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Network Analysis on Post Trade data: variation in topology and stability of Central nodes and Scale-free Behaviour over time

Monte Titoli Data Science

Milan, 03 September 2021

AGENDA

The aim of the study is the construction of Social Networks from Post trade Settlement Instructions from TARGET2-Securities (T2S).

The study can be divided in two main Network constructions:

- **Monthly** cumulative and noncumulative Networks:
  - The identication over time of a Scale-free behaviour
  - Definition of a ranking for the most central
  - Networks resiliency analysis is performed using random and targeted attacks.

- **Daily** Networks:
  - Two Case-Studies of disruptive events:
    - COVID19
    - BTP Italia and BTP Futura emissions

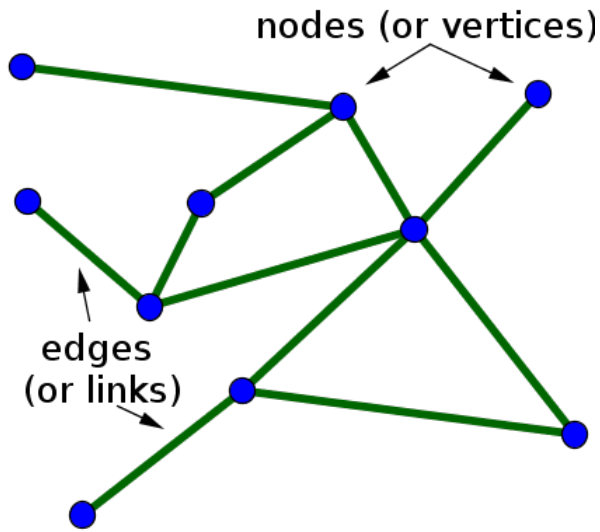
INTRODUCTION TO NETWORK ANALYSIS

Network Analysis is a set of integrated techniques to depict relations among actors in order to analyze the social structures.

Network analysis is based on Graph theory.

A Graph is composed by:

- **Nodes: representing agents**
- **Links: representing the relationship between two agents**



Potentiality:

1. **NA can be used in various fields: Sociology, Economics, Geography, History, Biology and Social Networks**
2. **NA is able to simplify complex systems**

DATA PRE-PROCESSING

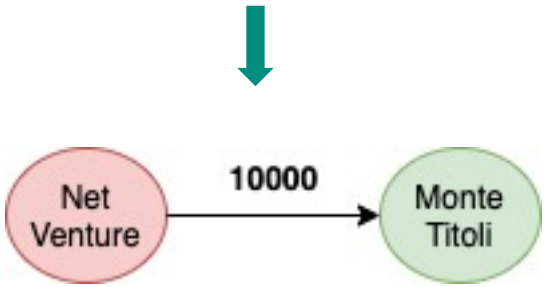
Deli	Rece	Sett Status	financial instr	ETF indicator	Amt pend	Amount
Net Venture	Monte Titoli	S	Corp. Bonds	0	10000	10000

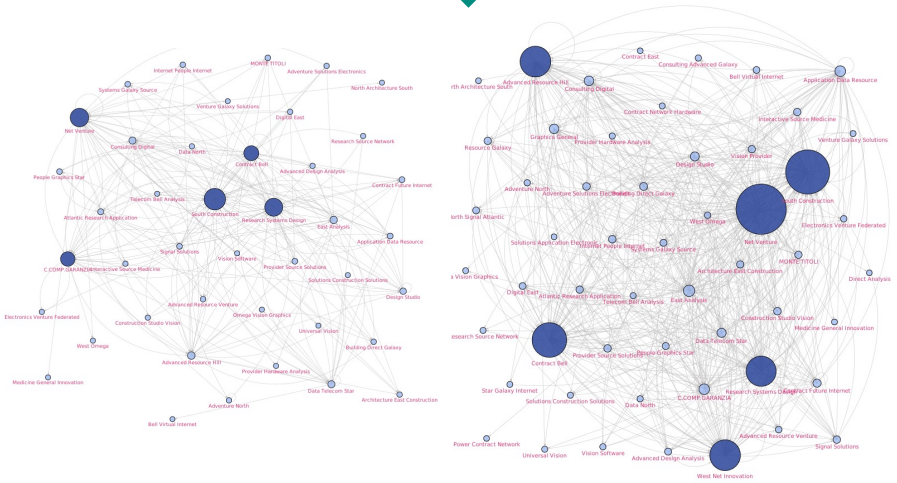
1. **Date range from May 2018 to end of July 2021**

2. **Datasets aggregated based on:**
   - Company couple (deli – rece)
   - Financial Instrument type: 'Corp. Bonds and similar', 'Government Bonds', 'Funds', 'Shares and similar', 'ETF', 'Other'.
   - Settlement Status: Settled (S) or Failed (N)
   - Free of payment instructions have been excluded

3. **Graph representation:**
   - Node: Company
   - Edge:
     - Directed: from Deli to Rece
     - Weighted: aggregated Amount Countervalue

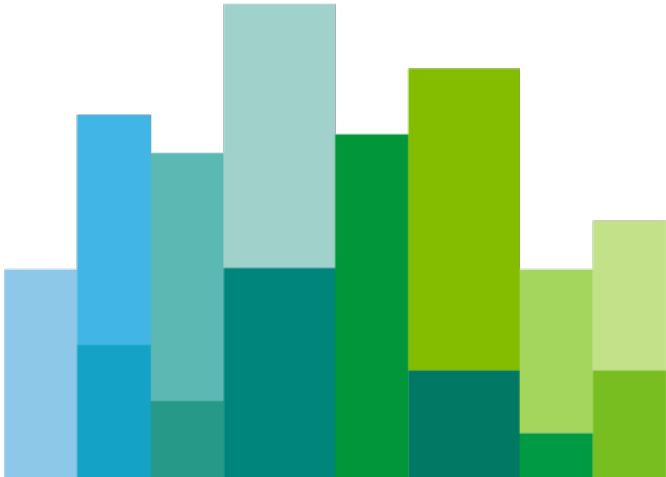
4. From Financial Instrument and Settlement Status groups **multiple graphs** are obtained





Monthly Analysis

- Definition of a ranking for the most central nodes
- The identication over time of a Scale-free behaviour
- Networks resiliency analysis is performed using random and targeted attacks



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Monthly Cumulative vs Monthly non-cumulative Networks

Monthly Cumulative

- Months are not independent; each network are based on the past.
- It preserve the temporal behavior of the data
- Simulate the adding of new nodes

Monthly non-cumulative

- Months are independent; each network in each month is different
- Node distribution is not growing and each months
- Node distribution is separated over time

Cumulative ETF_N over time growing

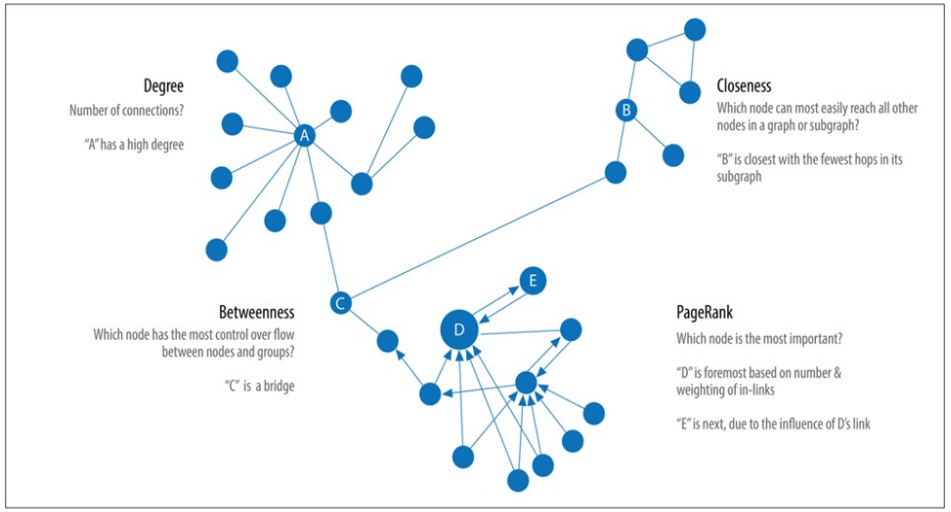
- Representation of cumulative ETF_N networks over time
- Each month the number of nodes and edges are increasing
- Central Nodes are getting bigger

Centrality

- Centrality is a measure that helps identifying the **most influential** nodes in a social network.

- Different **techniques** have been applied for the computation of the most Central nodes: Degree Centrality, Betweenness Centrality, Closeness Centrality, Eigenvector Centrality, PageRank Centrality.
  - For simplicity purpose, only PageRank and Betweenness centrality will be presented

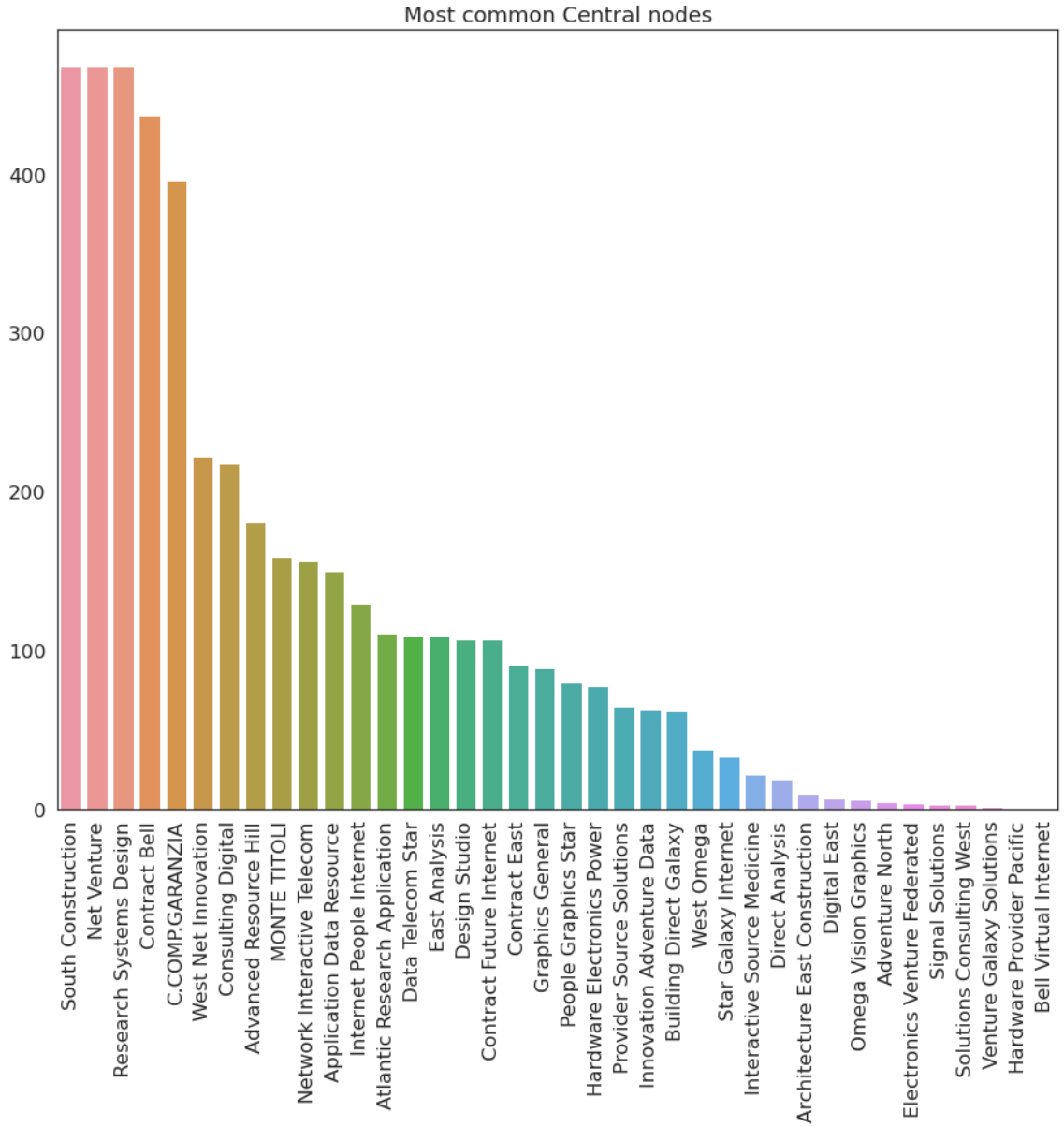
- These techniques help in obtaining a **rank of the nodes**.



Most common Central Nodes - cumulative

- South Construction, Net Venture, Research System Design are nodes that appear most **frequently** in the top-10 ranking of most Central nodes with a recurrency number close to 400

- Contract Bel, CC&G, West Net Innovation are nodes that appear most **frequently** in the top-10 ranking of most Central nodes with a recurrency number close to 200



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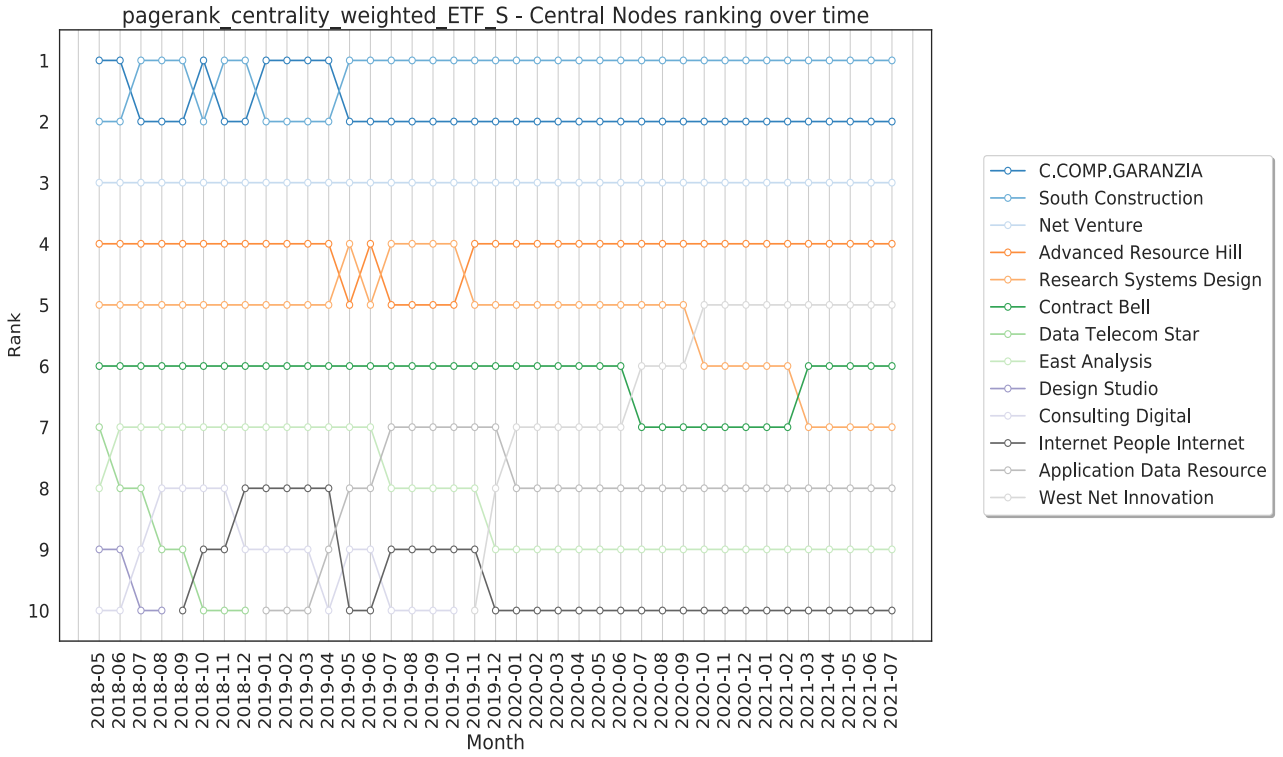
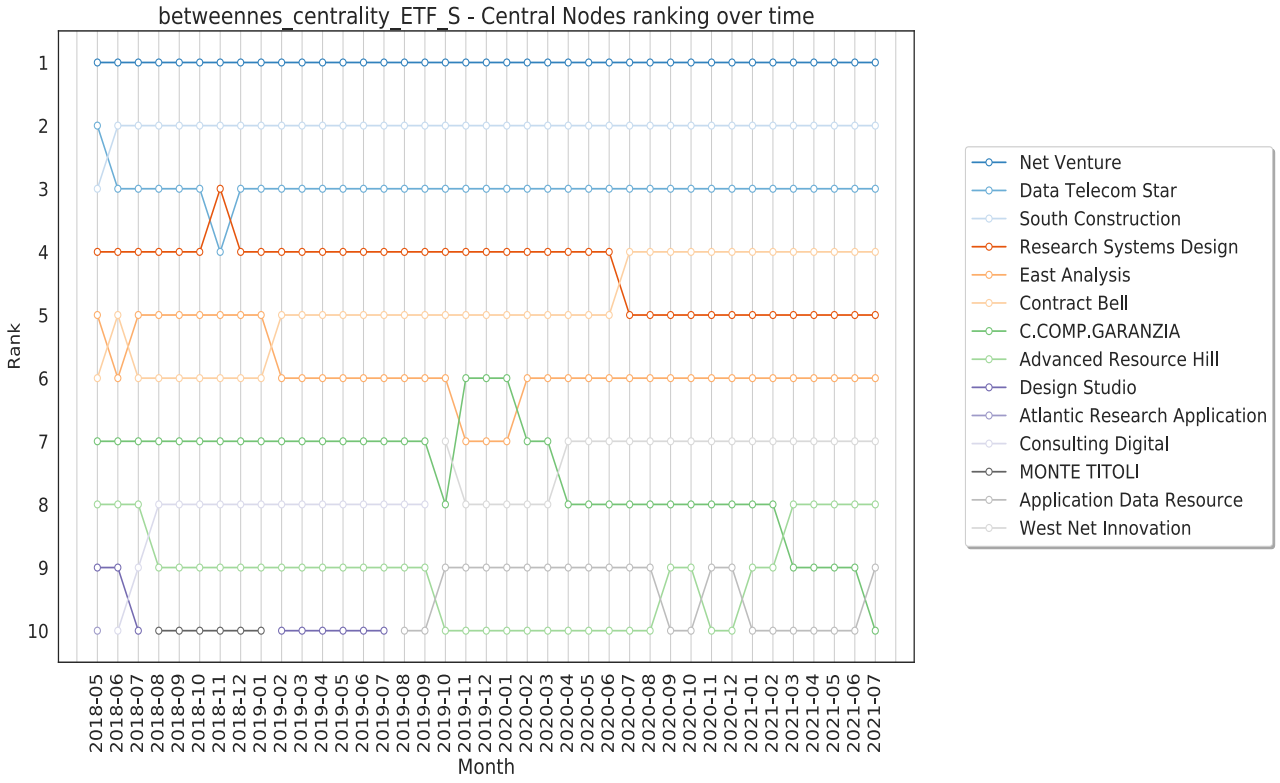
Central node Ranking – ETF_S cumulative





- Top3: South Construction, COMP.GARANZIA, Net Venture, are in the same rank for all the period
- Couple (South Construction, COMP.GARANZIA) and (Advanced Resource Hill, Research Systems Design) continuously switching position
- Last position are more variables

- Top3 are in the same rank for all the period.
- Last position are more variables

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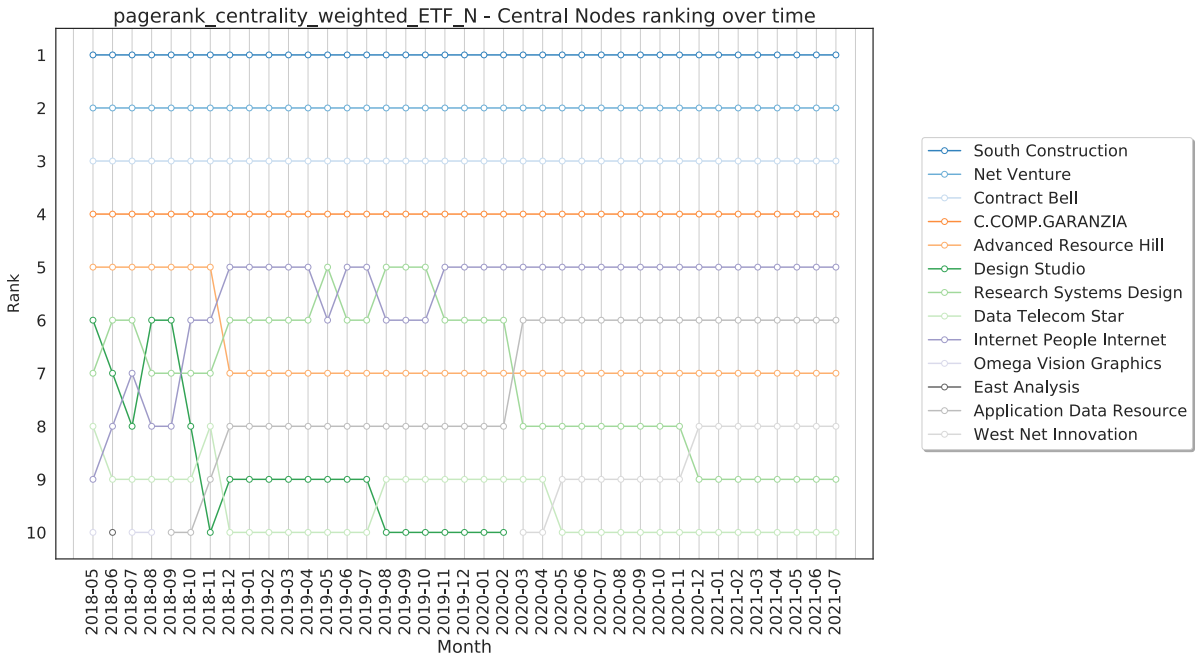
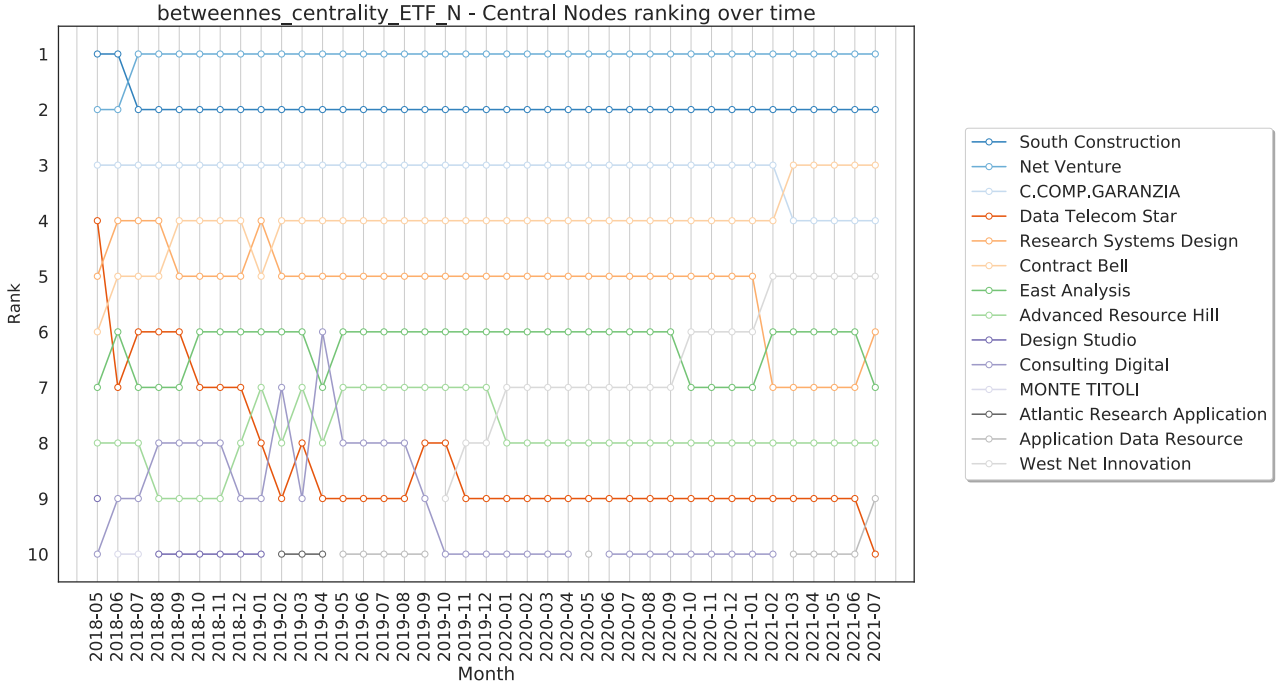
Central node Ranking – ETF_N cumulative



- Top4: South Construction, Net Venture, Contract Bell, C.COMP.GARANZIA and are in the same rank for all the period
- Last position are more variables



- Top3: Net Venture, South Construction, Contract Bell are in the same rank for all the period.
- Last position are more variables

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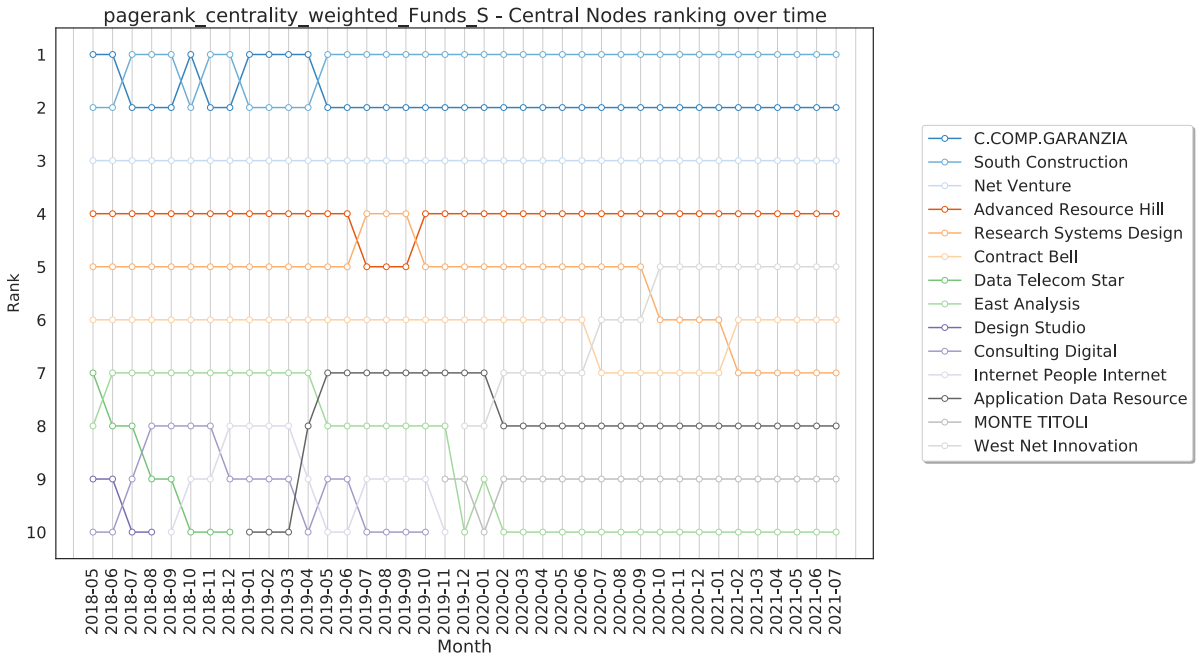
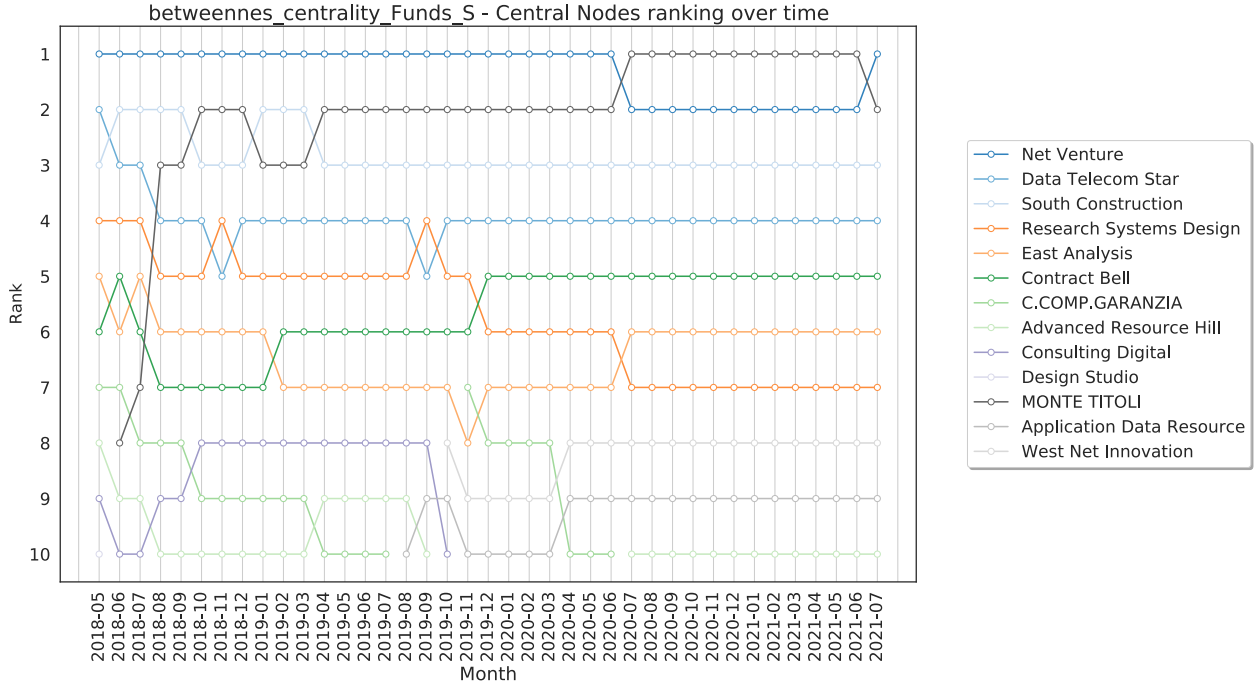
Central node Ranking – Funds_S cumulative





- Top3: CC&G, South Construction, Net Venture are in the same rank for all the period
- Couple (CC&G, South Construction) and a bit (Advanced Resource Hill, Research System Design) continuously switching position
- Last position are more variables

- Top3: Net Venture, Monte Titoli and South Construction
- MT stated as 8th to come 2nd at the end

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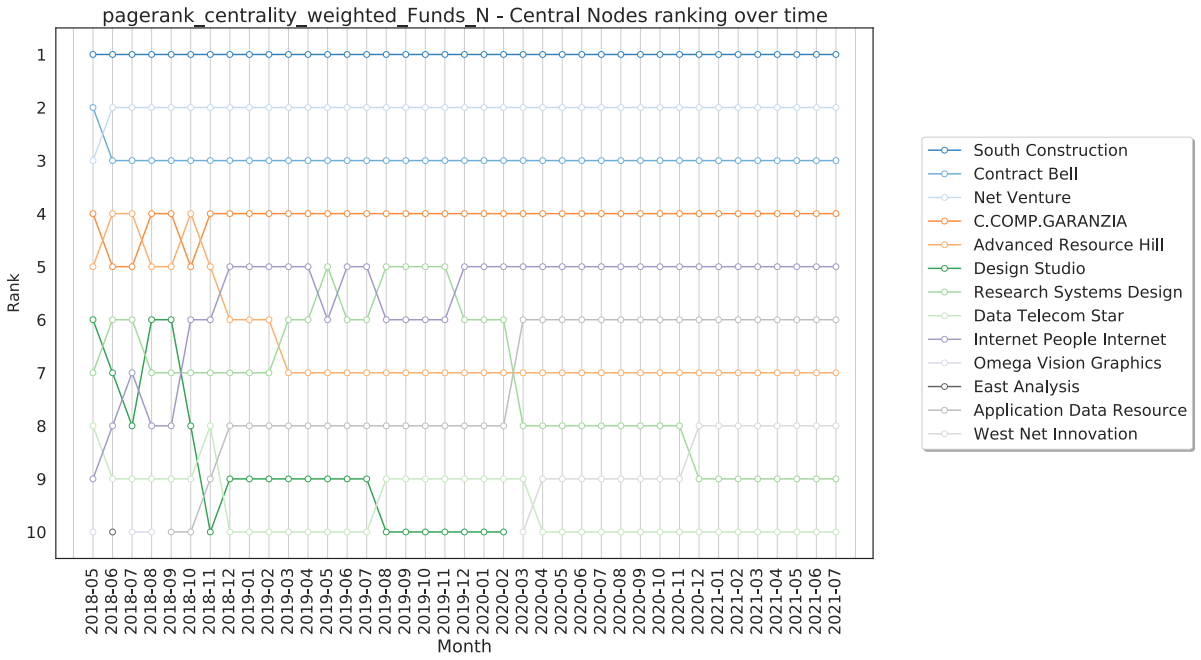
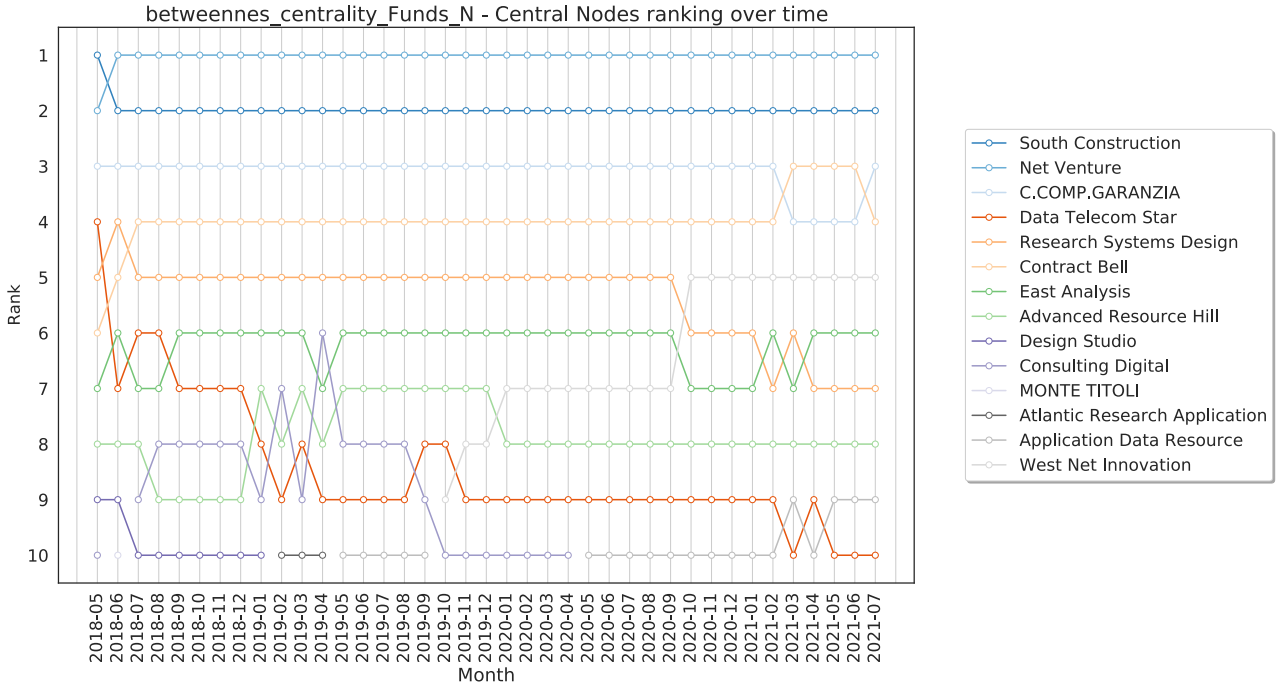
Central node Ranking – Funds_N cumulative





- Top3: South Construction, Net Venture, Contract Bell are in the same rank for all the period
- Couple (CC&G, Advance Resource Hill) first months are continuously switching position

- Top3: Net Venture, Construction, COMP.GARANZIA
- As time passing, networks are getting bigger and seem to present more a scale-free behavior.

