Network analysis using EMIR credit default swap data: Evidence from Irish domiciled special purpose vehicles (SPVs)

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- This presentation summarises the paper of the same title authored by Kitty Moloney, Neill Killeen and Oisin Kenny. The views expressed in this presentation are solely the views of the authors and are not necessarily those held by the Central Bank of Ireland or the European System of Central Banks (ESCB).

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1. Introduction

1. Introduction

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- First analysis of European Markets Infrastructure Regulation (EMIR) data

- **Dual-sided reporting**: Every undertaking established in the EU must report their side to a derivative trade to a trade repository
  - 60 fields for every CDS trade

- Additional obligations on financial counterparties (FCs) and non-financial counterparties (NFCs) trading in significant volumes:
  - Mark-to-market derivatives daily (in force)
  - Clear standardized products and post margin bilaterally for non-standardized products (being phased in)

1. EMIR Definitions

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- Financial counterparty:
  - Credit institutions
  - Investment funds – undertakings for collective investment in transferable securities (UCITS) and alternative investment funds (AIFs) – and their management companies
  - Institutions for occupational retirement provision
  - Undertakings in insurance, assurance, and reinsurance
- Non-financial counterparty:
  - An undertaking other than a central counterparty (CCP) or a financial counterparty

1. Objectives

- Irish CDS market
  - Observe network topology, identify key nodes
  - Analyze reference entities underlying these trades
- Discuss suitability of SPVs classification as NFCs under EMIR and financial stability implications
  - Examine two sub-samples – SPVs and non-financial corporations

1. Some Explanations

- Credit default swap = bond insurance
  - Buyer makes payments to the seller until maturity
  - In return, seller pays the buyer the par value of the bond in the event of a default by the bond's issuer
- Special purpose vehicles
  - Bankruptcy remote
  - Transforms counterparty risk into legal risk

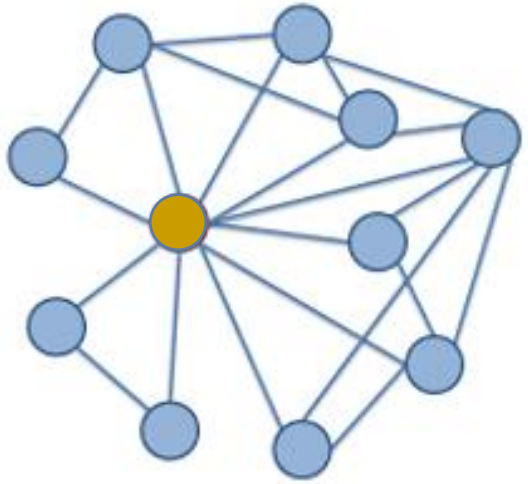
1. Literature

- Counterparty credit risk and the crisis – **Gregory (2012)**
- **IMF, BIS & FSB (2009)** define systemic risk:

  "The risk of disruption to financial services caused by an impairment of all or parts of the financial system with the potential for a large and negative impact on the real economy."

Networks

- More regulatory focus on highly interconnected firms to avoid financial contagion – **Haldane (2009)**
- Global bank lending – **Minoiu & Reyes (2013)**
- Credit default swaps
  - United States: **Markose et al. (2012)**
  - Europe: **Clerc et al. (2014)**
  - Global: **Peltonen et al. (2014)**



2. Data & Network Conventions/Metrics

2. Data Cleaning and Netting

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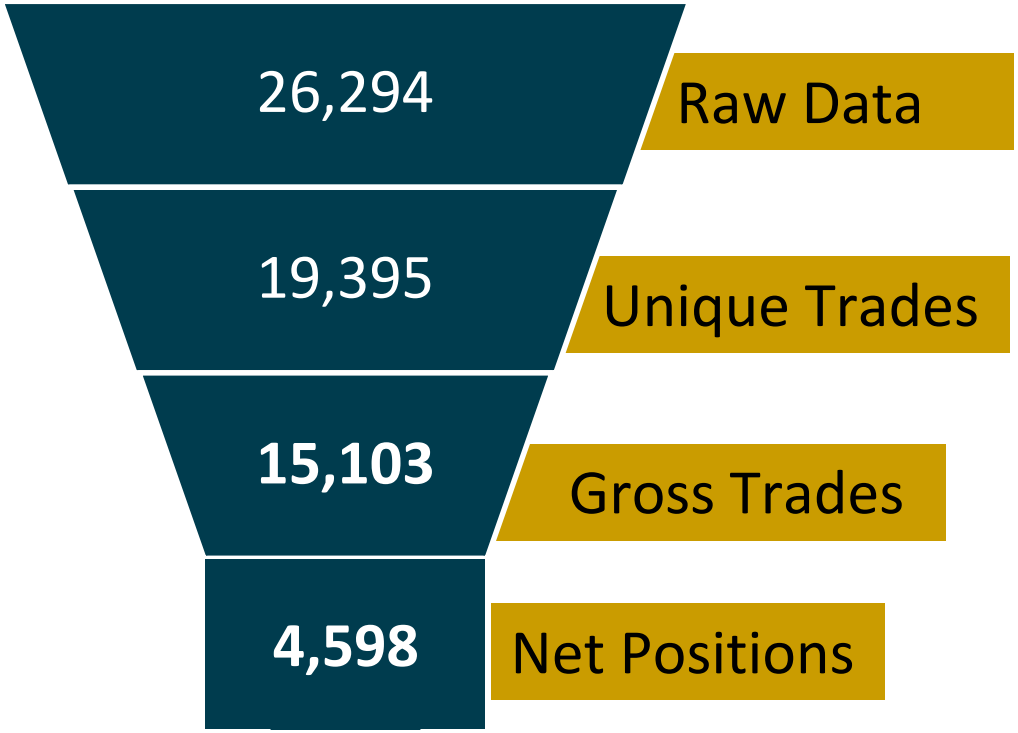
Data Snapshot at 1 September 2015



Netting Example

Bank A buys a CDS from **Bank B Securities** on **Caterpillar Inc.** for **$70** in notional

Bank A sells a CDS to **Bank B** on **Caterpillar Inc.** for **$100**

=> **Bank A Group net buyer**: $30

=> **Bank B Group net seller**: $30

…And so on for all reference entities per counterparty pair

2. Network Conventions

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Nodes

Color – sector (European Central bank)
Size – total gross/net notional

Shape – 

(net notional networks only)

- **Monetary Financial Institutions (MFIs)** – banks
- **Other Financial Intermediaries (OFIs)** – investment funds
- **Non-Financial Corporations (NFCs)** – utility companies, airlines, etc.
- **Pension Funds (PFs)**
- **Insurance Companies (ICs)**
- **Special Purpose Vehicles (SPVs)**

