Multiplex network analysis of the UK OTC derivatives market

Marco Bardoscia
Bank of England

Ginestra Bianconi
Queen Mary University of London

Gerardo Ferrara
Bank of England

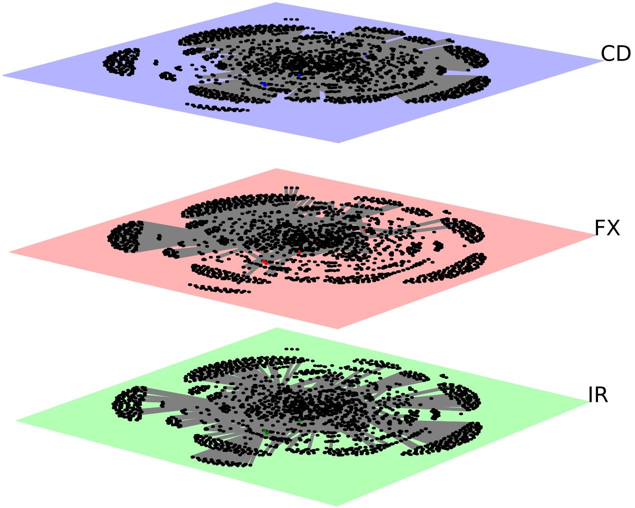
Conference on Economics of Payments IX

16 November 2018

Outline

- Motivation
- Research Question
- Literature
- Data & Network Construction
- PageRank and Eigenvector Centrality
- VM Shock and Contagion Model
- Comparison of different rankings
- Conclusions and Future Work

1.0 Motivation



1.1 Motivation

- The impact of VM shocks on financial markets is important for regulatory authorities.
- OTC derivatives can threaten financial stability through asymmetric and off-balance sheet exposures.
- Contagion does not require the default of an institution. Delayed payments can create liquidity stress.
- What is the most efficient centrality measure?

1.2 What We Do

- We use Trade Repository data to construct the multi-layered network of exposures in the IR, CD, and FX markets.
- We propose a PageRank centrality measure to rank the most important institutions in our network, and we compare it with the eigenvector centrality measure.
- Then we test the potential for liquidity contagion after a VM shock.
  - For each firm we estimate the stress they produce (and receive) under a generic shock.
  - We compare the rankings obtained by using different centrality measures with the ranking of deficiencies obtained by using our contagion algorithm.

1.3 Related Literature on CCPs

- Network structure and the risk of contagion
  - Allen and Gale (2000); Freixas et al. (2000); Gai et al. (2011); Cont et al. (2013)
- Central counterparty clearing and margin payments
  - Cont and Kokholm (2014); Cont and Minca (2014); Duffie et al. (2015)
- Network analysis
  - Bianconi et al. (2016); Heath et.al.(2016); Paddrik et al.(2017)
  - Abad et al. (2016)
  - El-Omari et al.(2018); Fiedor et al. (2017)

2.1 Data

- The Trade Repository data consists of reported transactions of derivatives when:
  - All transactions are through UK CCPs.
  - One of the counterparties is UK-domiciled.
  - For CDSs, either one of the counterparties and/or the underlying is UK-domiciled.
  - Contracts are sterling denominated.
- We use all open positions reported to DTCC and Unavista TRs on 30th June 2016.
- We focus only on the clearing members' transactions (centrally and non-centrally cleared).

2.2 Network Construction

- IR transactions dominate the cleared market, followed by CD transactions.
- Very few FX contracts are centrally cleared

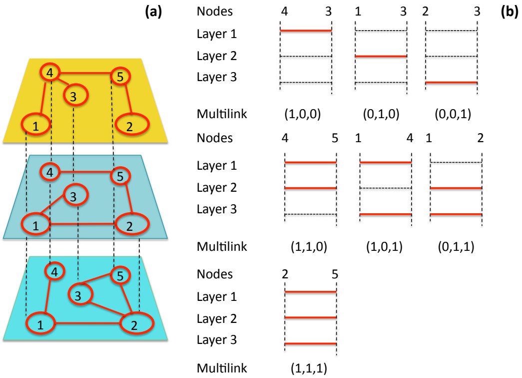
Fraction of centrally and non-centrally cleared transactions:

