Mapping the stocks in MICEX: Who is central in Moscow Stock Exchange?

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Outline

Introduction

Systemic risk

- The financial crisis of 2008 called for better understanding of the risks
- Specifically, systemic risk - ”the risk of a cascading failure in the financial sector”

- ”Too interconnected to fail”
- **Purpose** is to find the most interconnected and threatening firms in Russian economy and measure systemic risk

Connections

- Firms can be connected in different ways
  i.e. trading or loan relations - in firm's balance sheets
- However, it's not high-frequency data
- Connections between stock returns is a proxy of true unobservable links
- **Data** is stock returns of firms listed in MICEX:
  returns of 36 companies based on EOD stock prices
  data period: 01.12.2011 - 29.01.2016
- We bring together the ideas from financial econometrics and network theory

Network construction

Gaussian Graphical Model

- Consider m.r.v. $X = \{X_1, ..., X_n\}$ of stock returns
- We want to construct graph $G = (V, E)$, where
  set of **V**ertices $V = \{1, ..., n\}$ represents set of firms
  set of **E**dges is set of connections between them
- GGM measures dependence as partial correlation between each pair of nodes
- Partial correlation, $\rho_{i,j|.}$, between X_i and X_j shows linear dependence between them excluding influence of the rest of components of X
- If $\rho_{i,j|.} = 0 \Rightarrow X_i$ and X_j are independent $\Rightarrow (i, j) \notin E$

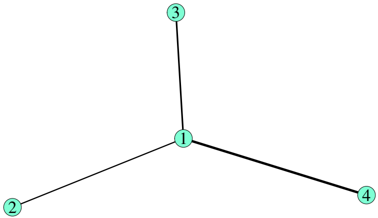
more

Network

The network can be represented with adjacency matrix with weights $w_{i,j} = \rho_{i,j|}$.

$$A = I + P$$

$$A = \begin{bmatrix} 0 & 0.3 & 0.4 & 0.6 \\ 0.3 & 0 & 0.2 & 0 \\ 0.4 & 0.2 & 0 & 0 \\ 0.6 & 0 & 0 & 0 \end{bmatrix}$$



Estimation

Partial correlation matrix P can be calculated as follows:

$$P = D_K^{-1/2} K D_K^{-1/2}$$

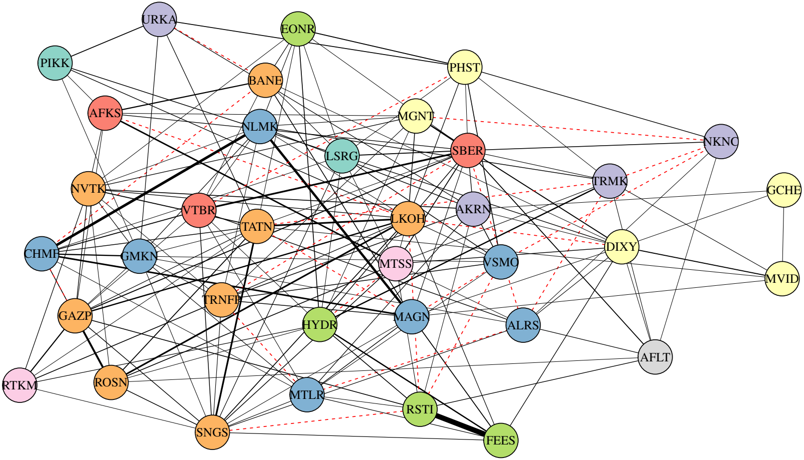
where $K = \Omega^{-1}$ or $K = R^{-1}$

To estimate $\hat{R}$ we use financial econometrics models:

