BANK FOR INTERNATIONAL SETTLEMENTS

Networks, leverage and risk-taking

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Bank for International Settlements

Closing remarks

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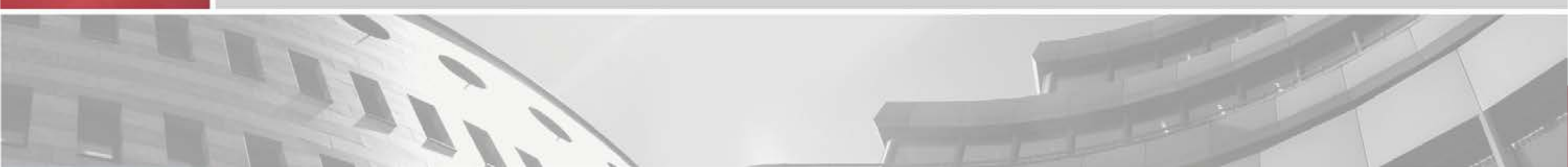
* The views expressed here are mine, not necessarily those of the Bank for International Settlements.



Perspective on connectivity and leverage

What are the relationships between

- Networks and connectivity
- Leverage
- Systemic risk

Variety of network channels

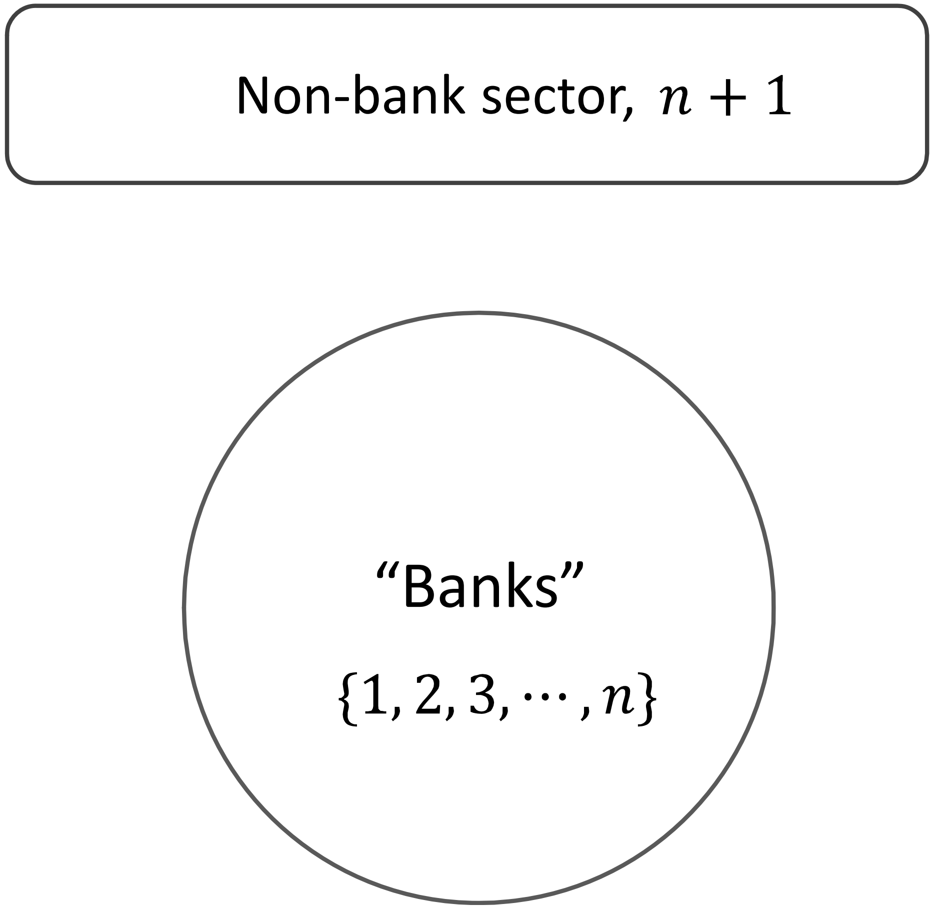
- Cai, Saunders and Steffen
  - Loan sydicates
  - Interconnectedness through overlapping asset portfolios
- Füss and Ruf
  - Information diffusion
  - Market entry of large informed traders, herding of small uninformed traders
- Hagströmer and Menkveld
  - Information flow across markets based on vector error correction model (VECM) of returns

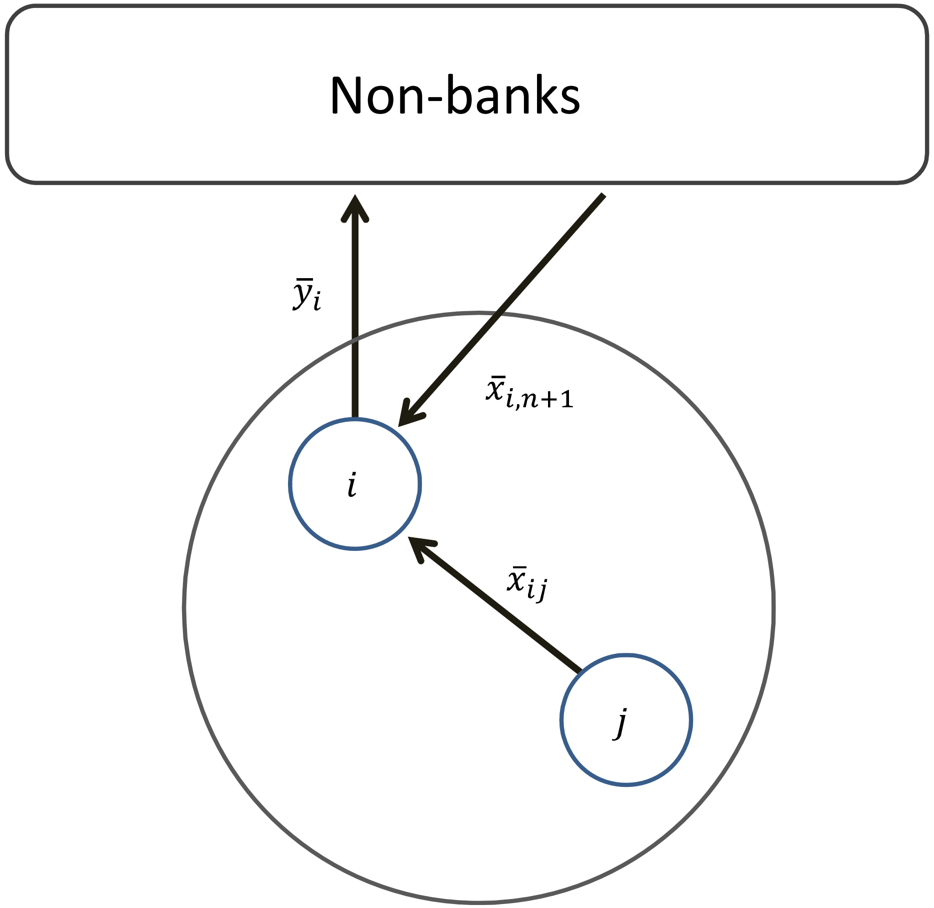
- Wang
  - Decentralised network formation game
  - Externalities due to liquidation costs

- Battiston, D'Errico, Peltonen and Scheicher
  - CDS exposures follow "bow tie" network architecture

Interconnectedness and deleveraging

- Hale, Kapan and Minoiu
  - Banks that intermediate between other banks have lower profitability
  - Historical perspective from Calomiris and Carlson (2015, in progress)
- Peltonen, Rancan and Sarlin
  - Do measures of bank interconnectedness enhance performance of early warning indicators?
- Barattieri, Moretti and Quadrini
  - In the run-up to the 2008 crisis, financial firms became more interconnected as well as being more leveraged


Non-bank sector, $n+1$
"Banks"
$\{1, 2, 3, \cdots, n\}$


Non-banks
$\bar{y}_i$
$\bar{x}_{i,n+1}$
i
$\bar{x}_{ij}$
j

Accounting framework

$n + 1$ entities in financial system

- n leveraged institutions ("banks")
- outside claim holders (indexed by $n + 1$))

Balance sheet of bank $i \in \{1, \cdots, n\}$ in face values

Assets	Liabilities
$\bar{y}_i$	$\bar{e}_i$
$\sum_{j=1}^{n} \bar{x}_j \pi_{ji}$	$\bar{x}_i$

$\bar{y}_i$ is face value of loans to end-users such as firms and households

$\bar{x}_i$ is the face value of bank i's debt

π_{ji} is the proportion of bank j's debt held by i.