	Cleared	Uncleared
IR	68.69%	31.31%
CD	8.47%	91.53%
FX	0.92%	99.08%

Summary statistics:

	Notional	# trades	Cleared notional
IR	2.64E+14	3,674,857	2.10E+14
CD	1.10E+14	1,033,158	2.87E+12
FX	6.90E+13	5,975,179	3.26E+12

2.3 Structural Properties and Correlation

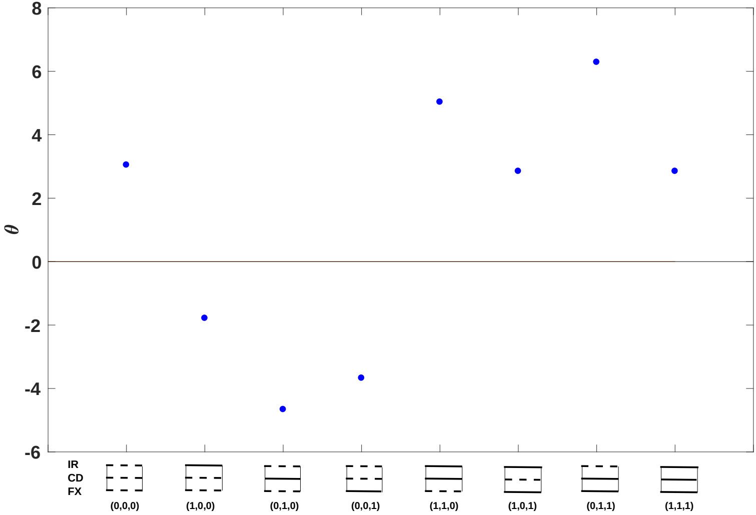


$N_{lay}^{[IR]}$	$N_{lay}^{[CD]}$	$N_{lay}^{[FX]}$
473	1469	553

$\delta(a=1)$	$\delta(a=2)$	$\delta(a=3)$
0.893	0.066	0.041

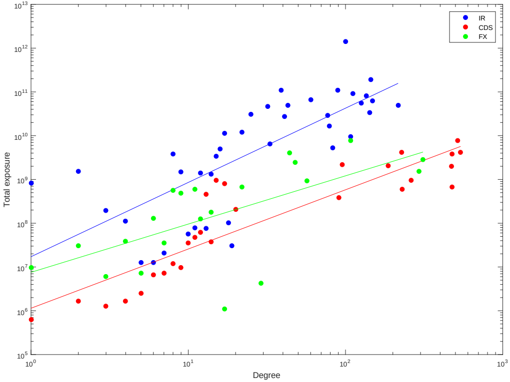
	IR	CD	FX
IR	1.00	-0.24(4)	0.14(3)
CD	-0.24(4)	1.00	-0.36(5)
FX	0.14(3)	-0.36(5)	1.00

2.4 Structural Properties and Correlation (cont'd)



2.5 Structural Properties and Correlation (cont'd)

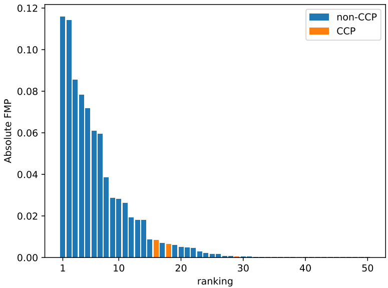
$$\ln s_k^{[\alpha]} = \beta_0 + \beta_1 \ln k + \epsilon$$



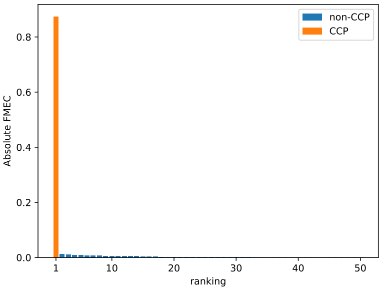
	IR	CD	FX
β_1	1.70	1.35	1.10
σ_{β_1}	0.25	0.13	0.29
R^2	0.55	0.812	0.43

3.1 PageRank Centrality

- Understanding the vulnerability of the system to failure by using the PageRank centrality measure.

