

# Contagion in Financial Networks

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- ▶ Research Question: Study the resilience of random financial networks against exogenous shocks to asset prices by performing computer simulations.
- ▶ Increased interdependencies among organisations ( governments, banks, central banks, etc) can lead of cascading failures and defaults which are avoided through massive bail-out of institutions deemed " too big to fail" .
- ▶ Recent examples include the European Commission's intervention in Greece.

- ▶ Analyse how the possibility of failure is affected by variations in fundamental factors in the model.
- ▶ Quantitative evaluation of the possibility of failure following exogenous shocks.
- ▶ Calibration of the model using December 2014 data on consolidated foreign claims of banks in reporting countries.

- ▶ Tool to better understand how various factors affect bank failure in random financial networks.
- ▶ Assist risk management involved in promoting financial stability.
- ▶ Through computer simulations I give a more realistic understanding of bank failure under different states of the economy.

# Main findings

- ▶ Through simulation exercises, I show that failure can propagate through the financial network at a certain threshold level.
- ▶ The failure of Greece in a 15-country closed economy can lead to contagion at threshold levels  $\geq 0.75$
- ▶ Following a Greek default on national debt, the countries most at risk are Brazil, Mexico, South Korea and Turkey.
- ▶ The network is more resilient to shocks as safe asset requirement increases.

# Relevant Literature

- ▶ There has been growing interest in the analysis of financial networks, Allen and Gale (2000) provide microeconomic foundations for financial contagion and suggest that contagion risk depends on the structure of the network.
- ▶ This idea is supported by other papers such as Freixas et al (1999) and Cifuentes et al (2007).
- ▶ Similar to my paper, these theoretical papers rely on an unexpected negative exogenous shock to the network.
- ▶ More recently, Glasserman and Young (2015) conclude that apart from the direct spill over effects from a negative shock, more dynamic effects are needed for contagion, for example, fire sales and bankruptcy costs.

- ▶ Acemoglu et al. (2015) find that the key to determine the extent of contagion lies in the *harmonic distance* of the distressed bank to the others and based on this measure, for a large shock, a complete network is more prone to contagion.
- ▶ Gai and Kapadia (2010) find that contagion risk is non-monotonic in connectivity and also depends on capital buffers and the liquidity of the market for failed banking assets.
- ▶ Elliott et al. (2014) study the propagation of shocks through a financial network and find that contagion is non-monotonic in integration and diversification.



- ▶ In parallel, the following empirical literature, Angelini et al. (1996), Furine (2003), Bech and Atalay (2010), Inaoka et al. (2004) and Upper and Worms (2004) examine how the failure of one entity affects the risk of contagion through banks' bilateral credit exposures for Italy, the United States, Canada, Japan and Germany, respectively. Overall, they find that the interbank network is stable and the risk of contagion is low.

- ▶ There are  $N$  entities.
- ▶ Each organisation's assets are composed of primitive assets and cross-holdings in other organisations.
- ▶ We denote this cross-holding by,  $C_{ij} \geq 0$ , which represents the fraction of organization  $j$  owned by organization  $i$ .
- ▶ The parameter  $\hat{C}_{ii} := 1 - \sum_{j \in N} C_{ji}$  represents the fraction of organisation  $i$  owned by outside shareholders.



$$V_i = \sum_k D_{ik} P_k + \sum_{j \neq i} C_{ij} V_j - \beta_i(P) I_{v_i < v_{-i}} \quad (1)$$

- 1 where  $D_{ik}$  denotes the share of the value of primitive asset  $k$  held by organization  $i$  and  $D_{ik} \geq 0$
  - 2  $I$  is a dummy variable taking the value of 1 when  $v_i < v_{-i}$  and 0 otherwise.
  - 3 Failure costs are denoted by  $\beta_i(P)$
- ▶ In matrix notation the book value is:

$$\mathbf{V} = (\mathbf{I} - \mathbf{C})^{-1}(\mathbf{D}\mathbf{p} - \mathbf{b}(\mathbf{v}, \mathbf{p})) \quad (2)$$

- ▶ And the market value of the organisation is:

$$\begin{aligned} \mathbf{v} &= \hat{\mathbf{C}}(\mathbf{I} - \mathbf{C})^{-1}(\mathbf{D}\mathbf{p} - \mathbf{b}(\mathbf{v})) \\ &= \mathbf{A}(\mathbf{D}\mathbf{p} - \mathbf{b}(\mathbf{v})). \end{aligned} \quad (3)$$

- ▶ Assumptions:
  - (i) The number of primitive assets is equal to the number of organisations, denoted by  $m = n$ .
  - (ii) All organisations start with asset values of  $P_i = 1$ .
  - (iii) Organisations with cross-holdings in organisation  $i$  hold an equal share of firm  $i$ .
- ▶ Scenarios:
  - 1 Failure cost is equal to the threshold value ( $\beta_i = v_{-i}$ ) where  $v_{-i} = \theta v_i \forall i$ .
  - 2 Failed organisations lose the value they had in the previous period,  $\beta_i = \mathbf{A} * \mathbf{D} * \mathbf{P}_{\text{inew}}$ .

- ▶ Sub-scenarios:
  - 1 *Sub-scenario 1* Pick an organisation  $i$  uniformly at random and drop the value ( $P_i$ ) of  $i$ 's proprietary asset to 0.
  - 2 *Sub-scenario 2* with 50 percent probability, the value ( $P_i$ ) of  $i$ 's proprietary asset either increases or decreases by 25 percent.
  - 3 *Sub-scenario 3* vary the value ( $P_i$ ) of  $i$ 's proprietary asset by a random number between  $(-\infty, \infty)$ .