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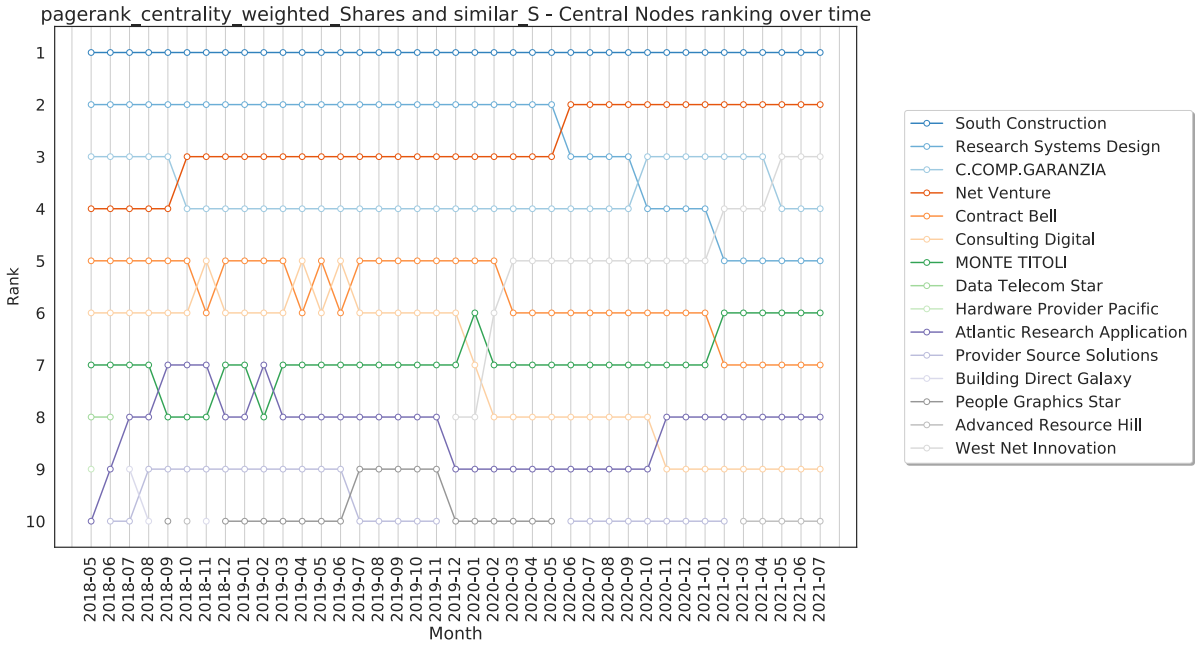
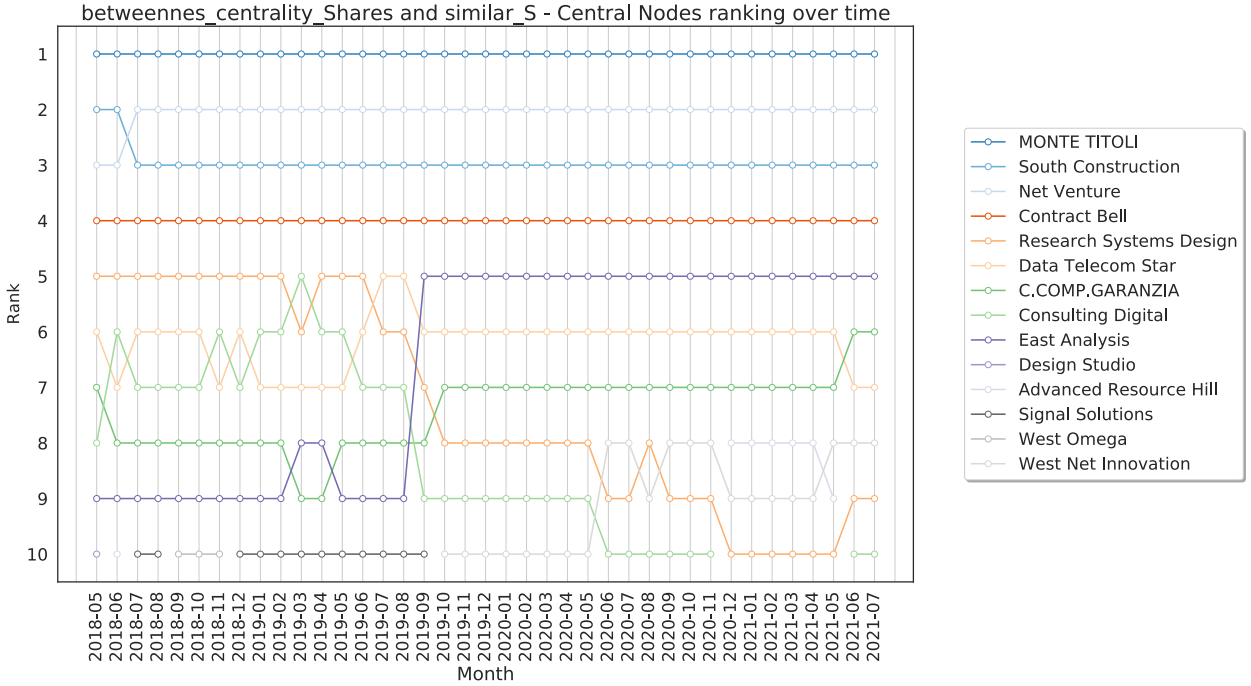
Central node Ranking – Shares_S cumulative





- Top3: CC&G, South Construction, Net Venture for the major part of the period
- West Net Innovation in the period started from last ranks to the reach 3rd place

- Top4: Monte Titoli, South Construction, Net Venture

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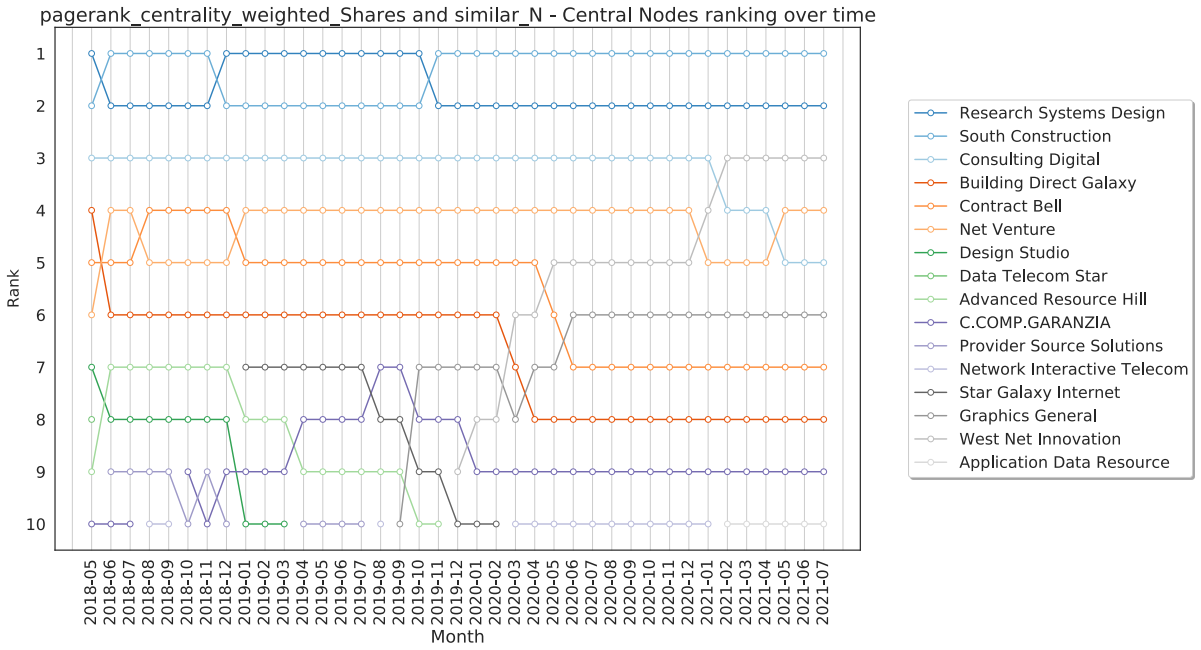
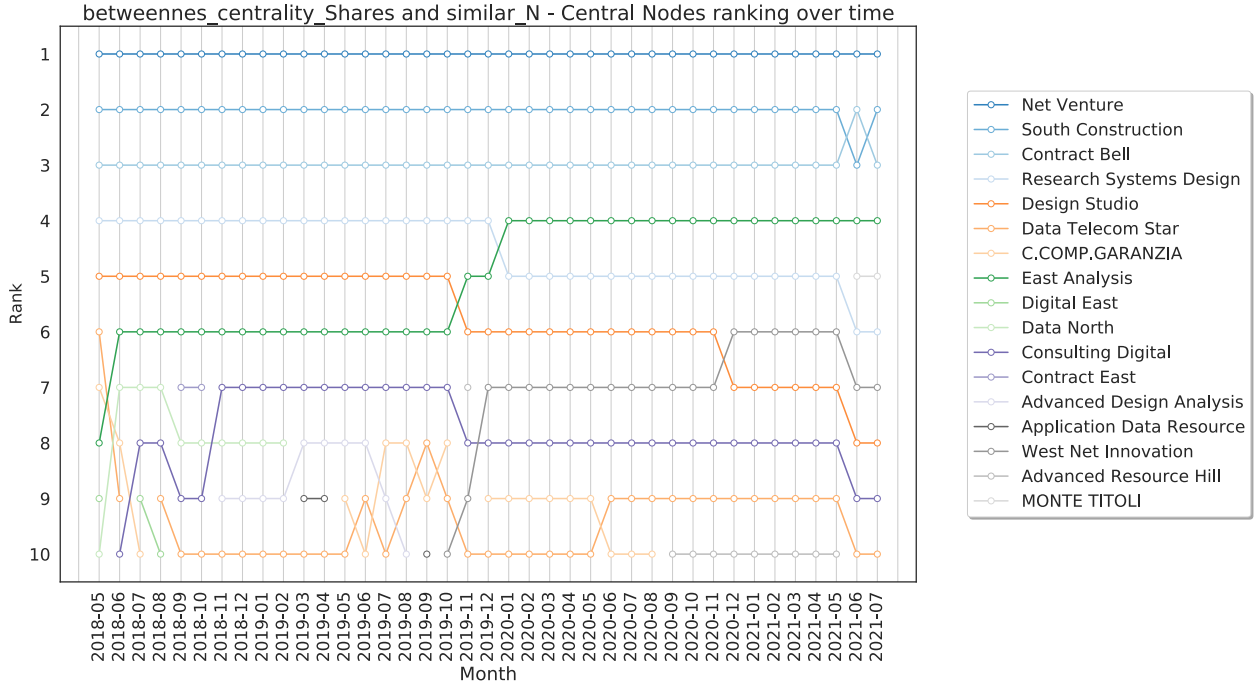
Central node Ranking - Shares_N cumulative

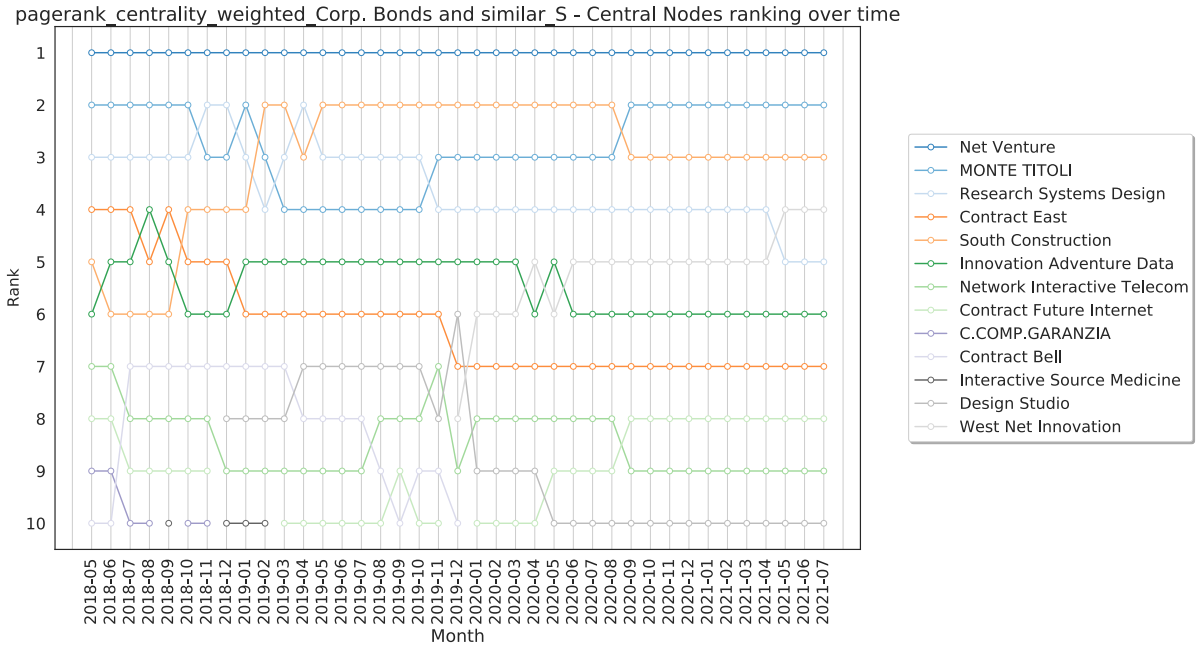


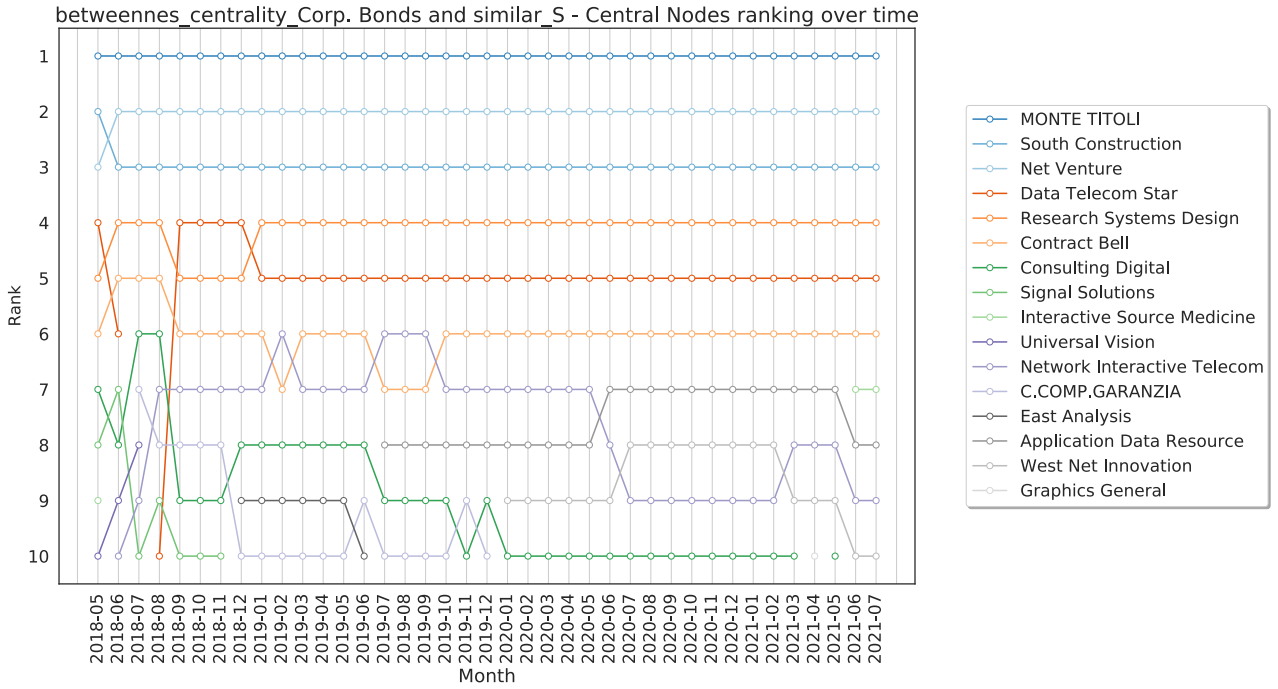


- Top3: South Construction, Research System Design, CC&G
- Last position are more unstable

- Top3: Net Venture, South Construction, Contract Bell

Central node Ranking – Corp. Bonds_S cumulative

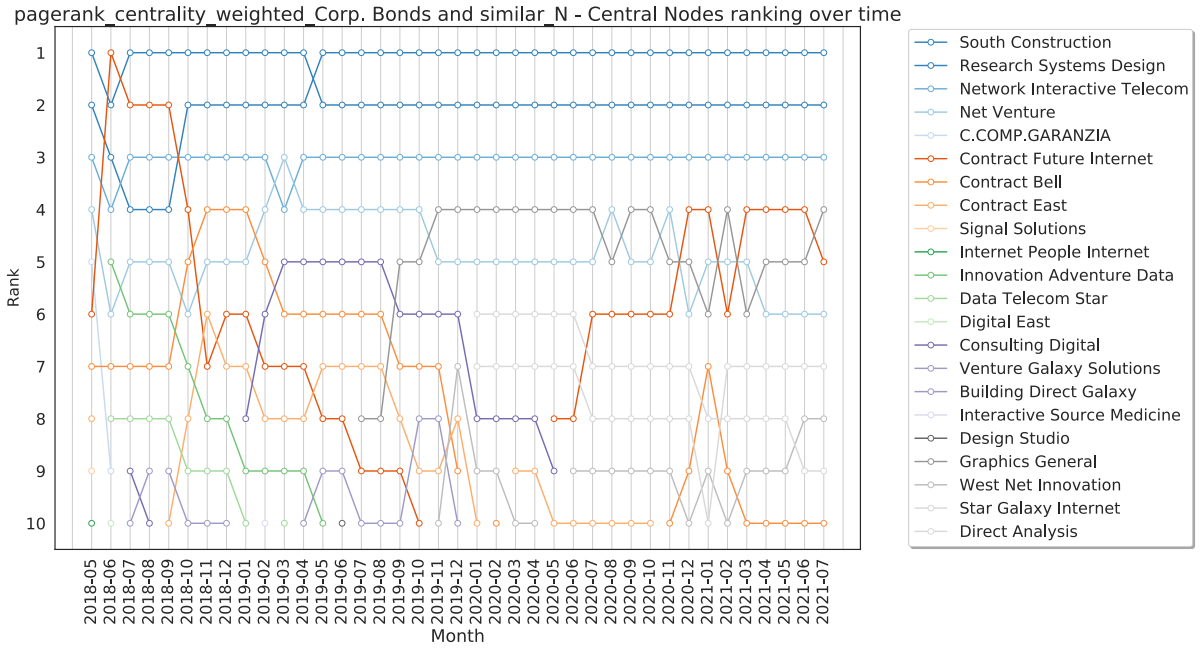


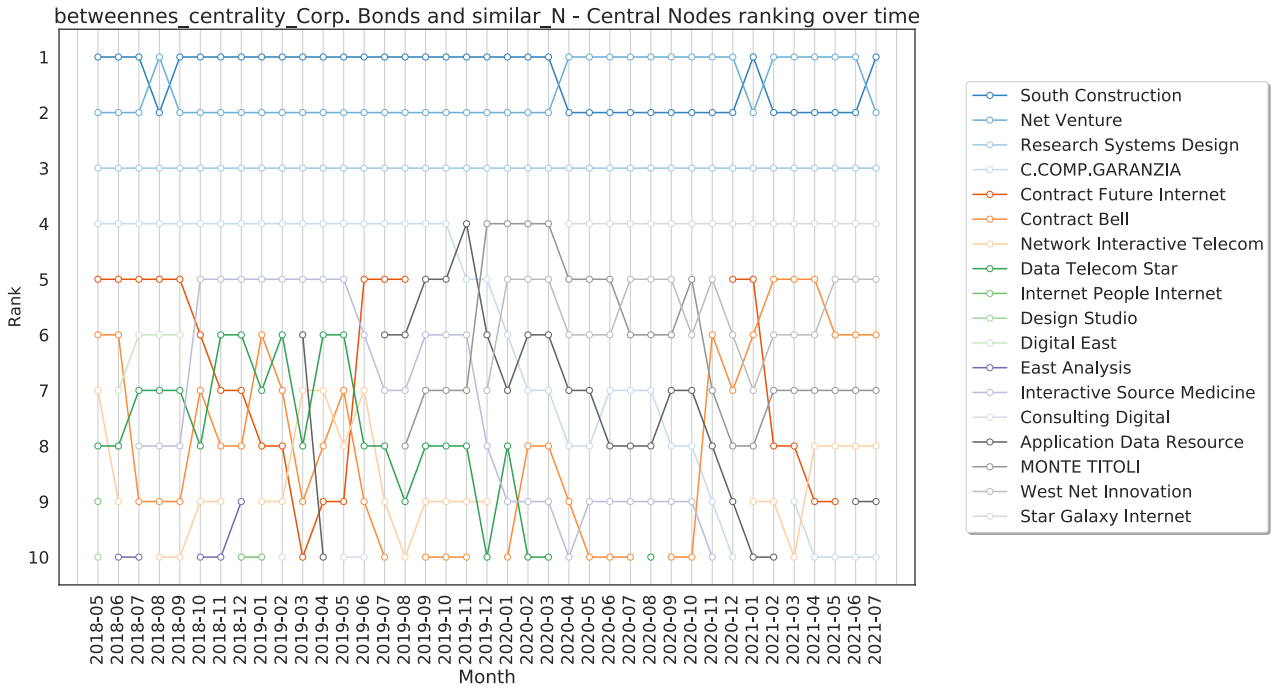


- Top4

- Top3:

Central node Ranking - Corp. Bonds_N cumulative





- Top3:

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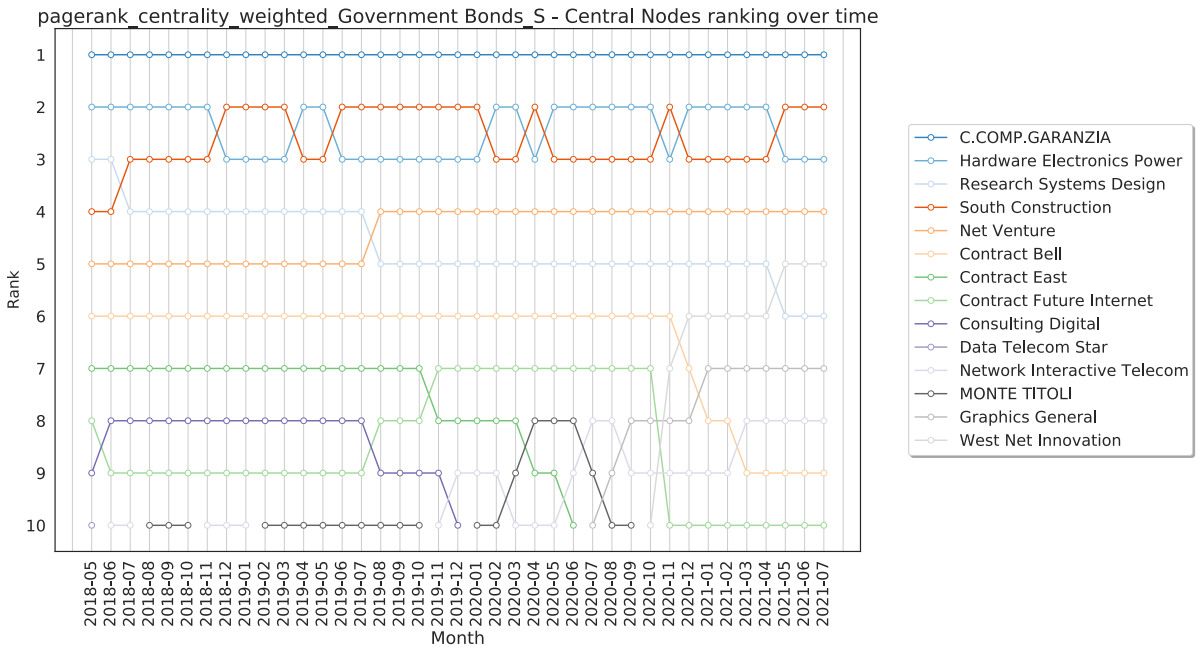

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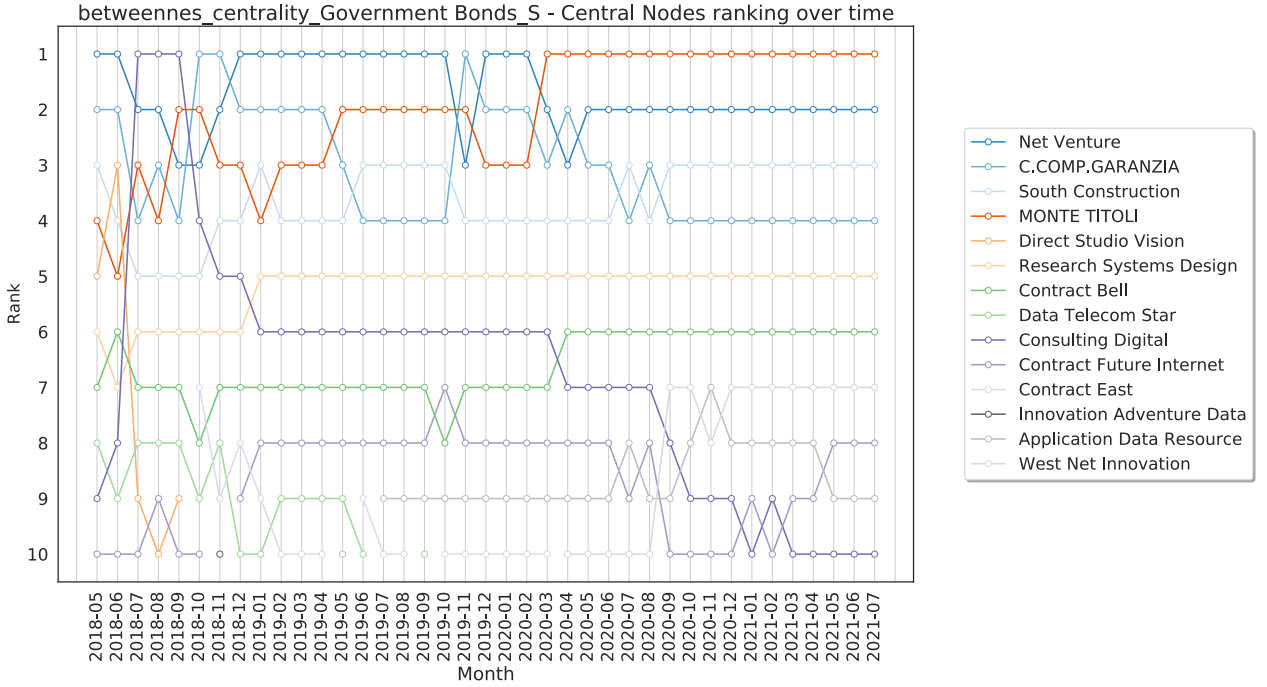

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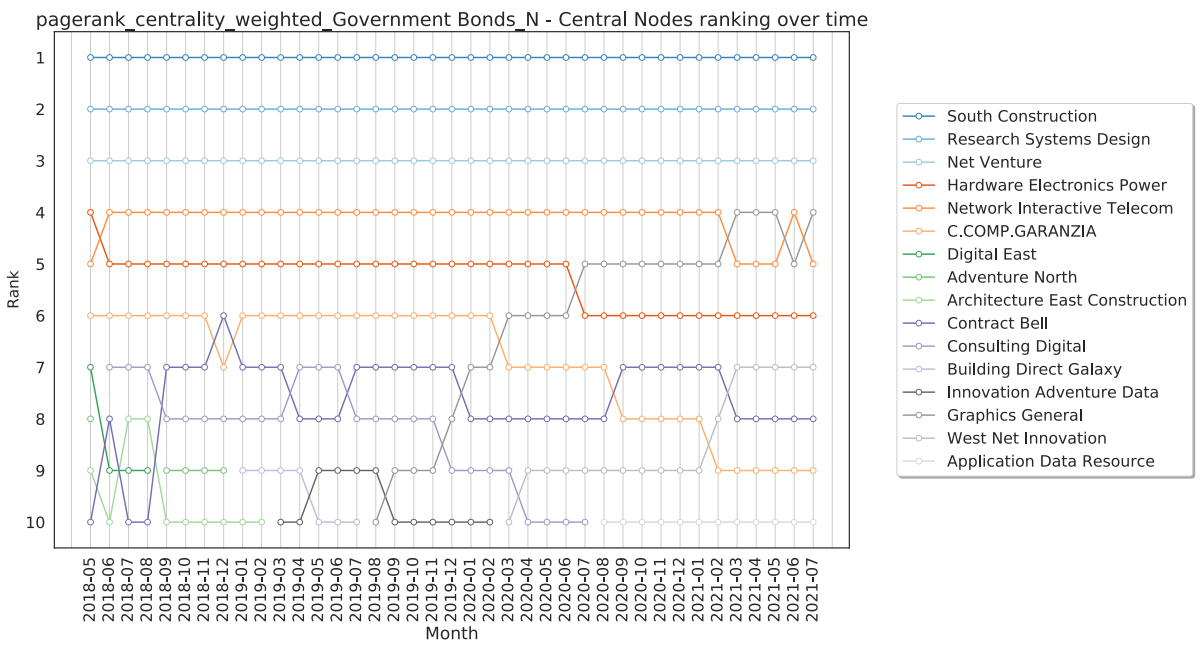
Central node Ranking - Gov. Bonds_N cumulative



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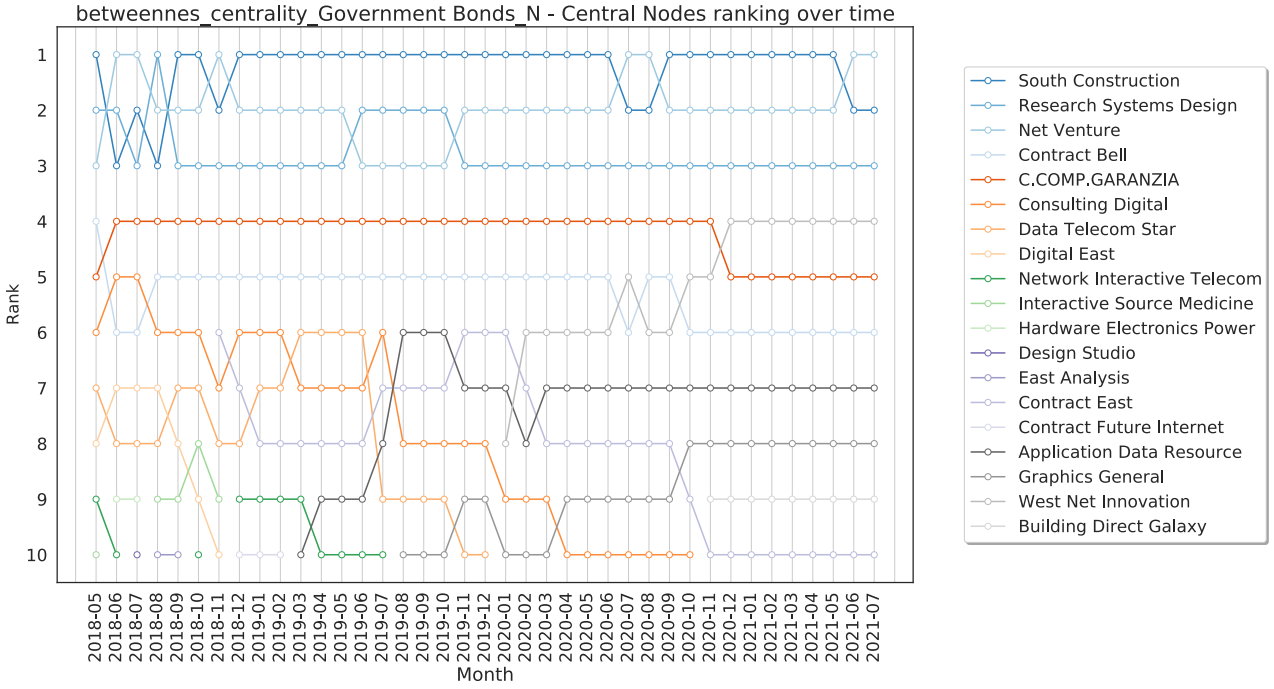

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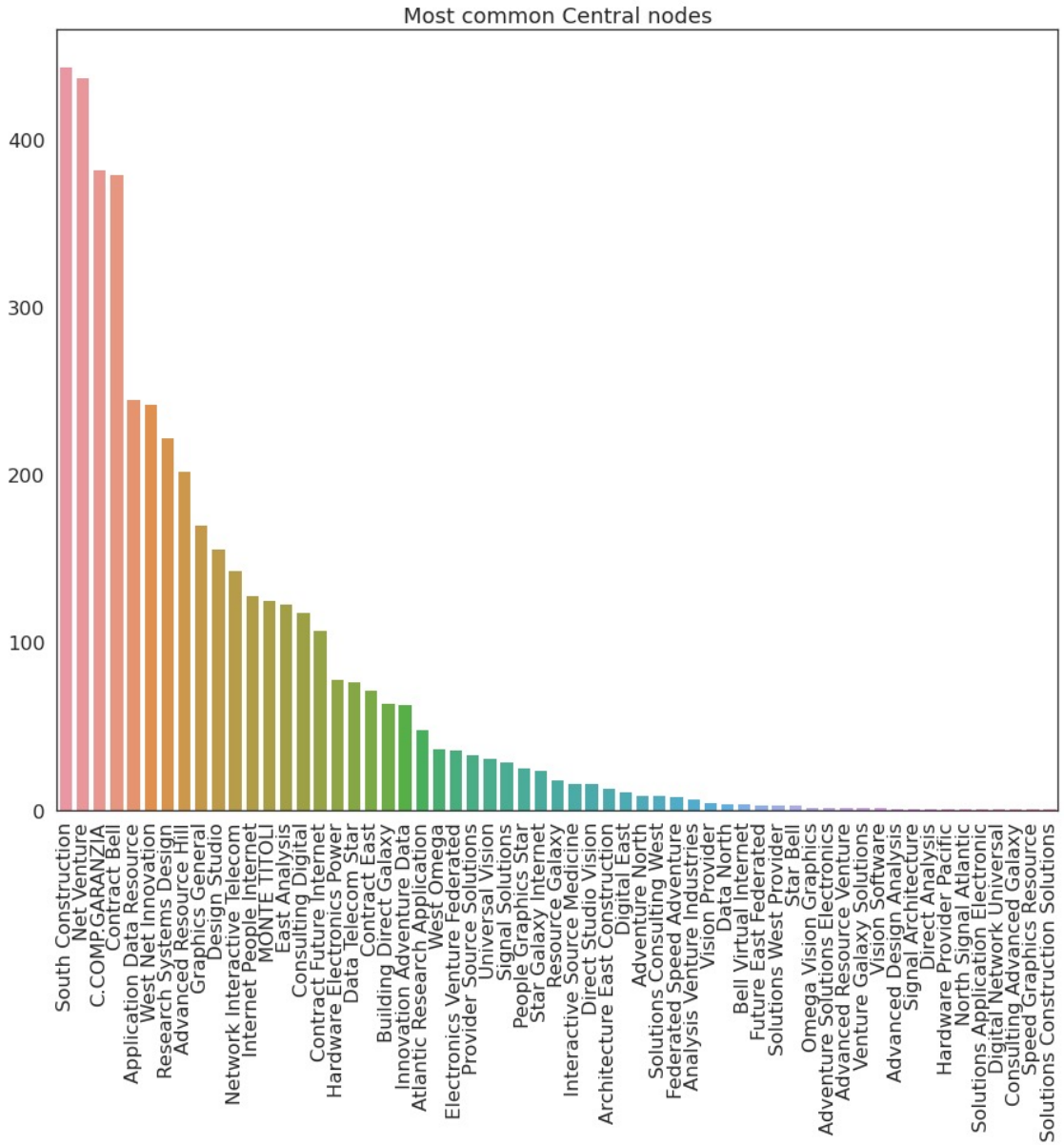
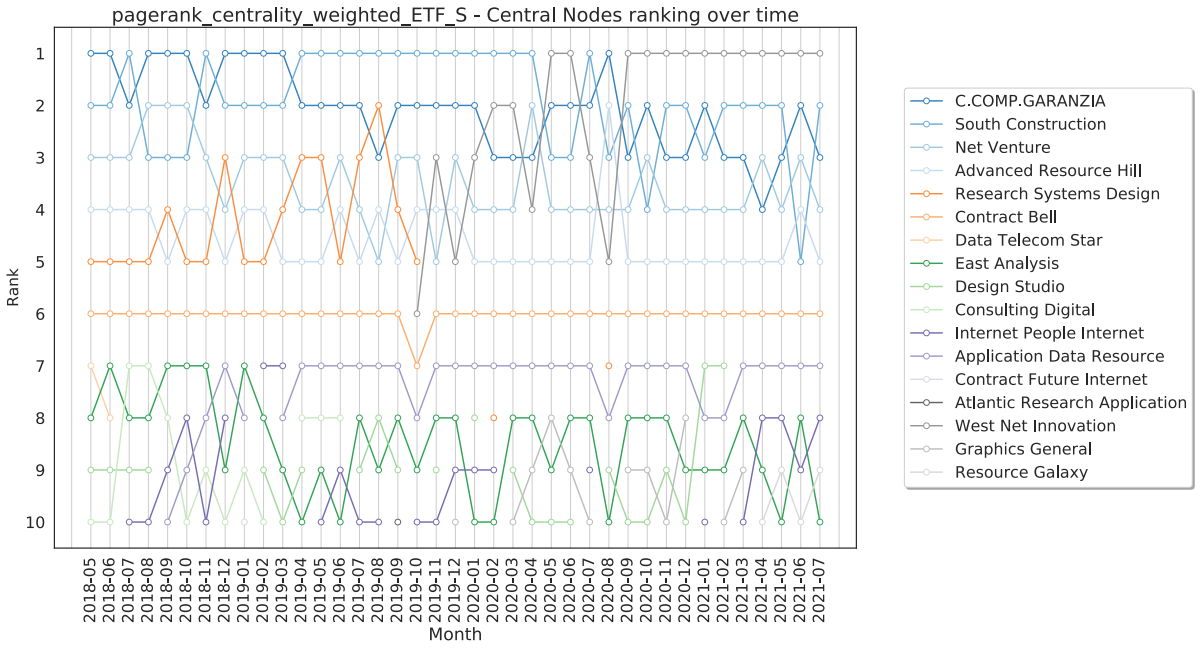


Central node Ranking – ETF_S monthly



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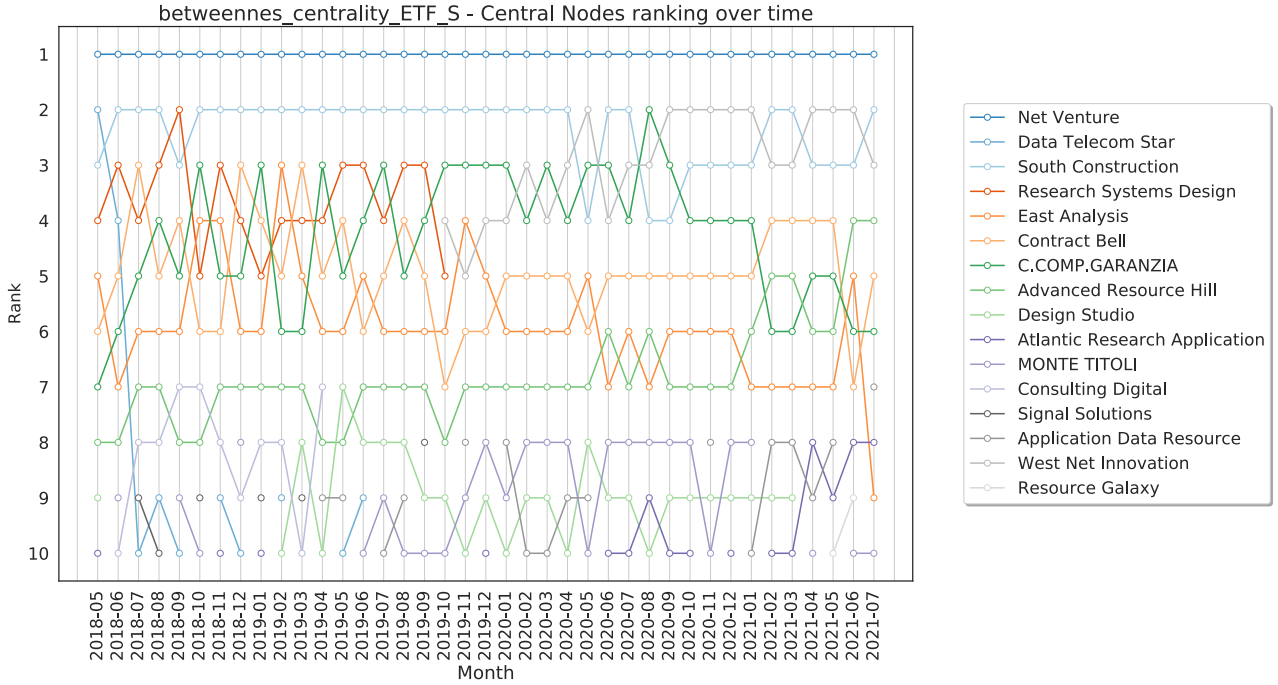

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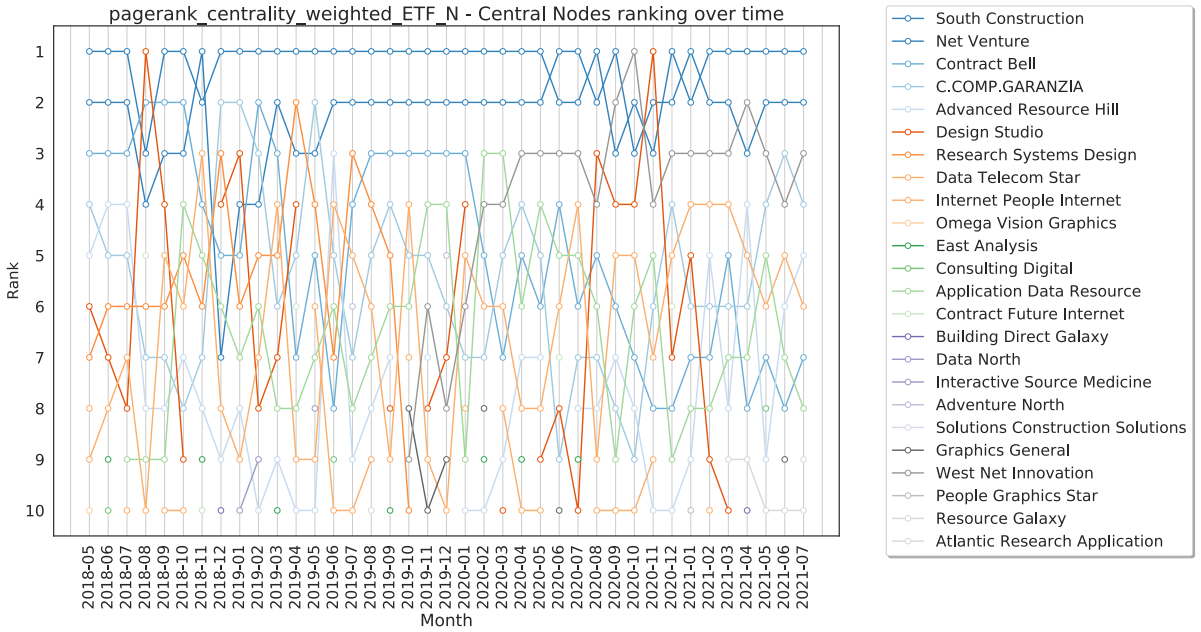
Central node Ranking – ETF_N monthly



