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Network analysis of the Hungarian interbank lending market

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Importance

- **Partner risk**

  Loans without collateral
- **Systemic risk**

  Large banks act as intermediary
- **Pre-crisis regulation**

  Early warning system on SIFIs

Data

- National Bank of Hungary
- Jan 2003 – Jan 2012 (*including Sept 2008*)
- 55 Hungarian banks
- 92,619 interbank lending transactions:
  - Lender
  - Borrower
  - Loan amount
  - Interest rate
  - Maturity
  - Date

Monthly aggregation (!)

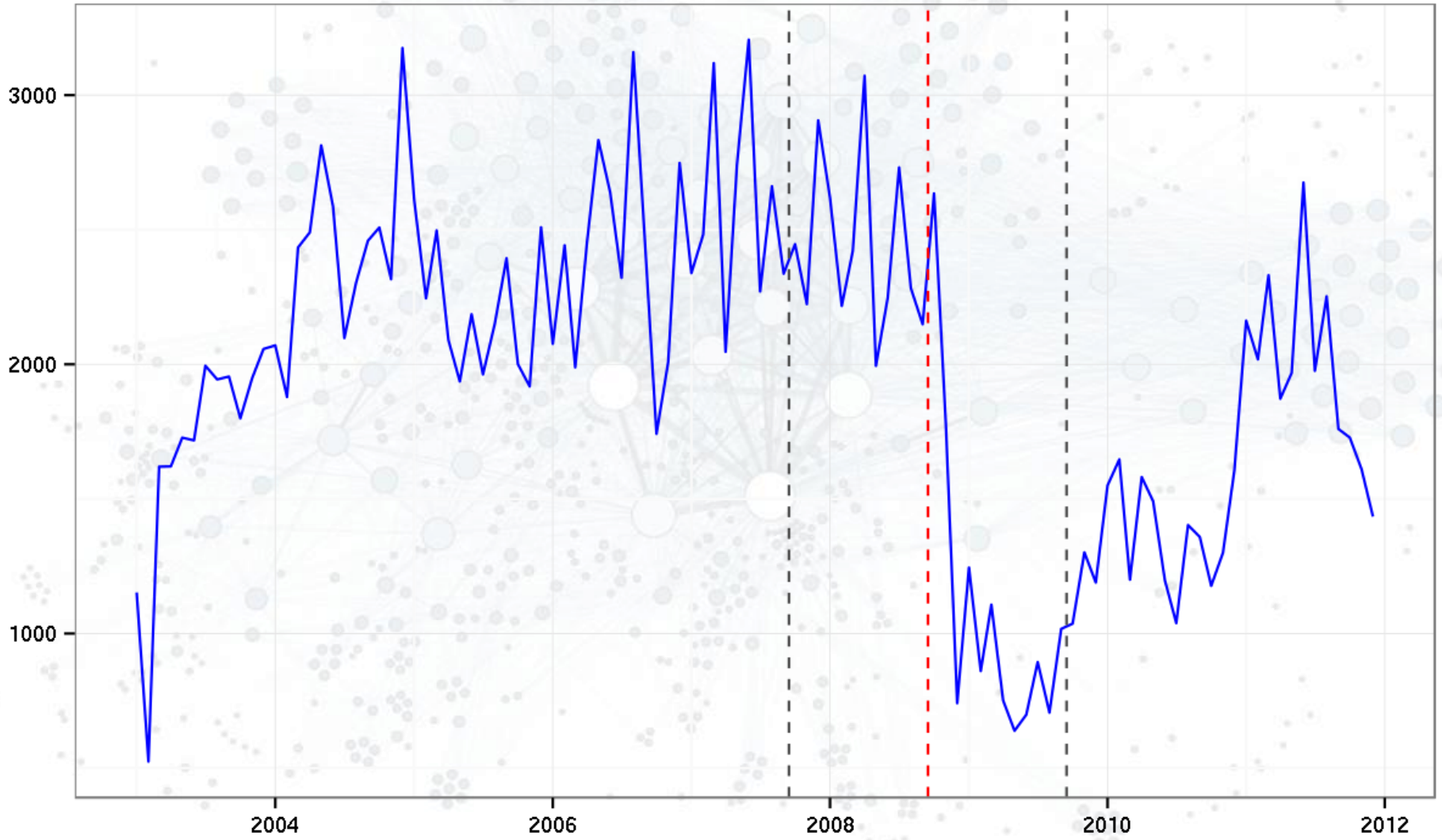
Lender	Borrower	Amount	Date
1	2	10	Jan 2013
1	3	5	Jan 2013
2	1	5	Jan 2013
2	3	8	Jan 2013
3	1	5	Jan 2013
3	2	12	Jan 2013
1	6	4	Jan 2013
1	4	8	Jan 2013
2	4	8	Jan 2013
6	2	6	Jan 2013
9	1	15	Jan 2013
5	2	5	Jan 2013
7	6	2	Jan 2013
4	8	42	Jan 2013

Factors contributing to systemic risk

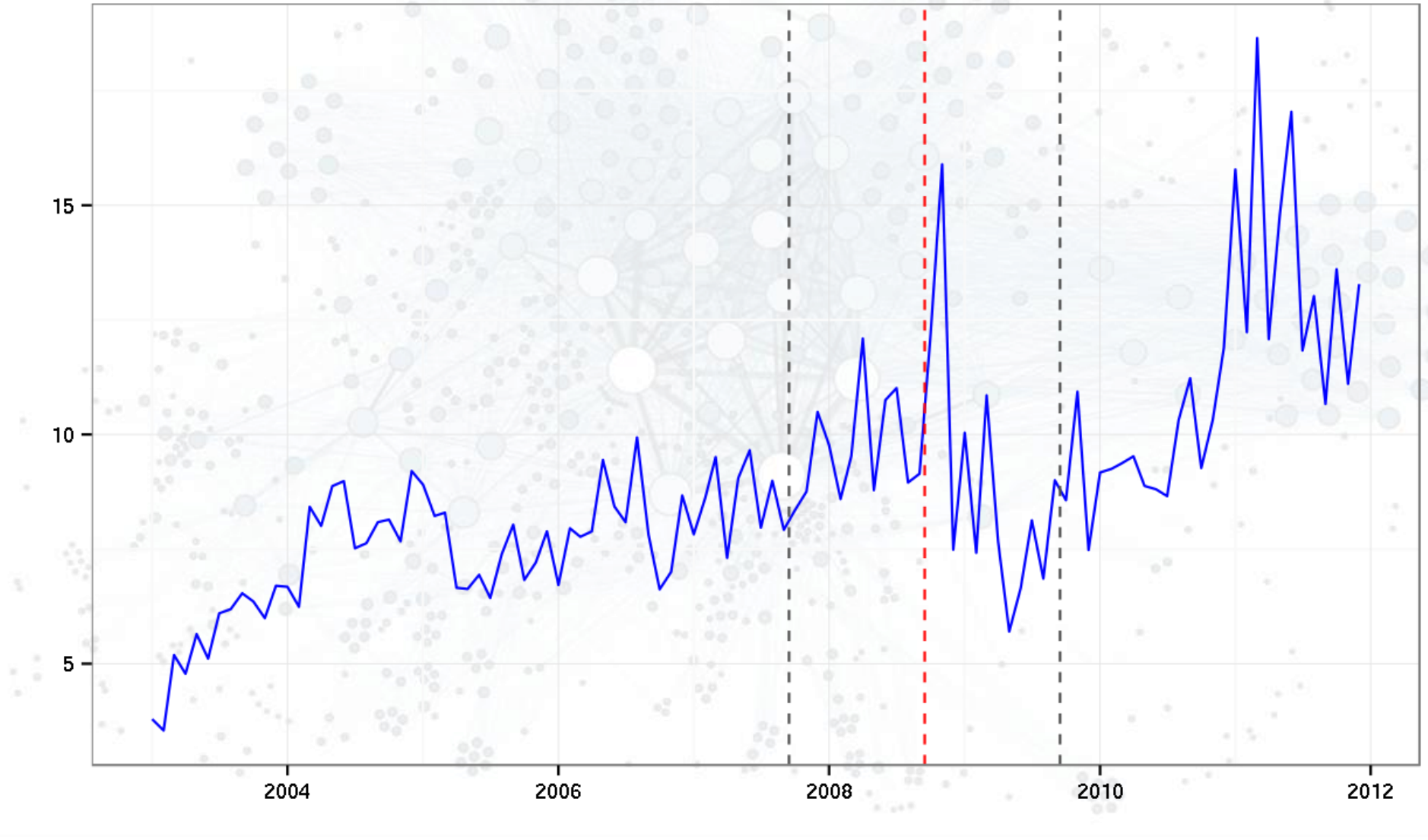
- Size
- Interconnectedness
- Lack of substitutes
- Cross-juridictional activity
- Complexity of the activities

Basel Committee on Banking Supervision (2011)

