



UNIVERSITÀ DEGLI STUDI DI MILANO

FACOLTÀ DI SCIENZE POLITICHE,
ECONOMICHE E SOCIALI

M.Sc. in Data Science and Economics

**SOCIAL NETWORK ANALYSIS ON POST TRADE DATA: CENTRALITY, SCALE
FREE BEHAVIOR AND RESILIENCY OF THE NETWORKS OVER TIME**

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Objective

The aim of the study is the construction of **Social Networks** from post trade settlement instructions of Monte Titoli systems.

The study can be divided in two main networks constructions:

- **Monthly** cumulative and non-cumulative Networks:
 - Centrality analysis
 - Scale-free networks pattern detection
 - Networks resiliency analysis
- **Daily** Networks two case studies of disruptive events:
 - Impact of Covid19
 - Impact of BTP Italia and BTP Futura emissions

Technologies



PySpark

Extracting settlement instructions



Amazon Web Services (AWS)

Data storing, processing and analysis



Python

Programming Language



Amazon S3

S3 buckets

Data storing



Amazon SageMaker

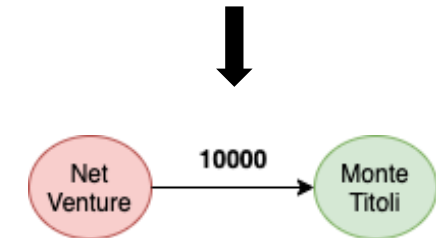
Sagemaker Notebooks

Data Analysis

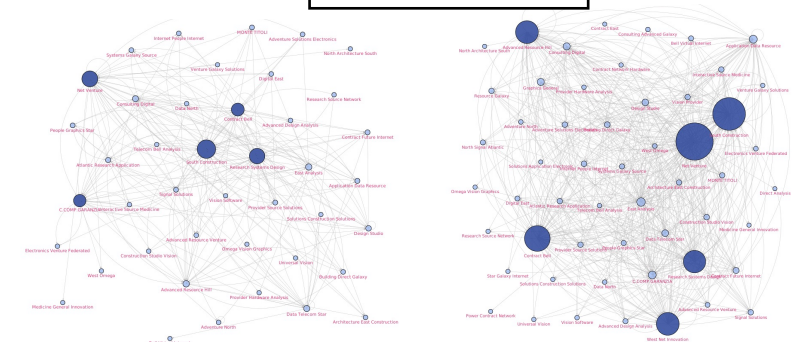
Networks construction

- Date range from **May 2018** to end of **July 2021**
- Companies' names have been anonymized except for Monte Titoli and CC&G
- Data are **aggregated** based on:
 - Company deliverer – receiver couple
 - Financial instrument type: Corporate Bonds, Government Bonds, Funds, Shares, ETF and others.
 - Settlement Status: settled (S) or failed (N)
- Graph representation:
 - **Nodes**: companies
 - **Edges**:
 - Directed: from deliverer to receiver
 - Weighted: with cash flow

Deliverer	Receiver	Sett Status	financial instr type	ETF indicator	Amount
Net Venture	Monte Titoli	S	Corp. Bonds	0	10000