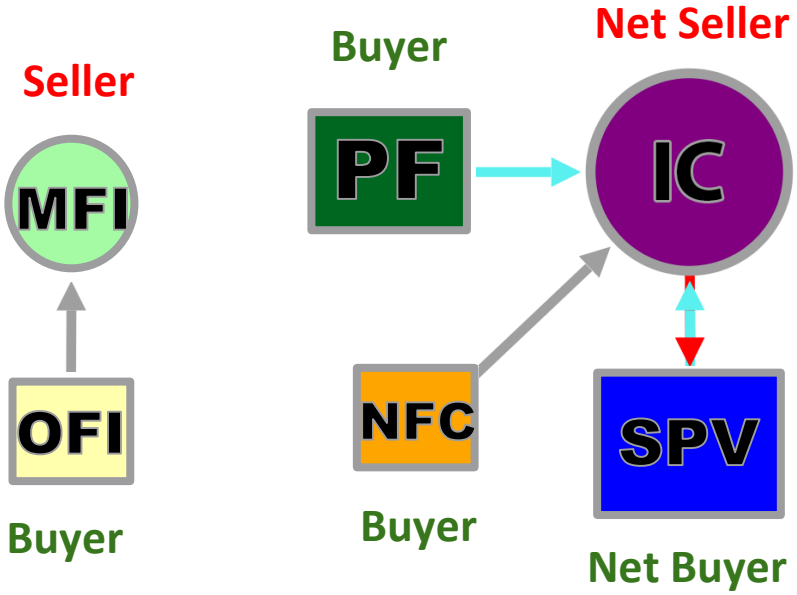
Edges

Grey < €100 mn

€100 mn < Red < €1 bn

Blue > €1 bn

Example Network



2. Network Analysis Metrics

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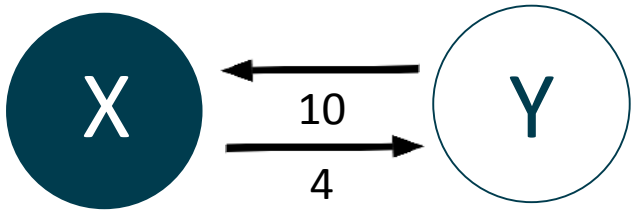
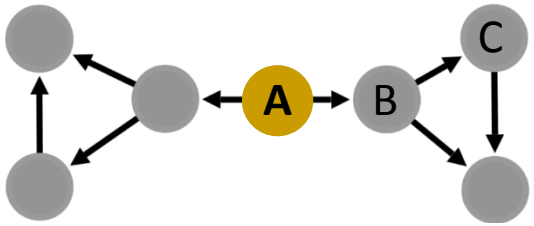
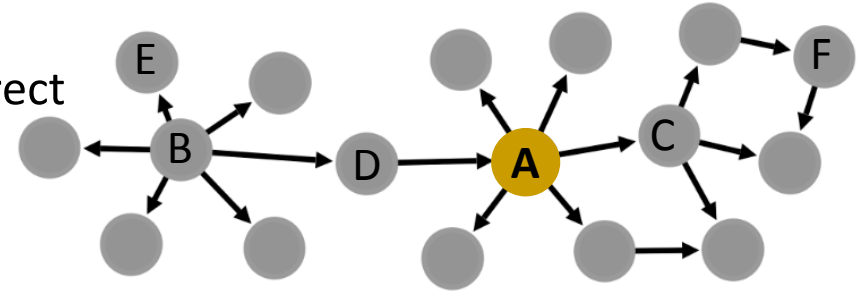
- **In- (out-) degree** – no. of counterparties a firm is selling (buying) to (from)
- **In- (out-) strength** – size of a counterparty's total selling (buying) position
- **Multilateral position** = in-strength – out-strength



- **Density** – ratio of actual links to possible links
- **Betweenness centrality*** – how often a node appears on shortest paths between nodes (i.e. identifies hubs/major dealers)



- **Eigenvector centrality*** – captures the direct and indirect connections of a node



*These measures are undirected.

2. Network Analysis Metrics

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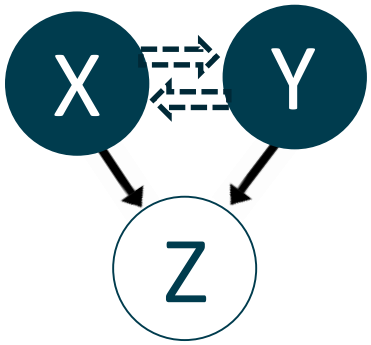
- **Transitivity (or clustering coefficient)*** – the probability that two nodes trade CDS with each other given that they both trade with another node



- **Assortativity*** – the tendency of nodes trading with the same number of counterparties to trade with each other

- **Average shortest distance** – the average of the shortest paths from every node to all others nodes in the network

- **Diameter** – the longest of all the shortest paths between any pair of nodes

*These measures are undirected.

3. CDS Networks in Ireland

3. (a) CDS Network in Ireland

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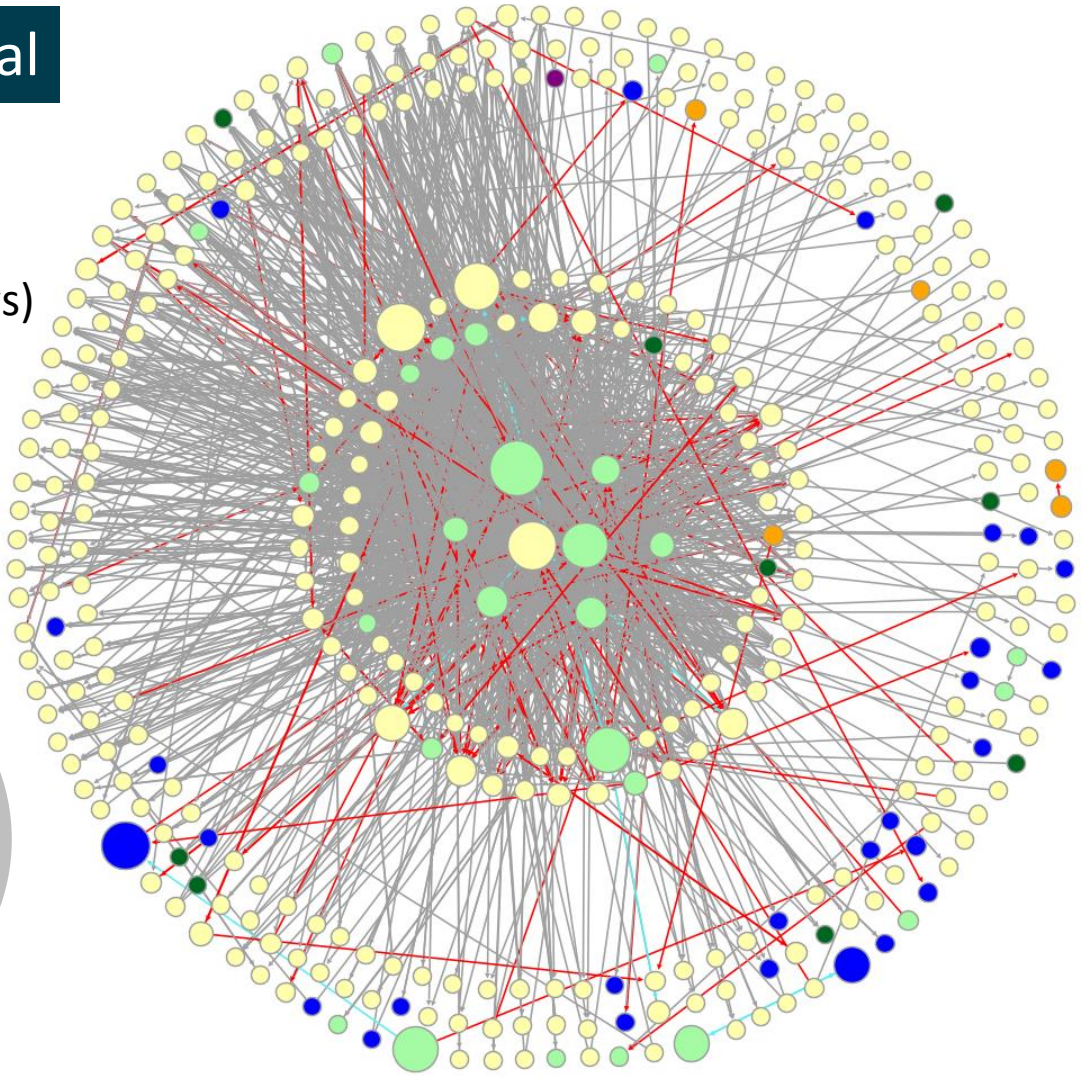
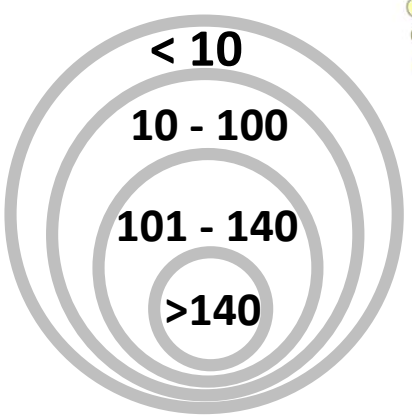
Gross Notional