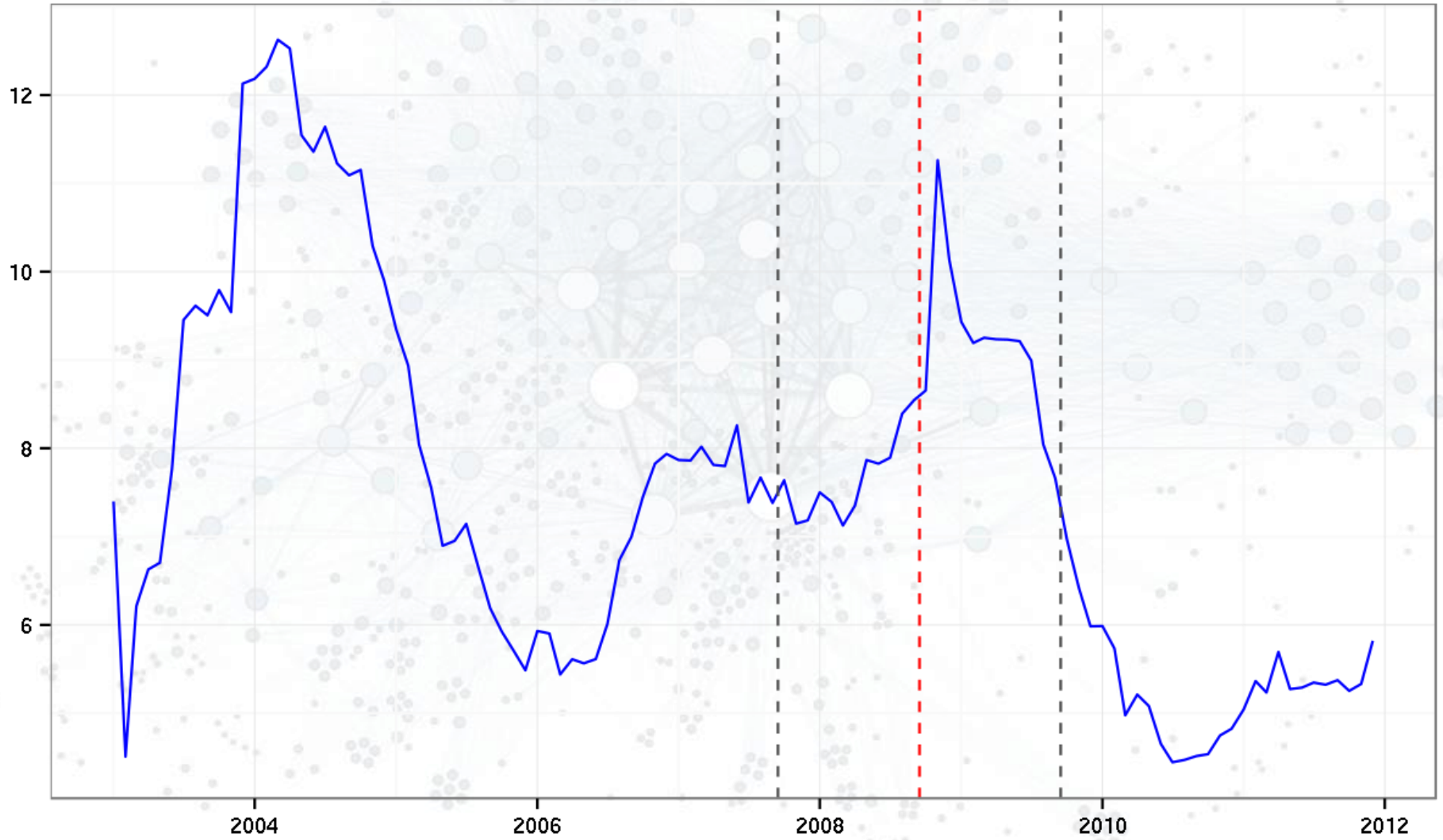
Total volume



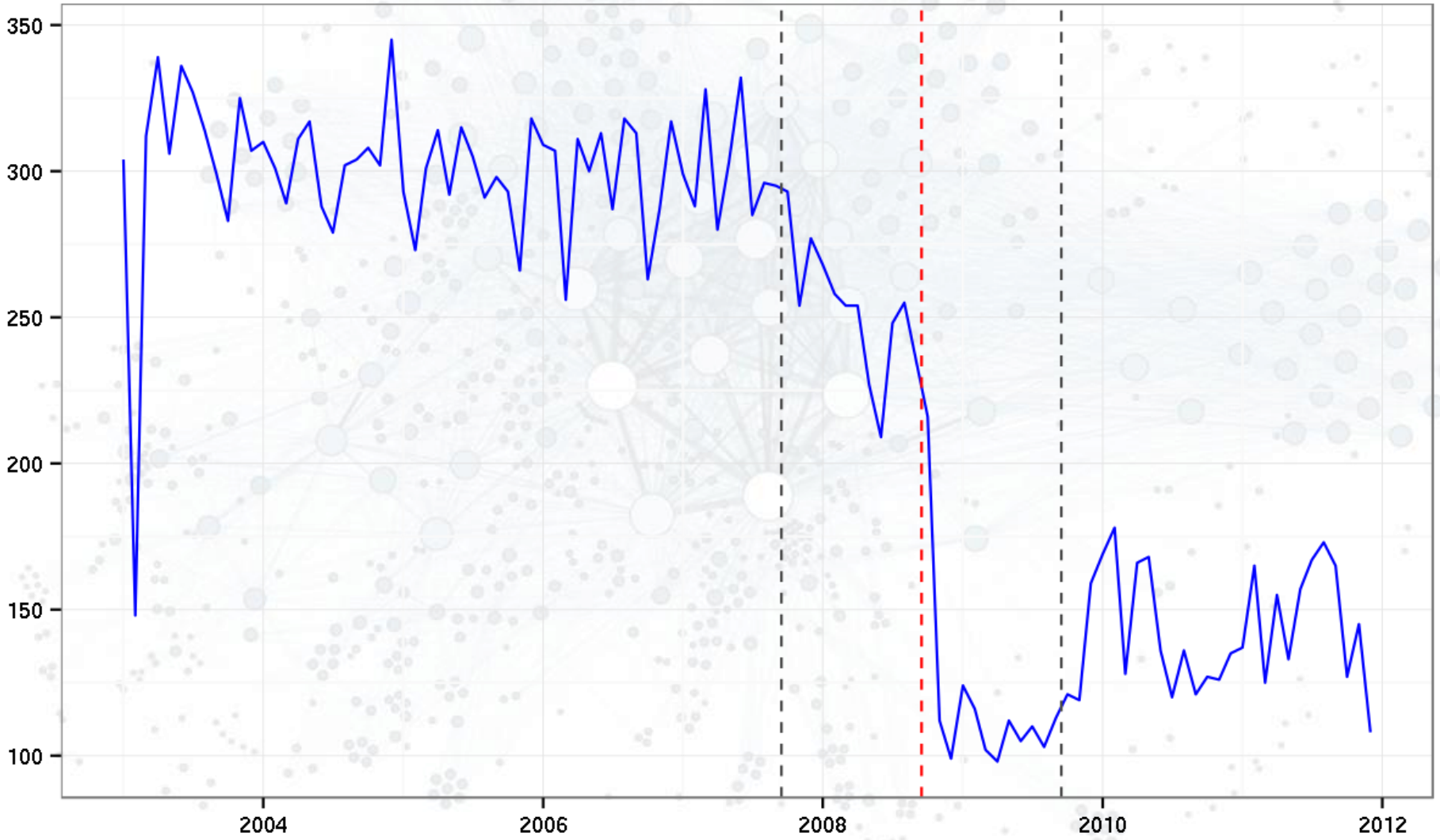
Average amount



Interest rate



Number of transactions



Factors contributing to systemic risk

- ~~Size~~
- **Interconnectedness**
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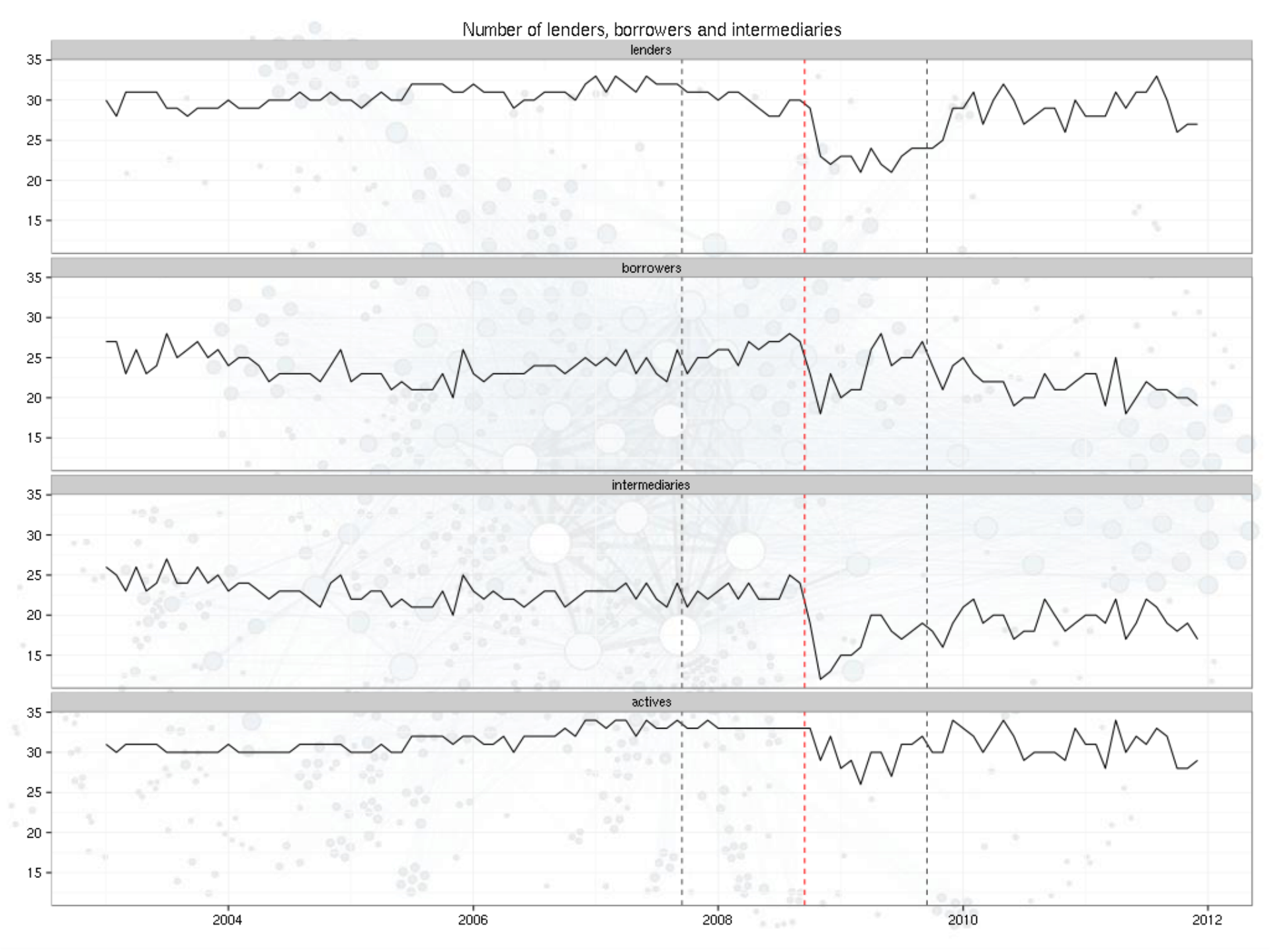
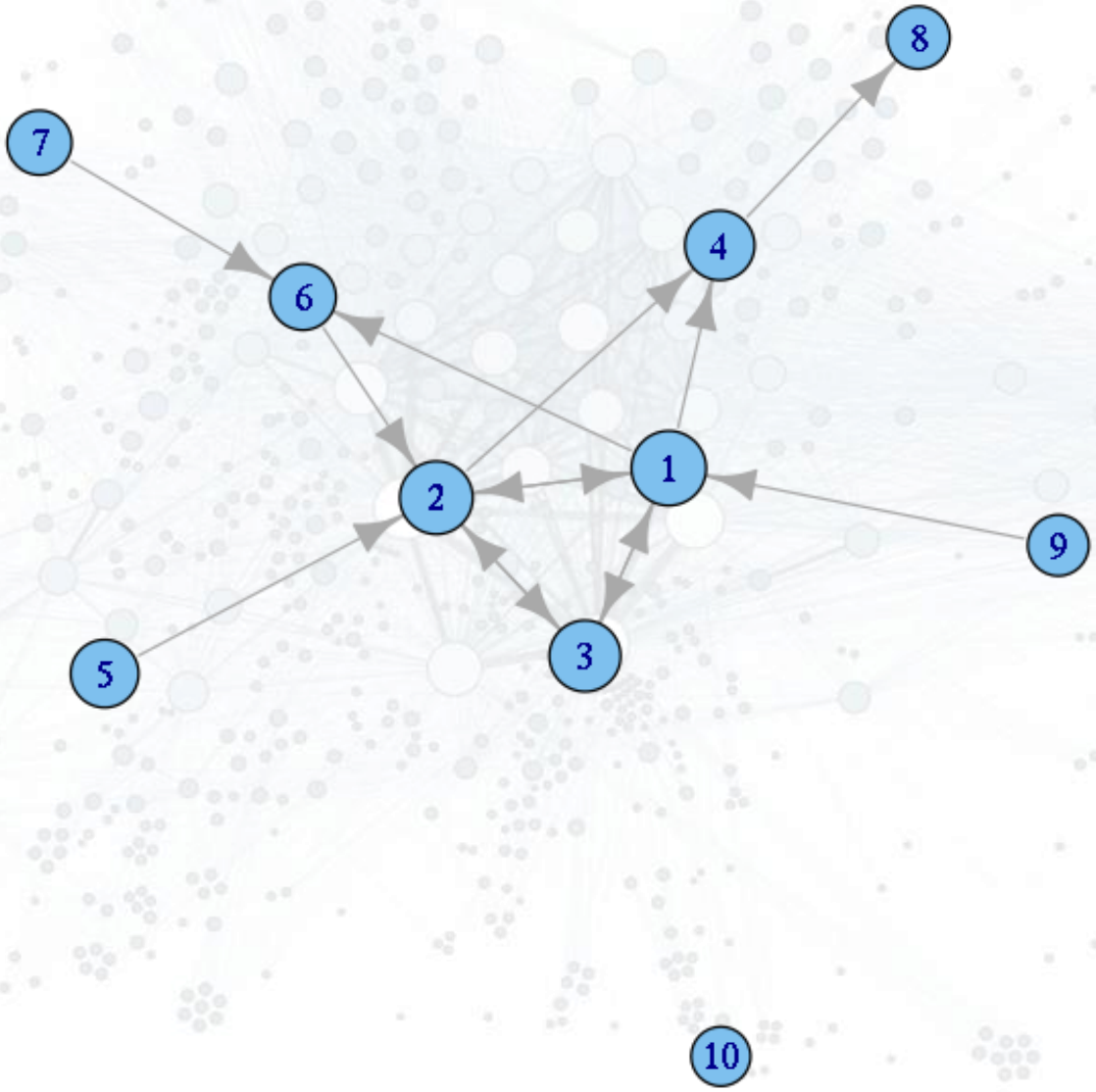