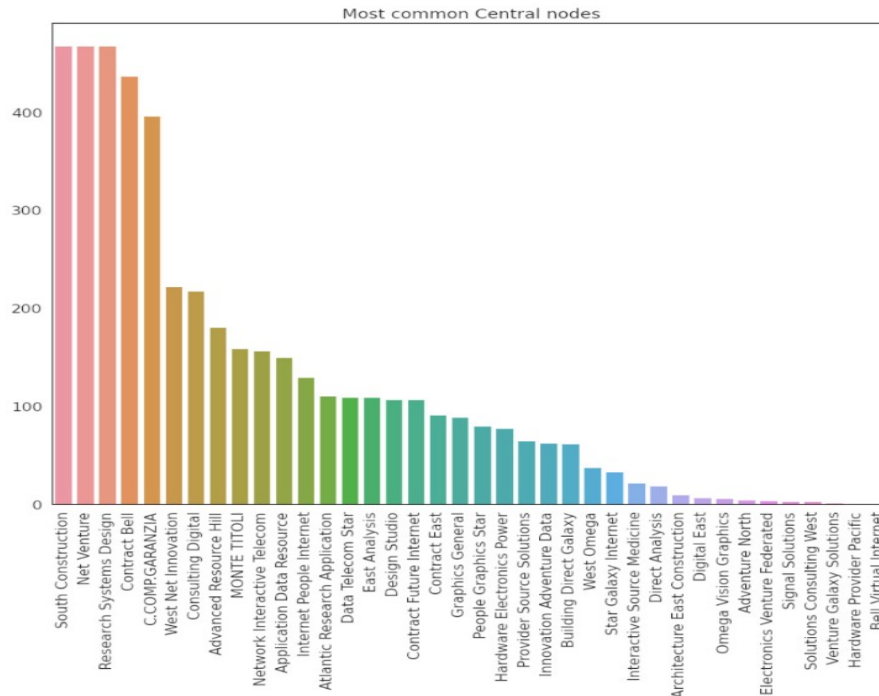


468 graphs

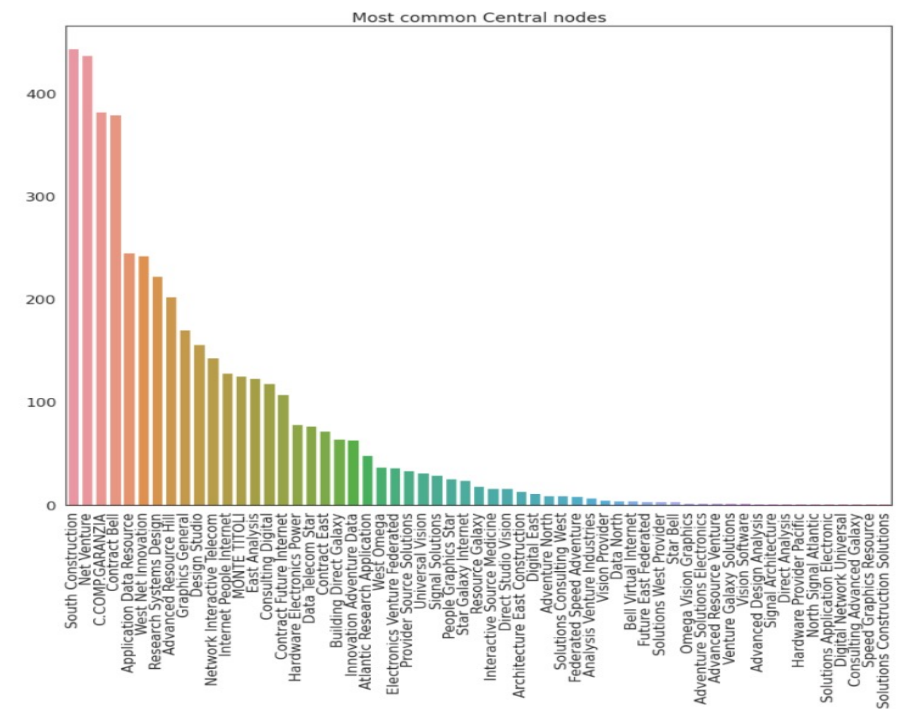


Central nodes - most frequent

Cumulative



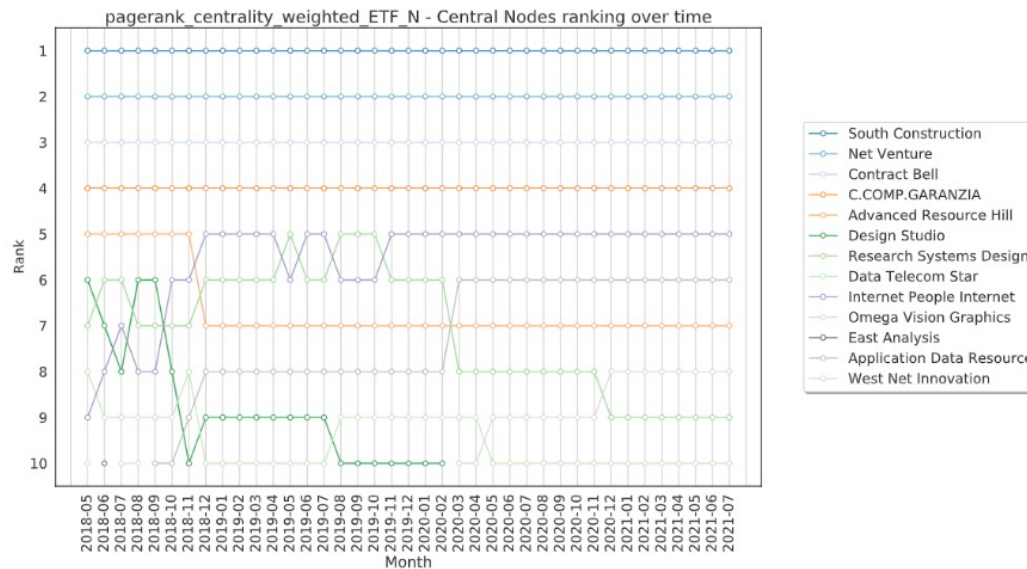
Non-Cumulative



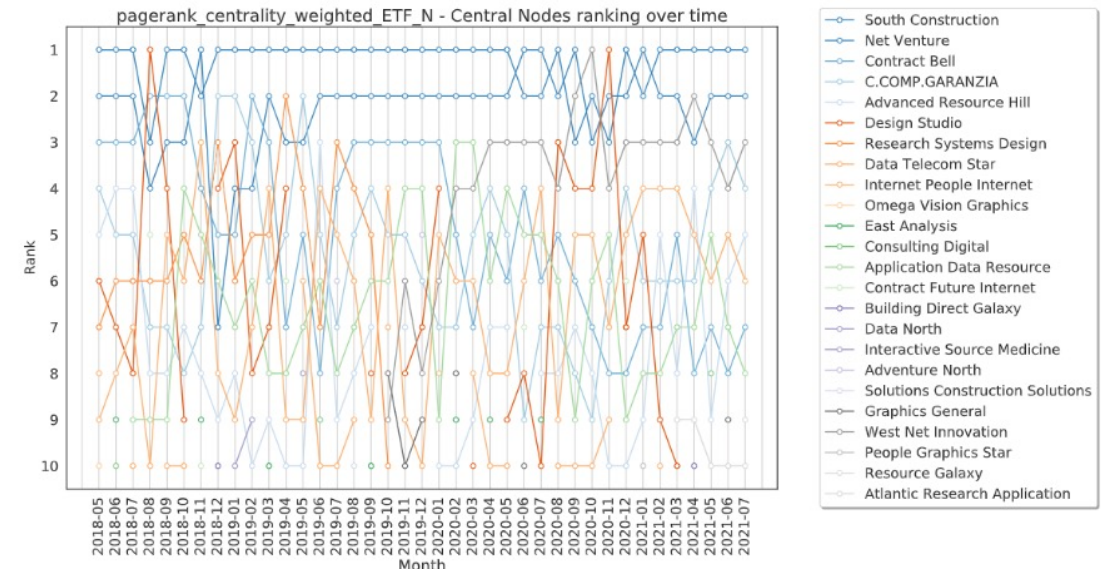
- Cassa Compensazione e Garanzia (CC&G) protects contracting parties against default risk
- CC&G has a high centrality because is deputed to clearing and netting