Dual Circle Layout (Modified)
Degree (sells + buys) descends counterclockwise



Degree



OFI	304
SPV	27
MFI	26
PF	9
NFC	6
IC	1

Note: Size of node is proportional to total gross exposure. Network drawn in Gephi.

3. (a) CDS Network in Ireland

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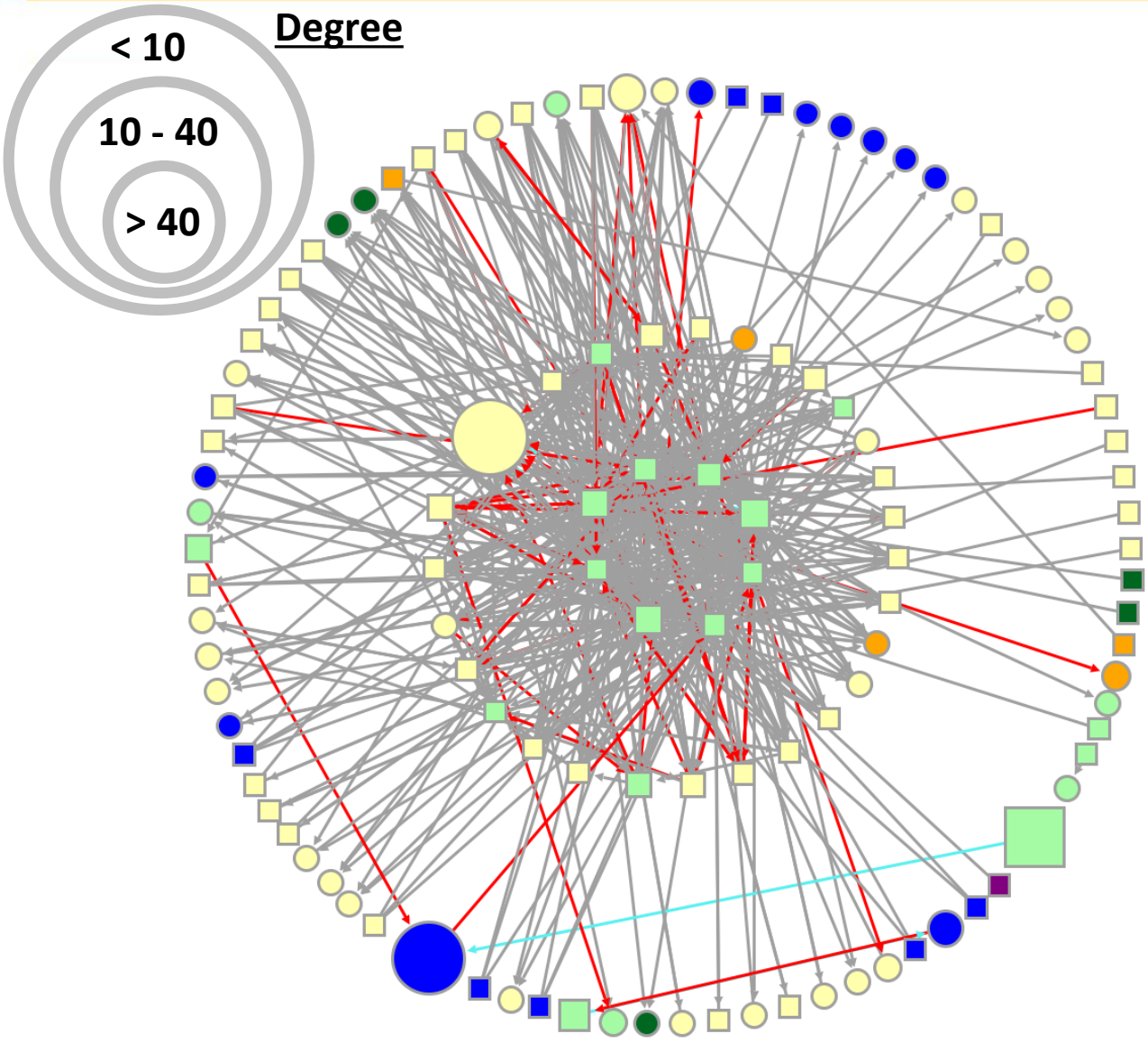

Net Notional

	Sellers		Buyers	
OFI	42	+	24	= 66
MFI	6	+	17	= 23
SPV	10	+	7	= 17
PF	3	+	2	= 5
NFC	3	+	2	= 5
IC			1	

Note: Size of node is proportional to total net multilateral exposure. Network drawn in Gephi.

