Economic Complexity for Innovation Policy

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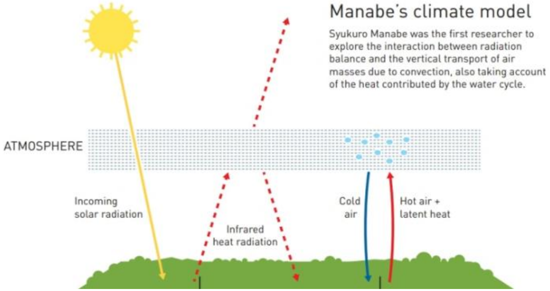
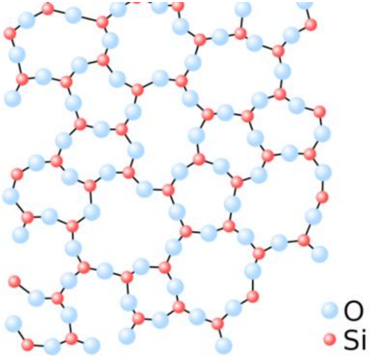
The Century of Complexity

2021's physics Nobel Prize on complexity science





What is Economic Complexity?

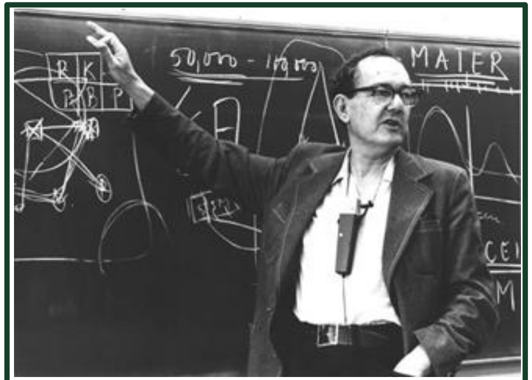
Economic complexity is the application of **complex systems** and **network thinking** to economics

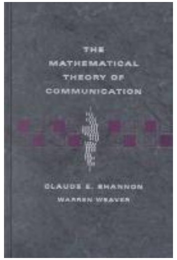
Paradigm shift from *isolated characteristics* to **systemic interactions**

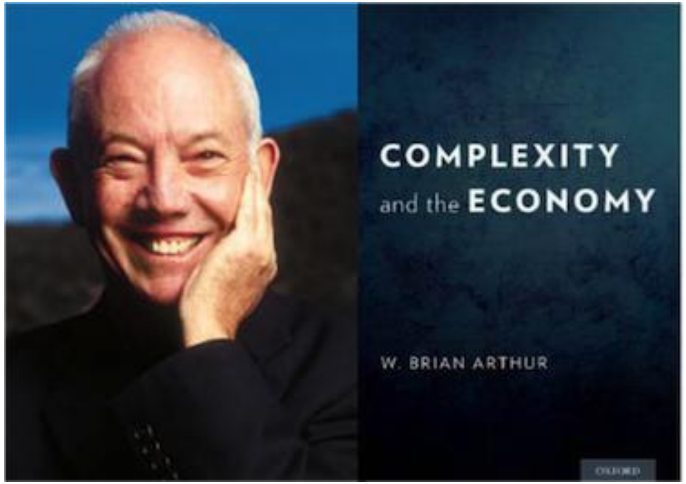
-> To understand emerging patterns of growth, regional evolution, technological change, inequality, sustainability…

Economic complexity produces useful **heuristics** and **metrics** to make better business and policy decisions

Founding parents







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Research Policy

Volume 51, Issue 3, April 2022, 104450

The new paradigm of economic complexity ☆

Pierre-Alexandre Balland [a, b], Tom Broekel [c], Dario Diodato [d, #], Elisa Giuliani [e], Ricardo Hausmann [f], Neave O'Clery [g], David Rigby [h]

Research Policy

Supports *open access*

Special Issue on Economic Complexity

Edited by Pierre-Alexandre Balland, Tom Broekel, Dario Diodato, Ricardo Hausmann, Neave O'Clery, David Rigby

Last update 17 January 2022

Programme

THURSDAY 27 April 2023

08.45 Registration of Participants

09.00 **Welcome and Introduction to the Course**

COMPLEXITY THINKING

09.15 **Using complexity thinking to solve real-world problems**

10.00 **Key concepts for research and innovation policy**

11.00 Coffee break

11.15 **A framework to improve the EU innovation system**

12.00 Lunch

STRUCTURAL NETWORK ANALYSIS

13.00 **Introduction to the R programming language**

14.00 **Network analysis of complex networks**

15.00 **Advanced network visualization**

16.00 End of first day

FRIDAY 28 April 2023

RELATEDNESS & COMPLEXITY

09.00 **Relatedness and economic complexity index**

10.00 **Mapping knowledge in countries/regions**

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COMPUTING RELATEDNESS & ECI

13.30 **Computing Relatedness (EconGeo Package)**

14.30 **Computing the ECI (EconGeo Package)**

15.30 **Plotting treemaps and the knowledge space**

16.30 Evaluation, wrap-up & discussion

17:00 End of second day

Programme

Design better systems (of innovation)

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Better prioritization

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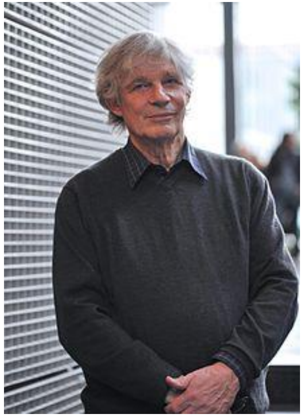
PART I: COMPLEX SYSTEMS THINKING



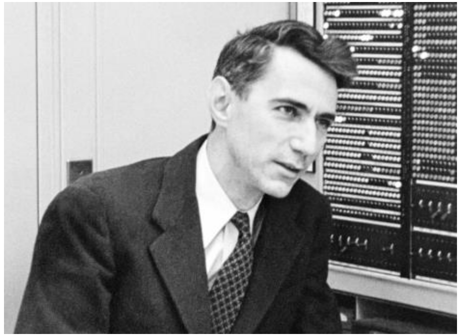
Stuart Kauffman
(biology)

Ilya Prigogine
(chemistry)

Albert-László Barabási
(physics)

Warren Weaver
(mathematics)

John Holland
(psychology and electrical engineering)



Claude Shannon
(information theory)

