Pandemic crises in financial system and liquidity emergency

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Introduction

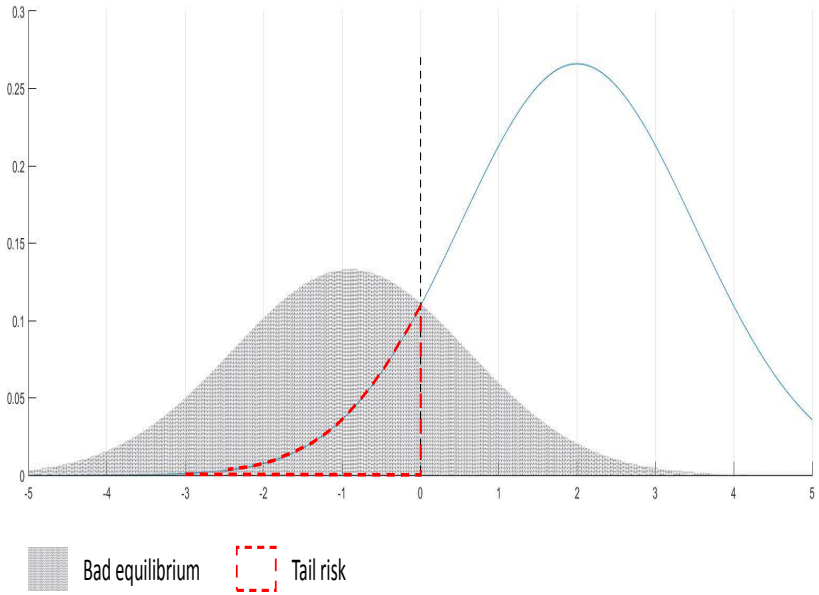
"The assessment of the Governing Council is that we are in a situation now where you have large parts of the euro area in what we call a "bad equilibrium"."

"What we have put in place today is an effective backstop to remove tail risks from the euro area."

President Draghi speech, 6 September 2012.

Introduction

Stylized representation of tail risk and bad equilibrium.



Introduction

- If policy makers manage tail risk, they manage extreme events characterized by low probability.
- If the extreme are not characterized by low probability, it may become a bad equilibrium where nothing stays under control since the "new norm" is the materialization of risk.
- In this paper we show how multiple channels of transmission/amplification may give rise to such bad equilibrium in individual bank equity (i.e. affecting probabilities of defaults)

Introduction

Interconnectedness

- The "Lehman" or "Euro Area sovereign" crises revealed the significance of risks interconnectedness.
- Interconnections are expected
  1. between financial institutions
  2. between markets (stocks, interbank)
  3. between markets and financial institutions

such that one challenge is to try to anticipate all the channels of transmission and amplification.

Interplay of multiple channels of contagion

- Exposures to common risk factors or common risk profile
- Cross-equity Holdings
- Market contagion and asset depreciation
- Interbank market and collateralized debt

Need to be analyzed in a joint framework especially for euro area banks characterized by cross border activities within a currency union

In stress-testing exercises, neglecting second round effects lead to underestimation of default probabilities

Solvency models

- Merton (1974) for the definition of default
- Gourieroux Heam Montfort (2012) for the cross holding of debt and equity
- Gabrieli Salhakova Vuillemey (2014) was for example a first application of this framework using target 2 data for interconnection proxies.

Contagion models

- Price Contagion: DCC models "a la" Engle and Sheppard (2002), Forbes and Rigobon (2001), Billio et al. (2011)
- Microstructure literature: Amihud (2002) as the impact of volume liquidation on prices

Firesales models

- Brunnermeier Perdersen (2010) on liquidity/funding spirals
- Greenwood, Landier and Thesmar (2014) on firesales and bank failure amplification

Objective of the paper: to combine in a single framework all these contagion channels and measure to what extent first round losses are amplified.

Key ingredients

- Stylized representation of bank balance sheet
- Bank default mechanisms
- Bank liquidation
- Interbank amplification
- Asset price depreciation

Solvency model

Balance sheets in a three banks universe

Assets i	Liabilities i
$\Pi_{i,1} Y_1 + \Pi_{i,2} Y_2 + \Pi_{i,3} Y_3$	L_i^I
$\Gamma_{i,1} L_1^I + \Gamma_{i,2} L_2^I + \Gamma_{i,3} L_3^I$	L_i^*
$X_i P$	
A_i	L_i

Table : Bank i balance sheet

with

- Π_i the fractions of equity cross holdings Y
- Γ_i the fractions of debt cross-holdings L divided in L^I (interbk, collateralized) and L^* (other liabilities like deposit)
- X_i the portfolio of non banking assets at price P

Bank 3 defaults

Let assume a shock on portfolio prices P becomes $P' < P$ such that bank 3 defaults.

Assets 1	Liabilities 1
$\Pi_{1,1} Y_1 + \Pi_{1,2} Y_2 + \cancel{\Pi_{1,3} Y_3}$	L_1^I
$\Gamma_{1,2} L_2^I + \cancel{\Gamma_{1,3} L_3^I}$	L_1^*
$\cancel{X_1 P} X_1 P' + \Gamma_{col}(1,3) L_3^I \frac{\mathbb{1}_{\bar{k}-1}}{\bar{k}-1}$	
A_1'	L_1

Table : Bank 1 balance sheet after bank 3 default

- Cross-holding equities and interbank debt holdings with bank 3 are lost

Bank 3 defaults

Assets 2	Liabilities 2
$\Pi_{2,1} Y_1 + \Pi_{2,2} Y_2 + \cancel{\Pi_{2,3} Y_3}$	L_2^I
$\Gamma_{2,1} L_1^I + \cancel{\Gamma_{2,3} L_3^I}$	L_2^*
$\cancel{X_2 P X_2 P'} + \Gamma_{col}(2,3) L_3^I \frac{\mathbb{1}_{\bar{k}-1}}{\bar{k}-1}$	
A_2'	L_2

Table : Bank 2 balance sheet after bank 3 default

- Similar balance sheet depreciation for bank 2 in the proportion to its exposure to bank 3

Bank 3 liquidation

Assets 3	Liabilities 3
$\Pi_{3,1} Y_1 + \Pi_{3,2} Y_2 + \cancel{\Pi_{3,3} Y_3}$	L_3^I
$\Gamma_{3,1} L_1^I + \Gamma_{3,2} L_2^I$	L_3^*
$\cancel{X_3 P X_3 P'} - (\Gamma_{col}(1,3) + \Gamma_{col}(2,3)) L_3^I \frac{\mathbb{1}_{\bar{k}-1}}{\bar{k}-1}$	
A_3'	L_3

Table : Bank 3 balance sheet ready for liquidation

- Γ_{col} as the collateral matrix $=\Gamma$ times a haircut rate,
- such that bank i recovers $\Gamma_{col}(i,3) L_3^I \frac{\mathbb{1}_{\bar{k}-1}}{\bar{k}-1}$, (if collateral is split equally across different $\bar{k}-1$ assets ie excluding cash).