3. (a) SPV and NFC Sub - Samples

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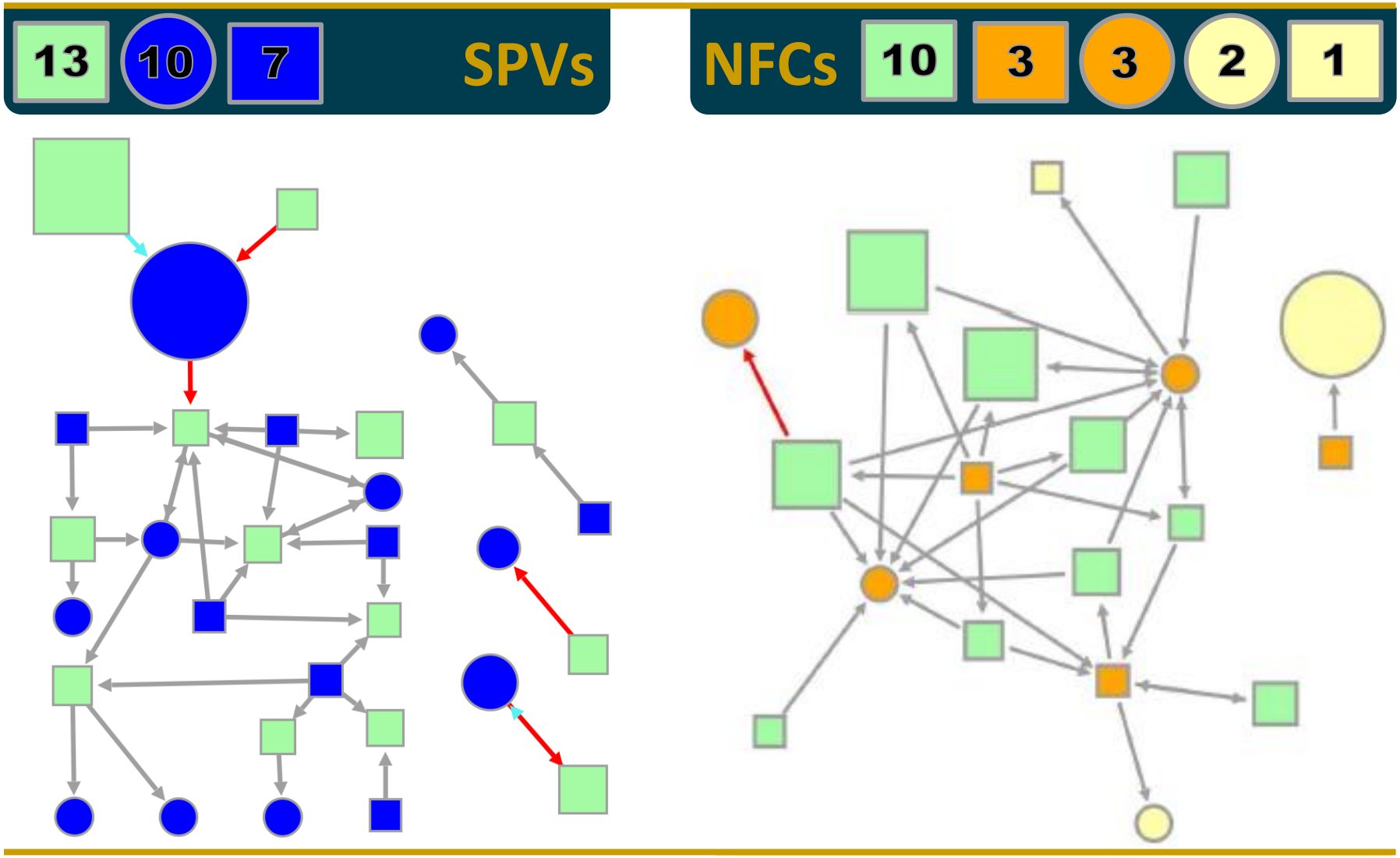

Note: Size of node is proportional to total net multilateral exposure. Network drawn in Gephi.

3. (b) Reference Entity Sectors

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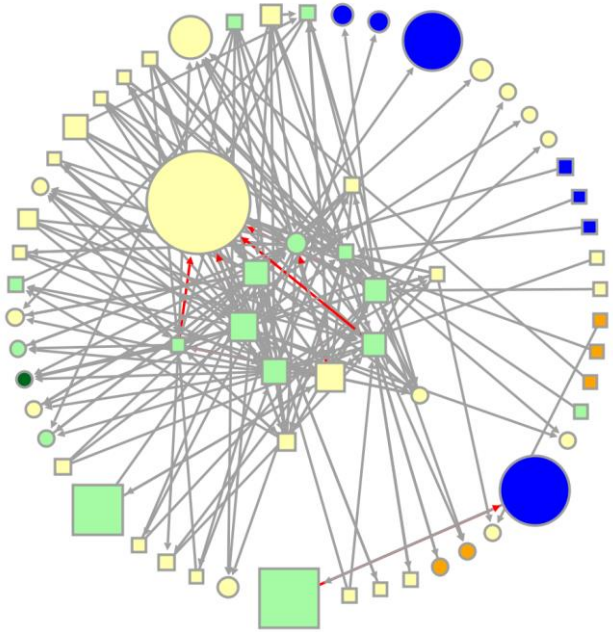
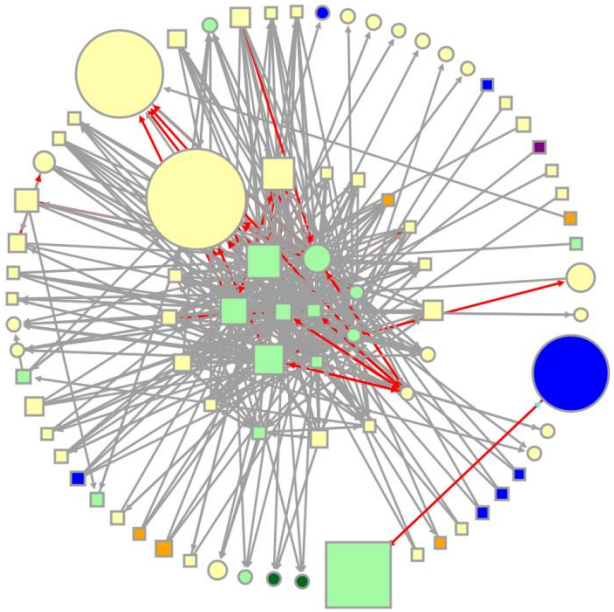
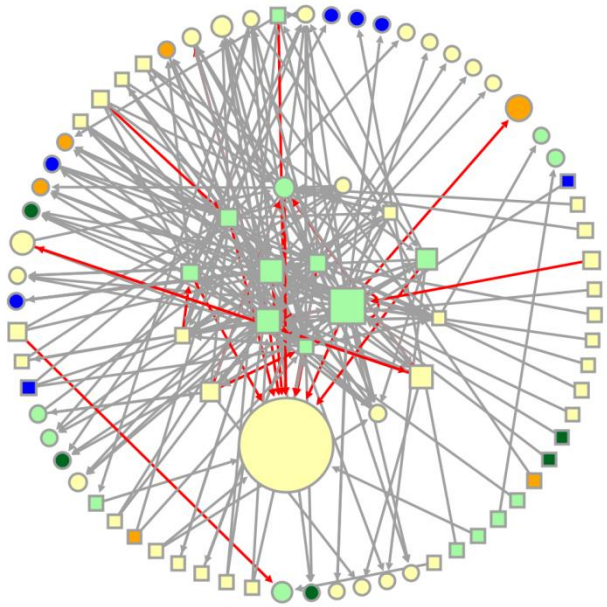
Financials



Non-Financials



Sovereigns



Note: Size of node is proportional to net multilateral exposure **on a sector basis (i.e. not over all sectors)**, buyers = squares and sellers = circles. There are 15 EU sovereigns and 35 non-EU sovereigns.

3. Network Topology

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	Gross	Net	Sub-Samples		Reference Entity Sectors		
			SPVs	*NFCs*	*Financials*	*Non-Financials*	*Sovereigns*
Nodes (entities)	373	117	30	20	63	82	84
Edges (links)	1,875	619	36	38	209	440	400
CDS trades	15,103	4,598	360	78	740	3,130	670
Reference entities	897	846	328	54	181	579	50

4. Network Analysis and Descriptive Statistics

4. Network Analysis Metrics

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	Median									
	In-/Out-Degree	In-Strength (€ m)	Out-Strength (€ m)	Eigen-vector Centrality	Between-ness Index	Density	Trans-itivity	Assort-ativity	Average Shortest Distance	Diam-eter
Gross	1.0	13.9	7.1	0.14	0.00	1.4%	0.0%	-61.5%	3.1	8
Net	2.0*	18.4	27.5	0.22	0.01	4.6%	4.9%	-72.1%	2.5	5
Sub-Sample										
SPVs	1.0	20.4	15.1	0.16	0.01	4.1%	0.0%	28.7%	2.2	6
NFCs	2.5	7.6	22.2	0.32	0.03	10.0%	0.0%	-55.5%	2.3	4
Reference Entity Sector										
Financials	1.0	6.4	10.0	0.24	0.01	5.4%	1.8%	-47.4%	2.7	5
Non-Financials	2.5	7.6	22.2	0.26	0.01	6.6%	2.6%	-70.4%	2.5	5
Sovereigns	1.0	7.1	9.5	0.26	0.01	3.7%	4.1%	-51.6%	2.8	6

*Kolmogorov-Smirnov test failed to reject null that the degree distribution follows a power law distribution at 1% significance level.