Influential contributors

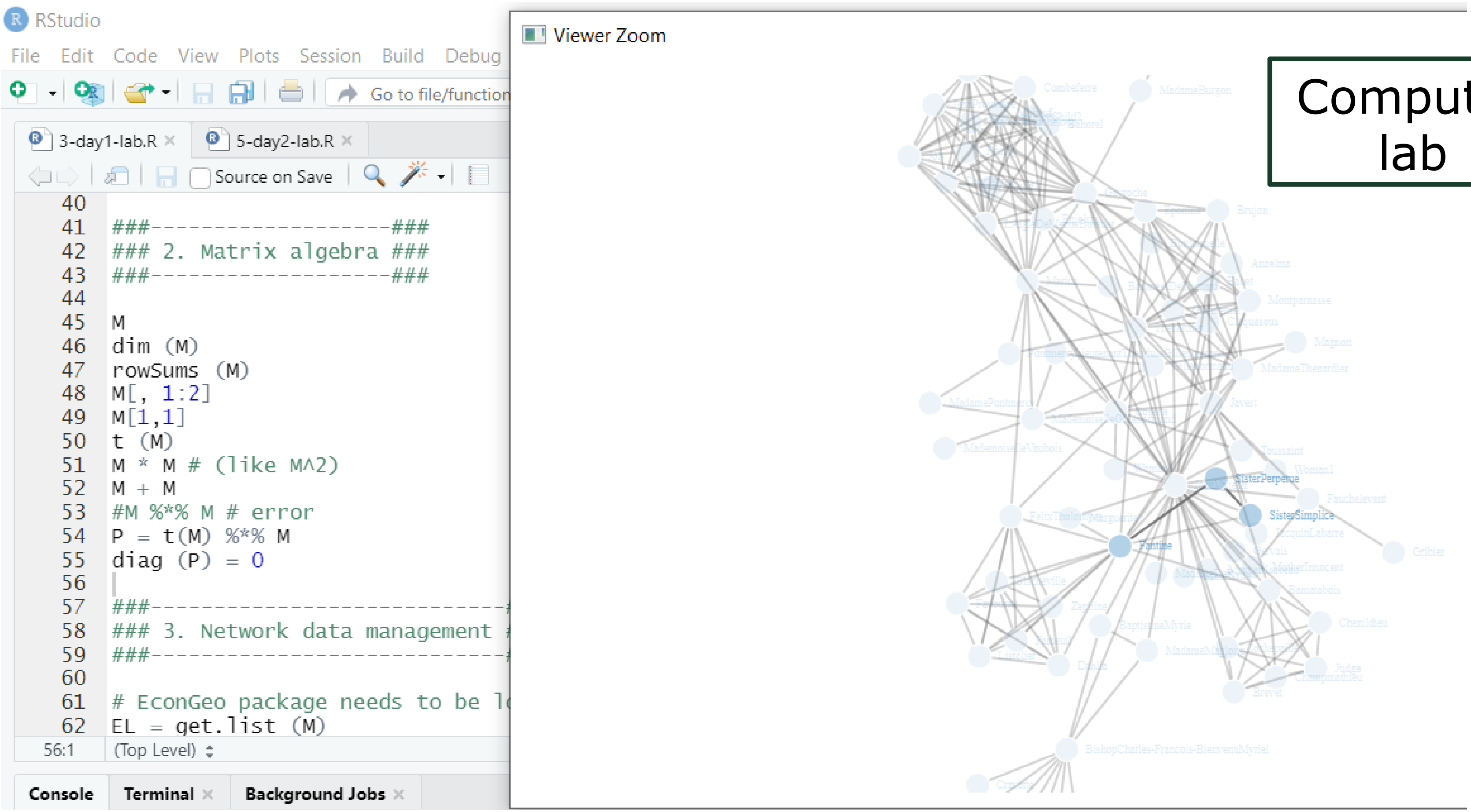
Complex systems thinking

Recognize that our society, economy, climate are **complex systems** and should be treated as such

Complex systems are understood by studying the **interrelationships** and **interactions** between different components or agents, rather than by analyzing the properties of individual components in isolation

The awareness and analysis of **inter-connectivity** is the starting point of complex systems thinking.