Number of lenders, borrowers and intermediaries
lenders
borrowers
intermediaries
actives
35
30
25
20
15
2004
2006
2008
2010
2012

Introduction to network analysis

Lender	Borrower	Amount	Date
1	2	10	Jan 2013
1	3	5	Jan 2013
2	1	5	Jan 2013
2	3	8	Jan 2013
3	1	5	Jan 2013
3	2	12	Jan 2013
1	6	4	Jan 2013
1	4	8	Jan 2013
2	4	8	Jan 2013
6	2	6	Jan 2013
9	1	15	Jan 2013
5	2	5	Jan 2013
7	6	2	Jan 2013
4	8	42	Jan 2013

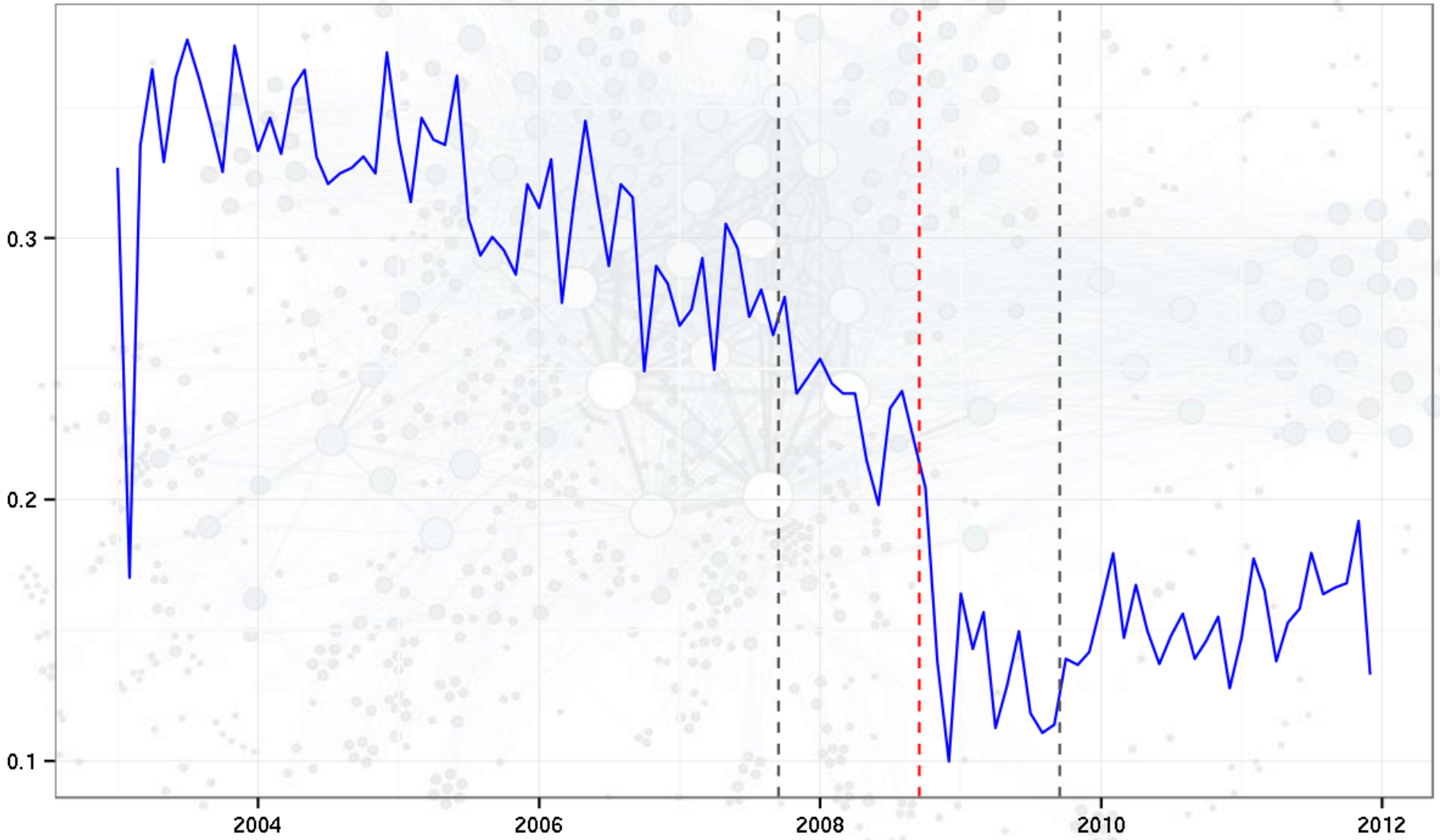
Introduction to network analysis



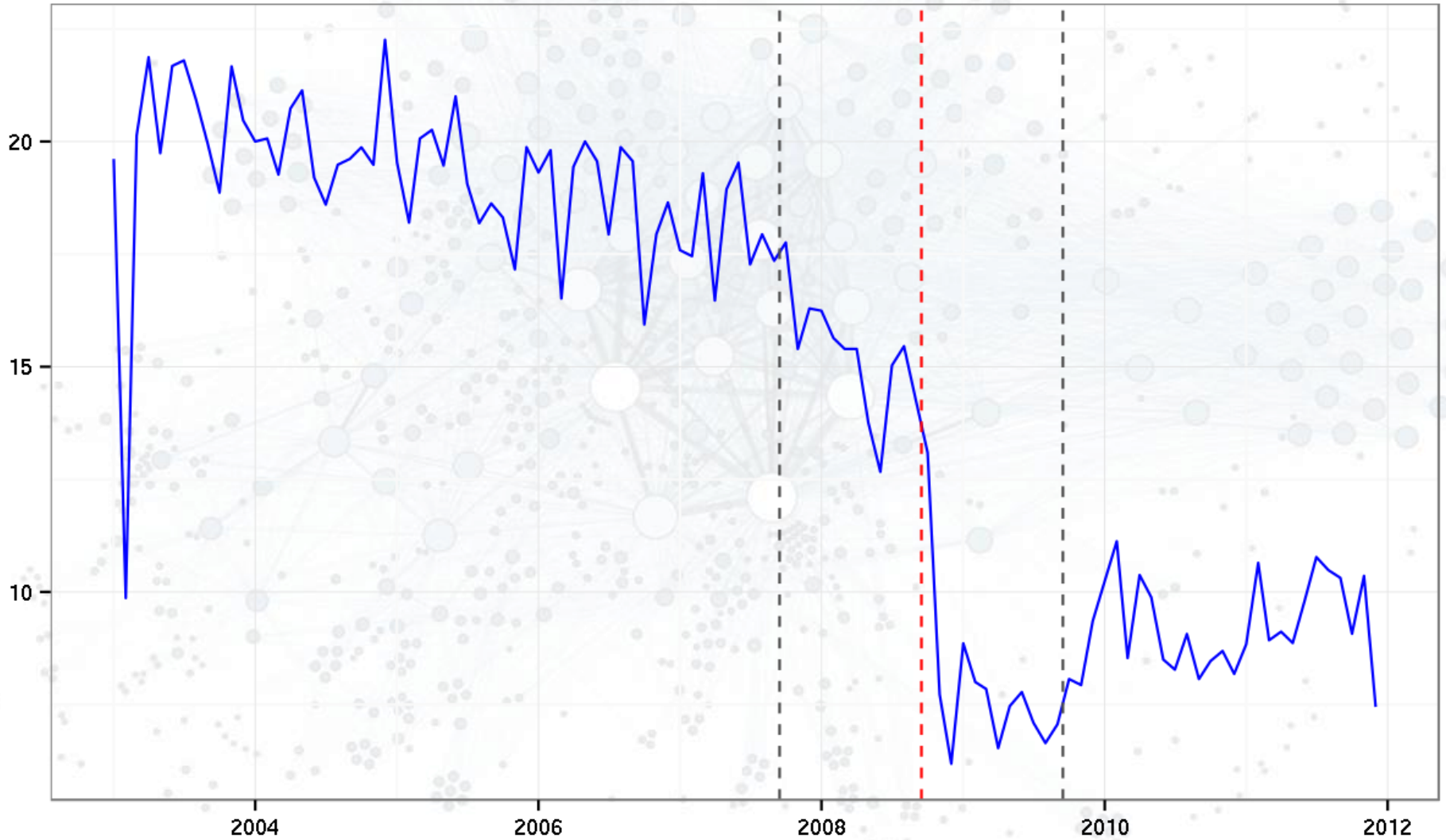
Network centrality metrics

- Density
- Degree in/out
- Betweeness
- Closeness
- Transitivity
- Average path length
- Eigenvalue

