Optimal Foreign Reserves and Central Bank Policy Under Financial Stress*

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(*): : The views expressed herein are exclusively those of the authors and do not necessarily reflect the position of the Central Bank of Chile.

Introduction and Motivation

Two recent trends:

1. *Unconventional* Policy, including FX Intervention

Chile	29-Sep-08	Reserve accumulation program was terminated, U.S. dollar 1-month repo operations announced (sales of U.S. dollar spot and purchases of 1-month U.S. dollar forward contracts through competitive auctions).	Term loan and/or liquidity facilities
	10-Oct-08	Broadening of eligible collateral for money market operations to include CDs; U.S. dollar repo program extended to six months.	Expand list of collaterals
	10-Dec-08	Extension of liquidity measures for all of 2009.	Term loan and/or liquidity facilities
		Enhancement of liquidity facility through credit lines accepting a broader range of collateral for longer tenors.	Expand list of collaterals
	9-Jul-09	Monetary policy rate at lower bound, short-term liquidity facility, suspension of debt emission of long maturities.	Term loan and/or liquidity facilities

Source: Céspedes, Chang and García-Cicco (2011)

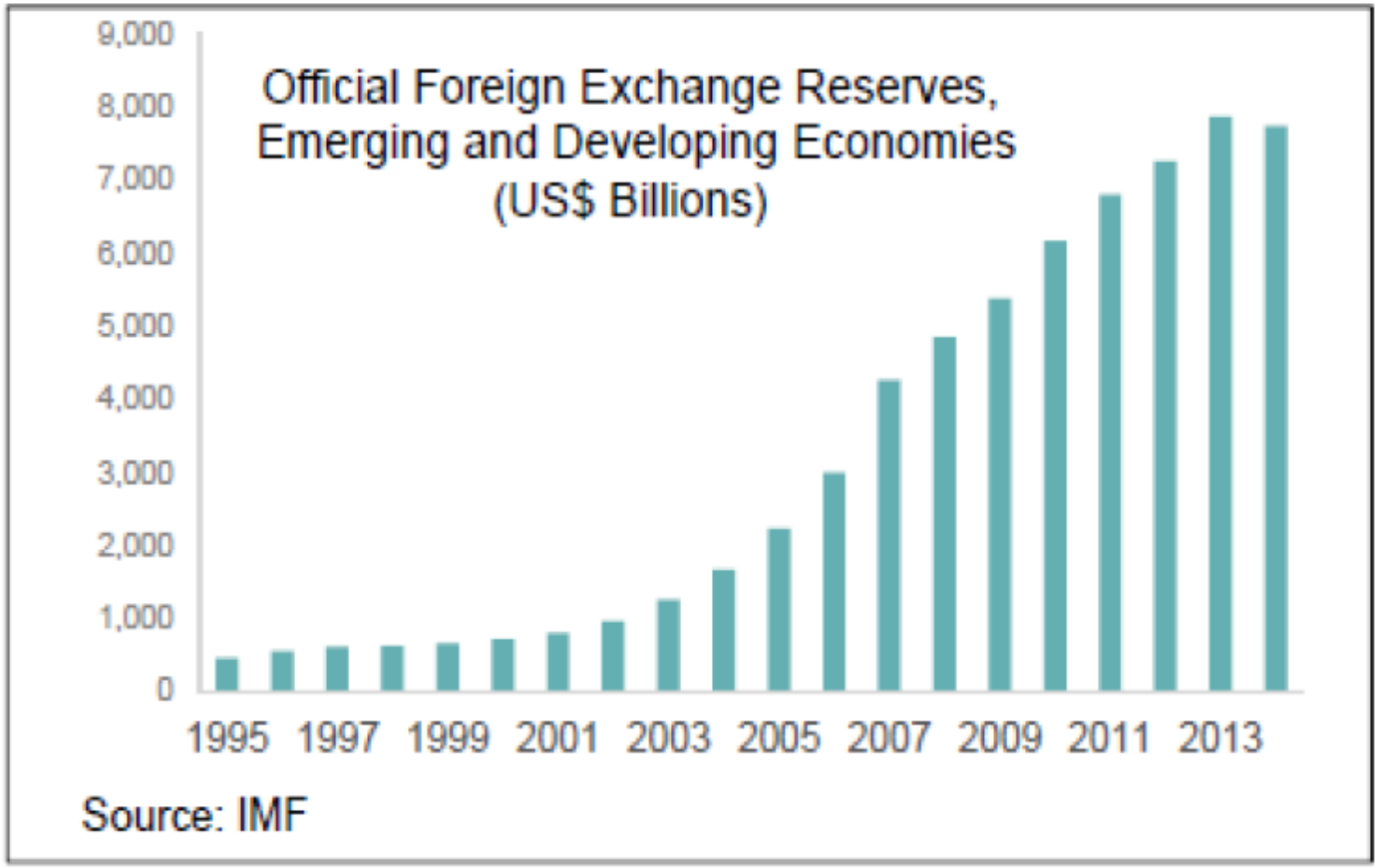
Sweden	22-Sep-08	Changed collateral requirements for credit in the Riksbank's funds transfer system (RIX).	Expand list of collaterals
	24-Sep-08	Central banks announce swap facilities with U.S. Federal Reserve.	Swap line with other central bank
	29-Sep-08	Riksbank announces new swap facility in U.S. dollars.	Term loan and/or liquidity facilities
	2-Oct-08	Riksbank lends 60 billion krona over three months.	Term loan and/or liquidity facilities
	6-Oct-08	Increased loans and longer maturity.	Term loan and/or liquidity facilities
	8-Oct-08	Changed collateral requirement for credit in RIX.	Expand list of collaterals

Source: Céspedes, Chang and García-Cicco (2011)

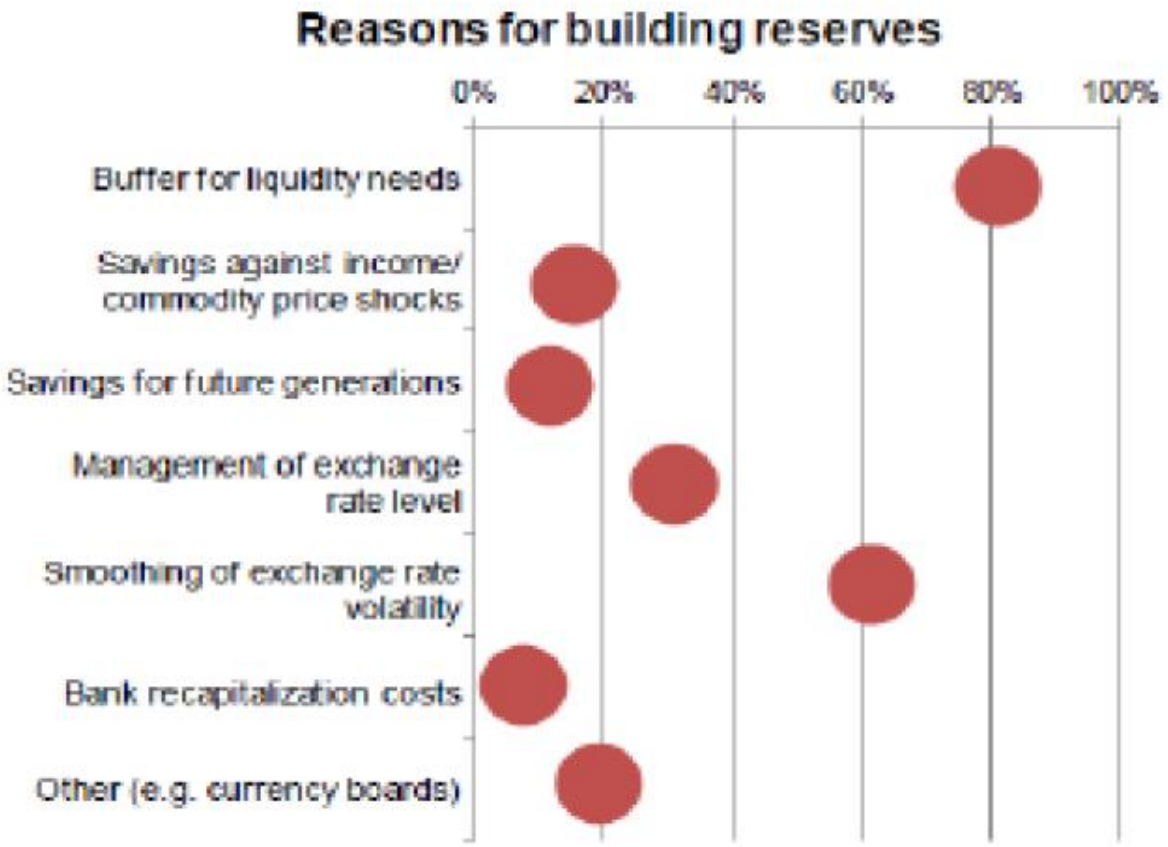
Introduction and Motivation

Two recent trends:

1. *Unconventional* Policy, including FX Intervention
2. Reserves Accumulation



From : Bunda (2016)



Source: IMF survey of reserve managers.

Introduction and Motivation

Two recent trends:

1. *Unconventional* Policy, including FX Intervention
2. Reserves Accumulation

- Both have generated lively, useful debates
- Debates, while connected, often occur in parallel

Why the Trends May Affect Each Other

- Central bankers hoard reserves to be able to intervene in case of need, i.e. a liquidity crunch
- The accumulation of reserves may change private incentives and lead to increase borrowing, making liquidity more scarce if there is a crisis

Key Questions

- What is the relation between reserves accumulation and central bank policy, especially liquidity provision, in a crisis?
- How do they interact and affect equilibrium?
- Does the financial system play a role?
- What are the determinants of optimal reserves?
- What are the costs and benefits of reserves?