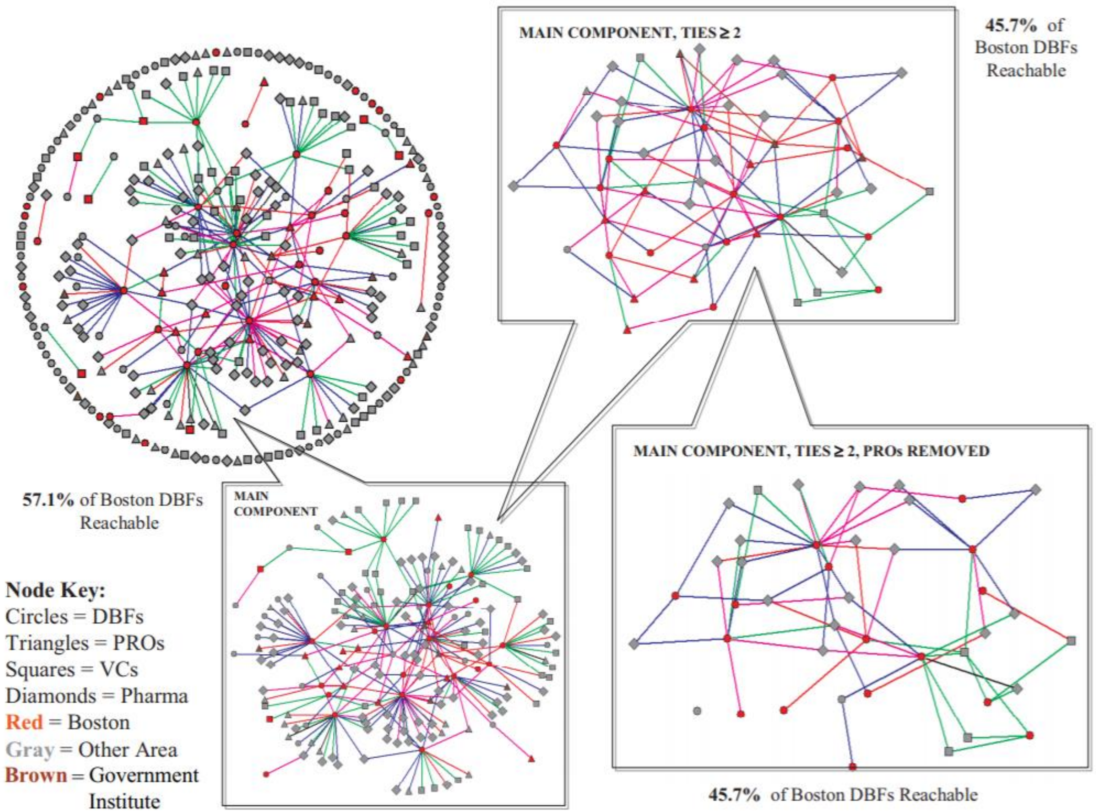
Mapping & network analysis



Computer lab

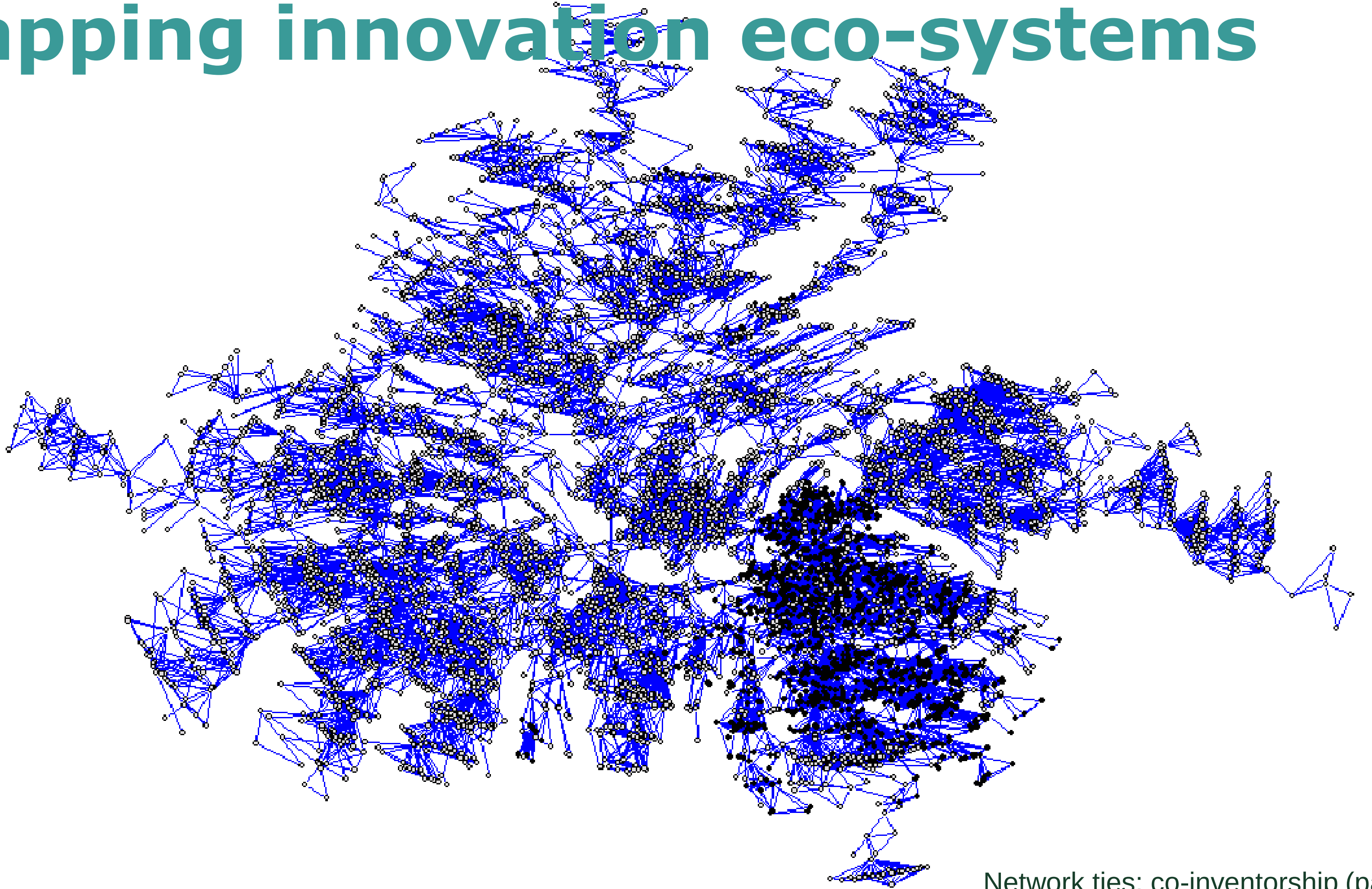
Mapping innovation eco-systems

Figure 2 The Boston+ Network, 1988



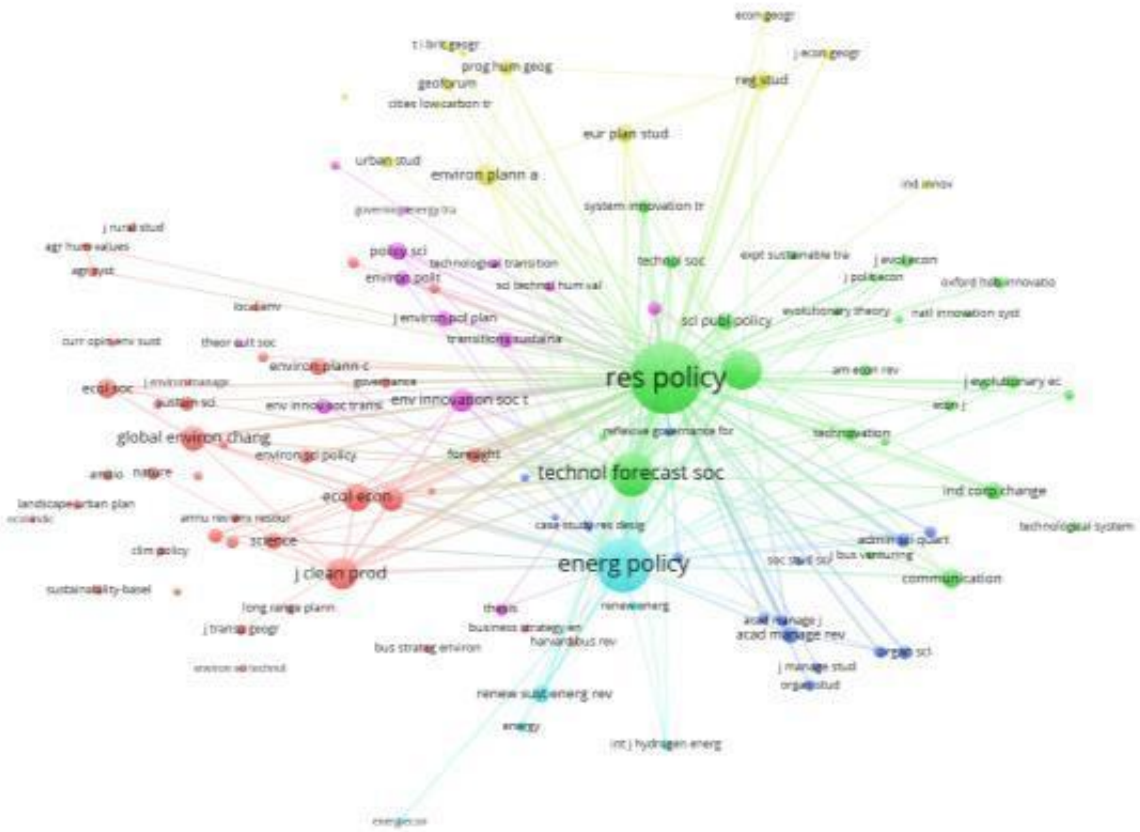
Network ties: formal contractual alliances

Mapping innovation eco-systems



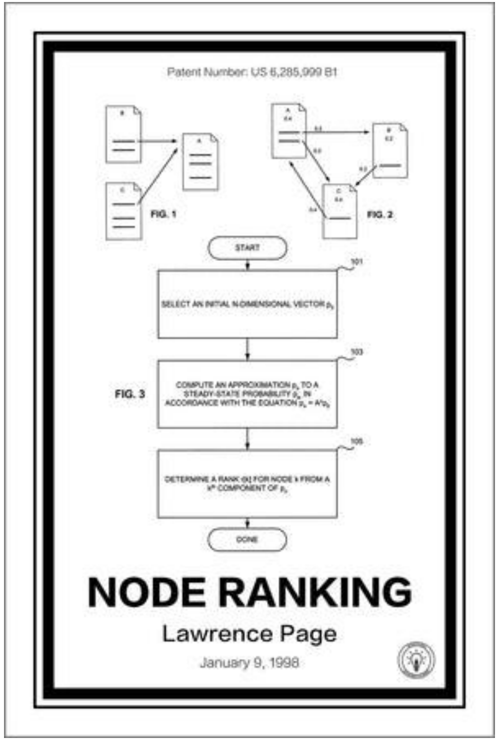
Network ties: co-inventorship (patents)

Mapping innovation eco-systems



Network ties: citations (publications)

From structure to predictions



NETFLIX

amazon

YouTube

Spotify

Google

AI applications extract information from ‘complex’ network structures

On complexity & growth

The division of knowledge and subsequent recombination is a necessary condition of **growth** and evolution.

On connectivity & systemic risk

Human connections: **spread of infectious** diseases to the point of human extinction

