Variance Decomposition Networks: Potential Pitfalls and a Simple Solution

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Outline

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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)
  - Chan-Lau (2015)
- Market-based
  - Billio et al (2012)
  - Kennet et al (2010)
  - Chan-Lau, Chuang, Duan and Sun (2016)

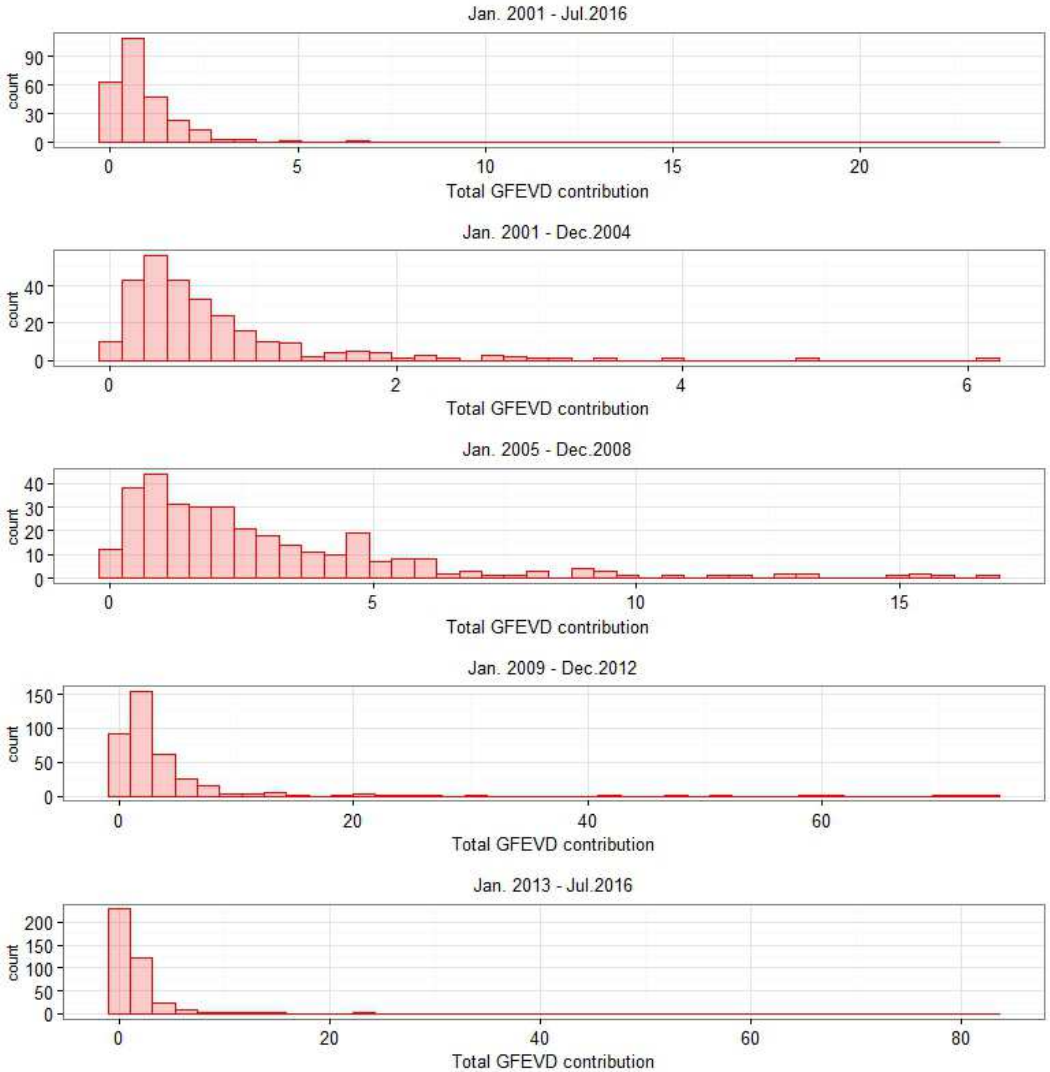
Outline

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!