Purpose of this Paper

- We build a model of financial intermediation with frictions
- In the model, external constraints can become binding endogenously and result in a credit crunch
- International reserves enable the central bank to provide international liquidity and alleviate financial constraints when they bind
- Reserves accumulation does provide incentives for private borrowing
- The optimal level of reserves is tightly linked to the impact and nature of *ex post* intervention

Some Lessons

1. Precautionary savings ameliorates but does not eliminate inefficient financial crunches
2. Optimal reserves depend on nature and degree of financial frictions and financial development
3. And on the specific policies that the central bank can use in the event of a liquidity crunch
4. An increase in *ex ante* uncertainty also justifies a buildup of reserves

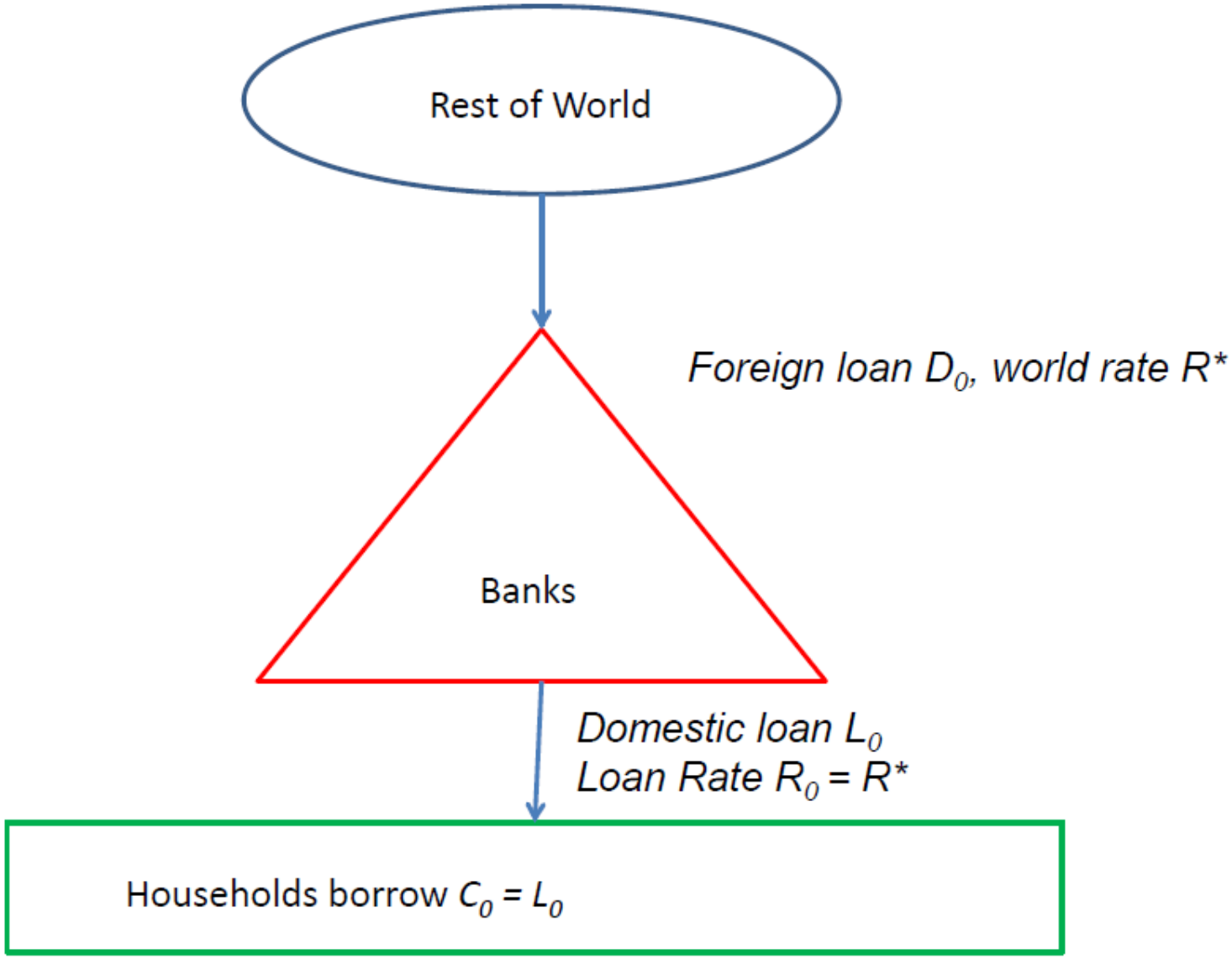
Related Literature

- Optimal Reserves: Jeanne-Korinek (2011)
- Crisis response and unconventional central banking: Gertler and Kiyotaki (2011) Céspedes, Chang, and Velasco (2017, CCV from now on)
- Foreign Exchange Intervenion: Chang (2018), Benes, Berg, Portillo and Vavra (2015), Vargas, González, and Rodríguez (2013), Cavallino (2017), Montoro and Ortiz (2017), Gabaix and Maggiori (2015).
- Macroprudential policy: Benigno, Chen, Otrok, Rebucci, and Young (2013), Jeanne and Korinek (2016)

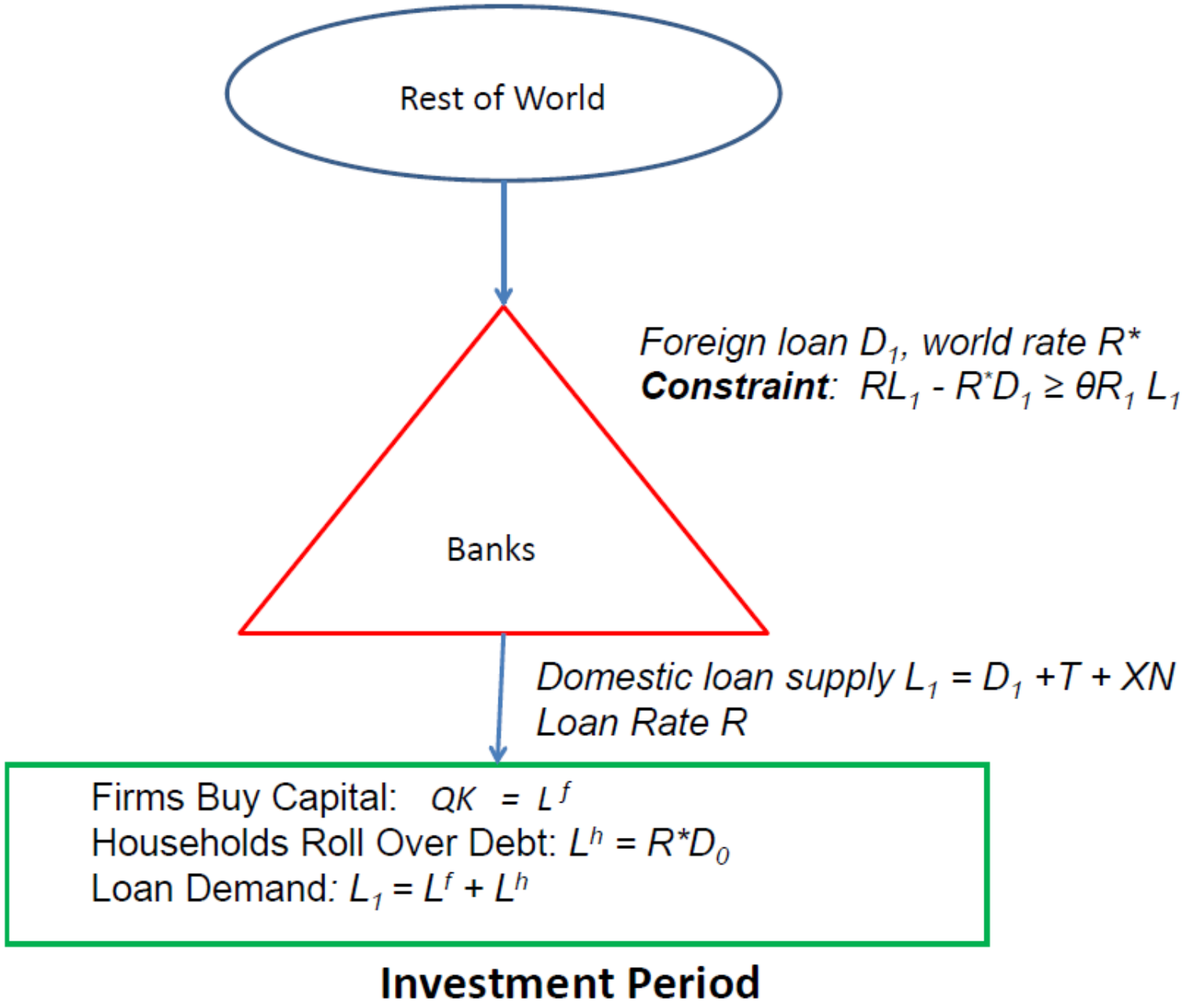
A Basic Model

Basic Model

- $t = 0, 1, 2$
- Small open economy
- Two goods: tradables (numeraire) and non tradables
- Domestic households and firms borrow from rest of the world via financial intermediaries (banks)
- Financial intermediation subject to frictions and shocks



Initial Period


Rest of World
Foreign loan D_1, world rate R^*
Constraint: $RL_1 - R^*D_1 \geq \theta R_1 L_1$
Banks
Domestic loan supply $L_1 = D_1 + T + XN$
Loan Rate R
Firms Buy Capital: $QK = L^f$
Households Roll Over Debt: $L^h = R^*D_0$
Loan Demand: $L_1 = L^f + L^h$
Investment Period