Further price impact...affecting other banks

- Prices were originally affected by an exogeneous shocks $P- > P'$
- then, if exante it worths P' (to allow for collateral pricing) liquidation of X_3 leads to $P'' < P'$
- still alive banks bear the price impact P"
- indirect deterioration of their balance sheet due to prices

Assets 1	Liabilities 1
$\Pi_{1,1} Y_1 + \Pi_{1,2} Y_2 + \cancel{\Pi_{1,3} Y_3}$	L_1^I
$\Gamma_{1,2} L_2^I + \cancel{\Gamma_{1,3} L_3^I}$	L_1^*
$X_1^{'} P^{''}$	
$A_1^{''}$	L_1

Table : Bank 1 balance sheet after liquidation

Assets 2	Liabilities 2
$\Pi_{2,1} Y_1 + \Pi_{2,2} Y_2 + \cancel{\Pi_{2,3} Y_3}$	L_2^I
$\Gamma_{2,1} L_1^I + \cancel{\Gamma_{2,3} L_3^I}$	L_2^*
$X_2^{'} P^{''}$	
$A_2^{''}$	L_2

Table : Bank 2 balance sheet after liquidation

Interbank amplification

What's next?

Margin calls between surviving banks on interbank debt

We introduce margin calls i.e. banks need to compensate the collateral depreciation with cash to obtain the same level of "safety".

The role of collateral in amplification mechanisms

- Banks 1 and 2 suffers collateral depreciation $\delta(1) = \frac{X_1' P''}{X_1 P}$ and $\delta(2) = \frac{X_2' P''}{X_2 P}$. The margin call matrix Mc:

$$Mc = \begin{pmatrix} 0 & (1-\delta(2))\Gamma_{col}(1,2)L_2^I \\ (1-\delta(1))\Gamma_{col}(2,1)L_1^I & 0 \end{pmatrix}$$

- such that banks 1 and 2 are characterized by their cash positions:

$$\begin{cases} X_1'(\bar{k}) + N(1) \\ X_2'(\bar{k}) + N(2) \end{cases}$$

- with $N(1) = -N(2) = Mc(1,2) - Mc(2,1)$ the cash a bank need to provide (or not)

- option 1: If the bank has a net negative position but enough cash to pay the compensation, its cash position decreases.
- option 2: if the bank has not enough cash to pay creditors, the bank has to sell part of its assets in order to fund liquidity. Let's assume bank 1 is short in liquidity, then the exante portfolio reduction is:

$$\forall j < \bar{k}, X_1^{''}(j) = X_1^{'}(j)(1 - \frac{X_1^{'}(\bar{k}) + N(1)}{\sum_{k=1}^{\bar{k}-1} X_1^{'}(k)P^{''}(k)})$$

- ... and bank 2 bears a second price impact due to this liquidation such that cash position are

$$\begin{cases} X_1^{''}(\bar{k}) = 0 \text{ (bank 1 is illiquid)} \\ X_2^{''}(\bar{k}) = X_2^{'}(\bar{k}) + N(2) - (X_1^{'} - X_1^{''})(P^{''} - P^{'''}) \end{cases}$$

we end up with bank 1:

Assets 1	Liabilities 1
$\Pi_{1,1} Y_1 + \Pi_{1,2} Y_2 + \cancel{\Pi_{1,3} Y_3}$	L_1^I
$\Gamma_{1,2} L_2^I + \cancel{\Gamma_{1,3} L_3^I}$	L_1^*
$X_1'' P'''$	
A_1'''	L_1

Table : Bank 1 at the end of the round

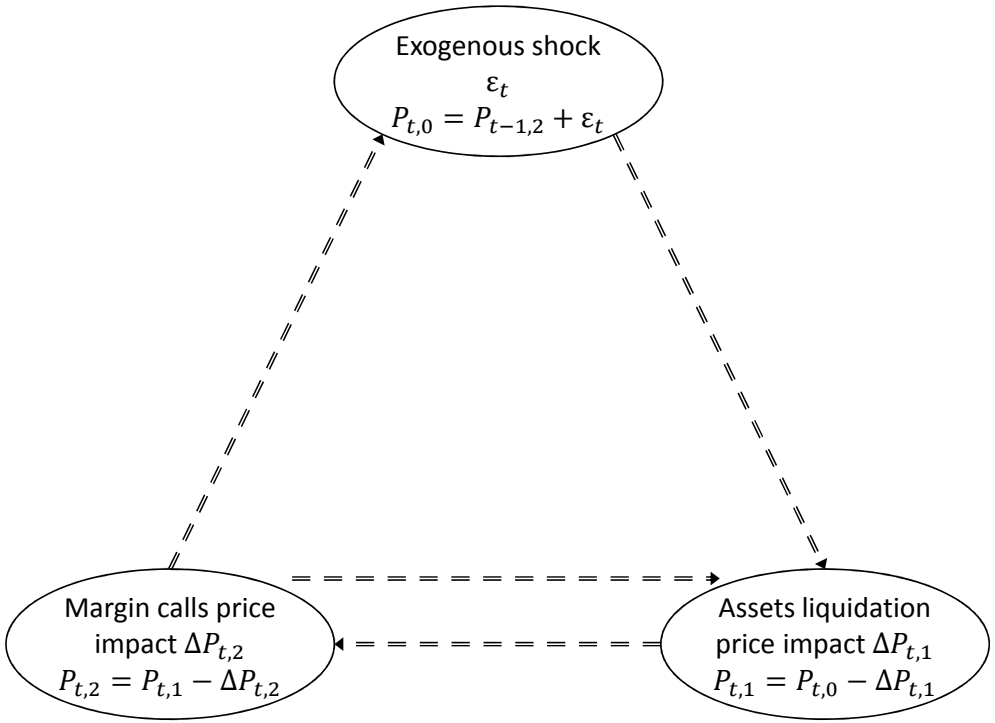
...and bank 2:

Assets 2	Liabilities 2
$\Pi_{2,1} Y_1 + \Pi_{2,2} Y_2 + \cancel{\Pi_{2,3} Y_3}$	L_2^I
$\Gamma_{2,1} L_1^I + \cancel{\Gamma_{2,3} L_3^I}$	L_2^*
$X_2'' P'''$	
A_2'''	L_2

Table : Bank 2 at the end of the round

And this goes on until no more bank fails.