Central nodes - ranking

Cumulative

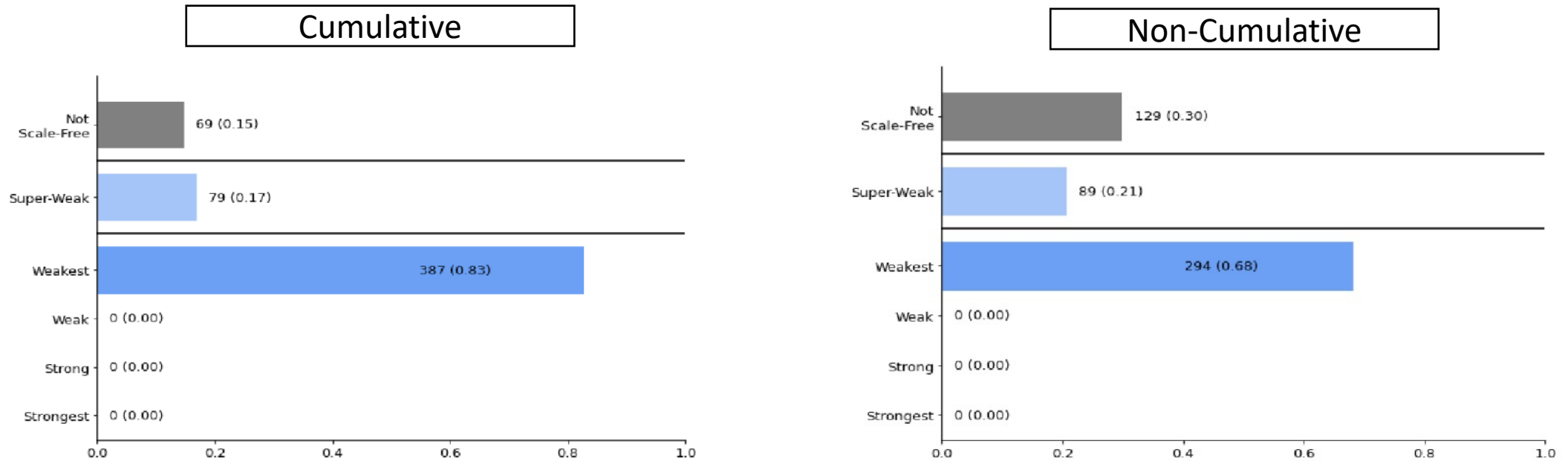


Non-Cumulative



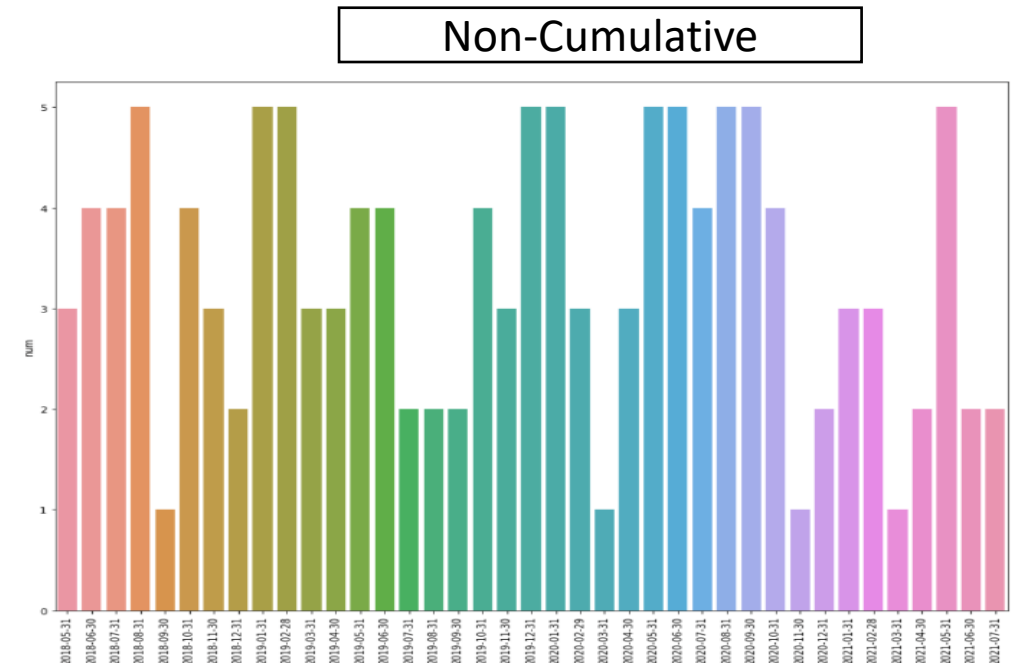
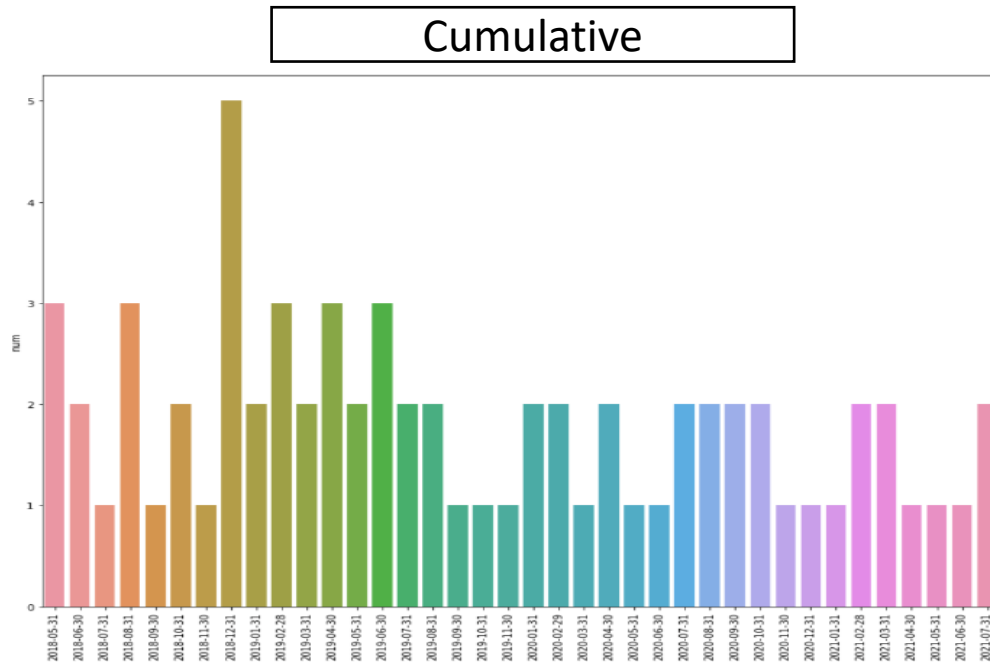
- Cumulative networks show a quite stable ranking over time
- Non-cumulative networks exhibit a non-stable pattern of firms' positions over time

Scale free networks - degrees



- Scale free networks follow Power law distribution.
- Cumulative networks are mostly scale-free.
- Non-cumulative are more non-scale-free with respect to cumulative.

Non-Scale free - over time



- In cumulative networks as number the nodes and links increase, the number of non-scale-free networks decreases.
- Non-cumulative networks does not show any pattern over time.

