Outline

1. Motivation
2. Variance Decomposition Networks
3. A Case Study
4. Conclusions
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Motivation

Systemic Risk in Financial Networks

- 2008 Crisis highlights systemic risk from interconnectedness
- Financial networks
  - Transmits shocks
  - Amplifies shocks
- Network analysis guiding financial sector policy
  - FSB Systemically Important Financial Institution designation
  - IMF Mandatory Financial Sector Assessment Program
  - Contagion and spillover analysis
  - Central banks, i.e. Banco de Mexico
  - IMF-World Bank FSAPs
Some related work

- Direct exposures
  - Eisenberg and Noe (2001)
  - Upper (2011)
  - Jo (2012)

- Systemic risk rankings
  - Battiston et al (2012)
  - D’Errico, Battiston and Gurciullo (2016)

- Agent-based model
  - Montagna and Kok (2013)
  - Bookstaber and Maddrik (2015)

- Market-based
  - Billio et al (2012)
  - Kennet et al (2010)
  - Chan-Lau, Chuang, Duan and Sun (2016)
Outline

1. Motivation

2. Variance Decomposition Networks
   - Diebold-Yilmaz Networks
   - Lanne-Nyberg Decomposition
   - Systemic Risk Measures

3. A Case Study

4. Conclusions
Diebold-Yilmaz Basics

- Start selecting number of firms
- Estimate unrestricted VAR model
  - Equity returns
  - Observable market-based measures
- Network construction
  - Each firm is a node
  - Edges
    - Directional, i.e. from $i$ to $j$
    - Contribution of $i$ to variance decomposition of $j$
Selection of Variance Decomposition Method

- Generalized Forecast Error Variance Decomposition (GFEVD)
  - Introduced by Pesaran and Shin (1998)
  - VAR ordering does not matter (Koop, Pesaran, and Potter, 1996)
- FEVD from structural VAR adds to unity ...
- ... bug GFEVD does not!
Patching up the GFEVD

- Start with MA representation of VAR

\[ Y_t = \sum_{j=0}^{\infty} A_j \epsilon_{t-j} \]

- Pesaran-Shin GFEVD, horizon \( h \)

\[ \theta_{ij}(h) = \frac{\sigma_{ii}^{-1} \sum_{k=0}^{h} (e_j' A_k e_j)^2}{\sum_{k=0}^{h} e_j' A_k \Sigma A_k' e_i} \]

- Diebold-Yilmaz normalization

\[ \hat{\theta}_{ij}(h) = \frac{\theta_{ij}(h)}{\sum_{k=1}^{n} \theta_{ik}(h)} \]

- Higher \( \sum_{j=1,\ldots,n} \hat{\theta}_{ij} \) implies higher systemic risk ranking
Pitfalls in interpreting DY GFEVD

- Economic interpretation of shocks (Koop et al, 1996)
- Good for systemic risk ranking snapshot in any given period ...
- ... but inconsistent to assess systemic risk contributions over time
A Simple Example

Period 1
- Firm A explains 20 percent of GFEVD of firm B
- Total GFEVD of firm B equals to 2

Period 2
- Firm A explains 50 percent of GFEVD of firm B
- Total GFEVD of firm B equals to 0.5

Has Firm A become more systemic to Firm B?
- Ambiguous answer
  - Yes (DY normalization), up 50 percent from 20 percent
  - No, 50 percent of 0.5 is less than 20 percent of 2
Patching Up the Diebold-Yilmaz Network

- Diebold-Yilmaz network provide the right intuition but ...
- ... variance decomposition method leads to ambiguous result
- Ambiguity invalidates systemic risk ranking dynamics
- How can we correct it?
- **Use Lanne-Nyberg variance decomposition**
Lanne-Nyberg Variance Decomposition

- Starts with Generalized Impulse Response Function (GIRF)
  \[ GI(h, \delta_t, \Omega_{t-1}) = A_h \sum e_j \sigma_{jj}^{-1} \delta_j \]

- Lanne-Nyberg GFEVD \( \lambda_{ij}(h) \)
  \[
  \lambda_{ij}(h) = \frac{\sum_{k=0}^{h} GI(h, \delta_t, \Omega_{t-1})}{\sum_{j=1}^{n} \sum_{k=0}^{h} GI(h, \delta_t, \Omega_{t-1})}
  \]
Systemic Risk Measures

- Directional connectedness from firm $j$ to firm $i$

$$C_{ij}(h) = \begin{cases} 
\hat{\theta}_{ij}(h) & \text{Diebold-Yilmaz} \\
\lambda_{ij}(h) & \text{Lanne-Nyberg}
\end{cases}$$

- Systemic Risk of a Firm

$$C_j(h) = \frac{\sum_{i\neq j}^{n} C_{ij}(h)}{\sum_{i,j=1}^{n} C_{ij}(h)} \times 100$$

