserve holdings and sudden stops

Optimal reserves are chosen to balance: (i) the opportunity cost of idle reserves due to reduced capital investment, (ii) the reduced interest rates payments, and (iii) the lower likelihood of a crisis due.

\[
J'(\phi_R) = - (A - 1)F_\sigma(\phi_R) - r'_N(\phi_R) \int_{0}^{\phi_R} (1 - \phi)dF_\sigma(\phi)
\]

\[
+ [A - (1 + r_N(\phi_R))] (1 - \phi_R)f_\sigma(\phi_R)
\]

where

\[
r_N(\phi_R) = \frac{1 + r_W - F_\sigma(\phi_R) - [1 - F_\sigma(\phi_R)] (\lambda + (1 - \lambda)\phi_R)}{\int_{0}^{\phi_R} (1 - \phi)dF_\sigma(\phi)}
\]
Comparative statics with respect to liquidity risk

Proposition (2)

(i) The optimal reserves ratio increases with aggregate liquidity risk:
\[ \frac{\partial \varphi^*_R}{\partial \sigma} > 0 \]

(ii) The crisis probability increases with aggregate liquidity risk:
\[ \frac{\partial \Pr(\psi(\varphi) = 1|\sigma)}{\partial \sigma} > 0 \]
application to sudden stop outbursts in emerging economies in the late 1990s
Capital openness in emerging economies

![Graph showing the average Chinn-Ito Index of capital openness from 1970 to 2005. The index ranges from -1 to 0.5, with a notable increase in the late 1990s and early 2000s.](image-url)
A multi-country dynamic environment

We model a dynamic world with N “emerging” economies

- Each period $t$ embeds the stages $s = 0, 1, 2$ of the simple model
- Liquidity shocks are i.i.d. with c.d.f. $F_{\sigma_t}$
- Using cross section of shocks, beliefs about $\sigma_t$ are updated
- At the end of each period, remaining reserves can be saved for next period or consumed
Extended timeline

Govt. sets reserves and investments using loan and savings

Govt. pays the debt called with reserves or liquidation

Govt. repays rolled over debt, saves reserves, and household consumes

Liquidity shocks realized

Final output occurs

$t$

$s = 0$

belief $\rho_t$ and saved reserves

$s = 1$

update $\rho_{t+1}$ using cross section of liquidity shocks

$s = 2$

Each lender chooses to roll over or not

$t + 1$
A multi-country dynamic environment

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- Each period $t$ embeds the stages $s = 0, 1, 2$ of the simple model
- Liquidity shocks are i.i.d. with c.d.f. $F_{\sigma_t}$
- Using cross section of shocks, beliefs about $\sigma_t$ are updated
- At the end of each period, reserves can be saved for next period
- Unanticipated increase in the “rollover risk” $\sigma_t$ from $\sigma_L$ to $\sigma_H$ (increased capital mobility + globalization)
Misaligned beliefs, learning, and sudden stops

Hur and Kondo (Pitt and FRB)
Given a belief $\rho$ about the rollover risk parameter, an optimal recursive contracts solves:

$$W(R_0; \rho) = \max_B \mathbb{E}_{\phi | \rho} \left[ C(R_0, \phi; \rho) + \beta W(R'_0(R_0, \phi; \rho); \rho'(\rho, \phi)) \right]$$

s.t. 

$$[RF], [IR], [PC], [RP]$$

where $R_0$ is the incoming level of reserves
results
## Calibration

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
<th>Target/Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount factor</td>
<td>$\beta$</td>
<td>0.935 sudden stop probability pre-1997 &amp; post-2002 (.25 %)</td>
</tr>
<tr>
<td>Rollover risk parameters</td>
<td>$\sigma_L$</td>
<td>0.05 median reserves-to-external debt liabilities</td>
</tr>
<tr>
<td></td>
<td>$\sigma_H$</td>
<td>0.185 in EMEs pre-1997 (17%), post-2002 (41%)</td>
</tr>
<tr>
<td>Bargaining parameter</td>
<td>$\theta$</td>
<td>0.83 average haircut in sovereign defaults (30%)</td>
</tr>
<tr>
<td>World interest rate</td>
<td>$r_W$</td>
<td>0.01 risk-free rate</td>
</tr>
<tr>
<td>Divestment parameter</td>
<td>$\lambda$</td>
<td>0.75 -</td>
</tr>
<tr>
<td>Productivity</td>
<td>$A$</td>
<td>1.2 -</td>
</tr>
<tr>
<td>Number of economies</td>
<td>$N$</td>
<td>23 number of emerging economies in sample</td>
</tr>
</tbody>
</table>
Sudden stop outbursts

Number of Sudden Stops

1990–1996

1997–2001

2002–2007

Hur and Kondo (Pitt and FRB)