Node deletion

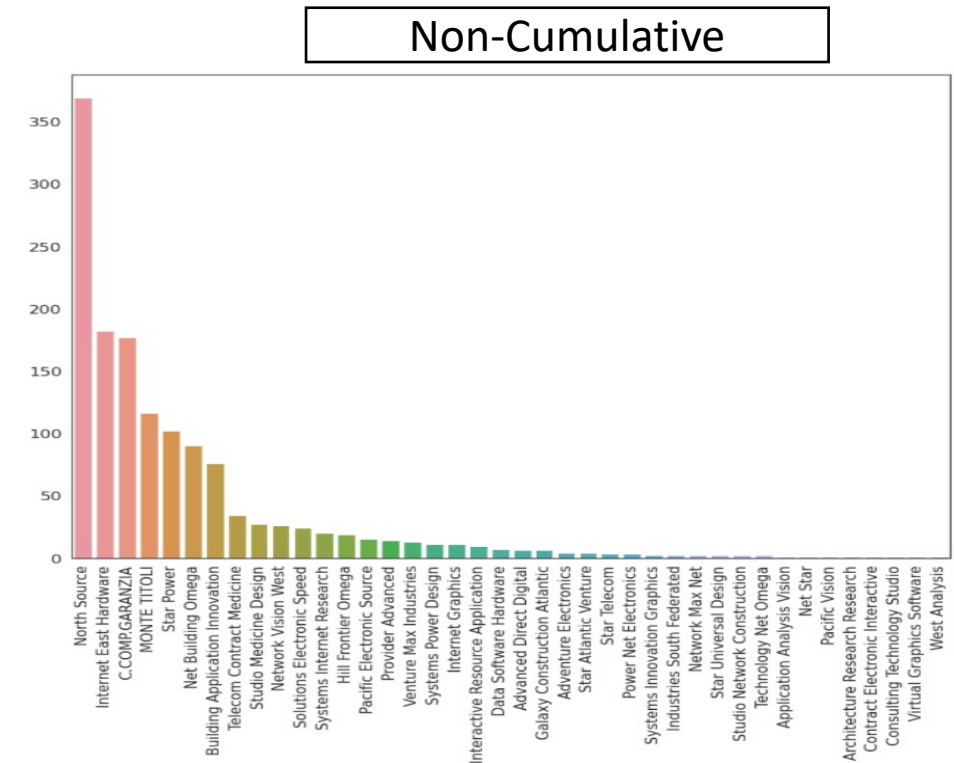
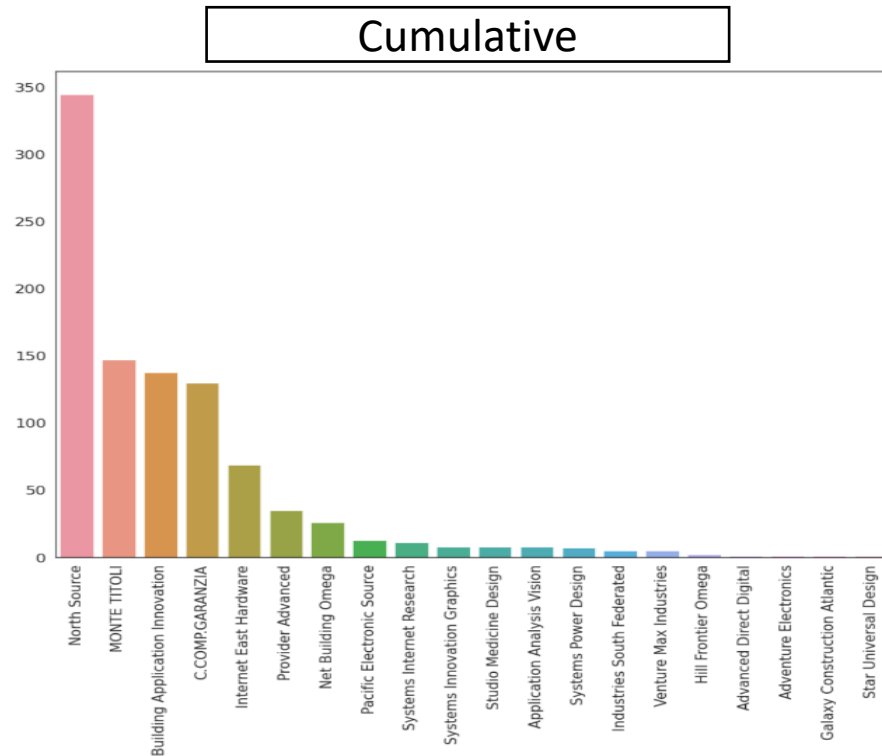
Different node deletion approaches are applied:

- **Random node deletion:** a node is deleted randomly from the network
- **Localized node deletion:** a deletion of a precisely selected node

We investigate if the structure of the network become divided into disconnected clusters after a node removal:

- Networks presents only one main weakly connected component
- If after node deletion, the network results with more than one weakly connected components, then the network is considered altered.