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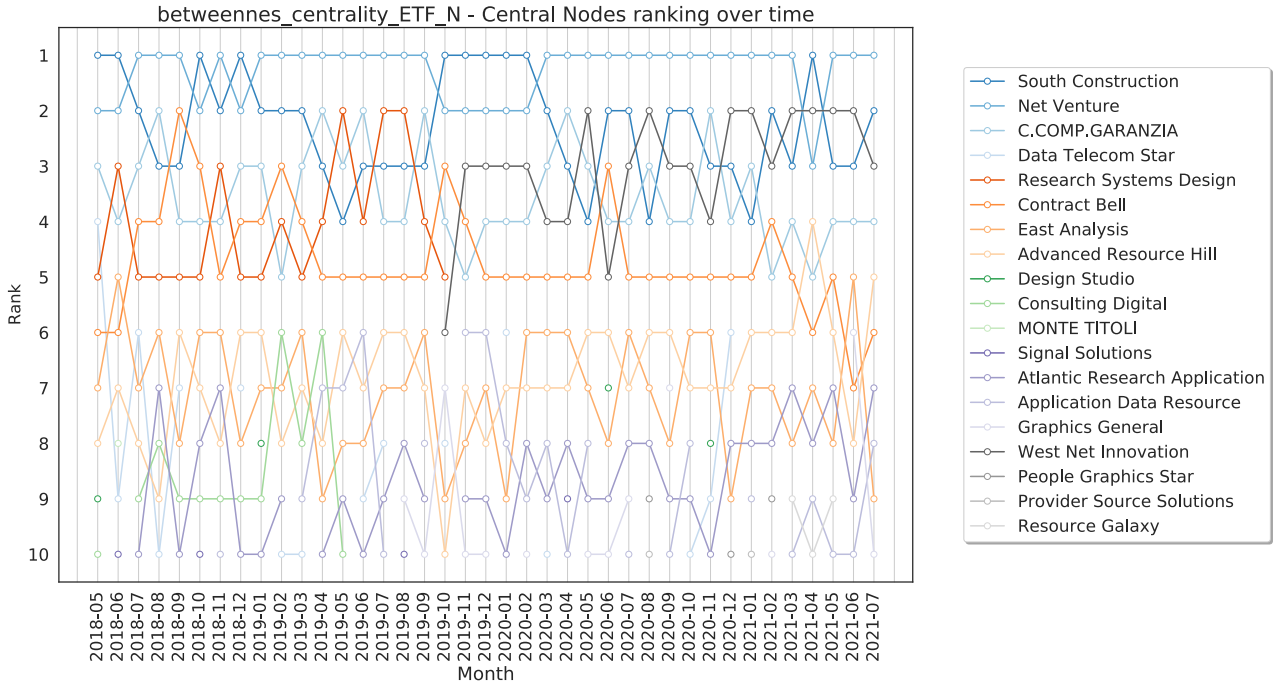
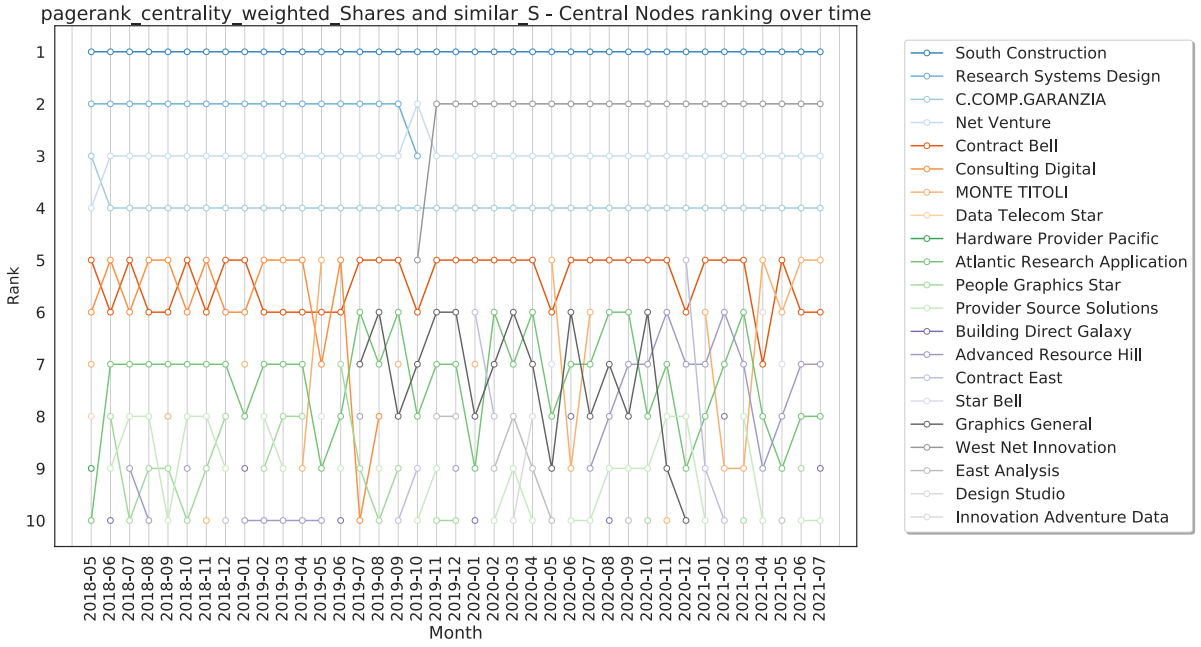


- Top3:

Central node Ranking – Shares_S monthly



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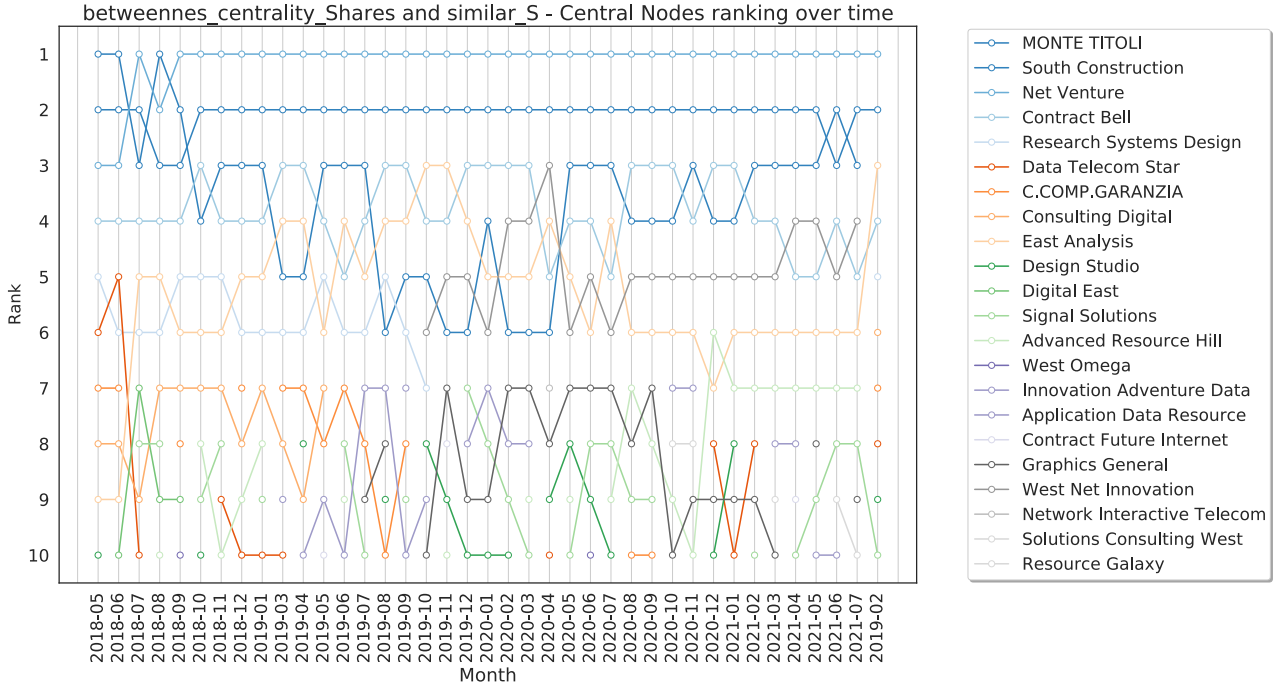
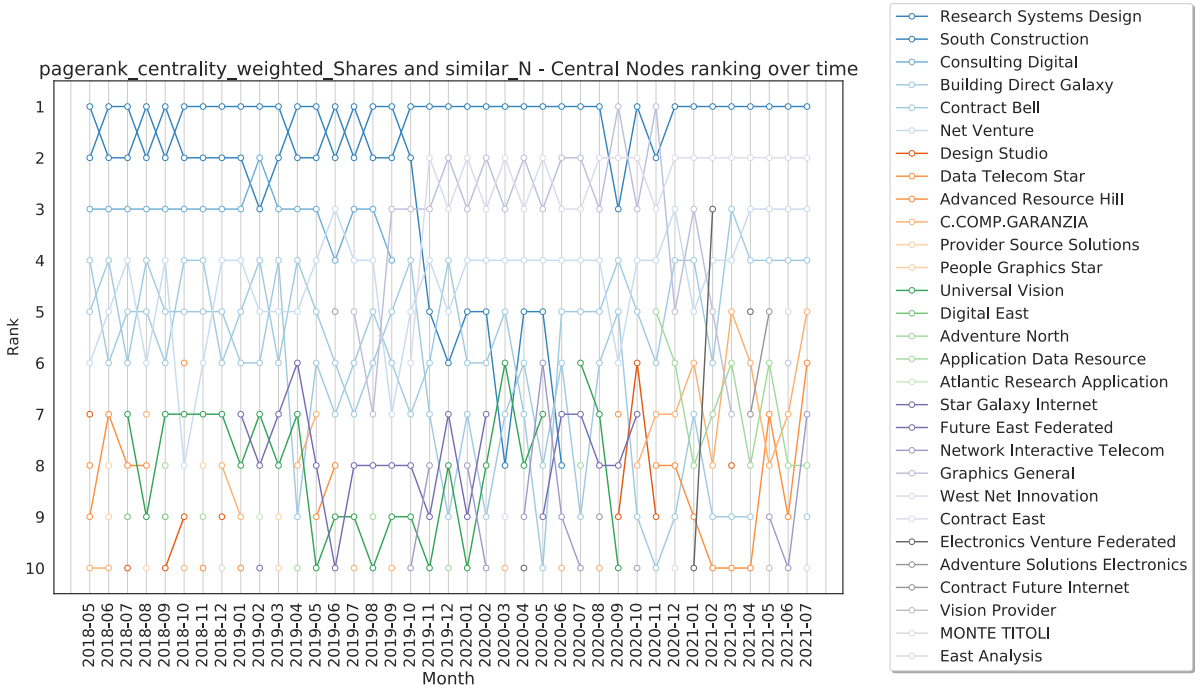


- Top3:

Central node Ranking – Share_N monthly



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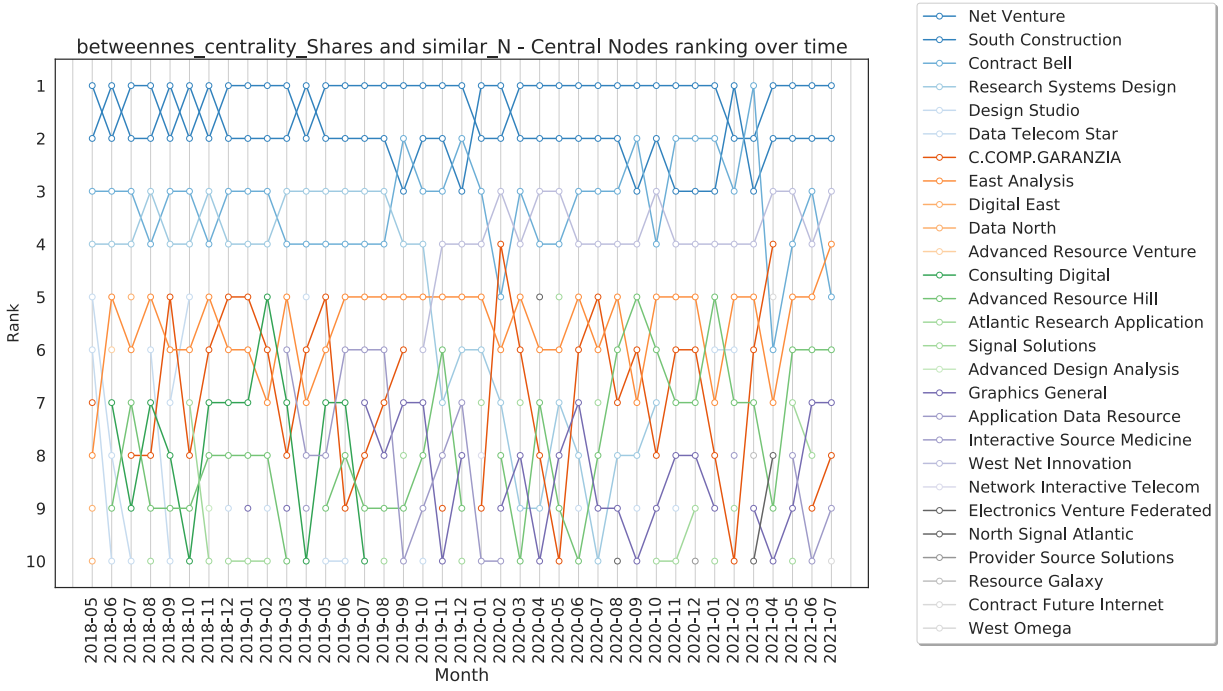
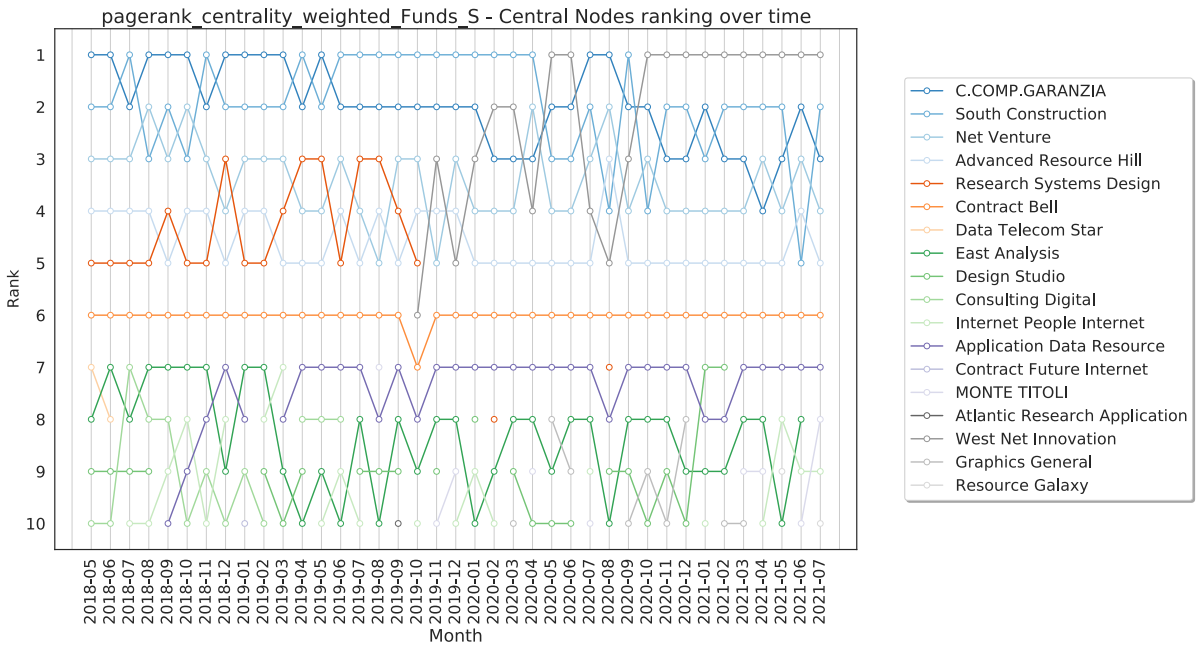


- Top3:

Central node Ranking – Funds_S cumulative



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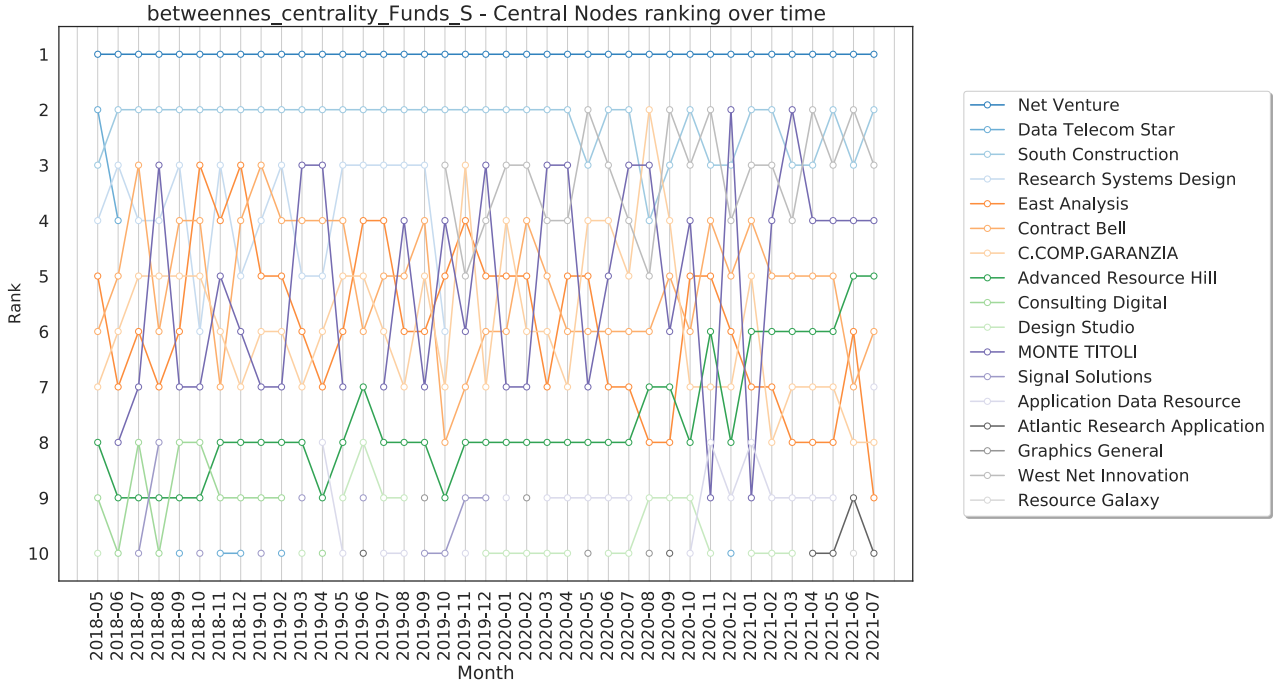

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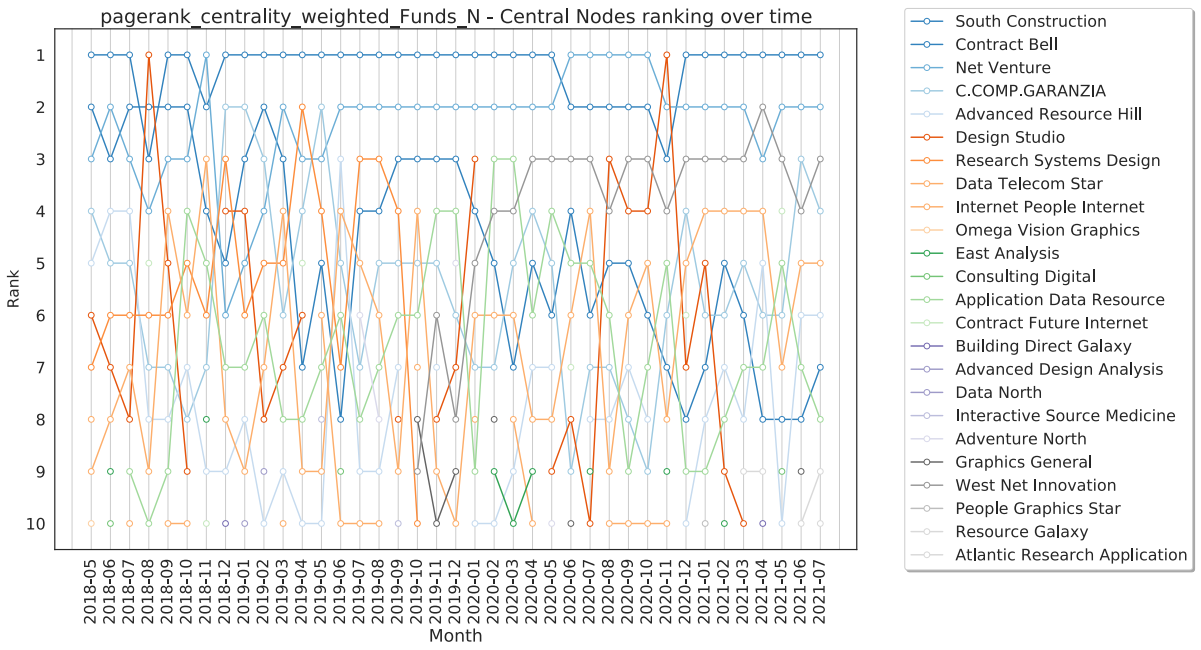
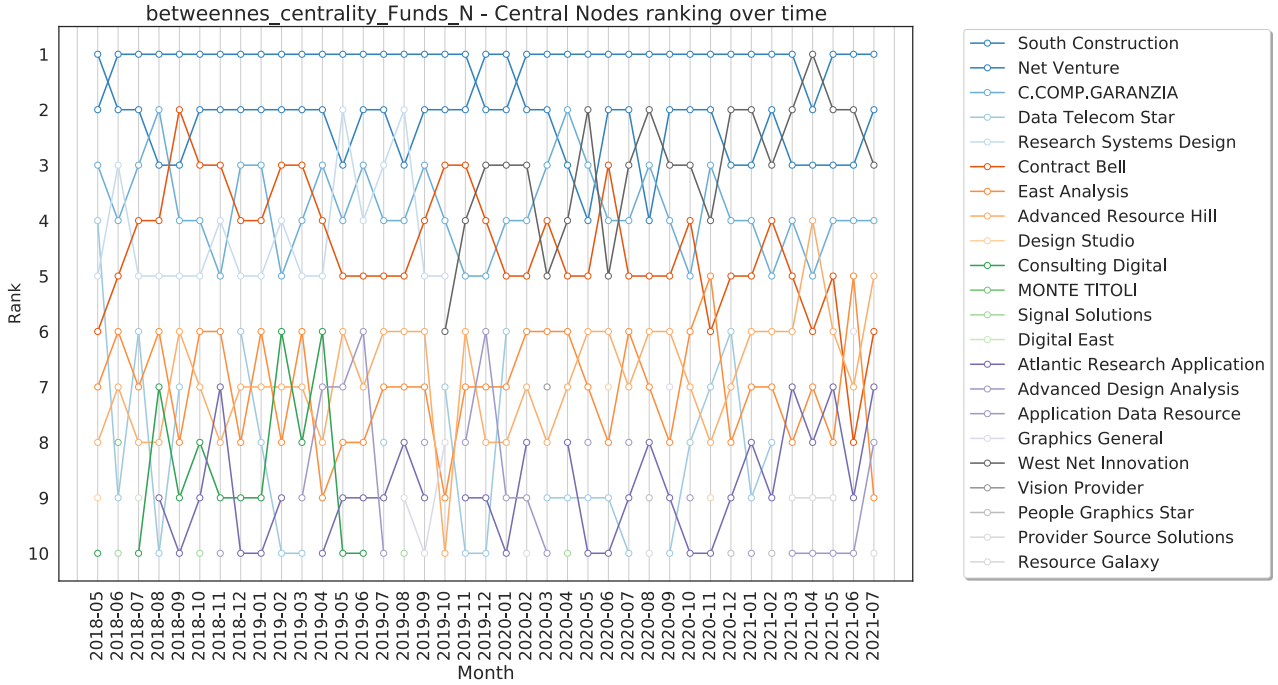
Central node Ranking – Funds_N monthly

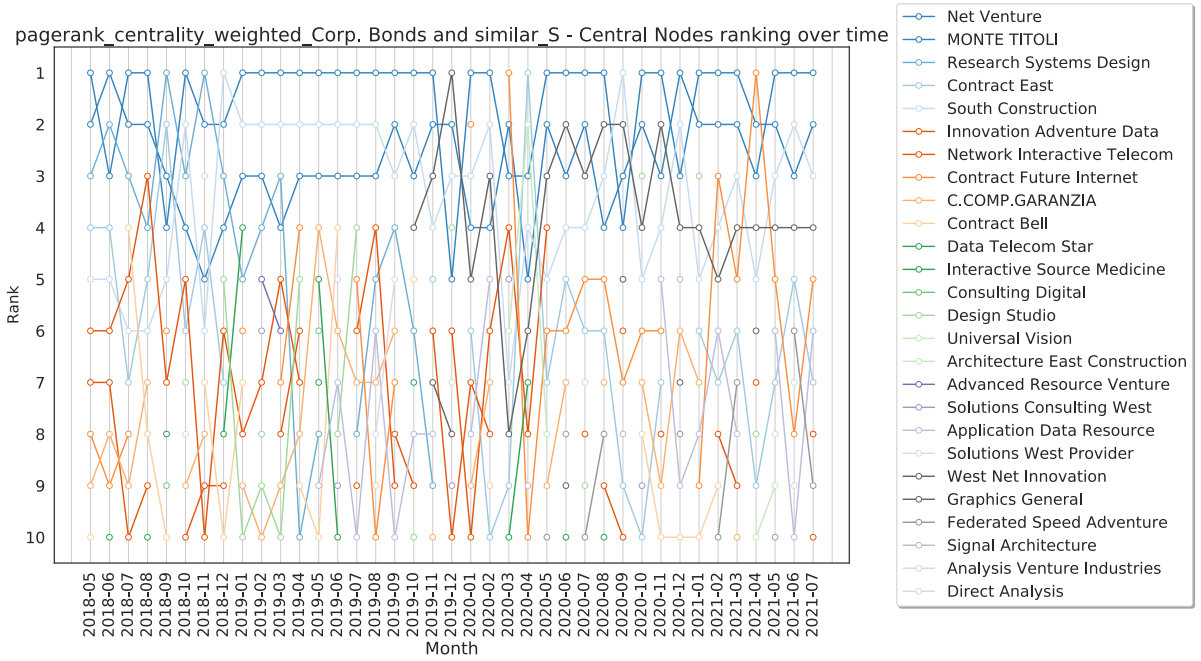


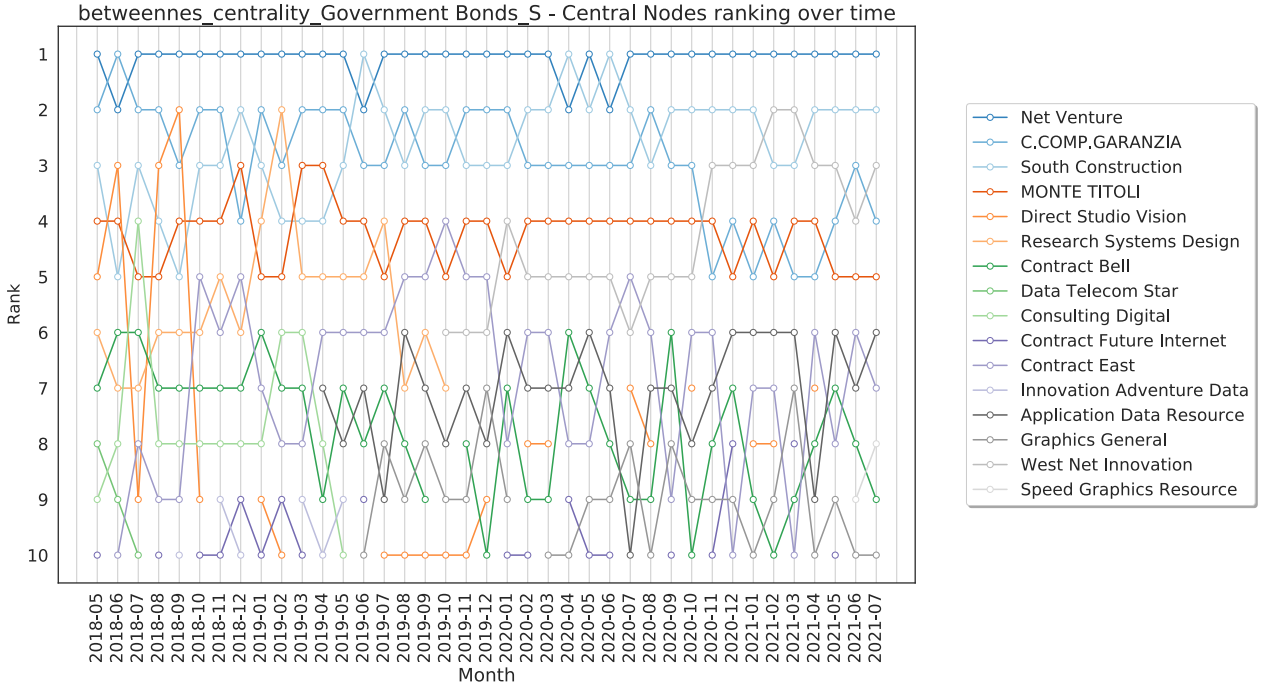


- Top3:

- Top3:

Central node Ranking – Corp. Bonds_S monthly





- Top3:

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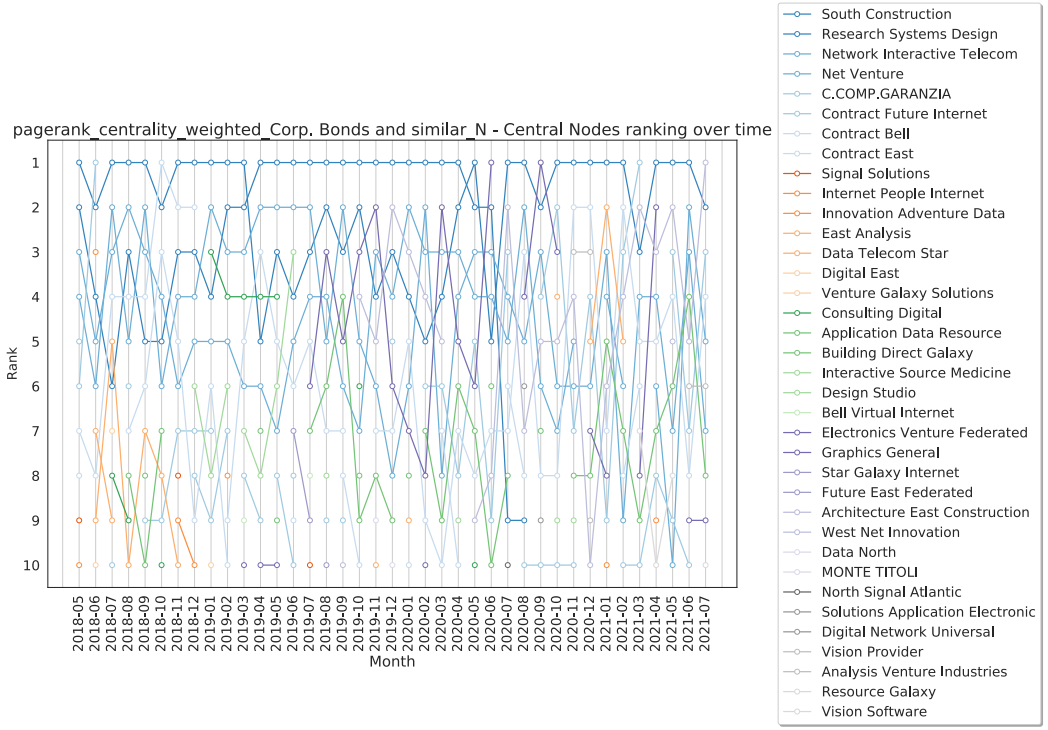
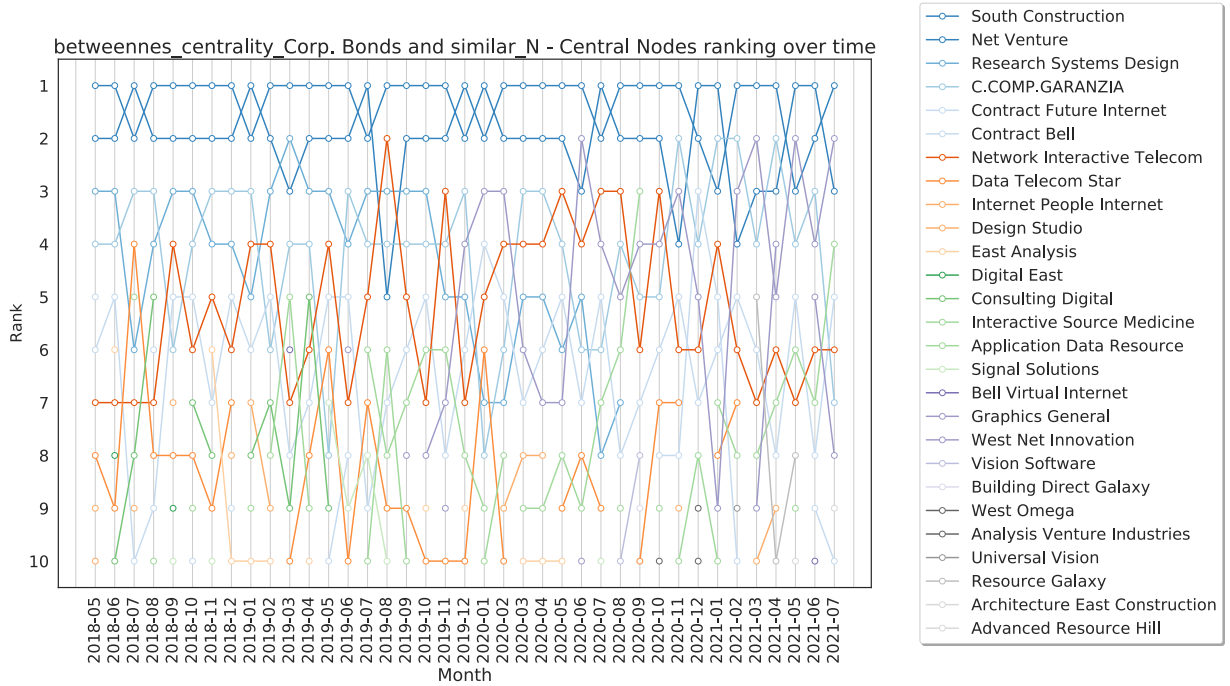
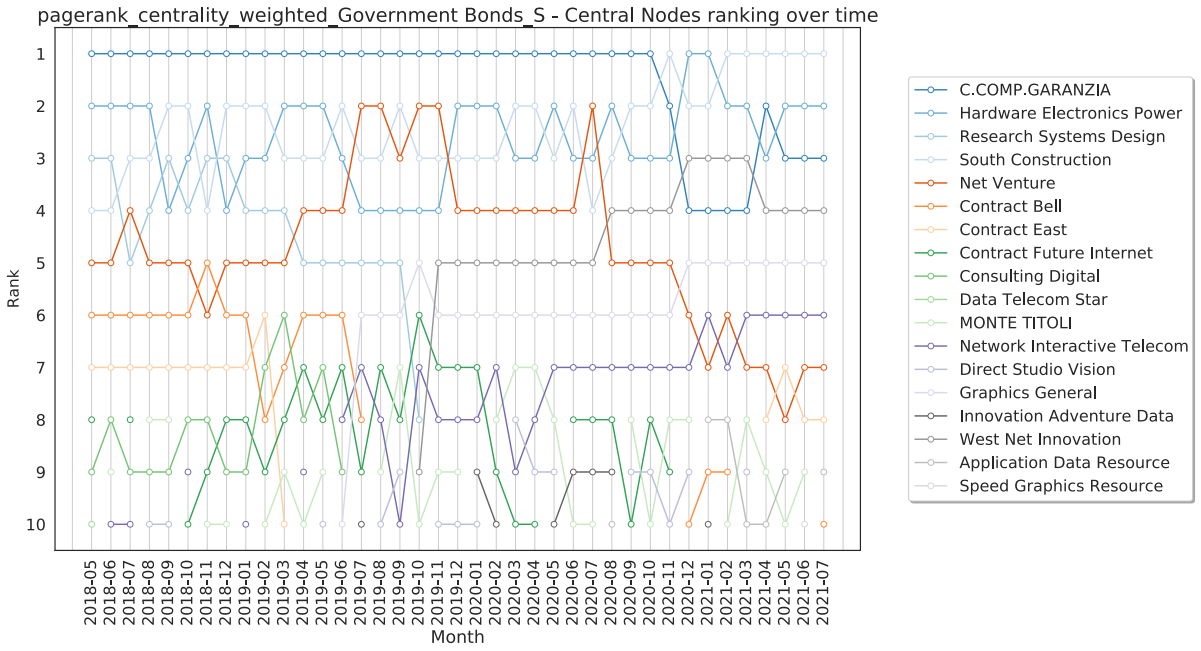
Central node Ranking – Corp. Bonds_N monthly

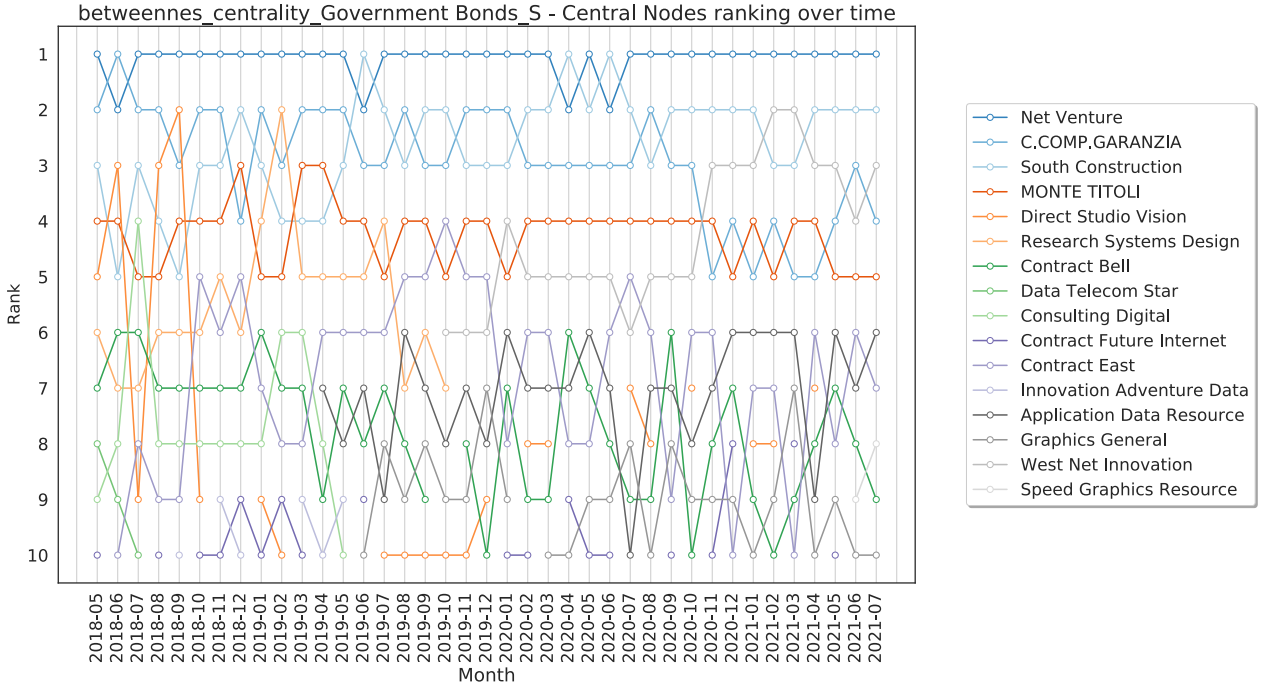




Central node Ranking – Gov. Bonds_S monthly

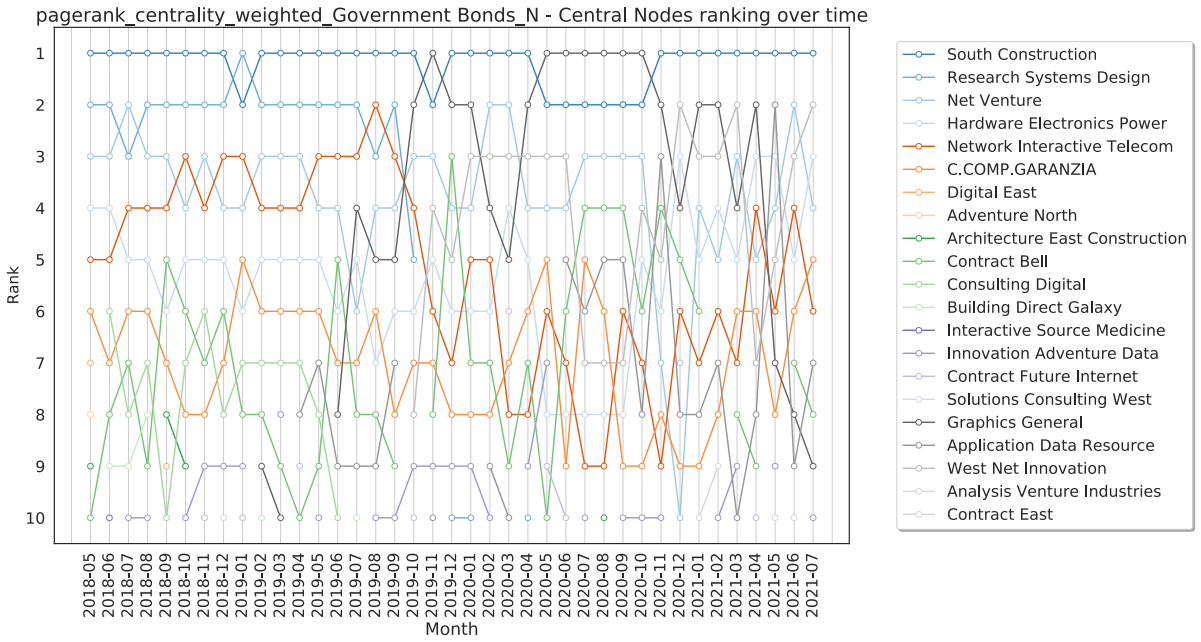


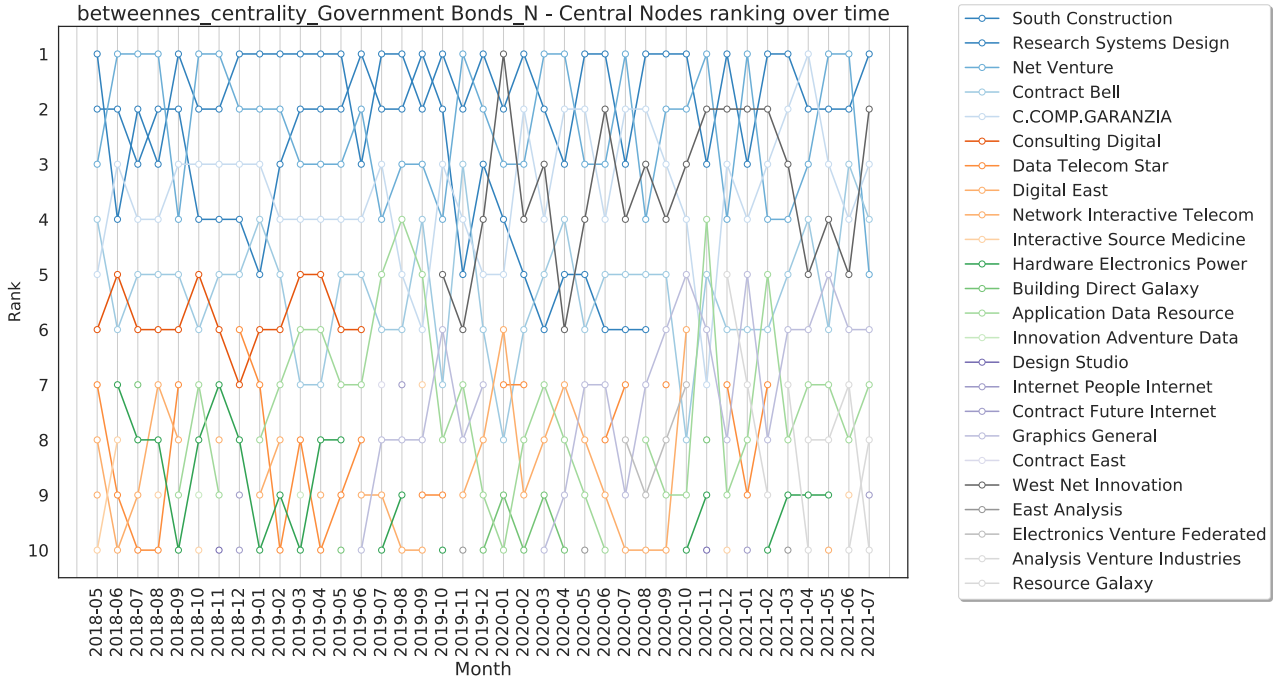
- Top3:



- Top3:

Central node Ranking – Gov. Bonds_N monthly





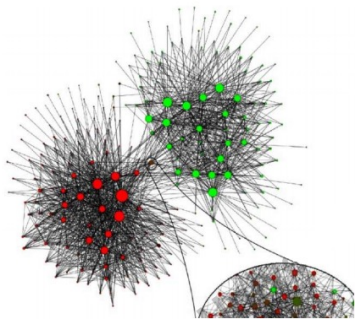
- Top3:

- Top3:

Scale-free networks – Introduction (1/2)

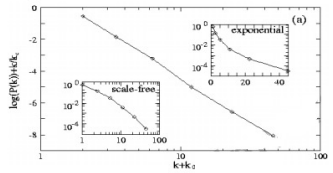
- A lot of Social Networks are Scale-Free (World Wide Web, Facebook, Biology etc.)