4. Net Multilateral Positions

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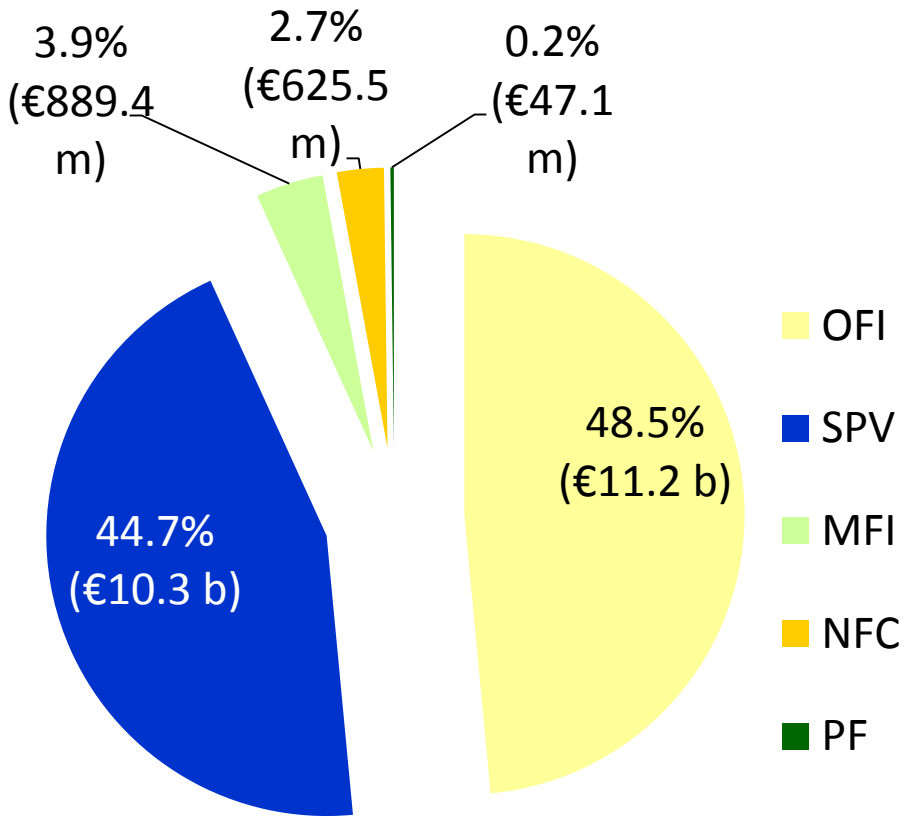
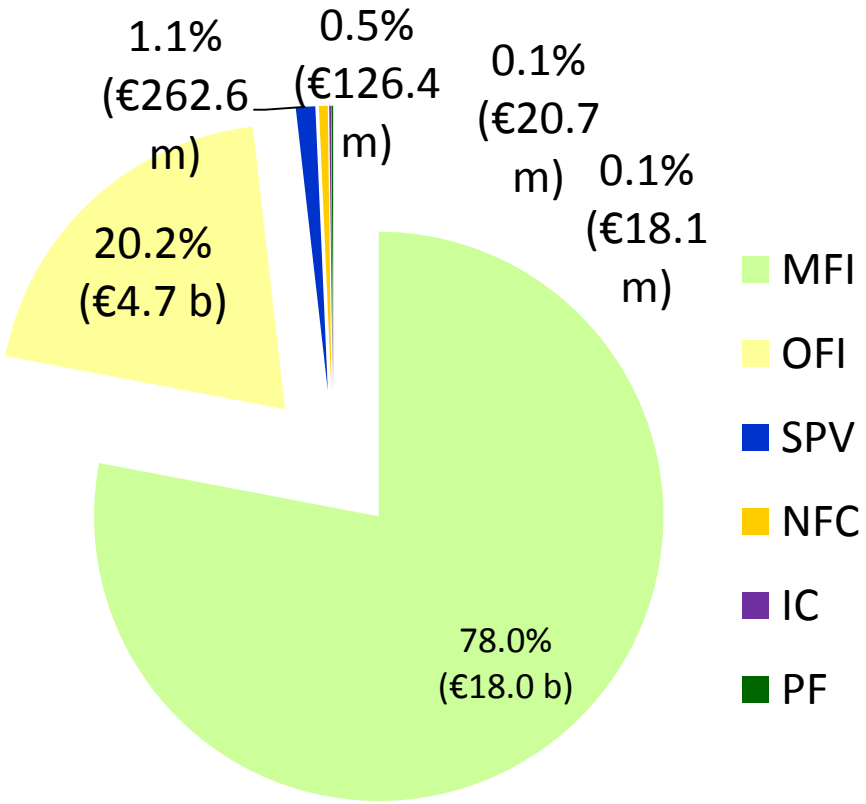
Net Sellers



Net Buyers



Note: Values are notional amounts.

4. Top Counterparties by Metric

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Rank	In-degree		Out-degree		In-strength (€ m)		Out-strength (€ m)		Multilateral selling position (€ m)		Between-ness	Eigen-vector centrality
1	MFI 5*	38	MFI 6*	37	OFI 22	8,548.2	OFI 16	7,349.6	OFI 22	8,390.1	MFI 5*	MFI 5*
2	MFI 12*	38	MFI 5*	35	SPV 19	8,268.3	MFI 5*	3,466.0	SPV 19	7,808.9	MFI 10*	MFI 12*
3	MFI 6*	36	MFI 41*	31	MFI 5*	2,222.4	MFI 9*	2,564.1	OFI 18	1,924.1	MFI 41*	MFI 6*
4	MFI 10*	34	MFI 12*	29	SPV 63	2,049.3	MFI 41*	2,492.5	SPV 63	1,804.2	MFI 6*	MFI 41*
5	MFI 41*	32	MFI 10*	28	OFI 18	1,944.8	MFI 13	2,049.3	MFI 30*	565.2	MFI 8*	MFI 8*
6	MFI 7*	31	MFI 9*	28	MFI 12*	1,444.6	OFI 1	1,736.0	NFC 54	555.9	MFI 12*	MFI 9*
7	MFI 9*	30	MFI 8*	28	MFI 7*	1,172.6	MFI 12*	1,574.0	SPV 59	506.6	MFI 7*	MFI 7*
8	MFI 8*	27	MFI 3*	27	MFI 41*	1,097.6	MFI 8*	1,554.4	OFI 20	336.4	MFI 9*	MFI 10*
9	MFI 3*	26	OFI 1	18	MFI 10*	1,087.8	MFI 6*	1,494.1	OFI 46	239.0	MFI 3	MFI 3
10	OFI 22	14	OFI 4	13	MFI 6*	966.2	MFI 10*	1,484.4	OFI 23	89.0	OFI 22	OFI 22

* Indicates a globally systemically important bank (G-SIB) and a G-16 dealer (i.e. the 16 major derivatives dealers).