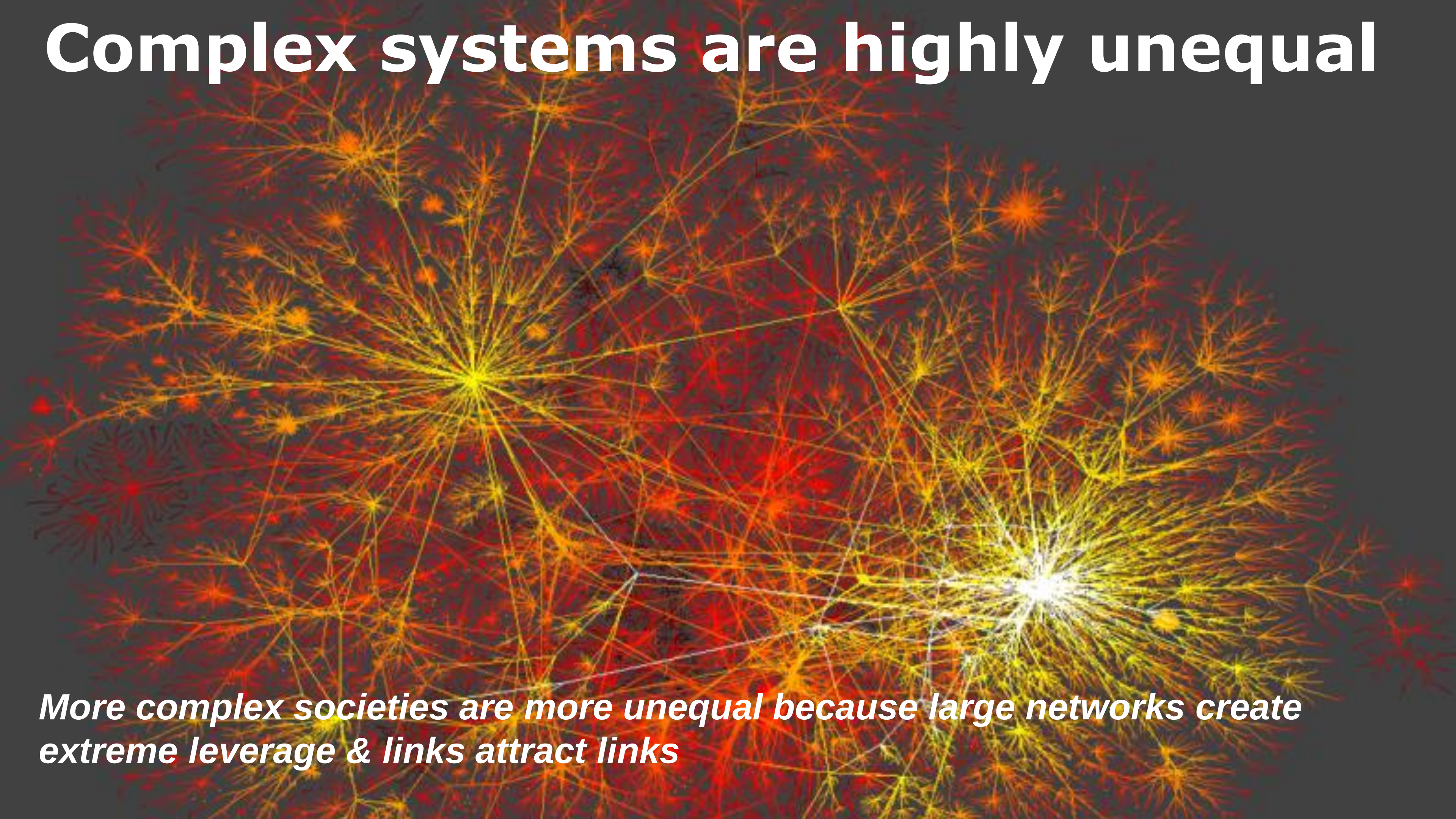
Social media: **misinformation**, hoaxes or conspiracy theories that can create panic, harm public health & geopolitical risk

Economy: large-scale bubbles, financial **crises** and contagion

Value chains: increased **dependence** of some countries on others for essential goods & single points of failure

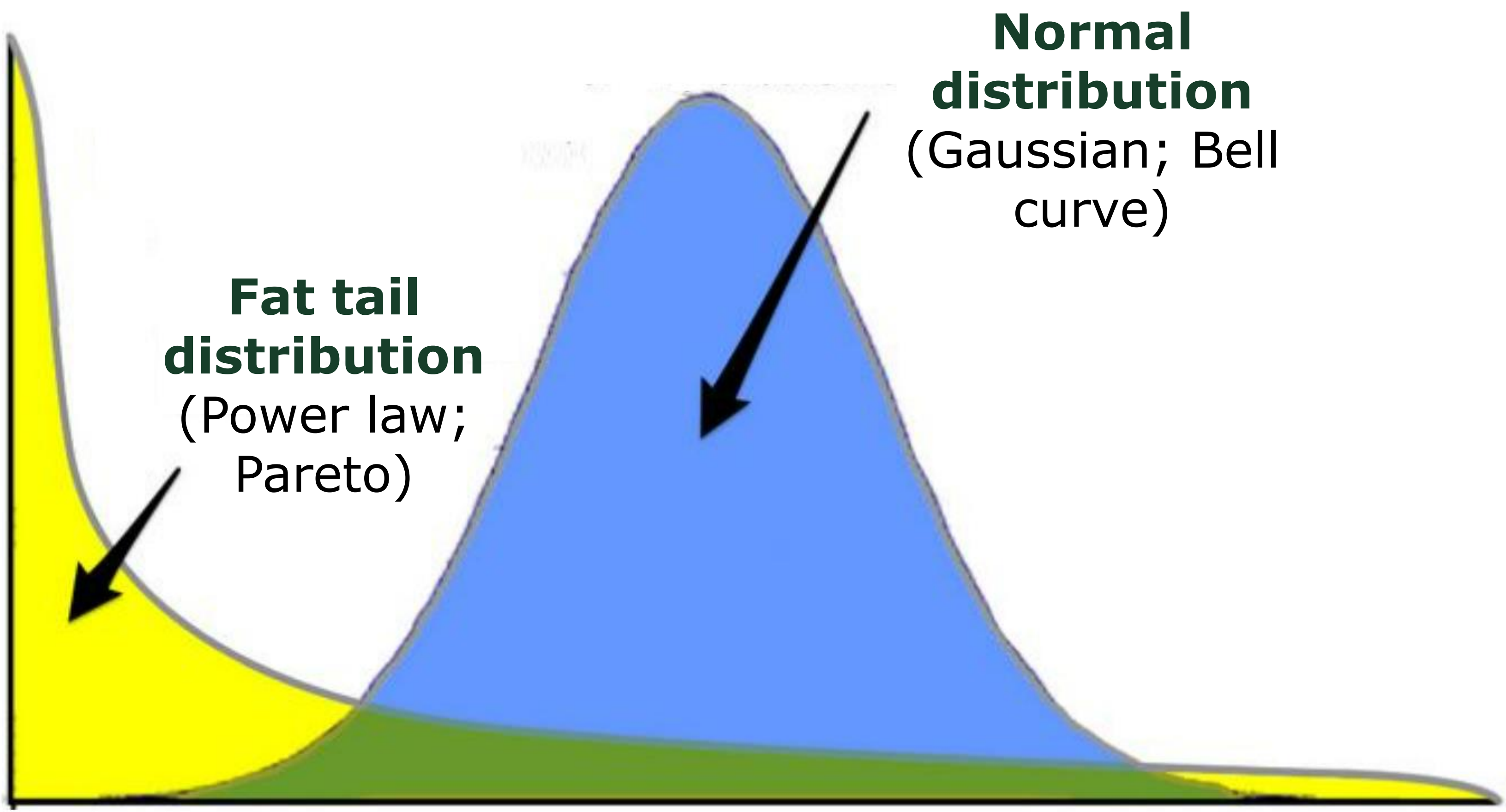
Knowledge & data: AGI & **singularity**

Complex systems are highly unequal



More complex societies are more unequal because large networks create extreme leverage & links attract links

Fat-tails


Normal distribution
(Gaussian; Bell curve)
Fat tail distribution
(Power law; Pareto)

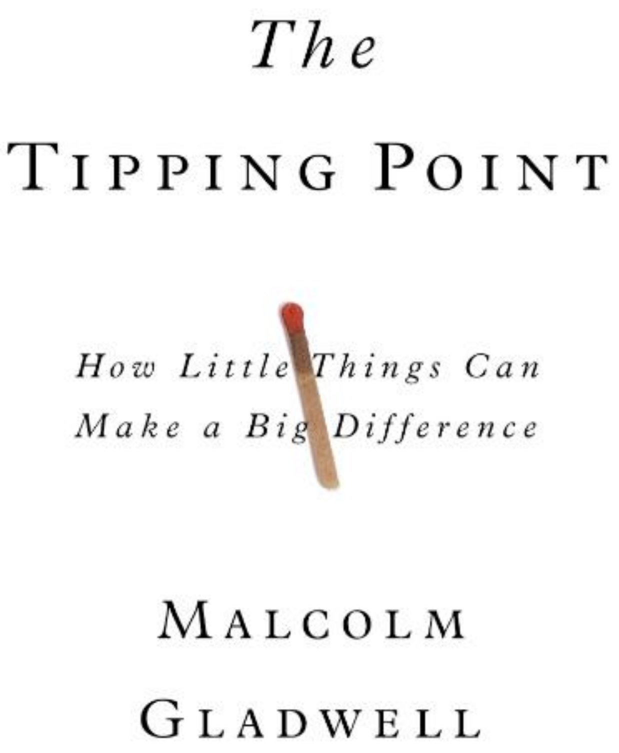
Other key concepts

Emergence: complex system behavior that arises from the interactions and feedback among individual components and not simply reducible to the sum of its parts.