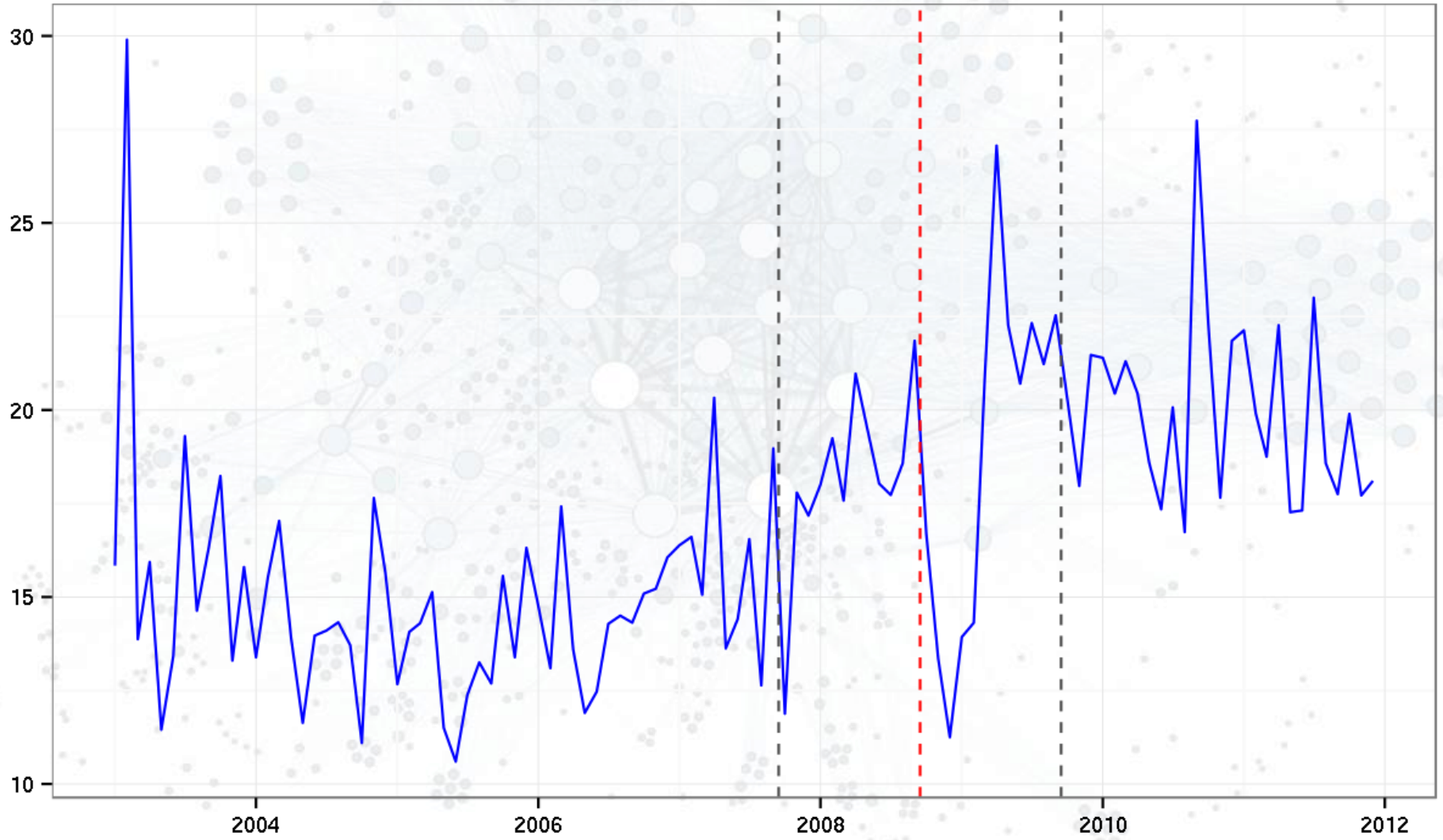
Average density



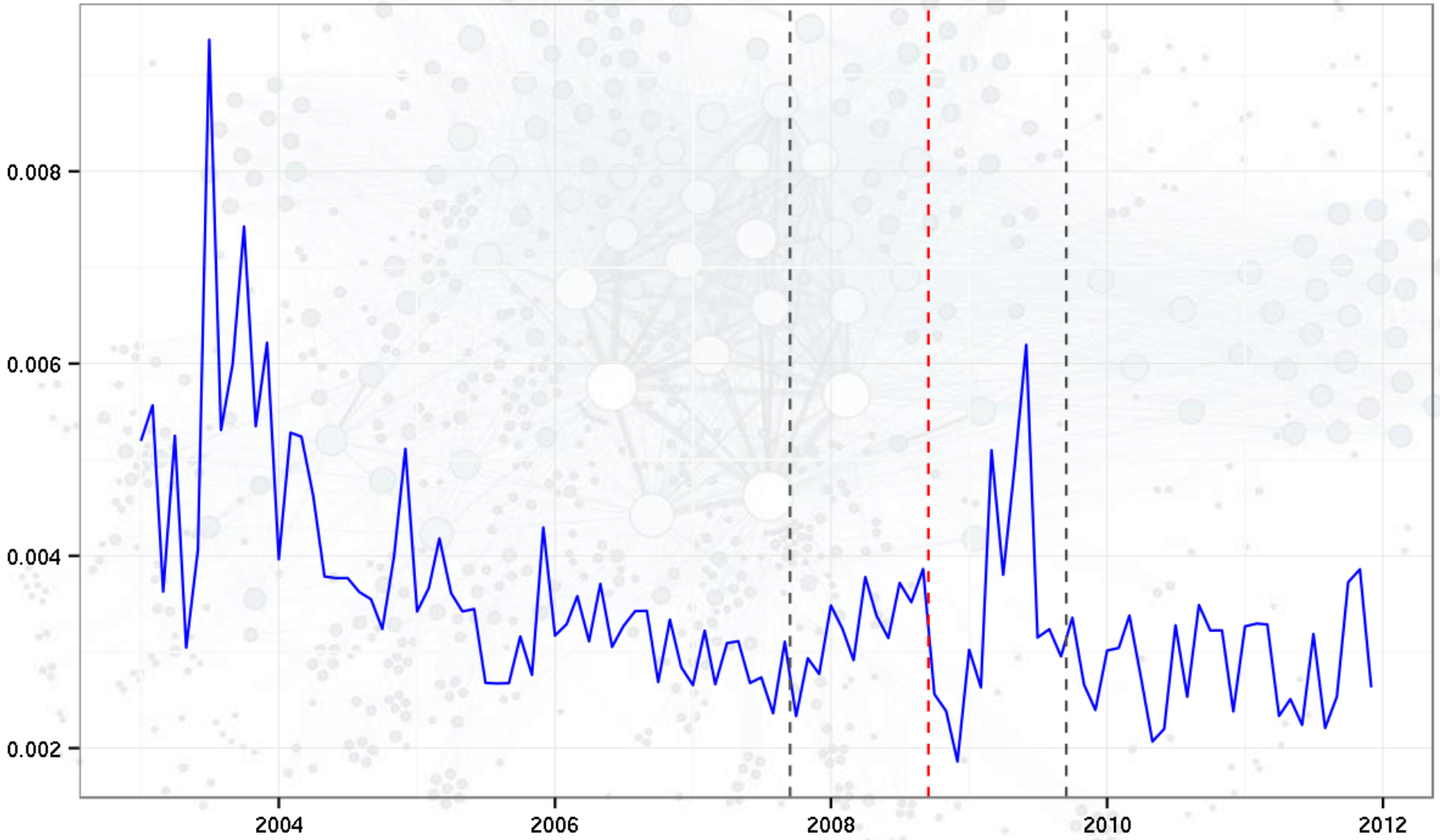
Average degree



Average betweenness



Average closeness



Interconnectedness

- ~~General, aggregated network centrality metrics~~
- Core/periphery models
  - Binary
  - **Three layers**
  - Continuous
  - Symmetric or asymmetric
- Simulation, infection models

Core, semi-periphery, periphery

1. Define every node as **semi-periphery**
2. Define all non-connected nodes as **exit**
3. Look for largest complete sub-graph of
   a) the directed graph
   b) the undirected graph (if *3a* failed)
   c) **core** nodes found
4. Temporarily merge all core nodes into one
5. Look for the largest sets of independent nodes
   a) remove sets which include the core node
   b) if empty, repeat *5* for smaller sets of independent nodes
   c) choose the set(s) with the minimal degree
   d) sample (if multiple sets found)
   e) **periphery** nodes found

Introduction to network analysis

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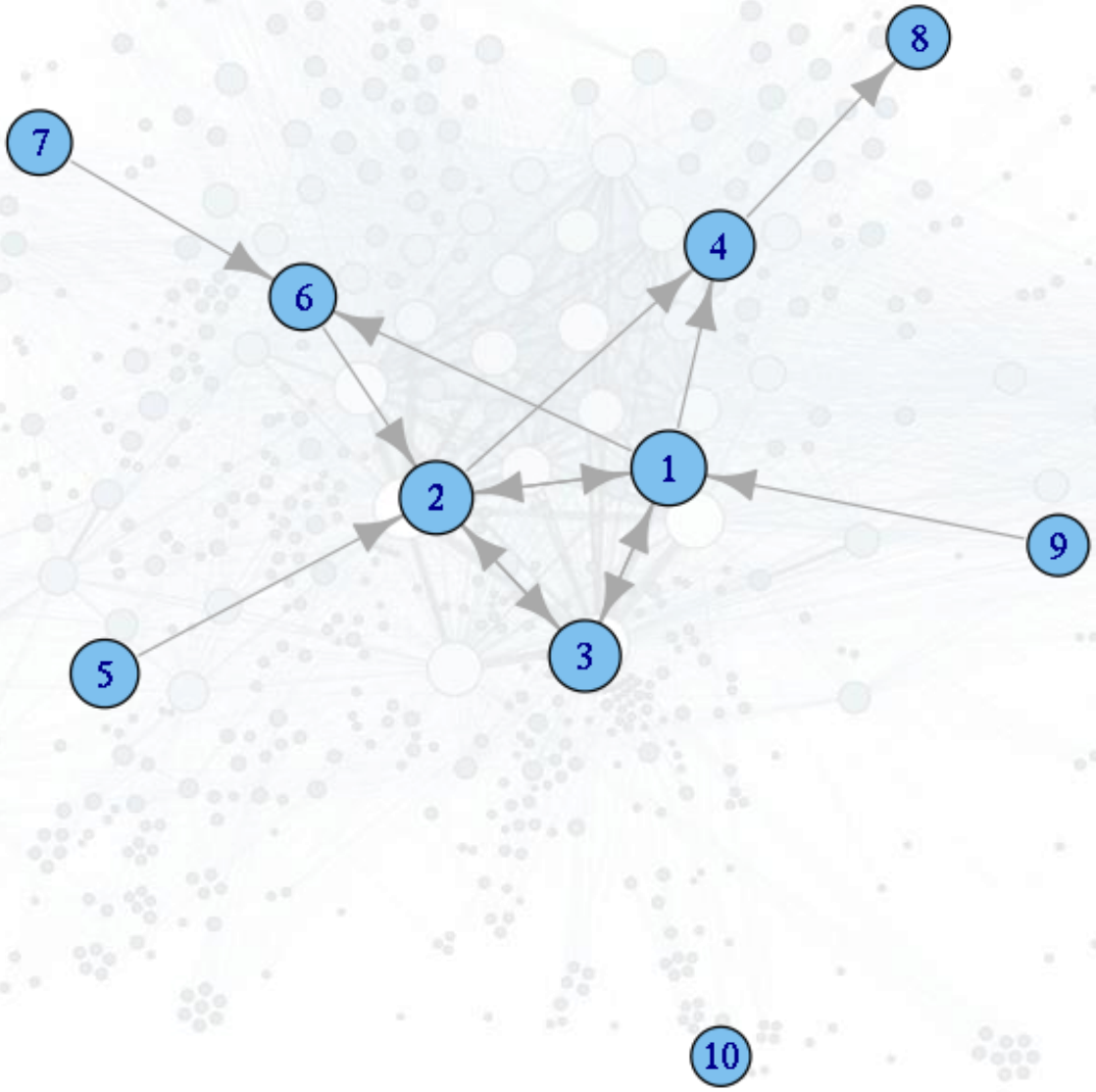
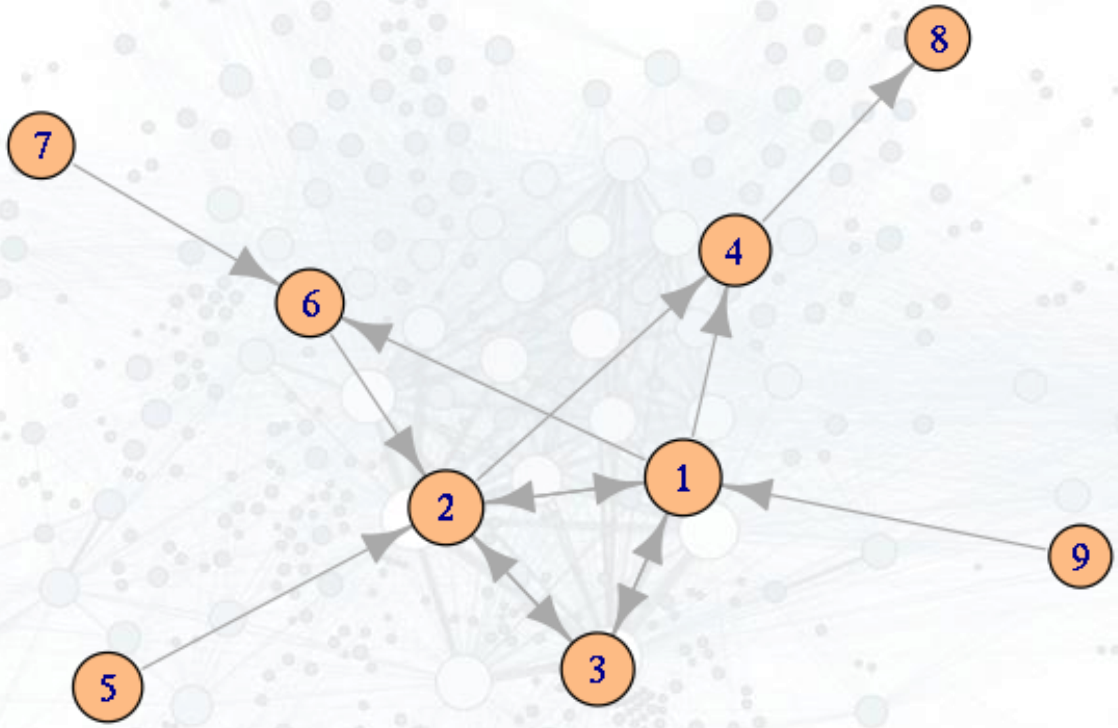
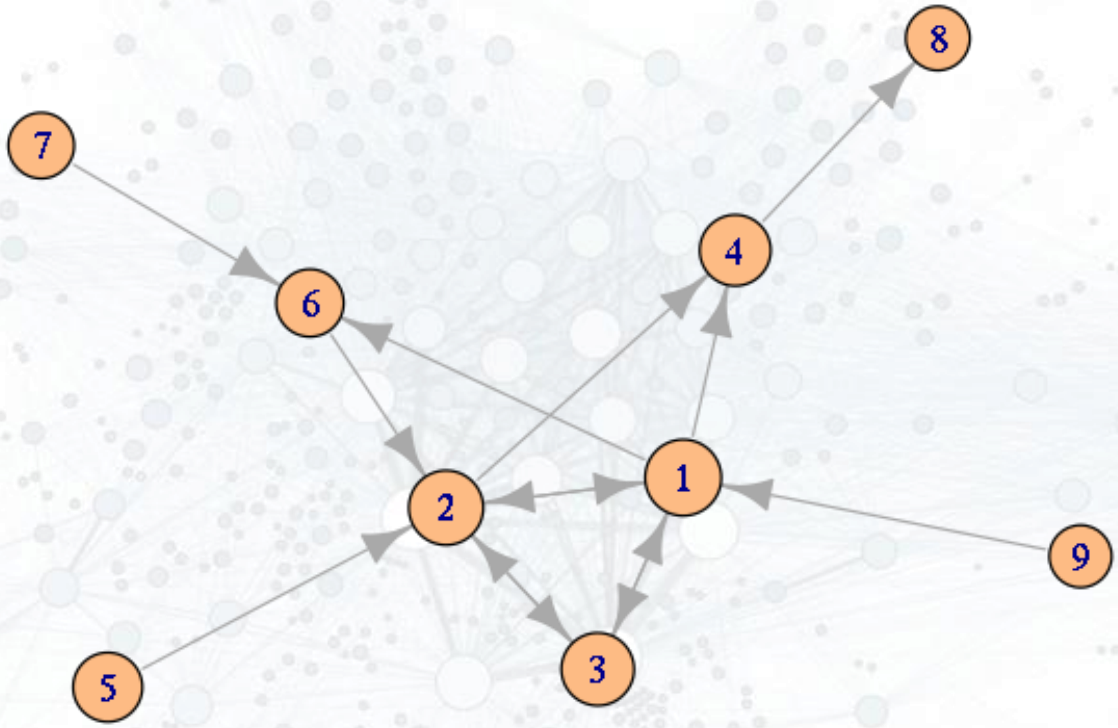
Introduction to network analysis