Regarding asset prices...

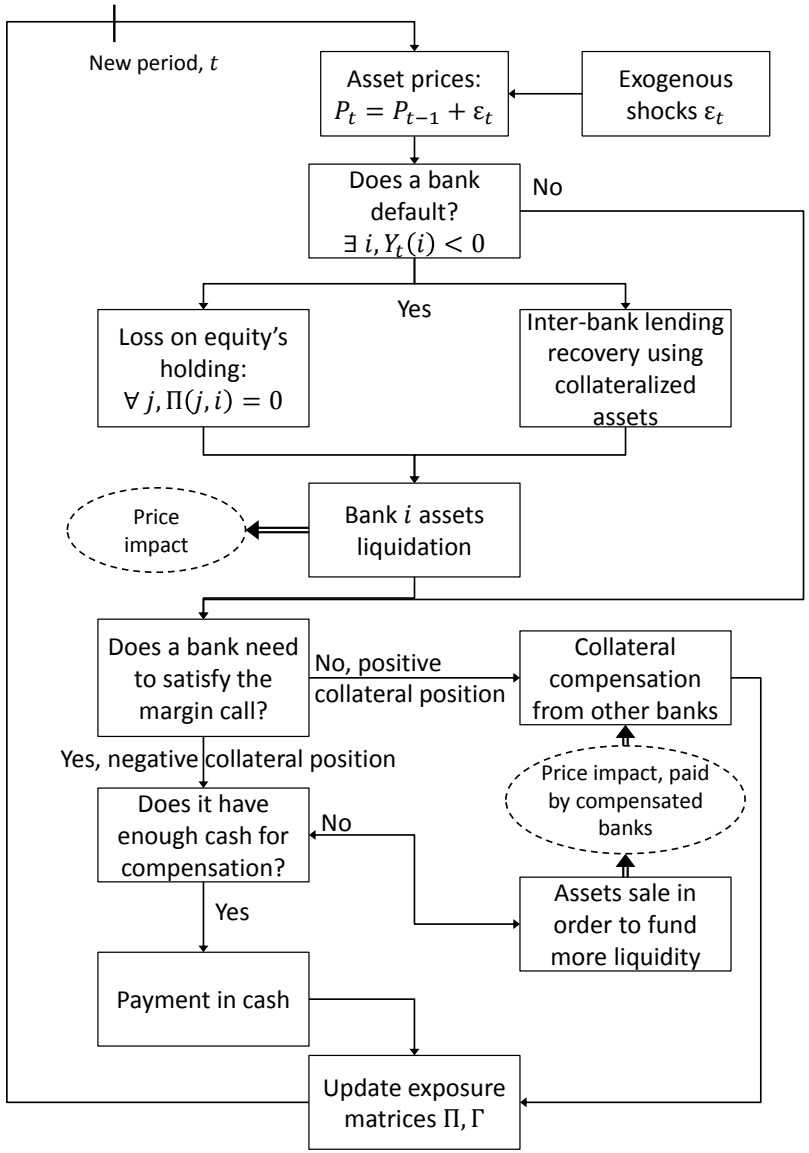


Regarding asset prices...

In each round of asset depreciation, price variations are such that $\Delta P = TV * Am * R_s$
with

- R_s a asset correlation matrix,
- Am the Amihud statistics
- TV the traded volume (amount of asset liquidation).

These matrices give a lot of flexibility: R_s can be state dependant, diagonal or full. The same applies to the Amihud statistics.


New period, t
Asset prices: $P_t = P_{t-1} + \varepsilon_t$
Exogenous shocks ε_t
Does a bank default? $\exists\, i, Y_t(i) < 0$
No
Yes
Loss on equity's holding: $\forall\, j, \Pi(j,i) = 0$
Inter-bank lending recovery using collateralized assets
Price impact
Bank i assets liquidation
Does a bank need to satisfy the margin call?
No, positive collateral position
Collateral compensation from other banks
Yes, negative collateral position
Price impact, paid by compensated banks
Does it have enough cash for compensation?
No
Assets sale in order to fund more liquidity
Yes
Payment in cash
Update exposure matrices Π, Γ

Data Needs

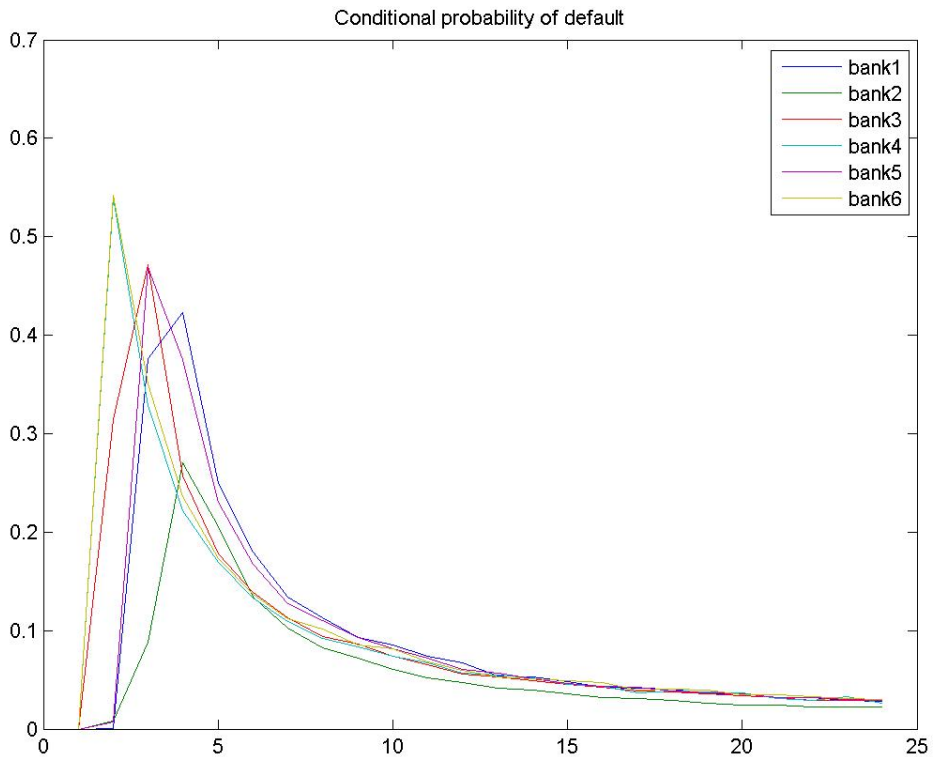
- Good news: the model is flexible enough to integrate granular information as soon as it is available.
- Bad news: some information are scarce to perfectly proxy interconnection dynamics. Data access is key, especially for cross border analysis.
- In this paper we take 6 EU banks (some are G-SiB, some are not) supposed to be interconnected.
- The application is done for illustration purpose (experiment) and should not be taken as a formal regulatory stress testing exercise!

