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UNIVERSITÀ DEGLI STUDI DI PALERMO

Institute for New Economic Thinking

CRISIS Complexity Research Initiative for Systemic InstabilitieS

EUROPEAN COMMISSION

SEVENTH FRAMEWORK PROGRAMME

Quantifying preferential trading in the e-MID interbank market

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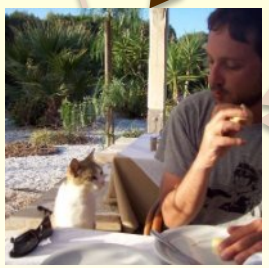
INET Workshop "Interlinkages and systemic risk", Ancona, 4-5 July 2013

1. Interlinkages amongst People

Rosario Mantegna
UNIPA

Giulia Iori
CITY

Salvatore Micciché
UNIPA



Vasilis Hatzopoulos
CITY

Michele Tumminello
UNIPA

directed preferential

2. Data

e-MID electronic market for Inter-bank Deposits in the Euro Area.

It was founded in Italy in 1990 for Italian Lira transactions and became denominated in Euros in 1999. When the financial crisis started, the market players were 246, members from 16 EU countries: Austria, Belgium, Switzerland, Germany, Denmark, Spain, France, United Kingdom, Greece, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, and Portugal.

Each line contains a code labeling the quoting bank, i.e. the bank that proposes a transaction, and the aggressor bank, i.e. the bank that accepts a proposed transaction.
The rate the lending bank will receive is expressed per year; the volume of the transaction is expressed in millions of Euros.
A label indicates the side of the aggressor bank, i.e. whether the latter is lending/selling ("Sell") or borrowing/buying ("Buy") capitals to or from the quoting bank.
We consider only the overnight ("ON") and the overnight long ("ONL") contracts.

2. Data

Lender aggressors

ONLY ITALIAN BANKS

Liquidity issues →

Lehman Brothers crisis →

The investigated maintenance periods

1	24-Dec-2004	23-Mar-2005
2	24-Mar-2005	23-Jun-2005
3	24-Jun-2005	23-Sep-2005
4	26-Sep-2005	23-Dec-2005
5	23-Dec-2005	07-Mar-2006
6	08-Mar-2006	14-Jun-2006
7	15-Jun-2006	05-Sep-2006
8	06-Sep-2006	12-Dec-2006
9	13-Dec-2006	13-Mar-2007
10	14-Mar-2007	12-Jun-2007
11	13-Jun-2007	11-Sep-2007
12	12-Sep-2007	11-Dec-2007
13	12-Dec-2007	11-Mar-2008
14	12-Mar-2008	10-Jun-2008
15	11-Jun-2008	09-Sep-2008
16	10-Sep-2008	09-Dec-2008
17	10-Dec-2008	10-Mar-2009
18	11-Mar-2009	09-Jun-2009
19	10-Jun-2009	08-Sep-2009
20	09-Sep-2009	07-Dec-2009

maintenance period is a period of about 23 market days

2. Data

2007 June 7: Bear Stearns & Co informs investors in two of its CDO hedge funds, the High-Grade Structured Credit Strategies Enhanced Leverage Fund and the High-Grade Structured Credit Fund that it was halting redemptions.

2007 August 9: French investment bank BNP Paribas suspends three investment funds that invested in subprime mortgage debt.

2007 August 10: Central banks coordinate efforts to increase liquidity for the first time after September 11.

PERIOD 11

2. Data

Lehman Brothers – Wikipedia, the free encyclopedia

en.wikipedia.org/wiki/Lehman_Brothers

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Lehman Brothers

From Wikipedia, the free encyclopedia

Lehman Brothers Holdings Inc. (former NYSE ticker symbol **LEH**) /ˈliːmən/ was a global financial services firm. Before declaring bankruptcy in 2008, Lehman was the fourth-largest investment bank in the US (behind Goldman Sachs, Morgan Stanley, and Merrill Lynch), doing business in investment banking, equity and fixed-income sales and trading (especially U.S. Treasury securities), research, investment management, private equity, and private banking.

At 1:45AM on September 15, 2008, the firm filed for Chapter 11 bankruptcy protection following the massive exodus of most of its clients, drastic losses in its stock, and devaluation of its assets by credit rating agencies. Lehman Brothers' bankruptcy filing is the largest bankruptcy in U.S. history,[2] and is thought to have played a major role in the unfolding of the late-2000s global financial crisis. The following day, Barclays announced its agreement to purchase, subject to regulatory approval, Lehman's North American investment-banking and trading divisions along with its New York headquarters building.[3][4] On September 20, 2008, a revised version of that agreement was approved by US Bankruptcy Court Judge James M. Peck.[5] The next week, Nomura Holdings announced that it would acquire Lehman Brothers' franchise in the Asia-Pacific region, including Japan, Hong Kong and Australia,[6] as well as Lehman Brothers' investment banking and equities businesses in Europe and the Middle E became effective on October 13, 2008.[7]

Contents [hide]

1 History
- 1.1 Under the Lehman family (1850–1969)
- 1.2 An evolving partnership (1969–1984)
- 1.3 Merger with American Express (1984–1994)
- 1.4 Divestment and independence (1994–2008)
- 1.5 Response to September 11 terrorist attacks
- 1.6 June 2003 SEC litigation

2 Collapse
- 2.1 Causes

Lehman Brothers

LEHMAN BROTHERS

Industry	Investment services
Fate	Chapter 11 bankruptcy liquidation
Founded	1850, Montgomery, Alabama, US[1]
Founder(s)	Henry Lehman Emanuel Lehman
Defunct	2008
Headquarters	New York City, United States
Area served	Worldwide
Key people	Robert Lehman

PERIOD 16

3. Question

We want to investigate whether this is a ***networked market*.**

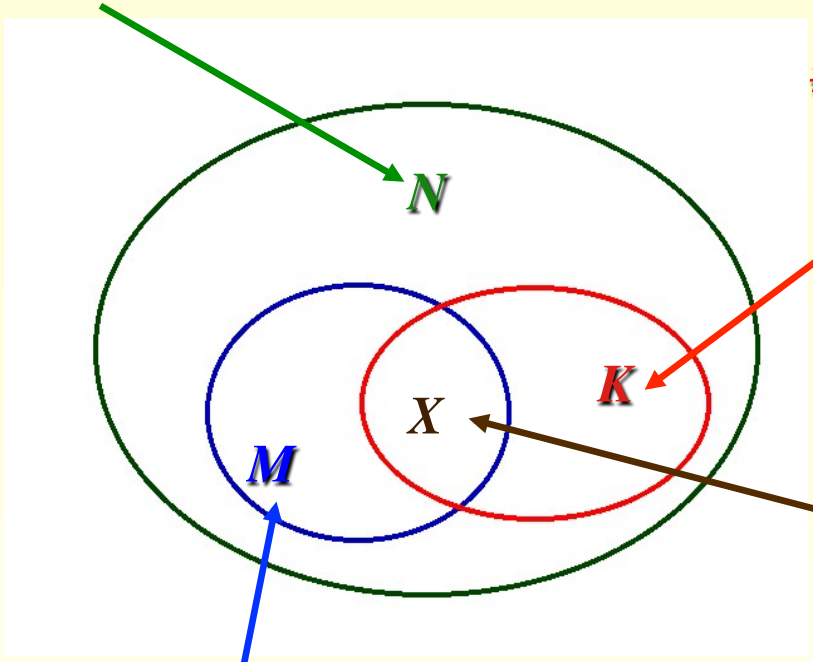
We want to investigate whether ***the system behaves differently before and after the crisis***. Are there possible ***precursors* *of the crisis?***

Specifically we are looking for ***"preferential links"*** between banks and we want to see whether they are ***different before and after the crisis***.

4. Networks: SVNs

We statistically validate each credit relationships between any two banks i (***lender***) and j (***borrower***).

Total # of transactions



# of transactions of bank i as a lender

# of transactions between the two banks

# of transactions of bank j as a borrower

The question is:
what is the probability that the number X occurs by chance ?

Given the heterogeneity in the system !!

A modification of:
Statistically validated networks in bipartite complex systems.
M. Tumminello, S. Micciché, F. Lillo, J. Piilo, R. N. Mantegna,
PLoS ONE, 6 (3), e17994, (2011).

4. Networks: SVNs

In other words: ***if I randomly pick K transactions in the set of N available transactions and count how many of them are intersecting with the M transactions of the other banks, what is the probability of having exactly X transactions in the intersection ?***

Hypergeometric distribution

$$P(X \mid N, M, K) = \frac{\binom{M}{X}\binom{N-M}{K-X}}{\binom{N}{K}}$$

p-value

OVER-expression

$$p = 1 - \sum_{i=0}^{X-1} \frac{\binom{M}{i}\binom{N-M}{K-i}}{\binom{N}{i}}$$

UNDER-expression

$$p = \sum_{i=0}^{X} \frac{\binom{M}{i}\binom{N-M}{K-i}}{\binom{N}{i}}$$

threshold t: 5%, 1%, ...: $p_i < t$

Multiple test comparison

in order to control false positives expected in multiple comparisons

Bonferroni

The threshold t must be divided by the number R of populated terms: $p_i < t/R$

False Discovery Rate

$P_1 < t/R$
$P_2 < 2\ t/R$
$P_3 < 3\ t/R$
...