Rollover Risk, Sudden Stops, and Reserves

IADB - May 2015 26 / 31
Sudden stop outbursts with regional learning

1990–1996

1997–2001

2002–2007

Number of Sudden Stops
### Results

<table>
<thead>
<tr>
<th></th>
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</tr>
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<tbody>
<tr>
<td><strong>Data</strong></td>
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<tr>
<td>Reserves-to-External Debt Liabilities</td>
<td>0.17</td>
<td>0.33</td>
<td>0.41</td>
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<tr>
<td>Sudden Stops</td>
<td>3</td>
<td>10</td>
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<td><strong>Model (1 region)</strong></td>
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<tr>
<td>Reserves-to-External Debt Liabilities</td>
<td>0.17</td>
<td>0.39</td>
<td>0.41</td>
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<tr>
<td>Sudden Stops</td>
<td>1.48</td>
<td>5.93</td>
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<td>Sudden Stop Probabilities (percent)</td>
<td>0.23</td>
<td>1.29</td>
<td>0.25</td>
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<td><strong>Model (3 regions)</strong></td>
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<tr>
<td>Reserves-to-External Debt Liabilities</td>
<td>0.17</td>
<td>0.38</td>
<td>0.41</td>
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<tr>
<td>Sudden Stops</td>
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<td>10.39</td>
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<td>Sudden Stop Probabilities (percent)</td>
<td>0.21</td>
<td>2.16</td>
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A mutual insurance mechanism may substantially reduce reserves

<table>
<thead>
<tr>
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<th>2002-2007</th>
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<tbody>
<tr>
<td>Rollover risk</td>
<td>$\sigma_H$</td>
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<tr>
<td>Individual reserves allocation (over liabilities)</td>
<td>$\varphi^*_R$</td>
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<tr>
<td>Coordinated reserves allocation (over liabilities)</td>
<td>$\varphi^C_R$</td>
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</table>
Did rollover risk vanish in the Euro periphery?

Euro Periphery behaved like EMEs 1990-1996 but not after.

![Bar chart showing foreign reserves over external debt liabilities in percent of external debt for emerging economies, advanced economies, and euro area periphery across two periods: 1990−1996 and 2002−2007.](chart.png)
Did rollover risk vanish in the Euro periphery?

Euro Periphery behaved like EMEs 1990-1996 but not after.

Change in rollover risk? anticipated mutual insurance? or oversight?
Conclusion

- We explicitly model the rollover decision of lenders
- Reserves and sudden stop risk are endogenous in this theory
- A small rise in rollover risk combined with learning can explain
  - the outburst of sudden stops in emerging economies
  - the rise in reserves and resilience to sudden stops ever since
- A mutual insurance arrangement may substantially cut reserves
thank you.
appendix
Reserves and spreads during the GFC

Y-o-Y changes in reserves to GDP

Korea  Mexico  Russia  VIX

Rollover Risk, Sudden Stops, and Reserves

Hur and Kondo (Pitt and FRB)
Reserves and imbalances: US Treasuries

Foreign Holdings of Outstanding US Treasuries

- Foreign official
- EMEs only
- Foreign private

Motivation

Hur and Kondo (Pitt and FRB)
Rollover Risk, Sudden Stops, and Reserves
Sudden stops

- Sudden stop: sudden slowdown or reversal of capital flows (year-on-year fall in capital flows of at least 1.65 standard deviations below the mean) and a recession

- Sudden stops:
  - Turkey (1994),
  - Argentina, Mexico (1995),
  - Korea, Thailand (1997),
  - Czech Republic, Indonesia, Philippines (1998),
  - Chile, Peru, Russia (1999),
  - Argentina, Turkey (2001).
The list of emerging economies includes:
Argentina, Brazil, Chile, China, Colombia, the Czech Republic, Egypt, Hungary, India, Indonesia, Malaysia, Mexico, Morocco, Pakistan, Peru, Philippines, Poland, Romania, Russia, South Africa, South Korea, Thailand, and Turkey
Foreign reserves are constructed as Total reserves minus Gold.
This includes convertible foreign exchange, SDR holdings, and IMF reserve position.
### Table: Detailed Foreign Reserves