Data Needs

- Π equity cross holdings (SNL data), mainly public
- Γ bank debt cross-holdings: reconstruction from the aggregate (proxy)
- X Exposures: balance sheet information in annual statements (as of 2014) on 6 asset classes: loans to non banking players, debt instruments, equity instruments, derivatives instruments, other securities and cash.
- R correlation matrix: asset prices/index and/or lending spreads

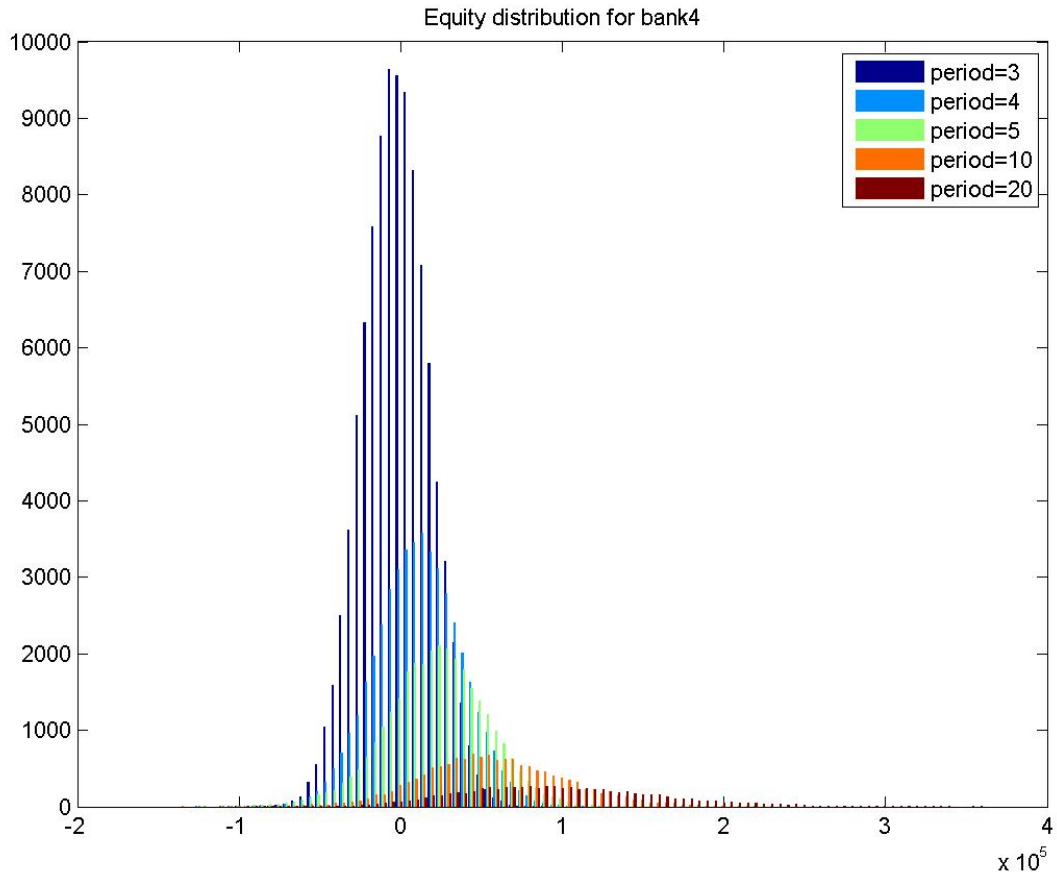
Probabilities of default

Even if the shock on trading assets is calibrated to cause no default in the first period, amplification phenomena are at play: first round evaluation underestimates the PDs.



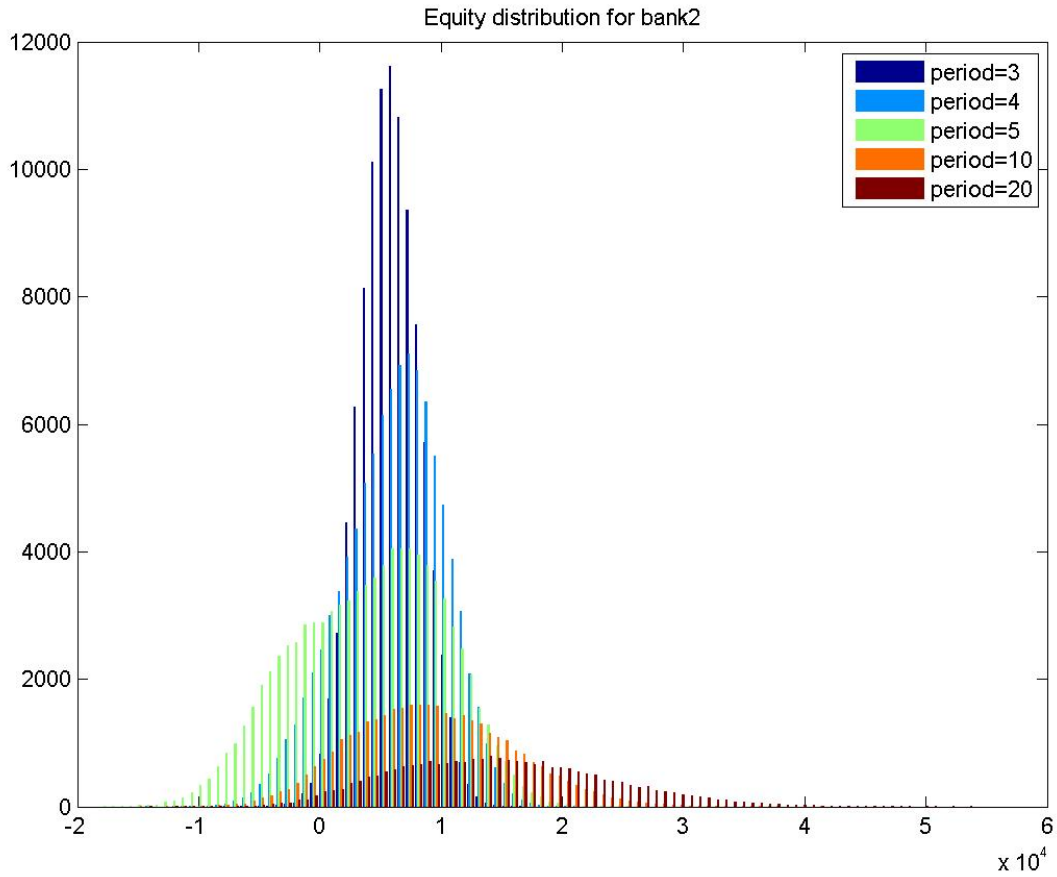
Equity distribution evolutions over time