Jan. 2001 - Jul.2016
count
Total GFEVD contribution
Jan. 2001 - Dec.2004
count
Total GFEVD contribution
Jan. 2005 - Dec.2008
count
Total GFEVD contribution
Jan. 2009 - Dec.2012
count
Total GFEVD contribution
Jan. 2013 - Jul.2016
count
Total GFEVD contribution

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 $\sum_{j=1,..,n} \hat{\theta}_{ij}$ 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)

$$GI(h, \delta_t, \Omega_{t-1}) = A_h \Sigma e_j \sigma_{jj}^{-1} \delta_j$$

- 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

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

- Systemic Vulnerability of a Firm

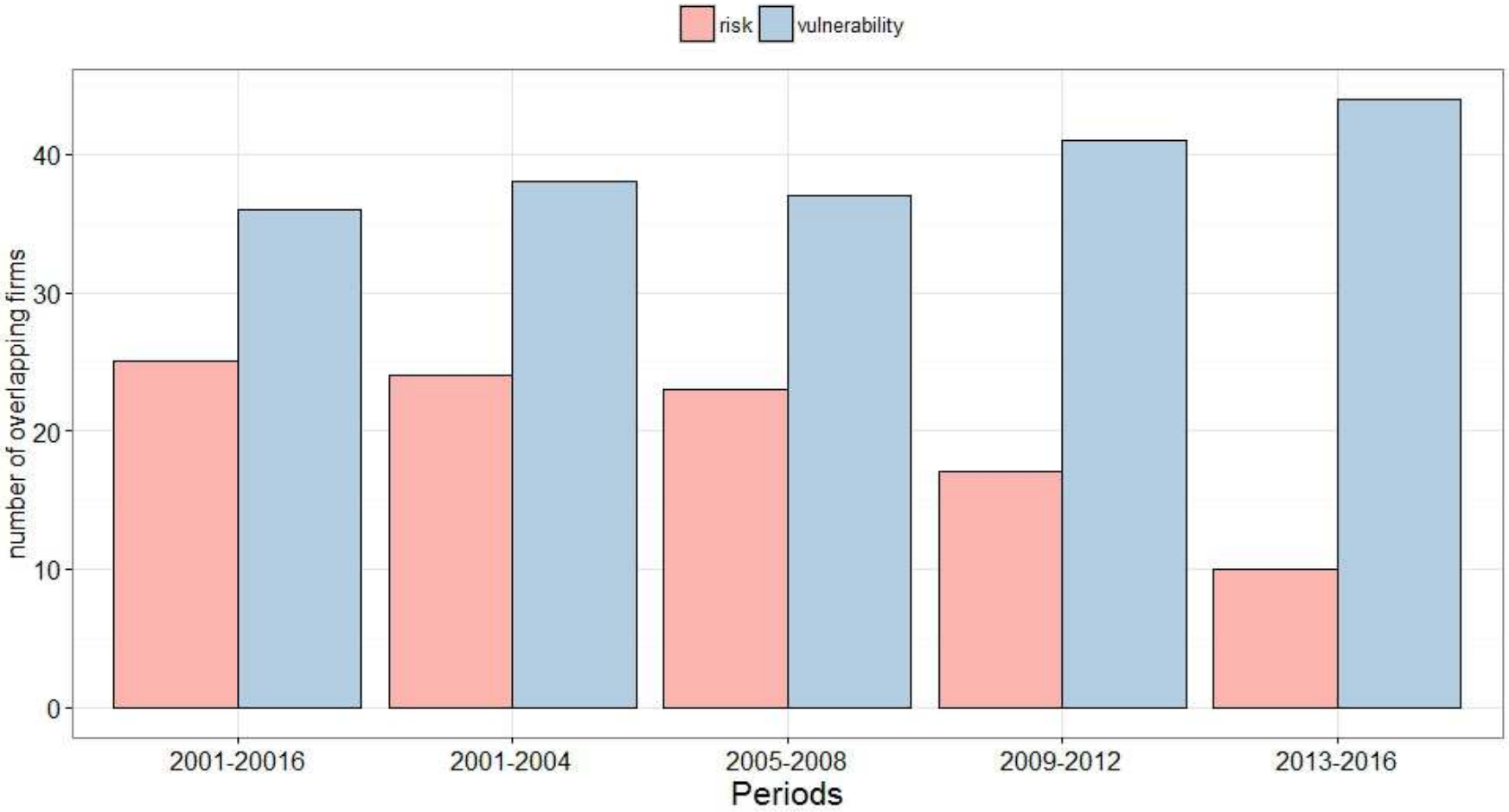
$$V_i(h) = \frac{\sum_{i \neq j, i=1}^{n} C_{ij}(h)}{\sum_{i,j=1}^{n} C_{ij}(h)} \times 100$$