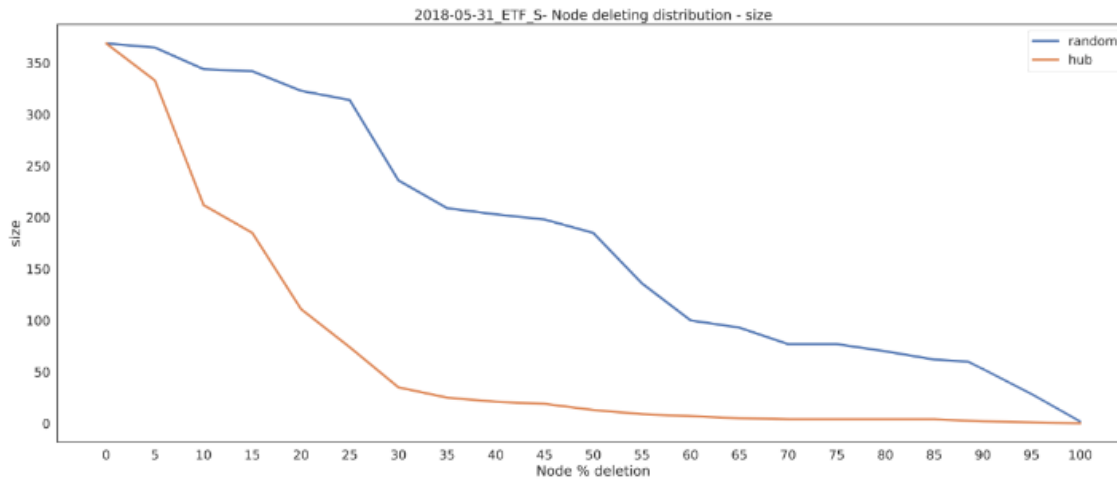
Node deletion - frequency



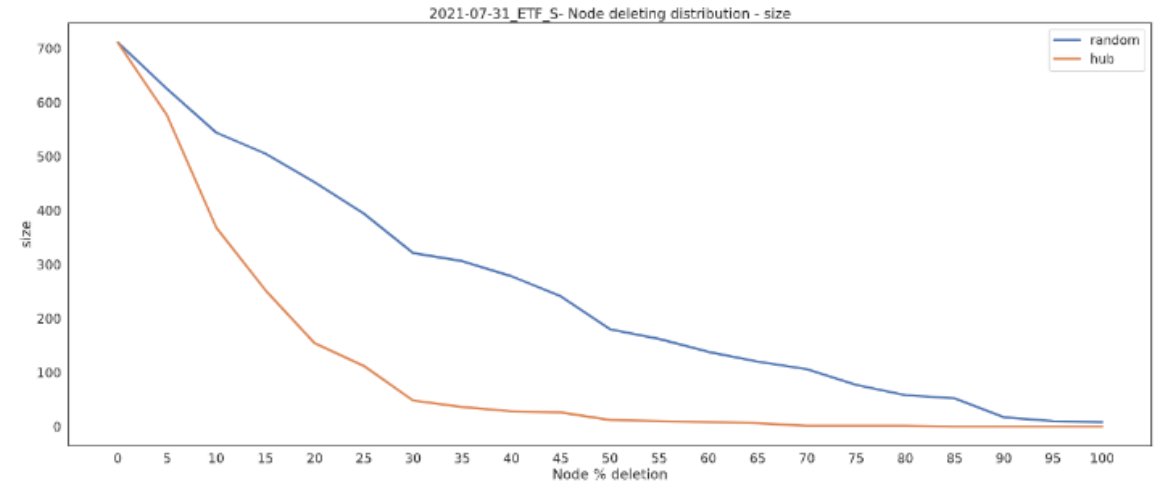
- Most frequent vulnerable nodes.
- CC&G and Monte Titoli exhibit a high vulnerability because of their centrality and importance in the system.