4. Networks: re-shufflings

This is an analytical procedure that corresponds to an appropriate reshuffling of the empirical networks that preserves the degree.

An edge swap selects two ordered pairs (x, y),(u, v) and swaps the endpoints (target nodes) while keeping the sources fixed

Not all edges swaps are accepted during a rewiring process as some swaps can produce graphs that are not simple, i.e. contain self loops.

This marks a possible difference with the hypergeometric approach, as the hypergeometric distribution does not forbid self links, that is trades can occur between a bank and itself. However, in our case, data are rather sparse, and therefore self links occur rarely.

In order to take into account weights, we consider a link with weight w as w links each of weight 1. We perform the re-shuffling as above and then we collapse back the links between same nodes.

Here Strenght is preserved. Degree is NOT preserved.

4. Networks: re-shufflings

$$p = 1 - P_{lb}(0)$$

$$P_{lb}(0) = H(0; N_T, n_l, n_b)$$

probability that a link between lender l and borrower b occurs in one re-shuffling simulation.
(*no matter how many transactions*)

$$P(n) = \binom{N_S}{n} p^n (1-p)^{N_S - n}$$

probability that a link between lender l and borrower b occurs in n out of N_s re-shuffling simulations.

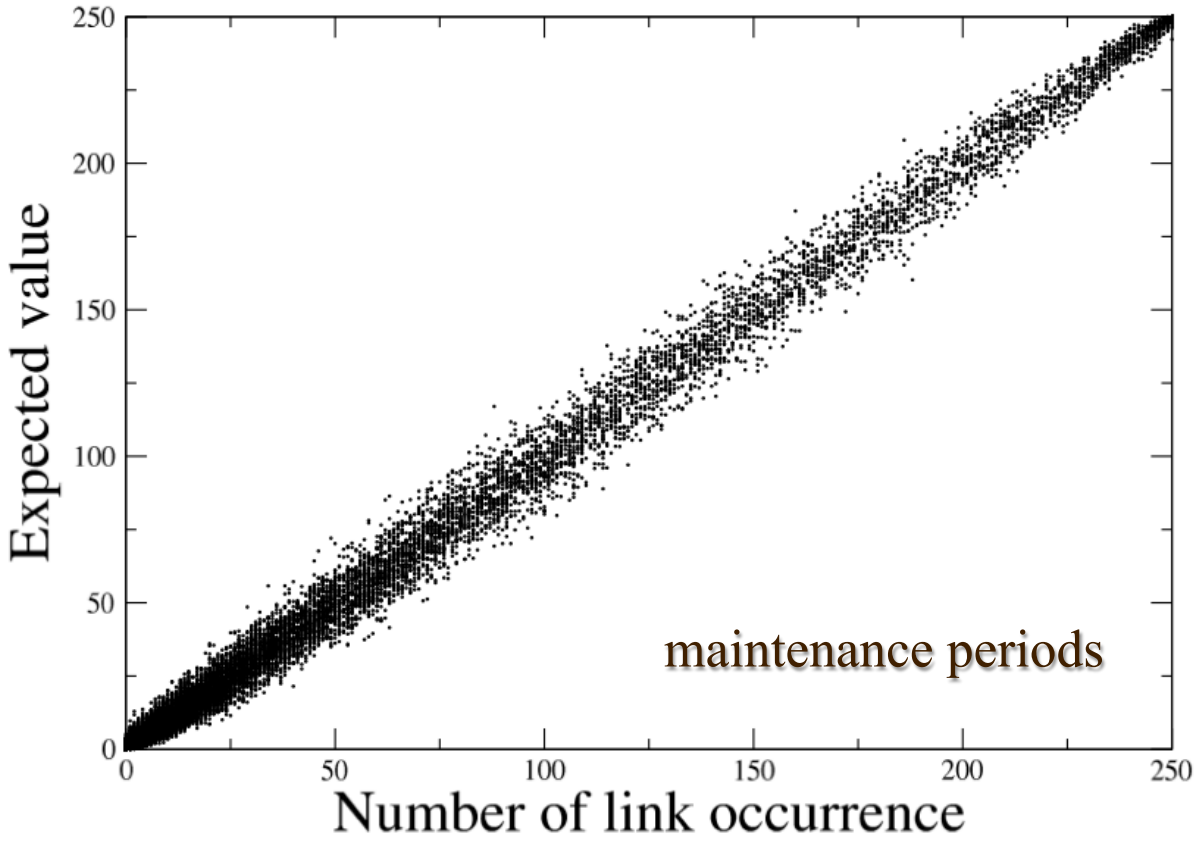
$$E(n_{lb}) = N_S \left(1 - \frac{\binom{N_T - n_l}{n_b}}{\binom{N_T}{n_b}} \right)$$

Expected number of times in which a link occurs in n out of N_s re-shuffling simulations.

4. Networks: re-shufflings

N_S=250

$$E(n_{lb})$$



This indicates that the links predicted by the model and those obtained in the re-shufflings are in agreement.

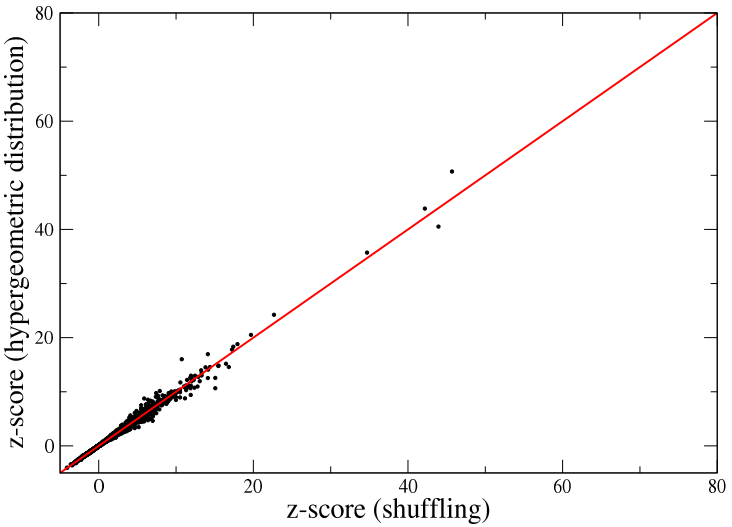
re-shufflings

4. Networks: Z-scores

There is even more!!

$$Z_{lb} = \frac{n_{lb} - E(n_{lb})}{sd(n_{lb})} \qquad Z_{lb} = \sqrt{T}\,\rho_{lb}$$

This indicates that the weights predicted by the model and those obtained in the re-shufflings are in agreement.

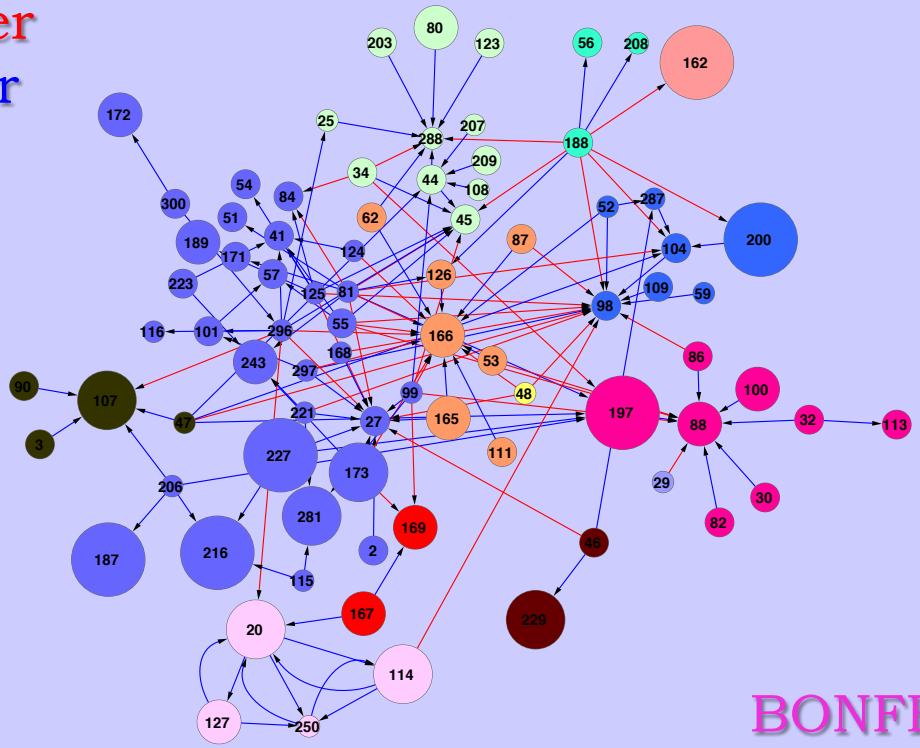


$$\rho_{lb} = \frac{\langle LB\rangle - \langle L\rangle\langle B\rangle}{\sqrt{\left(L-\langle L\rangle\right)^2}\sqrt{\left(B-\langle B\rangle\right)^2}} = \frac{\frac{n_{lb}}{N_T} - \frac{n_l n_b}{N_T^2}}{\sqrt{\frac{n_l}{N_T}\left(1-\frac{n_l}{N_T}\right)}\sqrt{\frac{n_b}{N_T}\left(1-\frac{n_b}{N_T}\right)}}$$

5. Preferential links

Is there any change in preferential trading during (or leading up to) the financial crisis of 2007/2008?