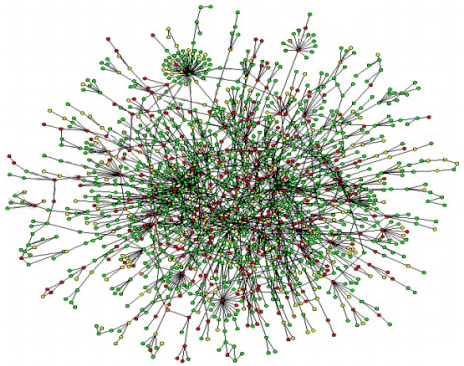
Example: mobile call



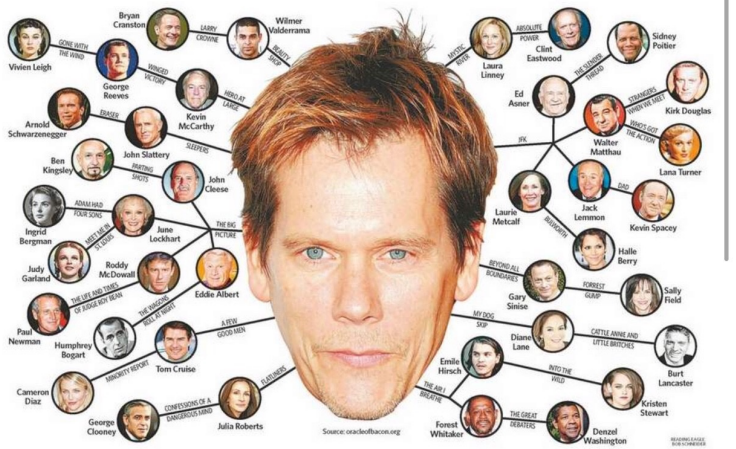
TOPOLOGY OF THE PROTEIN NETWORK

Nodes: proteins
Links: physical interactions-binding





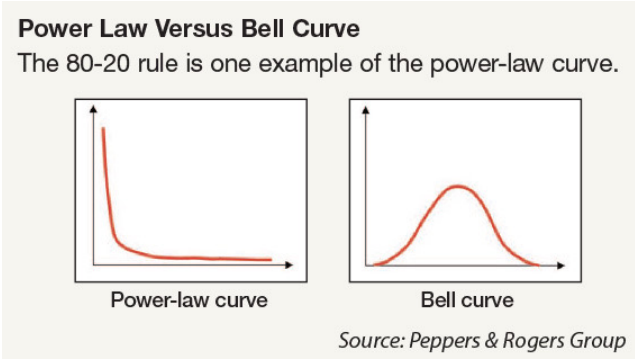
- **Small-world theory** where networks are characterized by short path-lengths:
  - **Six degrees of separation** of separations
  - HUBS allow connection between peripheral nodes



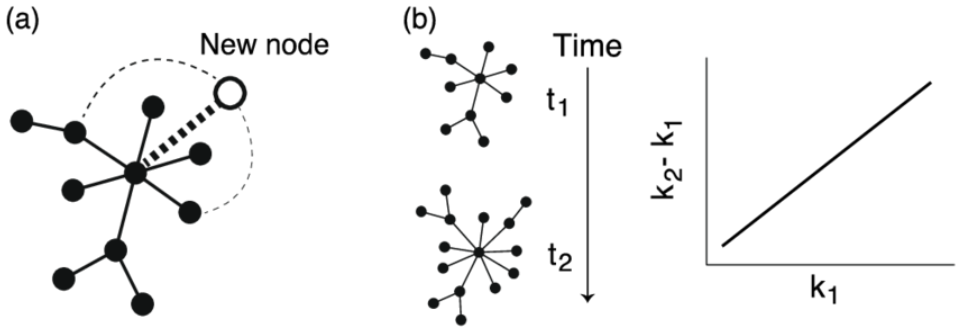
Six degrees of separation of separations from **Kevin Bacon**

Scale-free networks – Introduction (2/2)

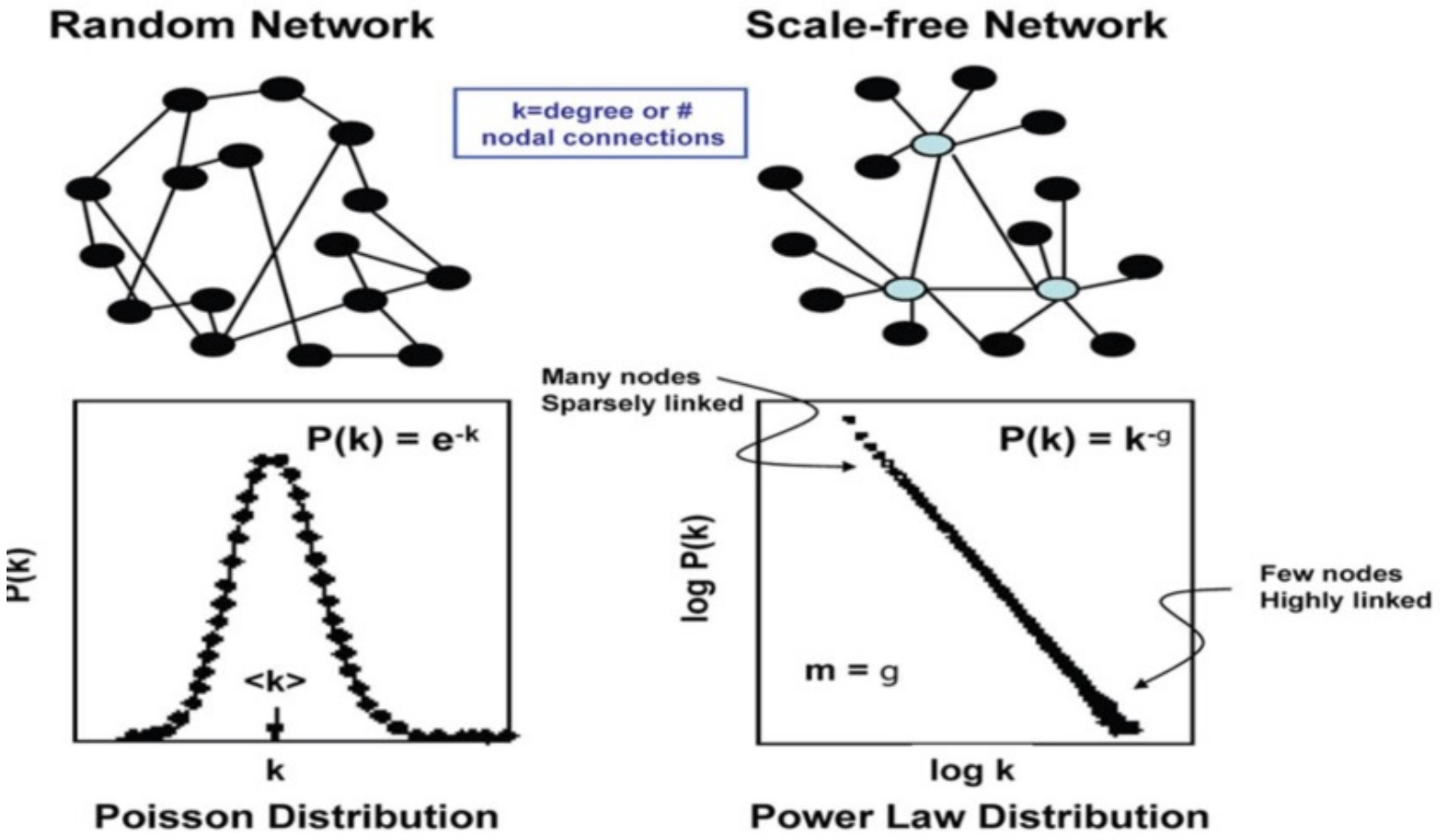
- Scale free networks follow **Power law distribution** $P(k) \sim k^{-\gamma}$



- Properties:
  - **Growth**: over an extended period of time, new nodes join an already existing system
  - **Preferential attachment**: new coming node who prefers to connect to another node which has already a certain number of links with others
  - **Scale-free Resiliency**: Scale-free networks are more resistant to random disconnection of nodes. It can be eliminated a considerable number of nodes randomly and the network's structure is preserved.



Scale-free networks vs Random-Networks representation



Random Networks:

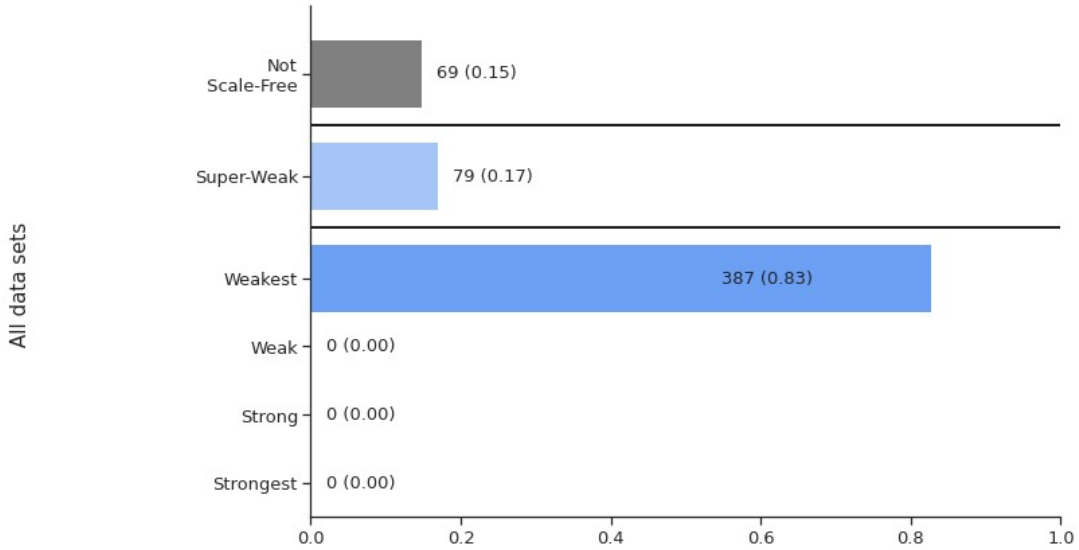
- Networks are generated randomly
- HUBS are not presents
- Few nodes have low and very high degree

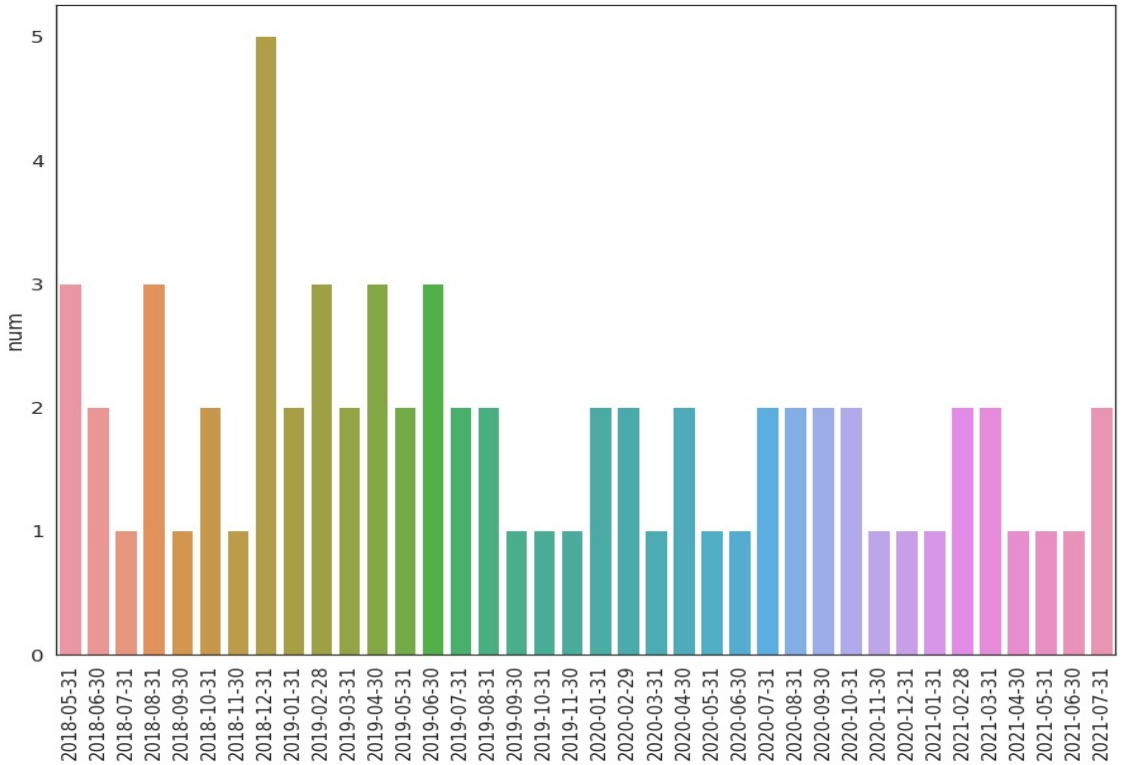
Scale-Free Networks:

- Allows HUBS
- Few nodes have an higher degree, while lot of nodes have a lower degree

Scale-Free Networks model can better approximate real world scenarios

Scale-free networks detection - cumulative

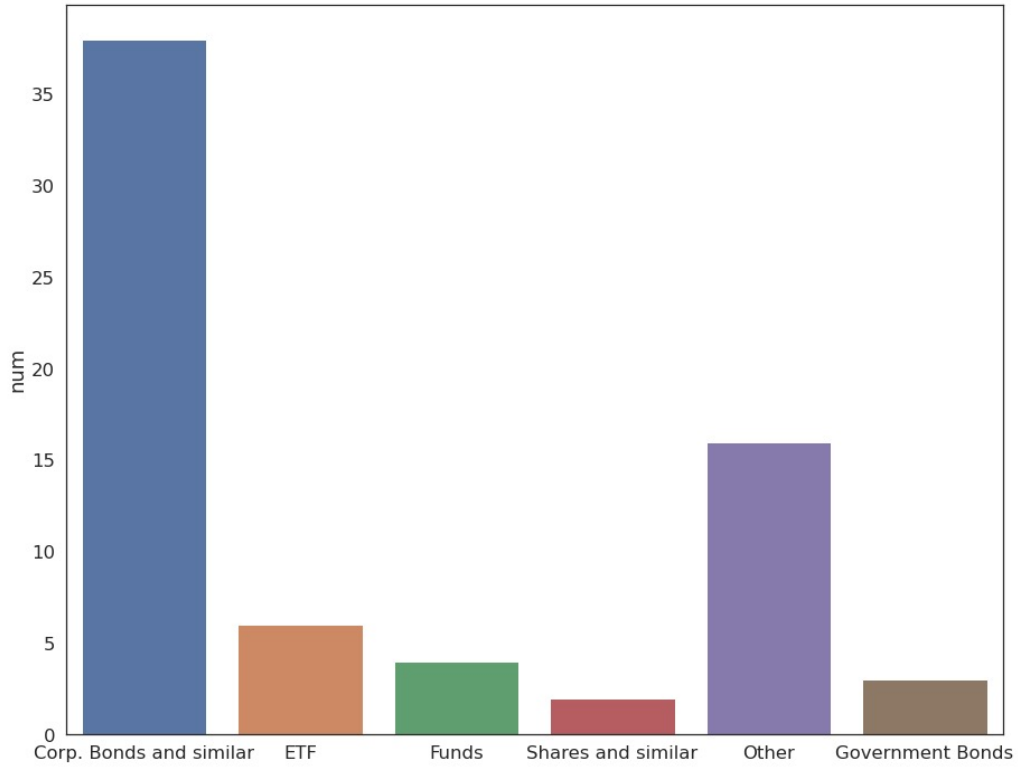


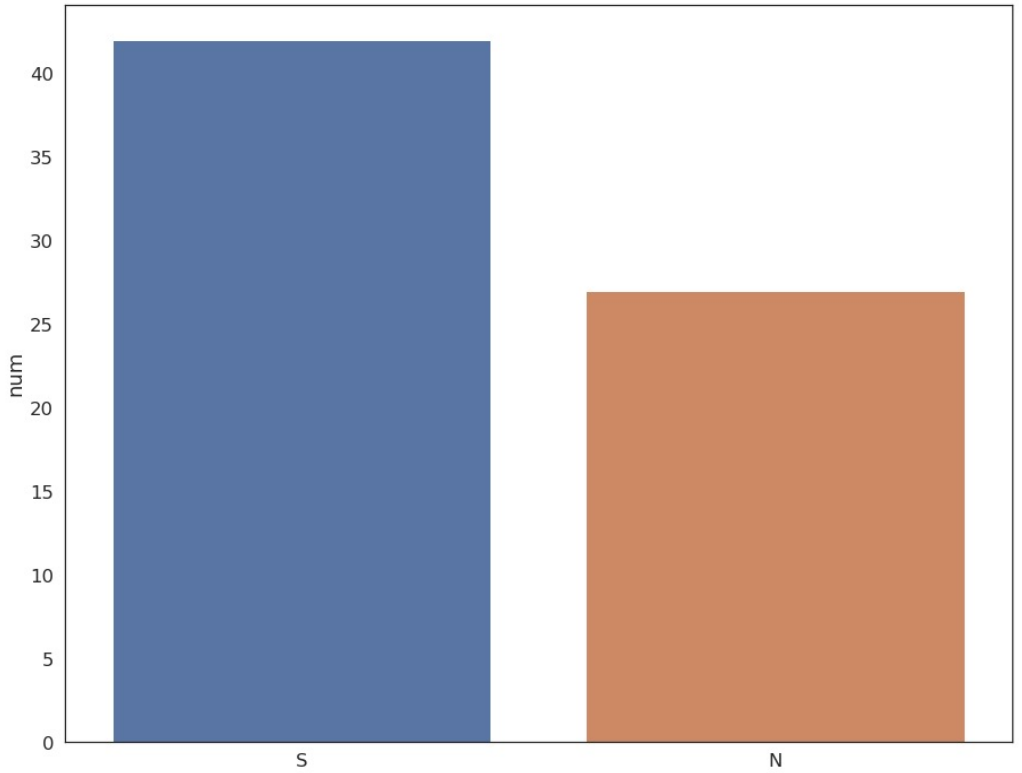


- Networks in the system are mostly **Weakest Scale-free**: 387
- **Super-Weak** Scale-free Networks comprehend a tiny part of the population: 79
- There are also Networks that are **not Scale-free**: 69

- As time passing, networks are getting bigger and seem to present more a scale-free behavior.

Scale-free networks detection - cumulative

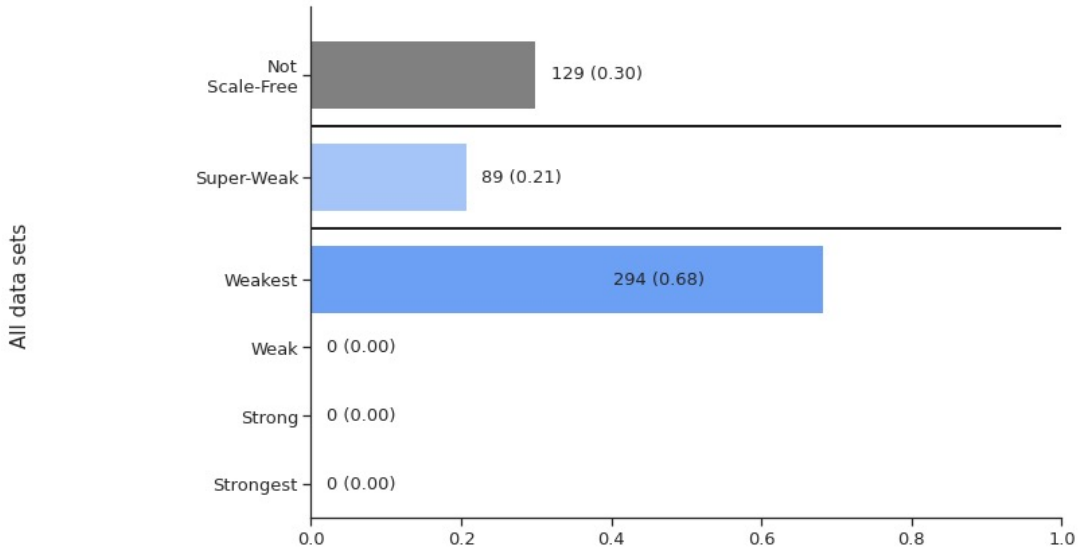


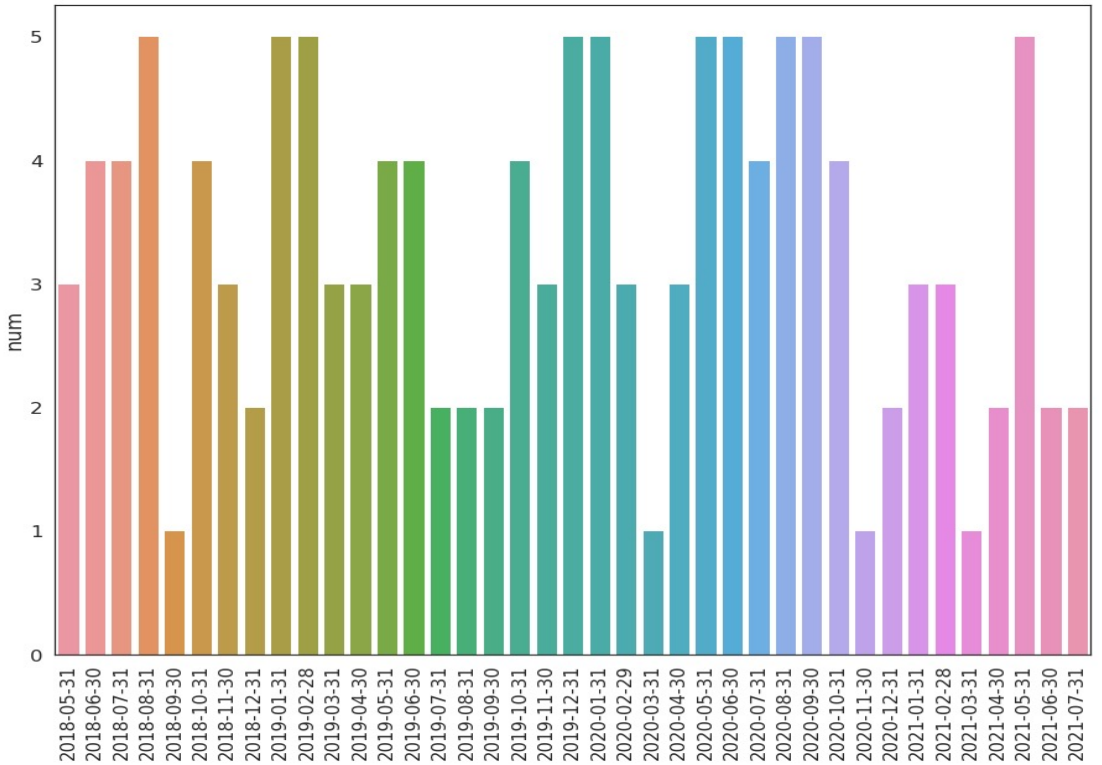


- **Scale free behavior** is not present mostly in Corp. Bonds and Other Networks.

- **Scale free behavior** is not present mostly in Networks Settled status.

Scale-free networks detection - monthly





- Networks in the system are mostly **Weakest Scale-free**: 294
- **Super-Weak** Scale-free Networks comprehend a tiny part of the population
- There are also Networks that are **not Scale-free**: 129

- Some months presents not scale-free behavior majorly

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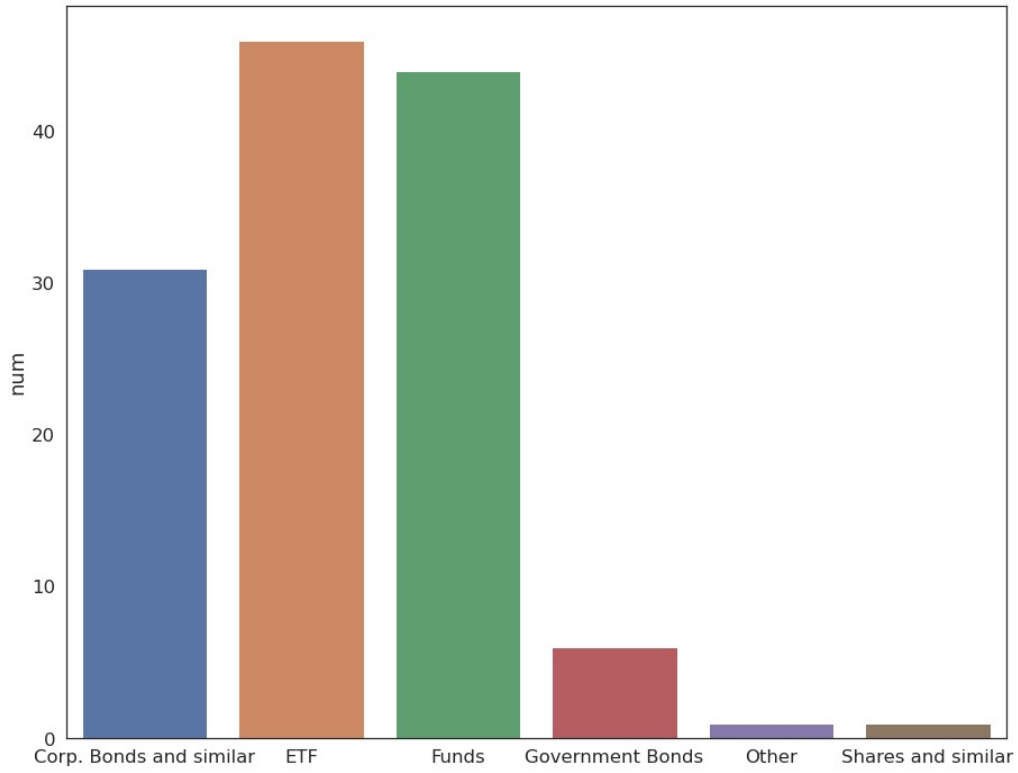
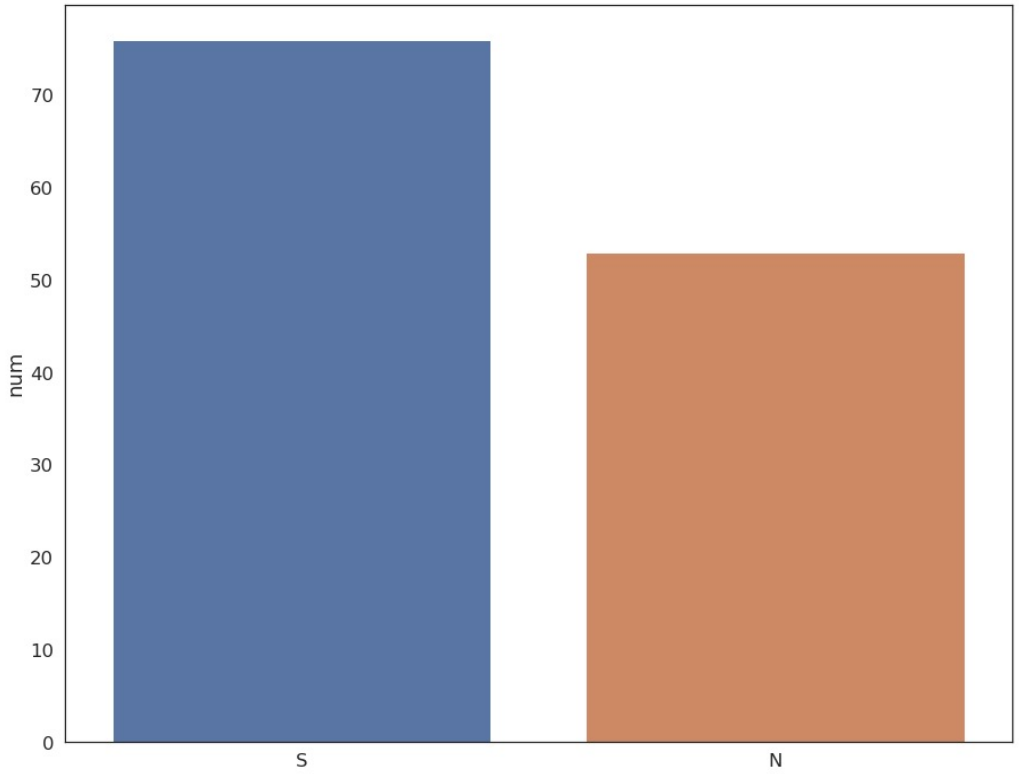
Scale-free networks detection - monthly





- **Scale free behavior** is not present mostly in ETF, Funds and Corp. Bonds Networks.

- **Scale free behavior** is not present mostly in Networks that are constructed with Instruction with status as Settled

Node Deletion

- In a network a node deletion means that a Company may goes to bankrupt or most commonly the company decides to exit the system.

- To verify the structure alterations, it is possible to detect any changes in the Connected Component (CC) of a Network:
  - If after a deletion, a change in the CCs is present, this means that the node is a vulnerable one and the Network has been damaged and compromised.
  - If after a deletion, there is no changes in the Connected Component, this implies that the networks has not been compromised.

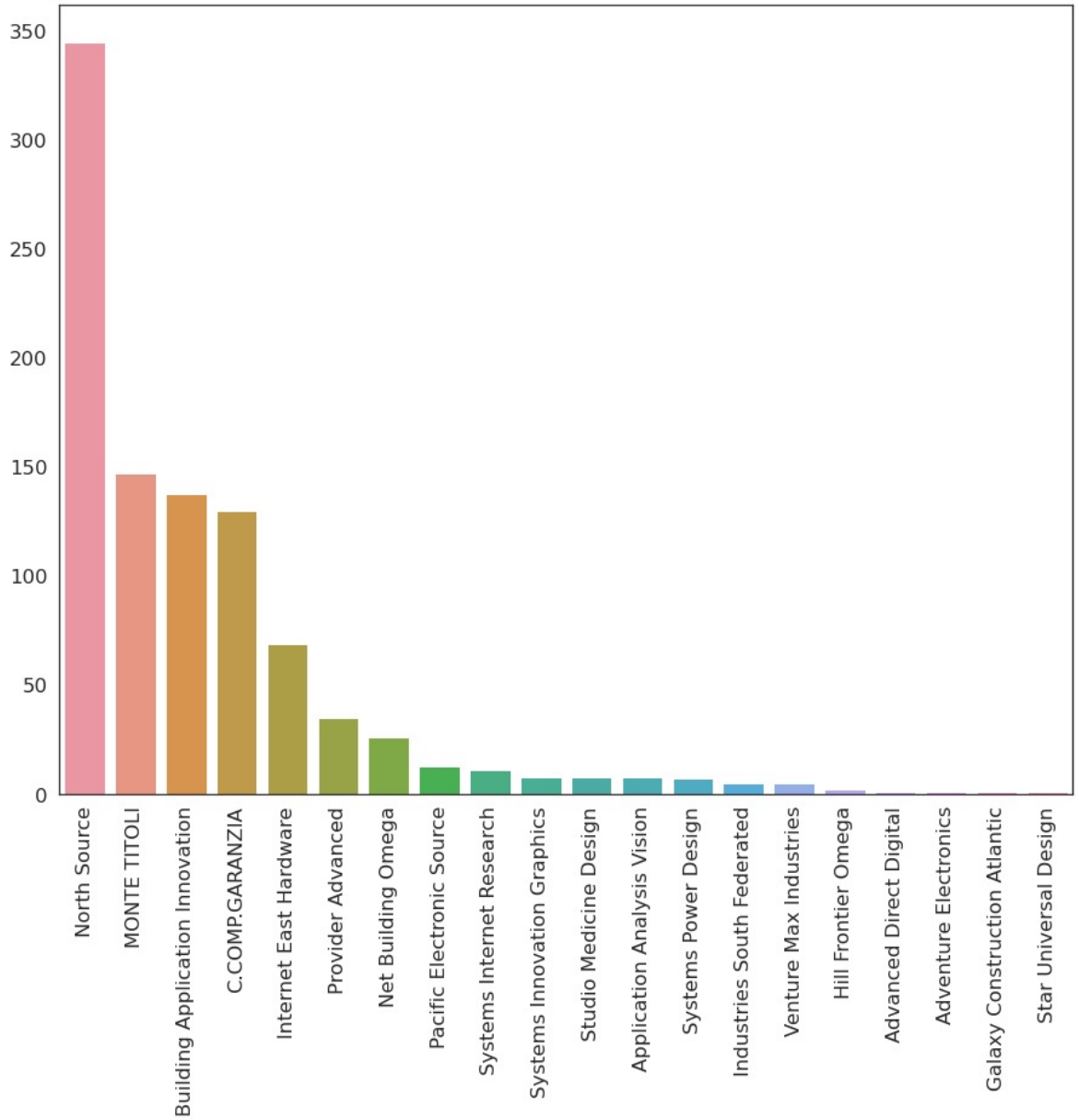
- Scale-free property strongly correlates with the network's robustness to failure:
  - The major hubs are closely followed by smaller ones. These smaller hubs, in turn, are followed by other nodes with an even smaller degree and so on.

- Node deletion approaches are applied:
  - Random Node deletion: a node is deleted randomly form the Network
  - Localized Node deletion: a deletion of a precisely selected node

Node deletion importance - cumulative

- **Central nodes** deletion may alter the structure of the network.

- North Source, Monte Titoli and Building Application Innovation are the central nodes that in most cases, if deleted, would have damaged the network.



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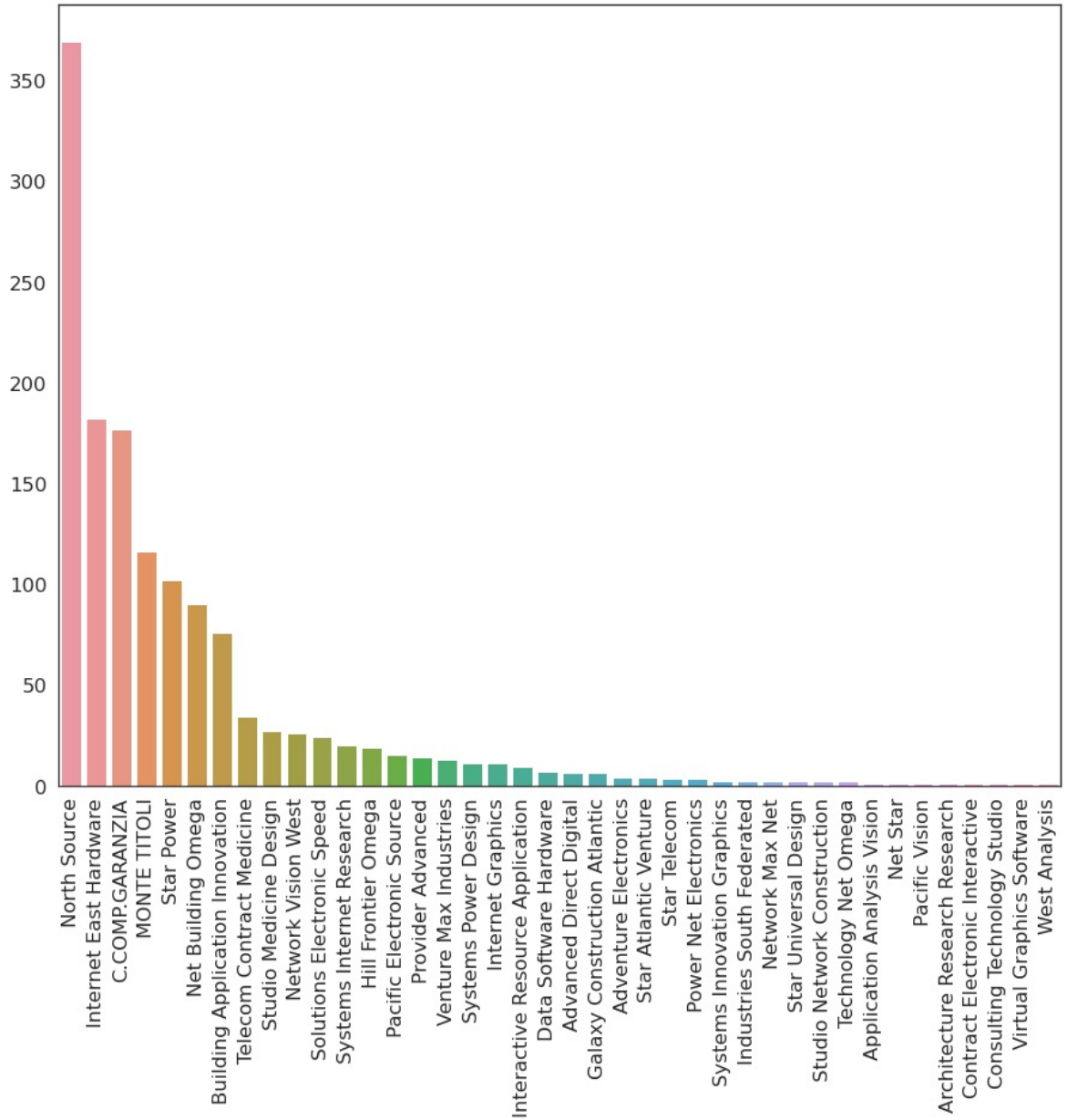
Node deletion importance - monthly

- **Central nodes** deletion may alter the structure of the network.

- North Source, Internet East Hardware and CC&G are the central nodes that in most cases, if deleted, damaged the network.