$\bar{e}_i$ is the book value of bank i's equity

The balance sheet identity in terms of face values:

$$\bar{y}_i + \sum_{j=1}^{n} \bar{x}_j \pi_{ji} = \bar{x}_i + \bar{e}_i$$

Claims Matrix

	bank 1	bank 2	$\cdots$	bank n	outside	debt
bank 1	0	$\bar{x}_{12}$	$\cdots$	$\bar{x}_{1n}$	$\bar{x}_{1,n+1}$	$\bar{x}_1$
bank 2	$\bar{x}_{21}$	0		$\bar{x}_{2n}$	$\bar{x}_{2,n+1}$	$\bar{x}_2$
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\vdots$	
bank n	$\bar{x}_{n1}$	$\bar{x}_{n2}$	$\cdots$	0	$\bar{x}_{n,n+1}$	$\bar{x}_n$
end-user loans	$\bar{y}_1$	$\bar{y}_2$	$\cdots$	$\bar{y}_n$		
total assets	$\bar{a}_1$	$\bar{a}_2$		$\bar{a}_n$		

Market Values

y_i is market value of $\bar{y}_i$.

x_i is market value of $\bar{x}_i$ (see appendix for details).

Balance sheet identity of bank i in market values

$$y_i + \sum_j x_j \pi_{ji} = e_i + x_i$$

	bank 1	bank 2	$\cdots$	bank n	outside	debt
bank 1	0	x_{12}	$\cdots$	x_{1n}	$x_{1,n+1}$	x_1
bank 2	x_{21}	0		x_{2n}	$x_{2,n+1}$	x_2
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\vdots$	
bank n	x_{n1}	x_{n2}	$\cdots$	0	$x_{n,n+1}$	x_n
end-user loans	y_1	y_2	$\cdots$	y_n		
total assets	a_1	a_2		a_n		

Write Π as $n \times n$ matrix where the (i,j)th entry is π_{ij}.

$$[x_1, \cdots, x_n] = [x_1, \cdots, x_n] \left[\quad \Pi \quad \right] + [y_1, \cdots, y_n] - [e_1, \cdots, e_n]$$

$$x = x\Pi + y - e$$

Recursive nature of debt values in a financial system: each bank's debt value is increasing in the debt value of other banks.

Leverage of financial system

From

$$x = x\Pi + y - e$$

we have

$$y = e + x\,(I - \Pi)$$

Leverage of bank i

$$\lambda_i \equiv \frac{a_i}{e_i}$$

Hence

$$y = e + e\,(\Lambda - I)\,(I - \Pi)$$

Vector z defined as

$$z \equiv (I - \Pi)\,u \quad \text{where} \quad u \equiv \begin{bmatrix} 1 \\ \vdots \\ 1 \end{bmatrix}$$

Aggregate lending is

$$\begin{aligned}\sum_{i=1}^{n} y_i &= \sum_{i=1}^{n} e_i + \sum_{i=1}^{n} e_i z_i (\lambda_i - 1) \\ &= \sum_{i=1}^{n} e_i (1 + z_i (\lambda_i - 1))\end{aligned}$$

- **Core liabilities**: funding from non-banks

- **Non-core liabilities:** funding from other banks

z_i is proportion of core funding in bank i's total funding

Assets	Liabilities
Loans to firms, households	Liabilities to non-banks (e.g. deposits)
Claims on other banks	Liabilities to other banks
	Equity