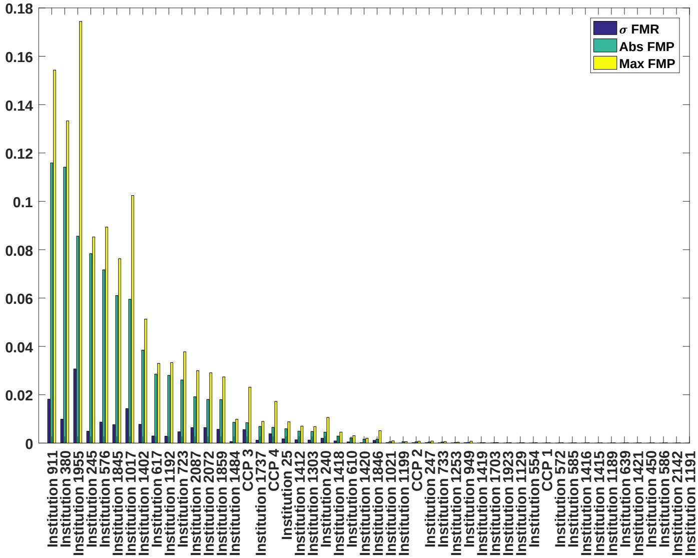


PageRank centrality



Eigenvector centrality

3.2 PageRank Centrality (cont'd)



4.0 VM Shock Estimation

- We use the same shock evaluation method used in Heath et.al. (2016).
- We define Δp as the change in the price of product k since the last variation margin payment (assumed to be normally distributed around zero).
- Then next variation margin payment is given by $VM_{ij}^{K} = E_{ij}^{K} \Delta p$.
- For participants i and j, the random variable for variation margin obligations over the margining period is $VM_{ij}^{K} \sim N(0, \sigma_{E_{ij}}^{2} E_{ij}^{2})$, where $\sigma_{E_{ij}}^{2} = e'\Omega e$.

4.1 Contagion Model

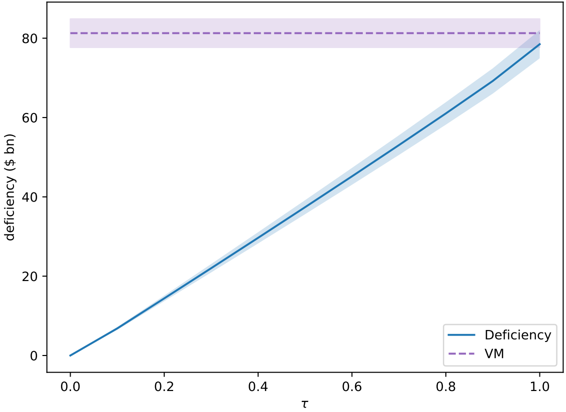
- The seminal paper by Eisenberg and Noe (2001) shows how to compute clearing payments in a network of obligations.
  - If my counterparties do not pay back their obligations in full to me, in turn I might not be able to make good on all my payments.
  - The vector of realised payments is the fixed point of a set of equations that can be computed iteratively.
- In order to study the network of CDSs, we extend the work of Paddrik et al. (2016):
  - To consider a multiplex network
  - To analyze a liquidity shock.

4.2 One Layer: Paddrik et al. (2016)

- First step: Each firm computes the maximum potential liquidity stress that it will transmit to its counterparties, i.e. its obligations minus its incoming payments.
  - CCPs will use their cash or other cash equivalents to absorb (part of) the stress.
- Second step: Liquidity buffers for each firm are difficult to calibrate.
  - Payments are computed assuming that each firm transmits a fraction τ of its stress to its counterparties. Stress is transmitted pro rata and is capped by the obligation.
- Third step: Each firm computes the deficiency in its payments (payments are computed pro-rata).

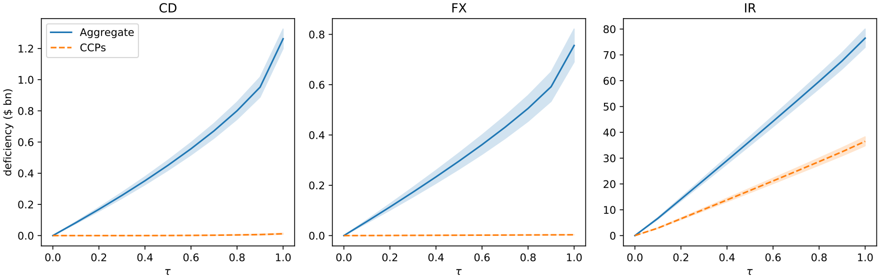
4.3 Transmission Factor

- Aggregate VM payments that institutions are requested to make (purple dashed line) and aggregate deficiencies in those VM payments (blue solid line) as a function of the transmission factor τ, both expressed in US billion dollars.