4. Reference Entity Jurisdictions

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Rank	Jurisdiction	Net Notional (€m)	% of Total	Cumulative %
1	Unknown (bespoke indices/baskets)	11,642.5	29.1	29.1
2	US	7,672.1	19.2	48.3
3	UK	2,463.2	6.2	54.4
4	Netherlands	2,129.8	5.3	59.8
5	France	1,798.3	4.5	64.3
6	Italy	1,369.4	3.4	67.7
7	Brazil	1,278.8	3.2	70.9
8	Russia	868.4	2.2	73.1
9	Mexico	863.8	2.2	75.2
10	Germany	860.5	2.2	77.4

4. Reference Entity Credit Ratings

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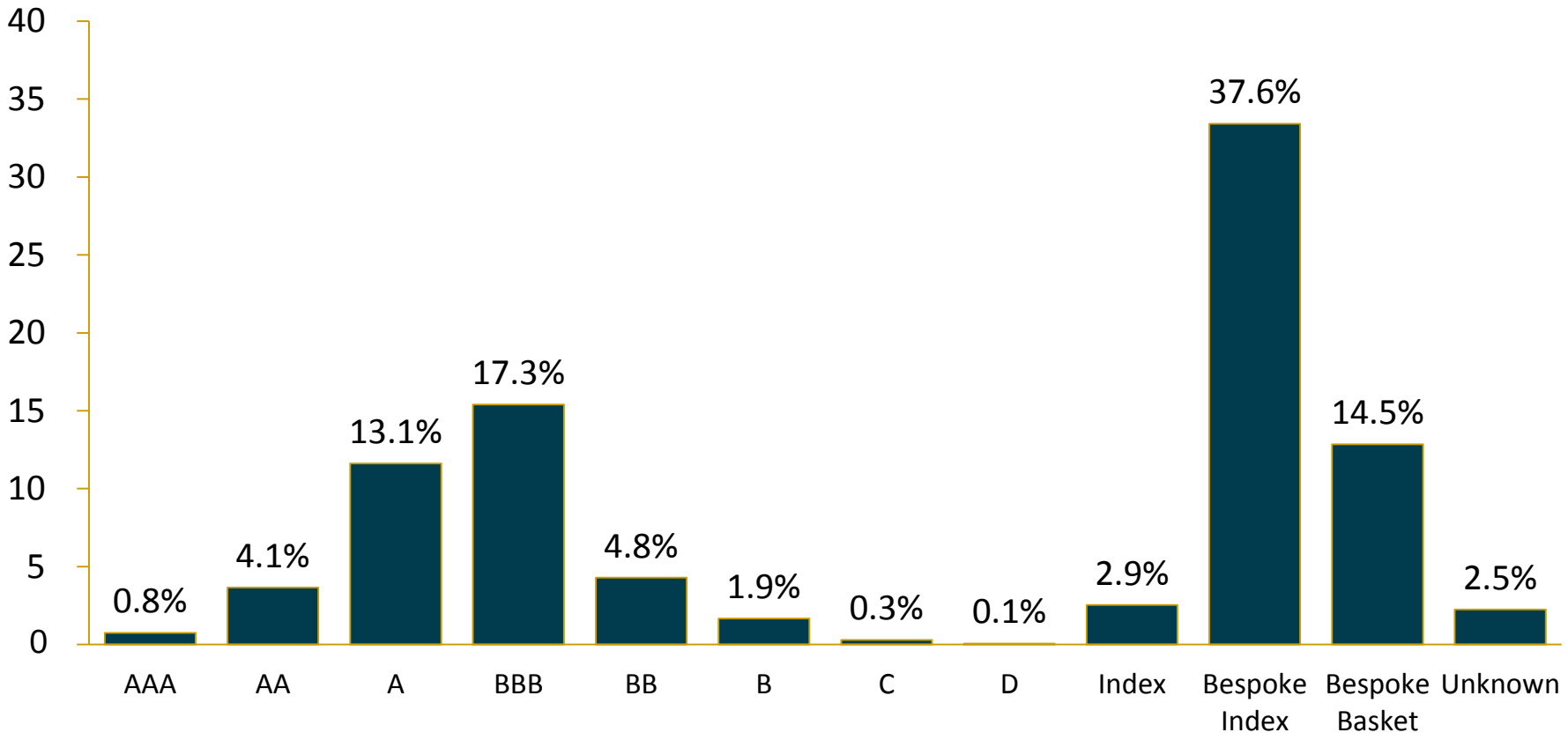
Total Gross Notional = €88.8 b

Credit Ratings by Gross Notional (€ b)



4. CDS Gross Notional Time Series

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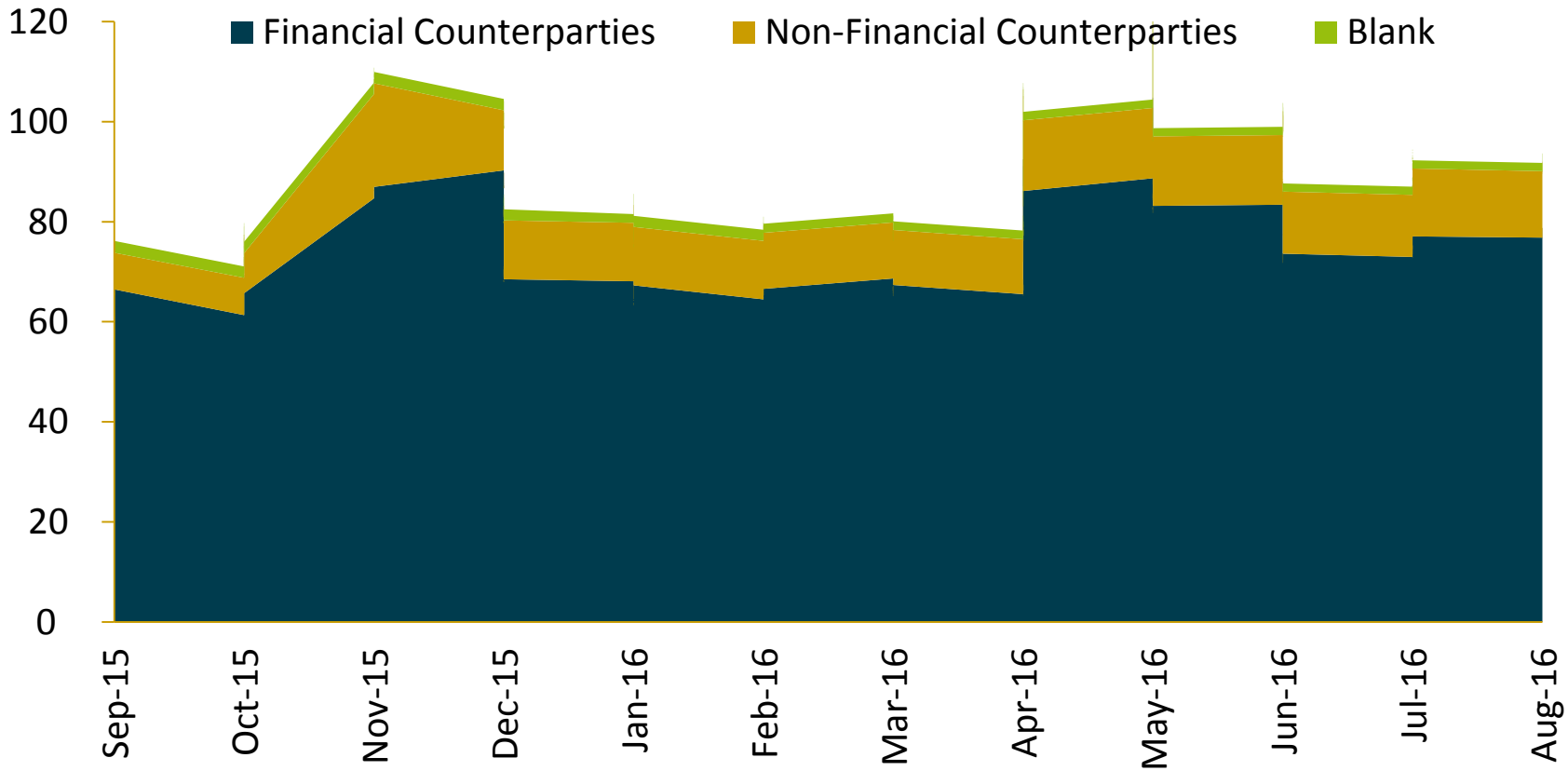
Gross Notional Time Series by Counterparty Classification (€ b)