Node deletion - size

Cumulative May 2018



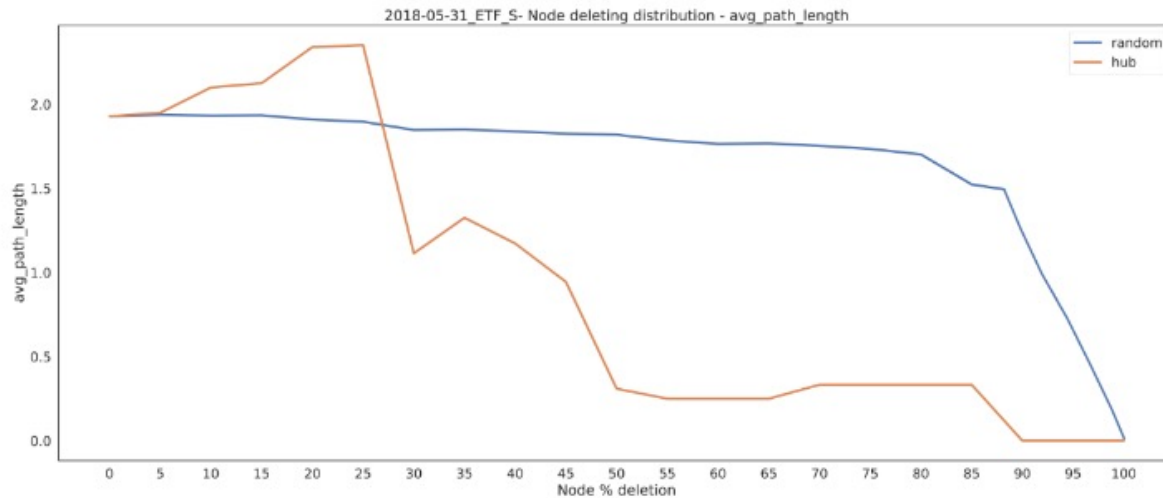
Cumulative July 2021



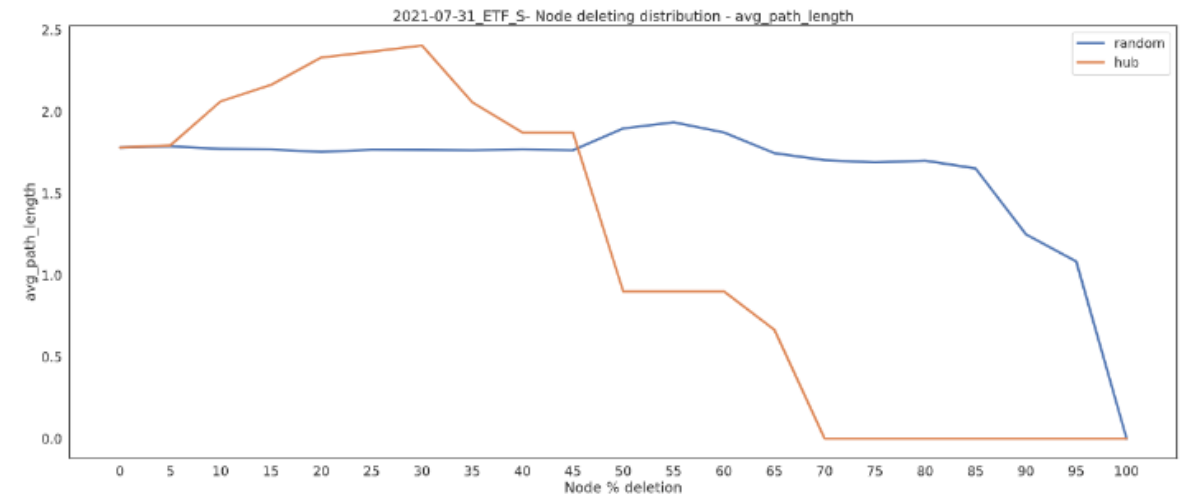
- After deleting 30% of the hub nodes, the size decreases rapidly to less than 50 links.
- Random node deletion results in a slower decrease in network size.
- In July 2021, the curve is smoother.

Node deletion - average shortest path

Cumulative May 2018



Cumulative July 2021



- The elimination of hub nodes results in increased distance
- After reaching 30% of hub node removal, the average shortest path length reduces significantly.
- Random removal presents a stable shortest path length.

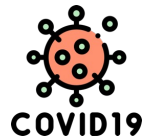
Daily analysis