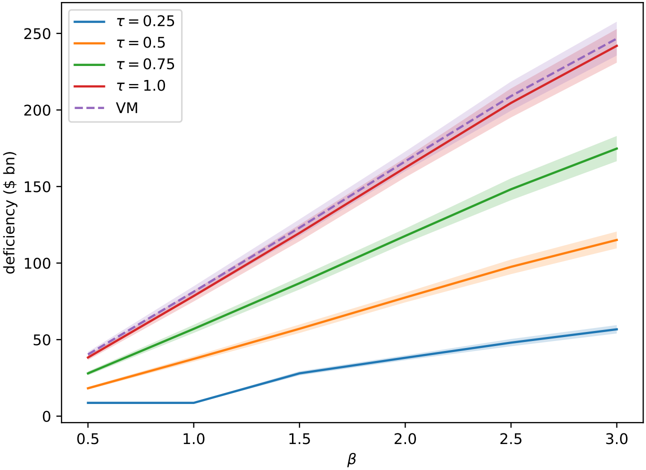
4.4 Transmission Factor (cont'd)

- Deficiencies in VM payments broken down by layer as a function of the transmission factor τ. Blue solid lines refer to US billion dollar aggregate deficiencies, orange dashed lines refer to US billion dollar deficiencies of CCPs only.



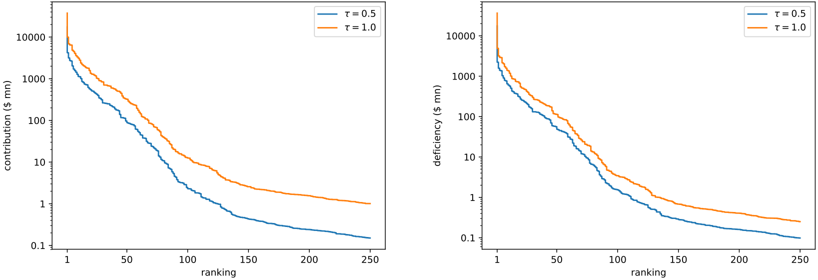
4.5 Shock Size

- Aggregate deficiencies in VM payments expressed in US billion dollars as a function of the shock factor β, for different values of τ.



4.6 Contributions to Deficiencies

- Top 250 individual institutions contributing to deficiencies (left panel) and experiencing deficiencies (right panel) in VM payments expressed in US million dollars.



4.7 Rank correlation

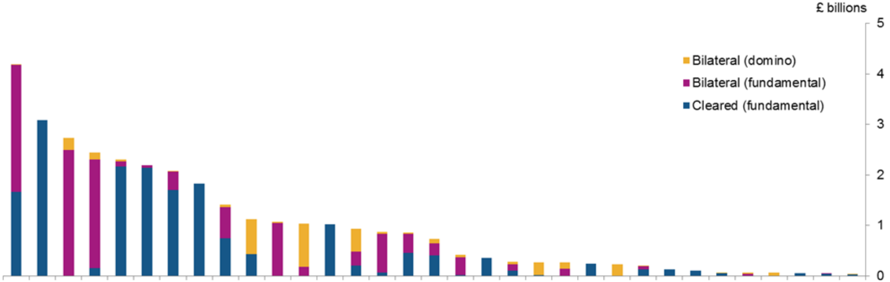
σ	$\sigma = 0.5$		$\sigma = 1.0$		$\sigma = 1.5$		$\sigma = 2.0$		$\sigma = 2.5$		$\sigma = 3.0$	
τ	FMT	FMEC	FMT	FMEC	FMT	FMEC	FMT	FMEC	FMT	FMEC	FMT	FMEC
0.1	0.453	0.352	0.510	0.373	0.420	0.358	0.491	0.285	0.492	0.342	0.468	0.393
0.2	0.453	0.352	0.495	0.324	0.422	0.357	0.428	0.280	0.494	0.344	0.463	0.357
0.3	0.453	0.355	0.497	0.325	0.425	0.360	0.428	0.280	0.494	0.344	0.468	0.362
0.4	0.455	0.357	0.497	0.328	0.428	0.363	0.430	0.282	0.495	0.345	0.471	0.365
0.5	0.456	0.358	0.503	0.335	0.430	0.365	0.433	0.282	0.495	0.345	0.473	0.366
0.6	0.458	0.360	0.503	0.335	0.435	0.370	0.438	0.286	0.499	0.348	0.459	0.321
0.7	0.458	0.360	0.503	0.338	0.438	0.373	0.443	0.291	0.499	0.348	0.461	0.326
0.8	0.440	0.340	0.508	0.343	0.422	0.326	0.448	0.293	0.484	0.301	0.464	0.329
0.9	0.445	0.345	0.508	0.346	0.425	0.329	0.453	0.298	0.484	0.304	0.471	0.335
1.0	0.458	0.365	0.515	0.320	0.432	0.345	0.461	0.309	0.504	0.324	0.480	0.345