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Node deletion importance - Literature

- **Paper:** On the topologic structure of economic complex networks: empirical evidence from large scale payment network of Estonia,
- **Comparison** of the node percentage when deleting Central node vs. random removal
- For central nodes results in an initial increase of the **Avg. shortest path length** to finally decrease. Random deletion maintains the measure stable
- For central nodes **size of GCC** is decreasing faster w.r.t. random nodes.

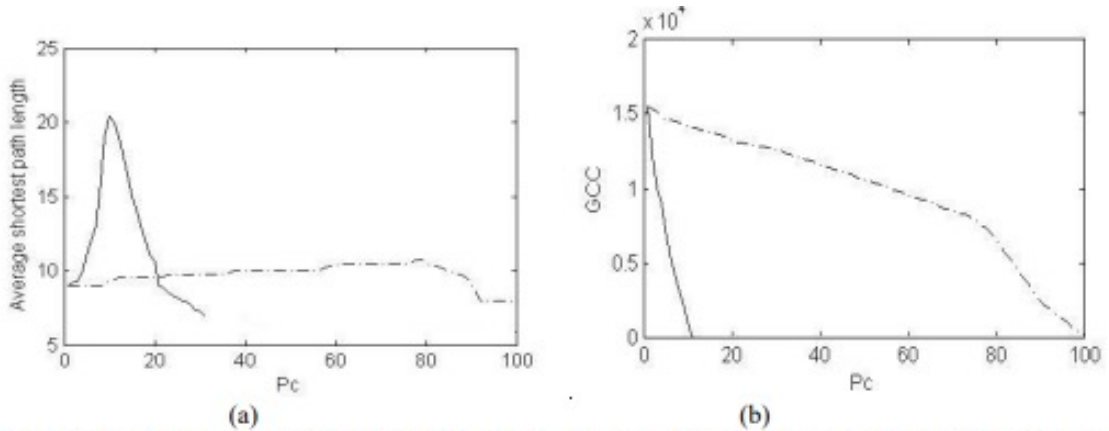
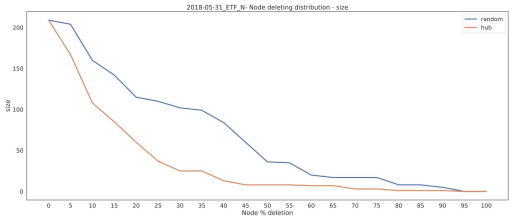
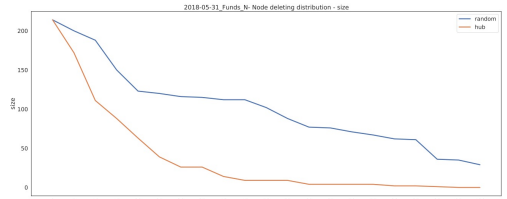


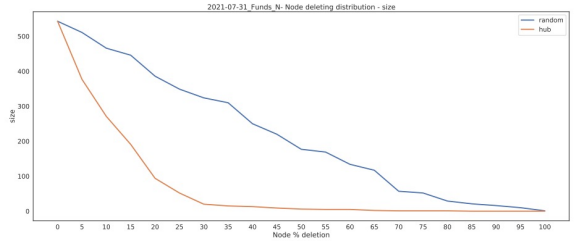
Fig. 7. Plots of the targeted and random damage over the network of payments. (a) The average shortest-path length $< l >$ in the GCC plotted against the percentage of removed nodes. (b) The GCC plotted against the percentage of removed nodes. Continuous lines display the effect of the targeted removal and the dashed lines display the effect of the random removal of nodes. p_c are the percolation thresholds, for each case.

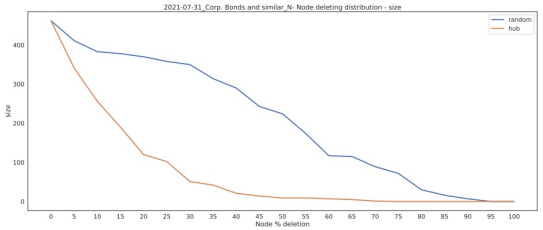
Stephanie Rendón de la Torre*, Jaan Kalda* , Robert Kitt*1, Jüri Engelbrecht* *Institute of Cybernetics at Tallinn University of Technology, Akadeemia tee 21, 12618, Tallinn, ESTONIA 1 Swedbank AS, Liivalaia 12, 15038, Tallinn, ESTONIA

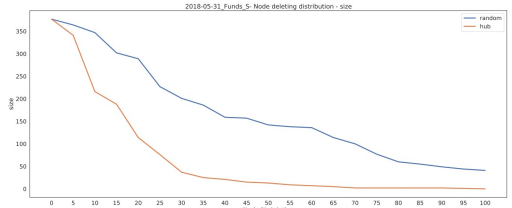
Central node Ranking – Cumulative vs non-cumulative

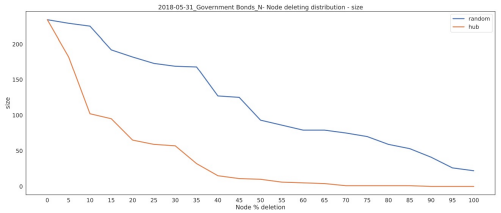


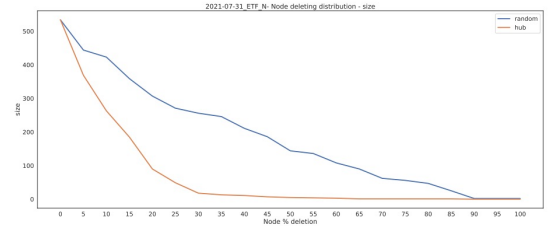


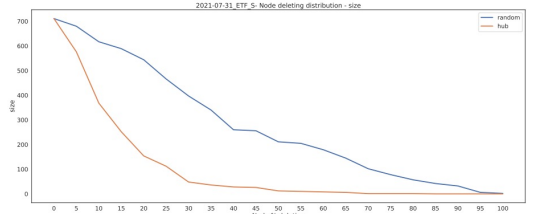


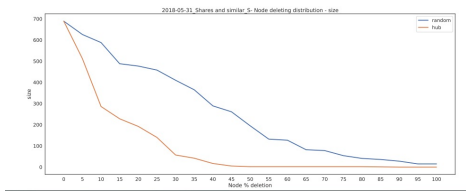


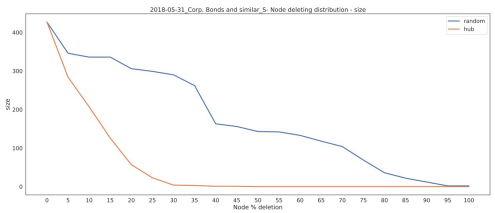


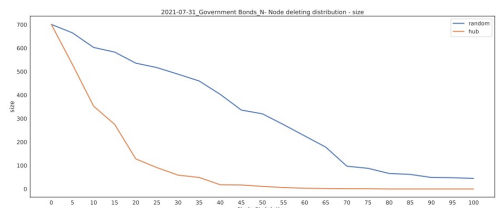


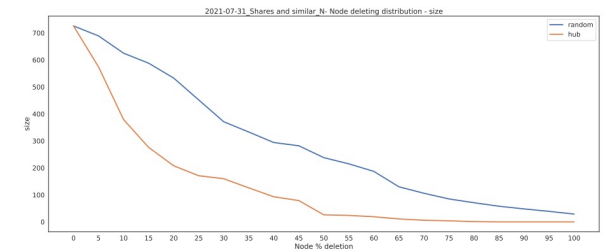


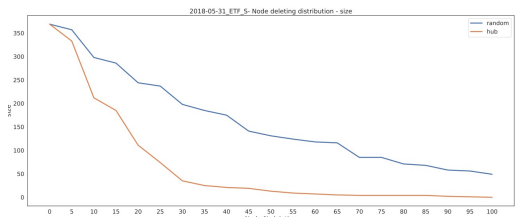


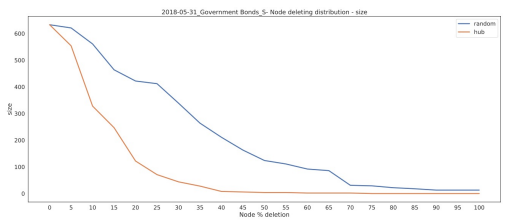


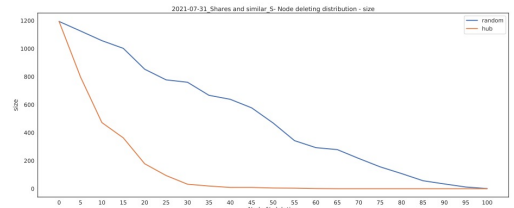


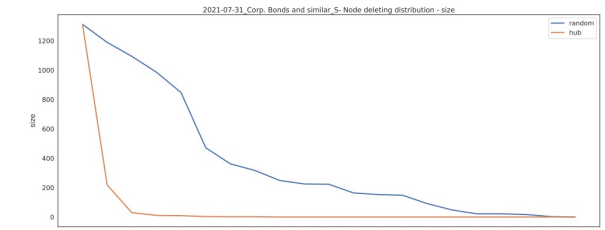


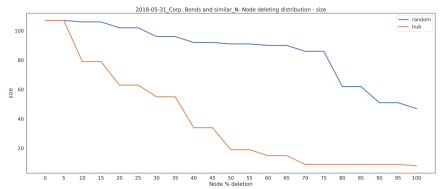


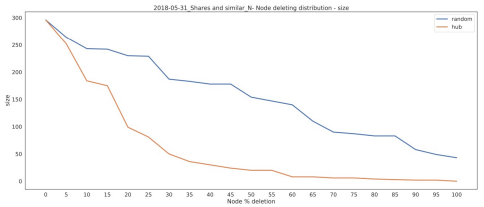


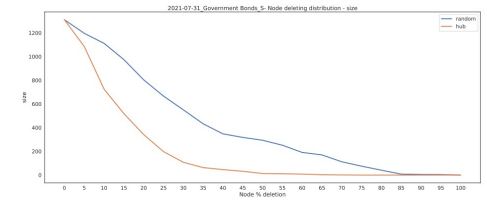


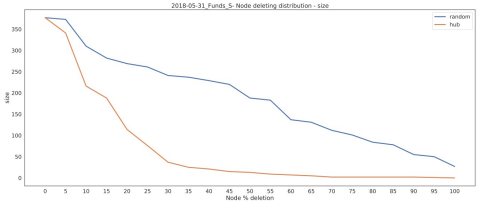






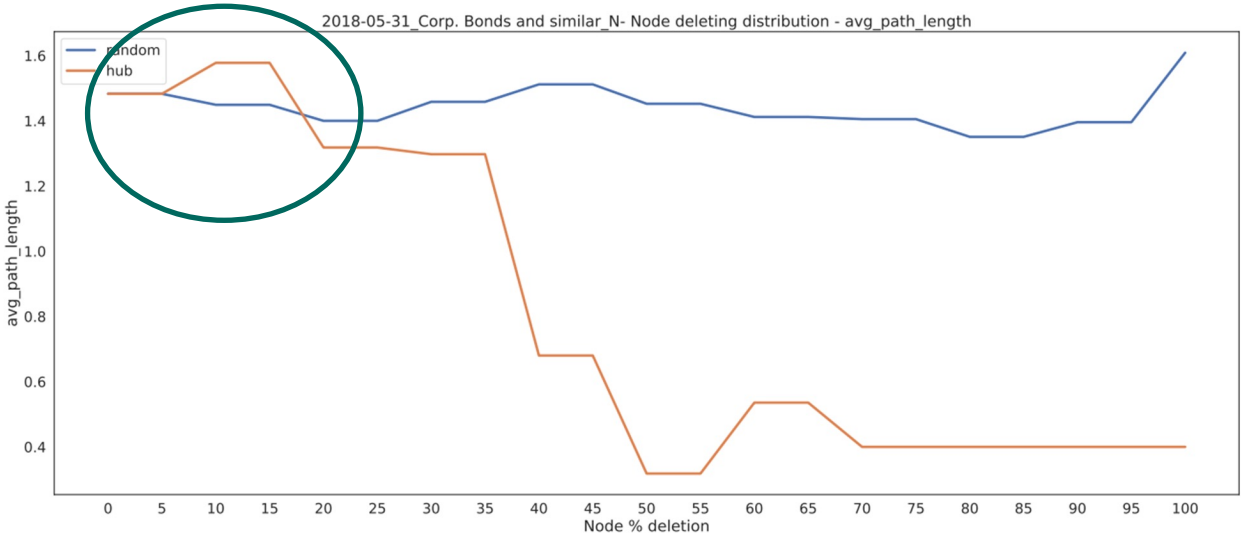


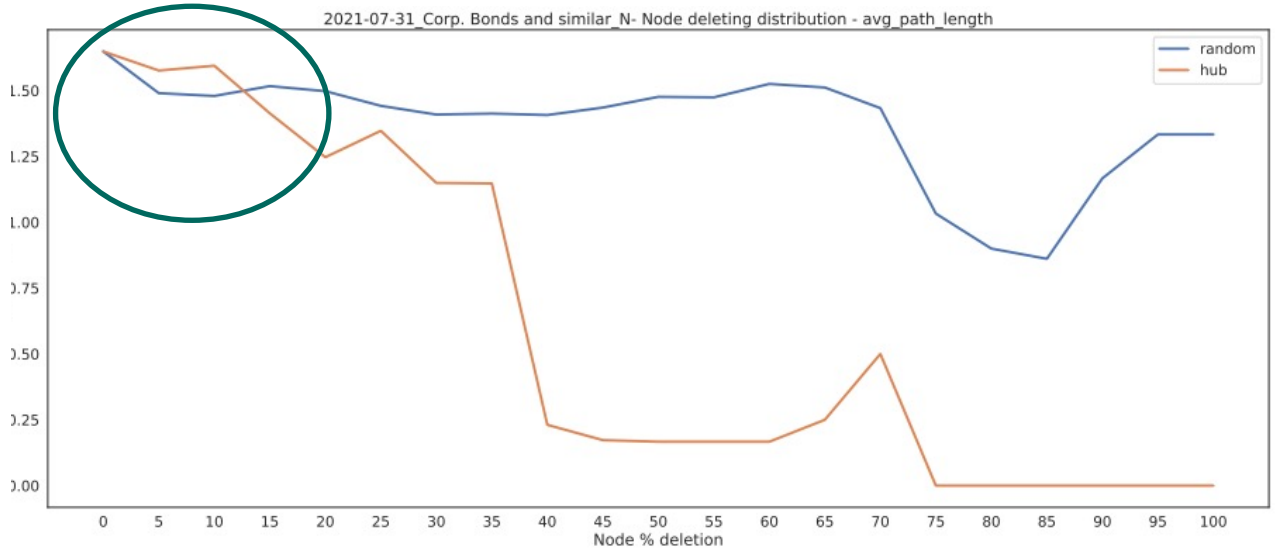




Central node Ranking – Cumulative vs non-cumulative

Corp. Bonds_N





- Initial avg_path_length is increasing, i.e. distance between nodes when hub is deleted is increasing
- After a little growing, the avg path is decreasing fastly
- avg path in Random deletion is stable

- Size of the connected component for Central nodes deletion is faster w.r.t. random deletion

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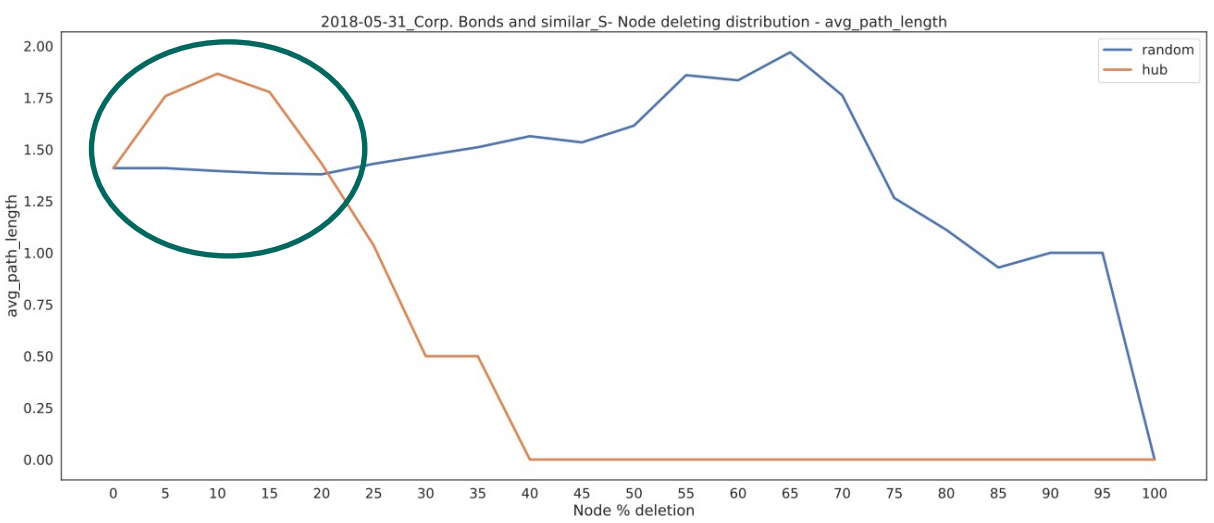
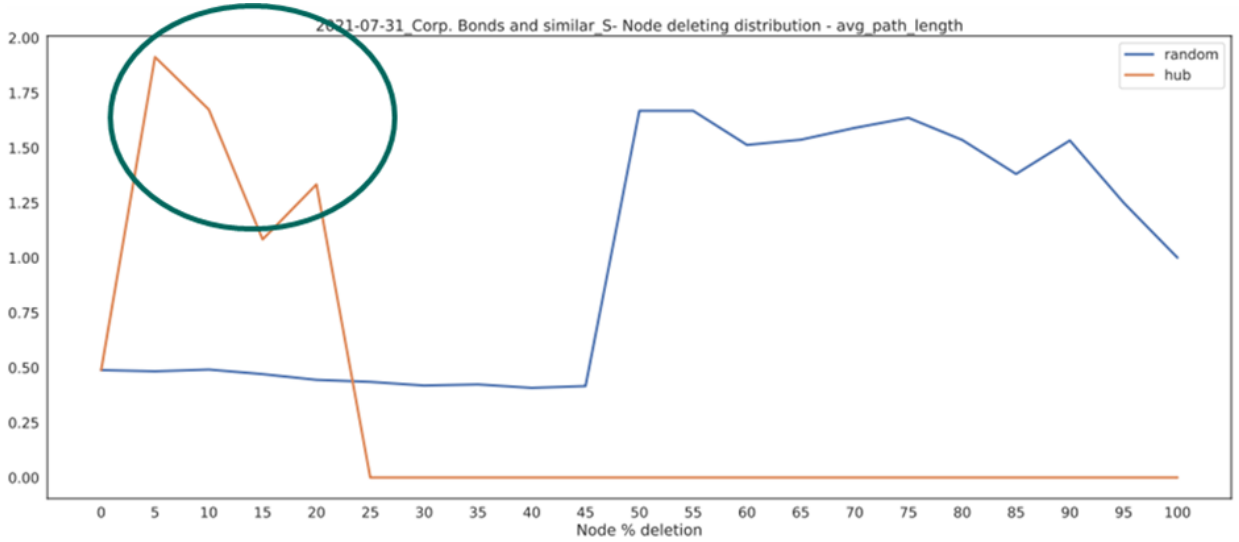
Central node Ranking – Cumulative vs non-cumulative

Corp. Bonds_S





- Initial avg_path_length is increasing, i.e. distance between nodes when hub is deleted is increasing
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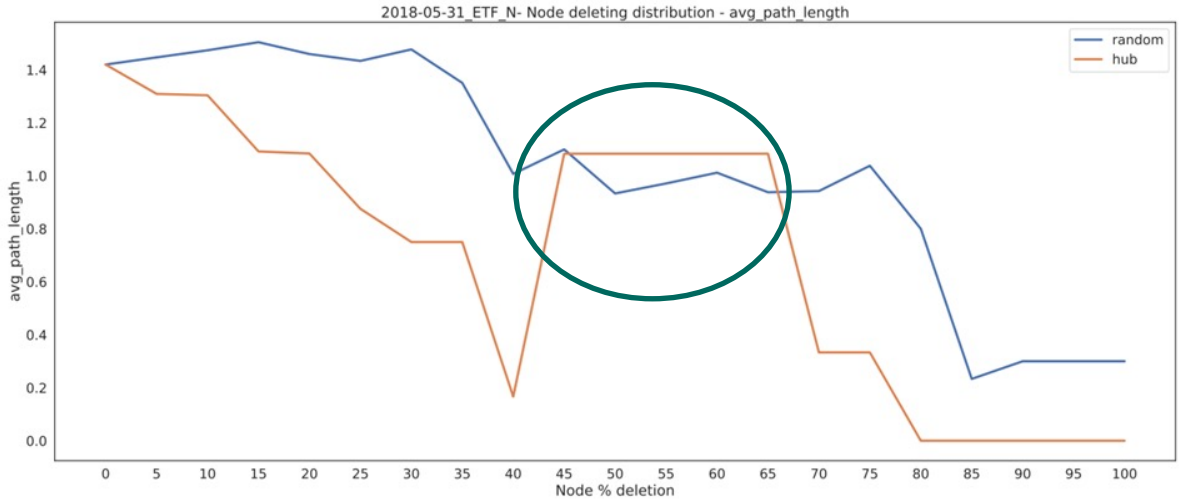
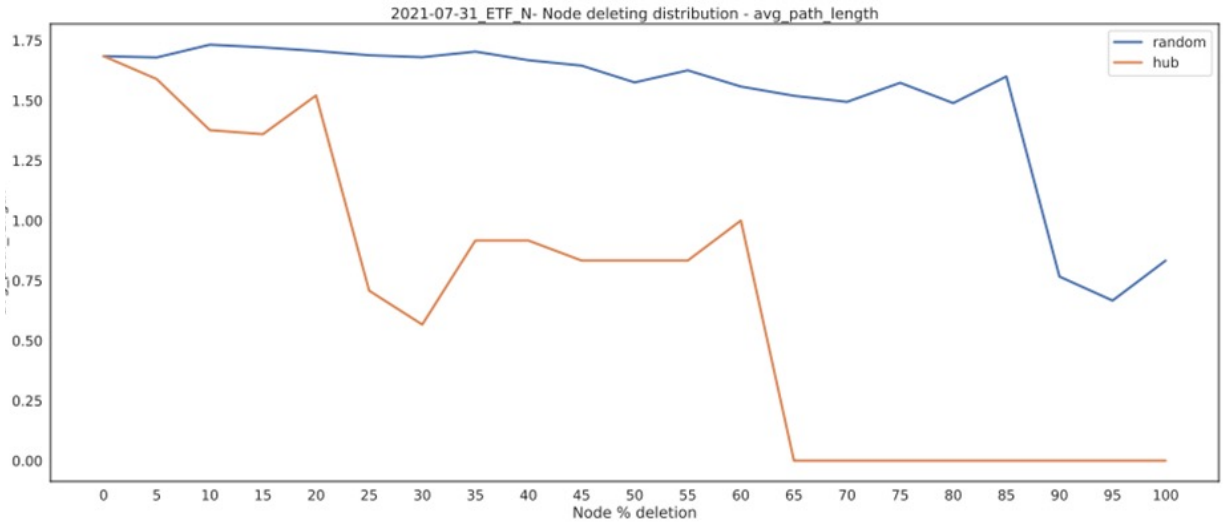
Central node Ranking – Cumulative vs non-cumulative

ETF_N



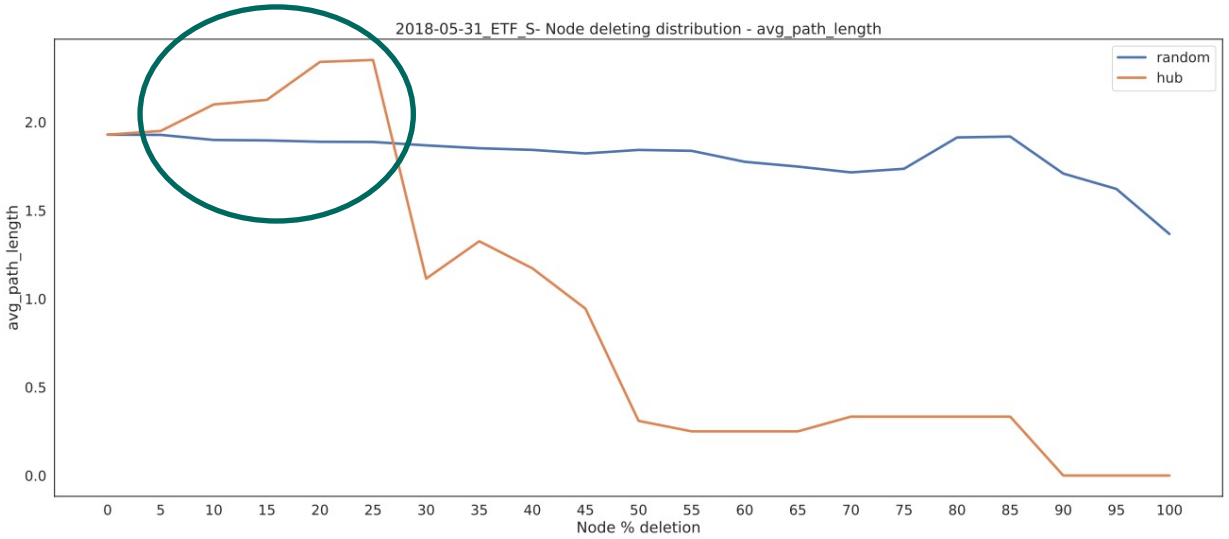


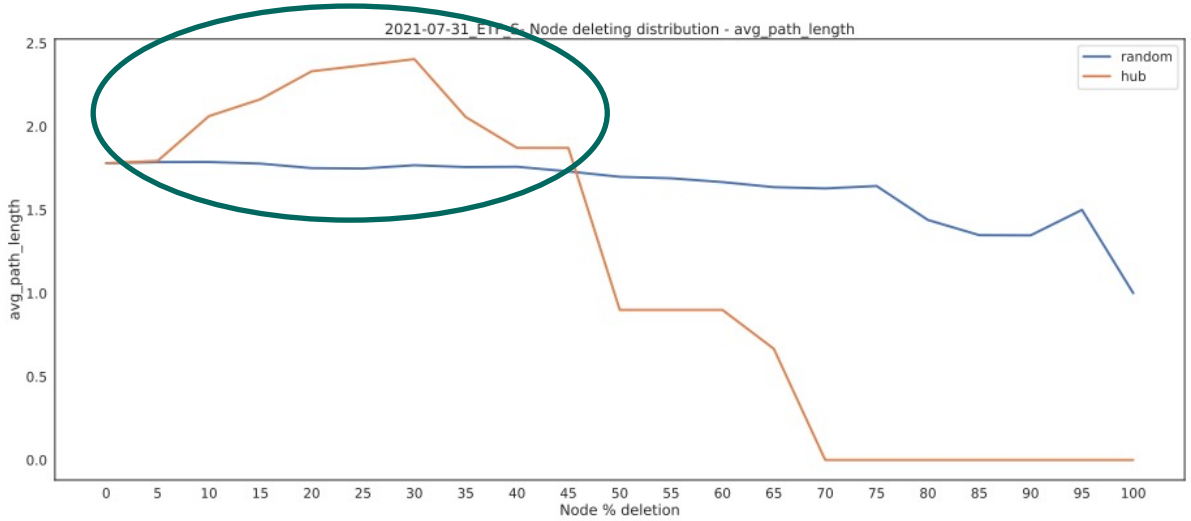
- Initial avg_path_length is decreasing and after some node it increases

- Similar as non-cumulative

Central node Ranking – Cumulative vs non-cumulative

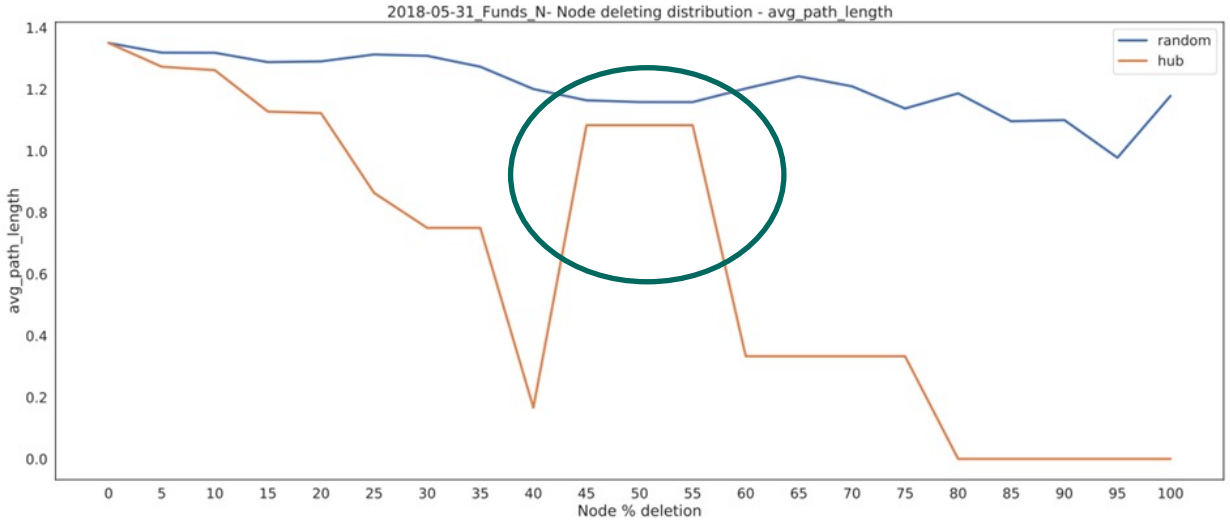
ETF_S

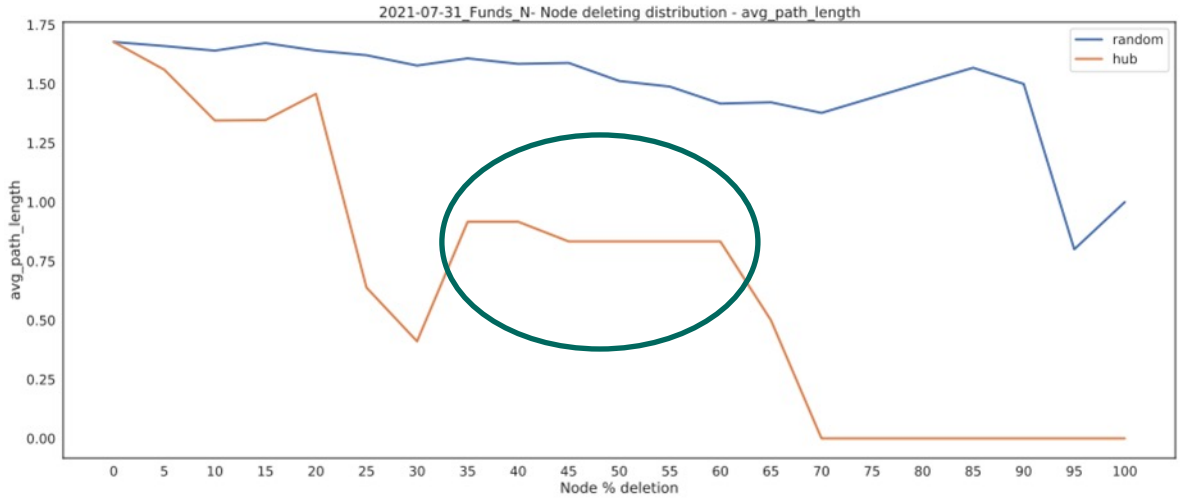




Central node Ranking – Cumulative vs non-cumulative

Funds_N





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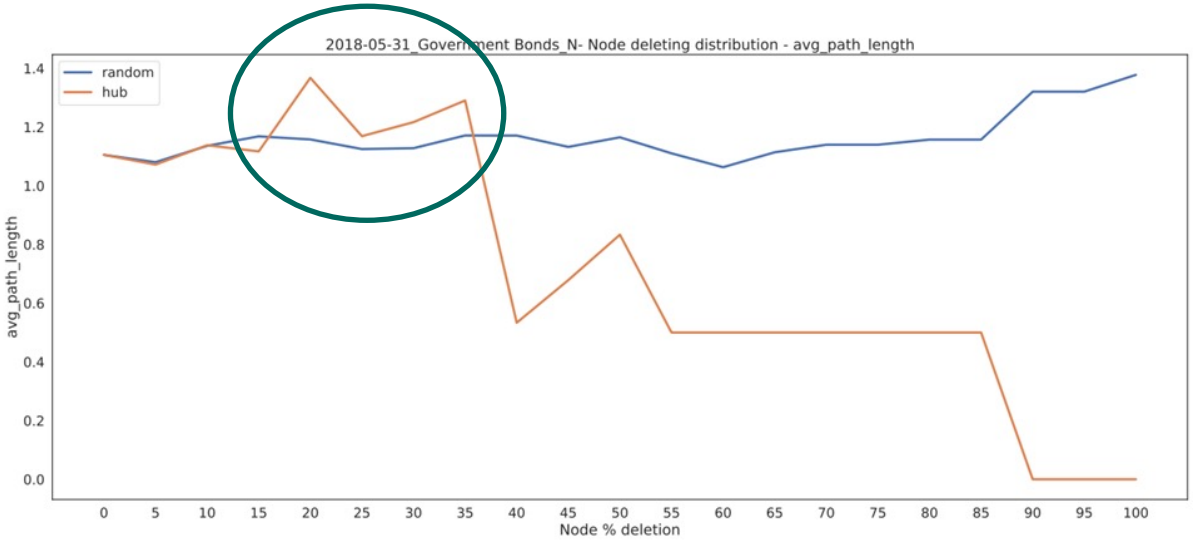
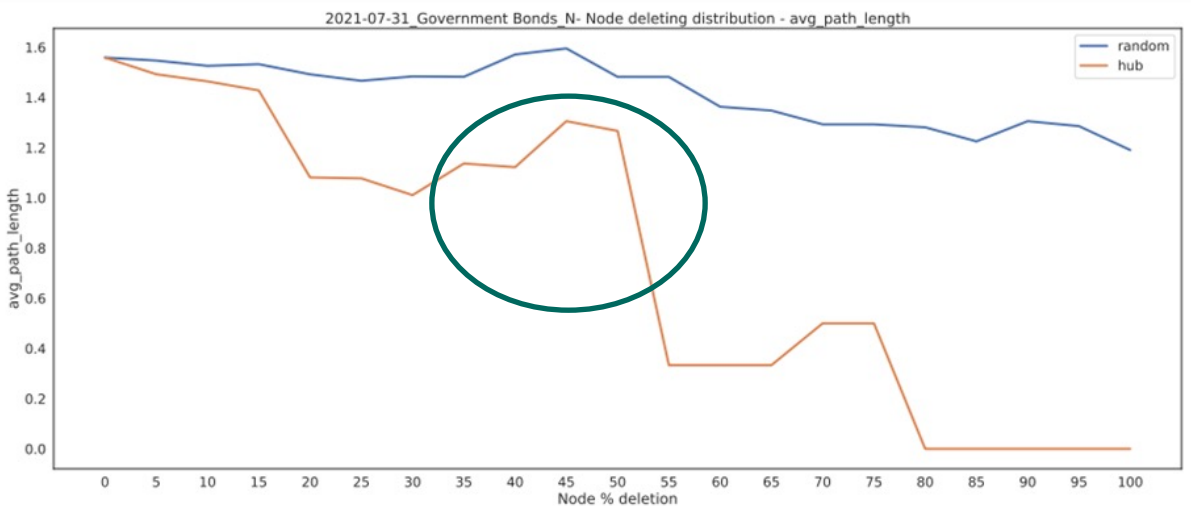
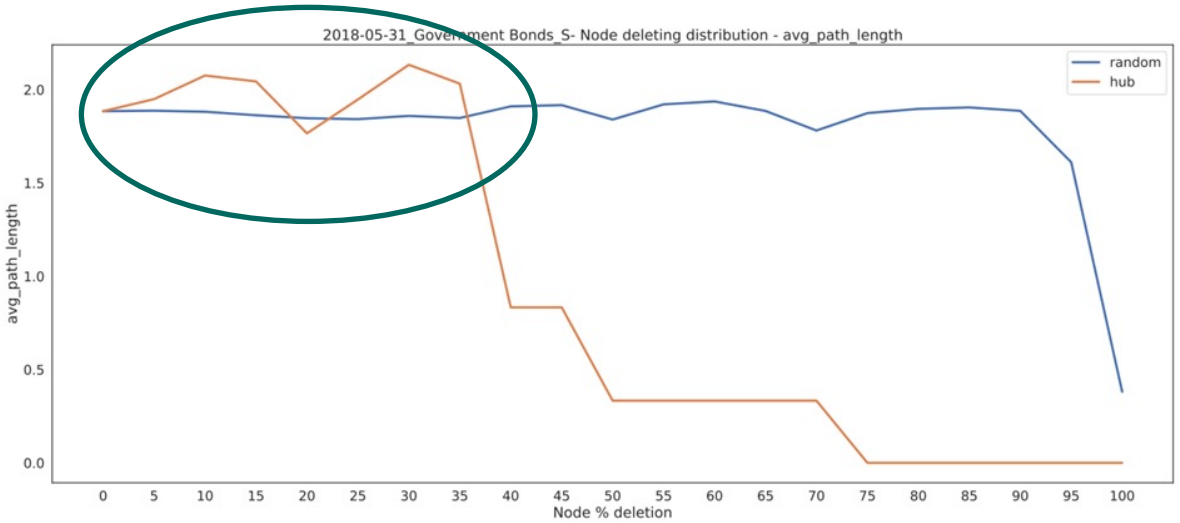
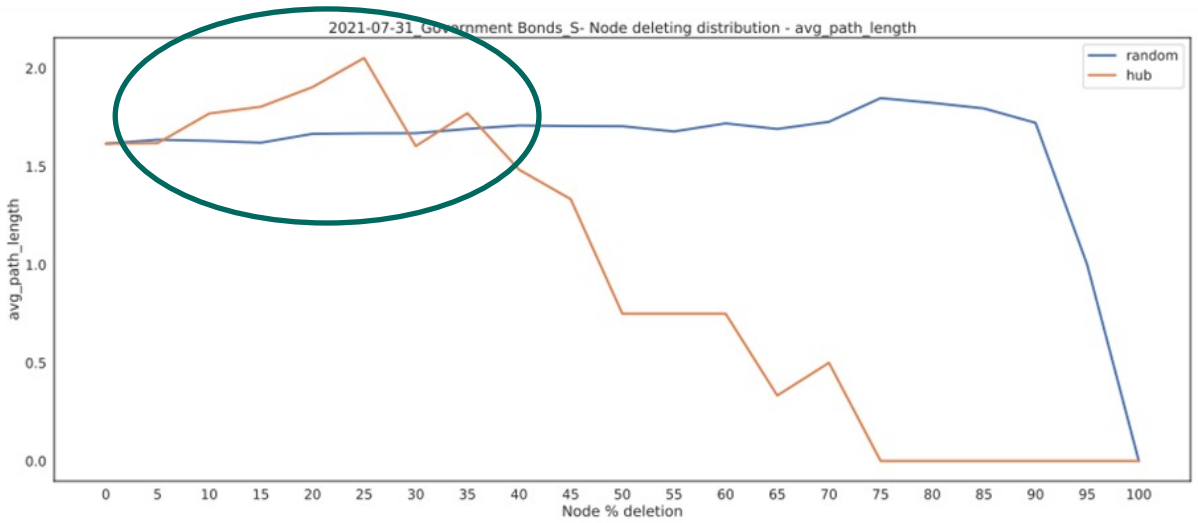
Central node Ranking – Cumulative vs non-cumulative