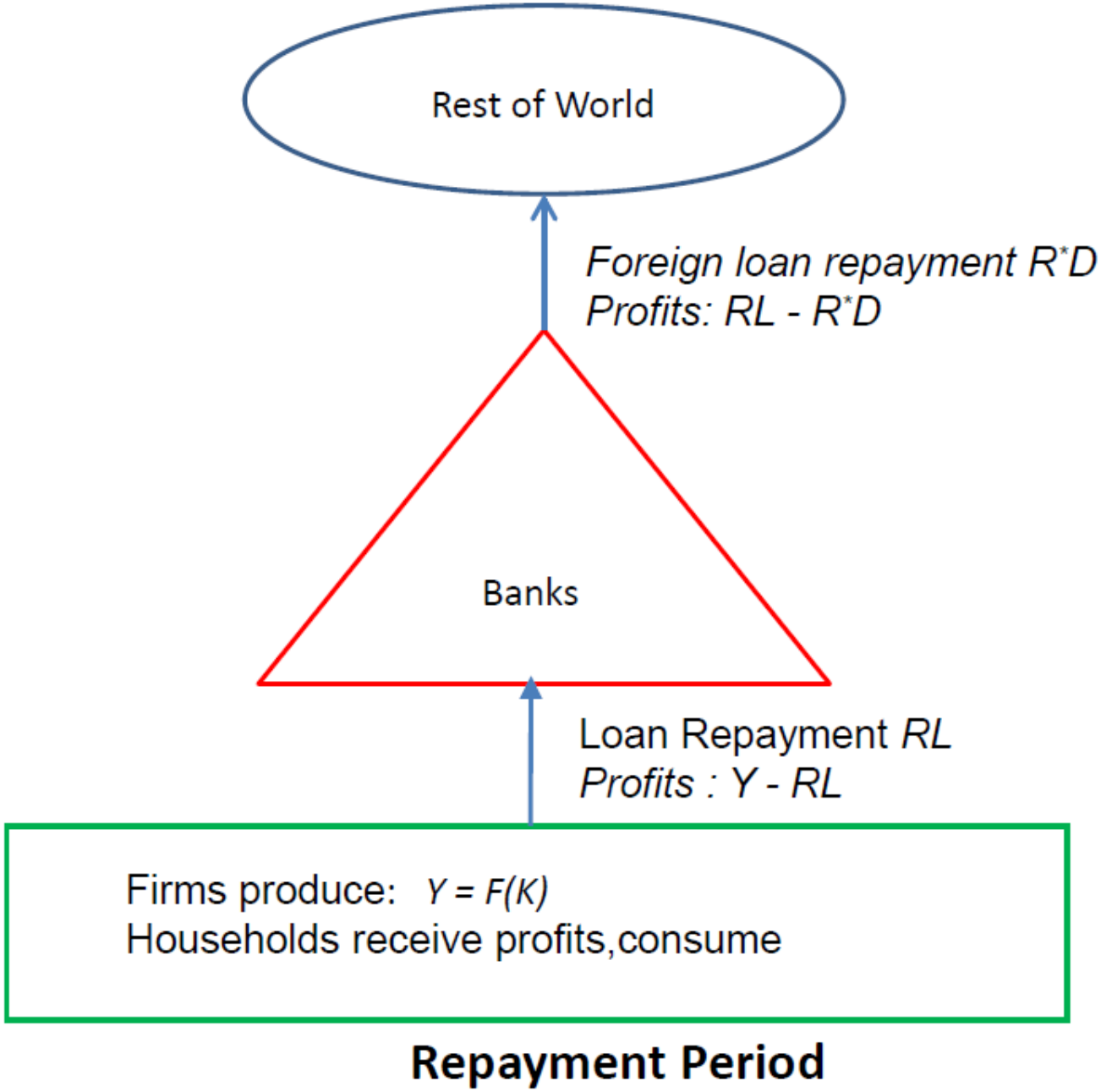
θ random variable

- International lenders will then only accept contracts that satisfy the above constraint. From this perspective, a high realization of θ may reflect an exogenous tightening of international financial conditions.

- This can be seen as a sudden stop.

- For concreteness, we assume that θ can take n values, denoted by θ(s); s = 1,…n; each with probability $\pi_s > 0$; and that this is the only source of uncertainty in the model.

- We also impose $\theta(1) = \underline{\theta} > 0$ and $\theta(n) = \bar{\theta} < 1$:


Rest of World
Foreign loan repayment R*D
Profits: RL - R*D
Banks
Loan Repayment RL
Profits : Y - RL
Firms produce: Y = F(K)
Households receive profits,consume
Repayment Period

Households

Households consume only tradables and have preferences

$$u(C_0) + \beta E C_2$$

- $t = 0$: households borrow from banks, so $C_0 = L_0^h$
- $t = 1$: they roll over their debt, and hence $L_1^h = R_0^* L_0^h$
- $t = 2$:

$$\begin{aligned} C_2 &= \Pi^b + \Pi^f - R_1 L_1^h \\ &= \Pi^b + \Pi^f - R_1 R_0^* C_0 \end{aligned}$$

Initial consumption (and debt) are then given by the first order condition:

$$u'(C_0) = \beta R_0^* E R_1$$

==> Note that if $ER_1 > R_1^*$, borrowing is inefficiently low

Production and Investment

- $t = 1$: firms buy capital K_2 at price Q_1 by borrowing from banks
- $t = 2$: they produce tradables via

$$Y_2 = AK_2^{\alpha}$$

- Profits are then

$$\Pi^f = AK_2^{\alpha} - R_1 Q_1 K_2$$

- Demand for capital is then given by:

$$\alpha AK_2^{\alpha-1} = R_1 Q_1$$

Capital

Capital is an aggregate of tradables and nontradables. For now, assume Cobb Douglas:

$$K_2 = \kappa I_H^{\gamma} I_W^{1-\gamma}$$

- Price of capital is

  $$Q_1 = X_1^{\gamma}$$

  where X_1 is the **real exchange rate** (price of nontradables in terms of tradables)
- The optimal input of nontradables is then given by:

$$I_H = \gamma \left(\frac{Q_1}{X_1} \right) K_2$$

- In equilibrium $I_{h1} = N$, so K_2 and Q_1 are pinned down by X_1

Banks

- $t = 0$: Banks borrow from ROW to lend to households:

$$D_0 = L_0 = C_0$$

- $t = 1$: Domestic loans are given by

$$\begin{aligned} L_1 &= T + X_1 N + D_1 + R_0^* L_0 - R_0^* D_0 \\ &= T + X_1 N + D_1 \end{aligned}$$

- $t = 2$: Bank profits are

$$\Pi^b = R_1 L_1 - R_1^* D_1$$

Credit Constraint

At $t = 1$, crucially, banks face the **financial constraint**

$$R_1 L_1 - R_1^* D_1 \geq \theta R_1 L_1$$

- Similar to CCV and others
- Departure: θ is a **random variable** realized at $t = 1$
- This is the only source of uncertainty (for now, at least)

Laissez Faire Equilibrium

Continuation Equilibrium

The economy from $t = 1$ on:

- $C_0 = D_0$ and θ are then given
- Version of CCV
- If $R_1 = R_1^*$, bank makes zero profits, and

$$L_1 \in [0, \frac{1}{\theta}(T + X_{1f}N)]$$

  where X_{1f} is the **frictionless** exchange rate
- If $R_1 > R_1^*$, the bank borrows as much as it can, and lends

$$L_1 = \frac{1}{1 - (1-\theta)\phi}(T + X_1 N)$$

  where $\phi = R_1 / R_1^*$ is the interest rate spread.

If financial constraints do **not** bind, $R_1 = R_1^*$, and all other variables take their frictionless (**f**) values:

$$\alpha A K_{2f}^{\alpha-1} = R_1^* Q_{1f} = R_1^* X_{1f}^{\gamma}$$

$$\frac{X_{1f} N}{I_{wf}} = \frac{\gamma}{1-\gamma}$$

$$K_{2f} = \kappa N^{\gamma} I_{wf}^{1-\gamma}$$

Hence the collateral constraint will not bind in the continuation if:

$$L_1 = R_0^* C_0 + Q_{1f} K_{2f} \leq \frac{1}{\theta}(T + X_{1f} N)$$

i.e. if $\theta \leq \hat{\theta}$, where

$$\hat{\theta} = \frac{T + X_{1f} N}{R_0^* C_0 + Q_{1f} K_{2f}}$$

- Hence, given C_0, the probability of binding constraints ("crisis") is $\Pr\{\theta > \hat{\theta}\}$
- Note that $\hat{\theta}$ is endogenous and, in particular, falls with C_0

If $\theta > \hat{\theta}$, then $R_1 > R_1^*$ and relative prices adjust to clear markets. In particular, the equilibrium exchange rate solves:

$$R_0^* C_0 + Q_1 K_2 = \frac{1}{1-(1-\theta)\phi}(T + X_1 N)$$

where the spread ϕ is given by

$$\phi = R_1 / R_1^* = \left(\frac{X_f}{X_1}\right)^{\gamma+(1-\alpha)(1-\gamma)}$$

Initial Debt

Recall that, in any continuation equilibrium

$$\begin{aligned} R_1 &= R_1^* \text{ if } \theta \leq \hat{\theta} \\ &= \rho(C_0, \theta) \text{ if } \theta > \hat{\theta} \end{aligned}$$

The Euler equation

$$u'(C_0) = \beta R_0^* E R_1$$

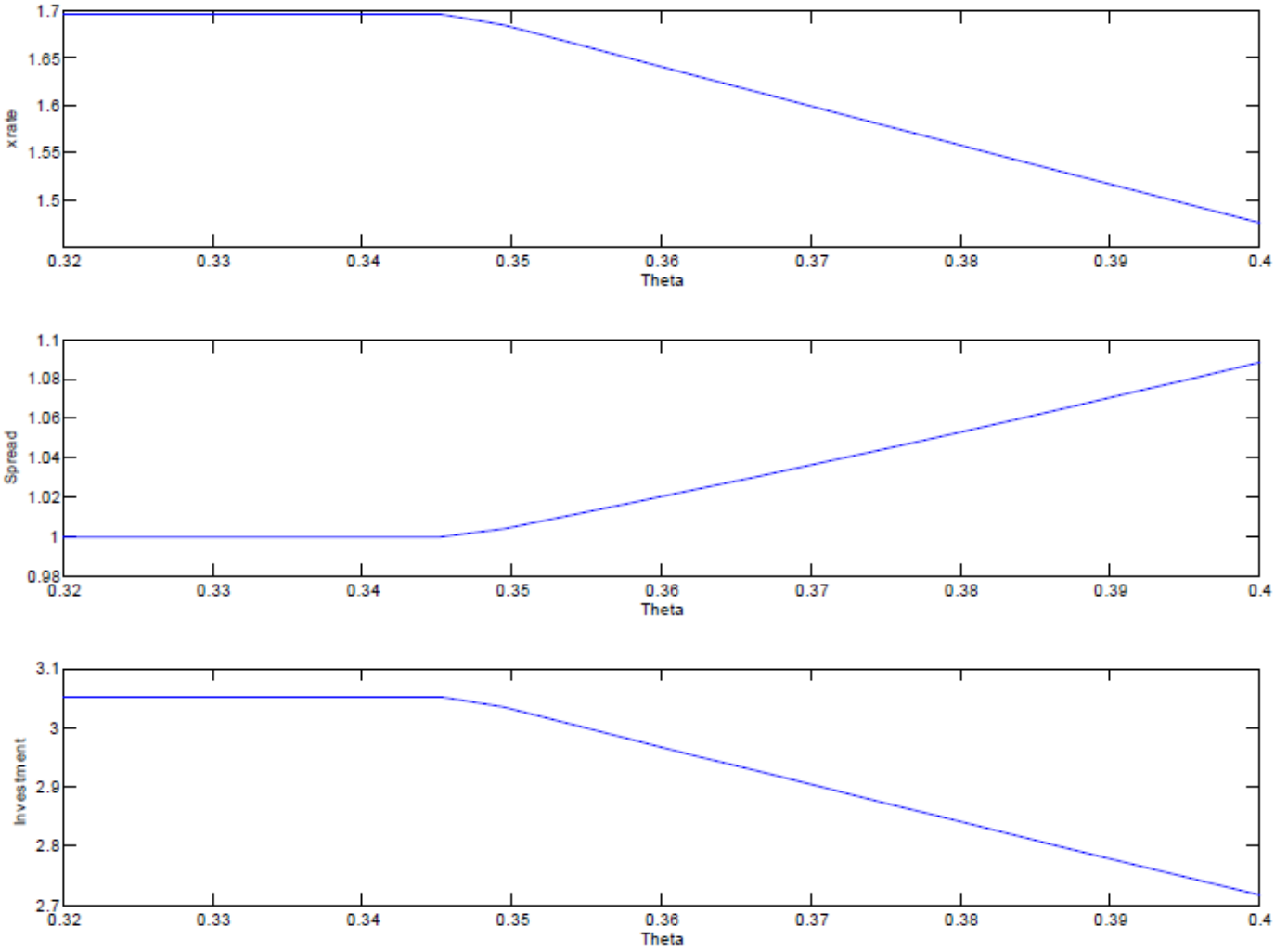
becomes

$$u'(C_0) = \beta R_0^* \left[R_1^* F(\hat{\theta}) + \int_{\hat{\theta}}^{\bar{\theta}} \rho(C_0, \theta) F(d\theta) \right]$$

where F is the cdf of θ

- This equation yields C_0
- (Note that $\hat{\theta}$ depends on C_0)