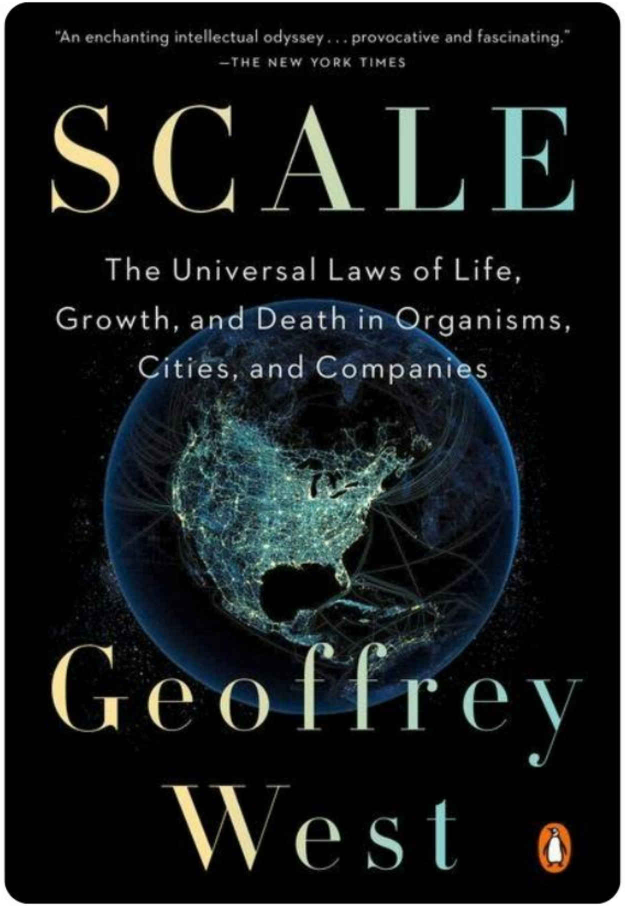
Non-linearity: the relationship between two variables is not proportional or linear. A small changes in one variable can result in disproportionately large changes in the other variable.

Self-organization: spontaneous organization of a set of components into a coherent and functional whole, without the need for external direction, control or coordination.

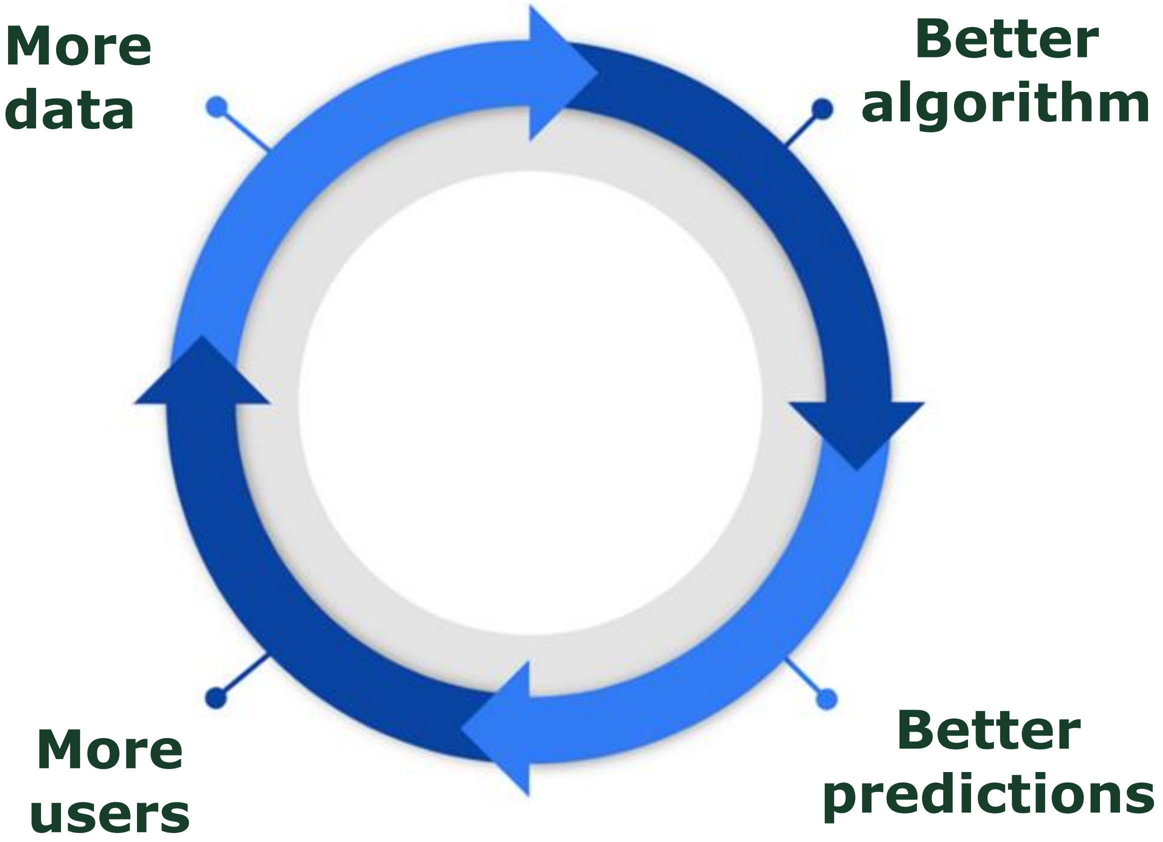
Tipping points



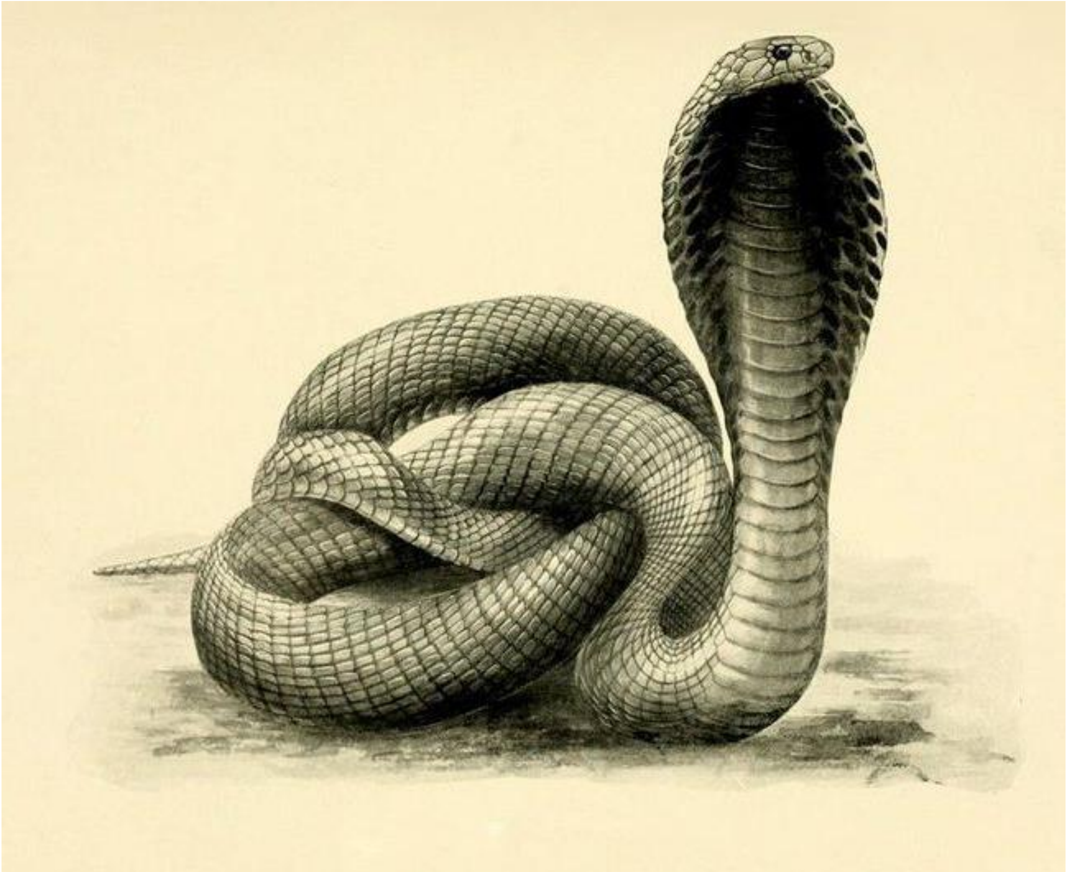
Scaling



Feedback loops



Second-order effects



System thinking at ESIR

Industry 5.0, a transformative vision for Europe : governing **systemic transformations** towards a sustainable industry