Example of a bank **not really affected** by second round effects [but significantly by 1st round]



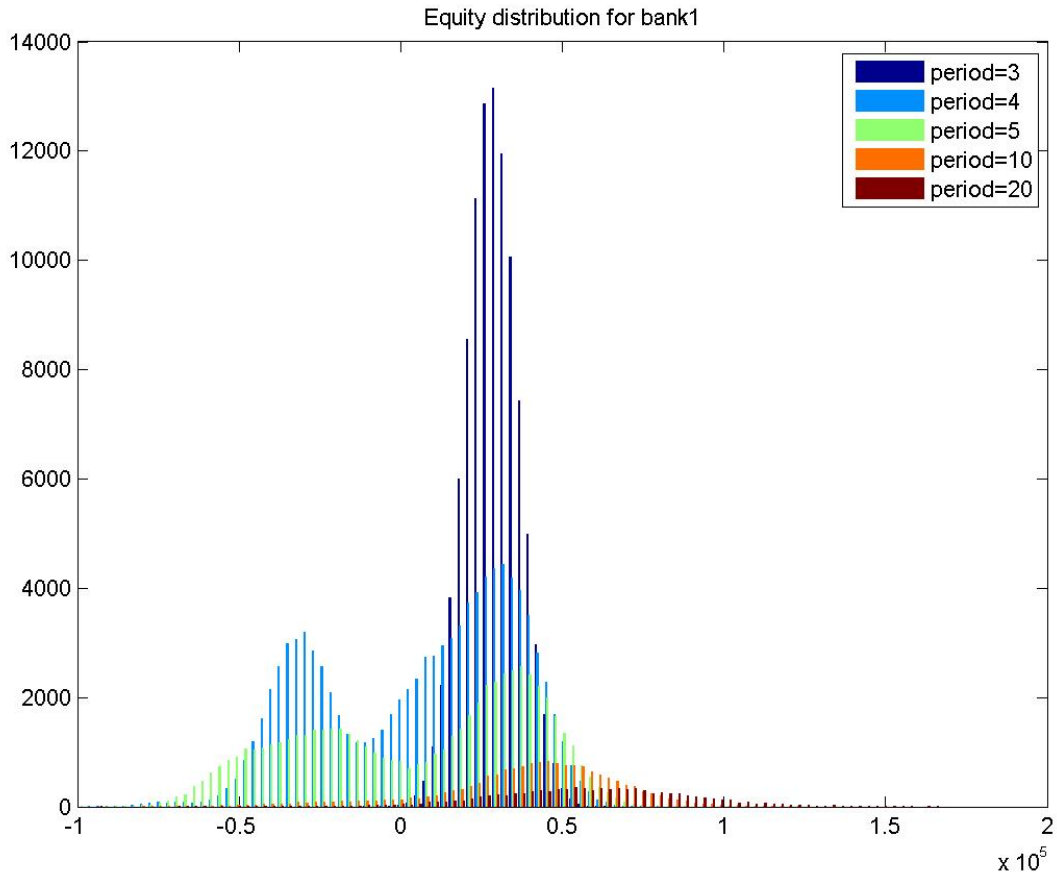
Equity distribution evolutions over time

Example of a bank **affected** by second round effects...



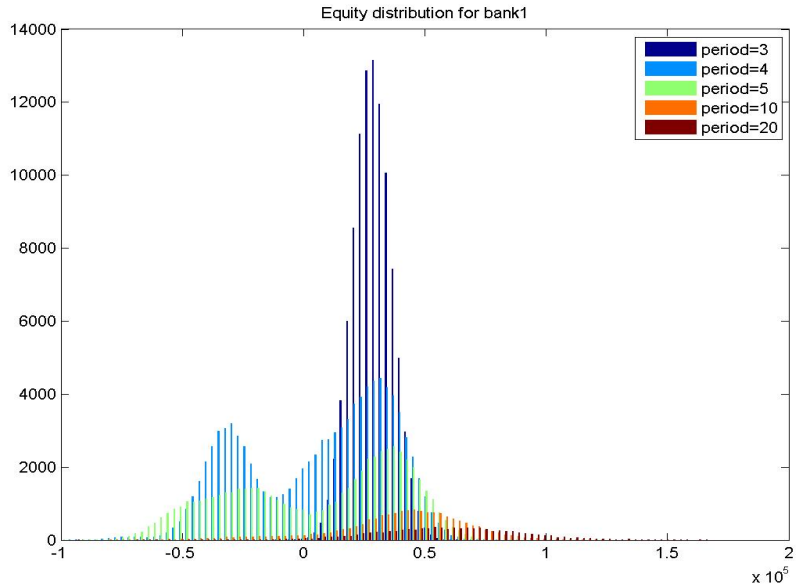
Equity distribution evolutions over time

Example of a bank **really affected** by second round effects...