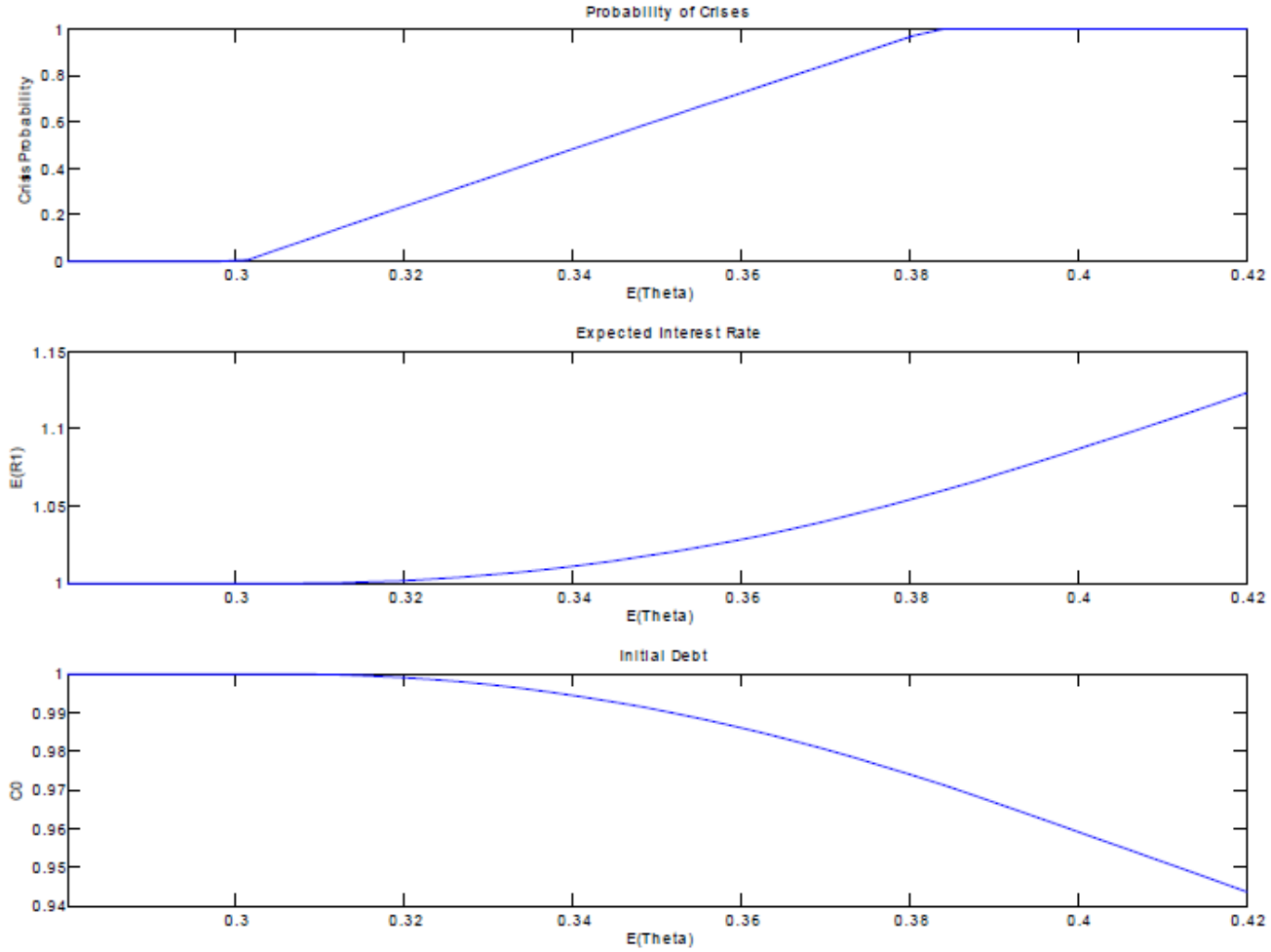
Some Implications



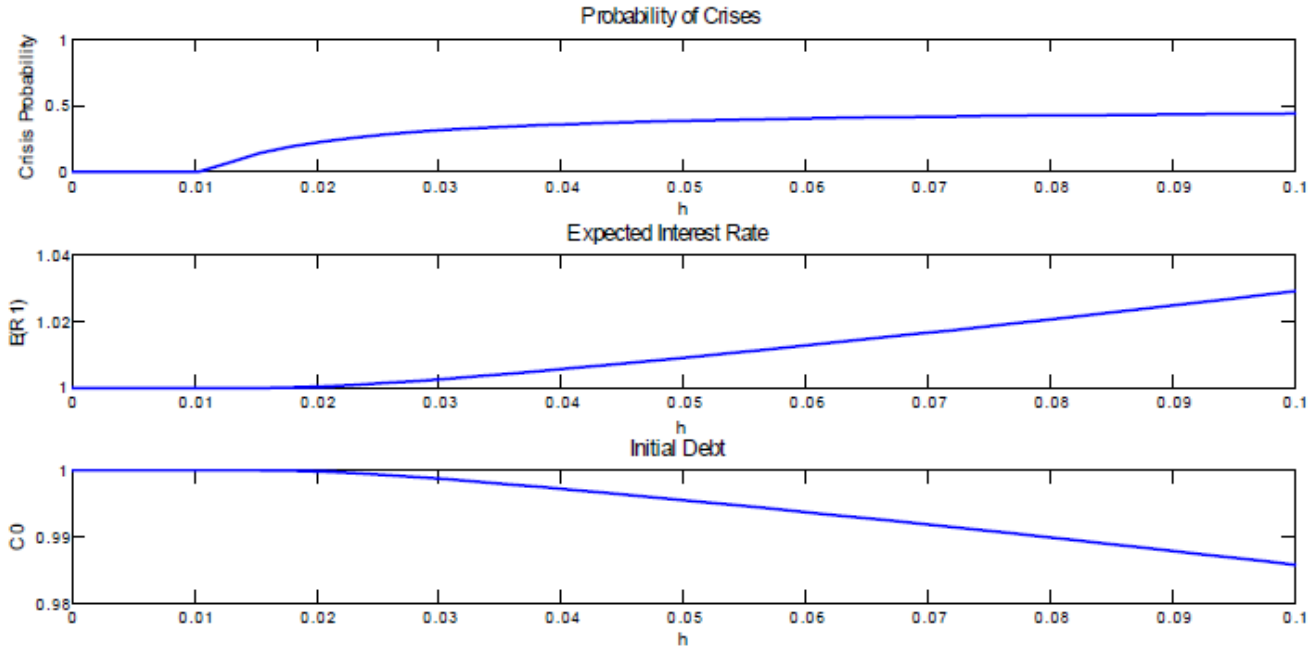
Laissez Faire: Equilibrium Continuation

Determinants of Crises

- The probability of crises is endogenous
- Some determinants are the "obvious" ones: i.e. lower productivity lead to lower $\hat{\theta}$ and higher probability of crises
- Other ones are novel
- Most interesting: an increase in uncertainty (a mean preserving spread in θ) can lead to higher crises probability