Outline

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

Correlation measure	Spearman			Kendall		
Number of lags in VAR	4	8	12	4	8	12
Panel A: Systemic Risk Rankings						
All firms						
Jan. 2001 - Jul. 2016	0.72	0.74	0.74	0.54	0.56	0.56
Jan. 2001 - Dec. 2004	0.68	0.64	0.65	0.50	0.46	0.47
Jan. 2005 - Dec. 2008	0.66	0.69	0.73	0.48	0.52	0.54
Jan. 2009 - Dec. 2012	0.74	0.77	0.73	0.56	0.59	0.54
Jan. 2013 - Jul. 2016	0.54	0.54	0.56	0.38	0.39	0.40
Top 100 firms in Diebold-Yilmaz network						
Jan. 2001 - Jul. 2016	0.17	0.32	0.34	0.11	0.22	0.23
Jan. 2001 - Dec. 2004	0.16	0.12	0.15	0.12	0.08	0.11
Jan. 2005 - Dec. 2008	0.17	0.29	0.28	0.12	0.20	0.20
Jan. 2009 - Dec. 2012	0.06	0.05	0.01	0.04	0.04	0.01
Jan. 2013 - Jul. 2016	-0.09	-0.15	-0.23	-0.07	-0.09	-0.16
Top 100 firms in corrected Lanne-Nyberg-Diebold-Yilmaz network						
Jan. 2001 - Jul. 2016	0.24	0.42	0.44	0.16	0.29	0.30
Jan. 2001 - Dec. 2004	0.69	0.64	0.63	0.50	0.44	0.44
Jan. 2005 - Dec. 2008	0.39	0.44	0.45	0.28	0.31	0.31
Jan. 2009 - Dec. 2012	0.10	0.22	0.04	0.07	0.15	0.03
Jan. 2013 - Jul. 2016	0.22	0.34	0.32	0.15	0.23	0.21

Rank Correlations - Systemic Vulnerability Rankings

Panel B: Systemic Vulnerability Rankings

All firms						
Jan. 2001 - Jul. 2016	0.80	0.82	0.79	0.63	0.63	0.62
Jan. 2001 - Dec. 2004	0.84	0.80	0.82	0.67	0.62	0.65
Jan. 2005 - Dec. 2008	0.81	0.85	0.84	0.63	0.66	0.66
Jan. 2009 - Dec. 2012	0.81	0.80	0.77	0.63	0.62	0.59
Jan. 2013 - Jul. 2016	0.79	0.76	0.75	0.61	0.59	0.57
Top 100 firms in Diebold-Yilmaz network						
Jan. 2001 - Jul. 2016	0.62	0.63	0.71	0.47	0.47	0.53
Jan. 2001 - Dec. 2004	0.71	0.73	0.71	0.54	0.55	0.52
Jan. 2005 - Dec. 2008	0.54	0.27	0.15	0.41	0.20	0.11
Jan. 2009 - Dec. 2012	0.61	0.62	0.46	0.46	0.47	0.34
Jan. 2013 - Jul. 2016	0.63	0.60	0.47	0.46	0.44	0.33
Top 100 firms in corrected Lanne-Nyberg-Diebold-Yilmaz network						
Jan. 2001 - Jul. 2016	0.78	0.77	0.79	0.59	0.58	0.61
Jan. 2001 - Dec. 2004	0.77	0.73	0.65	0.59	0.55	0.49
Jan. 2005 - Dec. 2008	0.55	0.26	0.20	0.39	0.18	0.13
Jan. 2009 - Dec. 2012	0.62	0.51	0.43	0.45	0.36	0.30
Jan. 2013 - Jul. 2016	0.51	0.41	0.38	0.36	0.28	0.25