RED under
BLUE over



BONFERRONI

Period 1
24-Dec-2004
23-Mar-2005

10 communities
31, 11, 8, 7, …

8 communities
size>2

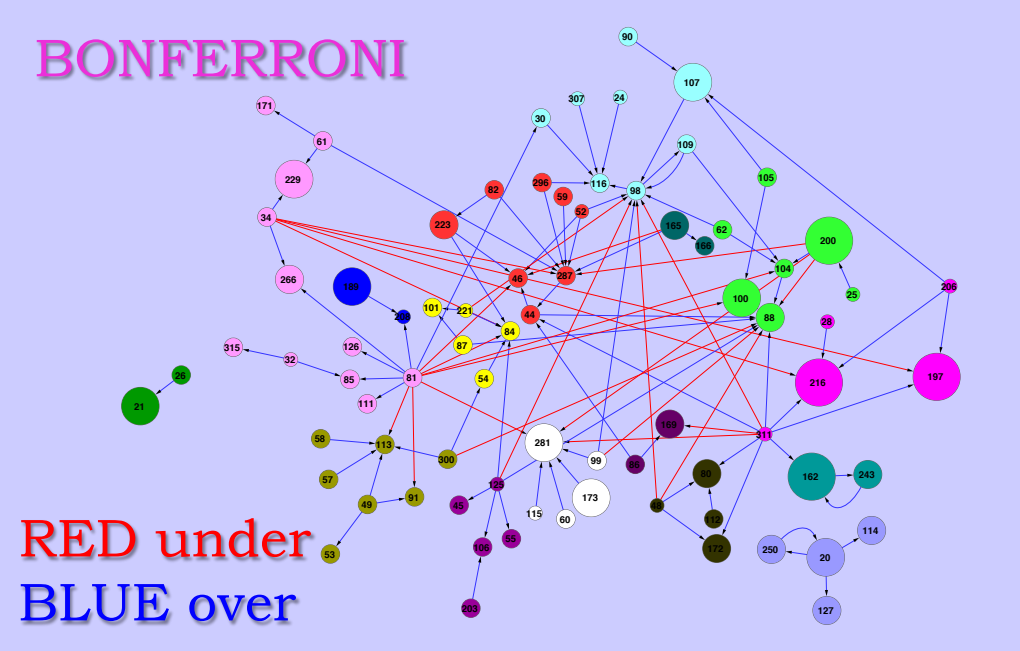
2260, 183, 101

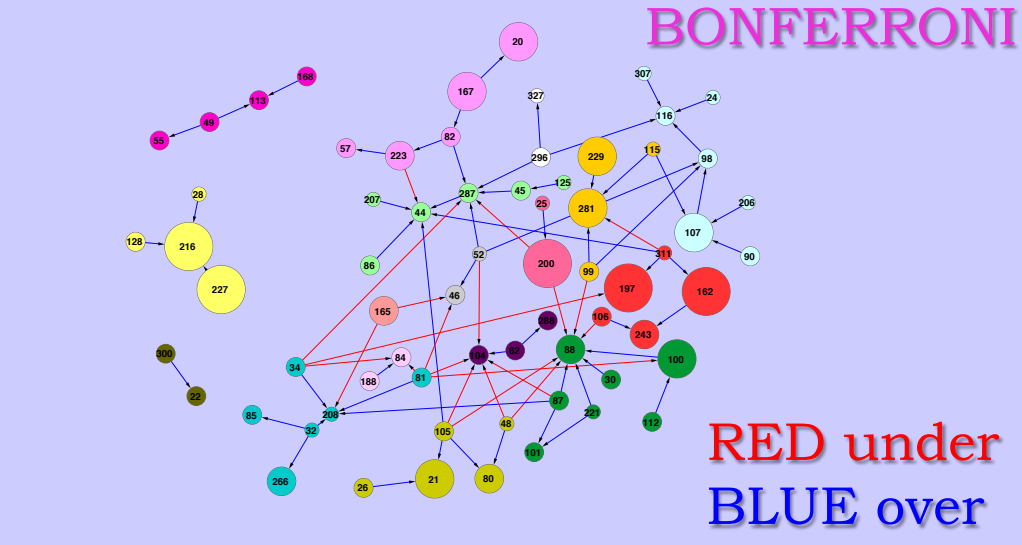
major
big
medium
small
minor

The size of the nodes is proportional to the size of each bank

Nodes colors correspond to communities/clusters of banks

5. Preferential links





Period 9
13-Dec-2006
13-Mar-2007

16 communities
11, 8, 8, 7, …

11 communities
size>2

2207, 170, 92

Period 10
14-Mar-2007
12-Jun-2007

16 communities