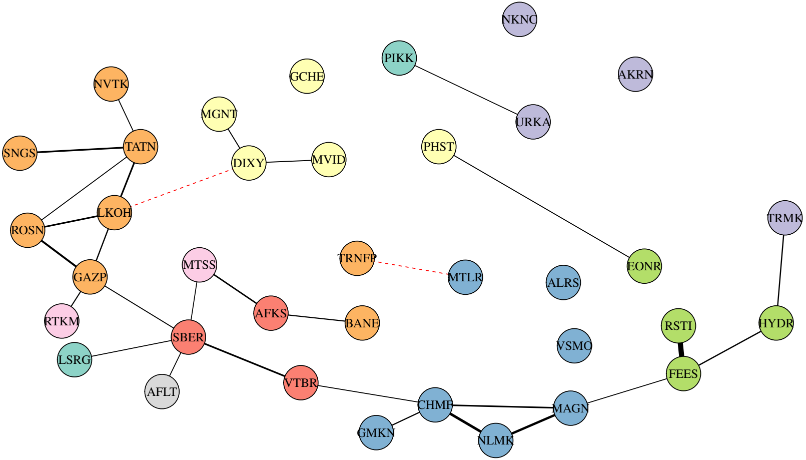
- CCC-GARCH model $\hat{R} \Rightarrow \hat{P}$
- cDCC-GARCH model $\hat{R}_t \Rightarrow \hat{P}_t$

Constant model

CCC-GARCH Network



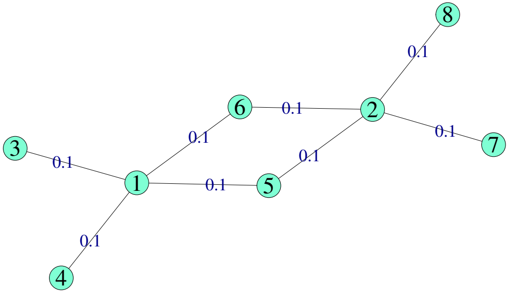
CCC-GARCH Network, Threshold=0.1



Degree centrality

For weighted graph *degree centrality* is the sum of the weights his edges

$$DC = \sum_{j=1}^{n} w_{i,j} = \sum_{j=1}^{n} a_{i,j}, \qquad DC = A \cdot 1$$



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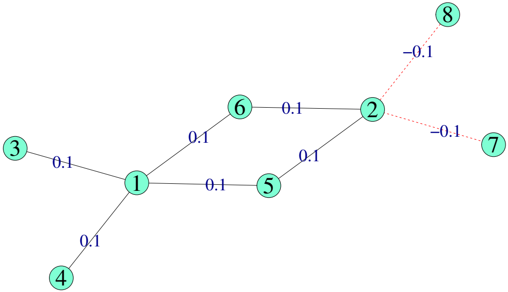

Degree centrality(II)

In terms of the graph with both positive and negative connections it is possible to distinguish DC as follows

- in terms of connections with others

$$DC_i^{abs} = \sum_{j=1}^{n} |a_{i,j}|, \qquad DC^{abs} = abs(A) \cdot 1$$

- in terms of systemic risk

$$DC_i^{net} = \sum_{j=1}^{n} a_{i,j}, \qquad DC^{net} = A \cdot 1$$

Eigenvector centrality

- *Eigenvector centrality* measures centrality based on the neighbours' centrality

$$\lambda C^e(i) = \sum_{j=1}^{n} w_{i,j} C^e(j) = \sum_{j=1}^{n} a_{i,j} C^e(j)$$

$$\lambda C^e = A C^e$$

λ is proportional parameter = (maximum) eigenvalue of A

- *Bonacich centrality* shows how central node in terms of systemic risk

$$C^B(1) = A \cdot 1 + A^2 \cdot + A^3 \cdot 1 + \cdots = (I - A)^{-1} \cdot 1 - 1$$

Measuring fall

- Let e be the negative shock experienced by some firm, i.e. by firm 1 $\Rightarrow e = (s, 0, \ldots, 0)^T$,

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- Let e be the negative shock experienced by some firm, i.e. by firm 1 $\Rightarrow e = (s, 0, \ldots, 0)^T$,
- First-order effect Ae
- Second-order effect A^2e
- $\ldots$
- k-th-order effect A^ke
- The total effect on the system

$$e + Ae + A^2e + \cdots + A^ke + \cdots = \sum_{k=0}^{\infty} A^ke = (I - A)^{-1}e$$