Laissez Faire and $E(\theta)$



Uncertainty and Equilibrium

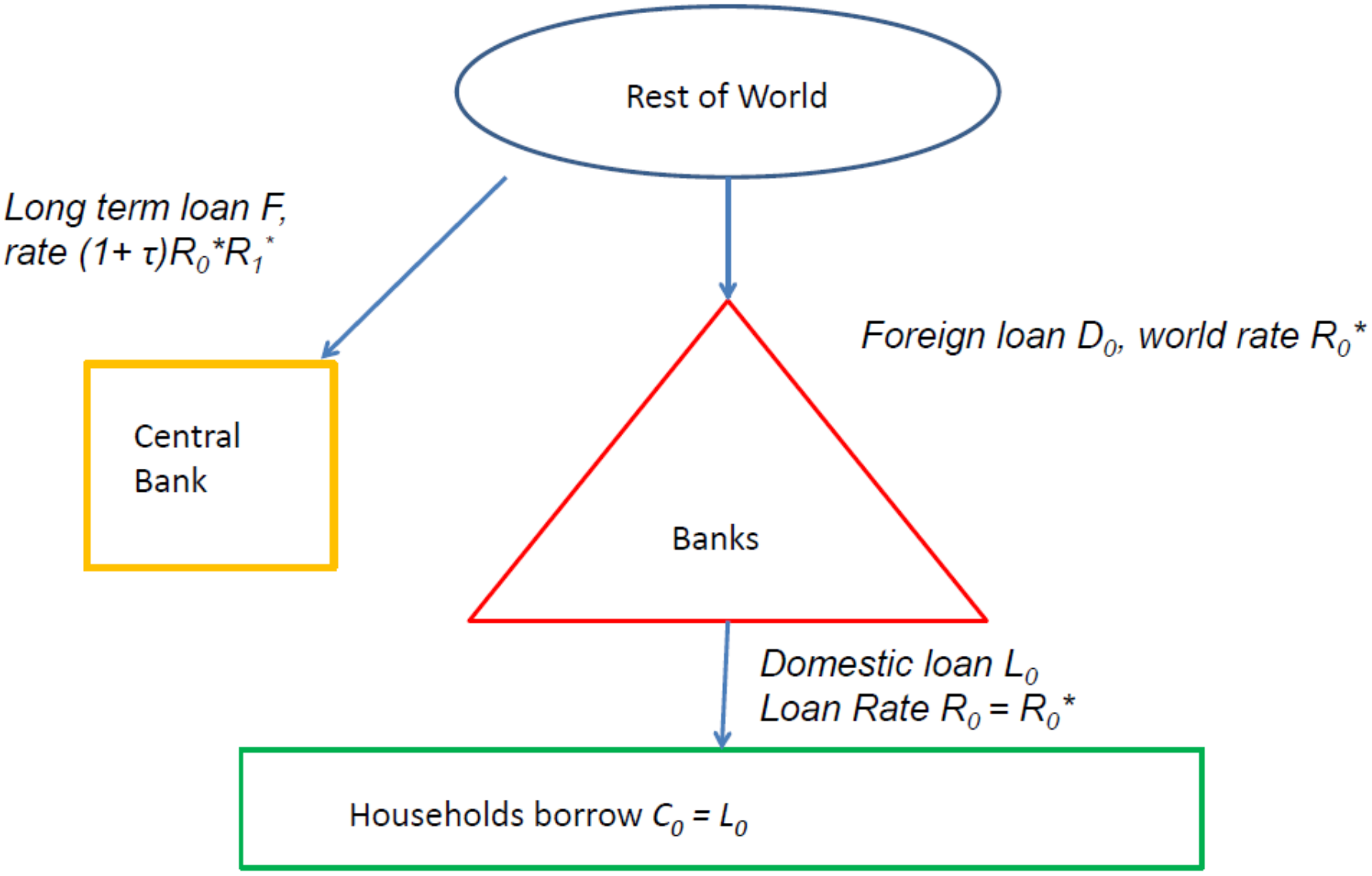
Forex Reserves and Intervention

Reserves Accumulation

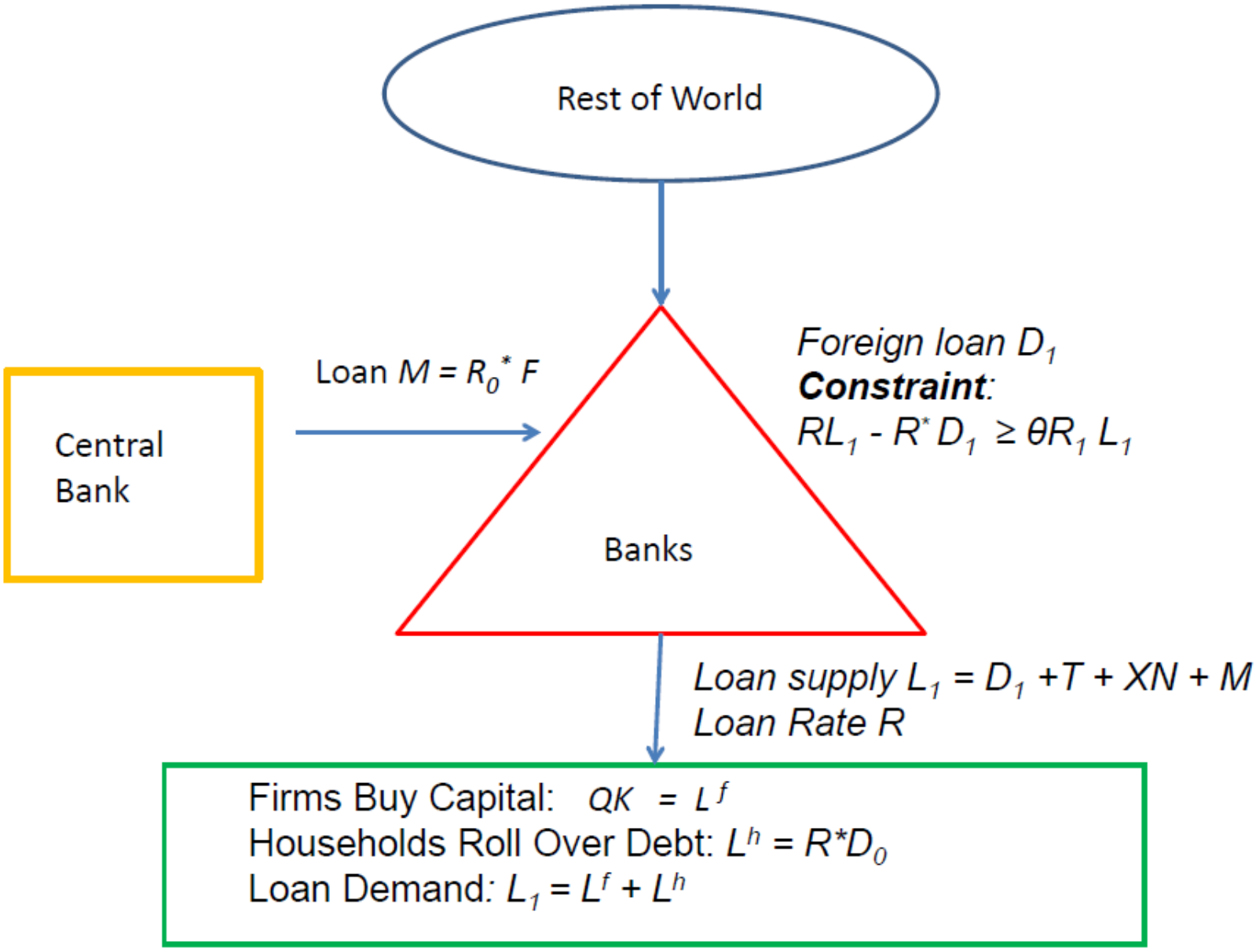
- Suppose now that, at $t = 0$, the central bank can borrow tradables in the world market.
- It has access to long term loans: if it borrows F dollars at $t = 0$, it repays $(1 + \tau)R_0^* R_1^* F$ dollars at $t = 2$, where $\tau \geq 0$ is a "term premium".
- The central bank can invest F in the world market and earn R_0^* and then R_1^*
- But in period $t = 1$ it also has the option to use $R_0^* F$ to enact policies aimed at alleviating financial frictions, if these turn out to be binding.
- We assume that the central bank cannot borrow (more) abroad at $t = 1$.

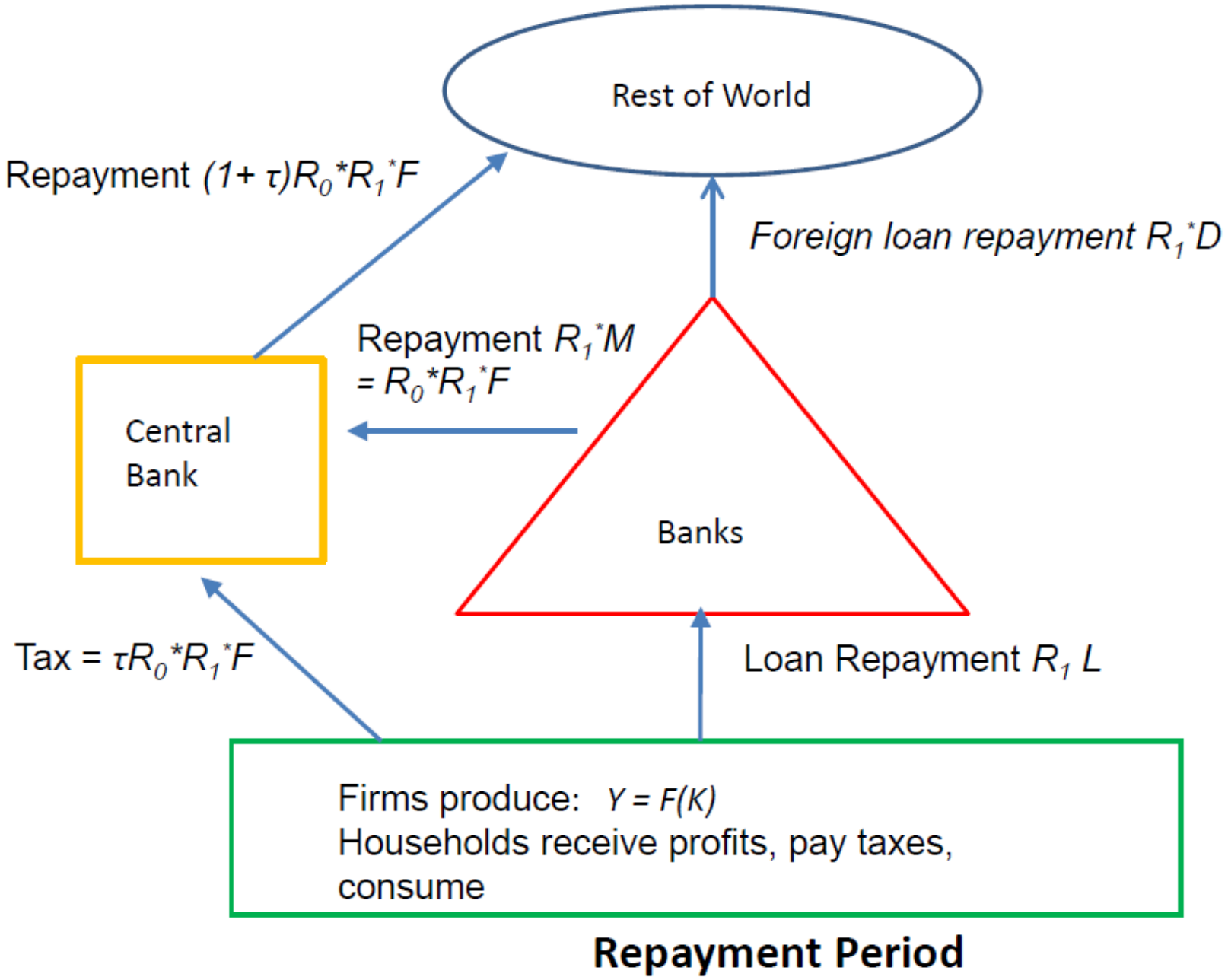
Reserves and Ex Post Policy

- Baseline: at $t = 1$, the central bank lends its reserves $R_0^* F$ to domestic banks when financial constraints bind.
- In terms of Gertler-Kiyotaki (2011), the central bank provides "liquidity facilities "
- CCV: this is equivalent to other interesting policies, and more effective than providing loans to households or firms, in particular.