7, 7, 6, 6, …

11 communities
size>2

2134, 143, 61

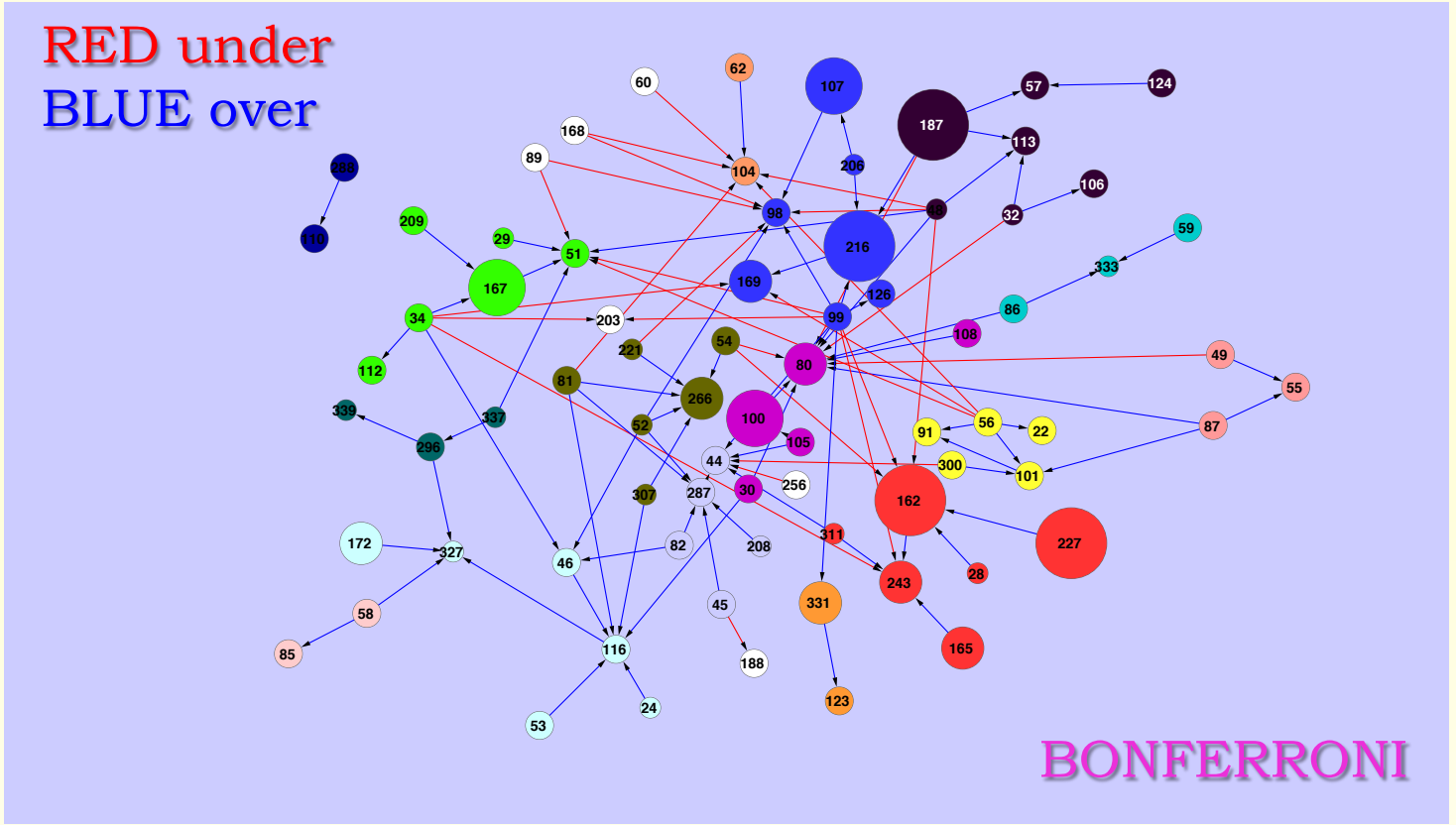
Period 11
13-Jun-2007
11-Sep-2007

15 communities
12, 8, 7, 6, …

10 communities
size>2

2354, 160, 70

5. Preferential links



Period 16
10-Sep-2008
09-Dec-2008

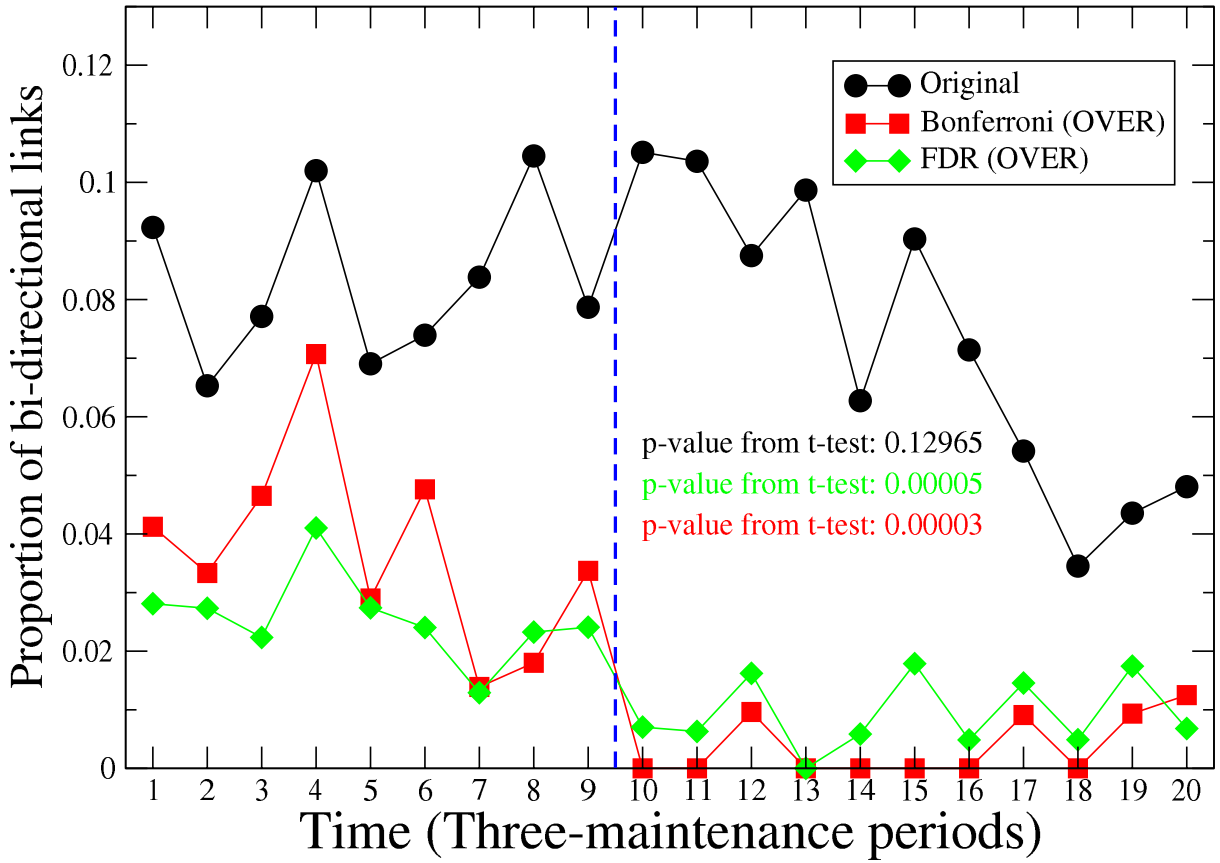
11 communities
35, 10, 9, 7,

7 communities
size > 2

1770, 207, 110

Nodes: 112 ->93, 97 -> 83, 79 -> 67

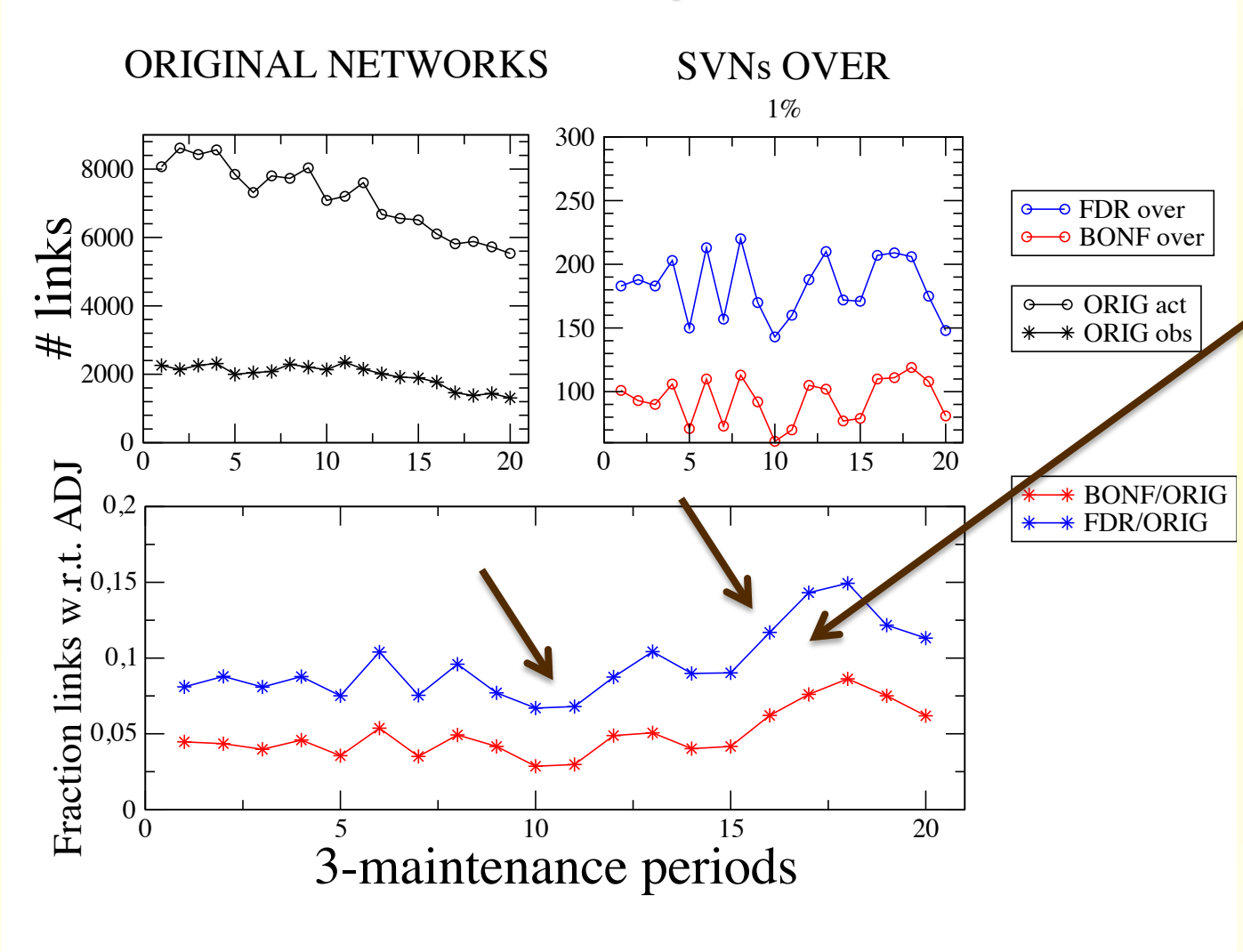
5. Preferential links



Roles become more polarized in the market after the 2007 credit crisis.

