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).
1. Introduction

2. Data & Network Conventions/Metrics

3. CDS Networks in Ireland
   a. Counterparties
   b. Reference entities

4. Network Analysis and Descriptive Statistics

5. Conclusion
1. Introduction
1. Introduction

- 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

• 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

Data Snapshot at 1 September 2015

- **Raw Data**: 26,294
- **Unique Trades**: 19,395
- **Gross Trades**: 15,103
- **Net Positions**: 4,598

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

Nodes

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

- **Shape** – [Net Seller] [Net Buyer] (net notional networks only)

Edges

- Grey < €100 mn
- €100 mn < Red < €1 bn
- Blue > €1 bn

Example Network

- **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)**
2. Network Analysis Metrics

- **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

- **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

Gross Notional

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

Degree
- < 10
- 10 - 100
- 101 - 140
- > 140

Note: Size of node is proportional to total gross exposure. Network drawn in Gephi.
3. (a) CDS Network in Ireland

Note: Size of node is proportional to total net multilateral exposure. Network drawn in Gephi.
3. (a) SPV and NFC Sub - Samples

**Note:** Size of node is proportional to total net multilateral exposure. Network drawn in Gephi.
3. (b) Reference Entity Sectors

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

<table>
<thead>
<tr>
<th></th>
<th>Gross</th>
<th>Net</th>
<th>Sub-Samples</th>
<th>Reference Entity Sectors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>SPVs</td>
<td>NFCs</td>
</tr>
<tr>
<td><strong>Nodes</strong></td>
<td>373</td>
<td>117</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>(entities)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Edges</strong></td>
<td>1,875</td>
<td>619</td>
<td>36</td>
<td>38</td>
</tr>
<tr>
<td>(links)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CDS</strong></td>
<td>15,103</td>
<td>4,598</td>
<td>360</td>
<td>78</td>
</tr>
<tr>
<td>trades</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Reference</strong></td>
<td>897</td>
<td>846</td>
<td>328</td>
<td>54</td>
</tr>
<tr>
<td>entities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4. Network Analysis and Descriptive Statistics
## 4. Network Analysis Metrics

### Median

<table>
<thead>
<tr>
<th></th>
<th>In-/Out-Degree</th>
<th>In-Strength (€ m)</th>
<th>Out-Strength (€ m)</th>
<th>Eigen-vector Centrality</th>
<th>Betweenness Index</th>
<th>Density</th>
<th>Transitivity</th>
<th>Assortativity</th>
<th>Average Shortest Distance</th>
<th>Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross</td>
<td>1.0</td>
<td>13.9</td>
<td>7.1</td>
<td>0.14</td>
<td>0.00</td>
<td>1.4%</td>
<td>0.0%</td>
<td>-61.5%</td>
<td>3.1</td>
<td>8</td>
</tr>
<tr>
<td>Net</td>
<td>2.0*</td>
<td>18.4</td>
<td>27.5</td>
<td>0.22</td>
<td>0.01</td>
<td>4.6%</td>
<td>4.9%</td>
<td>-72.1%</td>
<td>2.5</td>
<td>5</td>
</tr>
</tbody>
</table>

### Sub-Sample

<p>| | | | | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SPVs</td>
<td>1.0</td>
<td>20.4</td>
<td>15.1</td>
<td>0.16</td>
<td>0.01</td>
<td>4.1%</td>
<td>0.0%</td>
<td>28.7%</td>
<td>2.2</td>
<td>6</td>
</tr>
<tr>
<td>NFCs</td>
<td>2.5</td>
<td>7.6</td>
<td>22.2</td>
<td>0.32</td>
<td>0.03</td>
<td>10.0%</td>
<td>0.0%</td>
<td>-55.5%</td>
<td>2.3</td>
<td>4</td>
</tr>
</tbody>
</table>

### Reference Entity Sector

<p>| | | | | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
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<th>--------------</th>
<th>---------------</th>
<th>--------------------------</th>
<th>----------</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financials</td>
<td>1.0</td>
<td>6.4</td>
<td>10.0</td>
<td>0.24</td>
<td>0.01</td>
<td>5.4%</td>
<td>1.8%</td>
<td>-47.4%</td>
<td>2.7</td>
<td>5</td>
</tr>
<tr>
<td>Non-Financials</td>
<td>2.5</td>
<td>7.6</td>
<td>22.2</td>
<td>0.26</td>
<td>0.01</td>
<td>6.6%</td>
<td>2.6%</td>
<td>-70.4%</td>
<td>2.5</td>
<td>5</td>
</tr>
<tr>
<td>Sovereigns</td>
<td>1.0</td>
<td>7.1</td>
<td>9.5</td>
<td>0.26</td>
<td>0.01</td>
<td>3.7%</td>
<td>4.1%</td>
<td>-51.6%</td>
<td>2.8</td>
<td>6</td>
</tr>
</tbody>
</table>

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

Net Sellers

- 48.5% (€11.2 b)
- 44.7% (€10.3 b)
- 3.9% (€889.4 m)
- 2.7% (€625.5 m)
- 0.2% (€47.1 m)

Net Buyers

- 78.0% (€18.0 b)
- 20.2% (€4.7 b)
- 1.1% (€262.6 m)
- 0.5% (€126.4 m)
- 0.1% (€20.7 m)
- 0.1% (€18.1 m)