<table>
<thead>
<tr>
<th></th>
<th>Average Foreign Reserves to GDP</th>
<th>Average Foreign Reserves to External Debt Liabilities</th>
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<tbody>
<tr>
<td><strong>Emerging</strong></td>
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<tr>
<td>Argentina</td>
<td>4.9</td>
<td>13.5</td>
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<tr>
<td>Brazil</td>
<td>4.9</td>
<td>8.6</td>
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<td>Chile</td>
<td>20.4</td>
<td>16.5</td>
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<tr>
<td>China</td>
<td>8.4</td>
<td>33.2</td>
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<tr>
<td>Colombia</td>
<td>9.9</td>
<td>10.8</td>
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<tr>
<td>Czech Republic</td>
<td>17.4</td>
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<td>Egypt</td>
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<tr>
<td>Hungary</td>
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<td>16.6</td>
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<tr>
<td>India</td>
<td>3.5</td>
<td>18.4</td>
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<tr>
<td>Indonesia</td>
<td>6.5</td>
<td>12.4</td>
</tr>
<tr>
<td>Korea</td>
<td>5.4</td>
<td>24.6</td>
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<tr>
<td>Malaysia</td>
<td>28.5</td>
<td>47.1</td>
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<tr>
<td>Mexico</td>
<td>4.6</td>
<td>8.2</td>
</tr>
<tr>
<td>Morocco</td>
<td>10.4</td>
<td>28.6</td>
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<tr>
<td>Pakistan</td>
<td>1.8</td>
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<tr>
<td>Peru</td>
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<tr>
<td>Philippines</td>
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<tr>
<td>Poland</td>
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<td>Russia</td>
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<td>South Africa</td>
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<tr>
<td>Thailand</td>
<td>19.3</td>
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<td>Turkey</td>
<td>3.9</td>
<td>10.9</td>
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<tr>
<td><strong>Advanced</strong></td>
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</tr>
<tr>
<td>France</td>
<td>2.1</td>
<td>1.7</td>
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<tr>
<td>Germany</td>
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<td>1.8</td>
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<tr>
<td>United Kingdom</td>
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<td>1.9</td>
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<tr>
<td>United States</td>
<td>1.0</td>
<td>0.5</td>
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</tbody>
</table>
An optimal recursive contracts solves:

\[
W (R_0; \rho) = \max_B \mathbf{E}_{\bar{\varphi} | \rho} \left[ C (R_0, \bar{\varphi}; \rho) + \beta W (R'_0 (R_0, \bar{\varphi}; \rho); \rho' (\rho, \bar{\varphi})) \right]
\]

s.t.

\[
[RF], [IR], [PC], [RP]
\]

allocations are resource feasible

\[
R_1 + K \leq D + R_0
\]

\[
R_2 (\varphi) + \psi (\varphi) P_1 (\psi (\varphi)) \leq R_1 + \lambda L (\varphi)
\]

\[
C (\varphi) + (1 - \psi (\varphi)) P_2 (\psi (\varphi)) \leq R_2 (\varphi) - R'_0 (\varphi) + A (K - L (\varphi))
\]

\[
L (\varphi) \in [0, K], \quad 0 \leq R_1, R_2 (\varphi), C (\varphi)
\]

\[
R'_0 (\varphi) \in [0, R_2 (\varphi)]
\]
Individual Rationality

An optimal recursive contracts solves:

\[
W(R_0; \rho) = \max_B \mathbb{E}_{\tilde{\varphi} | \rho} [C(R_0, \tilde{\varphi}; \rho) + \beta W(R'_0(R_0, \tilde{\varphi}; \rho); \rho'(\rho, \tilde{\varphi}))] \\
\text{s.t.} \quad [RF], [IR], [PC], [RP]
\]

rollover policy is individually rational

\[
[IR] : V(\psi_i | \varphi, \varphi_i) \geq V(1 - \psi_i | \varphi, \varphi_i) \quad \forall \varphi, \varphi_i
\]

where

\[
V(\psi_i | \varphi, \varphi_i) = \begin{cases} 
P_1(\psi(\varphi)) & \text{if } \psi_i = 1 \\
1_{\varphi_i=0}P_2(\psi(\varphi)) & \text{if } \psi_i = 0
\end{cases}
\]
An optimal recursive contracts solves:

$$W(R_0; \rho) = \max_B \mathbb{E}_{\tilde{\varphi} | \rho} \left[ C(R_0, \tilde{\varphi}; \rho) + \beta W(R'_0(R_0, \tilde{\varphi}; \rho; \rho'(\rho, \tilde{\varphi})) \right]$$

s.t. 

$$[RF], [IR], [PC], [RP]$$

each lender rationally agrees to participate ex ante

$$[PC]: \mathbb{E}_{\varphi} \left[ V(\psi_i | \varphi, \varphi_i) \right] \geq (1 + r_W)D$$
Renegotiation Proofness

An optimal recursive contracts solves:

\[ W(R_0; \rho) = \max_B \mathbf{E}_{\bar{\varphi} | \rho} \left[ C(R_0, \bar{\varphi}; \rho) + \beta W(R'_0(R_0, \bar{\varphi}; \rho); \rho'(\rho, \bar{\varphi})) \right] \]

s.t.

\[ [RF], [IR], [PC], [RP] \]

the contract is consistent with post-default bargaining

\[ [RP]: (1 + r_s)D \geq \min\{ (1 + r_N)D, \theta(R_1 + \lambda K) \} \]
Assume liquidity shocks are:

- i.i.d. for $1 - \gamma$ countries, but
- perfectly correlated for $\gamma$ countries

$\Rightarrow \gamma$ measures correlation shocks across countries

Optimal pooled reserves allocation is

$$\gamma \varphi^*_R + (1 - \gamma) \varphi^C_R$$