Individual bank

Figure 1. Balance Sheet of Individual Bank

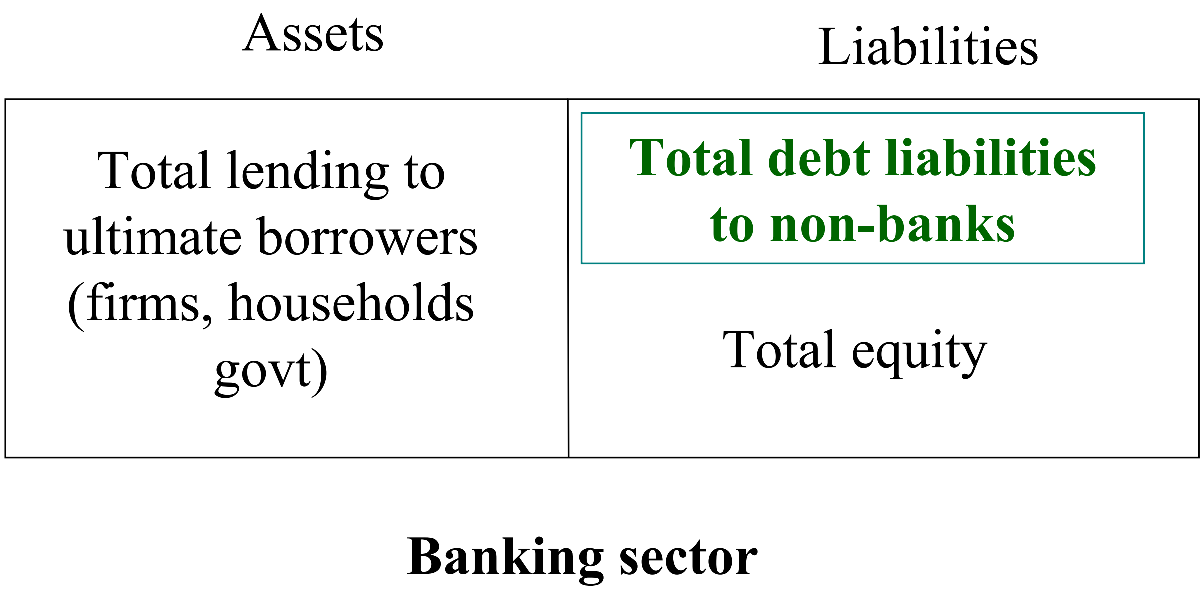


Figure 2. Aggregate Balance Sheet of Banking Sector

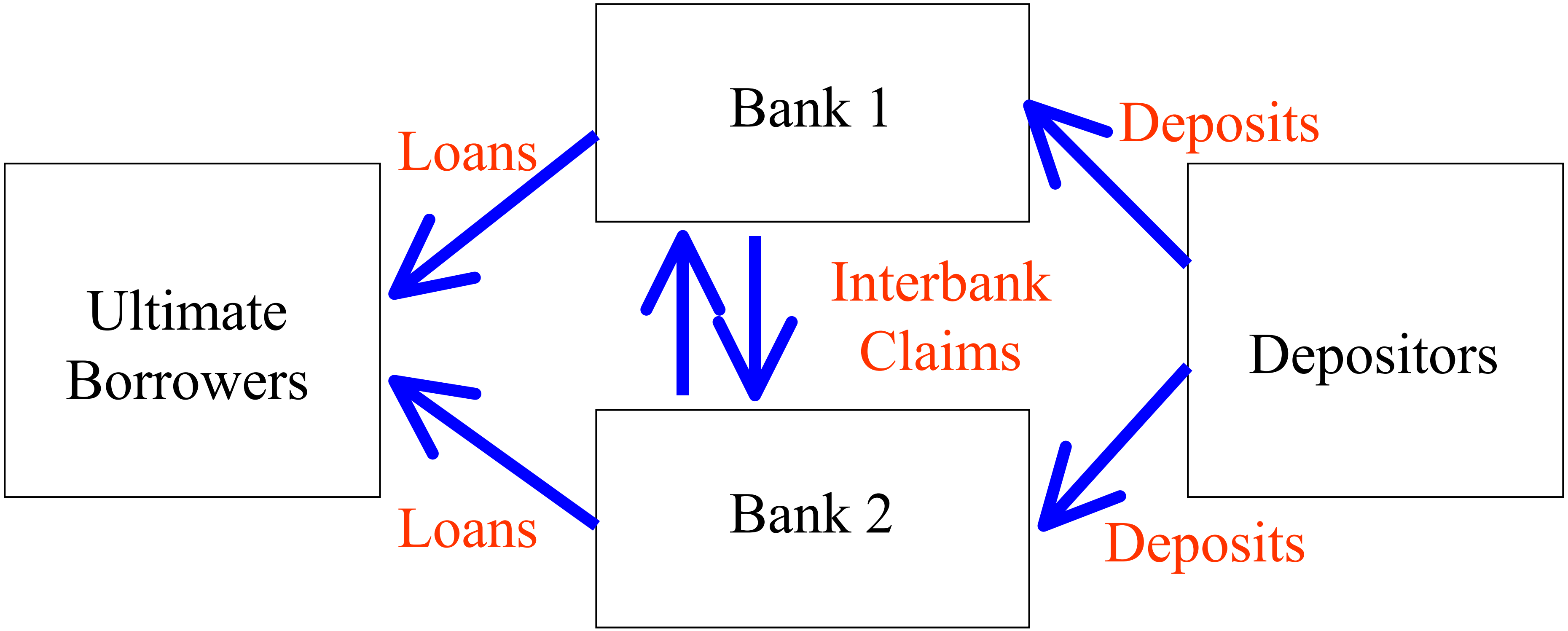
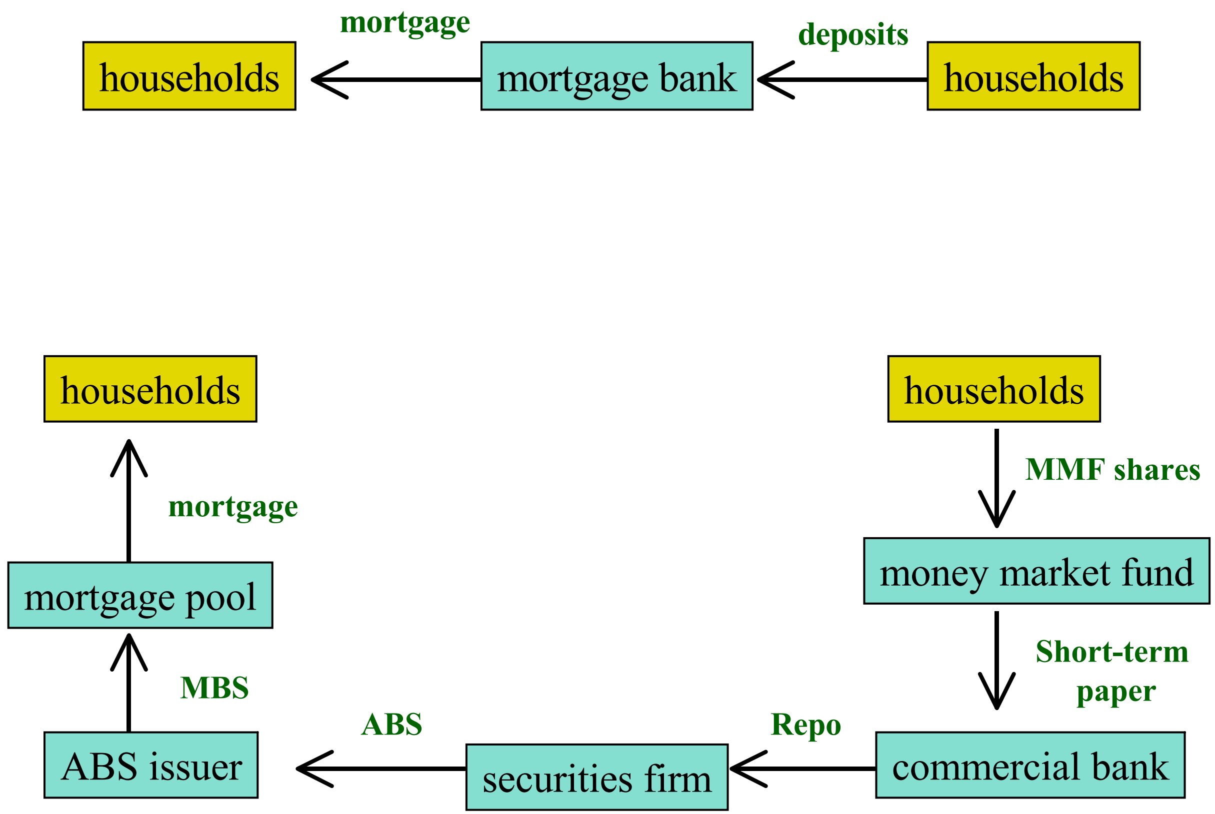


Figure 3. Complexity and leverage

Short and Long Intermediation Chains



Leverage of banks and leverage of system

Leverage for financial system is consistent with (almost) any leverage of individual banks

Vector $(\bar{e}, \bar{y}, \bar{x}, \Pi)$ satisfies balance sheet identity:

$$\bar{x} = \bar{x}\Pi + \bar{y} - \bar{e}$$

For any $\phi > 0$, construct financial system $(\bar{e}', \bar{y}', \bar{x}', \Pi')$ where $\bar{e}' = \bar{e}$, $\bar{x}' = \phi\bar{x}$ and Π' is any matrix of interbank claims whose ith row sum to $1 - z_i/\phi$.

Finally, $\bar{y}'$ is defined as

$$\bar{y}' = \bar{e}' + \bar{x}' (I - \Pi')$$

Aggregate lending is

$$\begin{aligned}
\sum\nolimits_{i=1}^{n} \bar{y}_i' &= \bar{e}'u + \bar{x}'\left(I - \Pi'\right)u \\
&= \sum\nolimits_{i=1}^{n} \bar{e}_i' + \sum\nolimits_{i=1}^{n} \bar{x}_i' \frac{z_i}{\phi} \\
&= \sum\nolimits_{i=1}^{n} \bar{e}_i + \sum\nolimits_{i=1}^{n} \bar{x}_i z_i \\
&= \sum\nolimits_{i=1}^{n} \bar{y}_i
\end{aligned}$$

Aggregate notional leverage in both financial systems is $\sum_{i=1}^{n} \bar{y}_i / \sum_{i=1}^{n} \bar{e}_i$.

However, by construction, the debt to equity ratio of all individual banks is ϕ times larger in the second financial system.

(only restriction on the constant ϕ comes from the feature that the ith row of Π' sums to $1 - z_i/\phi$, implying a lower bound).

The same construction holds for market values, but there is also upper bound for ϕ. Market value of debt x_i cannot be larger than the market value of assets a_i, and the market value of assets is underpinned by the value of fundamental assets $\{y_k\}$.

Leverage of the aggregate banking sector itself is related to the leverage of individual banks in the following way.

$$\begin{aligned} L &= \frac{\sum_{i=1}^{n} y_i}{\sum_{i=1}^{n} e_i} \\ &= 1 + \frac{\sum_{i=1}^{n} e_i z_i (\lambda_i - 1)}{\sum_{i=1}^{n} e_i} \end{aligned}$$

Proposition. For given profile of leverage for individual banks, leverage of financial intermediary sector is increasing in z.