Equity distribution evolutions over time

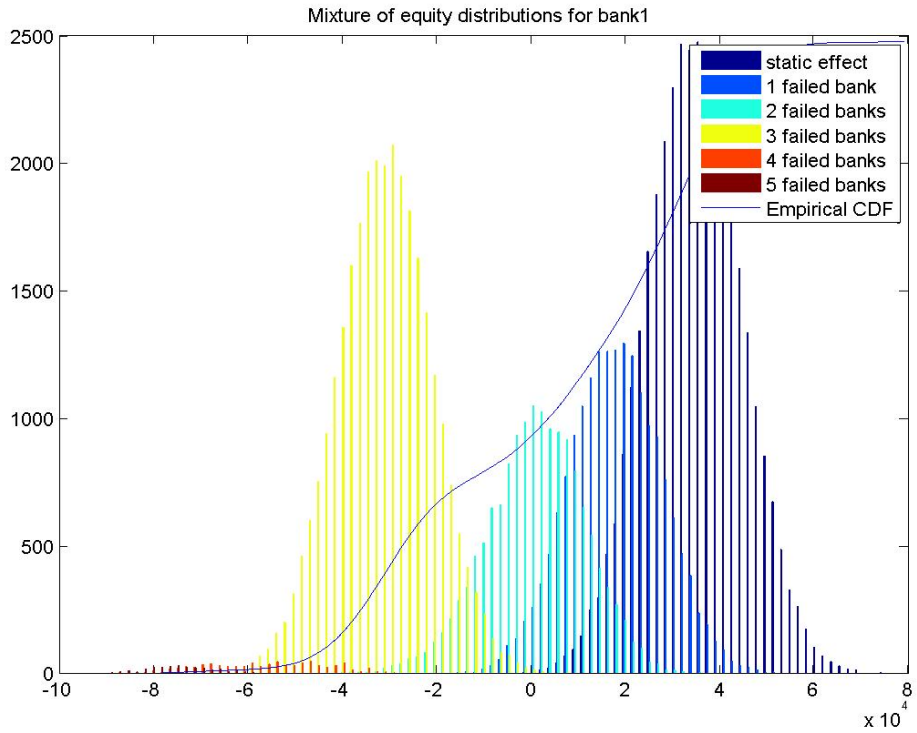
Example of a bank **really affected** by second round effects...



Why does this multimodality appear?.. due to amplification as soon as some domino effects threat the banking system.

Equity distributions multimodality

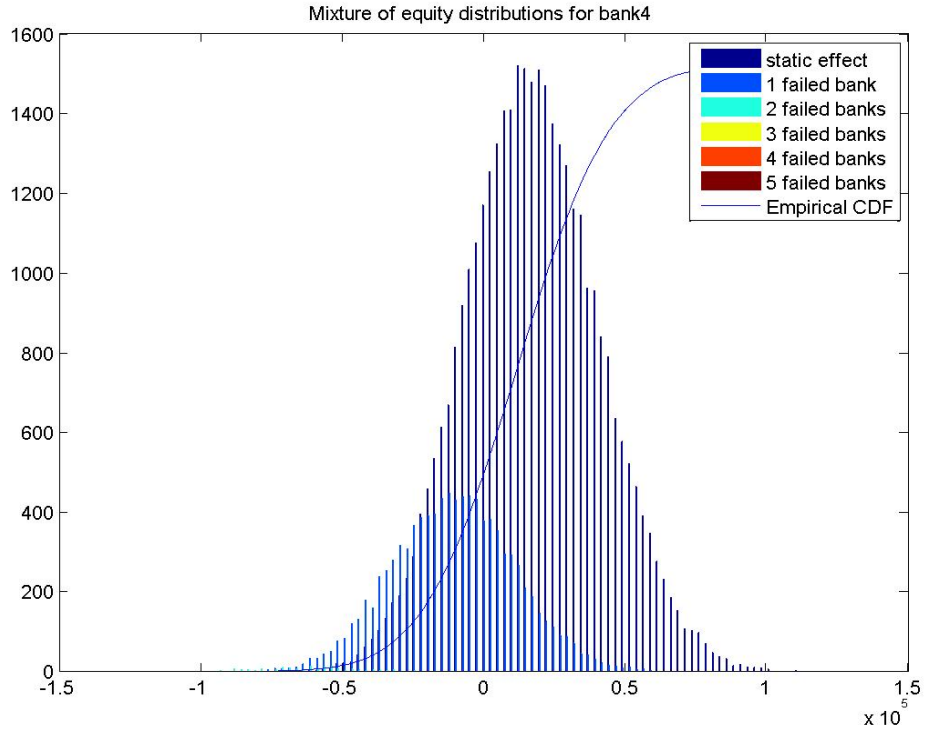
Let decompose the equity distribution of Bank 1 at period 4, conditional to the number of failing banks at the previous round.



The bad equilibrium appears as soon as other banks are defaulting.

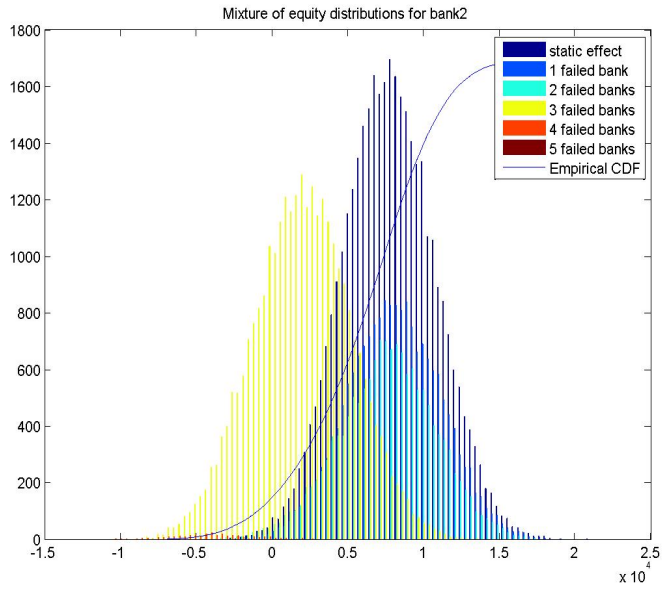
Equity distributions multimodality

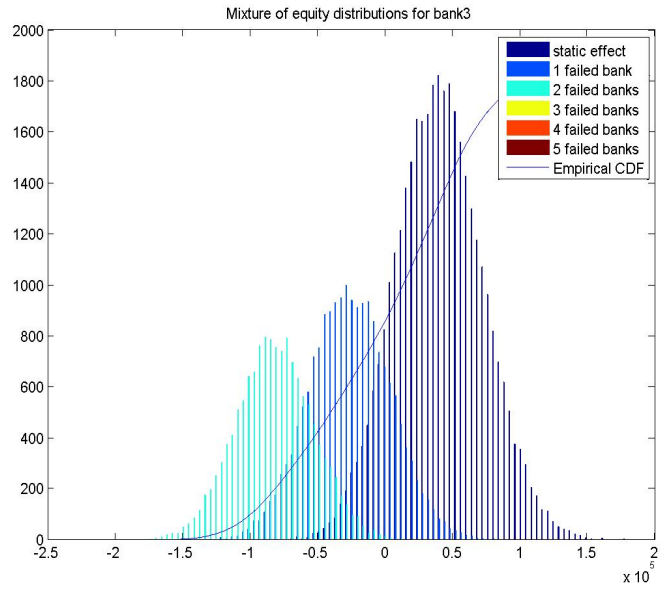
Is this by construction of a pessimistic model? NO because some banks are resilient.