Global value chains : harnessing innovation to protect and transform the **backbone** of global trade

Protect, prepare and transform Europe - Recovery and **resilience** post COVID-19

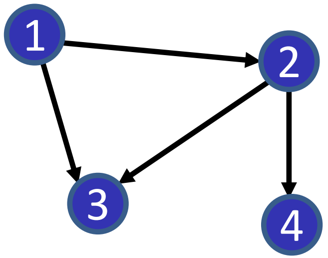
Unpacking tensions

An advice network

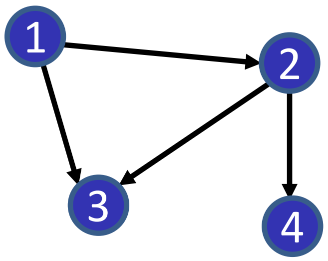
- Emma (1) helps Mason (2)
- Emma (1) helps William (3)
- Mason (2) helps William (3)
- Mason (2) helps Sophia (4)

A graph

- Emma (1)
- Mason (2)
- William (3)
- Sophia (4)



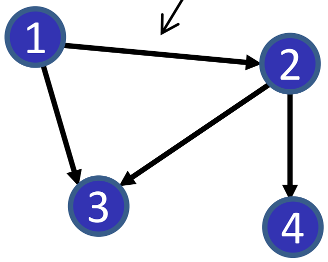
Network terms



Node
(vertex – vertices)

Network terms

Edge (tie, link)



Node
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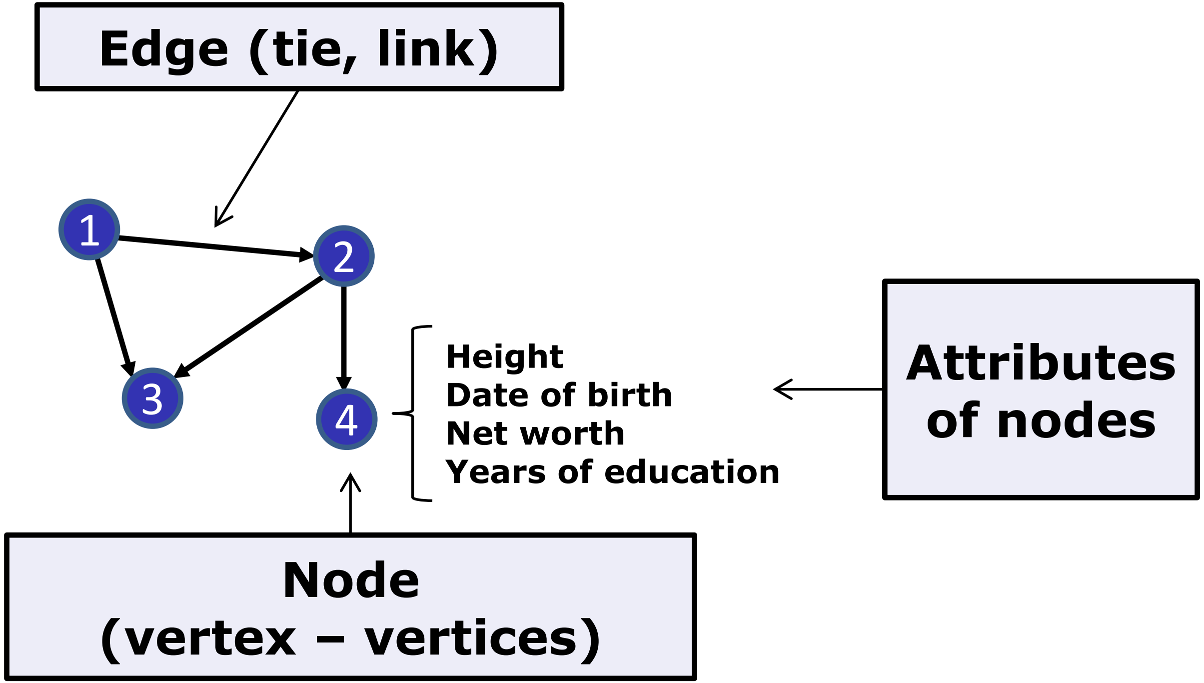
Network terms

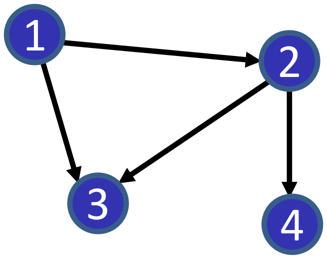


Network terms

- N = number of nodes (size of the network)
- $N = 4$
- The network is composed by the nodes $i = 1, 2, \ldots, N$
- L = number of links
- $L = 4$
- The connection between Mason and William [*Mason (2) helps William (3)*] is denoted as (2,3)
- A graph might be denoted as G, its vertex set as V(G), and its edge set as E(G)

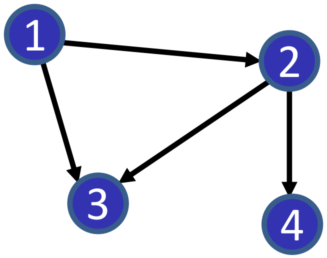
Different types of networks

Directed network

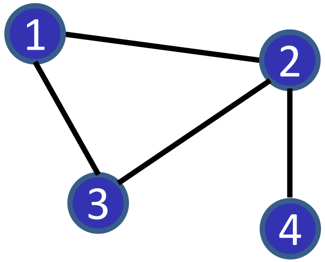


Different types of networks

Directed network

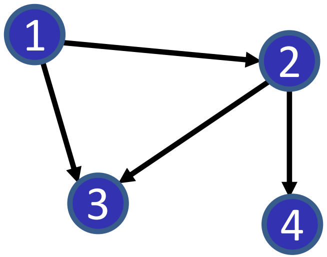


Undirected network

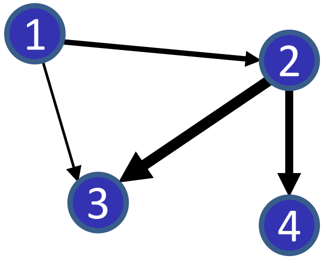


Different types of networks

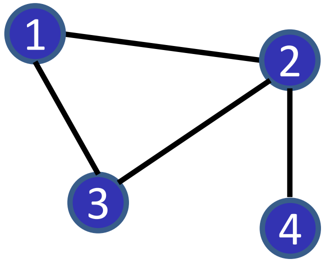
Directed network



Weighted network

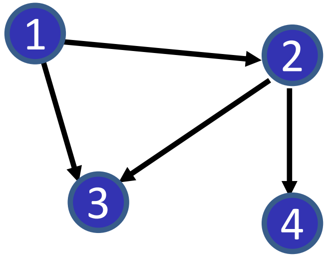


Undirected network



Network representations

Directed graph (digraph)