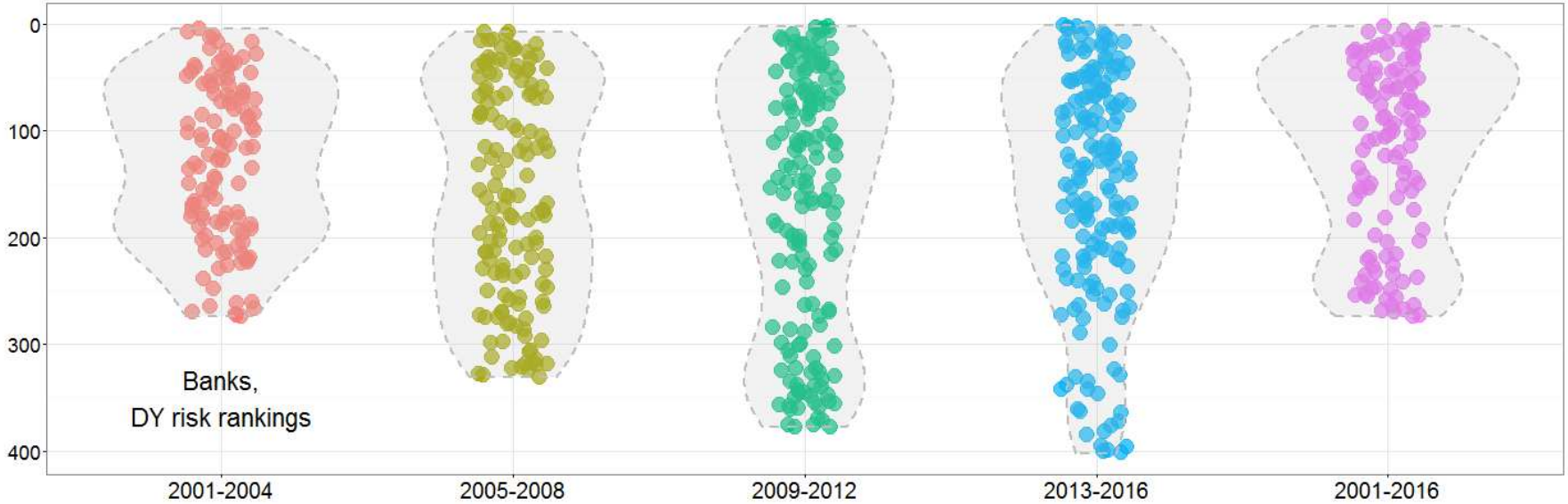
Rank Correlations - Systemic Vulnerability Rankings