$T = (I - A)^{-1} \Rightarrow Te$ is total effect of the shock e on all others

Centrality measures of CCC model

	k	DC^{net}		DC^{abs}		DC^{+}		DC^{tune}		EC		EC^{abs}		C^{B}	
FEES	7	1.147	(10)	1.147	(10)	1.147	(5)	2.833	(20)	1.000	(1)	0.999	(2)	7.487	(1)
GAZP	12	1.200	(2)	1.200	(7)	1.200	(3)	3.795	(6)	0.895	(2)	0.889	(4)	7.337	(2)
NLMK	11	1.159	(8)	1.159	(8)	1.159	(4)	3.571	(7)	0.760	(5)	0.776	(9)	6.449	(3)
RSTI	10	0.856	(11)	1.223	(4)	1.040	(9)	3.497	(8)	0.877	(3)	1.000	(1)	6.378	(4)
LKOH	16	1.040	(6)	1.478	(1)	1.259	(2)	4.863	(2)	0.764	(4)	0.999	(3)	6.326	(5)
SNGS	15	1.082	(5)	1.204	(5)	1.143	(6)	4.249	(3)	0.724	(6)	0.869	(6)	6.111	(6)
TATN	14	0.927	(7)	1.279	(3)	1.103	(7)	4.232	(4)	0.693	(8)	0.886	(5)	5.764	(7)
SBER	17	1.202	(1)	1.464	(2)	1.333	(1)	4.988	(1)	0.635	(11)	0.731	(11)	5.737	(8)
CHMF	10	0.863	(10)	1.152	(9)	1.007	(10)	3.394	(9)	0.694	(7)	0.815	(8)	5.705	(9)
MAGN	12	0.897	(8)	1.201	(6)	1.049	(8)	3.797	(5)	0.650	(9)	0.832	(7)	5.378	(10)
ROSN	9	0.771	(15)	0.957	(11)	0.864	(11)	2.934	(16)	0.638	(10)	0.774	(10)	5.185	(11)
NVTK	12	0.863	(9)	0.863	(16)	0.863	(12)	3.218	(12)	0.555	(12)	0.542	(15)	4.763	(12)

Dynamic model

Macro characteristics

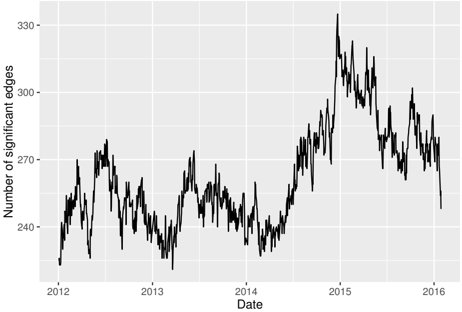
- The number of edges in the graph
- *The average path length* is the average shortest path between any two nodes

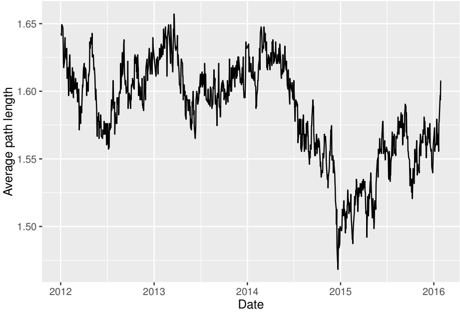
  The average number of steps needed to shock propagate from one node to another

- The more the number of the edges, the less is the average path length
- Average vulnerability is the average of the Bonacich centralities

  Sensitivity of the network to the negative shocks

Number of edges and average path length in dynamic





Vulnerability measure

Bonacich centrality shows how central node in terms of systemic risk

$$C^B(1) = A \cdot 1 + A^2 \cdot + A^3 \cdot 1 + \dots = (I - A)^{-1} \cdot 1 - 1$$