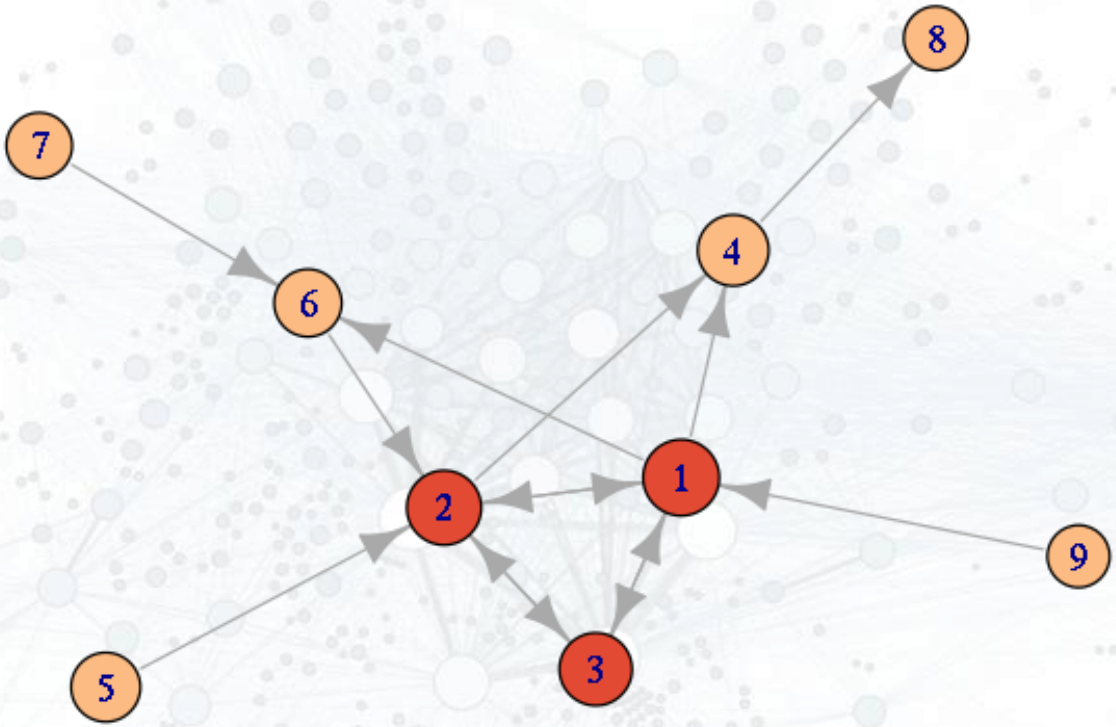
Every node is semi-periphery



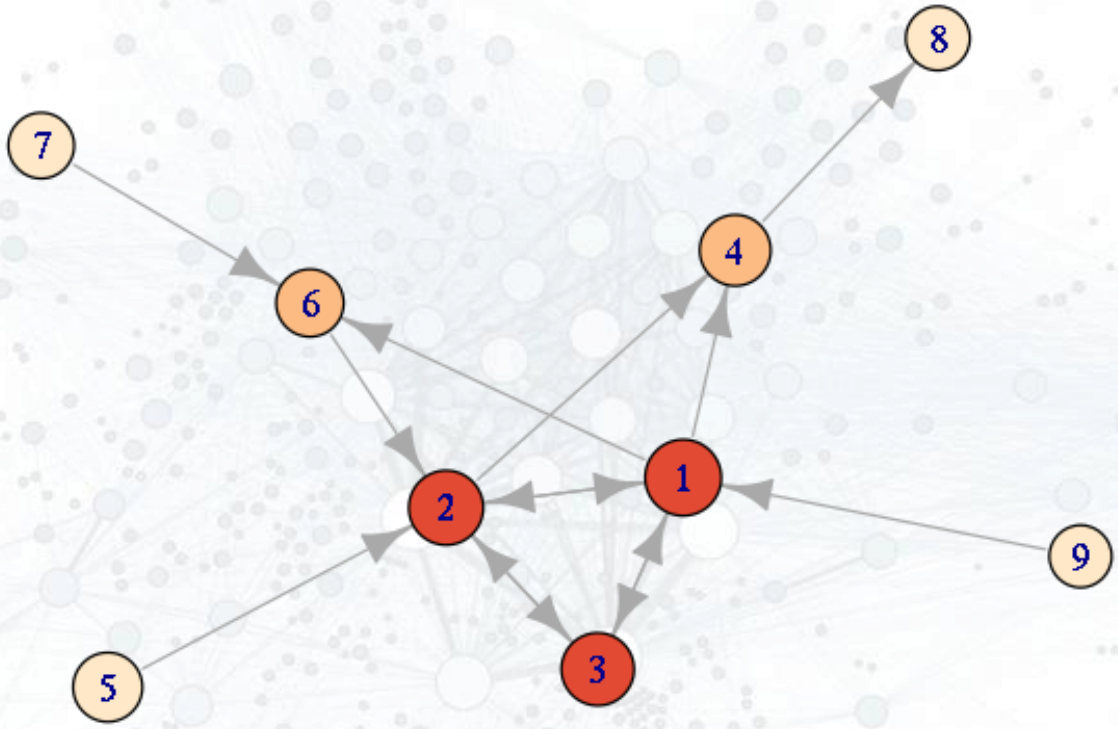
Non-connecting nodes



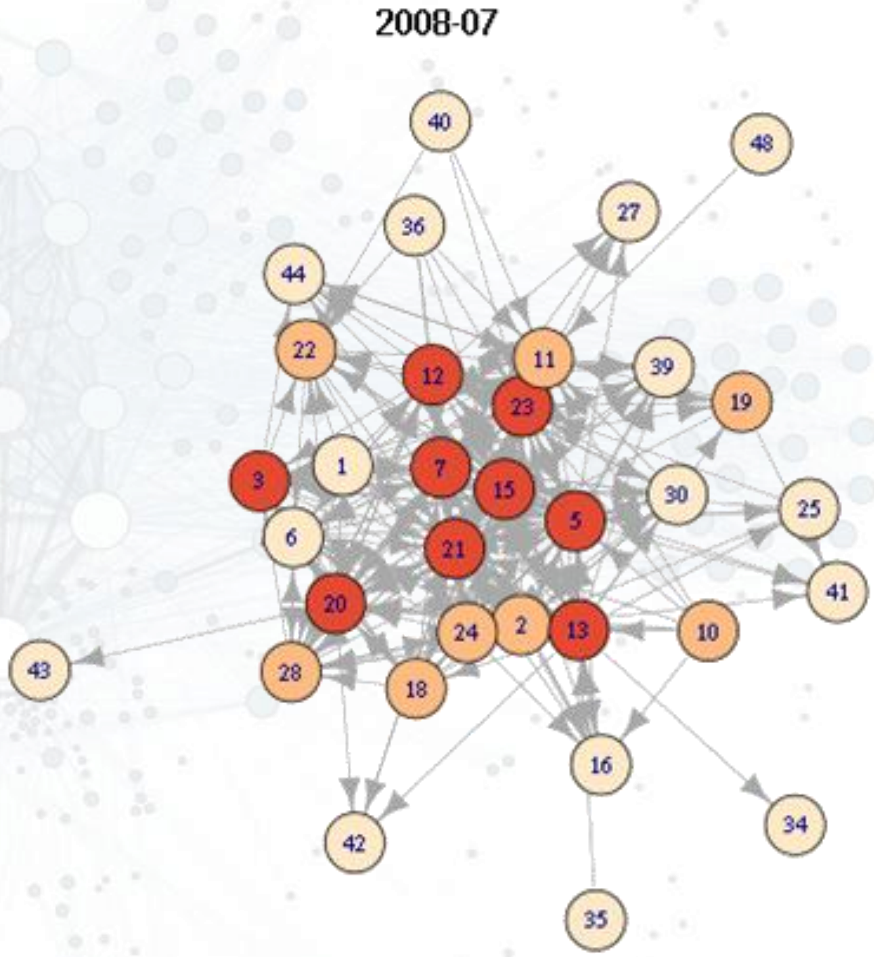
Largest complete sub-graph



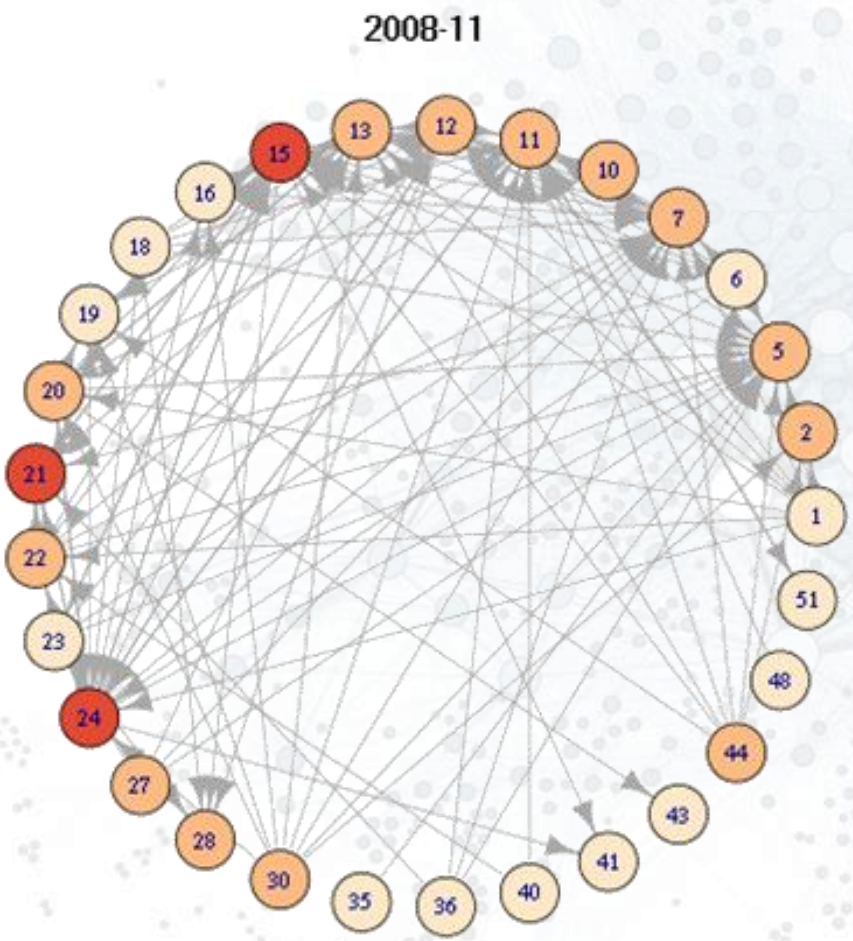
Largest set of independent nodes