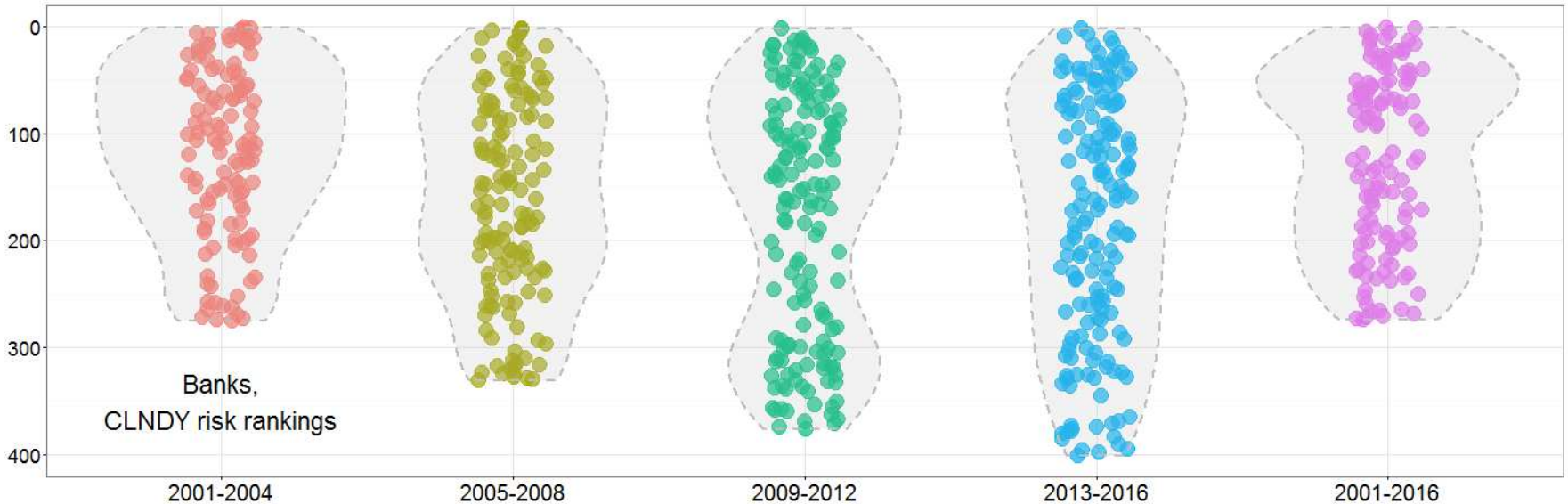
Table 5. Top fifty systemic firms, by headquarter location
(ranking based on a VAR (8) specification)

	Period				
	2001 to 2004	2005 to 2008	2009 - 2012	2013 - 2016	2001 - 2016
Panel A: Systemic risk ranking					
Diebold -Yilmaz					
Advanced economies	36	41	50	33	49
Emerging economies	14	9	0	17	1
Corrected Lanne-Nyberg-Diebold-Yilmaz					
Advanced economies	50	50	50	48	50
Emerging economies	0	0	0	2	0
Panel B: Systemic vulnerability ranking					
Diebold -Yilmaz					
Advanced economies	38	33	34	33	32
Emerging economies	12	17	6	7	18
Corrected Lanne-Nyberg-Diebold-Yilmaz					
Advanced economies	29	29	33	35	32
Emerging economies	21	21	7	5	18

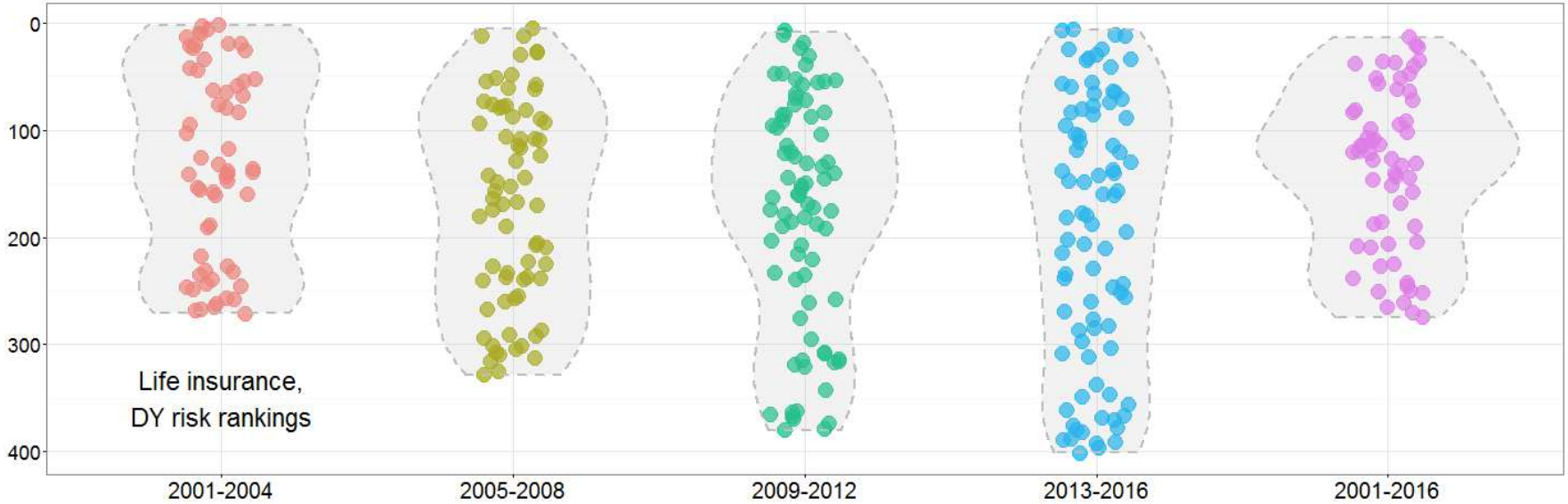
Source: Bloomberg LLP and author's calculations.