Reciprocity is going down after period 9

5. Preferential links

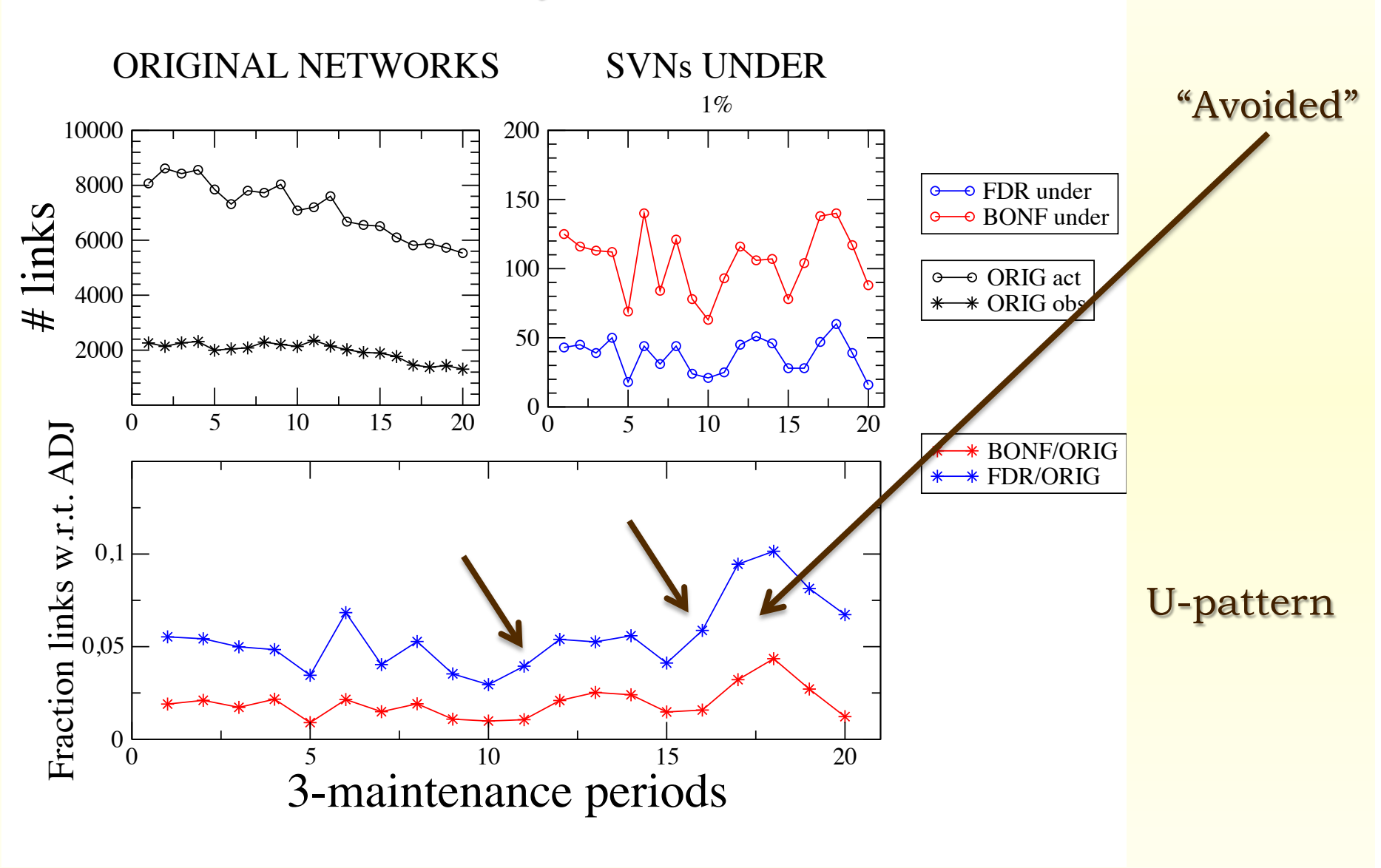


one-directional trustworthy

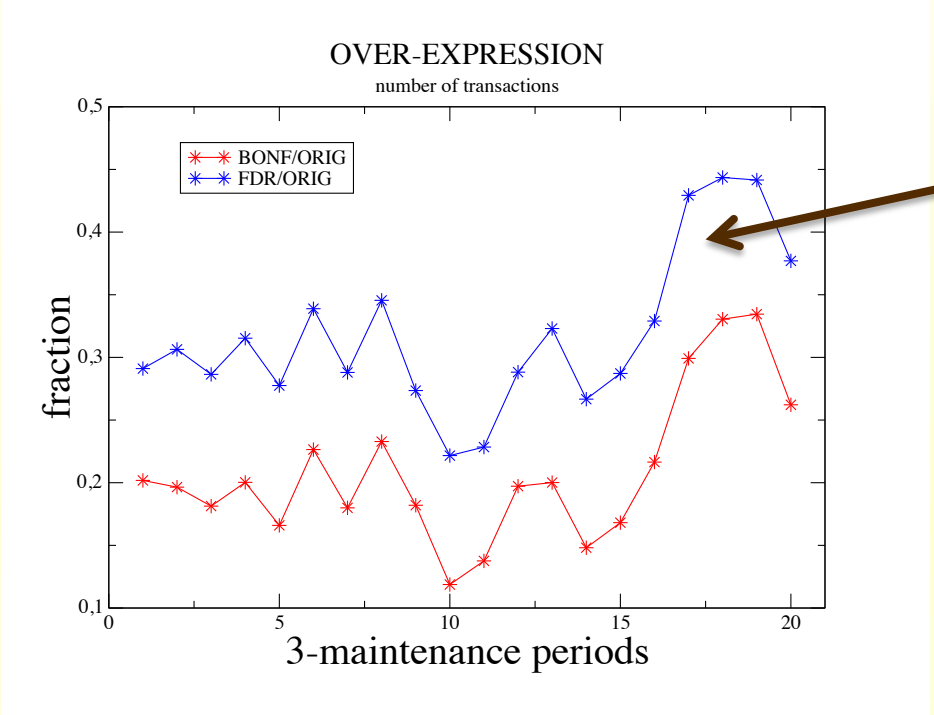
U-pattern

There is an ***increase*** of the fraction of links that are ***NOT explained*** by a null hypothesis of randomness.

5. Preferential links

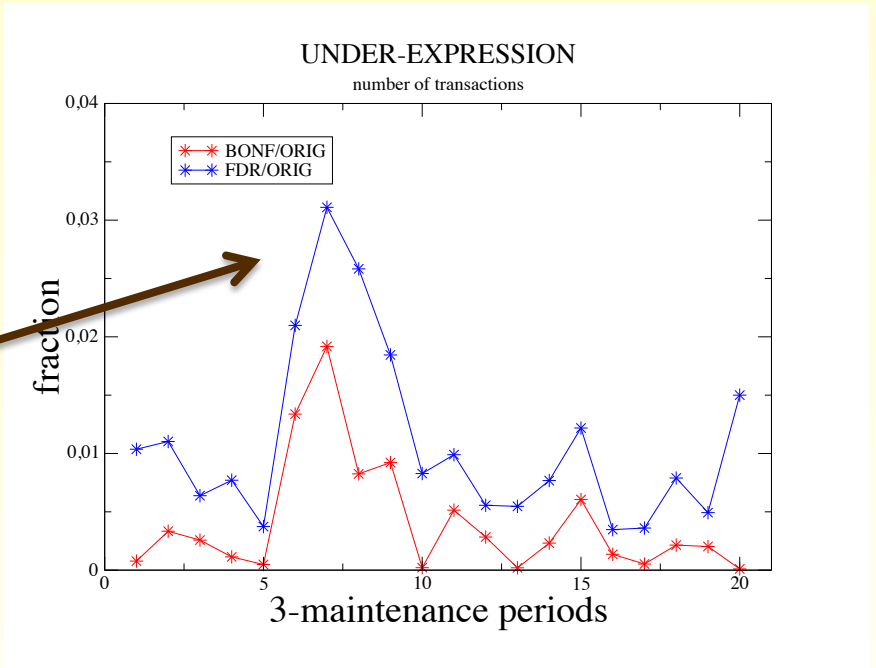


5. Preferential links



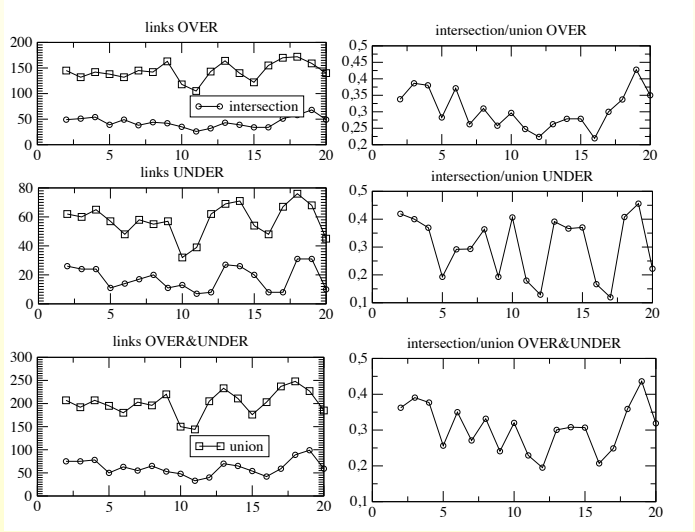
trustworthy

There is an ***increase*** of the fraction of transactions that are ***NOT explained*** by a null hypothesis of randomness?