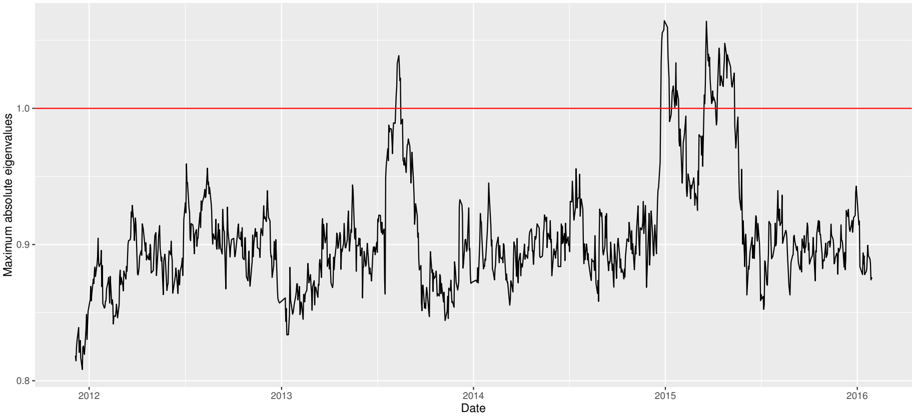
Assumption: all eigenvalues inside the unit circle

Average vulnerability is the average of Bonacich centralities of all firms

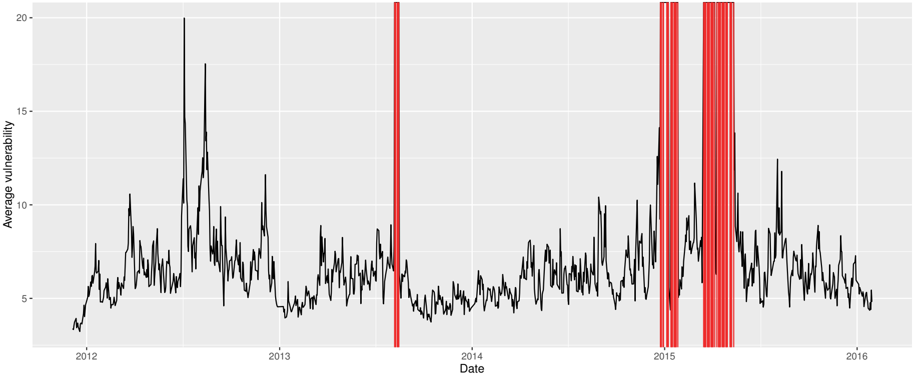
$$Av.vulenr. = \frac{sum(C^B(1))}{n}$$

Weighted vulnerability is Bonacich centralities weighted by market capitalization of each firms