4. CDS Gross Notional Time Series

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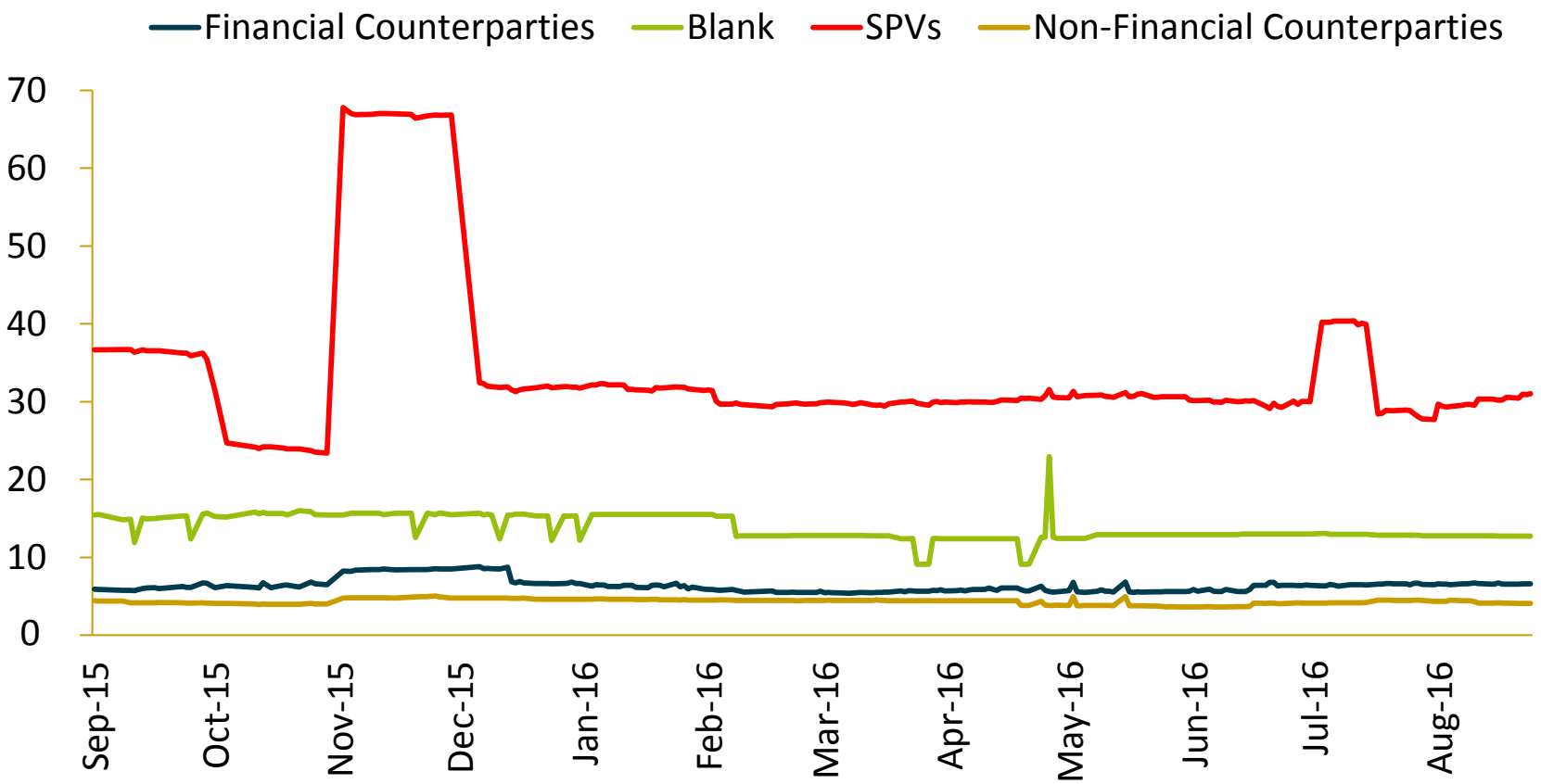
Average Gross Notional per CDS by Counterparty Classification (€ m)



Note: Some SPVs might be included in the NFC figure as we only know the SPVs that provide us with quarterly returns.

5. Conclusion

- Data limitations as restricted to jurisdiction only data
  - Inter-regulatory cooperation essential
- Irish CDS market is highly concentrated
  - Core of non-domestic G-16 dealers
  - Large periphery of firms with only a couple of links
- Non-bank financial institutions are largest net sellers in CDS market
  - SPVs and funds (OFIs) selling to non-domestic MFIs

5. Policy Implications

- SPVs may need to be reclassified as financial counterparties or even quasi-FCs under EMIR
  - SPVs average CDSs roughly 8x larger than NFCs *and* FCs
  - SPVs have been used by G-SIBs and major dealers to house derivative operations for over two decades
- Possible first step:
  - Require SPVs to mark-to-market their trades daily
- Remaining challenges:
  - Bespoke baskets and indices
  - Data quality

Thank you!