Shin (2009, EJ Lecture)

Debt capacity of financial system

From

$$x = x\Pi + y - e$$

we have

$$x_i = \underbrace{y_i + \sum_j \pi_{ji} x_j}_{\text{collateral value}} - \underbrace{e_i}_{\text{haircut}}$$

- Debt capacity of bank i is sum of
  - collateral value of its direct claims on end-users
  - collateral value of claims on other banks
  - minus the "haircut"

Define $\delta_i = 1 - \frac{1}{\lambda_i}$ (debt to asset ratio)

$$\begin{aligned} x_i &= \delta_i \left(y_i + \sum_j x_j \pi_{ji} \right) \\ &= \delta_i y_i + \left[\begin{array}{ccc} x_1 & \cdots & x_n \end{array} \right] \left[\begin{array}{c} \delta_i \pi_{1i} \\ \vdots \\ \delta_i \pi_{ni} \end{array} \right] \end{aligned} \qquad (1)$$

Let $x = \left[\begin{array}{ccc} x_1 & \cdots & x_n \end{array} \right]$, $y = \left[\begin{array}{ccc} y_1 & \cdots & y_n \end{array} \right]$, and

$$\Delta = \left[\begin{array}{ccc} \delta_1 & & \\ & \ddots & \\ & & \delta_n \end{array} \right]$$

Write (1) in vector form as:

$$x = y\Delta + x\Pi\Delta$$

Solving for x,

$$\begin{aligned} x &= y\Delta\left(I - \Pi\Delta\right)^{-1} \\ &= y\Delta\left(I + \Pi\Delta + (\Pi\Delta)^2 + (\Pi\Delta)^3 + \cdots\right) \end{aligned} \tag{2}$$

The matrix $\Pi\Delta$ is given by

$$\Pi\Delta = \begin{bmatrix} 0 & \delta_2\pi_{12} & \cdots & \delta_n\pi_{1n} \\ \delta_1\pi_{21} & 0 & & \delta_n\pi_{2n} \\ \vdots & & \ddots & \vdots \\ \delta_1\pi_{n1} & \delta_2\pi_{n2} & \cdots & 0 \end{bmatrix} \tag{3}$$

Infinite series in (2) converges since the rows of $\Pi\Delta$ sum to a number strictly less than 1. Hence, the inverse $(I - \Pi\Delta)^{-1}$ is well-defined.

$$\begin{aligned} x &= y\Delta\,(I - \Pi\Delta)^{-1} \\ &= y\Delta\left(I + \Pi\Delta + (\Pi\Delta)^2 + (\Pi\Delta)^3 + \cdots\right) \end{aligned} \qquad (4)$$

Interpretation. Securities of value y_i are the collateral securing a repurchase agreement.

For creditor, the collateral assets can be recycled (rehypothecated) to finance its own borrowing.

The same securities can be pledged many times in this chain of repurchase agreements.

The powered matrices $(\Pi\Delta)^t$ indicate the collateral value of assets in the tth round of this chain of repurchase agreements.

In practice, chain of repurchase of agreements are subject to netting agreements between the banks, so that the securities do not flow through the banks in such large quantities.

From (4), total borrowing capacity of the intermediary sector depends on:

- value of marketable securities (vector y)
- haircuts in the repo, which determine the debt ratios $\{\delta_i\}$, and hence the diagonal matrix Δ
- length of intermediation chains (row sums of Π matrix)

Suppose parameter σ captures measured risks, affecting both the price of marketable assets as well as the haircut (e.g. Value-at-Risk).

Then, comparative statics of the debt capacity can be decomposed into

- price decline effect
- leverage contraction effect

Define

$$M(\sigma) \equiv \Delta(\sigma)\left(I - \Pi\Delta(\sigma)\right)^{-1} \tag{5}$$

$\Delta(\sigma)$ is diagonal debt ratio matrix implied by σ.

$y(\sigma)$ is value of collateral assets as a function of σ.

Then for $\sigma < \sigma'$,

$$\begin{aligned} & x(\sigma) - x(\sigma') \\ = \; & y(\sigma) M(\sigma) - y(\sigma') M(\sigma') \\ = \; & \underbrace{(y(\sigma) - y(\sigma')) M(\sigma)}_{\text{collateral squeeze}} - \underbrace{y(\sigma')(M(\sigma') - M(\sigma))}_{\text{margin spiral}} \end{aligned} \tag{6}$$

$x(\sigma) - x(\sigma')$ is decline in debt capacity of the system

- The first term in (6) is the decline in the debt capacity due to the decline in the price of the marketable assets y. We can label this as the "collateral squeeze".

- Second term in (6) is the contraction in the debt capacity that comes from the de-leveraging in the financial system.

Perspectives on LOLR policies

In 2008 crisis, Federal Reserve's TSLF (Term Securities Lending Facility) replaced high haircut assets (MBS) with low haircut assets (treasuries). Such a policy may increase debt capacity of the financial system as a whole

By same logic, purchase of low haircut assets by central bank may be counterproductive if it reduces debt capacity by draining low haircut assets from the system

QUESTIONS

- What determines λ_i?
- How does it behave over the cycle?

Three Modes of Leveraging Up

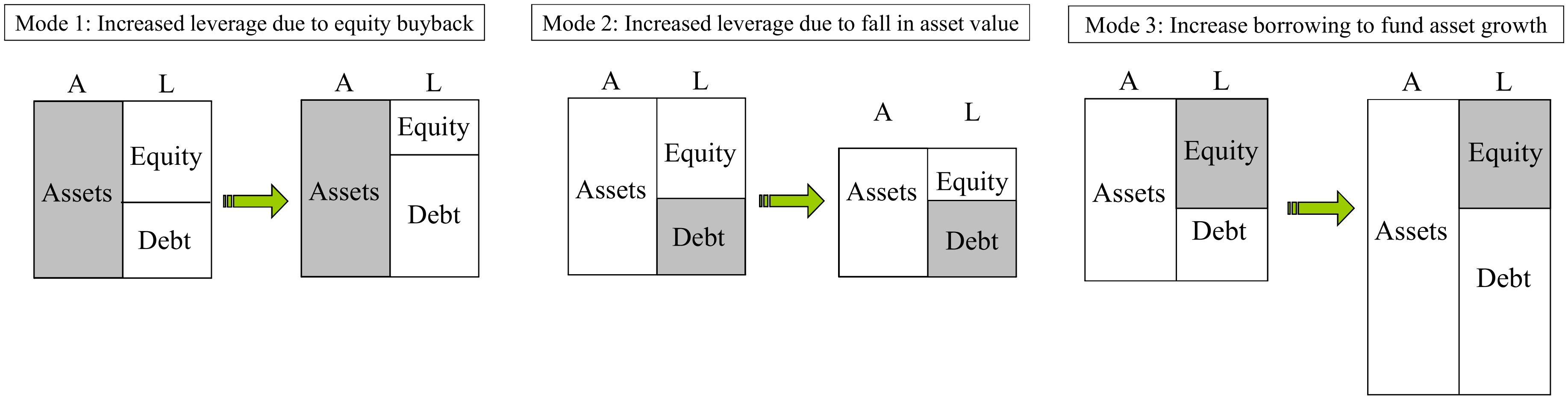


Figure 4. **Three modes of leveraging up:** Mode 1 is through an equity buyback through a debt issue. Mode 2 is through a dividend financed by asset sale. Mode 3 is through increased borrowing to fund new assets. In each case the grey area indicates balance sheet component that is held fixed