Equity distributions multimodality

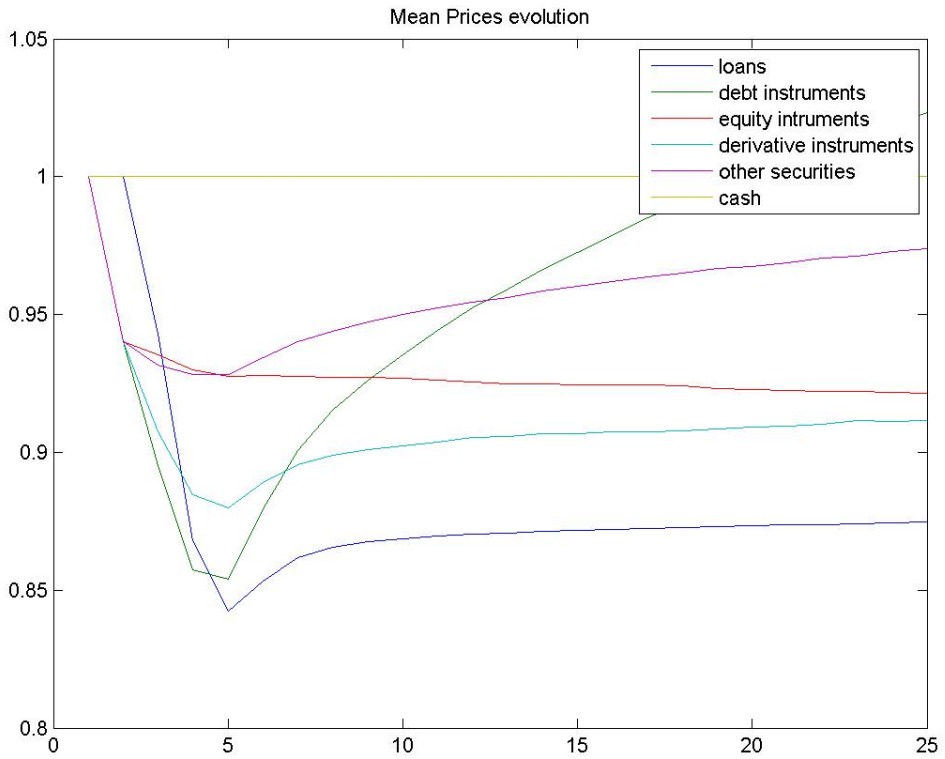
And some are intermediate cases





Asset price depreciation

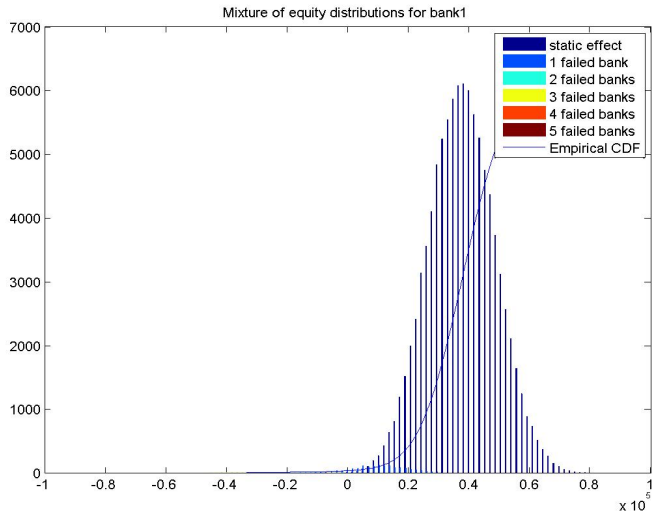
Asset prices suffer, depending on the type of securities.

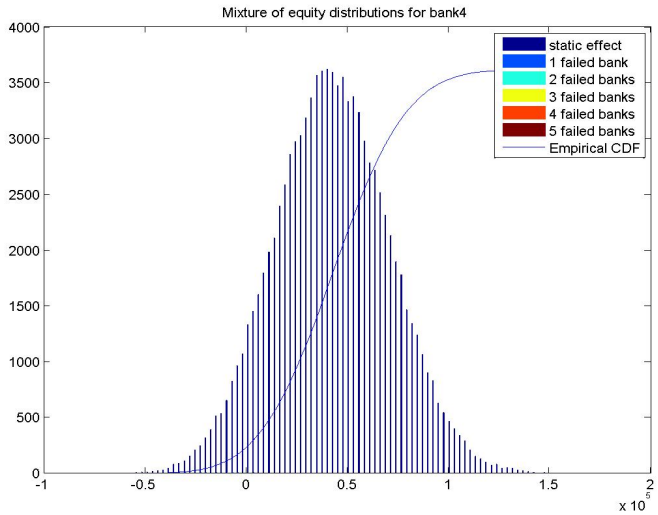


Policy implications

Playing with bank systemicity

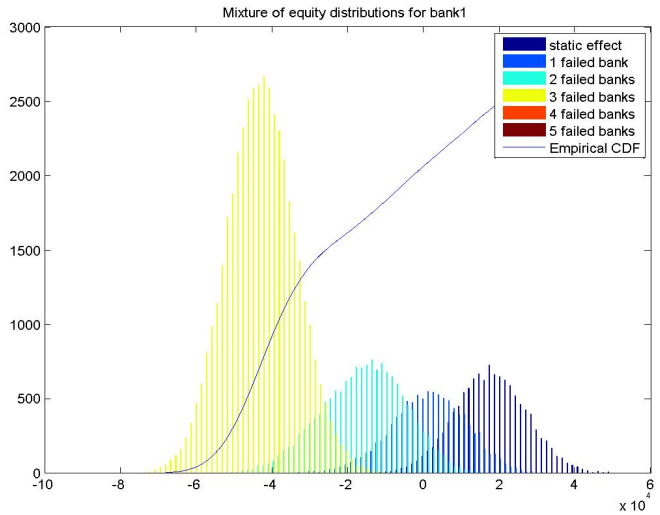
One can test the impact of individual defaults (as many other various shocks in this framework).
Here bank 2 defaults: no major direct and indirect impact = "manageable default" because of "unimodal" risk.