Disruptive events could irreversibly change topology and structure of the networks, such as the September 11th, 2001, terrorist attack.

Two different case-studies of disruptive events:

1. The impact of Covid-19:

- Changes in networks topology
- Period from January 2019 to December 2021



2. The impact of large BTP emissions:

- Changes in networks topology
- Emission of BTP Italia and BTP Futura

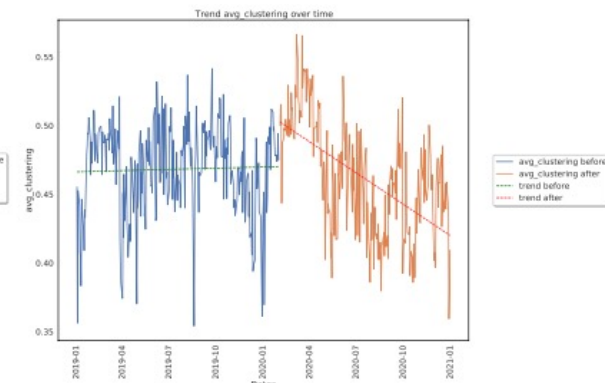
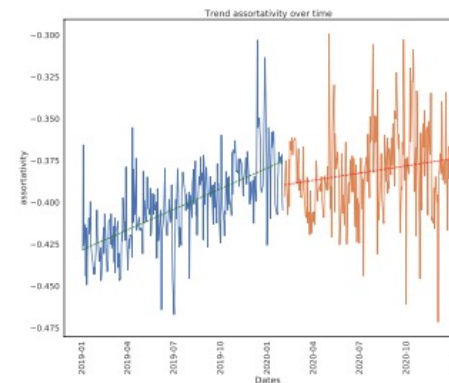
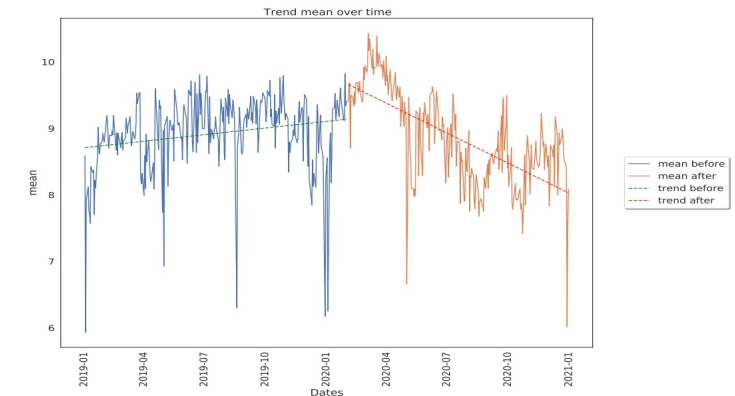


Impact of Covid19

The Coronavirus pandemic has impacted the networks:

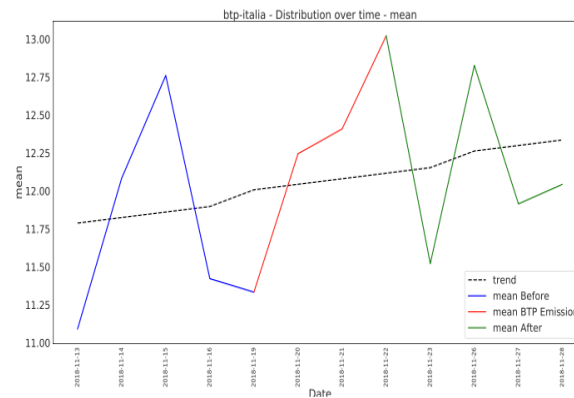
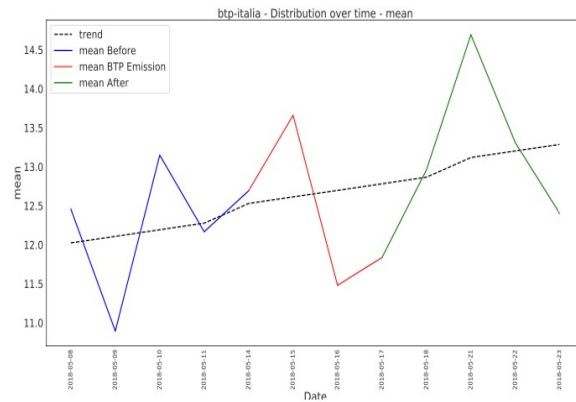
1. **Mean degree** decreases
2. **Assortativity** increases
3. **Average Clustering** decreases