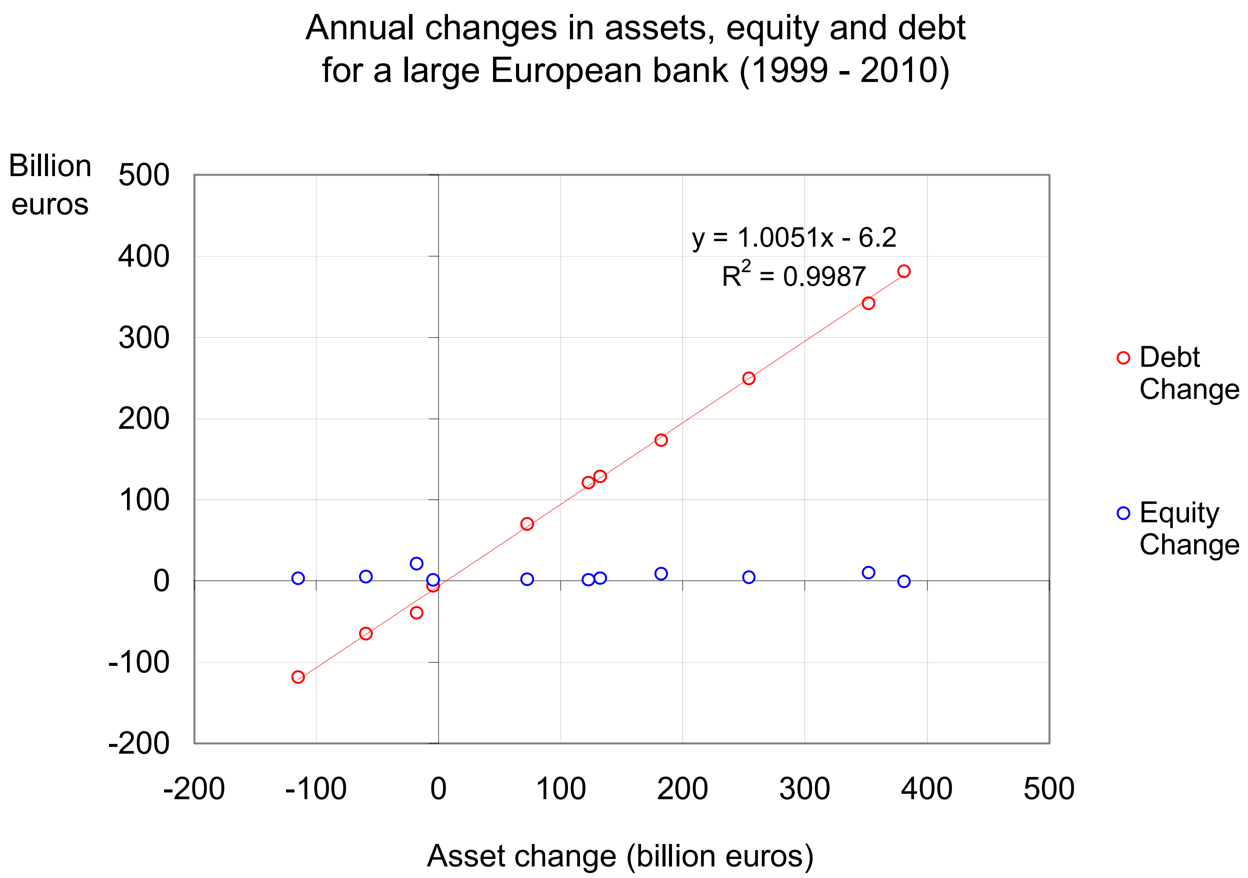

Annual changes in assets, equity and debt
for a large European bank (1999 - 2010)
Billion euros
500
400
300
200
100
0
-100
-200
-200
-100
0
100
200
300
400
500
y = 1.0051x - 6.2
R2 = 0.9987
Debt Change
Equity Change
Asset change (billion euros)

Figure 5

An Analogy

- Bank capital $\longmapsto$ Foundations of building
- Bank lending $\longmapsto$ Building itself
- Leverage $\longmapsto$ Relationship between height of building relative to its foundations

Leverage is procyclical, fluctuating in line with Value-at-Risk type measures (Adrian and Shin (2010, 2014))

Figure 6. Sutyagin House, Archangel

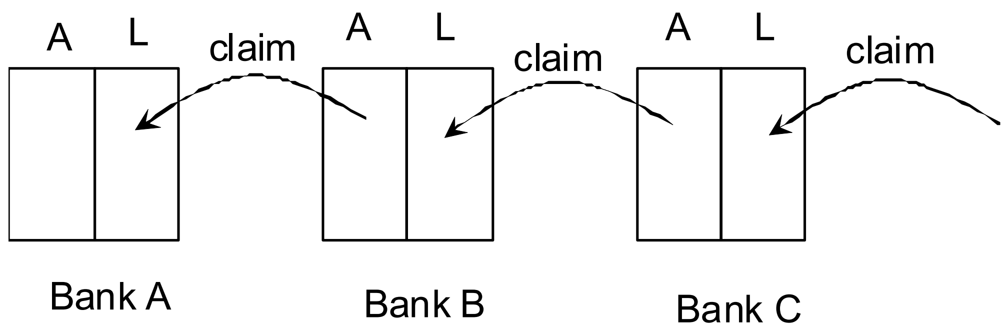
Conceptualising systemic risk

- "Domino" model of contagious failures

- Fire sales and marking to market

- Deleveraging and runs

Domino Hypothesis



- Channel of financial contagion is chain of defaults.
  - Passive players, who stand idly by while others fail
  - Only implausibly large shocks generate any contagion in simulations (Upper and Worms (2004))

In 2007/8 crisis, direction of contagion was reversed. Bear Stearns, Lehman Brothers and Northern Rock crises were **runs** on the liabilities side.

Bear Stearns

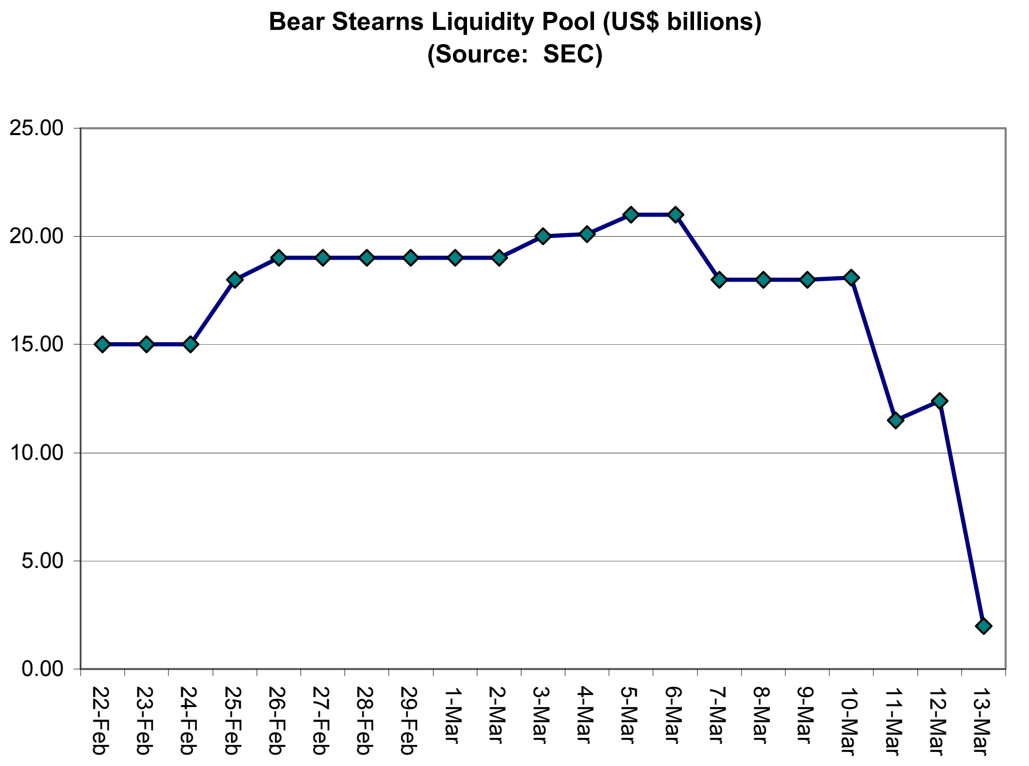


Figure 7

Domino model versus runs

https://www.sec.gov/news/press/2008/2008-48.htm
SEC letter to BCBS on new guidance on liquidity management