5.1 Conclusions and Future Work

- We find that, for τ between 0.5 and 1, between 0.3% and 0.6% of institutions experience materially large deficiencies, while between 0.5% and 1.2% of institutions give material contributions to the aggregate deficiency.
- We show that the rankings of vulnerability based on the Abs FMP centrality correlate reasonably well with rankings based on deficiencies computed via the contagion algorithm. This suggests that the Abs FMP centrality could be used as a proxy for calculating the potential vulnerability of institutions.
- The framework could be very useful to study solvency contagion risk.
- A possible future extension of our work could be to tie VM shocks to specific macroeconomic shocks.

5.2 Conclusions and Future Work (cont'd)

- Aggregate liquidity need = £33bn (vs. average daily cash borrowing in global repo markets of > £0.5tr).
- Aggregate liquidity need = £6bn if all (scaled down) liquid assets were used to pay margins.
- Aggregate liquidity need = £0 if all (non-scaled down) liquid assets were used to pay margins.



Source: Bardoscia, M., Ferrara, G., Vause, N and Yoganayagam, M., *Simulating liquidity stress in the derivatives market*, Working Paper (forthcoming)

THANK YOU!

References

- Abad, J., et al., *Shedding light on dark markets: First insights from the new EU-wide OTC derivatives dataset*, European Systemic Risk Board Occasional Paper Series, 11, 2016.
- Bianconi, G., *Statistical mechanics of multiplex networks: Entropy and overlap*, Physical Review E, 87(6), 062806, 2013.
- Boccaletti, S., et al., *The structure and dynamics of multilayer networks*, Physics Reports, 544(1), 1-122, 2014.
- Eisenberg, L., and Noe, T. H. *Systemic risk in financial systems*, Management Science, 47(2), 236-249, 2001.
- Heath, A., Kelly, G., Manning, M., Markose, S., and Shaghaghi, A. R., *CCPs and network stability in OTC derivatives markets*, Journal of Financial Stability, Vol. 27, pages 217-233, 2015.
- Iacovacci, J., Rahmede, C., Arenas, A., and Bianconi, G., *Functional Multiplex PageRank*, EPL (Europhysics Letters), 116(2), 28004, 2016.
- Markose, S., Giansante, S., and Shaghaghi, A. R., *Too interconnected to fail financialnetwork of U.S. CDS market: topological fragility and systemic risk*, Journal of Economic Behavior & Organization, Vol. 83, pages 627-646, 2012.
- Menichetti, G., Remondini, D., Panzarasa, P., Mondragón, R. J., and Bianconi, G., *Weighted multiplex networks*, PloS one, 9(6), e97857, 2014.
- Paddrik, M., Rajan, S., and Young, H. P., *Contagion in the CDS Market*, Office of Fiancial Research Working Paper, No. 16-12, 2016.
- Paddrik, M., and Young, H. P., *How Safe are Central Counterparties in Derivatives Markets?*, Office of Fiancial Research Working Paper, No. 17-06, 2017.