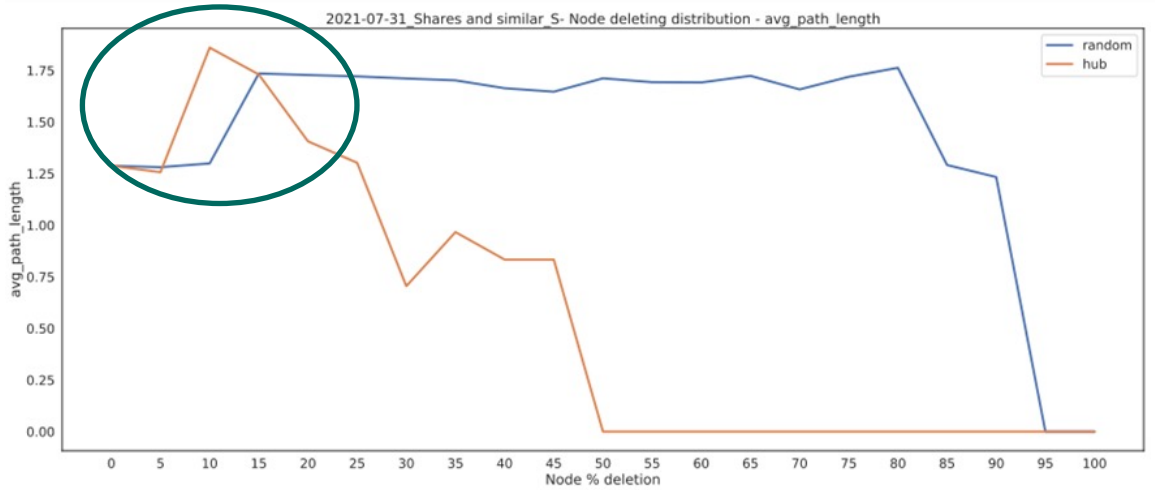


Central node Ranking – Cumulative vs non-cumulative





Central node Ranking – Cumulative vs non-cumulative



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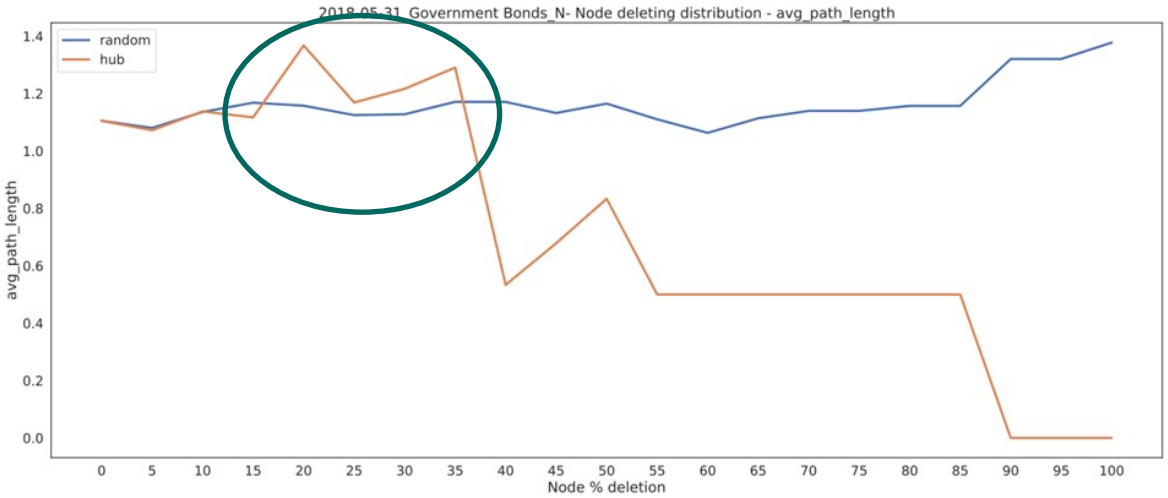
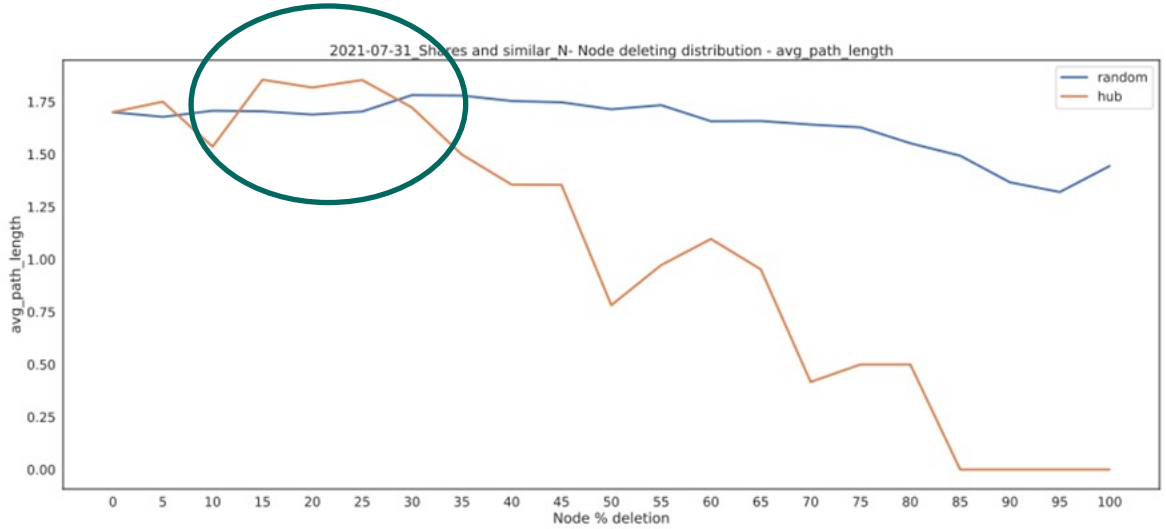
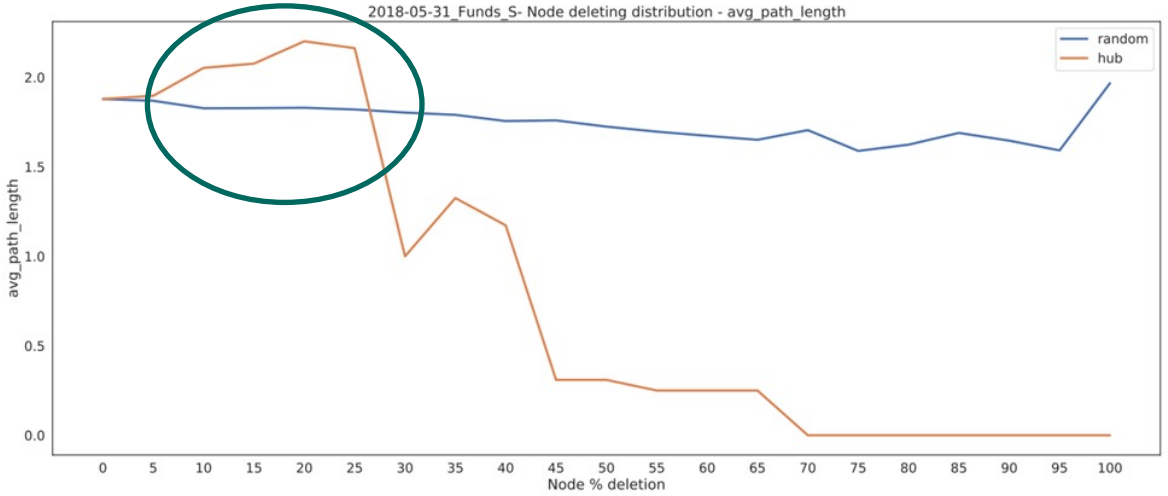
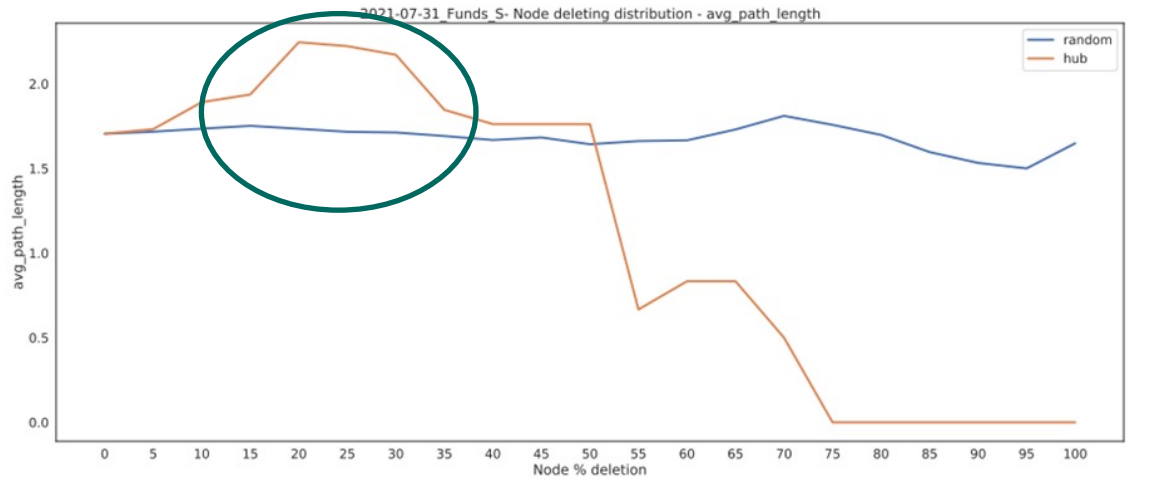
Central node Ranking – Cumulative vs non-cumulative





Central node Ranking – Cumulative vs non-cumulative





Daily Analysis

Two Case-Studies of disruptive events:

- COVID19
- BTP Italia and BTP futura emissions

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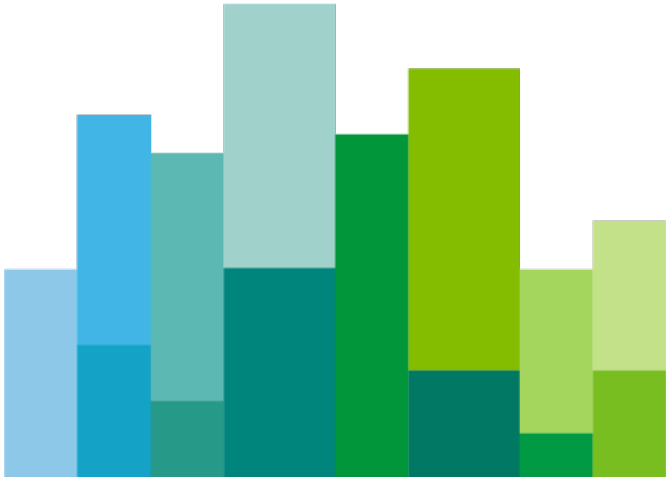


Disruptive Events

- Disruptive Events could reversely change the Network topology and structure.
- Events such as the September 11th 2001 terrorist attack have shown how this event can alter economics systems. In this case the Financial systems of the USA have been disrupted.

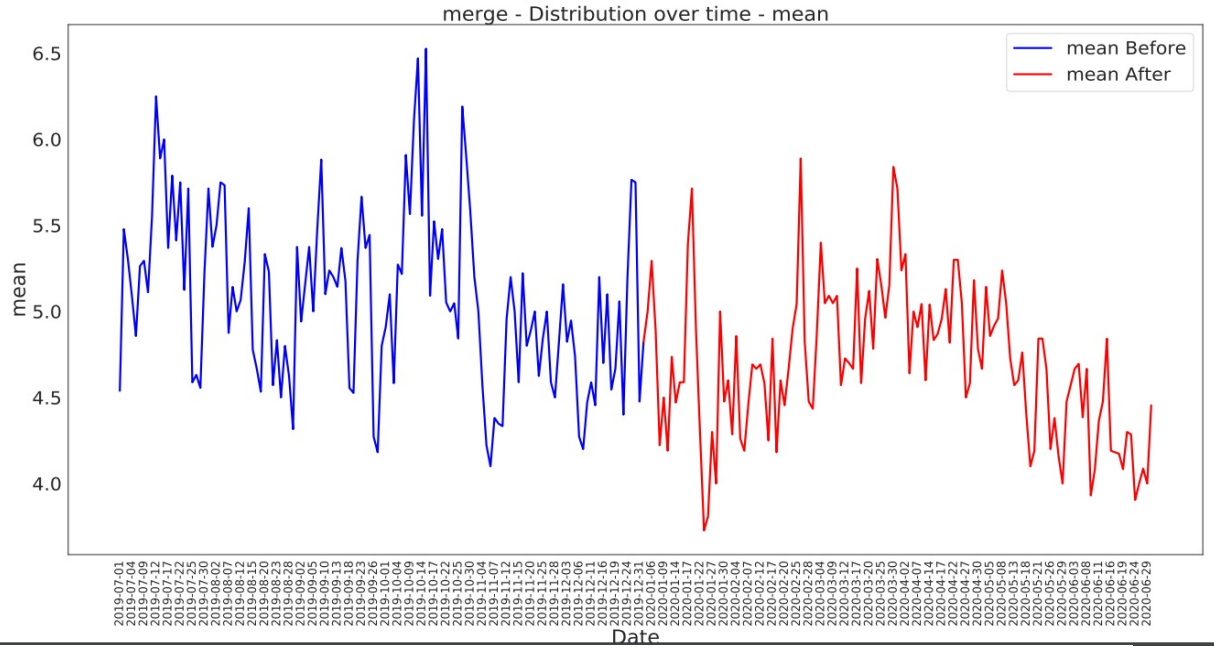
- **Two** different **case-studies** of disruptive events:
  - The **impact of Covid19** on the network metrics and topology during the first lockdown:
    - Period from January 2020 to June 2020
  - The **impact of large emission of BTP** Italia and BTP Futura:
    - The analysis takes into consideration the next ten days after the BTP announcement.
    - This is considered a disruptive event since large amount of instructions are exchanged during the emission dates.

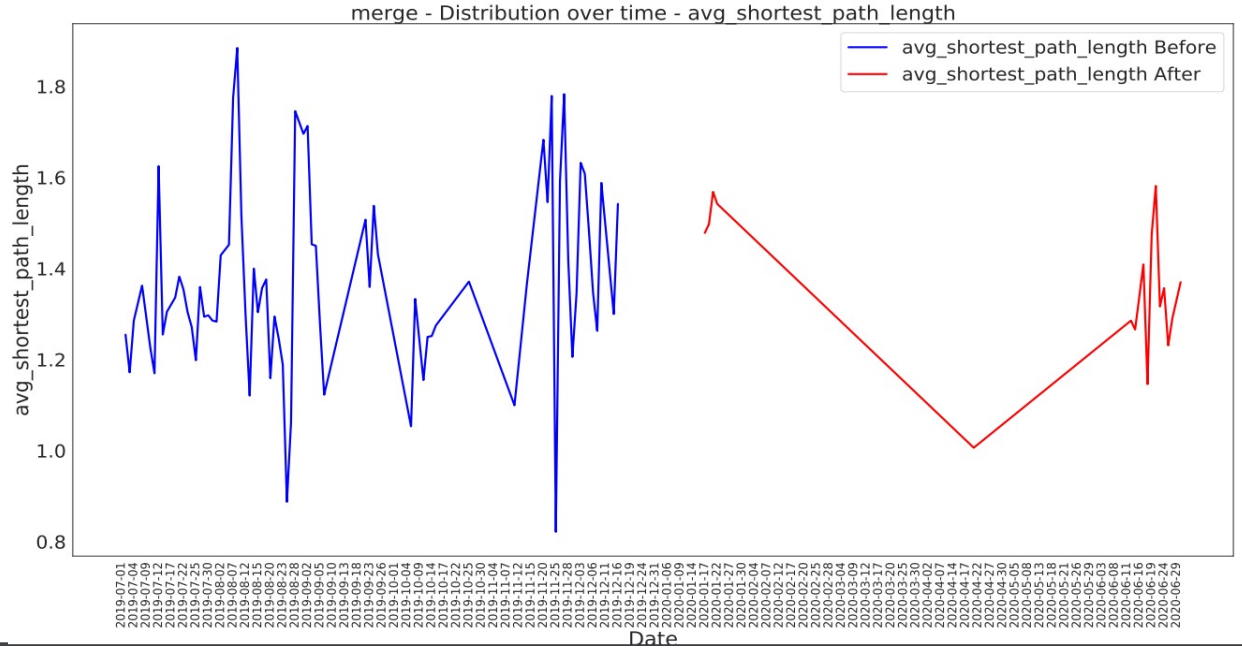
Case study: Covid 19 Effects

- **Impact of Covid19** on the network metrics and topology during the first lockdown
- The idea is obtaining daily networks of 6 month before the first lockdown and compare the connection and the size of the networks over time

- **Dates:** date are from 01-06-2019 to 01-06-2020
- **Before Covid19** period: 01-06-2019 to 31-12-2019
- **After Covid19** period: 01-01-2020 to 01-06-2020

Before and After Covid19 : Corp. Bonds and similar_N





- Mean degree appears to decrease during the lockdown

- Avg. shortest path length is unstable before Covid19 and then it is not computable:
  - The network is no more strongly and weakly connected
  - There are node that are isolated and a path length that tends to infinity

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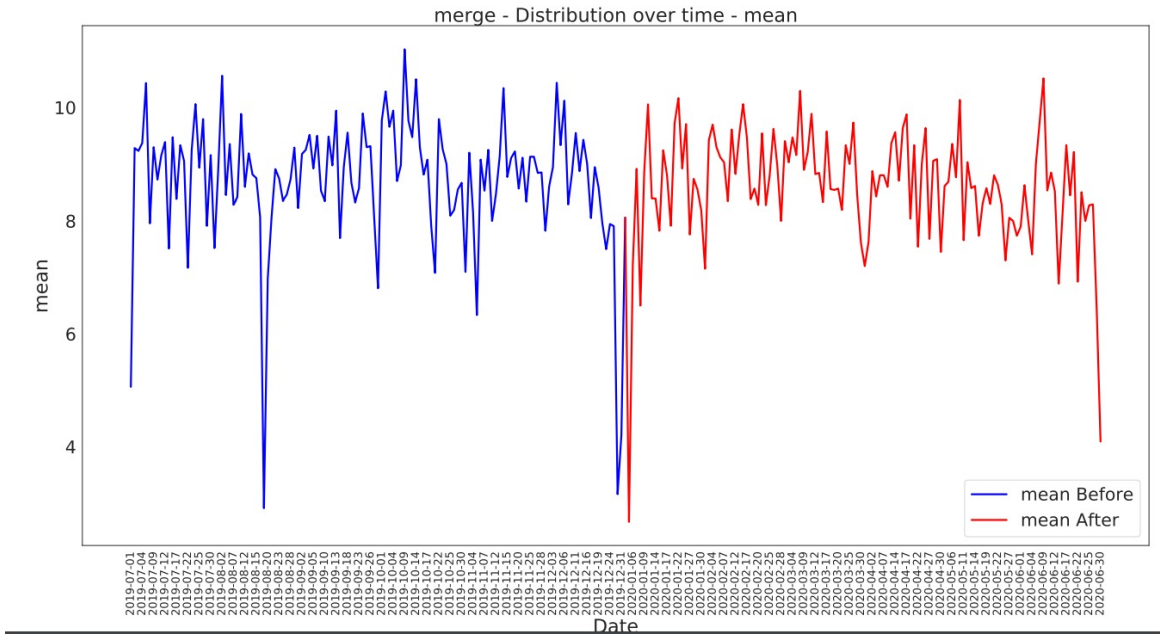
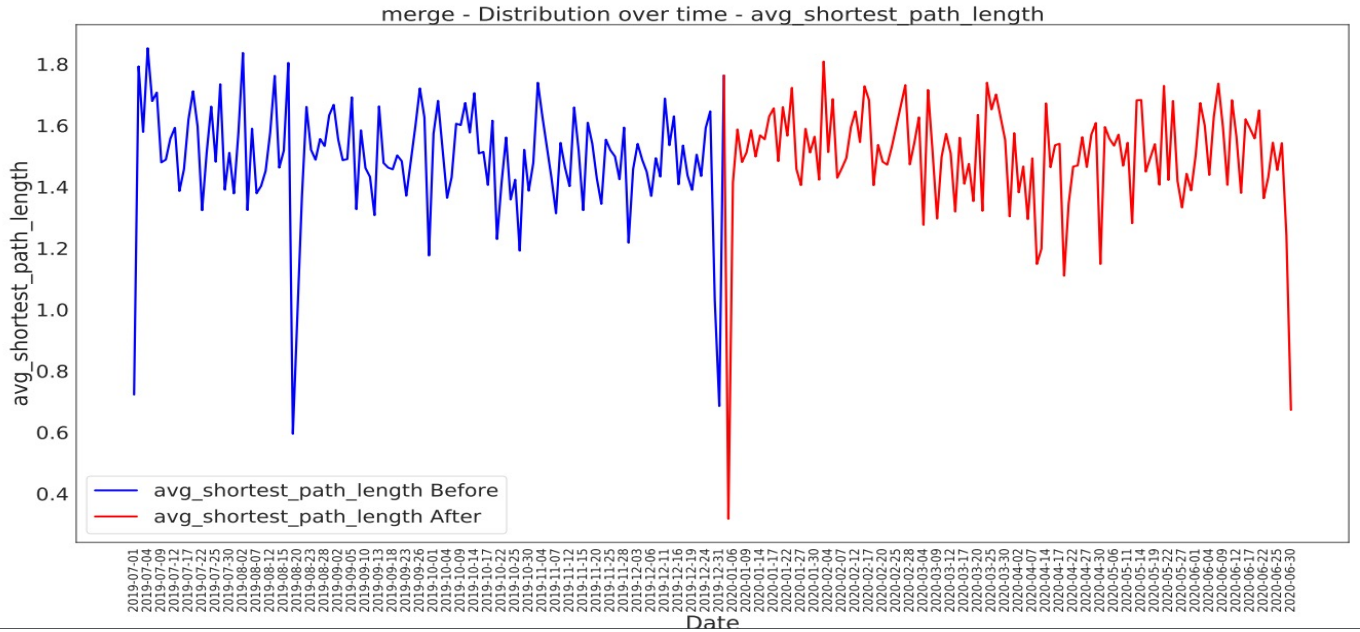
Before and After Covid19 : Corp. Bonds and similar_S





- Mean degree appears to be stable over time before and after Covid19

- Avg. shortest path length is stable over time

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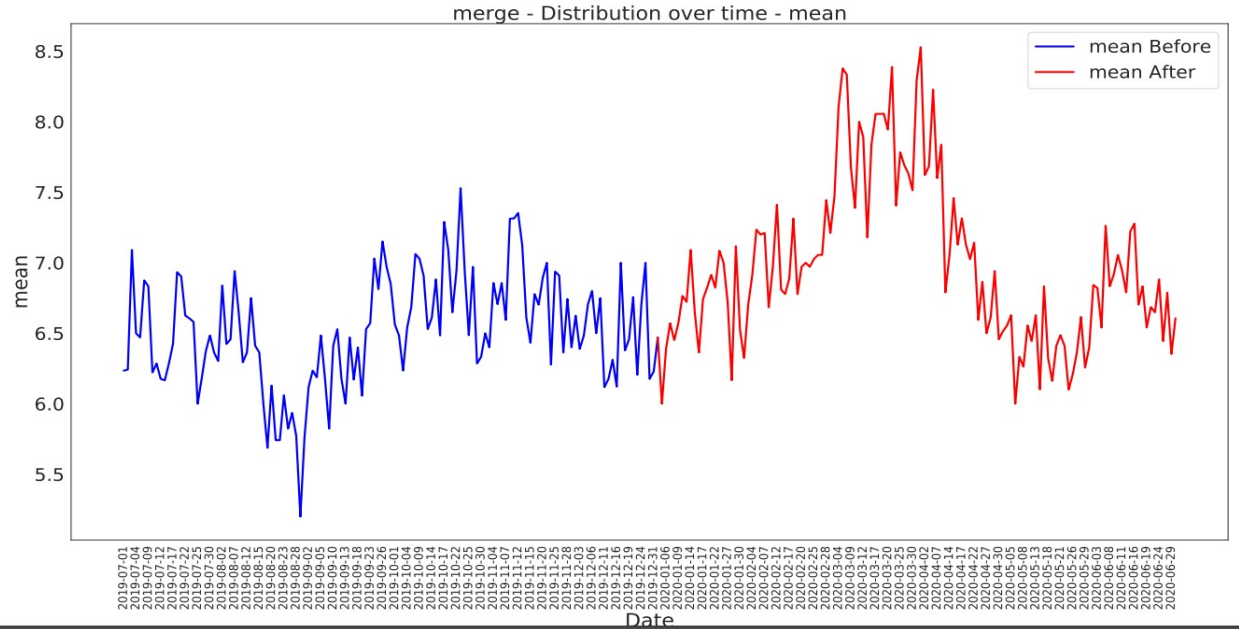
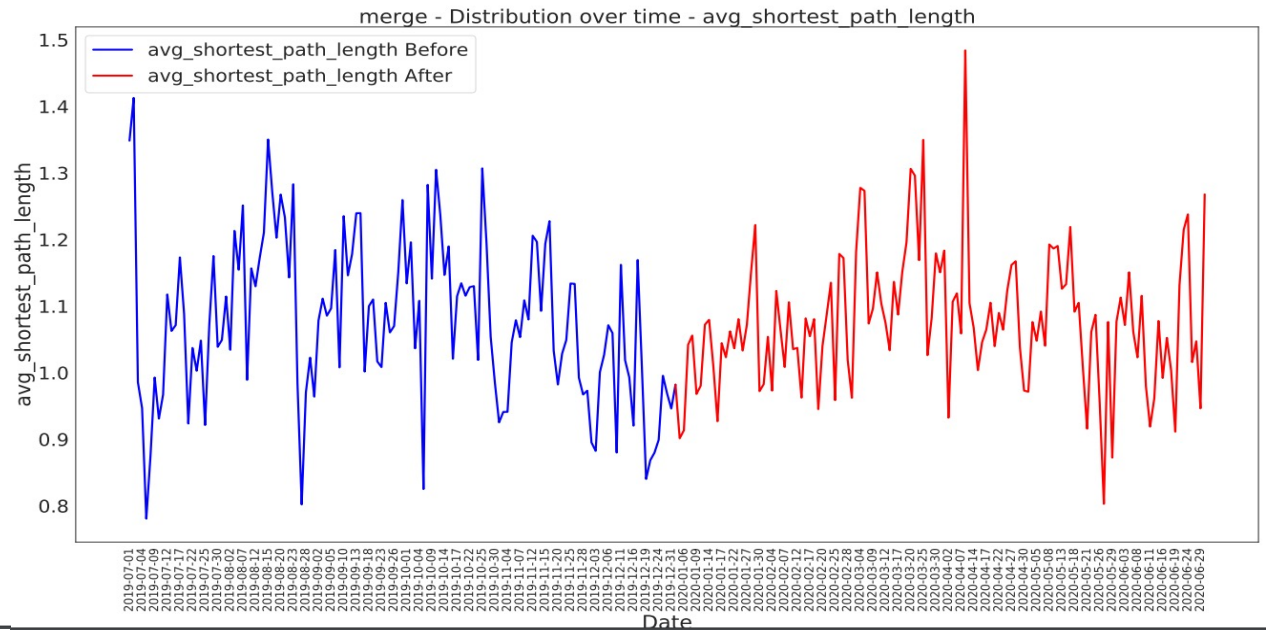
Before and After Covid19 : ETF_N





- Mean degree appears to increase during the lockdown

- Avg. shortest path length is unstable before and after Covid19.
- There is a spike on April 2020

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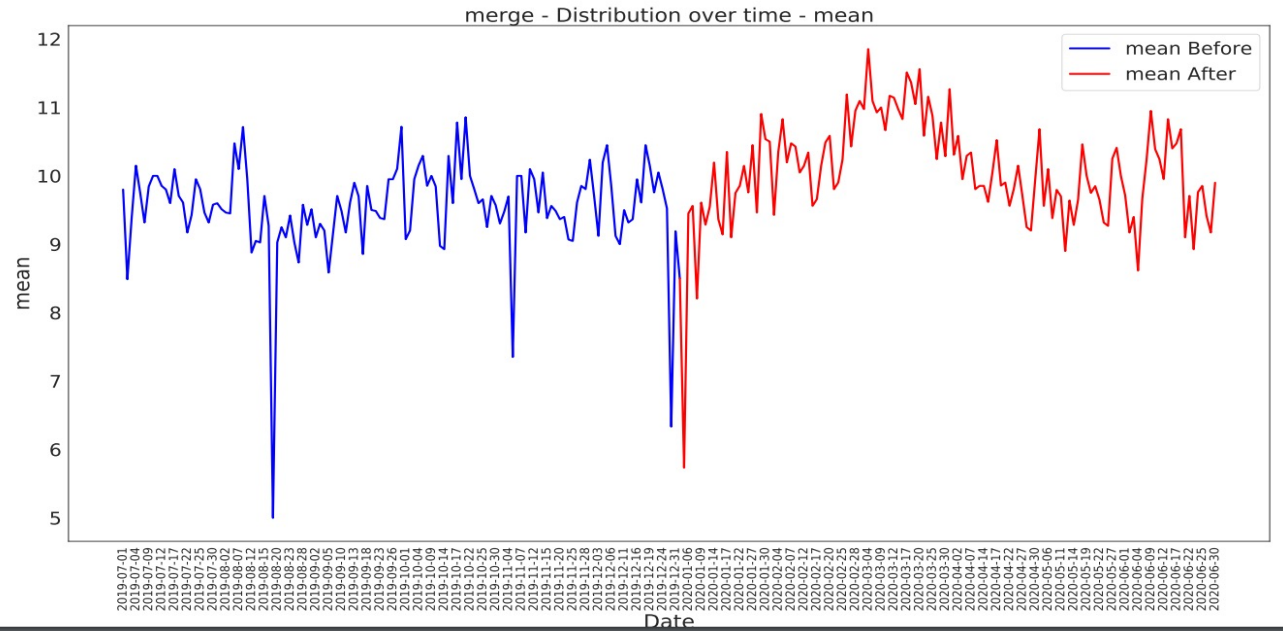
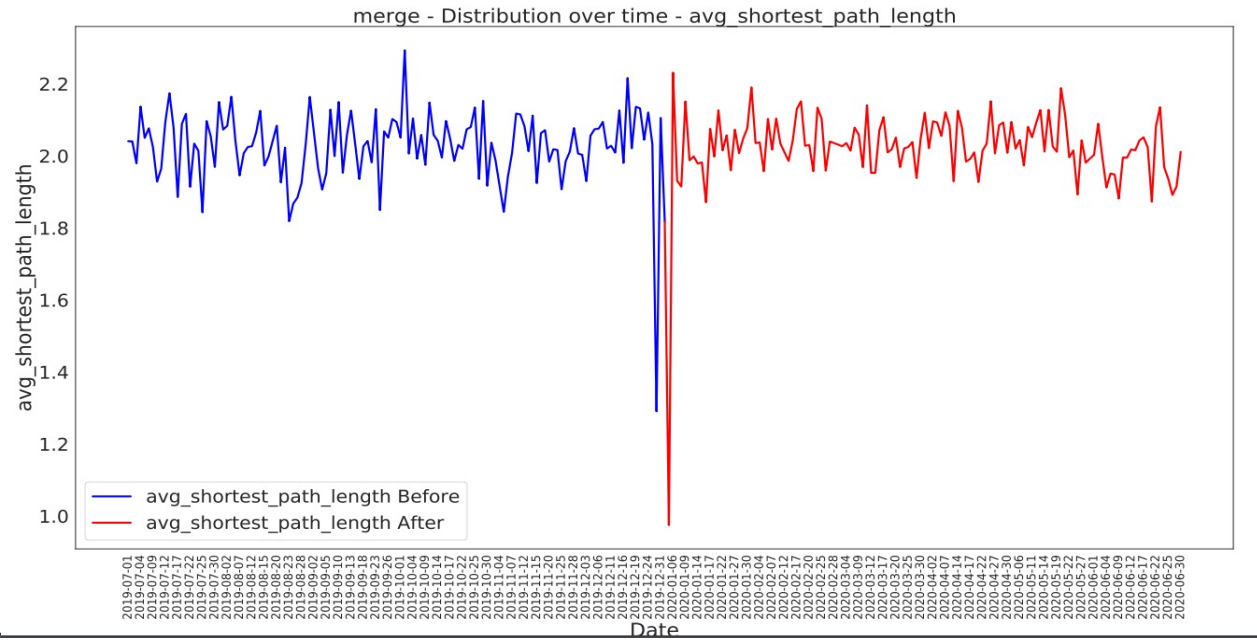
Before and After Covid19 : ETF_S





- Mean degree appears to slightly increase during the lockdown

- Avg. shortest path length is stable before and after Covid19

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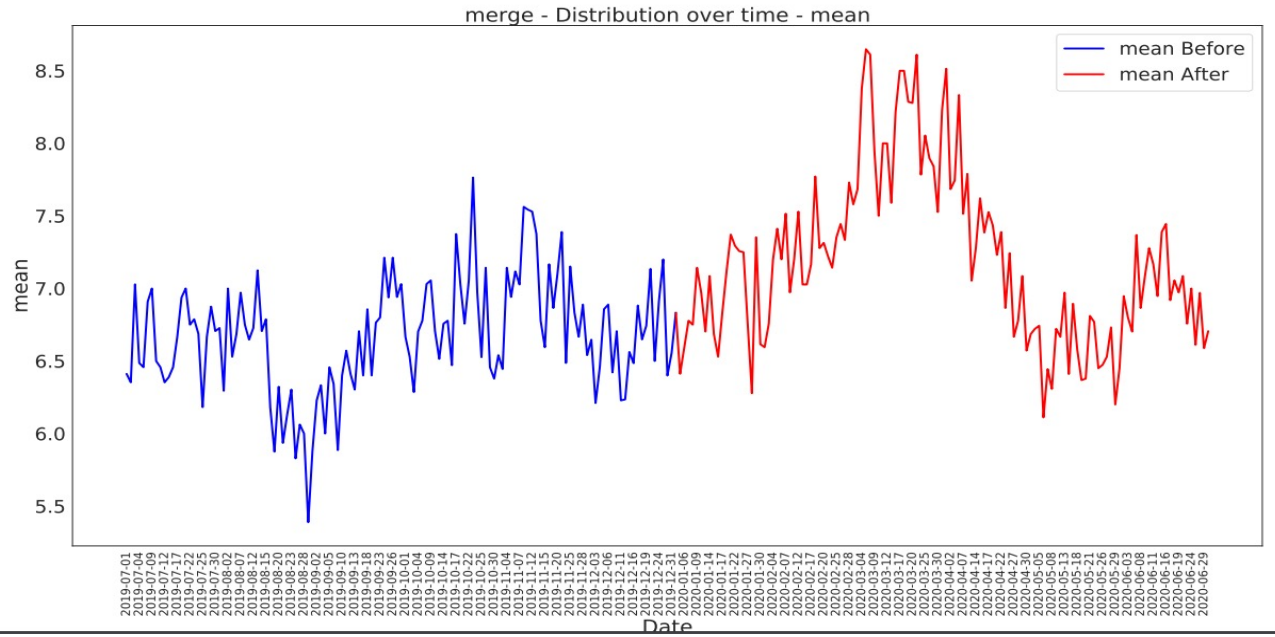
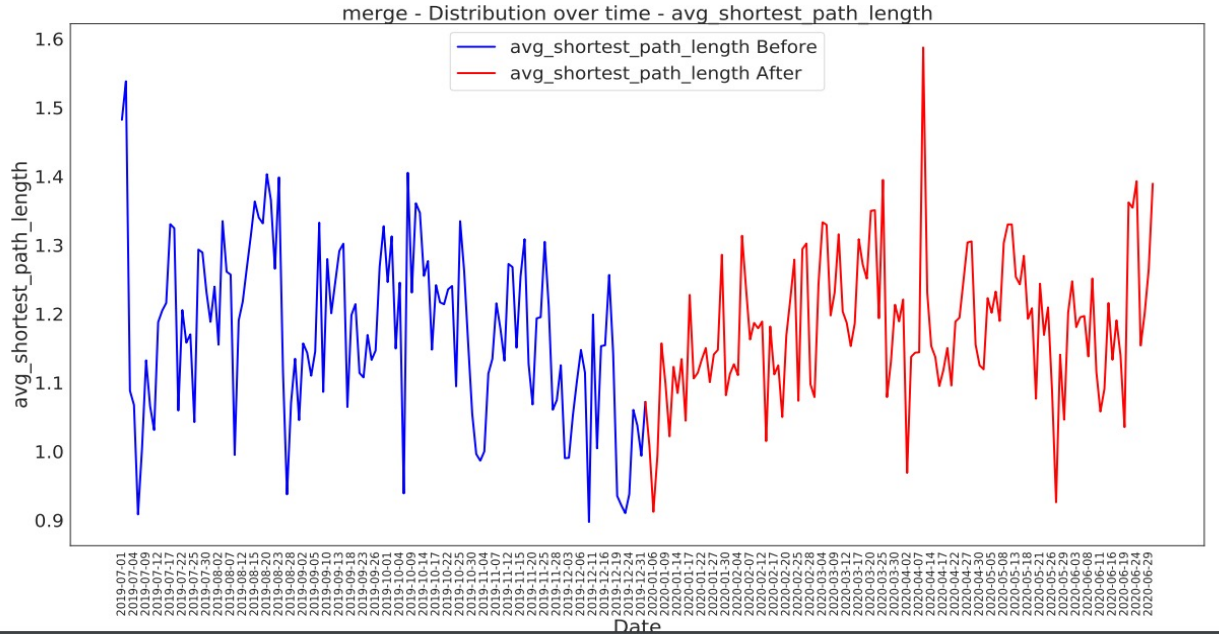
Before and After Covid19 : Funds_N





- Mean degree appears to increase during the lockdown

- Avg. shortest path length is unstable before and after Covid19
- Spike in April 2020

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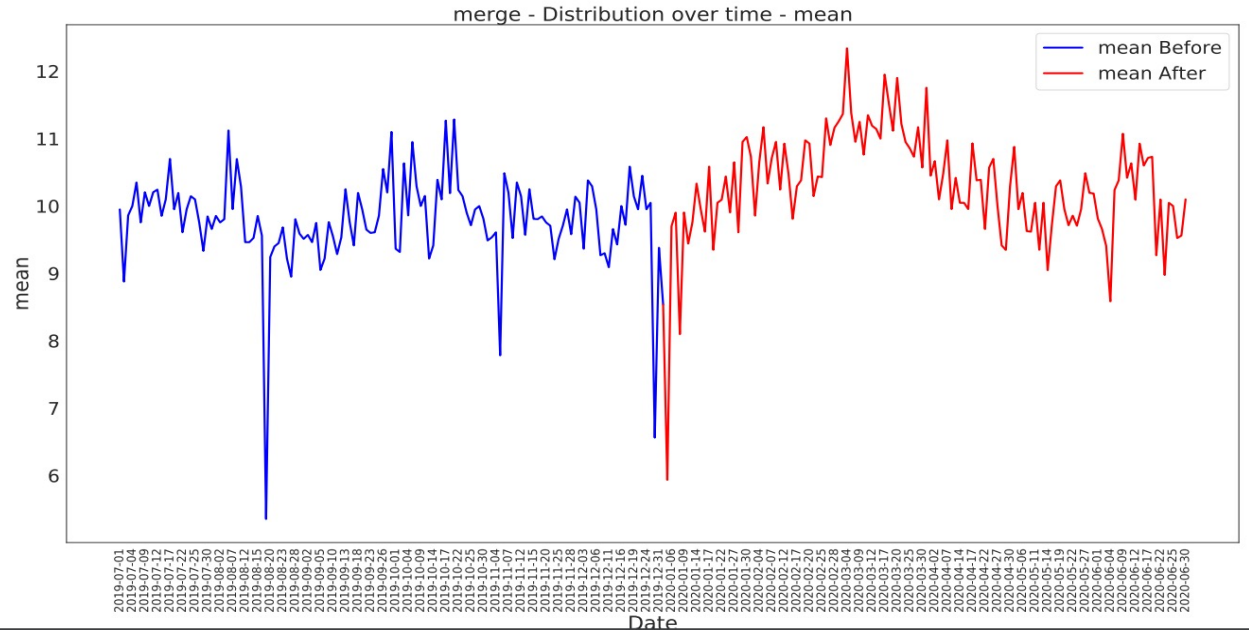
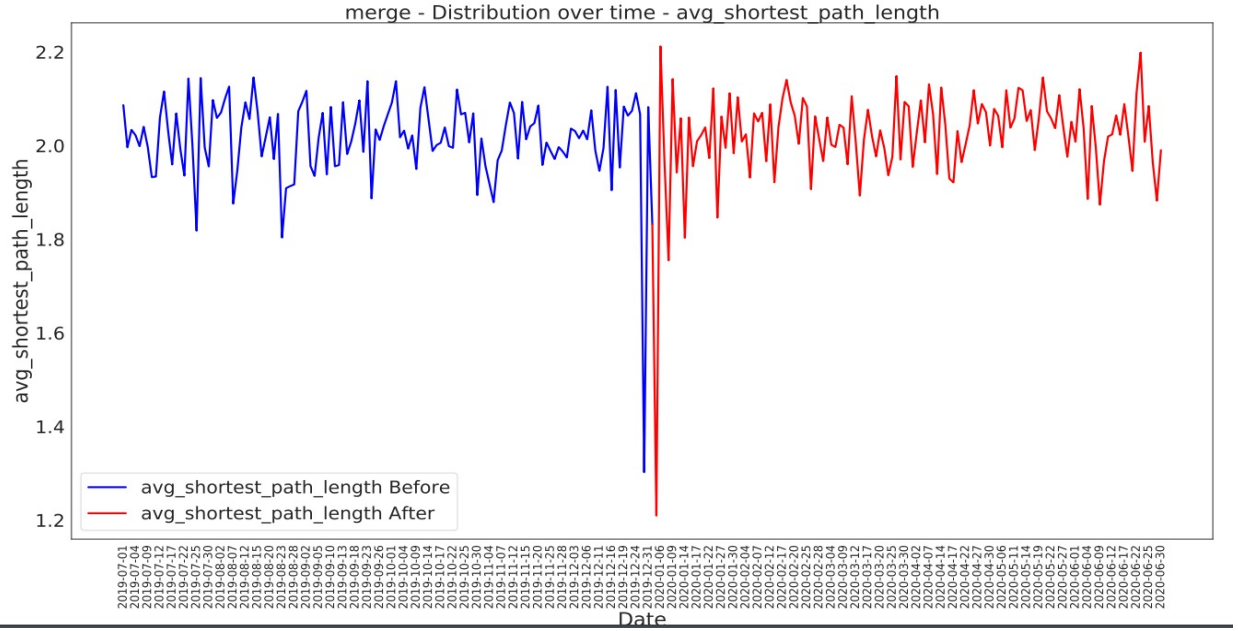
Before and After Covid19 : Funds_S