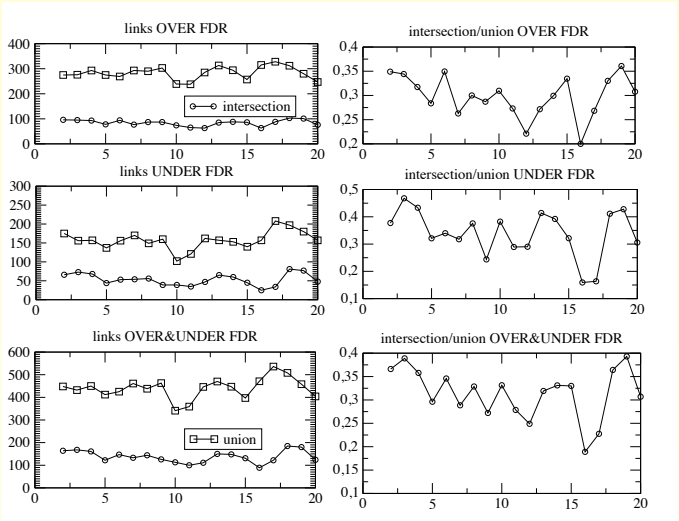


We do not have an explanation for this

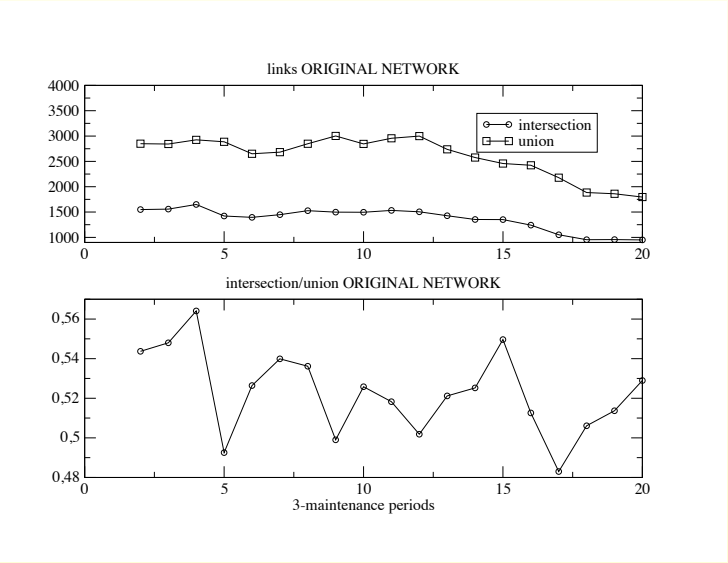
6. Conserved Links



BONF network



FDR network

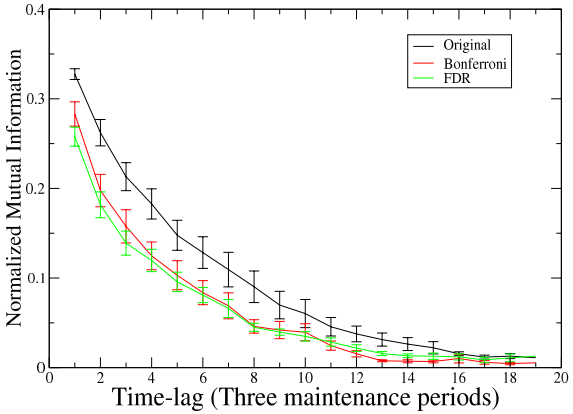


Original network

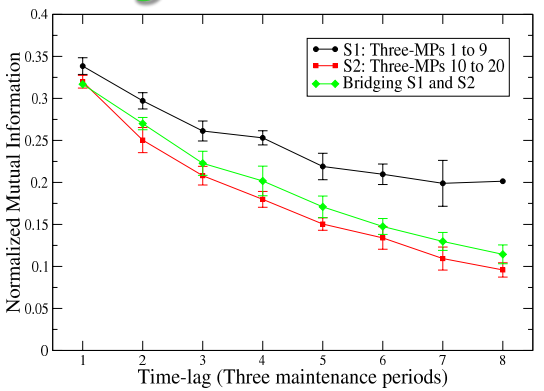
An apparent paradox: links in the original network are more conserved than in the SVNs.

LINKS stability is a different thing from PREFERENTIAL-LINKS stability

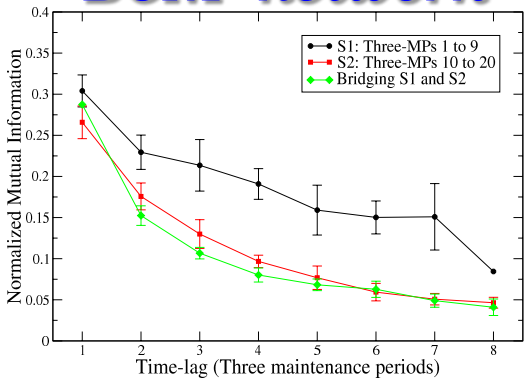
6. Conserved Links



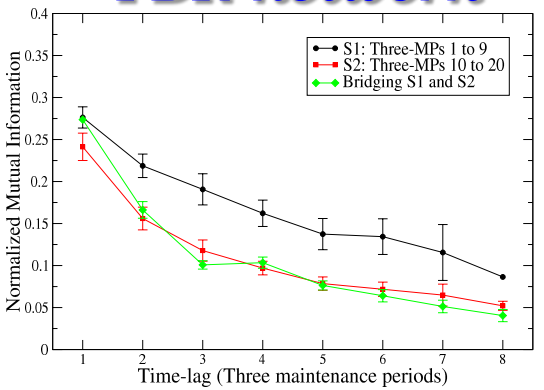
Original network



BONF network

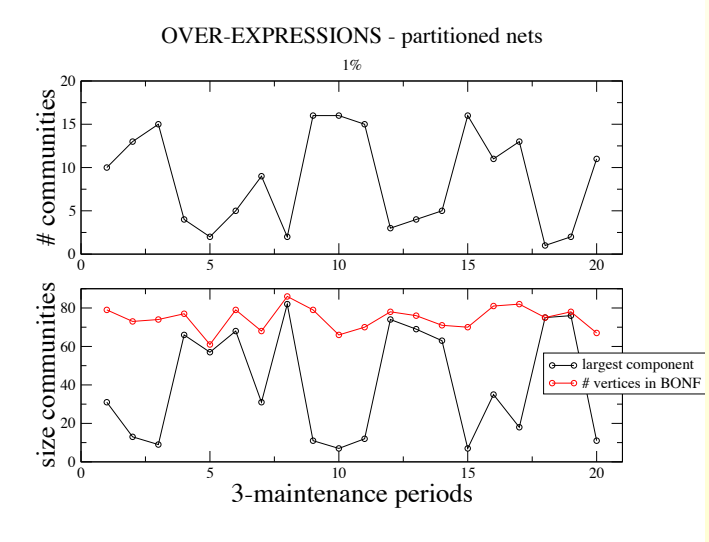


FDR network



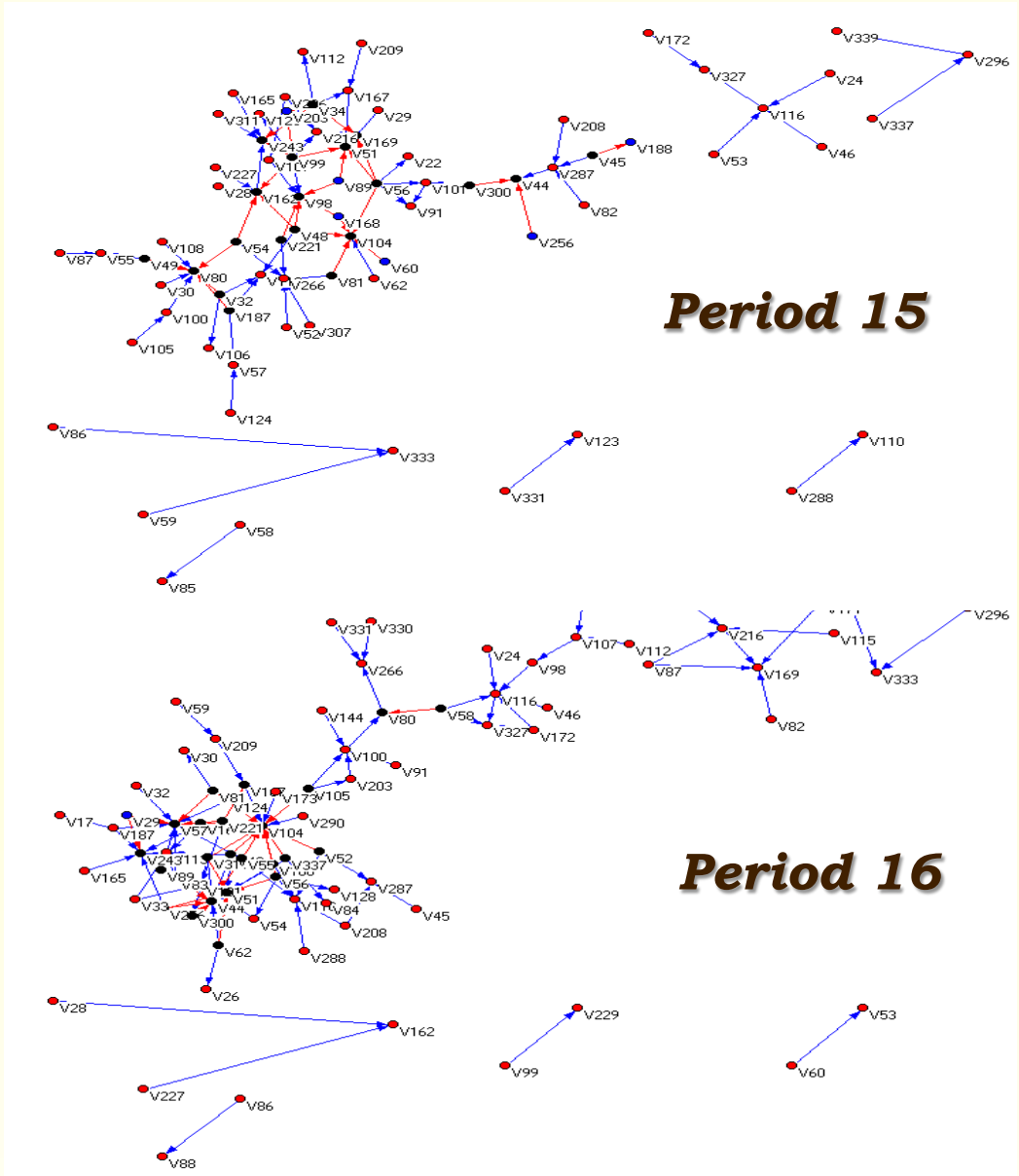
A more sophisticated investigation by using the MUTUAL INFORMATION confirms the previous findings