Appendix – Formulas

Betweennesss Centrality (Jackson 2008)

Normalized Betweenness Centrality (node k) $= \sum_{i \neq j \neq k} \frac{\left(\frac{P_k(ij)}{P(ij)}\right)}{(n\text{-}1)(n\text{-}2)/2}$

$P_k(ij)$ # of shortest paths from *i* to *j* that pass through node k

$P(ij)$ Total # of shortest paths from *i* to *j*

n # of nodes in the network

If there are no paths between *i* and *j, let*

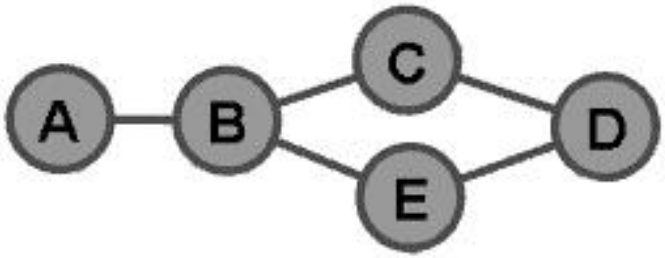
$$\frac{P_k(ij)}{P(ij)} = 0$$

Appendix – Formulas

Betweennesss Centrality

- Shortest path between A and D has 3 links
- 2 paths: A-B-C-D & A-B-E-D

$$P(AD) = 2$$



- Since B lies on both shortest paths

$$P_B(AD) = 2$$

$$\text{Betweenness}_\text{B} = 2/2 = 1$$

Appendix – Formulas

Eigenvector Centrality (Zafarni et al. 2014)

Eigenvector Centrality $=$ $Ax = \lambda x$

A	Adjacency matrix of the network
x	Eigenvector of degree centrality
λ	Eigenvalue

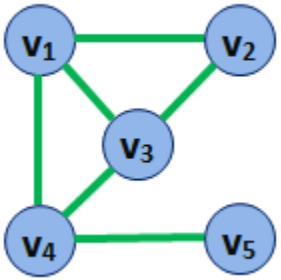
Eigenvector Centrality (node *i*):

$$x_i = \frac{1}{\lambda_{max}} \sum_{k=1} A_{k\,i}, x_k$$

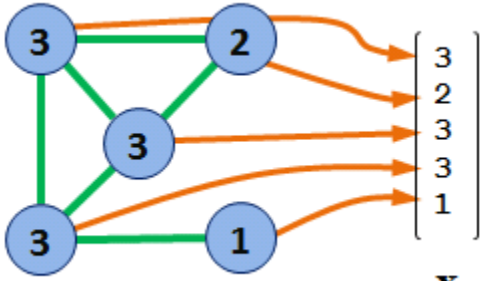
- Let n be the number of nodes in the network
- A = $n * n$
  - Assign 1 to a node pair if there is a link, 0 if no link
- x = $n * 1$
  - x contains each node's degree centrality
- Normalize by dividing each node's eigenvector centrality by the maximum value

Appendix – Formulas

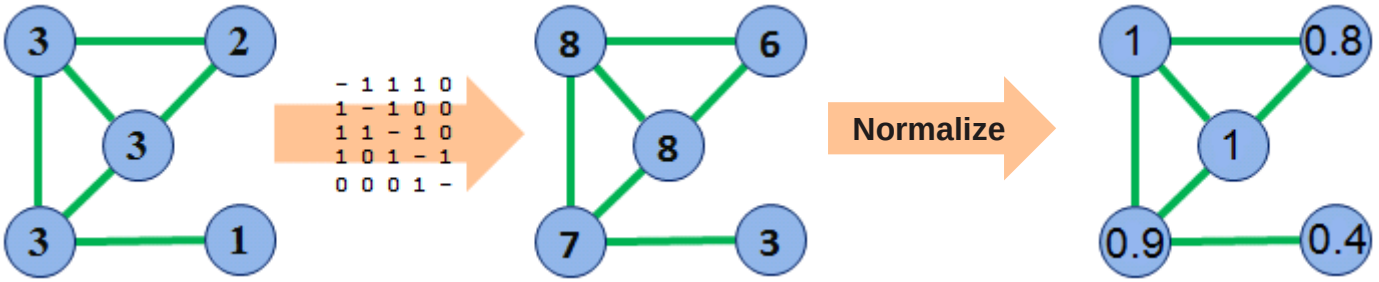
Eigenvector Centrality



$$\mathbf{A} = \begin{pmatrix} - & 1 & 1 & 1 & 0 \\ & - & 1 & 0 & 0 \\ & & - & 1 & 0 \\ & & & - & 1 \\ & & & & - \end{pmatrix}$$



$$\mathbf{A} \times \mathbf{x} = \begin{pmatrix} - & 1 & 1 & 1 & 0 \\ 1 & - & 1 & 0 & 0 \\ 1 & 1 & - & 1 & 0 \\ 1 & 0 & 1 & - & 1 \\ 0 & 0 & 0 & 1 & - \end{pmatrix} \begin{pmatrix} 3 \\ 2 \\ 3 \\ 3 \\ 1 \end{pmatrix} = \begin{pmatrix} 0x3 + 1x2 + 1x3 + 1x3 + 0x1 \\ 1x3 + 0x2 + 1x3 + 0x3 + 0x1 \\ 1x3 + 1x2 + 0x3 + 1x3 + 0x1 \\ 1x3 + 0x2 + 1x3 + 0x3 + 1x1 \\ 0x3 + 0x2 + 0x3 + 1x3 + 0x1 \end{pmatrix} = \begin{pmatrix} 8 \\ 6 \\ 8 \\ 7 \\ 3 \end{pmatrix}$$



Note: Thanks to Dan Ryan (2012) for the example: http://djjr-courses.wikidot.com/soc180:eigenvector-centrality.

Appendix – Formulas

Transitivity

(Jackson 2008)

Transitivity/Clustering Coefficient (node *i*) $= \frac{2ei}{k_i(k_i - 1)}$

[0,1]

Transitivity/Clustering Coefficient (network) $= \frac{1}{n}\sum_i Transitivity_i$

[0,1]

e_i # of connected pairs between all neighbors of i

k_i # of neighbors of node *i*

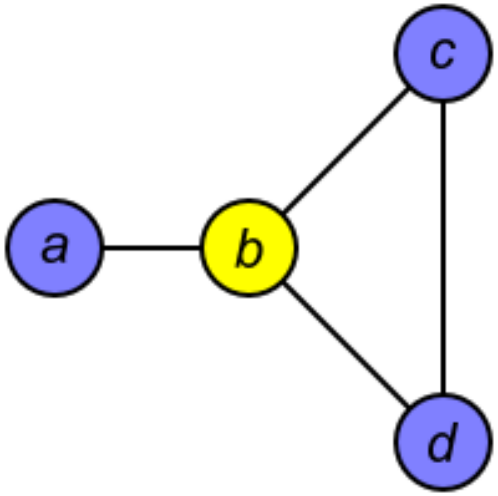
n # of nodes in the network

Appendix – Formulas

Transitivity

- One triangle passes through node b (b,c,d)

- Maximum number of triangles that could pass through b = 3
  - a,b,c
  - a,b,d
  - d,c,d



Transitivity (node *b*) = 1/3 = 33.3%

Note: Thanks to the author for the example: http://med.bioinf.mpi-inf.mpg.de/netanalyzer/help/2.6.1/.

Appendix – Formulas

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Assortativity

(Newman 2002)

$$\text{Assortativity } [-1,1] = \frac{\sum_{jk} jk(e_{jk} - q_j q_k)}{\sigma^2_q} \qquad q_k = \frac{(k+1)p_{k+1}}{\sum_j j p_j}$$

e_{jk} The joint probability distribution of the remaining degrees of the two nodes at either end of a randomly chosen edge.

q_k The probability that a randomly chosen edge leads to a node of degree k+1.

p_k The probability that a randomly chosen node will have degree k (i.e. degree distribution).

Variance of the distribution q_k

$$\sigma^2_q = \sum_k k^2 q_k - \{\sum_k k q_k\}^2$$

Obeys the following sum rules:

$$\sum_{jk} e_{jk} = 1 \qquad \sum_j e_{jk} = q_k$$