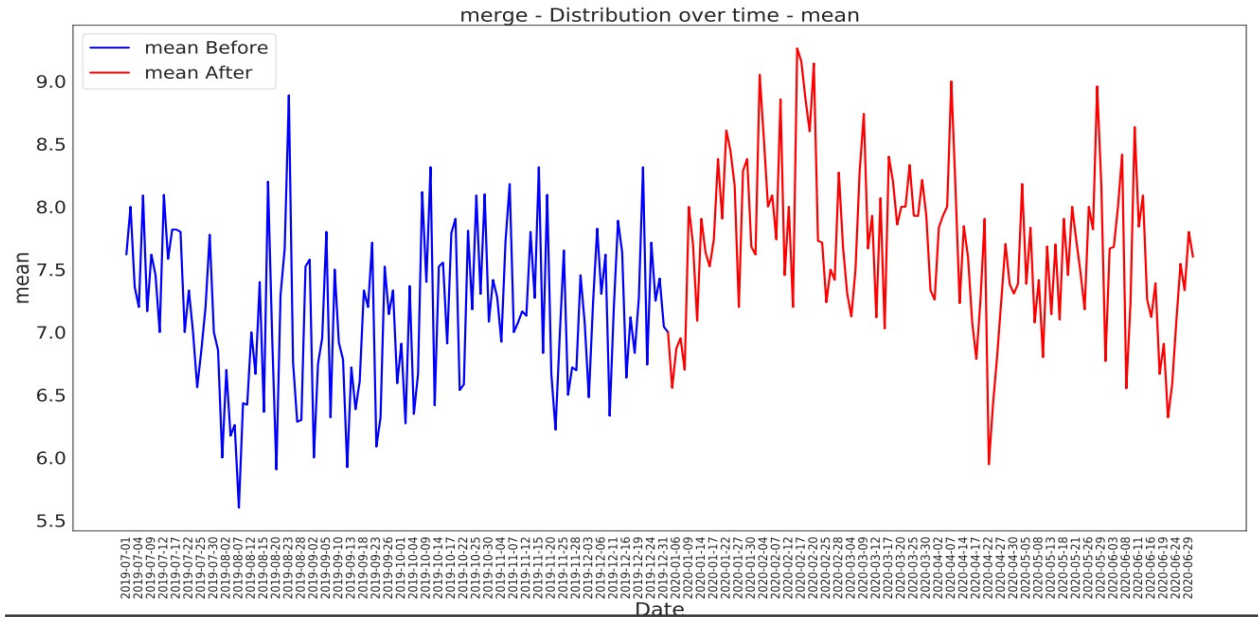


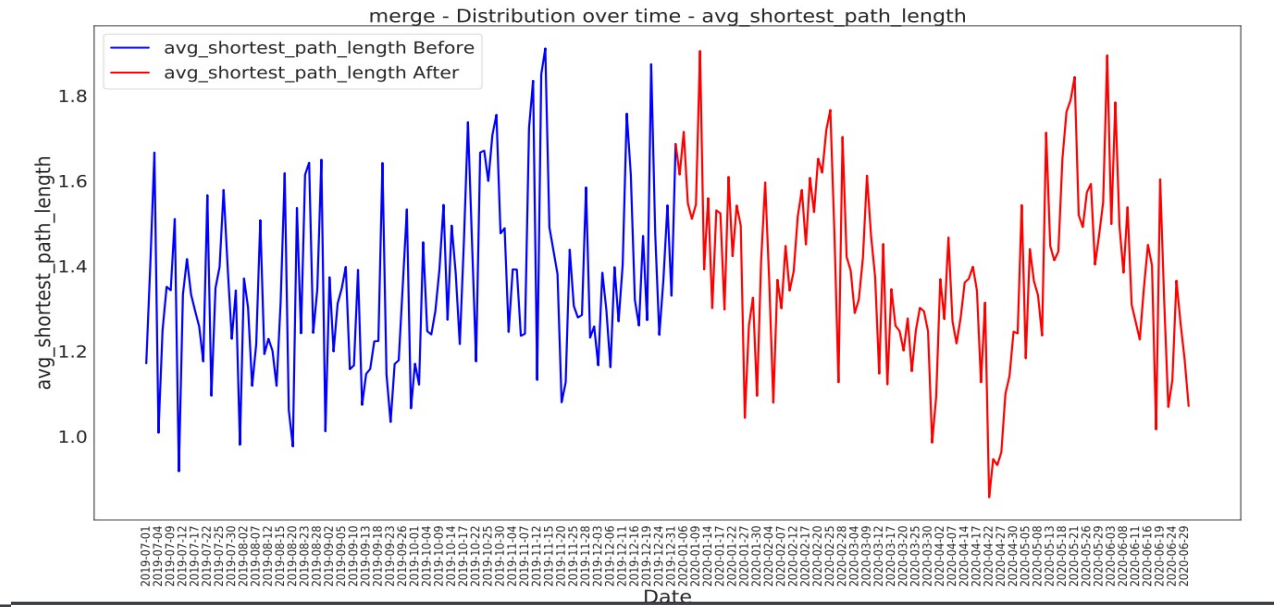


- Mean degree appears to slightly increase during the lockdown

- Avg. shortest path length is stable before and after Covid19

Before and After Covid19 : Government Bonds_N





- Mean degree appears to increase during the lockdown

- Avg. shortest path length decreased on April 2020, but then it increases after Covid

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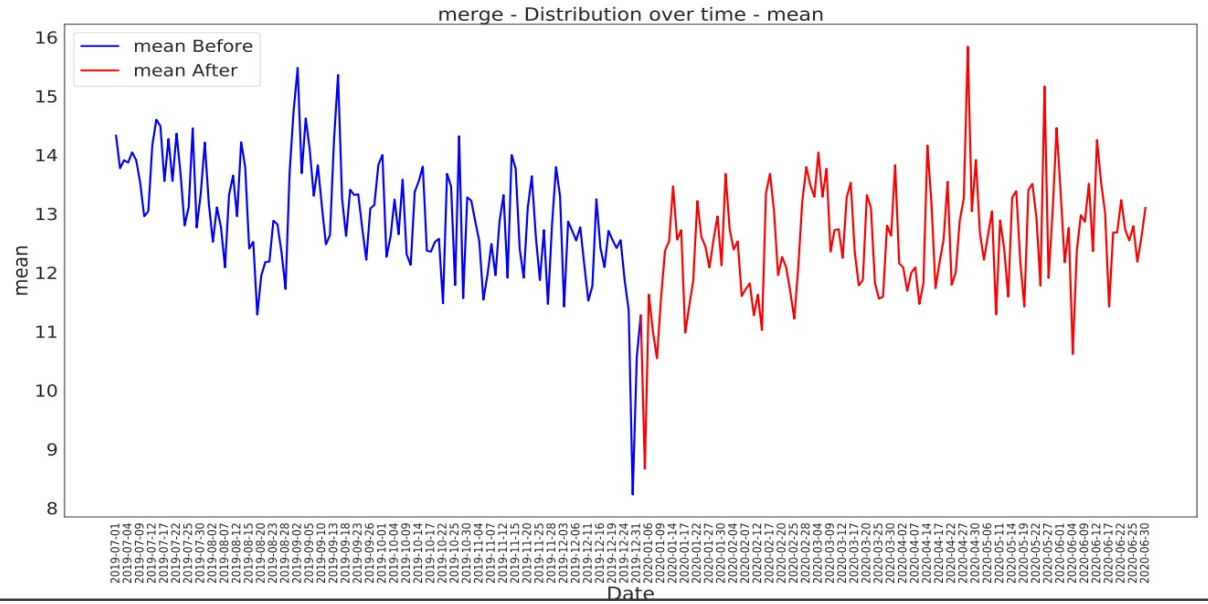
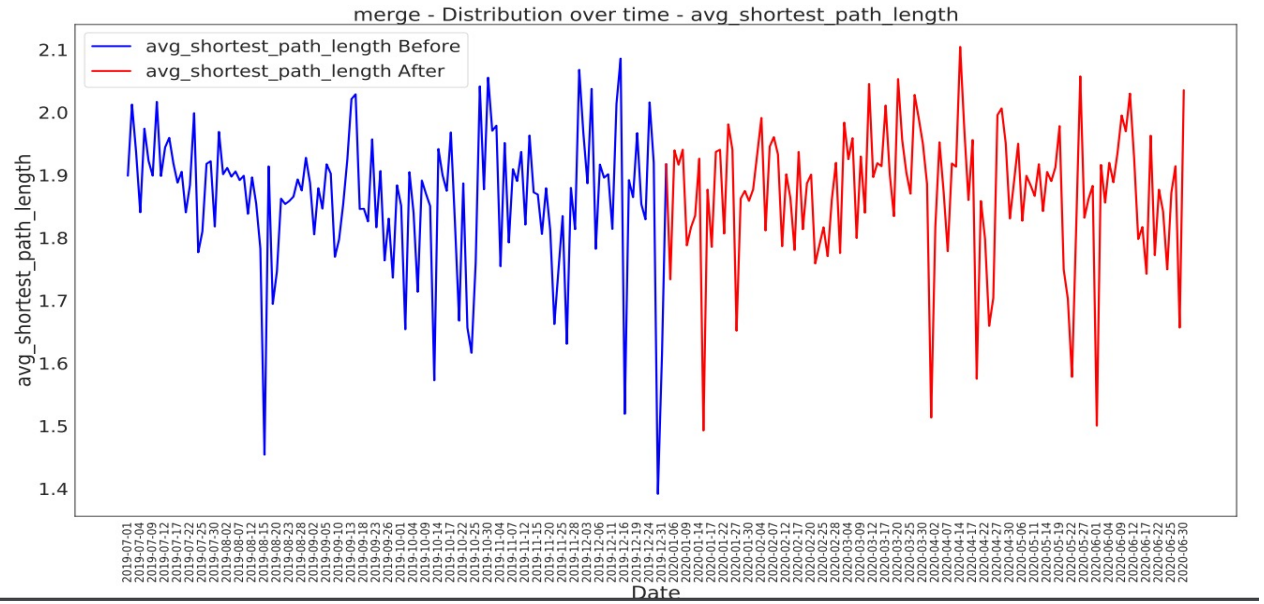
Before and After Covid19 : Government Bonds_S

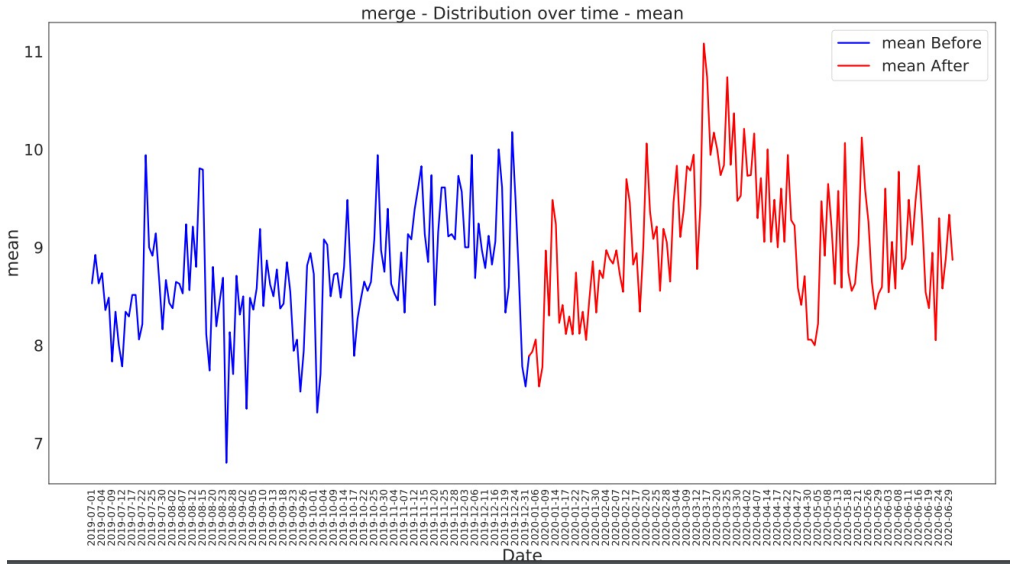


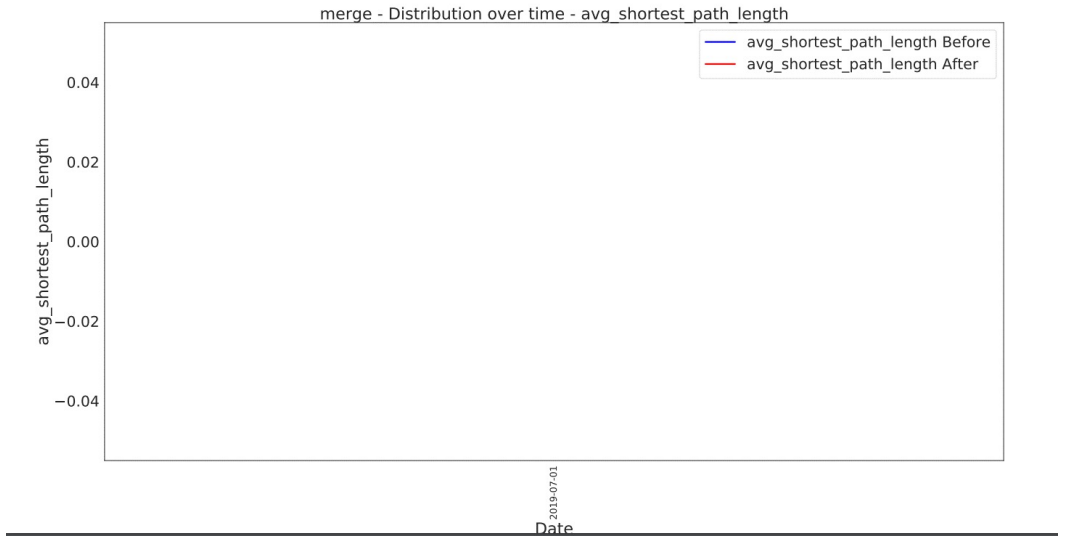


- Mean degree appears to increase during the lockdown but also before the lockdown

- Avg. shortest path length is unstable before and after Covid

Before and After Covid19 : Shares and similar_N





- Mean degree appears to increase during the lockdown

- In this case we have not information about the shortest path length, this is due to the fact that the graph is not totally connected
- There are companies that are isolated (usually self loops)

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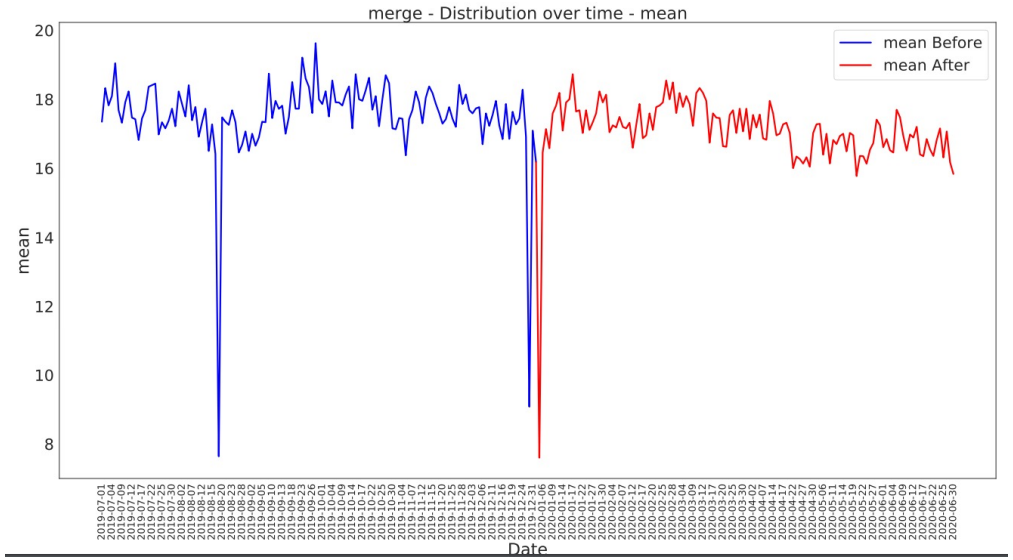
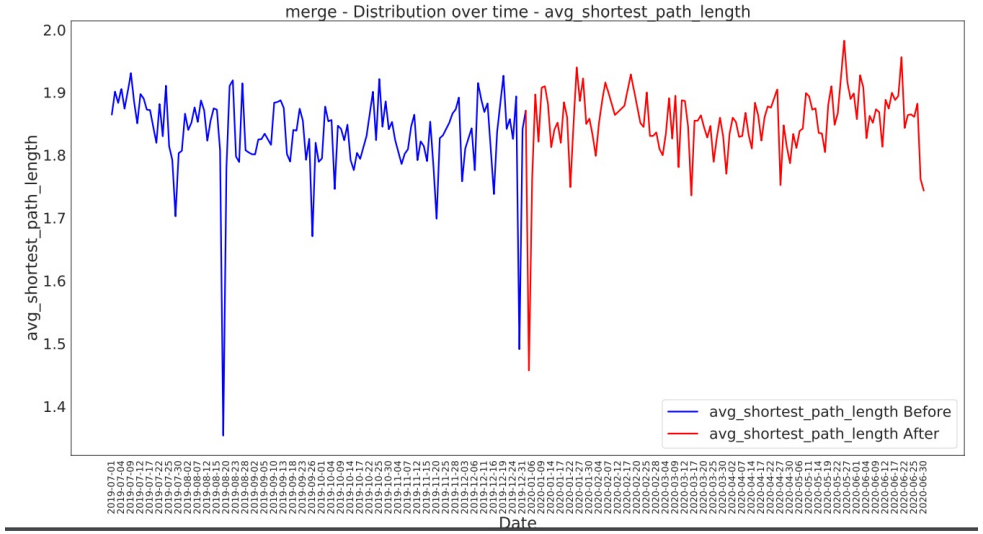
Before and After Covid19 : Shares and similar_S





- Mean degree appears is stable
- Avg. shortest path length is stable before and after Covid19

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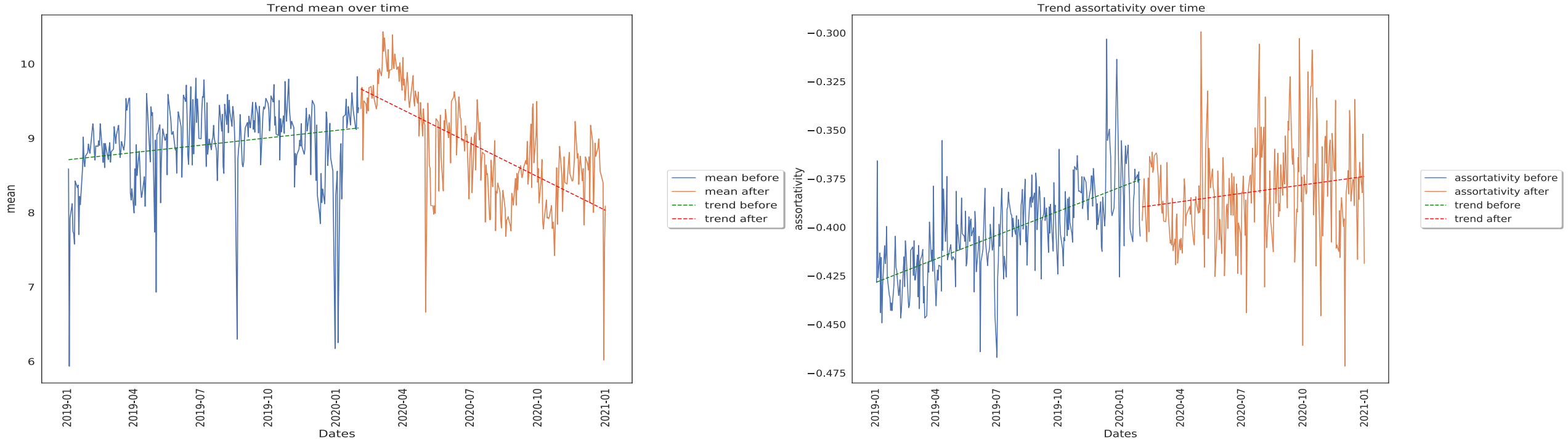
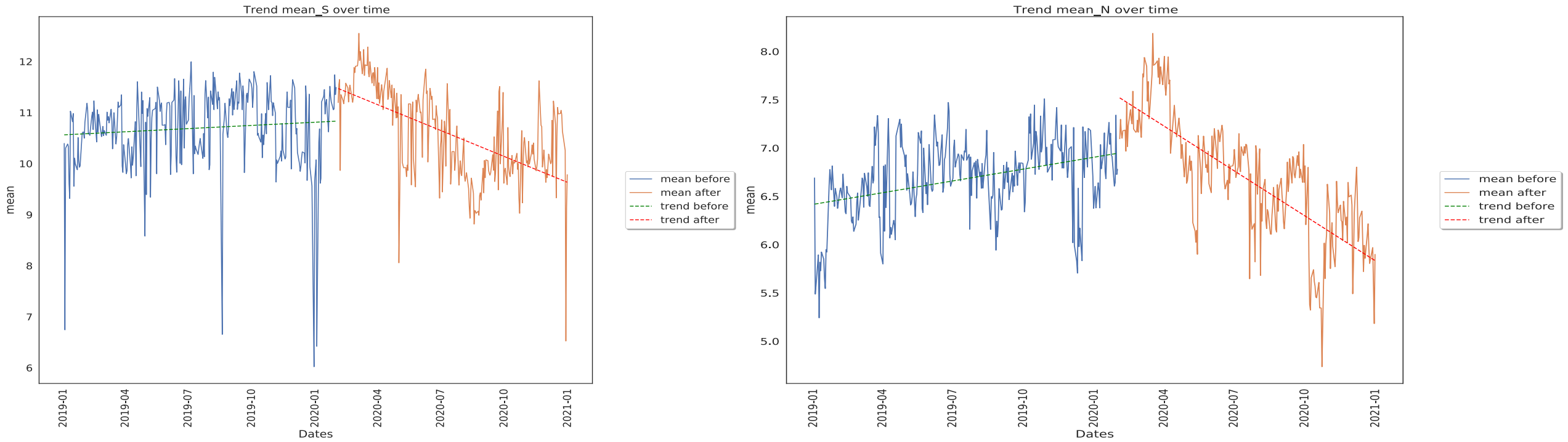
Trend Mean degree average for Settle and Unsettle instructions



- Overal trend is decreasing during Covid19

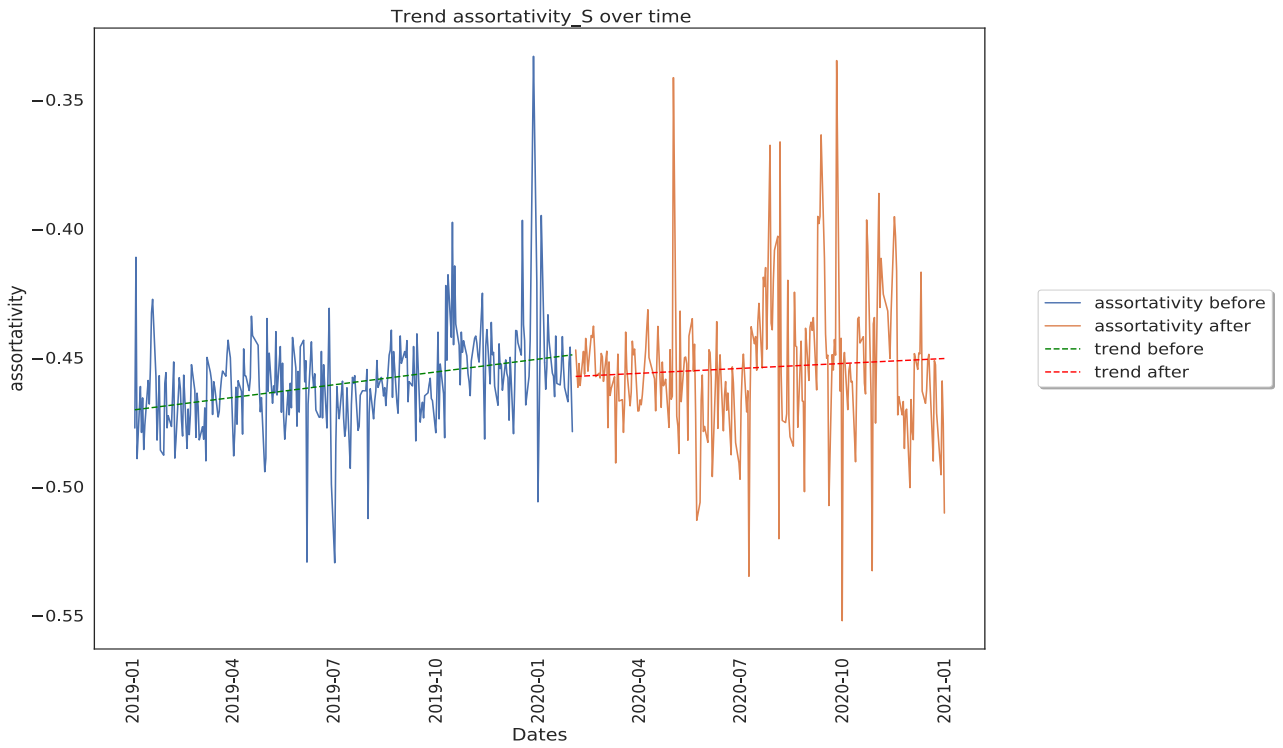
- Assortativity before Covid19 is increasing, while during Covid19 increase slowly

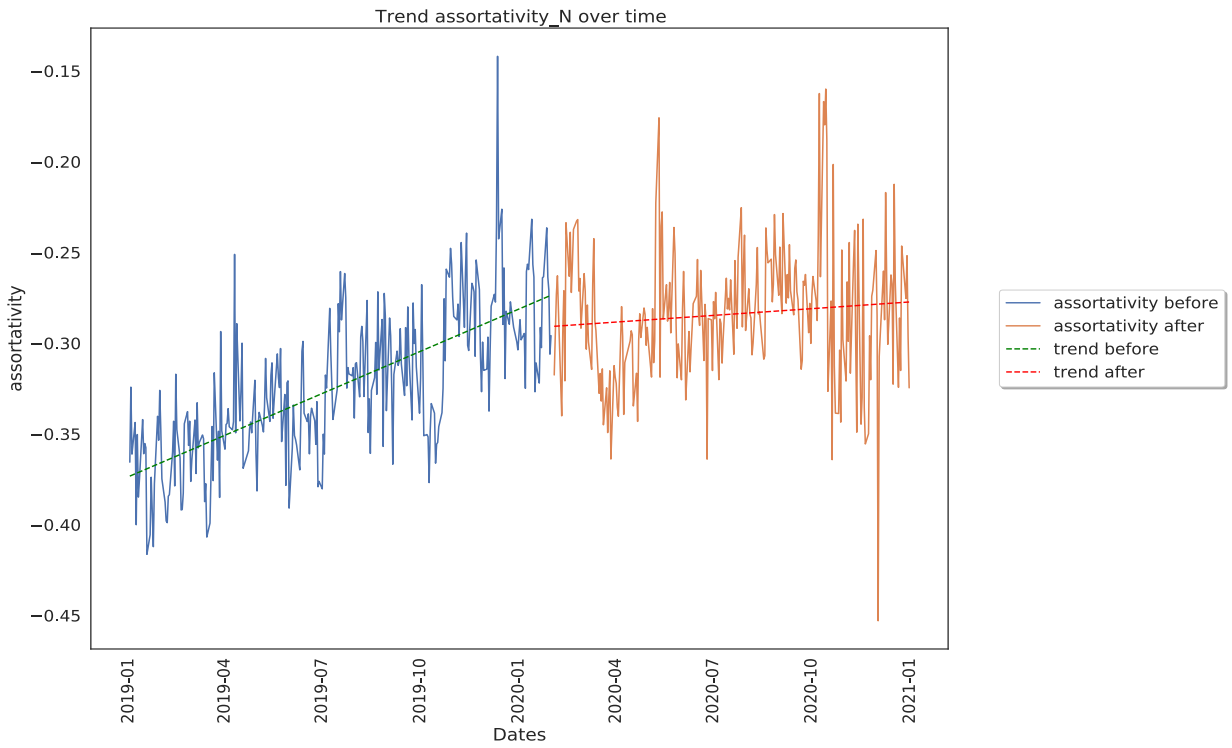
Trend Mean degree average for Settle and Unsettle instructions



- Mean degree is decreasing after COVID19 for Settle instruction
- Mean degree is decreasing after COVID19 for Unsettle instructions

Trend Assortativity averaged for Settle and Unsettle instructions





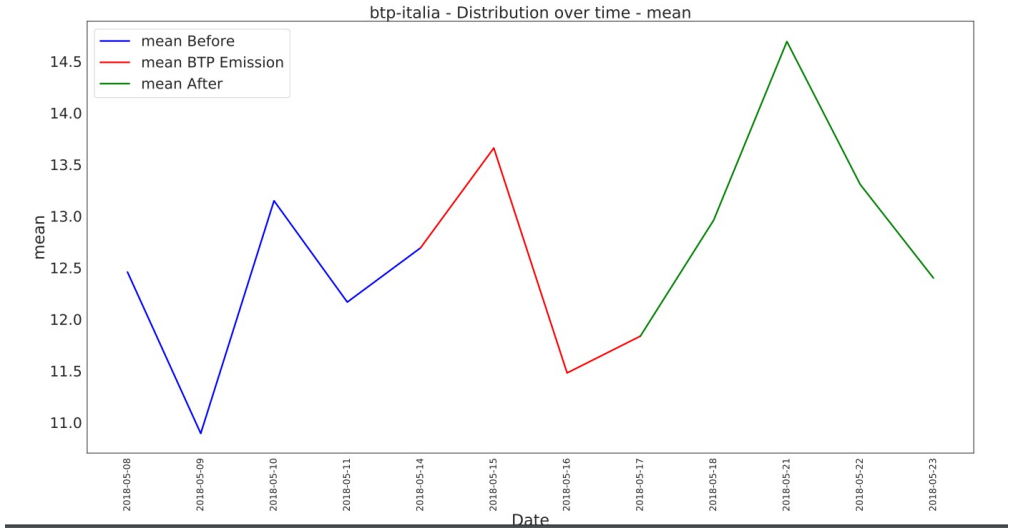
- Assortativity is slightly increasing before, and during COVID19 is stable for Settle instructions

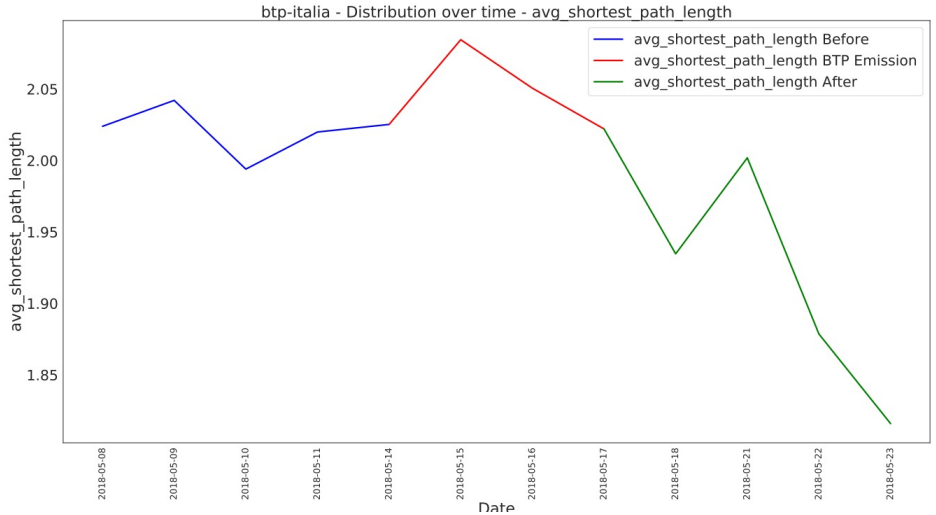
- Assortativity is increasing before and during COVID19 is stable

BTP Italia and Futura emissions effect

- The impact of large emission of Government Bonds such as BTP Italia and BTP Futura on the network metric and topology. The analysis takes into consideration the next ten days after the BTP announcement. This is considered a disruptive event since large amount of instructions are exchanged during the emission dates.
- BTP Italia Emission dates:
  - From 14th to 17th May 2018
  - From 19th to 22nd November 2018
  - From 21st to 23rd October 2019
  - From 18th to 20th May 2021
- BTP Futura Emission dates:
  - From 6th to 10th July 2020
  - From 09th to 13th November 2020
  - From 19th to 23rd April 2021

Before and After BTP Italia Emissions : May 2018 - Gov. Bonds_S





- Mean degree during and after emissions is increasing
- Avg. shortest path length is stable and after emission is decreasing

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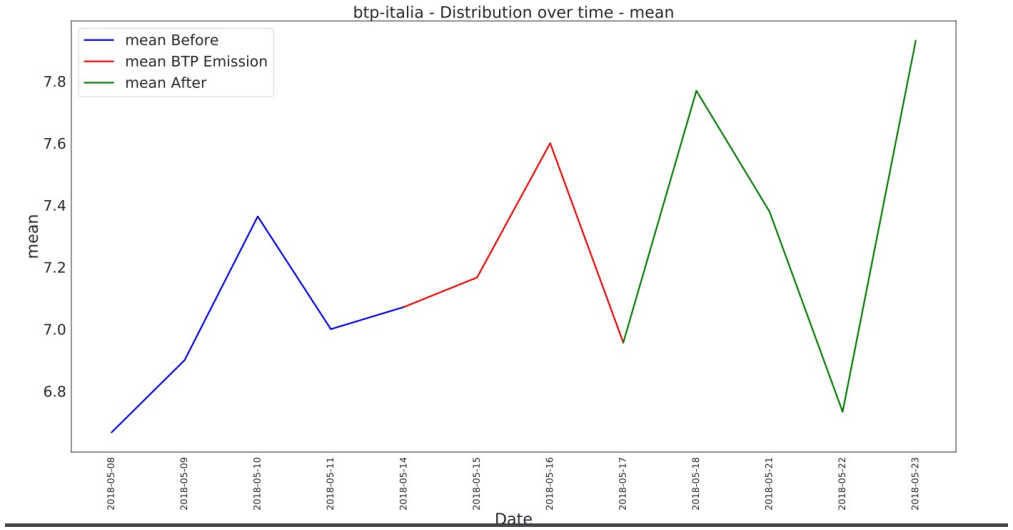
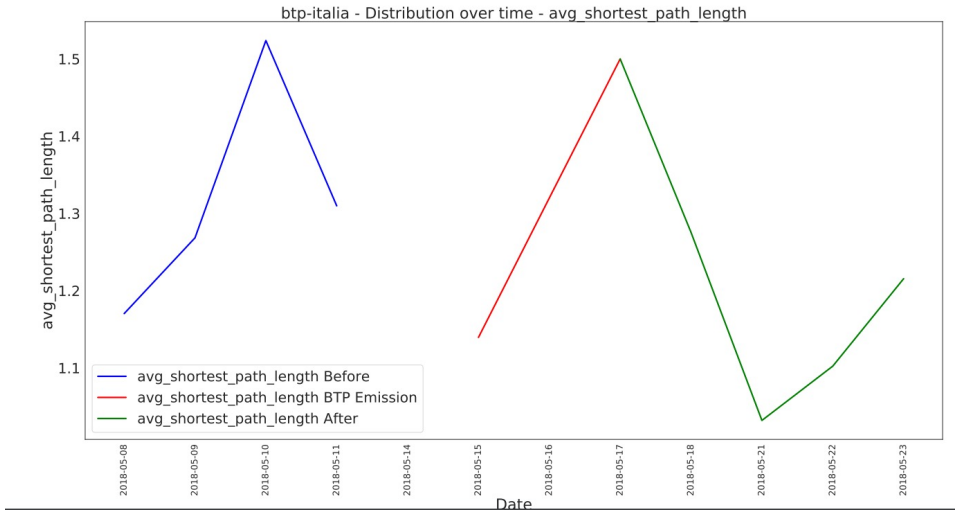
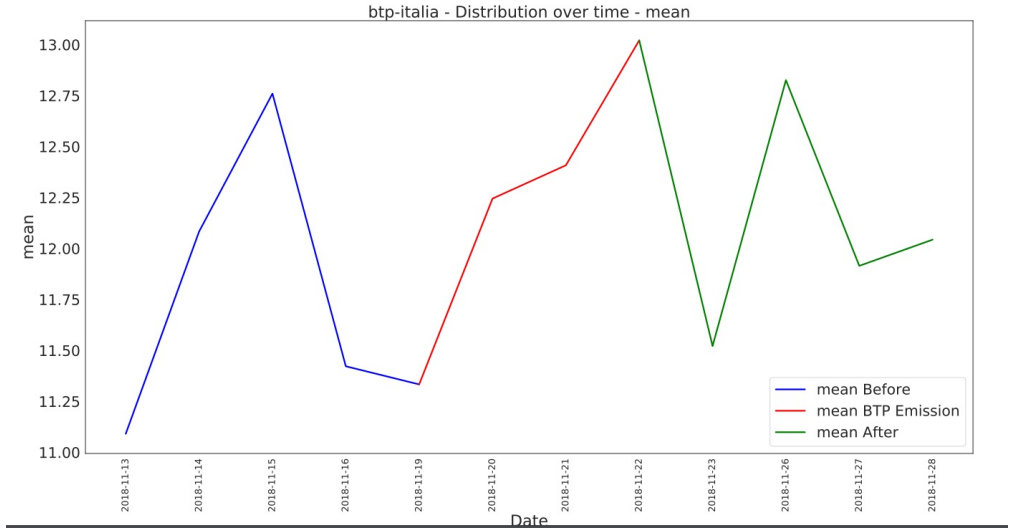
Before and After BTP Italia Emissions : May 2018 - Gov. Bonds_N

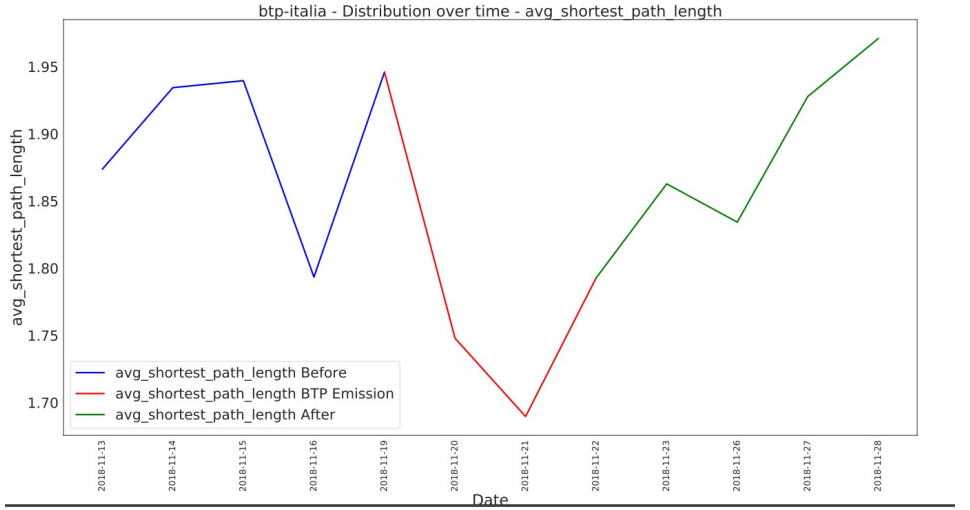




- Mean degree is increasing during and after emissions
- Avg. shortest path length during 2 dates of emission is not computable due isolates nodes

Before and After BTP Italia Emissions : Nov 2018 - Gov. Bonds_S





- Mean degree during and after emissions is increasing
- Avg. shortest path length is decreasing during emissions and increasing after