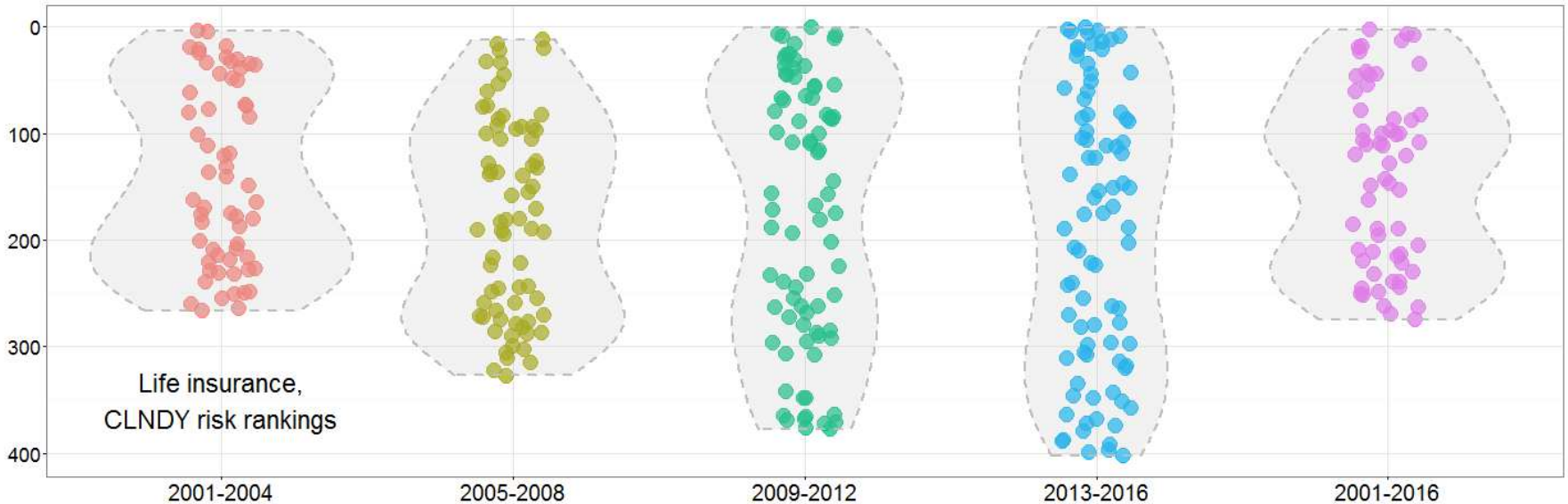
Banks: systemic risk rankings, distribution