Initial Period


Rest of World
Central Bank
Loan $M = R_0^* F$
Banks
Foreign loan D_1
Constraint:
$RL_1 - R^* D_1 \geq \theta R_1 L_1$
Loan supply $L_1 = D_1 + T + XN + M$
Loan Rate R
Firms Buy Capital: $QK = L^f$
Households Roll Over Debt: $L^h = R^* D_0$
Loan Demand: $L_1 = L^f + L^h$
Investment Period


Rest of World
Repayment $(1+\tau)R_0{}^*R_1{}^*F$
Foreign loan repayment $R_1{}^*D$
Repayment $R_1{}^*M$
$= R_0{}^*R_1{}^*F$
Central Bank
Banks
Tax = $\tau R_0{}^*R_1{}^*F$
Loan Repayment $R_1\,L$
Firms produce: $Y = F(K)$
Households receive profits, pay taxes, consume
Repayment Period

- As in CCV, we assume that central bank loans to domestic banks carry the world interest rate R_1^*
- And that the repayment of these loans can be enforced perfectly
- The banks ' collateral constraint then changes to

$$R_1 L_1 - R_1^*(D_1 + M) \geq \theta R_1 L_1 - R_1^* R_0^* F$$

- loan supply is now constrained by

$$L_1 \leq \frac{1}{1-(1-\theta)\phi}(T + X_1 N + R_0^* F)$$

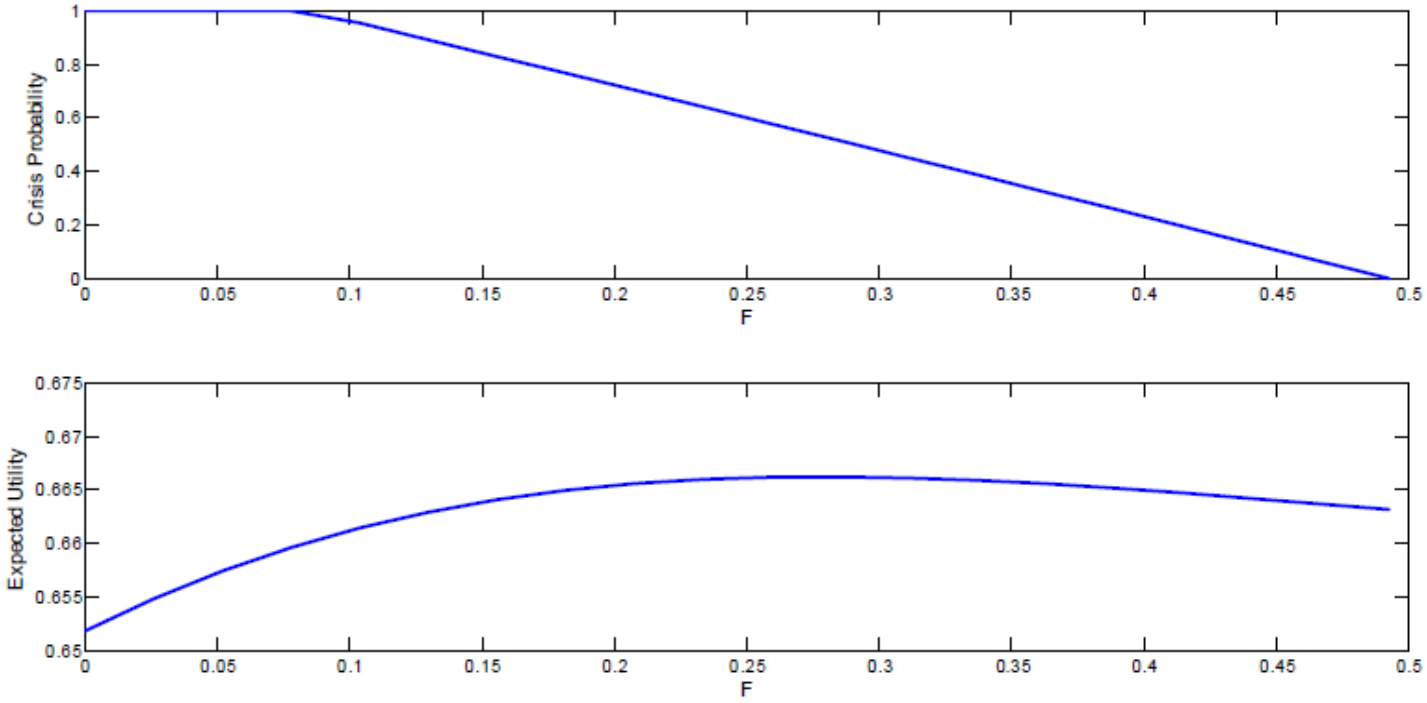
Is It Optimal to Eliminate Crises?

In this model, it is possible to eliminate crises completely: this is the case if $F = \bar{F}$, with

$$R_0^* \bar{F} = \bar{\theta}(R_0^* C_{0f} + Q_{1f} K_{2f}) - (T + X_{1f} N)$$

However, we have:

Proposition: If the term premium $\tau = 0$, F will be large enough to drive the probability of crises to zero. If $\tau > 0$, however, it is not optimal to eliminate crises completely.



Reserves, Crisis Probability, and Utility

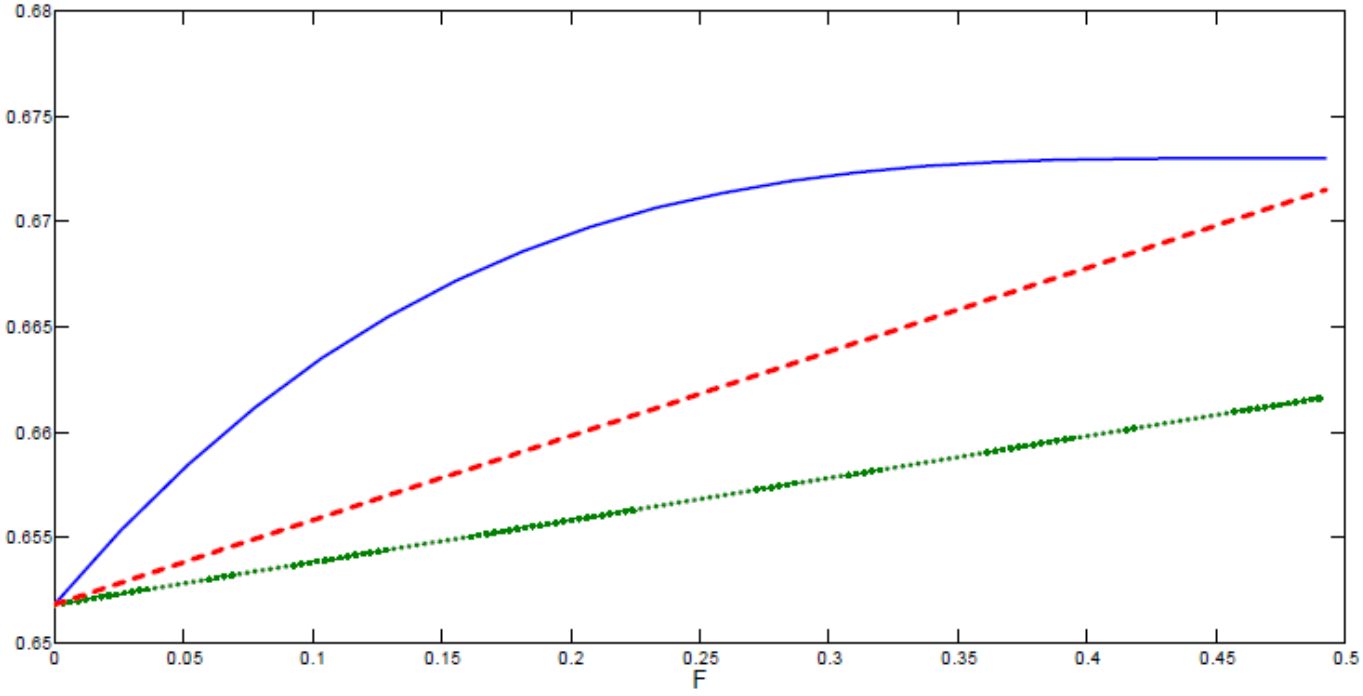
The Role of the Central Bank

- Suppose that any domestic bank can borrow, say F', for two periods, at interest cost $(1+\tau)R_0^*R_1^*$, just like the government.
- It can be shown that borrowing $F' > 0$ cannot increase bank profits, and must reduce them if $\tau > 0$.
- In other words, the private banking sector has no incentives to accumulate liquidity in this model.

Optimal Reserves: Determinants

The Cost of Reserves

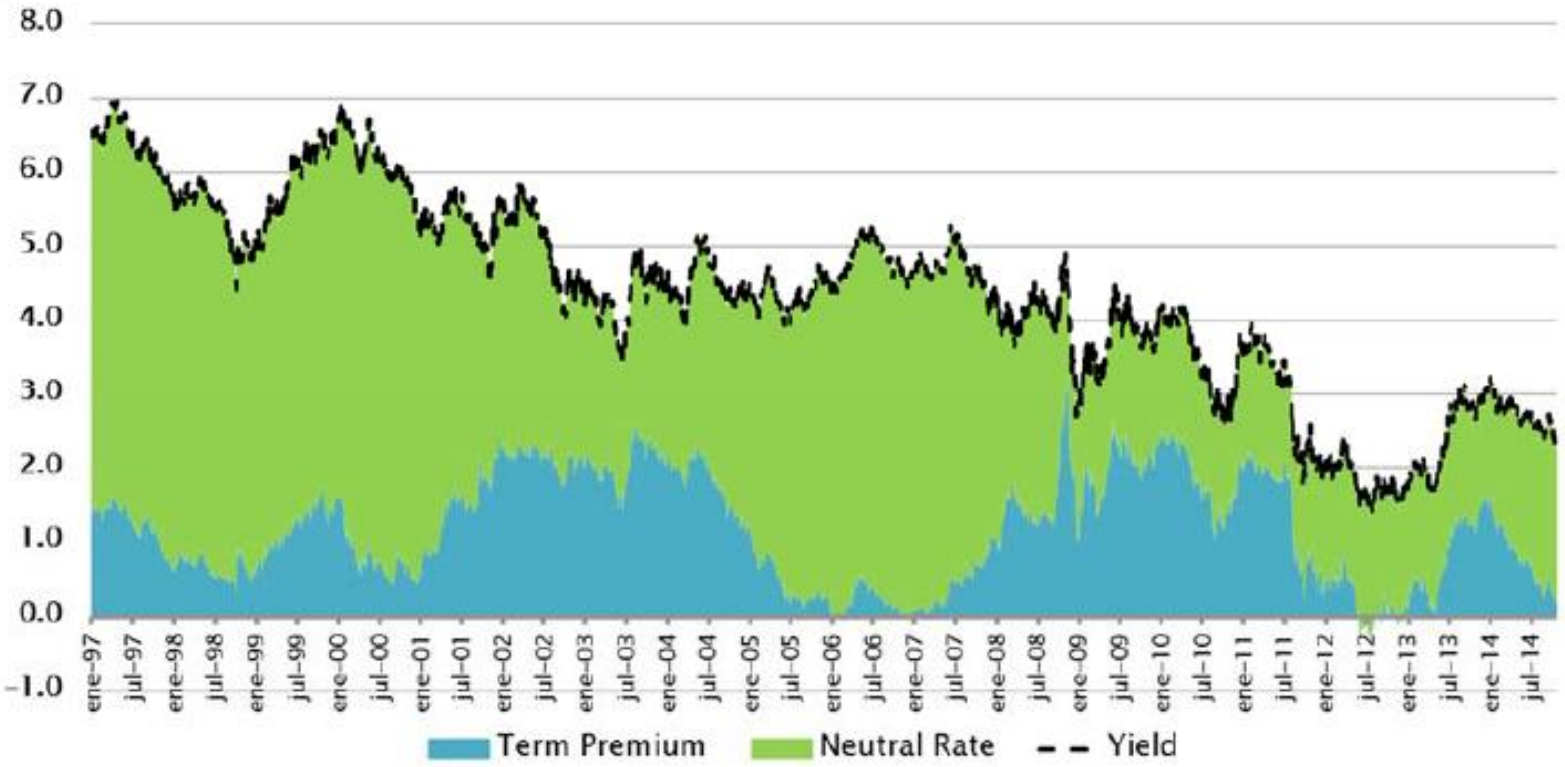
Here the relevant cost is the term premium τ