- ▶ The default parameters of the simulation exercises are:
  - (1)  $\theta = 0.5$ .
  - (2)  $p = 0.5$ , where  $p$  represents the probability of attachment.
  - (3) Selected organisations hit by the shock = 1.
  - (4) Total number of organisations = 10.
  - (5) Number of iterations = 100.

Parameters 6 - 8 are part of *sub-scenario 2* only:

- (6) Probability of the negative shock  $\mu = 0.5$ .
- (7) Probability of a positive shock =  $1 - \mu$ .
- (8) Increase (decrease) in asset price = 0.25.

- ▶ All shocks (sub-scenarios) and failure costs (scenarios) I consider, the network is more fragile as the failure threshold level increases, *ceteris paribus*.
- ▶ The effect from the exogenous shocks on the networks is very similar and the networks is less resilient to the first exogenous shock (sub-scenario 1).

- ▶ Illustrate the methodology with the data on consolidated foreign claims of banks from Greece, Portugal, Spain and all G20 countries except for Argentina, China, India, Indonesia, Russia, Saudi Arabia and South Africa.
- ▶ Data on cross-holdings are for the end of December 2014 from the Bank of International Settlements (BIS) Quarterly Review (Table 9B).



# Calibration Analysis

**Figure:** The data gives the following *raw* cross-holdings matrix where the *columns* represent the country whose debt is being held and the *row* is the country which holds that debt. For instance, through their banking sector Greece owes Germany \$28,360 million and Germany owes Greece only \$ 2,347 million.

	Australia	Brazil	Canada	France	Germany	Greece	Italy	Japan	Mexico	Portugal	Spain	SouthKorea	Turkey	UnitedKingdom	UnitedStates
Australia	0	904.0	12424.0	10288.0	9086.0	47.0	514.0	19850.0	536.0	137.0	200.0	4867.0	266.0	143878.0	100343.0
Brazil	38.0	0	135.0	1558.0	1667.0	0	534.0	109.0	528.0	627.0	1380.0	1192.0	117.0	9397.0	49171.0
Canada	0	0	0	18324.0	0	0	1964.0	0	0	0	1129.0	0	2077.0	113693.0	764612.0
France	22515.0	23539.0	16434.0	0	159326.0	1850.0	309385.0	177501.0	7047.0	12562.0	130495.0	18797.0	41510.0	194588.0	545057.0
Germany	32790.0	7232.0	28404.0	182140.0	0	28360.0	108570.0	24178.0	4146.0	18313.0	102413.0	13952.0	18133.0	391126.0	460134.0
Greece	35.0	0	55.0	1145.0	2347.0	0	496.0	64.0	0	36.0	125.0	0	31212.0	10479.0	1872.0
Italy	0	776.0	2110.0	36231.0	180943.0	0	0	3640.0	0	3673.0	26610.0	181.0	0	52083.0	28412.0
Japan	108636.0	30058.0	62809.0	164469.0	110149.0	305.0	31380.0	0	20719.0	710.0	20634.0	48061.0	12237.0	186491.0	1252399.0
Mexico	0	27.0	28.0	17.0	41.0	0	6.0	14.0	0	0	177.0	0	0	139.0	3179.0
Portugal	42.0	3677.0	196.0	4826.0	637.0	248.0	5506.0	20.0	129.0	0	17319.0	1.0	21.0	3320.0	4382.0
Spain	2104.0	165547.0	1778.0	41767.0	49788.0	377.0	46442.0	7909.0	156290.0	68346.0	0	390.0	23572.0	372979.0	240902.0
SouthKorea	3106.0	922.0	1172.0	699.0	1649.0	317.0	364.0	7770.0	1324.0	209.0	153.0	0	1012.0	2766.0	21471.0
Turkey	33.0	0	9.0	467.0	1940.0	47.0	143.0	30.0	0	1.0	236.0	0	0	6351.0	2570.0
UnitedKingdom	51713.0	69436.0	90370.0	175585.0	132239.0	13364.0	38408.0	90702.0	43230.0	11714.0	49578.0	72386.0	31803.0	0	990931.0
UnitedStates	97839.0	75538.0	122993.0	180980.0	136838.0	12736.0	60214.0	282200.0	114096.0	4314.0	43777.0	86180.0	24459.0	469528.0	0

# Network Graph Panel A

Figure: Interdependencies between countries (matrix **A** upper diagonal).

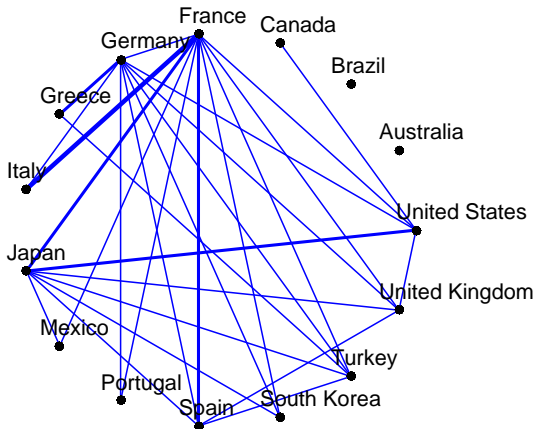


Figure: Interdependencies between countries (matrix **A** lower diagonal).



- ▶ Policy: Countries must hold a percentage of their initial wealth in safe assets, not subjected to shocks.
- ▶ Results are consistent and support the simulation analysis results, as failure threshold increases, countries are more likely to fail.

- ▶ Brazil, Mexico, South Korea and Turkey are most at risk, in a 15-country closed economy.
- ▶ The network is more resilient to exogenous shocks as safe asset requirement increases.
- ▶ Overall, the failure threshold level at which Greece fails increases as the proportion of initial wealth held in safe assets rises.