- Systemic Vulnerability of a Firm

$$V_i(h) = \frac{\sum_{i\neq j}^{n} C_{ij}(h)}{\sum_{i,j=1}^{n} C_{ij}(h)} \times 100$$
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1. Motivation

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3. A Case Study
   - Systemic Risk in the Global Financial System

4. Conclusions
Case Study: Systemic Risk in Global Financial System

- Weekly equity returns
  - 402 firms
  - 34 advanced and emerging market economies

- Sample dates
  - Full sample: 01/01/2001 - 07/31/2016
  - Pre-crisis period: 01/01/2001 - 12/31/2004
  - Lehman Brothers: 01/01/2005 - 12/31/2008
  - Sovereign debt crisis: 01/01/2009 - 12/31/2012
  - Secular stagnation: 01/01/2013 - 07/31/2016

- Lasso Estimation, with 8 lags

- Variance decomposition horizon = 52 weeks
  - Diebold-Yilmaz
  - Lanne-Nyberg
Number of overlapping firms in the top 50 DY and CLNDY rankings
### Rank Correlations - Systemic Risk Rankings

<table>
<thead>
<tr>
<th>Correlation measure</th>
<th>Spearman</th>
<th>Kendall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of lags in VAR</td>
<td>4</td>
<td>8</td>
</tr>
</tbody>
</table>

#### Panel A: Systemic Risk Rankings

**All firms**

<table>
<thead>
<tr>
<th>Period</th>
<th>Spearman</th>
<th>Kendall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan. 2001 - Jul. 2016</td>
<td>0.72</td>
<td>0.54</td>
</tr>
<tr>
<td>Jan. 2001 - Dec. 2004</td>
<td>0.68</td>
<td>0.50</td>
</tr>
<tr>
<td>Jan. 2005 - Dec. 2008</td>
<td>0.66</td>
<td>0.48</td>
</tr>
<tr>
<td>Jan. 2009 - Dec. 2012</td>
<td>0.74</td>
<td>0.59</td>
</tr>
<tr>
<td>Jan. 2013 - Jul. 2016</td>
<td>0.54</td>
<td>0.39</td>
</tr>
</tbody>
</table>

**Top 100 firms in Diebold-Yilmaz network**

<table>
<thead>
<tr>
<th>Period</th>
<th>Spearman</th>
<th>Kendall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan. 2001 - Jul. 2016</td>
<td>0.17</td>
<td>0.11</td>
</tr>
<tr>
<td>Jan. 2001 - Dec. 2004</td>
<td>0.16</td>
<td>0.12</td>
</tr>
<tr>
<td>Jan. 2005 - Dec. 2008</td>
<td>0.17</td>
<td>0.12</td>
</tr>
<tr>
<td>Jan. 2009 - Dec. 2012</td>
<td>0.06</td>
<td>0.04</td>
</tr>
<tr>
<td>Jan. 2013 - Jul. 2016</td>
<td>-0.09</td>
<td>-0.09</td>
</tr>
</tbody>
</table>

**Top 100 firms in corrected Lanne-Nyberg-Diebold-Yilmaz network**

<table>
<thead>
<tr>
<th>Period</th>
<th>Spearman</th>
<th>Kendall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan. 2001 - Jul. 2016</td>
<td>0.24</td>
<td>0.16</td>
</tr>
<tr>
<td>Jan. 2001 - Dec. 2004</td>
<td>0.69</td>
<td>0.50</td>
</tr>
<tr>
<td>Jan. 2005 - Dec. 2008</td>
<td>0.39</td>
<td>0.28</td>
</tr>
<tr>
<td>Jan. 2009 - Dec. 2012</td>
<td>0.10</td>
<td>0.07</td>
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<tr>
<td>Jan. 2013 - Jul. 2016</td>
<td>0.22</td>
<td>0.15</td>
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</tbody>
</table>
### Rank Correlations - Systemic Vulnerability Rankings

**Panel B: Systemic Vulnerability Rankings**

- **All firms**

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Jan. 2001 - Jul. 2016</td>
<td>0.80</td>
<td>0.82</td>
<td>0.79</td>
<td>0.63</td>
<td>0.62</td>
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<tr>
<td>Jan. 2001 - Dec. 2004</td>
<td>0.84</td>
<td>0.80</td>
<td>0.82</td>
<td>0.67</td>
<td>0.62</td>
</tr>
<tr>
<td>Jan. 2005 - Dec. 2008</td>
<td>0.81</td>
<td>0.85</td>
<td>0.84</td>
<td>0.63</td>
<td>0.66</td>
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<tr>
<td>Jan. 2009 - Dec. 2012</td>
<td>0.81</td>
<td>0.80</td>
<td>0.77</td>
<td>0.63</td>
<td>0.62</td>
</tr>
<tr>
<td>Jan. 2013 - Jul. 2016</td>
<td>0.79</td>
<td>0.76</td>
<td>0.75</td>
<td>0.61</td>
<td>0.59</td>
</tr>
</tbody>
</table>