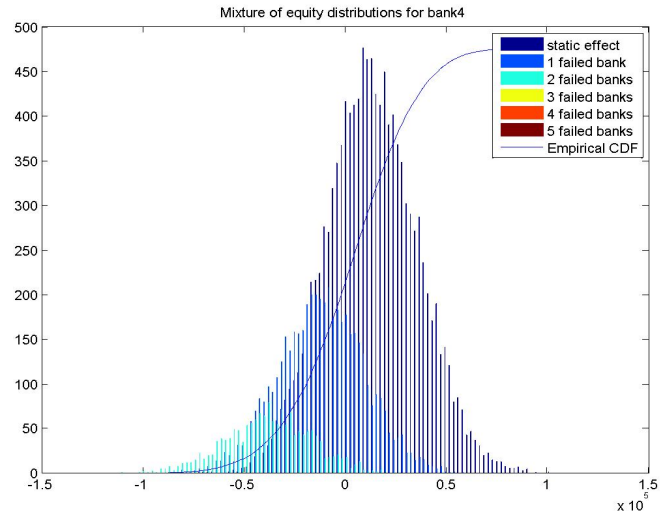




Playing with bank systemicity

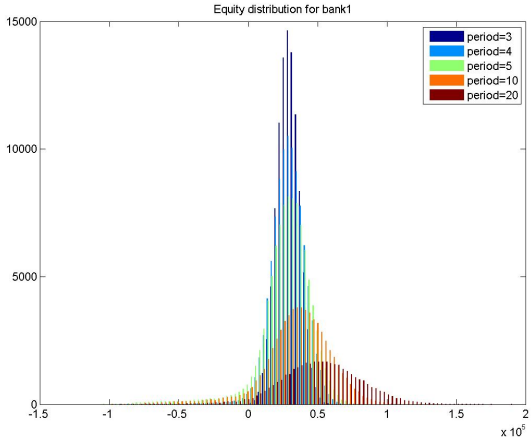
Here bank 3 defaults: Major direct and indirect impact = need to manage a bad equilibrium (amplification)

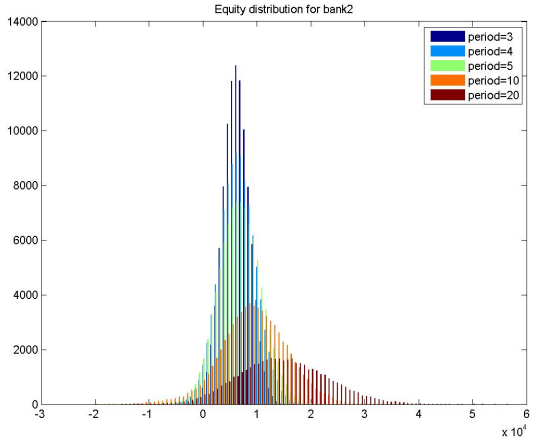


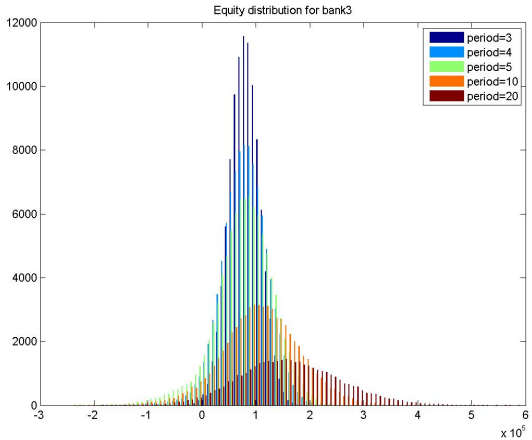


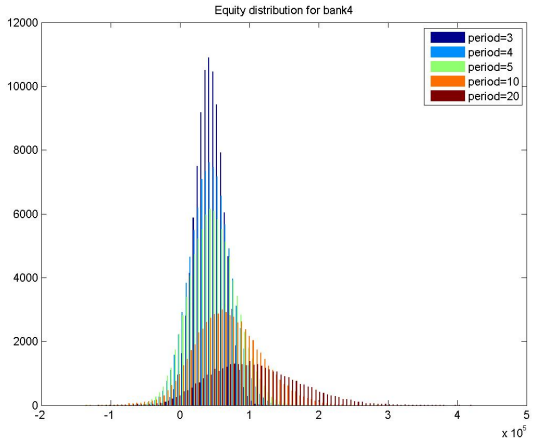
Emergency Liquidity

- To test the ability of Central bank to act as a lender of last resort
- We calibrate the central bank intervention in such a way that it compensates the full losses at the first round of our stress testing exercise.
- it works if and ONLY if the Central bank fully compensates the losses = huge cost


Equity distribution for bank1
period=3
period=4
period=5
period=10
period=20
x 10^5


Equity distribution for bank2
period=3
period=4
period=5
period=10
period=20
x 10^4


Equity distribution for bank3
period=3
period=4
period=5
period=10
period=20
x 10^5


Equity distribution for bank4
period=3
period=4
period=5
period=10
period=20
x 10^5

Policy alternatives

- The model is flexible enough to allow alternatives in policy making, beyond the only LOLR role of Central banks.
- Some alternatives:
  - Introducing exante capital or liquidity regulation
  - Introducing CCPs on the interbank market: in such a way margin calls are lower since the CCP fully compensates cash positions of banks
  - Variation margins: as a macroprudential tools, haircuts may be revised in times of distress to lower collateral constraints
  - Introducing hybrid instruments as convertible debt instruments
  - Introducing fair value pricing of assets used as collateral to lower depreciation and firesales probability.

Conclusion

- We introduce in this paper a fully fledge model for assessing the vulnerabilities of banking systems with the advantage of:
  - being flexible enough to incorporate as much granular information is available
  - that takes into account second round effects of shock (interbank contagion, market contagion, shock amplification)
- The model has the main advantage to allow for complete stress testing and in a unified framework to test for a wide set of policy alternatives, with "nice" visualisation of intended effects.