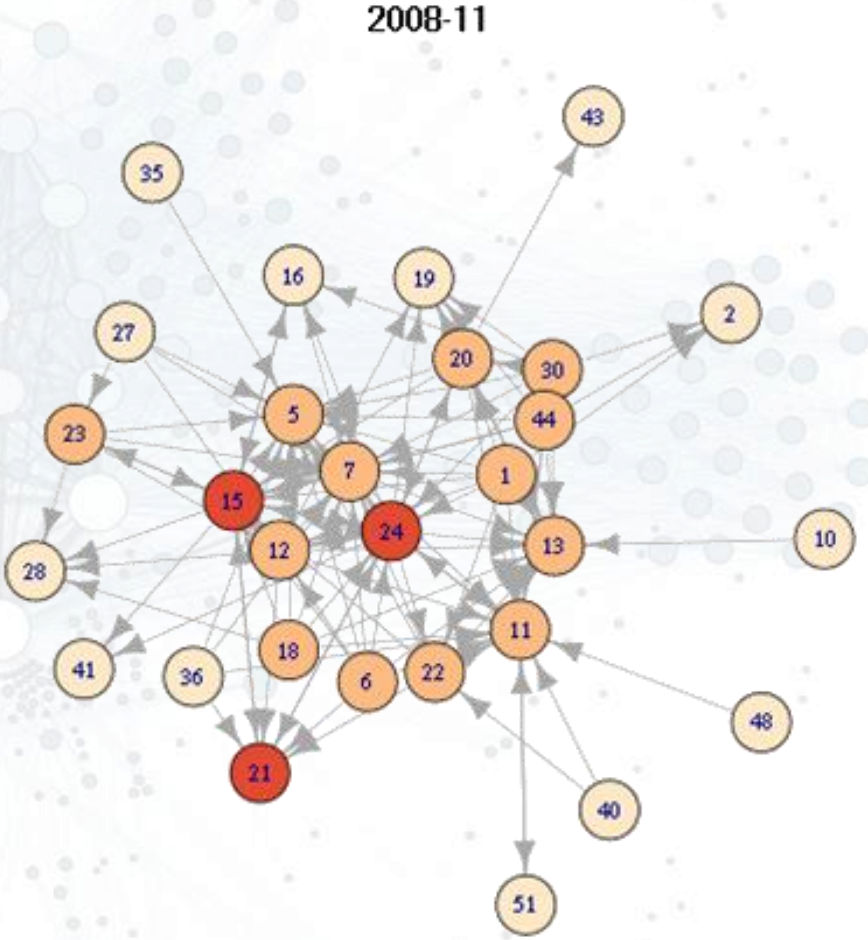


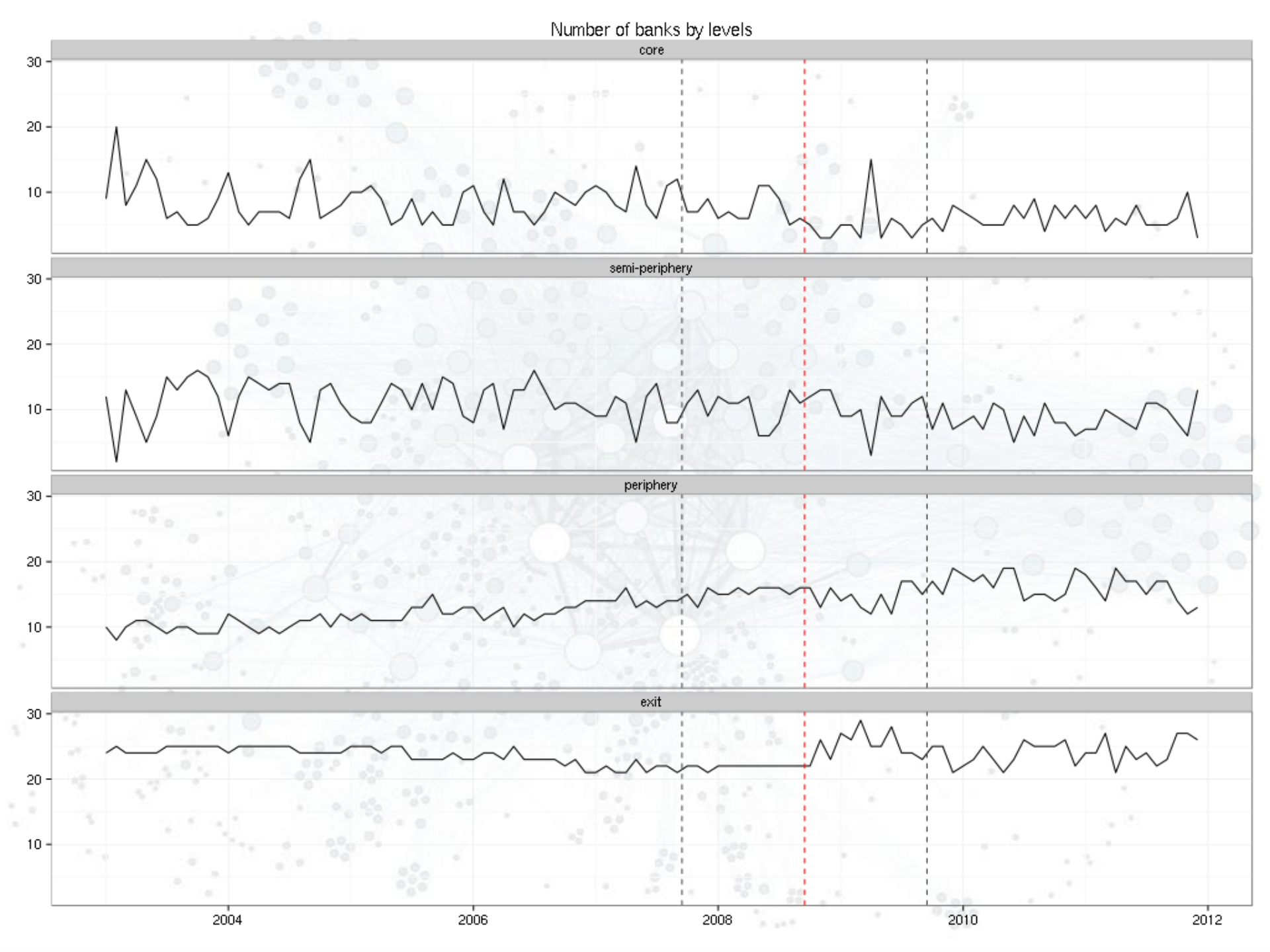
Coreness: before the Lehman-fall

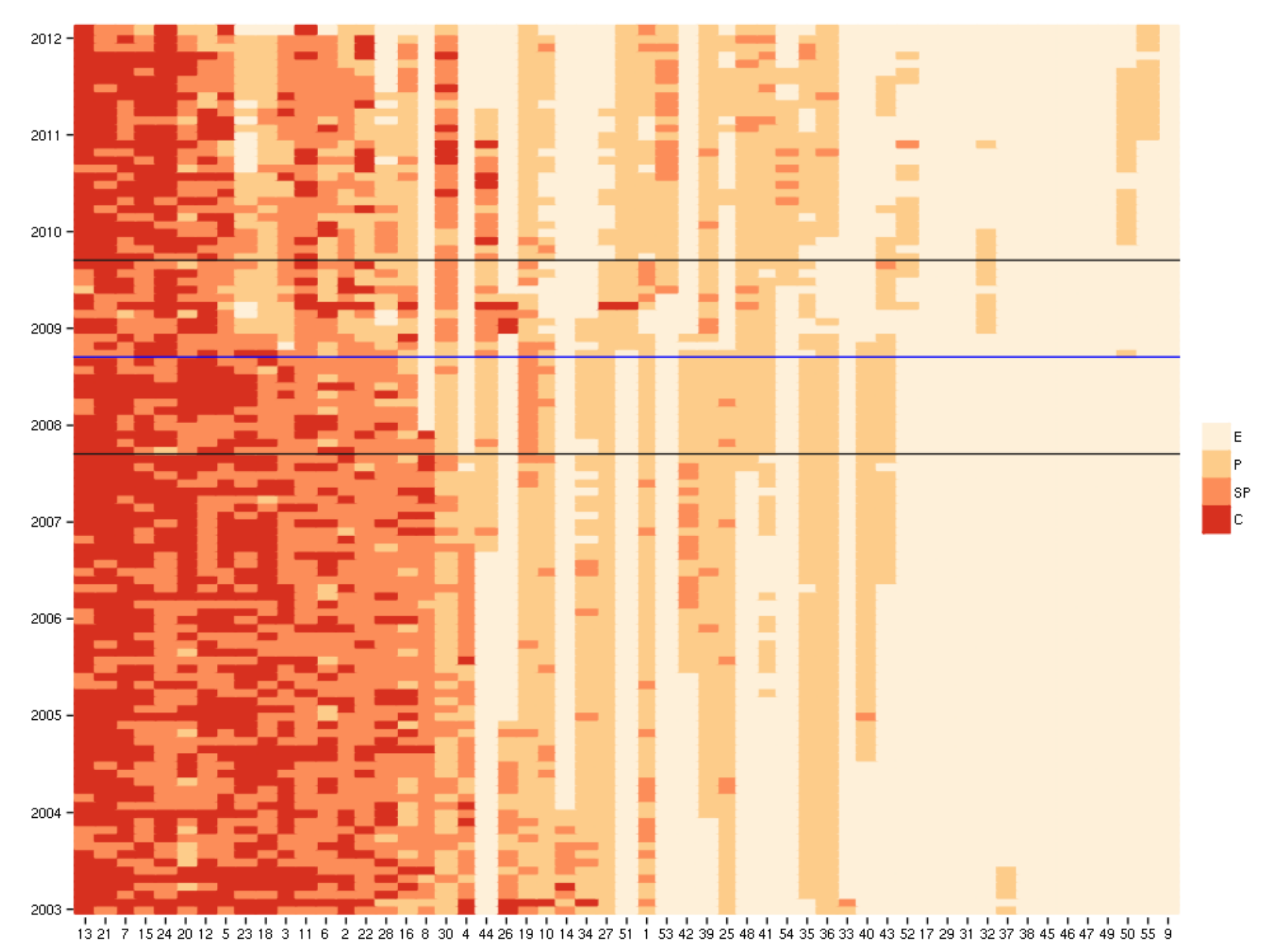


Coreness: after the Lehman-fall

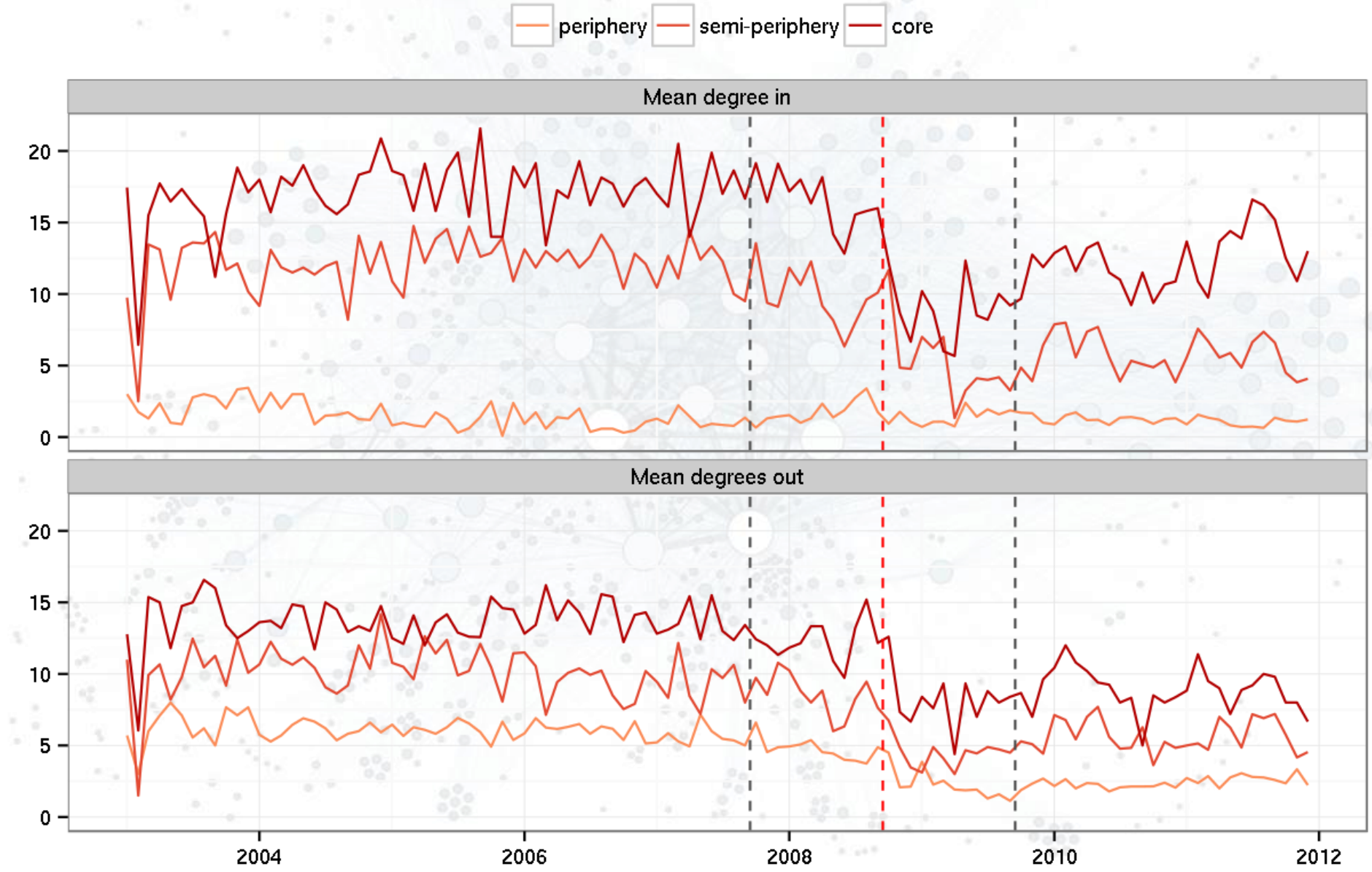




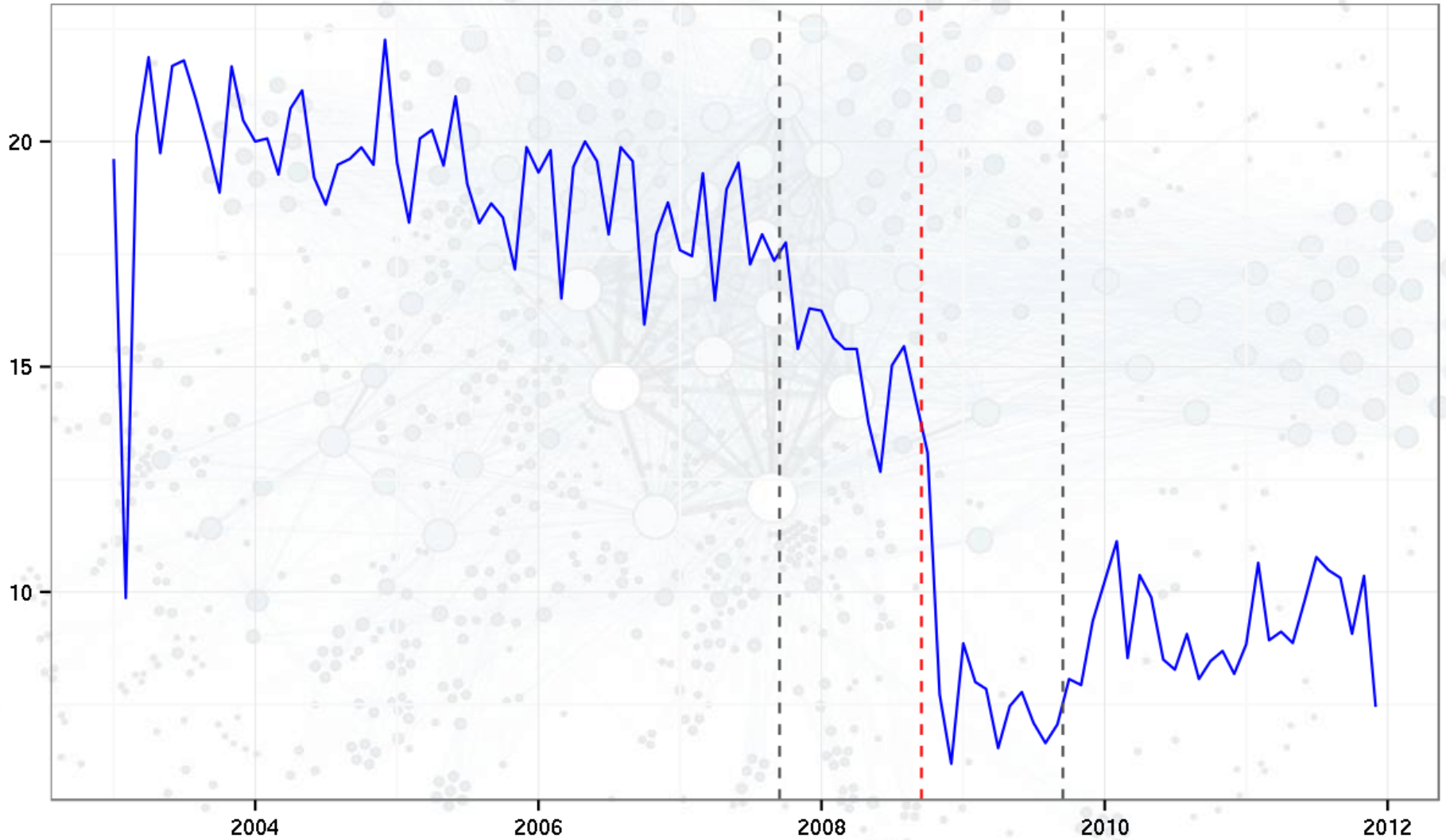

Number of banks by levels
core
semi-periphery
periphery
exit
30
20
10
2004
2006
2008
2010
2012


2012
2011
2010
2009
2008
2007
2006
2005
2004
2003
13 21 7 15 24 20 12 5 23 18 3 11 6 2 22 28 16 8 30 4 44 26 19 10 14 34 27 51 1 53 42 39 25 48 41 54 35 36 33 40 43 52 17 29 31 32 37 38 45 46 47 49 50 55 9
E
P
SP
C