- **Top 100 firms in Diebold-Yilmaz network**

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Jan. 2001 - Jul. 2016</td>
<td>0.62</td>
<td>0.63</td>
<td>0.71</td>
<td>0.47</td>
<td>0.47</td>
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<tr>
<td>Jan. 2001 - Dec. 2004</td>
<td>0.71</td>
<td>0.73</td>
<td>0.71</td>
<td>0.54</td>
<td>0.55</td>
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<tr>
<td>Jan. 2005 - Dec. 2008</td>
<td>0.54</td>
<td>0.27</td>
<td>0.15</td>
<td>0.41</td>
<td>0.20</td>
</tr>
<tr>
<td>Jan. 2009 - Dec. 2012</td>
<td>0.61</td>
<td>0.62</td>
<td>0.46</td>
<td>0.46</td>
<td>0.47</td>
</tr>
<tr>
<td>Jan. 2013 - Jul. 2016</td>
<td>0.63</td>
<td>0.60</td>
<td>0.47</td>
<td>0.46</td>
<td>0.44</td>
</tr>
</tbody>
</table>

- **Top 100 firms in corrected Lanne-Nyberg-Diebold-Yilmaz network**

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Jan. 2001 - Jul. 2016</td>
<td>0.78</td>
<td>0.77</td>
<td>0.79</td>
<td>0.59</td>
<td>0.58</td>
</tr>
<tr>
<td>Jan. 2001 - Dec. 2004</td>
<td>0.77</td>
<td>0.73</td>
<td>0.65</td>
<td>0.59</td>
<td>0.55</td>
</tr>
<tr>
<td>Jan. 2005 - Dec. 2008</td>
<td>0.55</td>
<td>0.26</td>
<td>0.20</td>
<td>0.39</td>
<td>0.18</td>
</tr>
<tr>
<td>Jan. 2009 - Dec. 2012</td>
<td>0.62</td>
<td>0.51</td>
<td>0.43</td>
<td>0.45</td>
<td>0.36</td>
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<tr>
<td>Jan. 2013 - Jul. 2016</td>
<td>0.51</td>
<td>0.41</td>
<td>0.38</td>
<td>0.36</td>
<td>0.28</td>
</tr>
</tbody>
</table>
## Rank Correlations - Systemic Vulnerability Rankings

Table 5. Top fifty systemic firms, by headquarter location
(ranking based on a VAR (8) specification)

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td><strong>Panel A: Systemic risk ranking</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Diebold - Yilmaz</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Advanced economies</td>
<td>36</td>
<td>41</td>
<td>50</td>
<td>33</td>
<td>49</td>
</tr>
<tr>
<td>Emerging economies</td>
<td>14</td>
<td>9</td>
<td>0</td>
<td>17</td>
<td>1</td>
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<tr>
<td><strong>Corrected Lanne-Nyberg-Diebold-Yilmaz</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Advanced economies</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>48</td>
<td>50</td>
</tr>
<tr>
<td>Emerging economies</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td><strong>Panel B: Systemic vulnerability ranking</strong></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Diebold - Yilmaz</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Advanced economies</td>
<td>38</td>
<td>33</td>
<td>34</td>
<td>33</td>
<td>32</td>
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<tr>
<td>Emerging economies</td>
<td>12</td>
<td>17</td>
<td>6</td>
<td>7</td>
<td>18</td>
</tr>
<tr>
<td><strong>Corrected Lanne-Nyberg-Diebold-Yilmaz</strong></td>
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<td></td>
</tr>
<tr>
<td>Advanced economies</td>
<td>29</td>
<td>29</td>
<td>33</td>
<td>35</td>
<td>32</td>
</tr>
<tr>
<td>Emerging economies</td>
<td>21</td>
<td>21</td>
<td>7</td>
<td>5</td>
<td>18</td>
</tr>
</tbody>
</table>

Source: Bloomberg LLP and author’s calculations.
Banks: systemic risk rankings, distribution

[Graph showing systemic risk rankings for banks over different periods, with color-coded data points for various years (2001-2004, 2005-2008, 2009-2012, 2013-2016).]
Life insurers: systemic risk rankings, distribution

- Life insurance, DY risk rankings
- Life insurance, CLNDY risk rankings
P/C insurers: systemic risk rankings, distribution
Outline

1. Motivation
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Conclusions

- Variance decomposition networks
  - Complement direct exposure networks
  - Capture direction of spillovers
- Diebold-Yilmaz use Pesaran-Shin GFEVD
  - Do not add up to unity
  - Normalization prevents comparing risk distributions in different points in time
- Use Lanne-Nybert decomposition instead
  - Preserves Diebold-Yilmaz intuition
  - Consistent along time dimension
- Numerical study
  - Choice of decomposition method matters
  - Rank correlations low, especially for risk rankings
Thank You


Chan-Lau, J.A. 2015. ABBA: an agent-based model of the banking system. IMF WP.