> “[T]he fate of Bear Stearns was the result of a lack of confidence, not a lack of capital. When the tumult began last week, and at all times until its agreement to be acquired by JP Morgan Chase during the weekend, the firm had a capital cushion well above what is required to meet supervisory standards calculated using the Basel II standard.
>
> Specifically, even at the time of its sale on Sunday, Bear Stearns' capital, and its broker-dealers' capital, exceeded supervisory standards. *Counterparty withdrawals and credit denials, resulting in a loss of liquidity - not inadequate capital - caused Bear's demise.*”

Deleveraging and systemic risk

Start from

$$x = x\Pi + y - e \tag{7}$$

Solve for y as

$$\begin{aligned} y &= e + x\left(I - \Pi\right) \\ &= e\left(I + D\left(I - \Pi\right)\right) \end{aligned}$$

where

$$D = \begin{bmatrix} d_1 & & \\ & \ddots & \\ & & d_n \end{bmatrix} \quad \text{and} \quad d_i = \frac{x_i}{e_i}, \quad \text{(debt to equity ratio)}$$

Leverage is $\lambda_i = d_i + 1$

$$y = e\left(\Lambda\left(I - \Pi\right) + \Pi\right) \tag{8}$$

where Λ is the diagonal matrix whose ith element is λ_i, the leverage of bank i.

Total lending capacity depends on

(i) how much equity e there is in the banking system

(ii) how much leverage is permitted in the system (given by the diagonal matrix Λ)

(iii) the structure of the interbank market (given by Π).

Example of single chain

$$
\begin{aligned}
y_1 &= \lambda_1 e_1 \\
y_2 &= \lambda_2 e_2 - (\lambda_1 - 1)\, h_1 e_1 \\
y_3 &= \lambda_3 e_3 - (\lambda_2 - 1)\, h_2 e_2 \\
&\vdots \\
y_n &= \lambda_n e_n - (\lambda_{n-1} - 1)\, h_{n-1} e_{n-1}
\end{aligned}
$$

where $h_i = 1 - \pi_{i,n+1}$ is proportion of non-core liabilities.

Consider further special case where $y_i = 0$ for all $i > 1$ and $h_j = 1$ for all $j < n$.

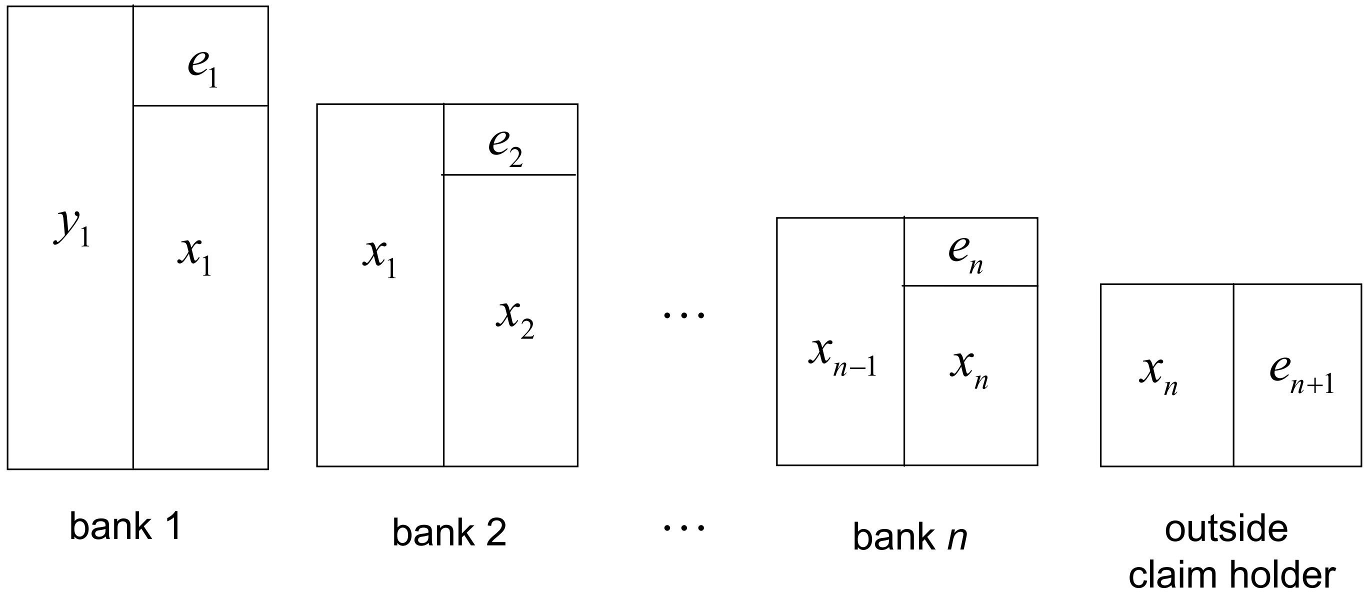


Figure 8.

Outside asset y is held by bank 1 only, while all other banks hold assets that are the obligations of other banks higher up the chain.

$$y_1 = \lambda_1 e_1 = e_1 + \lambda_2 e_2 = \cdots = e_1 + e_2 + \cdots + e_{n-1} + \lambda_n e_n$$

For the financial system as a whole to support total lending of y_1, all of the following inequalities must hold.

$$
\begin{aligned}
y_1 &\leq \lambda_1 e_1 \\
y_1 &\leq e_1 + \lambda_2 e_2 \\
y_1 &\leq e_1 + e_2 + \lambda_3 e_3 \\
&\vdots \\
y_1 &\leq e_1 + e_2 + \cdots + e_{n-1} + \lambda_n e_n
\end{aligned}
$$

Define y^* as

$$y^* = \min_i \left\{ \sum_{j=1}^{i-1} e_j + \lambda_i e_i \right\}$$

Here y^* is lending capacity of the financial system. Bank with lowest $\sum_{j=1}^{i-1} e_j + \lambda_i e_i$ is “pinch point” of financial system.

If lending capacity y^* falls below existing y_1, then the repo contract cannot be rolled over as before. This will result in a Bear Stearns or Lehman Brothers style run on bank 1. System as a whole runs out of lending capacity.

Further questions

- How to use quantities as early warning indicators?
  - Credit together with debt service ratio (Drehmann and Juselius (2013))
  - Liabilities side aggregates, including monetary aggregates
- Where to draw the line between core and non-core liabilities?
  - depends on financial system and context
  - eg. corporate deposits in EME banks
- When does double-counting add to usefulness of the non-core measure?
  - Double-counting may enhance signal/noise ratio

Risk-taking channel of currency appreciation

- Cerutti, Claessens and Ratnovski
  - Currency composition of cross-border bank claims
  - Examine G4 currencies, but USD is special
  - USD exchange rate drives flows (table 4)
- Feyen, Ghosh, Kibuuka, Farazi
  - Risk-taking channel of currency appreciation also works for bond issuance
- Avdiev and Takats
  - Currency composition of cross-border bank claims
  - USD, EUR and JPY

- Passerman
  - Sovereign bonds of countries with worse corruption score are more sensitive to global liquidity

Risk-taking channel of currency appreciation

- What is the relationship between exchange rates and domestic long-term interest rates?

- If there is a relationship, which exchange rate matters?
  - Effective exchange rate
  - Bilateral exchange rate versus USD

- If there is a relationship, what is the mechanism at play?
  - Risk premium or expected policy rates?
  - Evidence from quantities?