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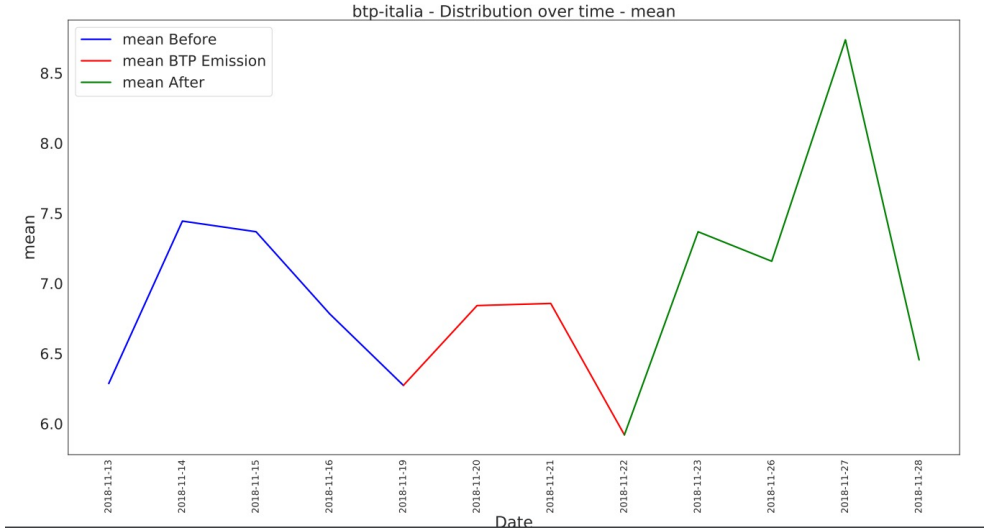
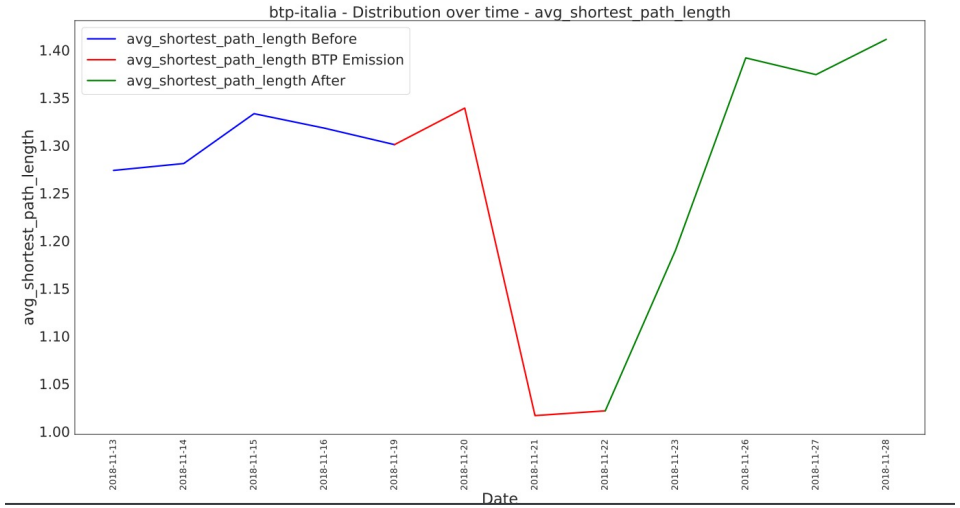
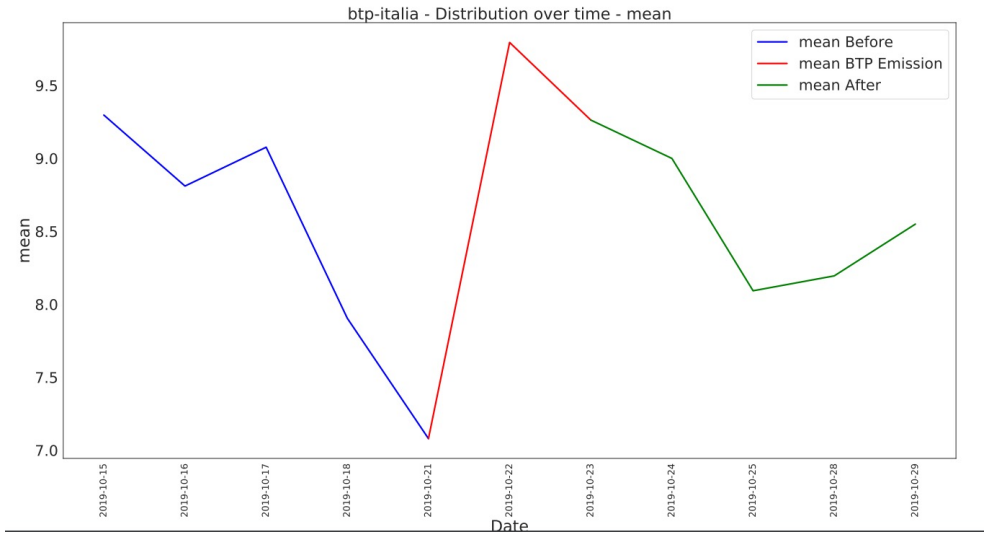
Before and After BTP Italia Emissions : Nov 2018 - Gov. Bonds_N

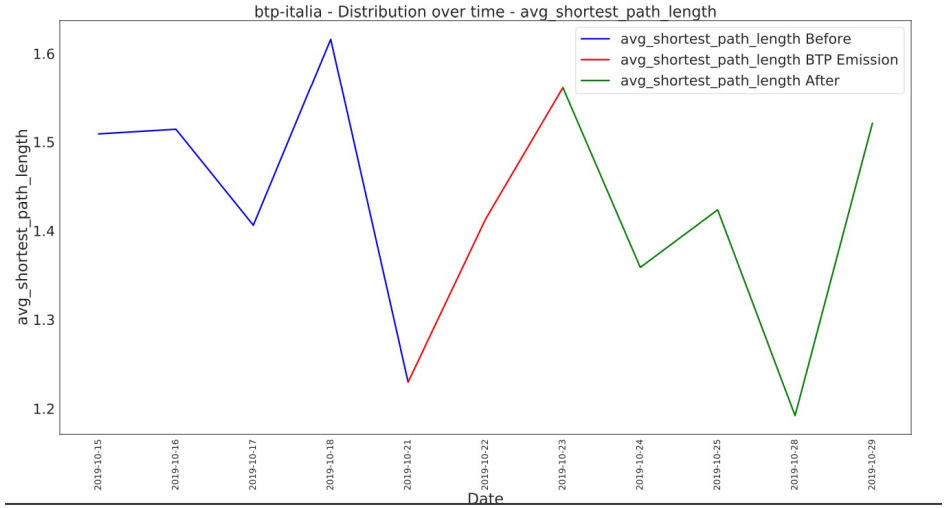




- Mean degree during and after emissions is increasing
- Avg. shortest path length is stable, during emission it decreases and after it increases

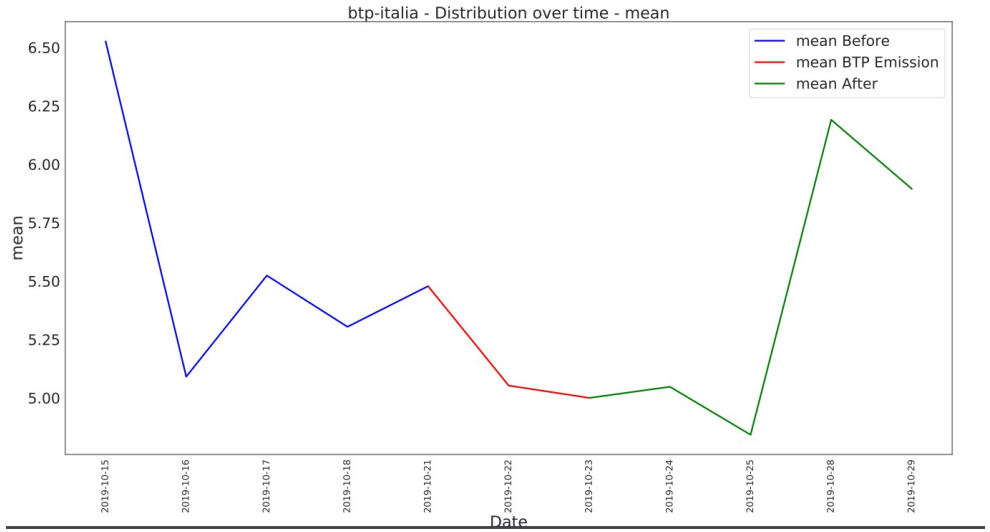
Before and After BTP Italia Emissions : Oct 2019 - Gov. Bonds_S

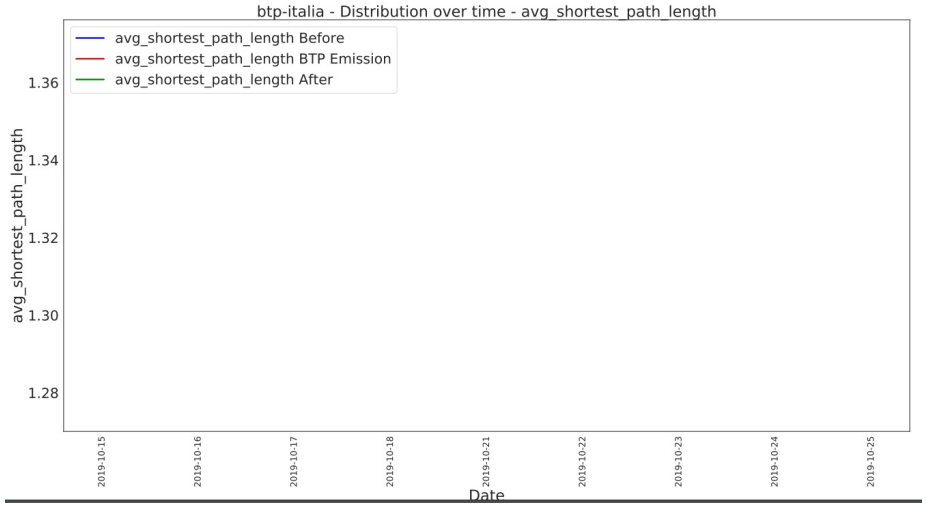




- Mean degree is increasing during emissions
- Avg. shortest path length has a decreasing trend

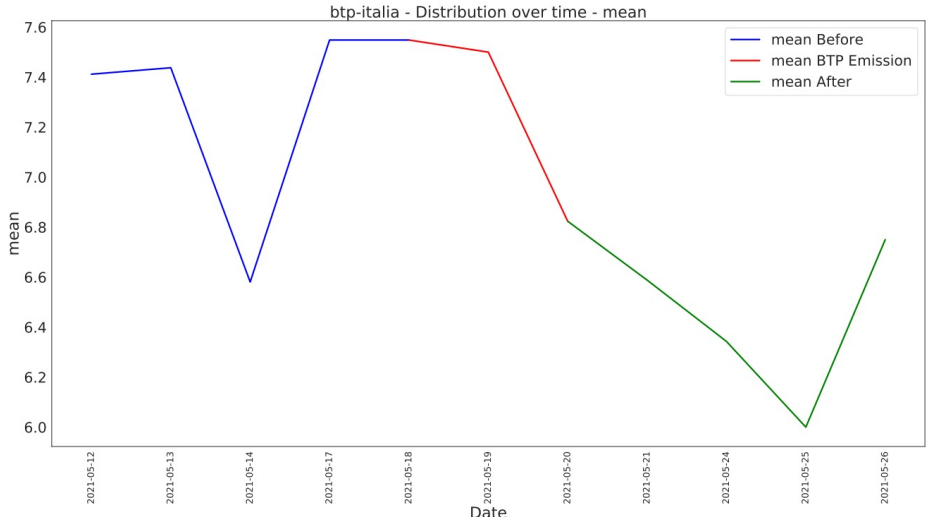
Before and After BTP Italia Emissions : Oct 2019 - Gov. Bonds_N

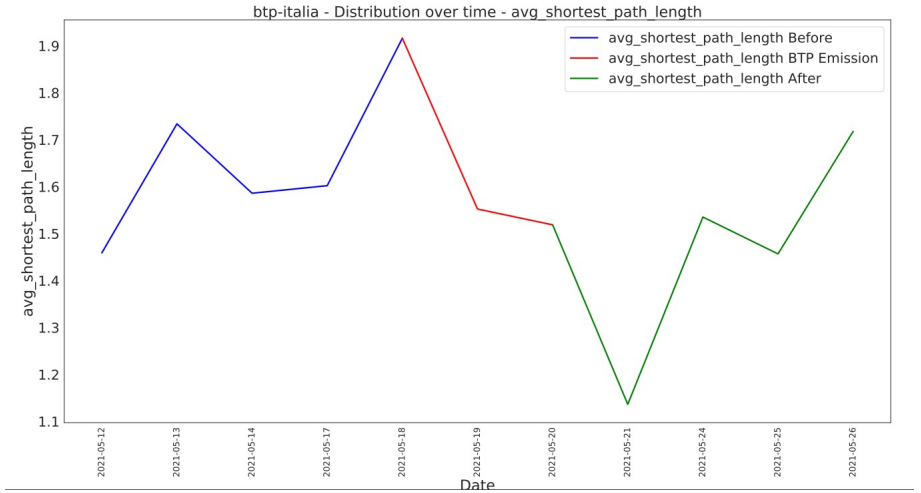




- Mean degree during and after emissions is increasing
- During Oct. 2019 we have networks with isolated nodes

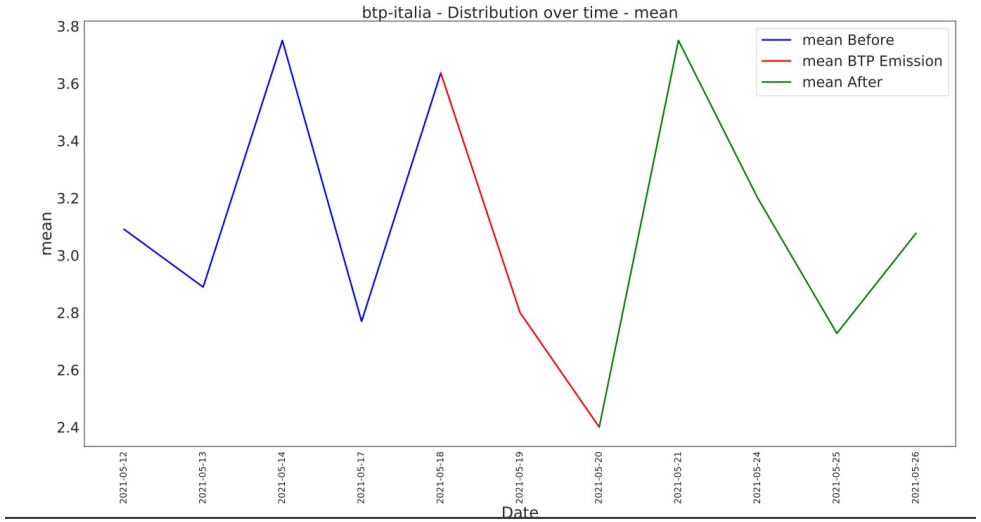
Before and After BTP Italia Emissions : May 2021 - Gov. Bonds_S

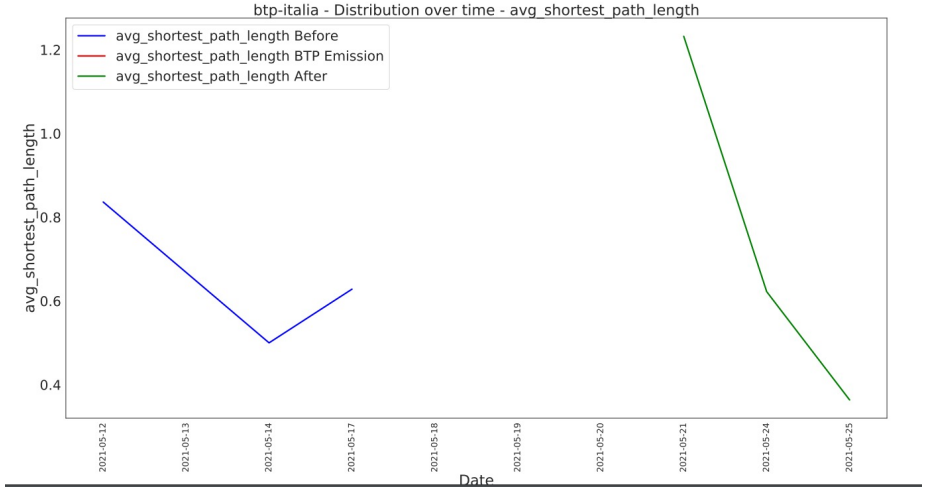




- Mean degree during emission is increasing, and after emissions is deacresing
- Avg. shortest path length after emission is decreasing

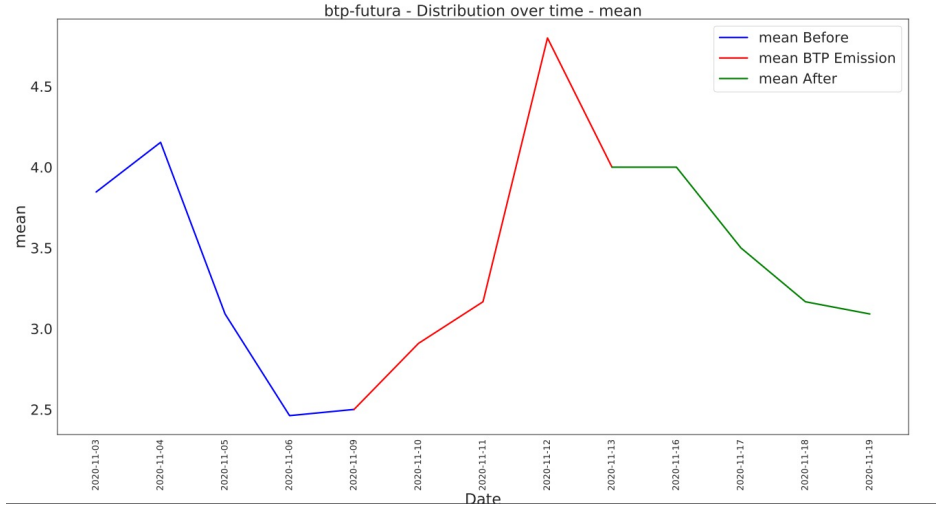
Before and After BTP Italia Emissions : May 2021 - Gov. Bonds_N





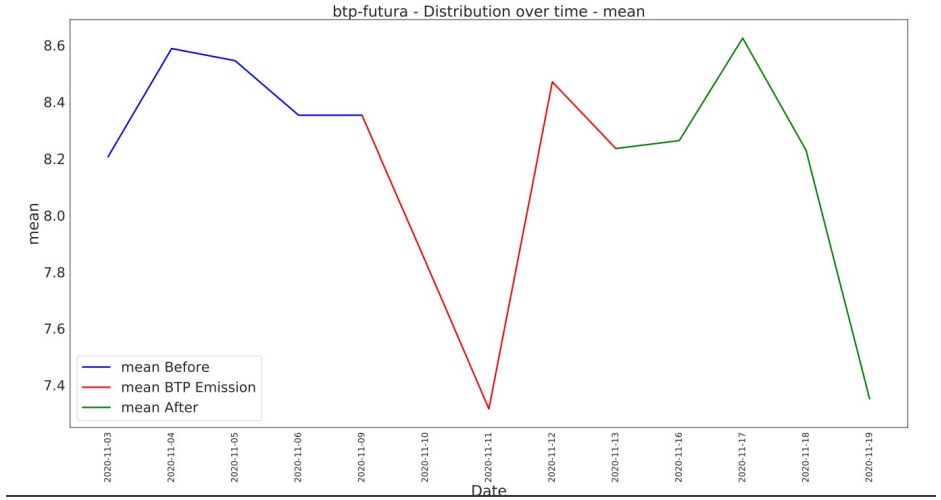
- Mean degree during emissions is decreasing and after is increasing
- Avg. shortest path length during emissions is not computable

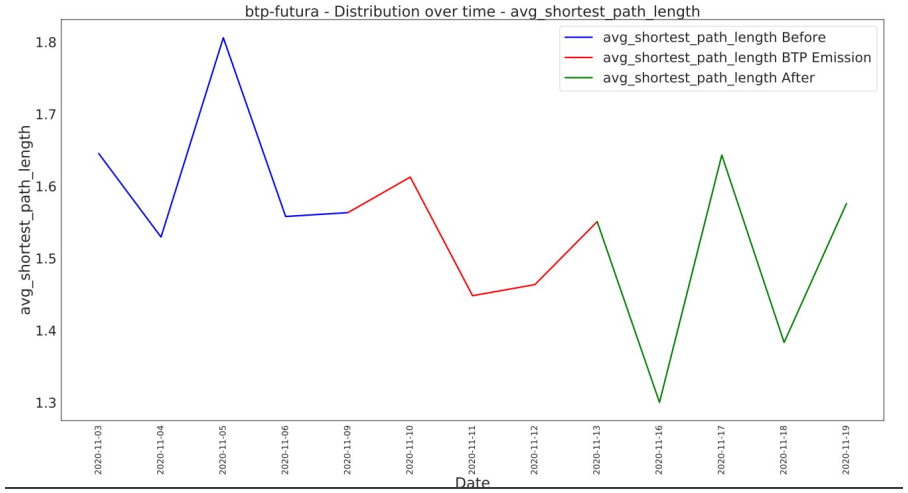
Before and After BTP Futura Emissions : Nov 2020 - Gov. Bonds_N



- Mean degree during emissions is increasing
- Avg. shortest path length is not computable before emission and then is decreasing after emission

Before and After BTP Futura Emissions : Nov 2020 - Gov. Bonds_S

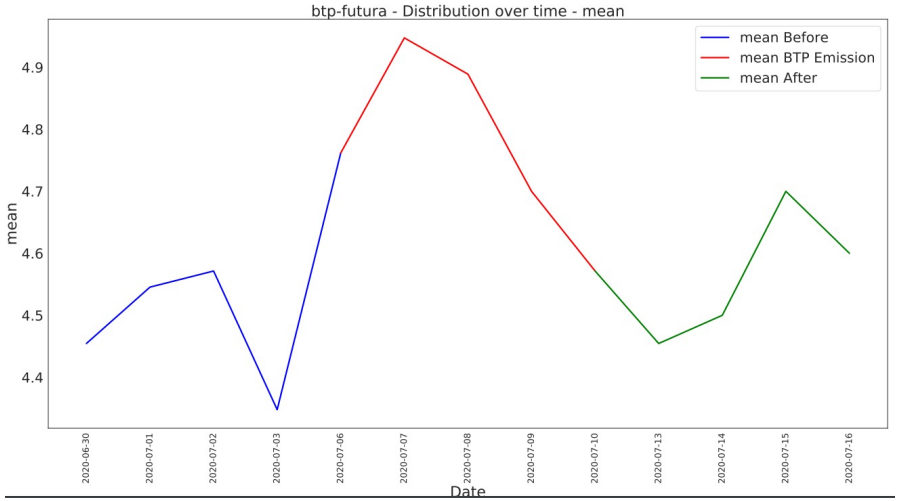


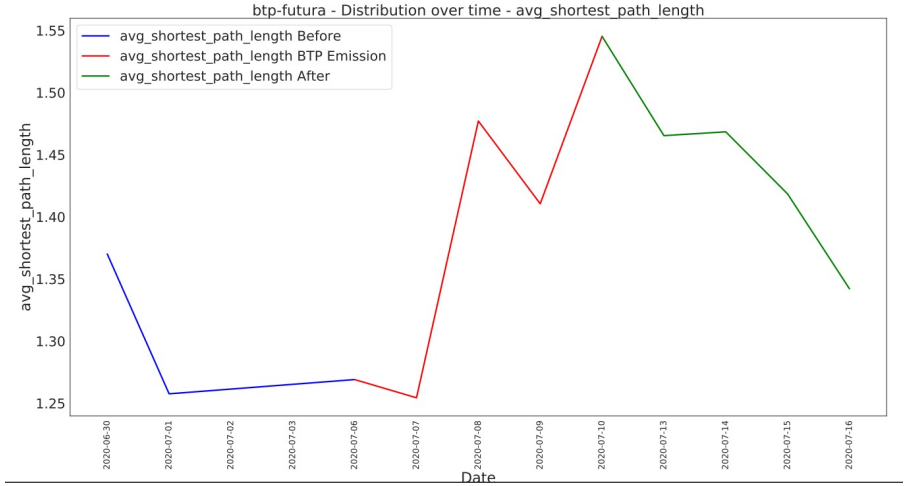


- Mean degree during emissions is decreasing

- Avg. shortest path length is decreasing after emissions

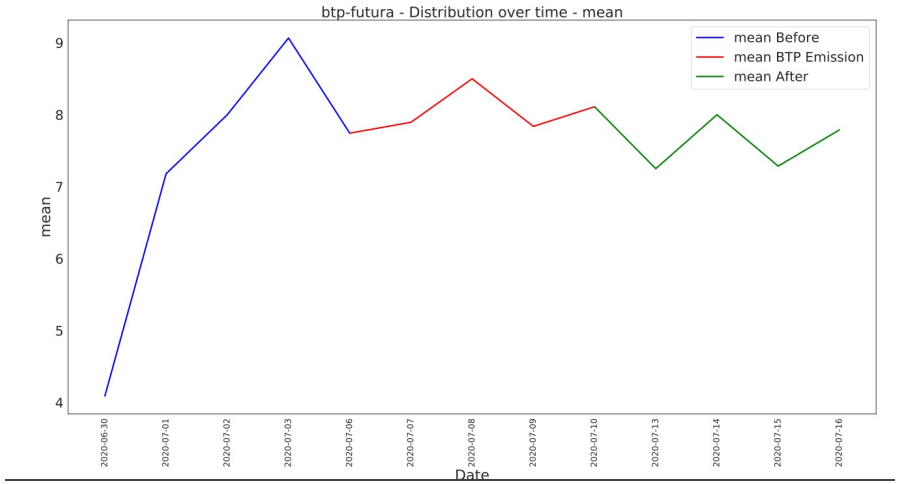
Before and After BTP Futura Emissions : Jul 2020 - Gov. Bonds_N

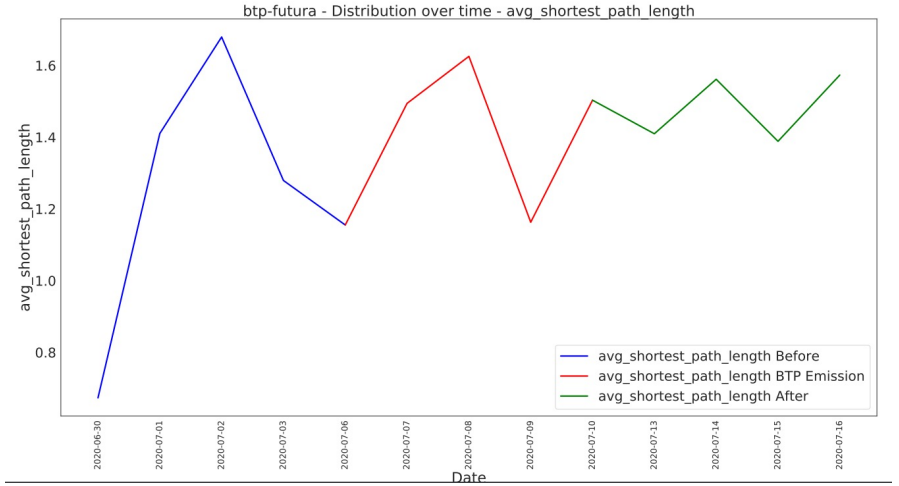




- Mean degree during and after emissions is increasing
- Avg. shortest path length is increasing during emission and decreasing after

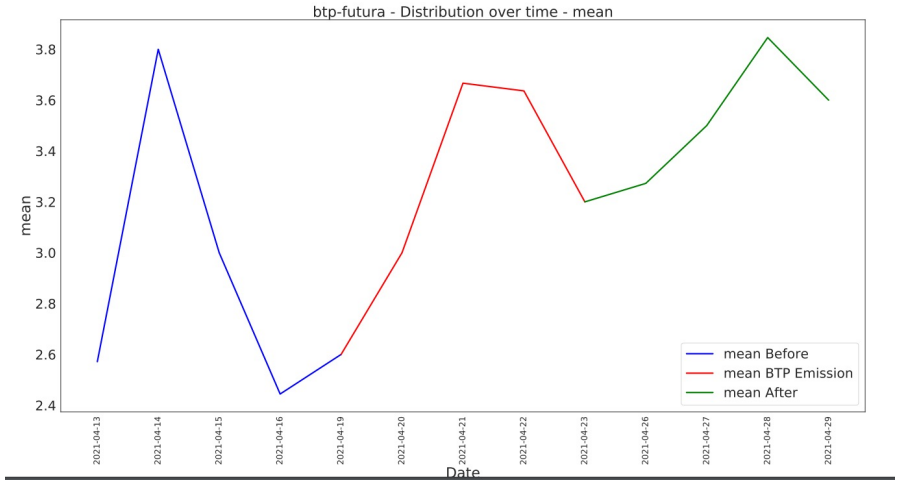
Before and After BTP Futura Emissions : Jul 2020 - Gov. Bonds_S

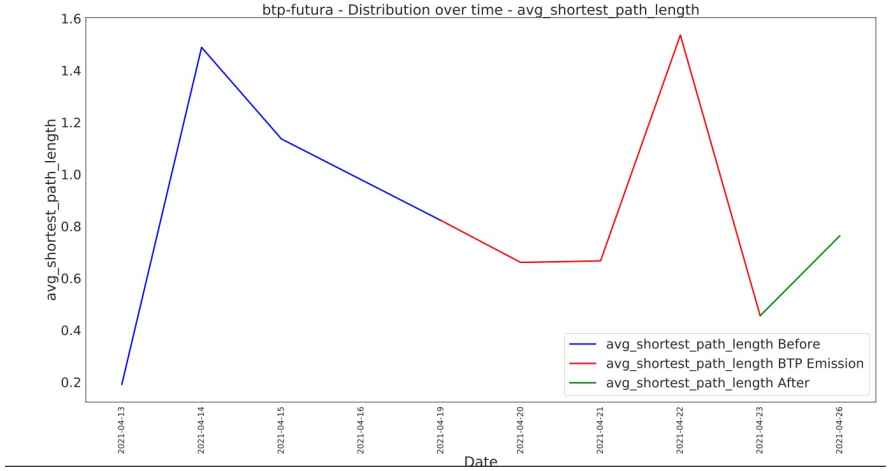




- Mean degree is stable
- Avg. shortest path length is unstable

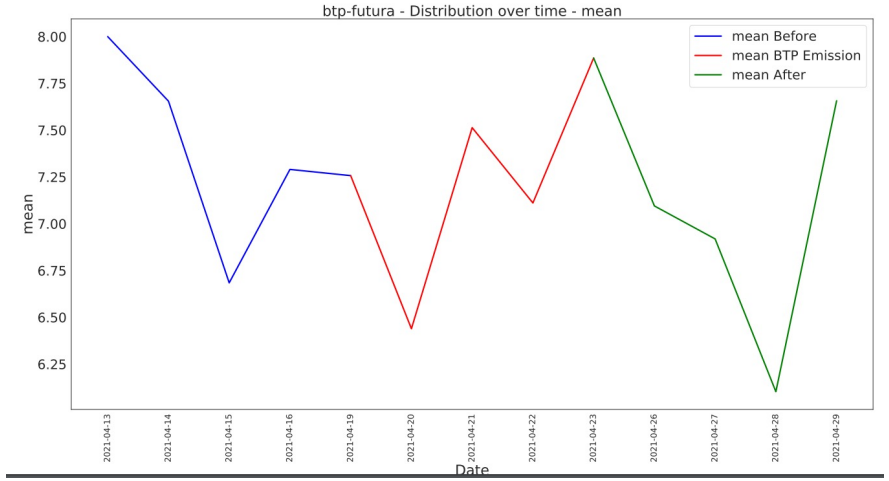
Before and After BTP Futura Emissions : Apr 2021 - Gov. Bonds_N

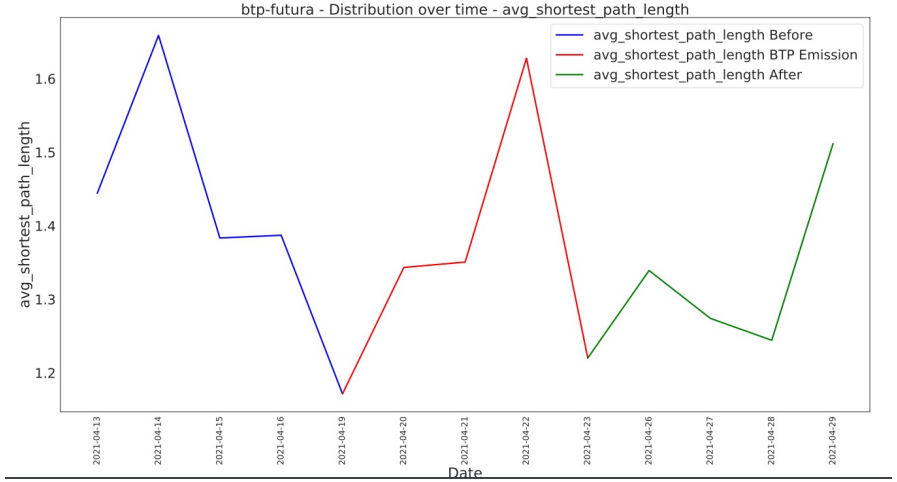




- Mean degree during and after emissions is increasing
- Avg. shortest path length during emission is increasing and after decreasing (then we have disconnected components)

Before and After BTP Futura Emissions : Apr 2021 - Gov. Bonds_S





- Mean degree during and after emissions is increasing
- Avg. shortest path length is increasing during emission and decreasing after emissions

Conclusions and next steps

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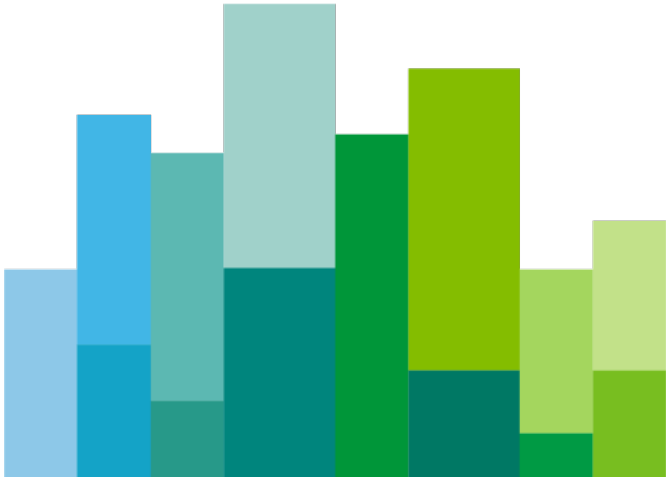

Conclusions

- **Monthly Analysis**:
  - Definition of a **ranking** for the most central nodes help understanding which companies are the most important in the different type of financial instrument and Settlement status and also how they varied over time:
    - … are the most frequent central node in the different networks
    - Cumulative Network Central nodes are more stable according to the ranking
  - The identification over time of **a Scale-free behaviour** suggested that cumulative Networks are more prone to have a scale-free behaviour w.r.t. non-cumulative
  - Network of payments that have shown scale-free properties in literature are **resilient** to random damage. It is barely possible to destroy the network of payments by random removal, but if an exact portion of particularly selected nodes is removed, it breaks completely:
    - In most cases the elimination of Central nodes largely degenerate the network structures
    - In most cases, random removal of nodes do not affect the network structures largely
- **Daily Analysis**:
  - **COVID19** Case study demonstrates that it affected the networks in different ways:
    - Networks with Settled instruction appears to be the most affected: avg. shortest path in some cases is not computable
    - In most cases the mean degree after Covid19 has an increasing trend
  - **BTP Italia and BTP Futura** emissions:
    - Networks appears to be affected but without a certain rule

Thank You for Your Questions!

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Degree analysis

Graph Type	Order	Size	Mean degree
Government Bonds_S	72	1311	36.4
Funds_S	67	754	22.5
Shares and similar_S	114	1194	20.9
Other_S	56	448	16.0
ETF_S	419	2158	10.3
Corp. Bonds and similar_S	346	1312	7.5
ETF_N	68	1087	31.9
Shares and similar_N	60	726	24.2
Government Bonds_N	61	701	22.9
Funds_N	54	543	20.1
Corp. Bonds and similar_N	55	462	16.8
Other_N	30	125	8.3

- Orders, sizes and degrees differs among all the different financial instrument types and instruction status
- Each Company with type of instructions *Government Bonds*, *Funds*, *Share and similar* tend to exchange on average **Settled** Instruction with more than 20 other companies
- Each Company with type of instructions ***ETF***, *Funds*, *Government Bonds* *and* *Share and similar* tend on average to exchange **Failed** Instructions with more than 20 other companies

Order: Number of nodes

Size: Number of edges

Mean degree: average number of edges per node in the graph

Average clustering, Assortativity and Transitivity measures

Graph Type	Avg. Clustering Coeff.	Assortativity	Transitivity
Government Bonds_S	0.70	-0.51	0.53
Other_S	0.64	-0.41	0.51
Funds_S	0.61	-0.48	0.45
Shares and similar_S	0.40	-0.50	0.53
ETF_S	0.13	-0.57	0.19
Corp. Bonds and similar_S	0.12	-0.67	0.12
Funds_N	0.75	-0.49	0.36
ETF_N	0.75	-0.47	0.47
Government Bonds_N	0.73	-0.55	0.38
Shares and similar_N	0.73	-0.47	0.45
Corp. Bonds and similar_N	0.68	-0.41	0.37
Other_N	0.43	-0.23	0.37

- Average Clustering Coefficient is high in Settled and Failed Instructions:
  - Companies tend to exchange a lot of instructions with each other
  - Only in **ETF** and Corp. Bonds, companies NOT exchange much **Settled** instructions with each other
- Assortativity is around -0.5 which means instructions tend to fail/settle more between companies that are not similar
- Transitivity measure imply companies tends to deliver fail/settle instructions in triplets

Average Clustering: degree measure of how nodes tend to be connected to each other

Assortativity: preference for a network's nodes to attach to others that are similar

Transitivity: ratio between the observed number of closed triplets and the maximum possible number of closed triplets

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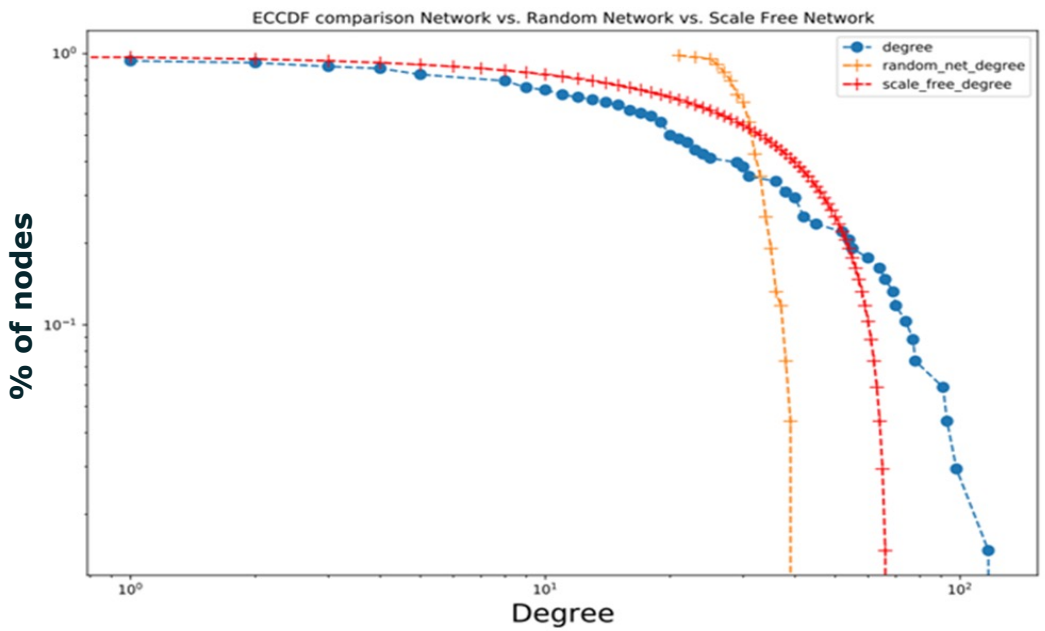
ETF Failed instructions – Scale free example

Empirical Cumulative Distribution Function



- Blue Line is the log log ECDF of ETF Network
- Orange line is the log log ECDF of a Random Network
- Red Line is the log log ECDF plot of a generated Scale-Free network with the same number of nodes of ETF Network

ECDF: Distribution of how much % of nodes with a certain degree

In this example: As the degree increase, the % of nodes with degree higher than 100 is decay slowly to 0

- Considering the ECDF plot, ETF graph could be approximate to a **Scale-free Network:**
  - ETF and SF has a similar shape distribution (ECDF representation helps on identifying it)
  - ETF point distribution are more concentrated in the “center” as in SF Network