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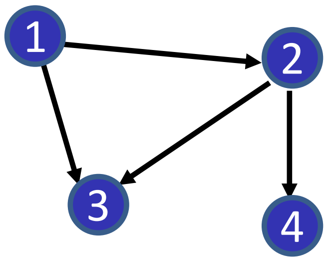
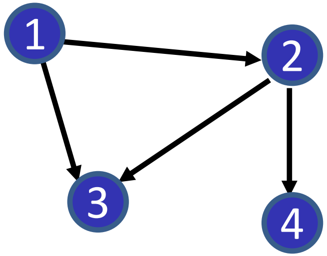


Edge list

Vertex	Vertex
1	2
1	3
2	3
2	4

Network representations

Directed graph (digraph)



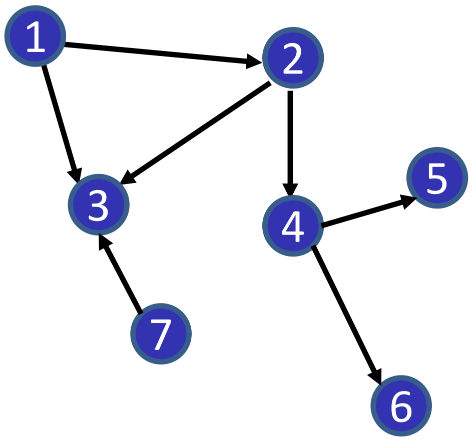
Edge list

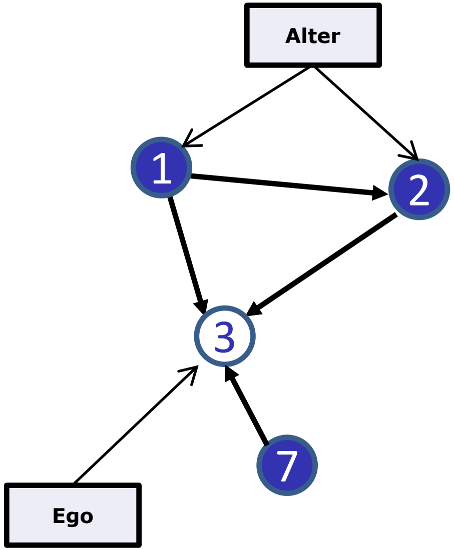
Vertex	Vertex
1	2
1	3
2	3
2	4

Adjacency matrix

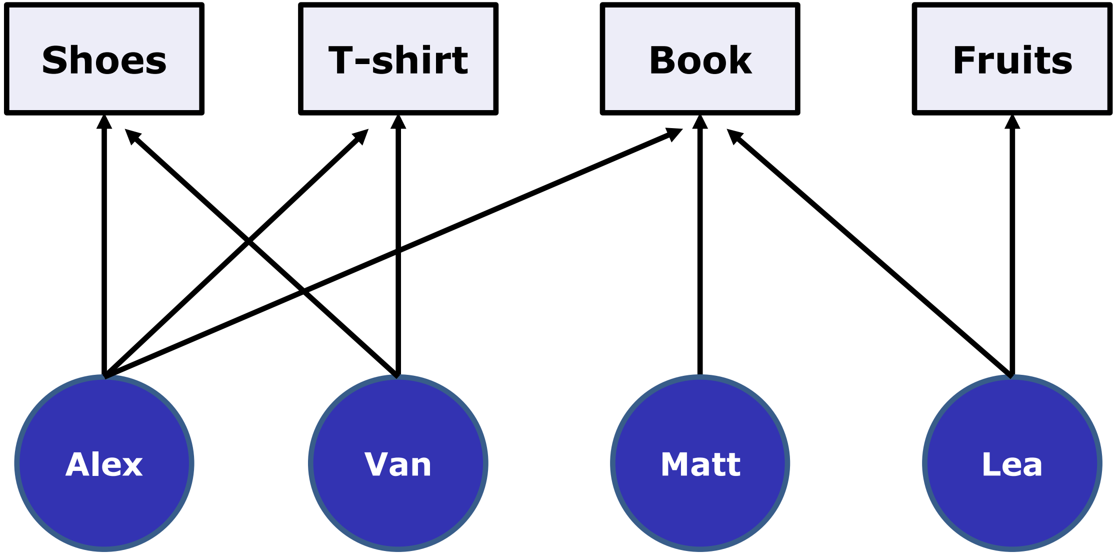
Vertex	1	2	3	4
1	-	1	1	0
2	0	-	1	1
3	0	0	-	0
4	0	0	0	-

Ego networks and whole networks





Bipartite network (2-mode)



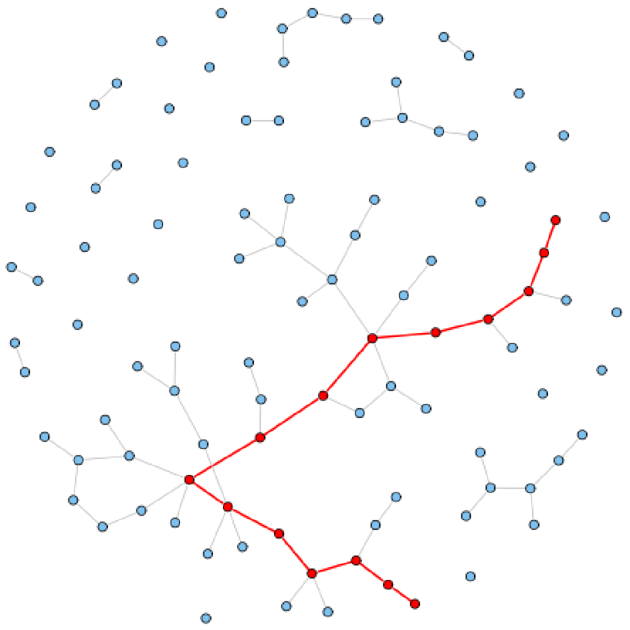
Multiplex networks

- Emma (1) helps Mason (2)
- Emma (1) is friends with Mason (2)
- Emma (1) works with Mason (2)
- …