8. Network Partitions - Infomap

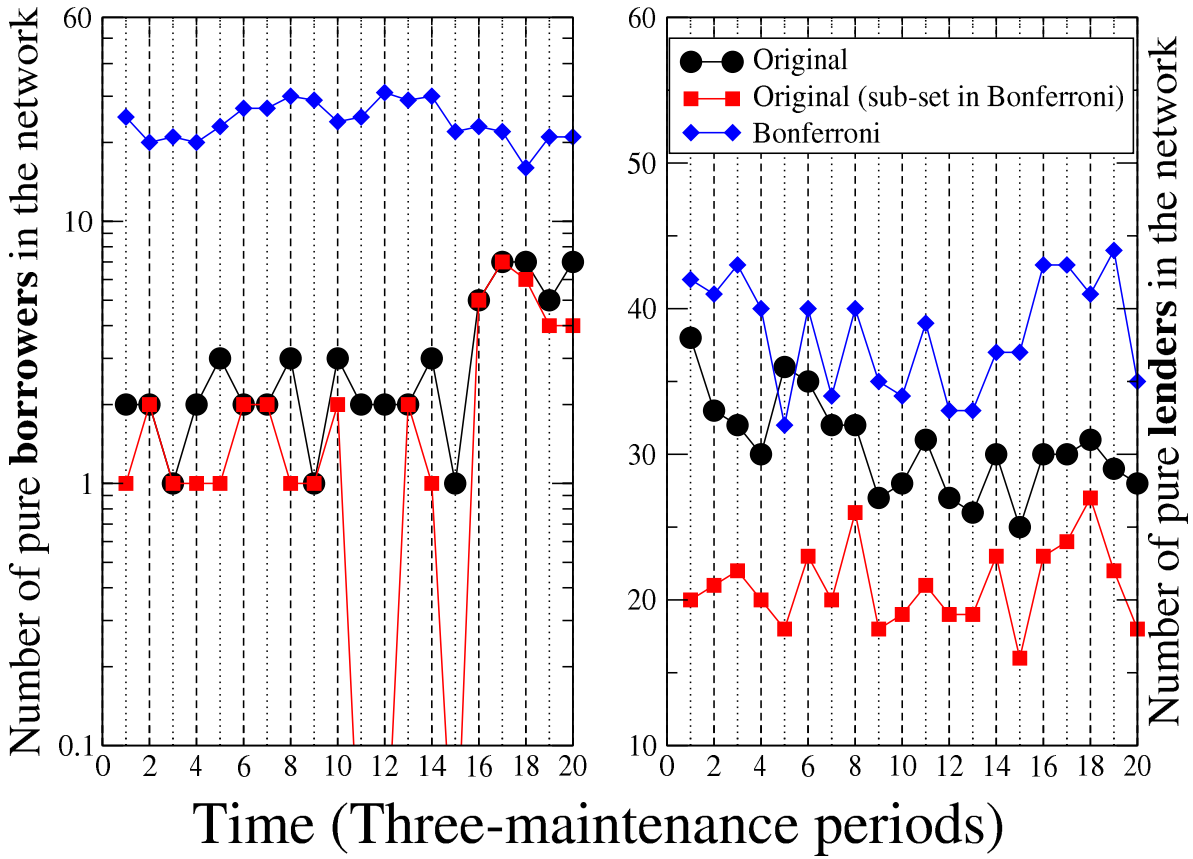


Under-expressed links connect communities

High-degree nodes have both OVER- (blue) and UNDER-expressed (red) links.

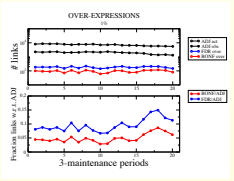


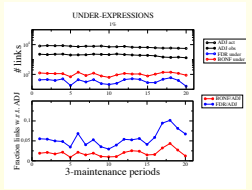
9. Specialization of roles



The BONF selects nodes that are specialized.

10. Conclusions

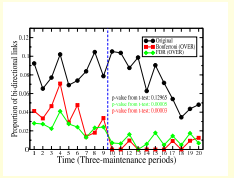




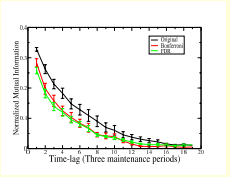
We have preferential links

We observe polarization of role

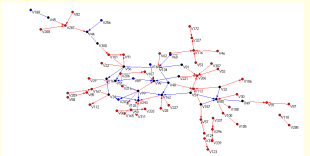
Less bi-directional links



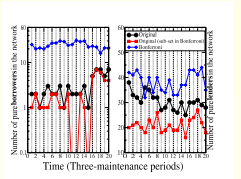
Preferential links are less conserved than original ones



Under-expressed links connect communities



The BONF selects nodes that are more specialized.



The End

thanks !!!

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We consider two networks with the same vertices but, in general, with different sets of links. Let N be the number of vertices in both networks. Let us indicate the number of links in the first network with n_1 and the number of links in the second network with n_2. We associate a binary random variable x with all pairs of vertices in the first network and a binary random variable y with all pairs of vertices in the second network. The variable x takes the value 1 if two vertices are linked in the first network, and it is 0 otherwise. Similarly, y describes links between vertices of the second network. The probability $p_1(1)$ [$p_2(1)$] is the probability that a randomly selected pair of vertices is linked in the first (second) network. This definition implies that

$$p_1(1) = 2n_1/(N2 - N),\ p_1(0) = 1 - p_1(1),\ p_2(1) = 2n_2/(N2 - N),\ p_2(0) = 1 - p_2(1).$$

The joined probability p(x,y) of the two variables x and y is given by

$$p(1,1) = 2n_{1,2}/(N2 - N),$$
$$p(1,0) = 2(n_1 - n_{1,2})/(N2 - N),\ p(0,1) = 2(n_2 - n_{1,2})/(N2 - N),\ p(0,0) = 1 - 2(n_1 + n_2 - n_{1,2})/(N2 - N),$$

where $n_{1,2}$ is the number of the same links that are present in both networks. The mutual information of the random variables x and y is given by

$$I(x,y) = \sum_{x=0,1}\sum_{y=0,1} p(x,y)\log\frac{p(x,y)}{p1(x)p2(y)}$$

The mutual information I(x,y) can be suitably normalized by dividing it by the geometric mean of the entropies H(x) and H(y) [22,23]:

$$i(x,y) = I(x,y)/\sqrt{H(x)H(y)},$$

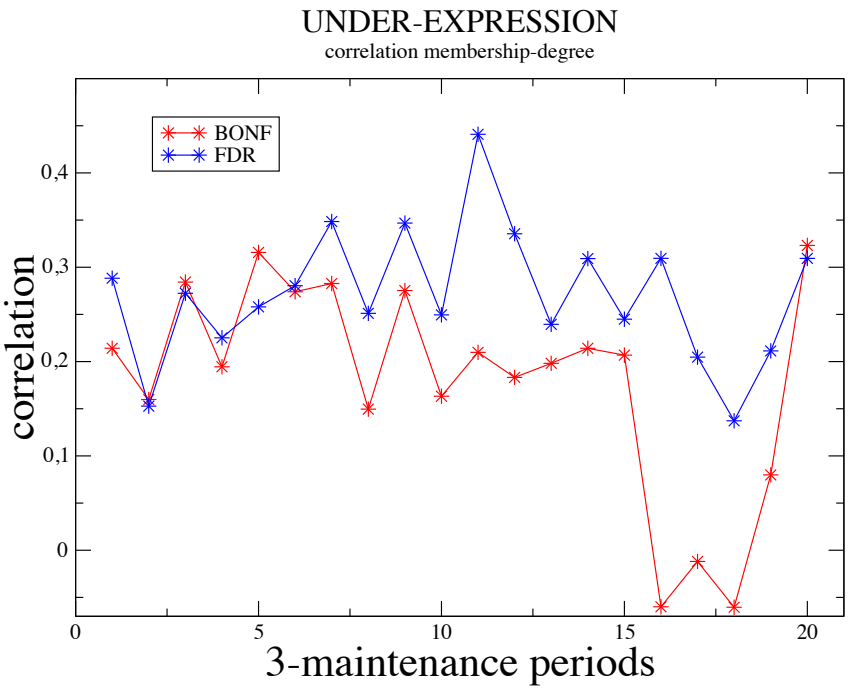
where H (x) is the entropy of variable x and H (y) is the entropy of variable y :

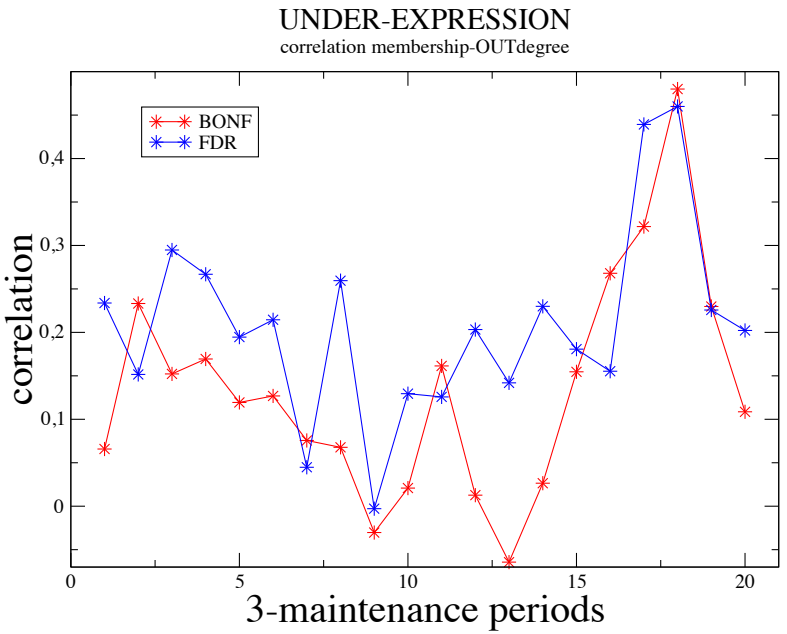
$$H(x) = -p1(0)\log p1(0) - p1(1)\log p1(1),$$