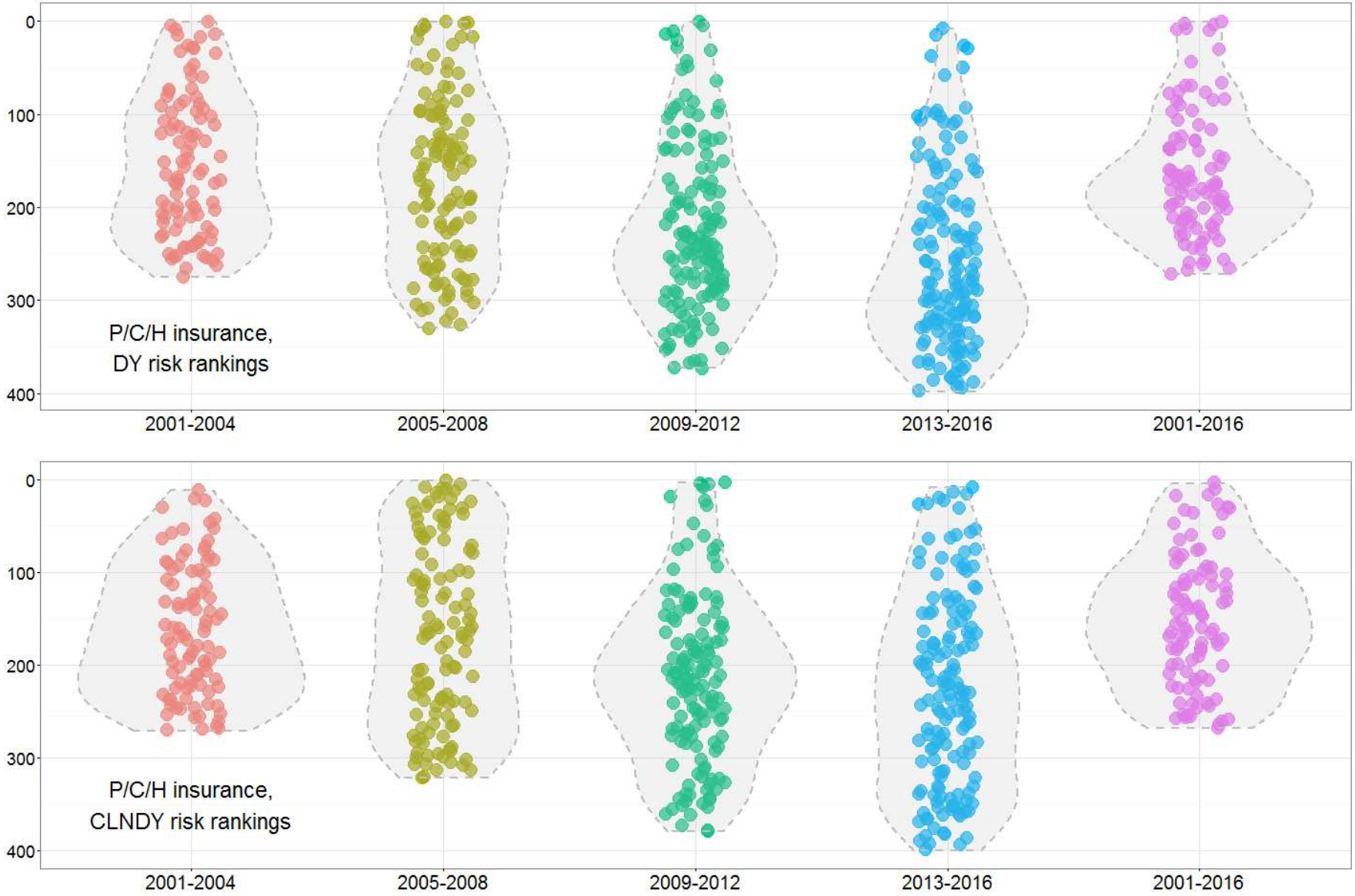


Life insurers: systemic risk rankings, distribution





P/C insurers: systemic risk rankings, distribution



Outline

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

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