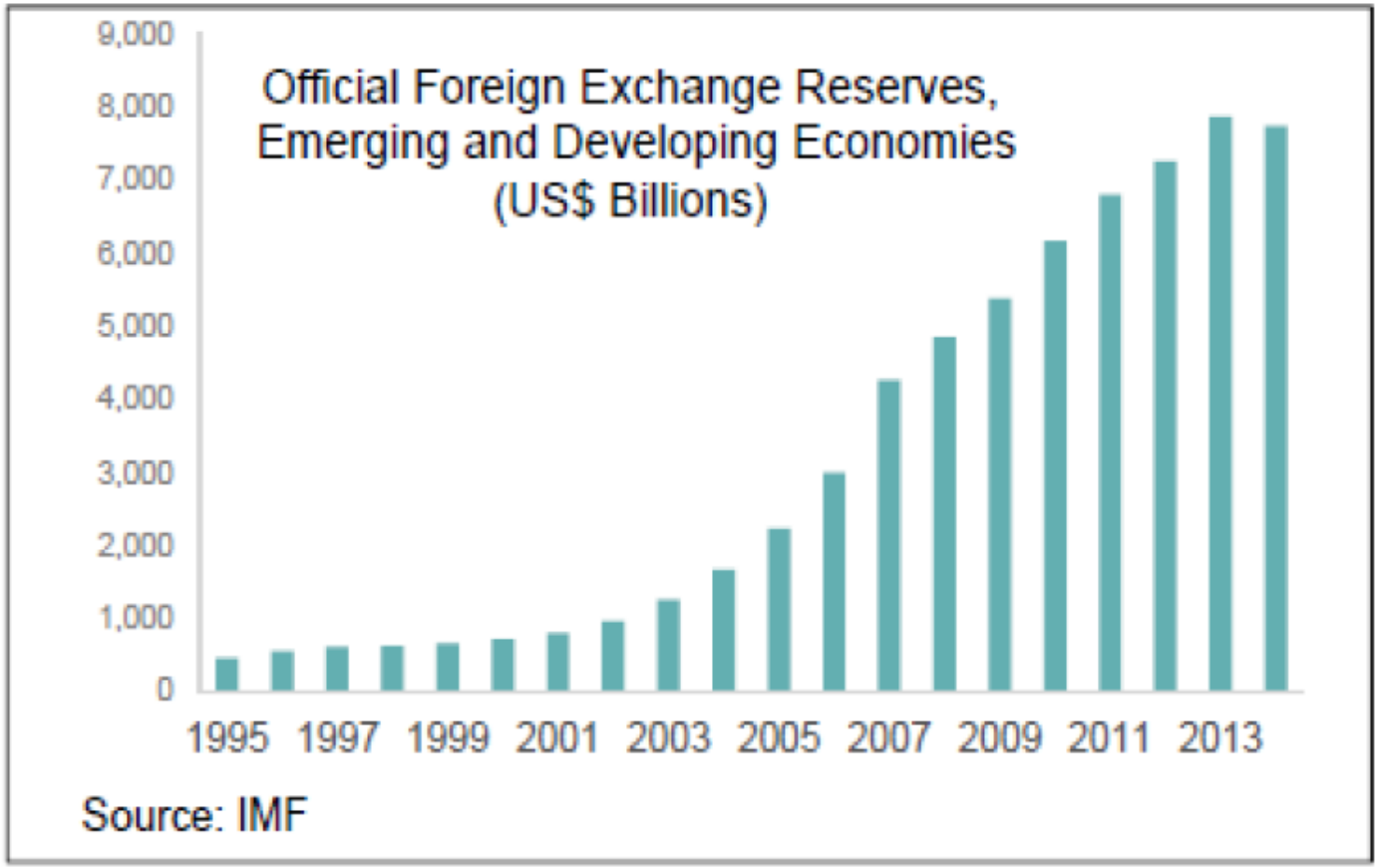
Optimal Reserves and the Term Premium

US Treasuries 10-year interest rate decomposition: 1997–2014

(Percent) Graph 2



Source: Federal Reserve Bank of New York based on Adrian et al (2013).

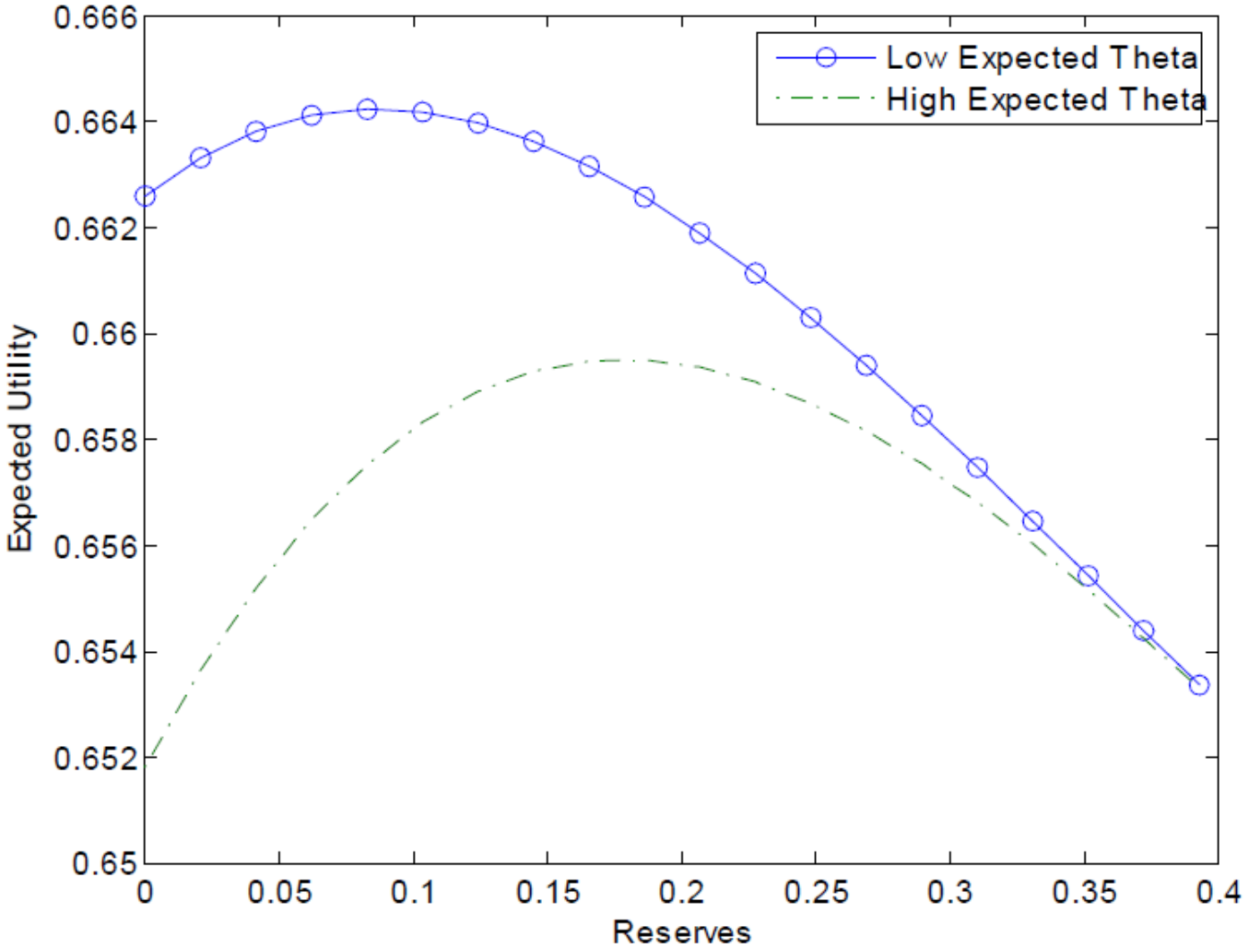


From : Bunda (2016)

Reserves and Financial Development

- Consider a fall in the mean value of θ
- This captures differences in financial development
- Correspondingly, one would expect that optimal reserves should be smaller