$$H(y) = -p2(0)\log p2(0) - p2(1)\log p2(1).$$

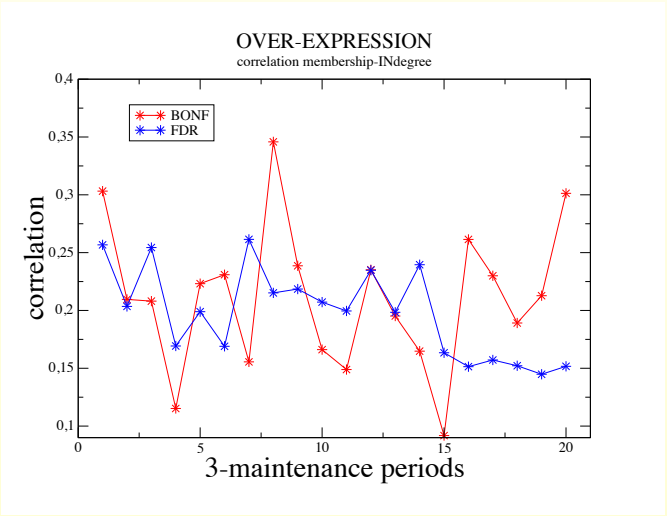
It should be noted that the normalized mutual information i(x,y) between identical networks is equal to 1.

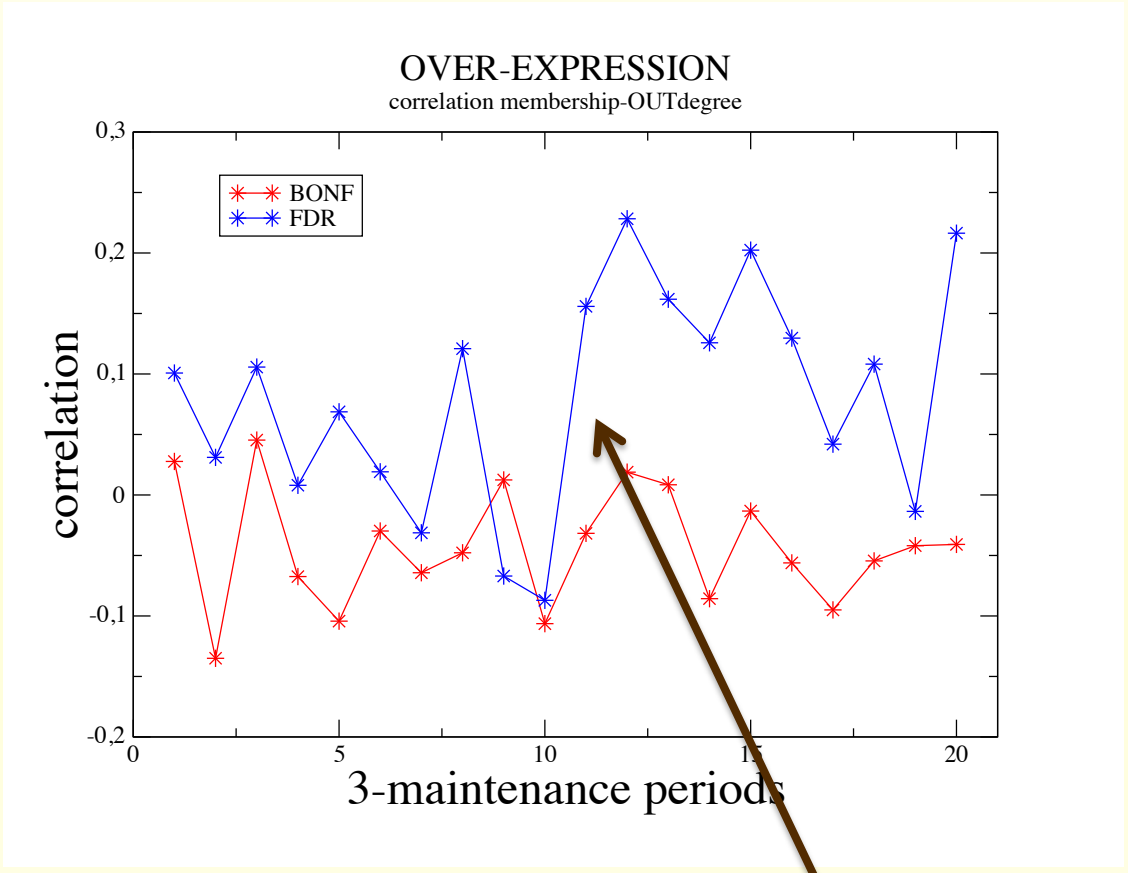
7. Determinants of Membership





7. Determinants of Membership (preliminary)





MEMBERSHIP
0 if bank is absent
1 if bank is present
in a certain period

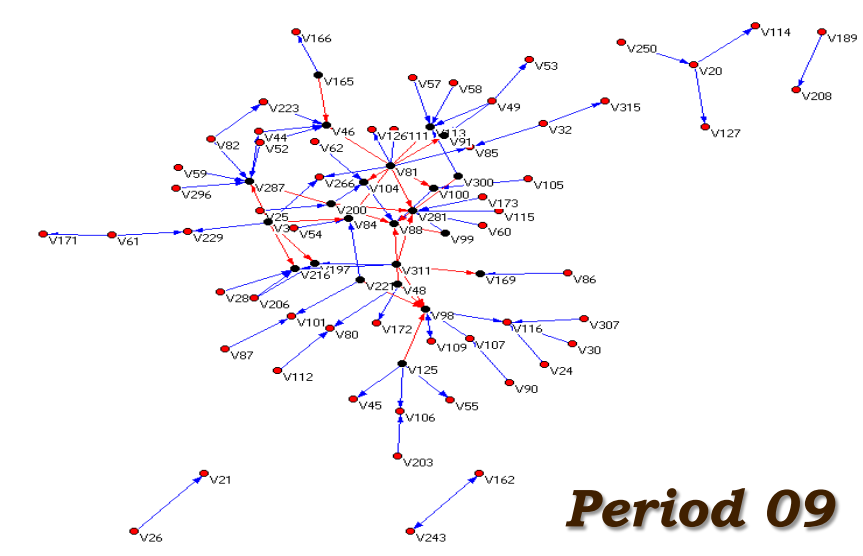
IN degree: incoming transactions - borrower

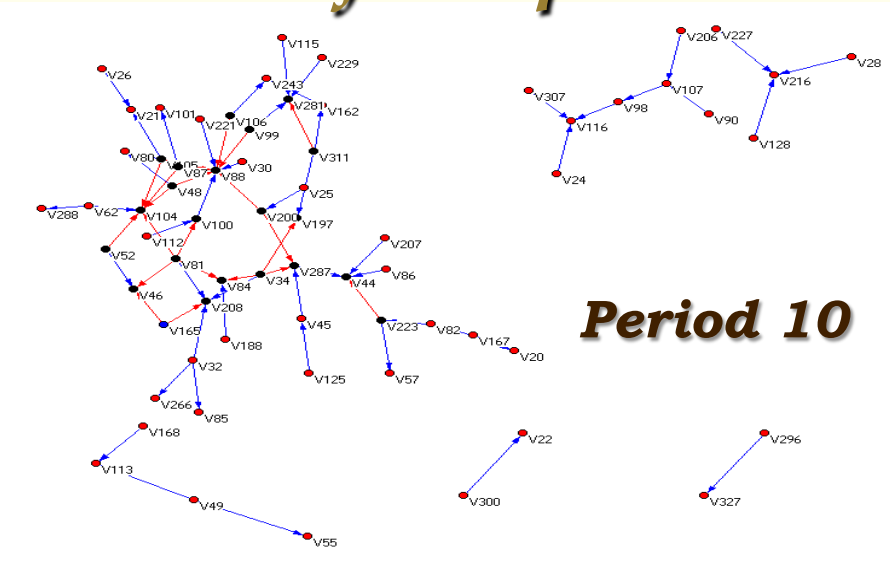
OUT degree: outgoing transactions - lender

CORRELATION measures at which extent the membership to the net is affected by the degree.

large jump period 10 to 11 (liquidity issues).

8. Network Partitions - Infomap





year_i	year_j	clus_i	clus_j	intersection_	population_i	population_j	union_ij	p-value	thresh
1	2	2	7	4	4	4	89	4.10E-07	3.003E-05
2	3	3	7	5	8	6	86	9.35E-06	3.003E-05
2	3	6	6	3	3	3	86	9.77E-06	3.003E-05
2	3	7	1	4	4	5	86	2.35E-06	3.003E-05
3	4	1	2	4	5	4	88	2.14E-06	3.003E-05
3	4	6	3	3	3	3	88	9.11E-06	3.003E-05
4	5	2	2	4	4	4	85	4.94E-07	3.003E-05
5	6	2	2	4	4	4	83	5.44E-07	3.003E-05
6	7	2	2	4	4	6	86	7.06E-06	3.003E-05
7	8	2	2	4	6	4	89	6.14E-06	3.003E-05
8	9	2	9	4	4	4	91	3.74E-07	3.003E-05
9	10	1	1	6	8	7	88	3.54E-07	3.003E-05

Statistical validation of the Communities STABILITY