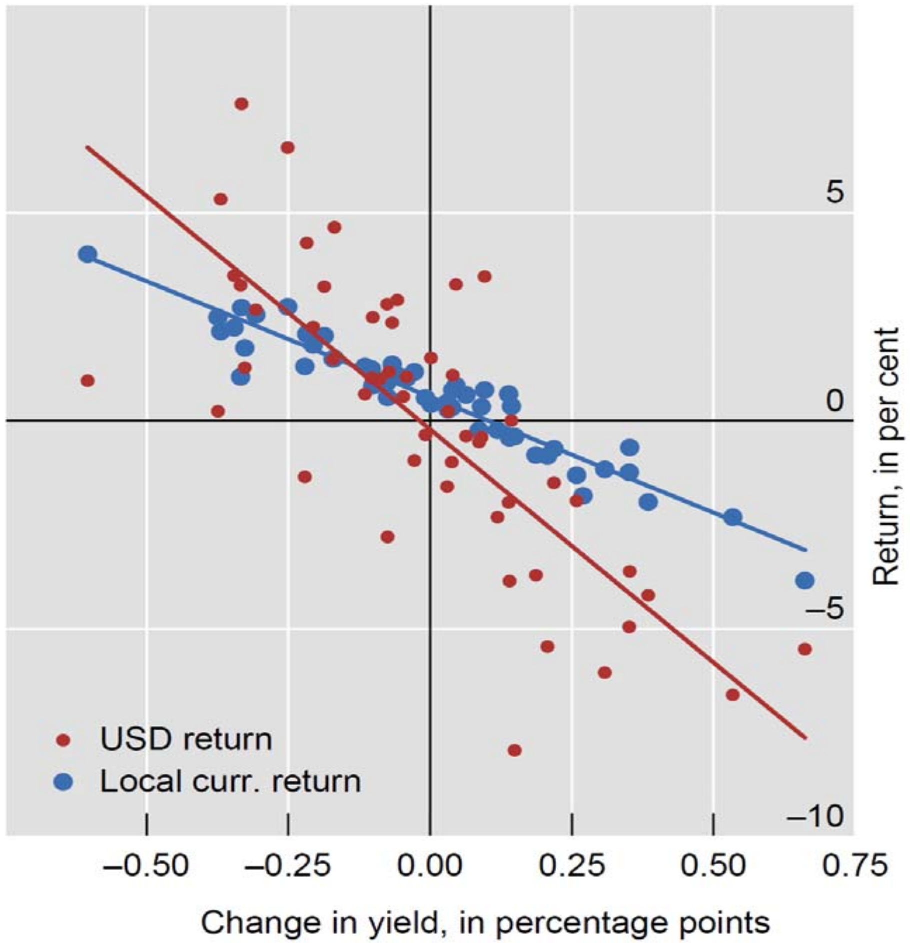
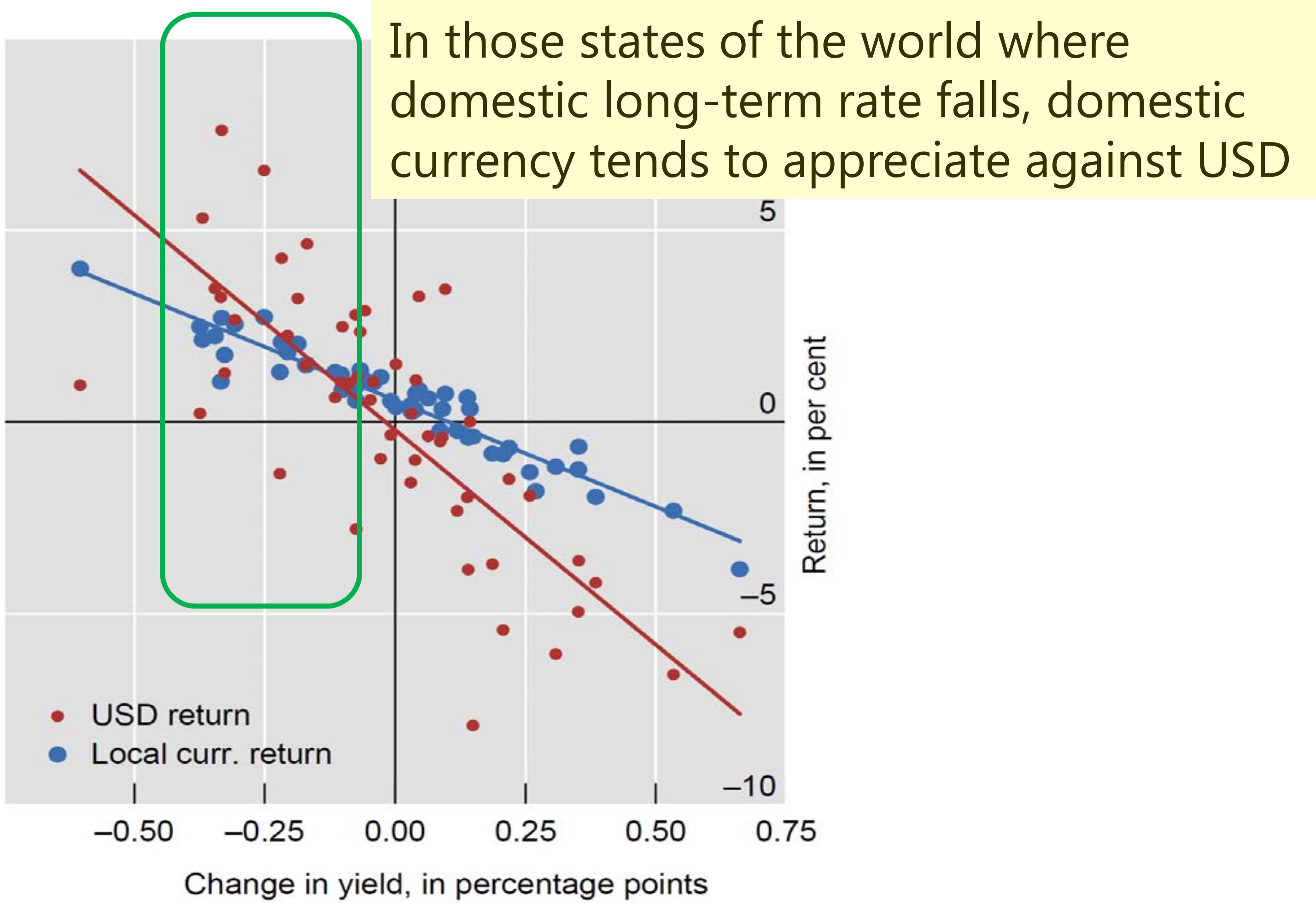
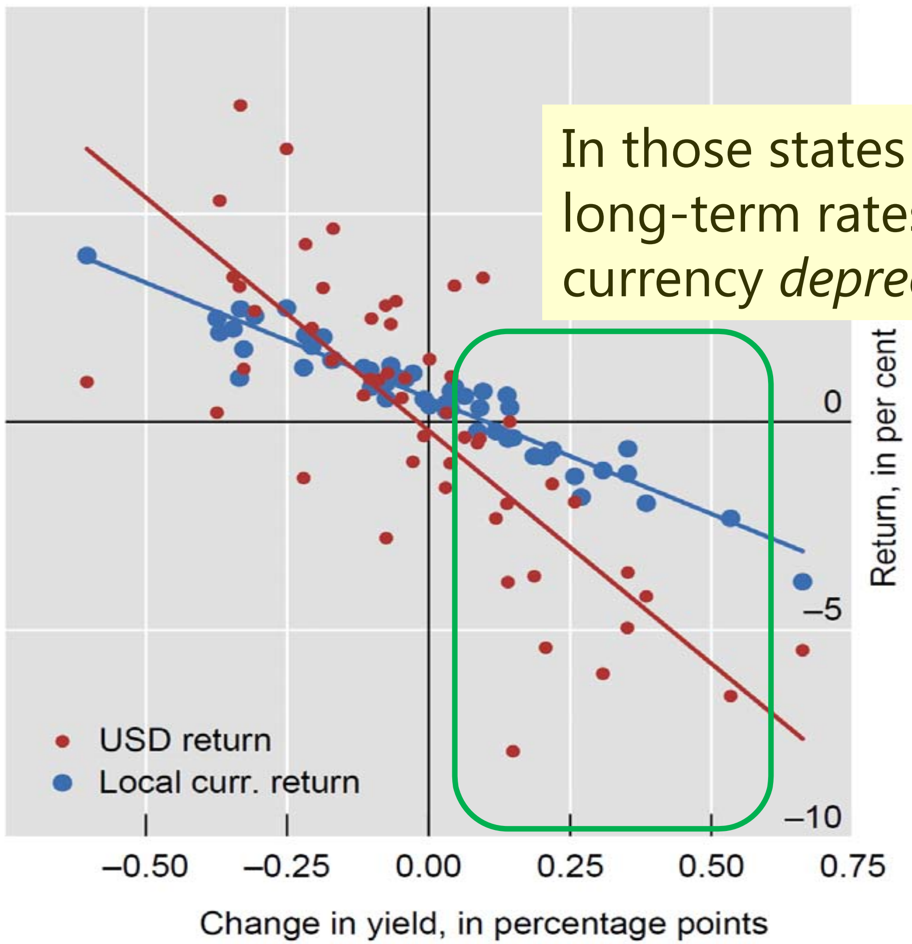