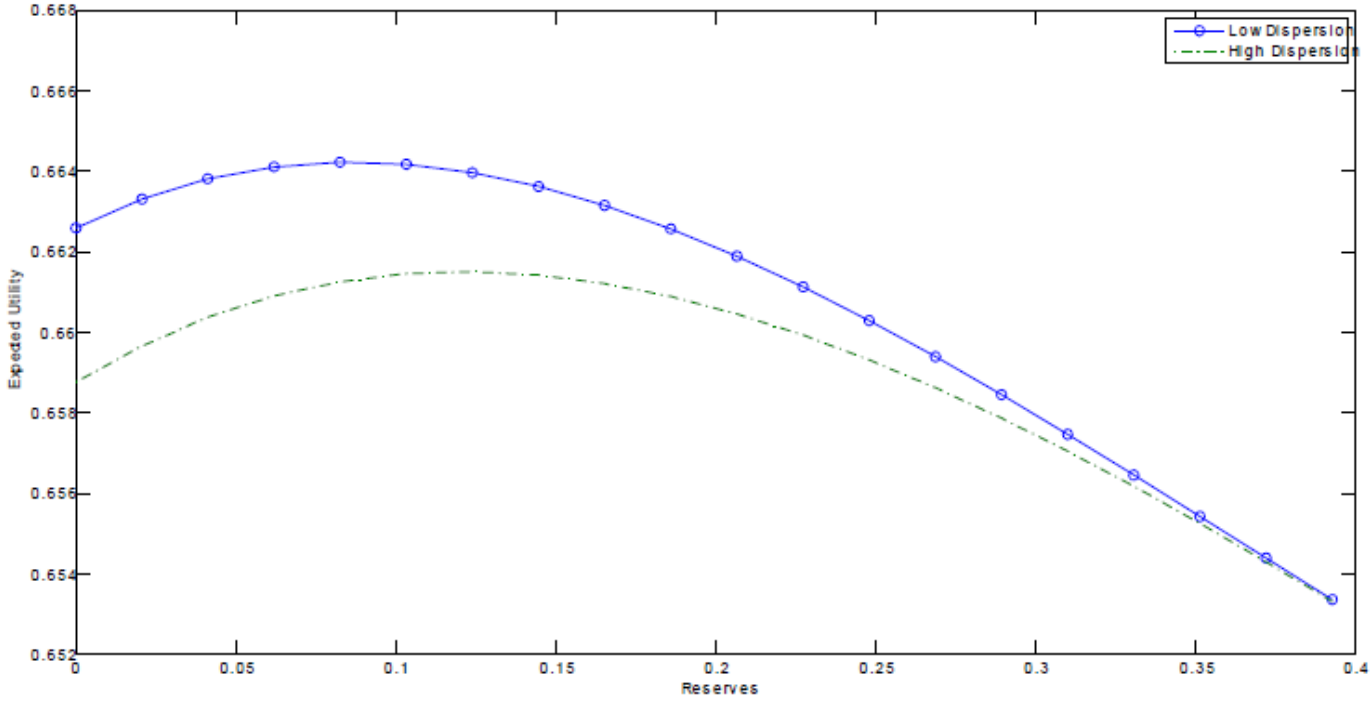
Evidence: Dominguez (2010)



Reserves and $E(\theta)$

Optimal Reserves and Uncertainty

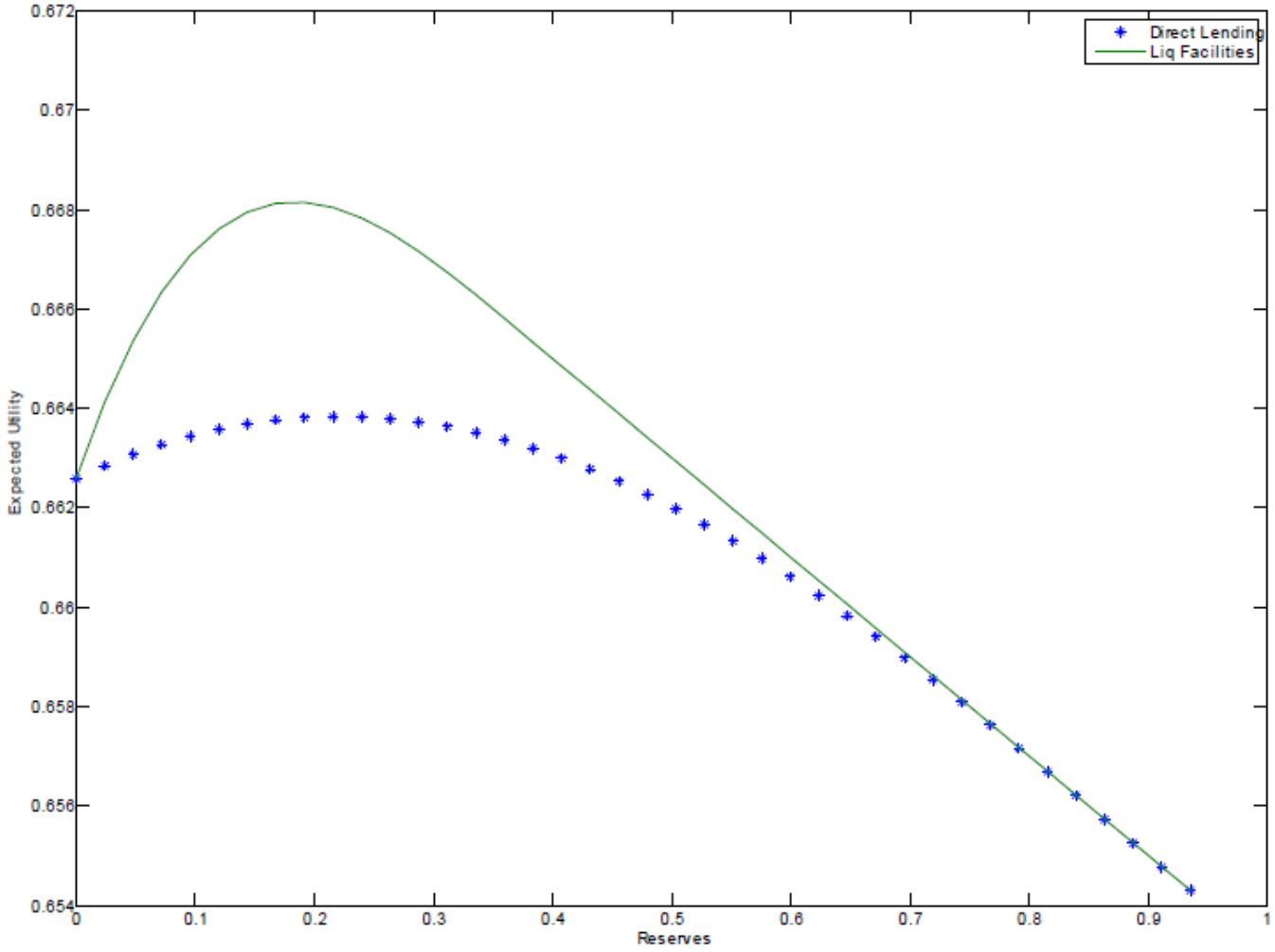
- A mean preserving spread of θ leads to higher reserves
- This is in line with intuition, and with observed experiences



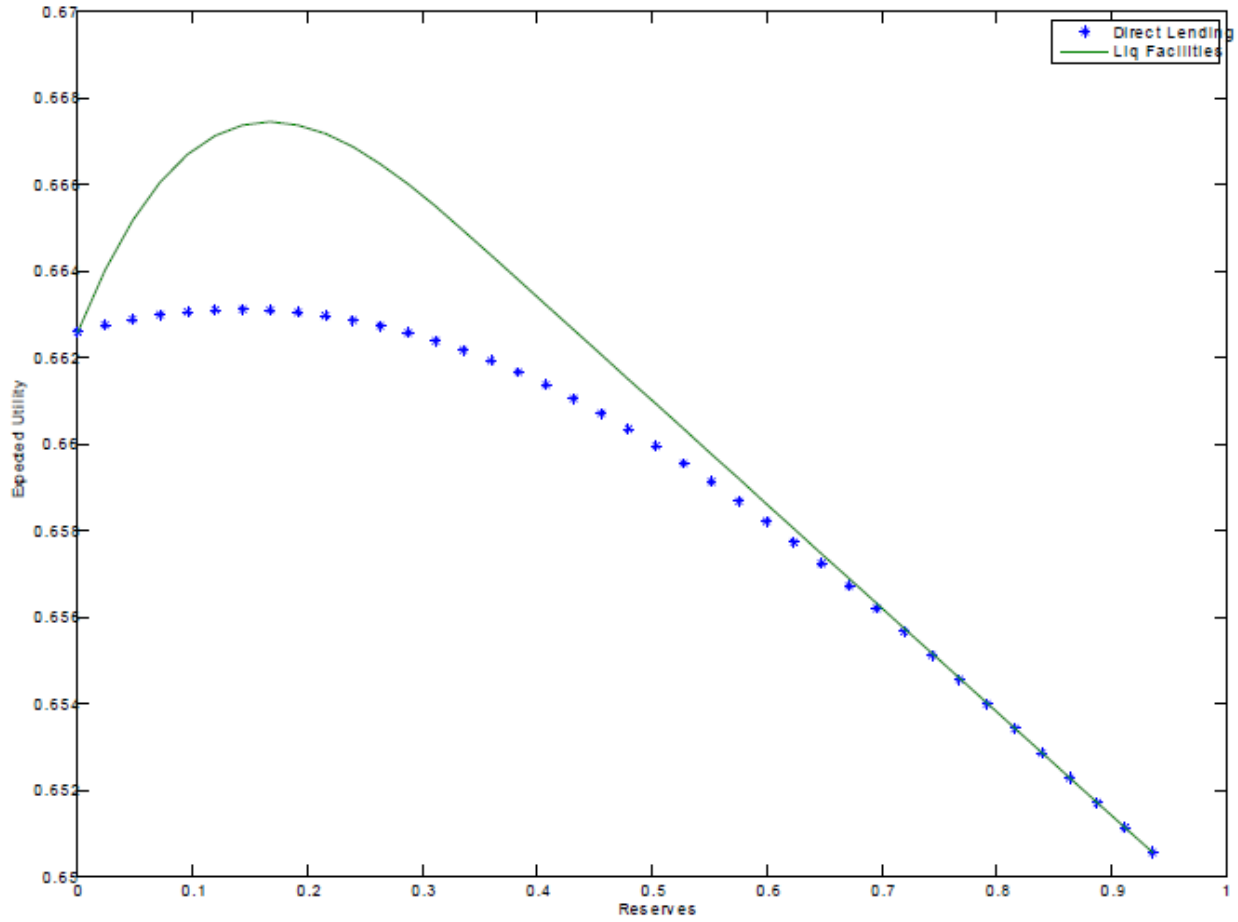
Uncertainty and Optimal Reserves

Reserves Accumulation and Ex Post Policy

- As in CCV, the central bank uses reserves more effectively if it lends them to banks instead of firms or households in a credit crunch
- But direct lending may be more feasible because of other reasons (e.g. political)
- With direct lending, optimal reserves must be larger



Expected Utility, Reserves, and Ex Post Policy



Same, but with higher τ

Final discussion

- Multiplicity of equilibria.
- Role for macroprudential policy (capital flow management).

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