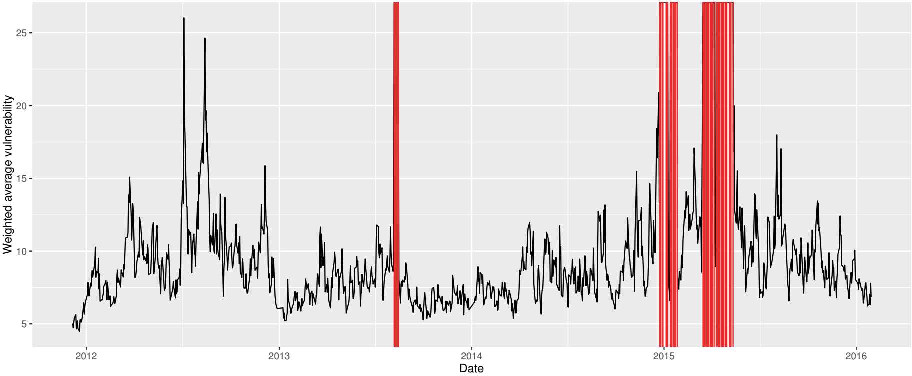
Maximum absolute eigenvalue



Average vulnerability



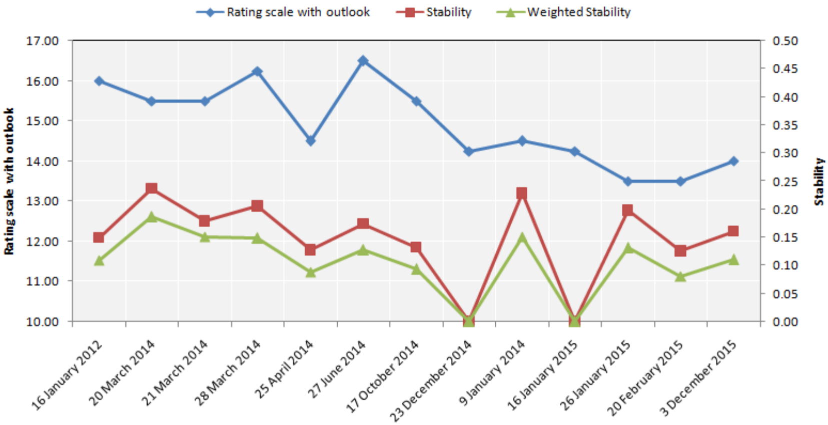
Weighted average vulnerability



Credit ratings history

Agencies	Credit rating	Outlook	Dates	R.S.	R.S., out	Avg. Vuln.	W. Avg. Vuln.	Stability	W. Stab.
Fitch	BBB	stable	16.01.2012	16.00	16.00	6.71	9.19	0.15	0.11
S&P	BBB	negative	20.03.2014	16.00	15.50	4.22	5.37	0.24	0.19
Fitch	BBB	negative	21.03.2014	16.00	15.50	5.58	6.63	0.18	0.15
Moody's	Baa1	neg. watch	28.03.2014	17.00	16.25	4.87	6.74	0.21	0.15
S&P	BBB-	negative	25.04.2014	15.00	14.50	7.83	11.36	0.13	0.09
Moody's	Baa1	negative	27.06.2014	17.00	16.50	5.73	7.83	0.17	0.13
Moody's	Baa2	negative	17.10.2014	16.00	15.50	7.59	10.70	0.13	0.09
S&P	BBB-	neg. watch	23.12.2014	15.00	14.25	Inf	Inf	0	0
Fitch	BBB-	negative	09.01.2015	15.00	14.50	4.38	6.61	0.23	0.15
Moody's	Baa3	neg. watch	16.01.2015	15.00	14.25	Inf	Inf	0	0
S&P	BB+	negative	26.01.2015	14.00	13.50	5.05	7.62	0.20	0.13
Moody's	Ba1	negative	20.02.2015	14.00	13.50	7.95	12.32	0.13	0.08
Moody's	Ba1	stable	03.12.2015	14.00	14.00	6.22	9.05	0.16	0.11

Credit rating and vulnerability measures



Conclusion

Conclusions

- We mapped most liquid and major firms in Russian Stock Market
- We proposed to distinguish degree centrality for network with positive and negative connections
- Most connected firms: Sberbank and Lukoil. Most central in terms of systemic risk: Gazprom and FGC UES.
- The key network measures were examined over time
- Interconnectedness strengthen during the crisis
- We calculate vulnerability of the system to systemic risk

Partial Correlation

- Partial correlation, $\rho_{i,j|.}$, between X_i and X_j shows linear dependence between them excluding influence of the rest of components of X
- Recall,

$$R = D_{\Omega}^{-1/2} \Omega D_{\Omega}^{-1/2} \qquad r_{i,j} = \frac{\sigma_{i,j}}{\sqrt{\sigma_{i,i}, \sigma_{j,j}}}$$

$$D_{\Omega} = diag\{\sigma_1^2, ..., \sigma_n^2\}, \ \Omega = cov(X)$$

- Similarly,

$$P = D_K^{-1/2} K D_K^{-1/2} \qquad \rho_{i,j|.} = \frac{k_{i,j}}{\sqrt{k_{i,i}, k_{j,j}}}$$

where $K = \Omega^{-1}$ or $K = R^{-1}$

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