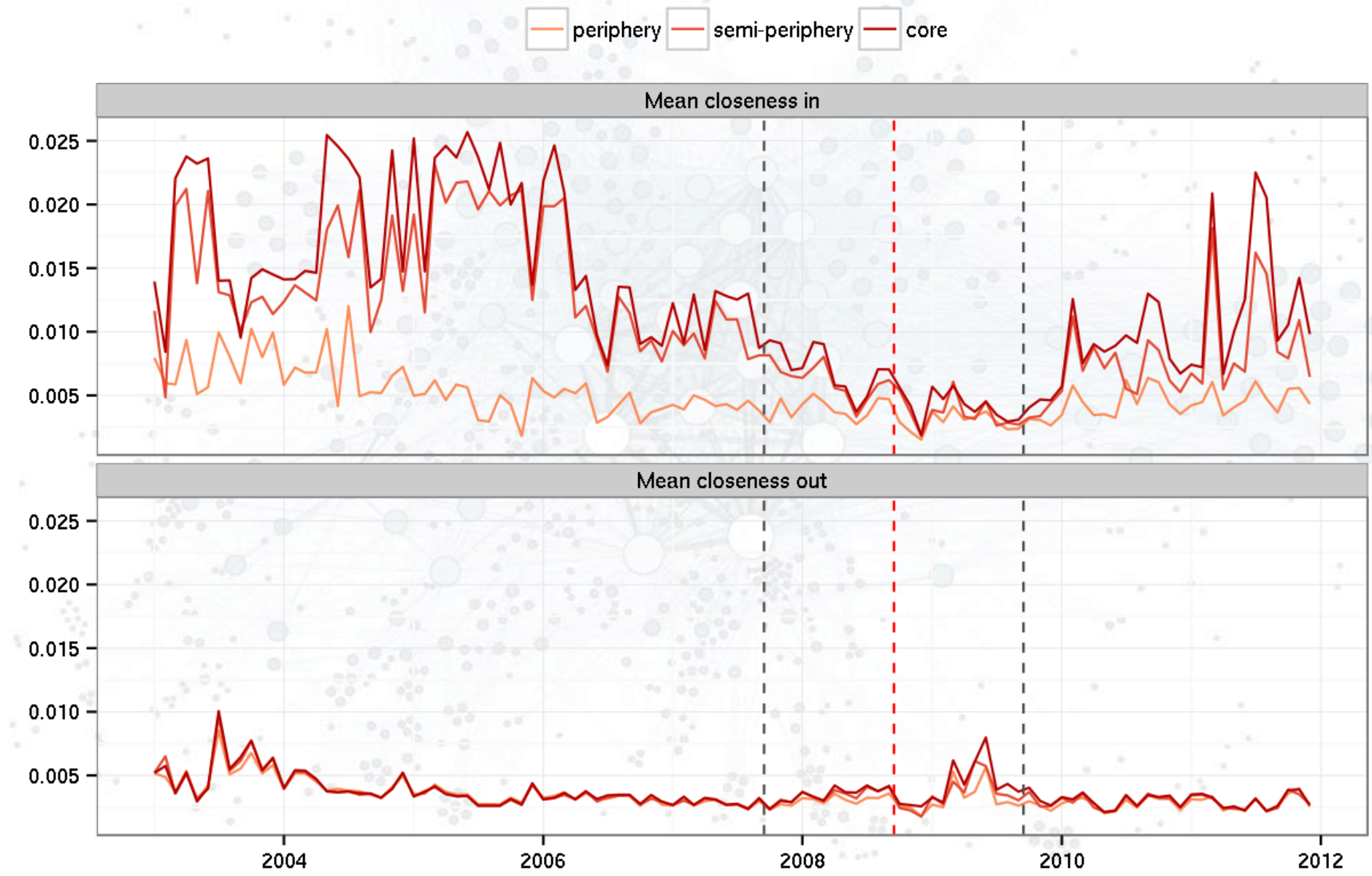
Coreness and degree



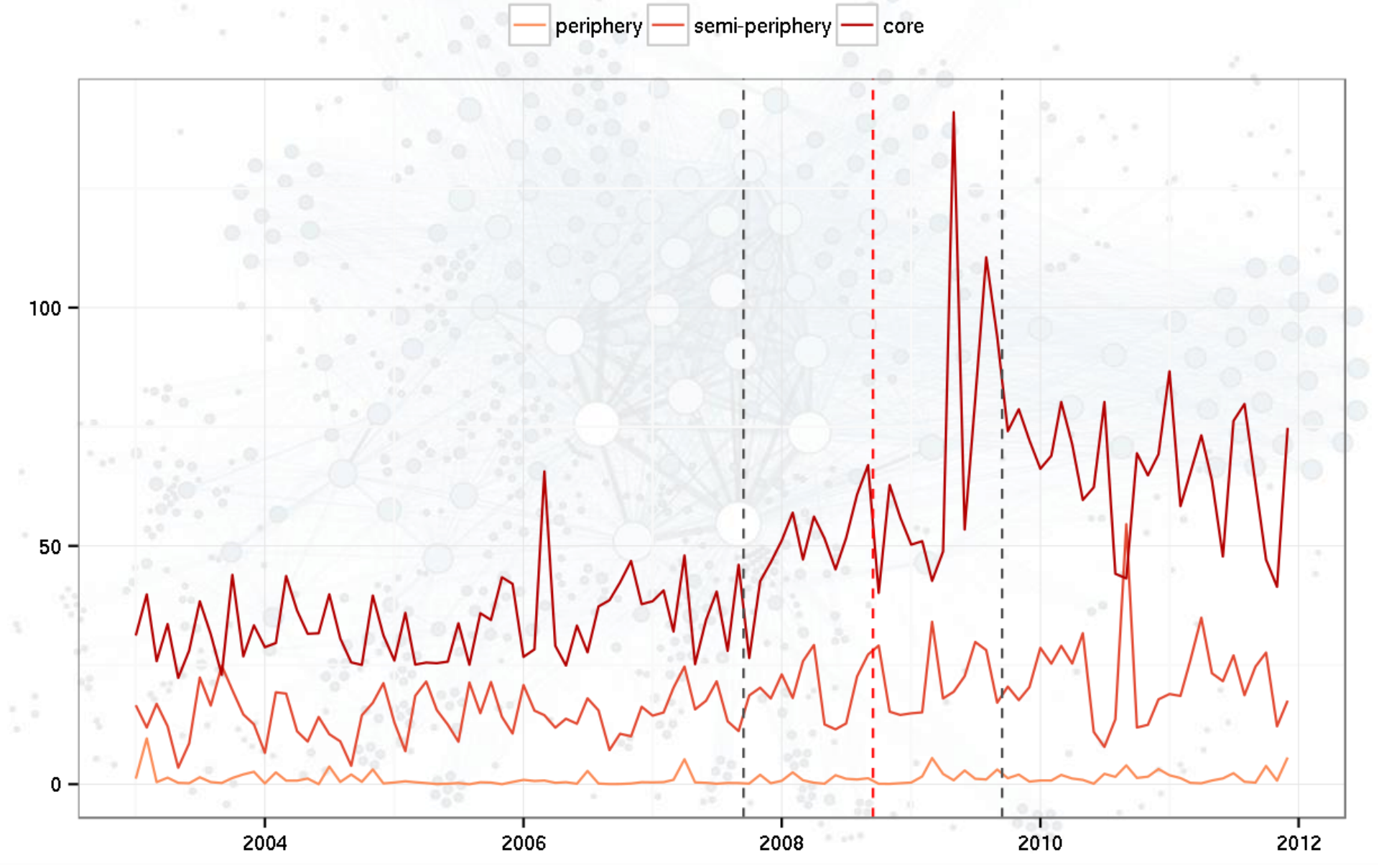
Average degree



Coreness and closeness



Coreness and betweeness



http://bit.ly/rfin2015-hunbanks

Network analysis of the Hungarian interbank lending market

Start date:
2008-09-15

End end:
2008-09-30

Shift start and end date:
+24 hours | -24 hours

Filter transaction amount:
0 47
0 5 10 14 19 24 29 34 38 43 48

Consider edges as:
directed

Merge transactions:
yes

Data | Volume metrics | Network metrics | Flow of funds | Graph

Bank	Partner	Amount	Interest
All	All	All	All
10	20	6.6	8.8
10	45	1.9	8.5
11	20	1	8.8
12	15	7.8	8.6
12	20	1.5	8.8
12	21	10	8.1
12	5	26.1	8.4
15	18	4.5	8.8
16	28	2.5	8.5
2	20	21.1	9.1
21	44	9	9
21	39	5.6	8.5
23	20	4.4	8.5
23	28	0.5	8.6
25	15	4.4	8

Previous 1 2 3 4 5 … 11 Next

Simulated data

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Filter transaction amount:

0 47

0 5 10 14 19 24 29 34 38 43 48

Consider edges as:

directed

Merge transactions:

yes

Data | Volume metrics | Network metrics | Flow of funds | Graph

Number of transactions	158
Minimal amount	0.06
Average amount	4.790443
Maximum amount	32.2
Overall amount	756.89

Network analysis of the Hungarian interbank lending market

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Shift start and end date:

+24 hours | -24 hours

Filter transaction amount:

0 — 47

0 5 10 14 19 24 29 34 38 43 48

Consider edges as:

directed

Merge transactions:

yes

Data | Volume metrics | Network metrics | Flow of funds | Graph

```
# Graph summary

  55  nodes
 158  edges
 The network is not connected.

# Centrality measures

 Density: 0.05319865
 Average number of transactions: 5.745455
 Average betweenness: 9.109091
 Transitivity: 0.5203349
 Average closeness: 0.0004342939
 Average path length: 1.934701
 Eigenvalue: 15.59897
```

Bank	Degree (in)	Degree (out)	Degree (all)	Betweeness	Closeness	Eigenvector
1	0	12	12	0	0.000575	0.4306
2	4	10	14	37.93	0.0005574	0.529
3	3	8	11	1.99	0.0005565	0.549
4	0	0	0	0	0.0003367	4.927e-18
5	17	9	26	64.88	0.0005549	0.859
6	0	0	0	0	0.0003367	4.927e-18
7	0	0	0	0	0.0003367	4.927e-18
8	0	0	0	0	0.0003367	4.927e-18
9	0	0	0	0	0.0003367	4.927e-18

Network analysis of the Hungarian interbank lending market

Start date:

2008-09-15

End end:

2008-09-30

Shift start and end date:

+24 hours | -24 hours

Filter transaction amount:

0 33 48

0 5 10 14 19 24 29 34 38 43 48

Consider edges as:

directed

Merge transactions:

yes

Data | Volume metrics | Network metrics | Flow of funds | Graph

Bank	C	SP	P
C	110.20	100.60	35.11
SP	159.48	120.80	40.62
P	77.73	112.35	0.00

Network analysis of the Hungarian interbank lending market

Start date:

2008-09-15

End end:

2008-09-30

Shift start and end date:

+24 hours | -24 hours

Filter transaction amount:

0 33 48

0 5 10 14 19 24 29 34 38 43 48

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directed

Merge transactions:

yes

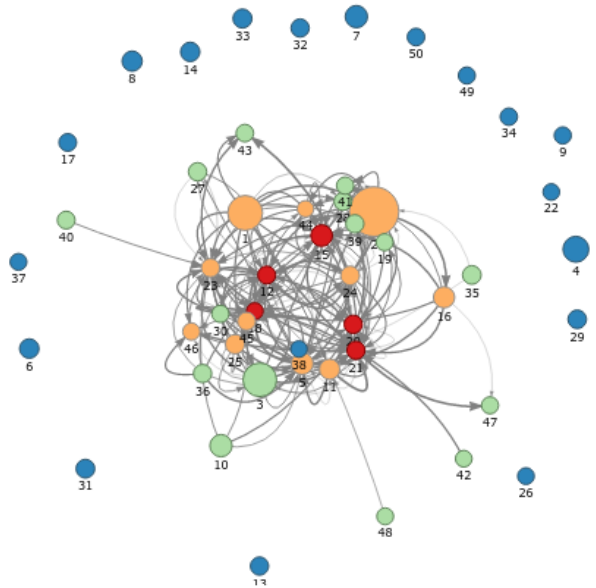
Data | Volume metrics | Network metrics | Flow of funds | Graph

SP

P

C

E



R packages

- data.table (1.9.4)
- reshape2 (0.8.5)
- ggplot2 (1.0.1)
- RColorBrewer (1.1-2)
- igraph (0.7.1)
- shiny (0.12.0)
- visNetwork (0.0.3)
- pander (0.5.3)

Q&A

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Hungary, 2014