	Mean Degree			Assortativity			Average Clustering		
	before	during	Δ	before	during	Δ	before	during	Δ
ETF _N	9.803	9.629	-0.173	-0.428	-0.411	0.017	0.594	0.588	-0.006
ETF _S	15.974	15.284	-0.69	-0.502	-0.507	-0.005	0.703	0.665	-0.037
Government Bonds _S	22.217	22.138	-0.08	-0.555	-0.554	0.001	0.673	0.671	-0.003
Government Bonds _N	10.632	10.383	-0.249	-0.463	-0.402	0.061	0.605	0.575	-0.03
Shares _S	22.453	21.319	-1.134	-0.472	-0.49	-0.018	0.771	0.754	-0.016
Shares _N	12.711	12.843	0.131	-0.447	-0.435	0.013	0.607	0.588	-0.019
Corp. Bonds _S	8.098	7.784	-0.315	-0.61	-0.602	0.008	0.274	0.261	-0.013
Corp. Bonds _N	7.619	6.745	-0.874	-0.345	-0.291	0.054	0.484	0.432	-0.052
Funds _S	15.579	14.811	-0.768	-0.491	-0.491	0.0	0.673	0.633	-0.039
Funds _N	9.948	9.803	-0.145	-0.438	-0.412	0.026	0.613	0.601	-0.012
Other _S	4.515	6.511	1.996	-0.537	-0.479	0.058	0.188	0.294	0.105
Other _N	3.134	2.987	-0.147	-0.184	-0.129	0.055	0.105	0.065	-0.039

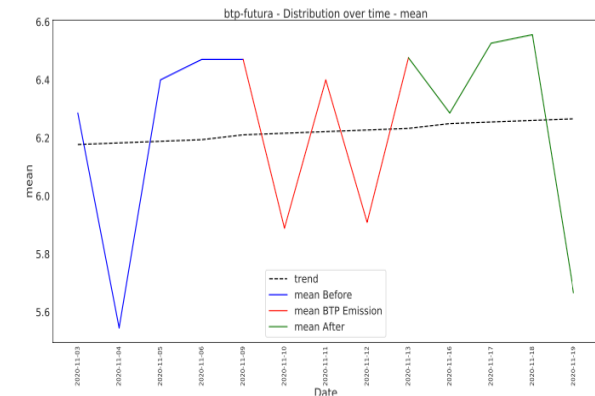
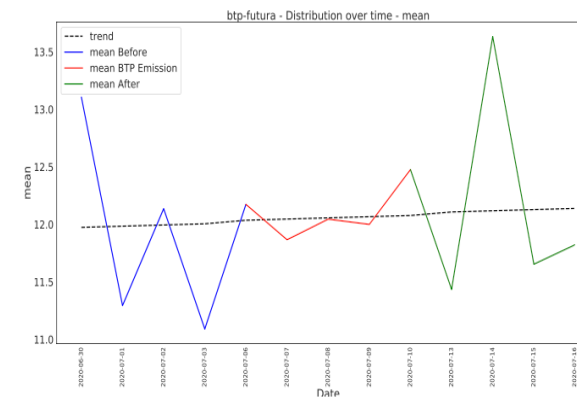


Impact of BTP emissions

BTP Italia



BTP Futura



- Only Government Bonds networks are considered.
- There is no evidence that the emission of BTP Italia and Futura impacts the topology of the networks.

Conclusions

- **Monthly Networks:**

- Centrality analysis: central nodes in cumulative networks show a stable pattern in ranking, non-cumulative does not exhibit any recognizable behaviors.
- Scale-free networks: cumulative networks show a predominance of scale-free behavior with respect to non-cumulative.
- Networks resiliency: eliminating an important node has a greater impact on the network topology than randomly eliminating.

- **Daily Networks:**

- Covid19 had a negative impact on networks topology: decreased mean degree, disassortativity, clustering coefficient.
- BTP Italia and BTP Futura emissions had no impact on networks topology.

Future works

For future works, there are several possibilities:

- Monthly networks analysis **also on daily networks** (centrality, scale-free, resiliency)
- Similar studies apply to **data from different contexts** and environments.
- Try **other types** of node elimination: almost-failures attack and efficient link attack
- Impact analysis on **settlement discipline** (penalty on instructions with long time failed status) that went live on 1st February 2022.

Thank you