Figure 9. EME local currency sovereign mutual fund returns (source: Hofmann, Shim and Shin (2015) "Risk-taking channel of currency appreciation")



Sources: EPFR; JPMorgan Chase; authors' calculations

Figure 10

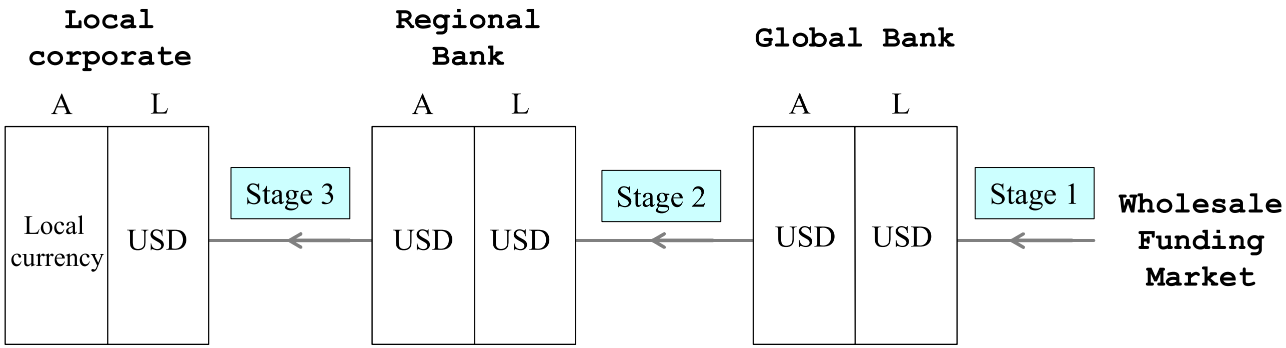


In those states of the world where long-term rates rise, domestic currency *depreciates* against USD

Sources: EPFR; JPMorgan Chase; authors' calculations

Figure 11

Currency appreciation and bank lending boom



- Local currency appreciation strengthens borrower balance sheet
- Creates slack in lending capacity of local banks; creates slack in global bank lending capacity; local and global banks drive credit boom

Bruno and Shin (RES 2015) http://www.bis.org/publ/work458.pdf

Figure 12

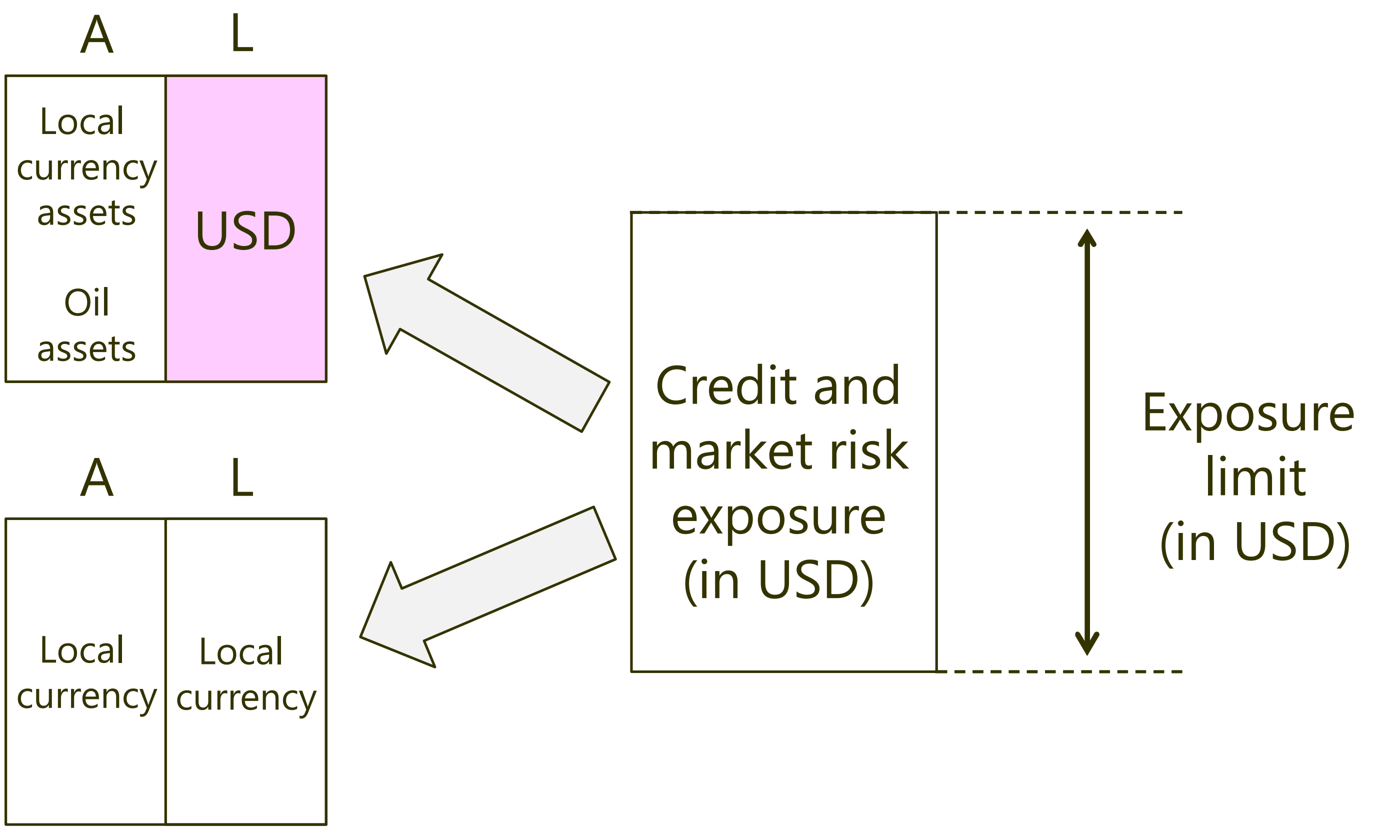

A
L
Local currency assets
Oil assets
USD
A
L
Local currency
Local currency
Credit and market risk exposure (in USD)
Exposure limit (in USD)

Figure 13

	(1)	(2)	(3)
VARIABLES	5y CDS spread	5y CDS spread	5y CDS spread
ΔUSRER	0.027***		
	[5.06]		
ΔREER		0.017*	
		[1.95]	
Orth ΔREER			0.017
			[1.60]
Controls	Y	Y	Y
Country dummies	Y	Y	Y
Observations	805	805	805
Groups	21	21	21
R-squared	0.57	0.55	0.55

Figure 14. Also holds for returns on EME sovereign bonds on a swapped basis for USD investors (using Du-Schreger spreads)