Note: Values are notional amounts.
## 4. Top Counterparties by Metric

<table>
<thead>
<tr>
<th>Rank</th>
<th>In-degree</th>
<th>Out-degree</th>
<th>In-strength (€ m)</th>
<th>Out-strength (€ m)</th>
<th>Multilateral selling position (€ m)</th>
<th>Between-ness</th>
<th>Eigen-vector centrality</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MFI 5*</td>
<td>MFI 6*</td>
<td>OFI 22</td>
<td>OFI 16</td>
<td>OFI 22</td>
<td>MFI 5*</td>
<td>MFI 5*</td>
</tr>
<tr>
<td>2</td>
<td>MFI 12*</td>
<td>MFI 5*</td>
<td>SPV 19</td>
<td>MFI 5*</td>
<td>SPV 19</td>
<td>MFI 10*</td>
<td>MFI 12*</td>
</tr>
<tr>
<td>3</td>
<td>MFI 6*</td>
<td>MFI 41*</td>
<td>MFI 5*</td>
<td>MFI 9*</td>
<td>OFI 18</td>
<td>MFI 41*</td>
<td>MFI 6*</td>
</tr>
<tr>
<td>4</td>
<td>MFI 10*</td>
<td>MFI 12*</td>
<td>SPV 63</td>
<td>MFI 41*</td>
<td>SPV 63</td>
<td>MFI 6*</td>
<td>MFI 41*</td>
</tr>
<tr>
<td>5</td>
<td>MFI 41*</td>
<td>MFI 10*</td>
<td>OFI 18</td>
<td>MFI 13</td>
<td>MFI 30*</td>
<td>MFI 8*</td>
<td>MFI 8*</td>
</tr>
<tr>
<td>6</td>
<td>MFI 7*</td>
<td>MFI 9*</td>
<td>MFI 12*</td>
<td>OFI 1</td>
<td>NFC 54</td>
<td>MFI 12*</td>
<td>MFI 9*</td>
</tr>
<tr>
<td>7</td>
<td>MFI 9*</td>
<td>MFI 8*</td>
<td>MFI 7*</td>
<td>MFI 12*</td>
<td>SPV 59</td>
<td>MFI 7*</td>
<td>MFI 7*</td>
</tr>
<tr>
<td>8</td>
<td>MFI 8*</td>
<td>MFI 3*</td>
<td>MFI 41*</td>
<td>MFI 8*</td>
<td>OFI 20</td>
<td>MFI 9*</td>
<td>MFI 10*</td>
</tr>
<tr>
<td>9</td>
<td>MFI 3*</td>
<td>OFI 1</td>
<td>MFI 10*</td>
<td>MFI 6*</td>
<td>OFI 46</td>
<td>MFI 3</td>
<td>MFI 3</td>
</tr>
<tr>
<td>10</td>
<td>OFI 22</td>
<td>OFI 4</td>
<td>MFI 6*</td>
<td>MFI 10*</td>
<td>OFI 23</td>
<td>OFI 22</td>
<td>OFI 22</td>
</tr>
</tbody>
</table>

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

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

Total Gross Notional = €88.8 b

Credit Ratings by Gross Notional (€ b)

- AAA: 0.8%
- AA: 4.1%
- A: 13.1%
- BBB: 17.3%
- BB: 4.8%
- B: 1.9%
- C: 0.3%
- D: 0.1%
- Index: 2.9%
- Bespoke Index: 37.6%
- Bespoke Basket: 14.5%
- Unknown: 2.5%
4. CDS Gross Notional Time Series

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

- Financial Counterparties
- Blank
- SPVs
- Non-Financial Counterparties

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!
Normalized Betweenness Centrality

\[ \text{(node } k\text{)} \]

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

- \( P_k(ij) \): \# 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

\[ P_B(AD) = 2 \]

Betweenness \(B = \frac{2}{2} = 1\)
Eigenvector Centrality  $= A x = \lambda x$

- $A$  Adjacency matrix of the network
- $x$  Eigenvector of degree centrality
- $\lambda$  Eigenvalue

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

Eigenvector Centrality (node $i$):

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

(Zafarni et al. 2014)
Eigenvector Centrality

\[
A = \begin{pmatrix}
-1 & 1 & 1 & 0 \\
-1 & 0 & 0 & 0 \\
-1 & 0 & 0 & 0 \\
0 & 0 & 0 & 1
\end{pmatrix}
\]

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

\[
\begin{pmatrix}
3 \\
2 \\
3 \\
3 \\
1
\end{pmatrix}
\]

Normalize

\[
\begin{pmatrix}
1 \\
1 \\
0.9 \\
0.4 \\
0.8
\end{pmatrix}
\]

Appendix – Formulas

Transitivity

Transitivity/Clustering Coefficient (node $i$)

$[0,1]$

$\frac{2e_i}{k_i(k_i - 1)}$

Transitivity/Clustering Coefficient (network)$[0,1]$

$\frac{1}{n} \sum_{i}^{n} Transitivity_i$

$e_i$ \# of connected pairs between all neighbors of $i$

$k_i$ \# of neighbors of node $i$

$n$ \# of nodes in the network

(Jackson 2008)
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**

**Assortativity**

\[ \text{Assortativity } [-1,1] = \sum_{jk} jk (e_{jk} - q_j q_k) \]

\[ \sigma^2_q = \frac{(k+1)p_{k+1}}{\sum_j j p_j} \]

- **Assortativity**
  - 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).

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

Variance of the distribution \(q_k\)

\[ \sigma^2_q = \sum_k k^2 q_k - \left( \sum_k k q_k \right)^2 \]

Obeys the following sum rules:

\[ \sum_{jk} e_{jk} = 1 \]
\[ \sum_j e_{jk} = q_k \]