Key features of real-world networks

1. Short average **path length**

Geodesic distance = number of edges in a shortest path connecting two nodes

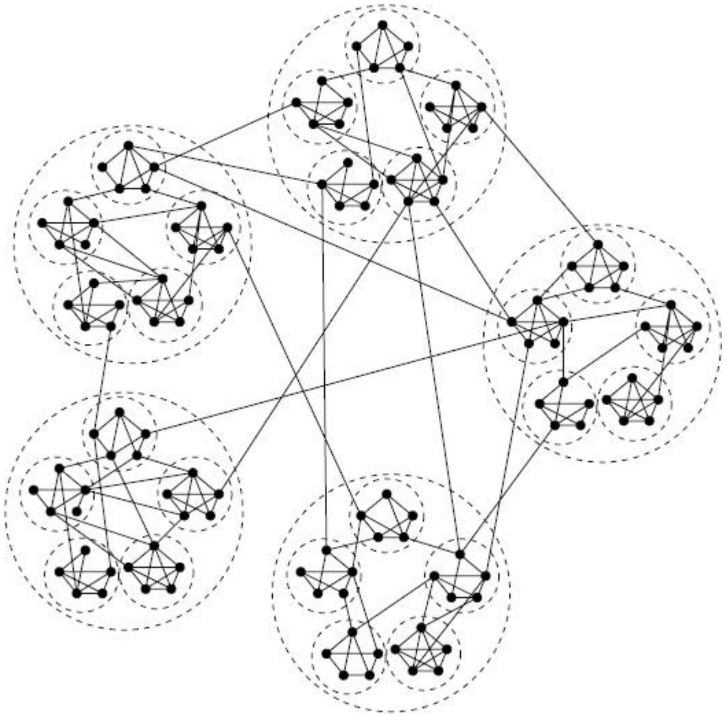


Key features of real-world networks

1. Short average path length

2. High **clustering** coefficient

Tendency of the network to form sub-groups

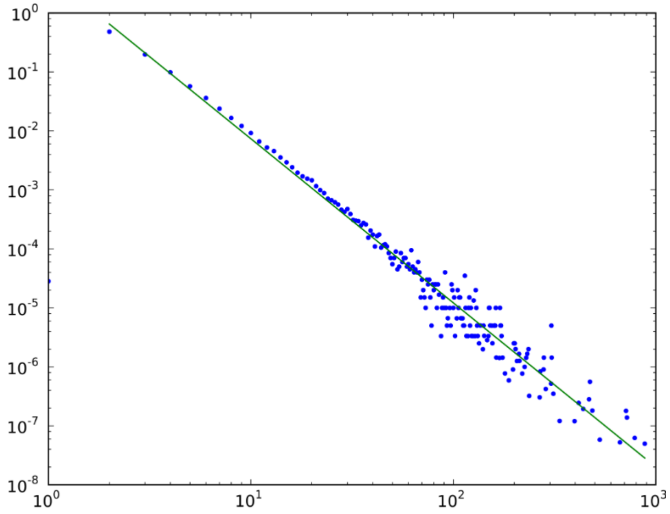


Key features of real-world networks

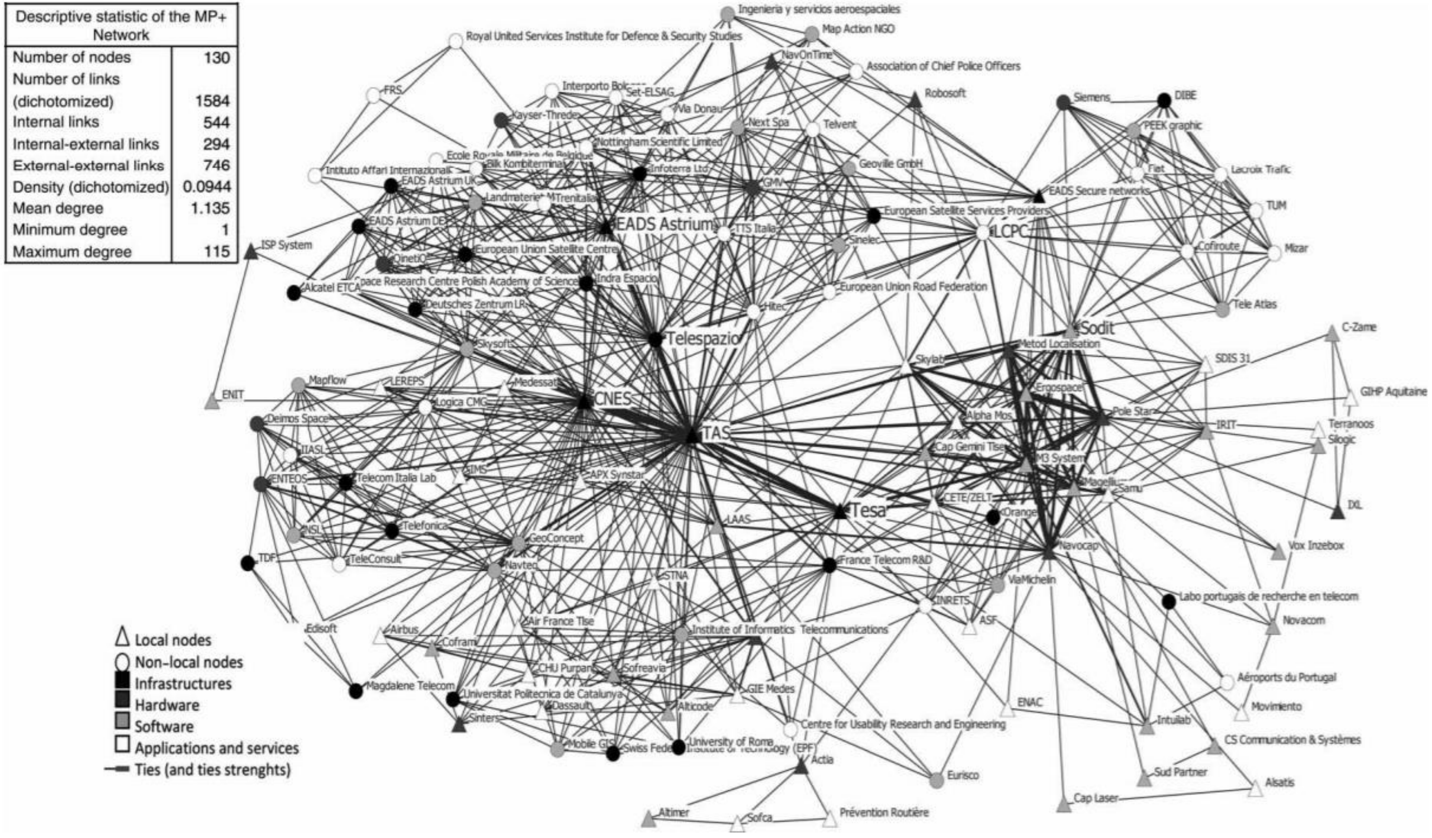
1. Short average path length

2. High clustering coefficient

3. Highly **unequal** degree distribution



Policy problem: finding key players



Descriptive statistic of the MP+ Network	
Number of nodes	130
Number of links (dichotomized)	1584
Internal links	544
Internal-external links	294
External-external links	746
Density (dichotomized)	0.0944
Mean degree	1.135
Minimum degree	1
Maximum degree	115

Fig. 3. MP+ Network

Network ties: R&D projects (reg;nat; EU)

The big 4 centrality measures

1. Degree centrality

The big 4 centrality measures

1. Degree centrality

2. Betweenness centrality

The big 4 centrality measures

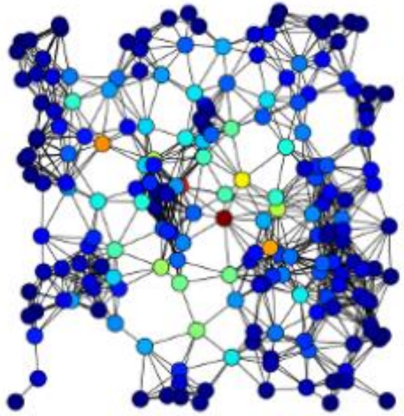
1. Degree centrality

2. Betweenness centrality

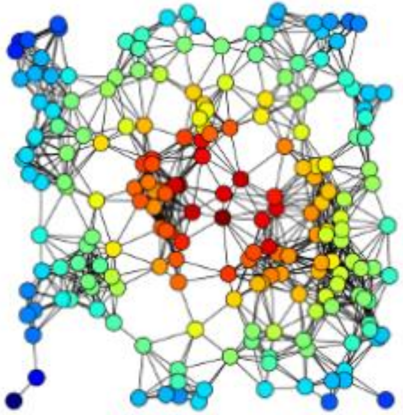
3. Closeness centrality

The big 4 centrality measures

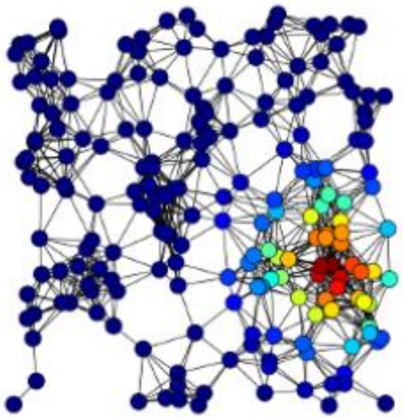
1. Degree centrality
2. Betweenness centrality
3. Closeness centrality
4. Eigenvector centrality



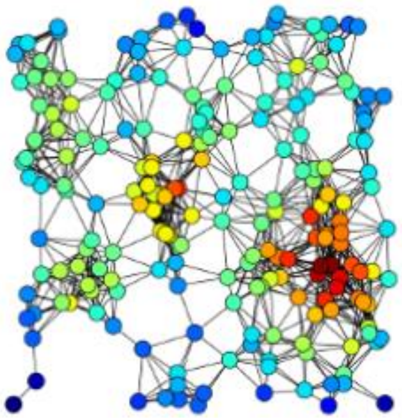
Betweenness



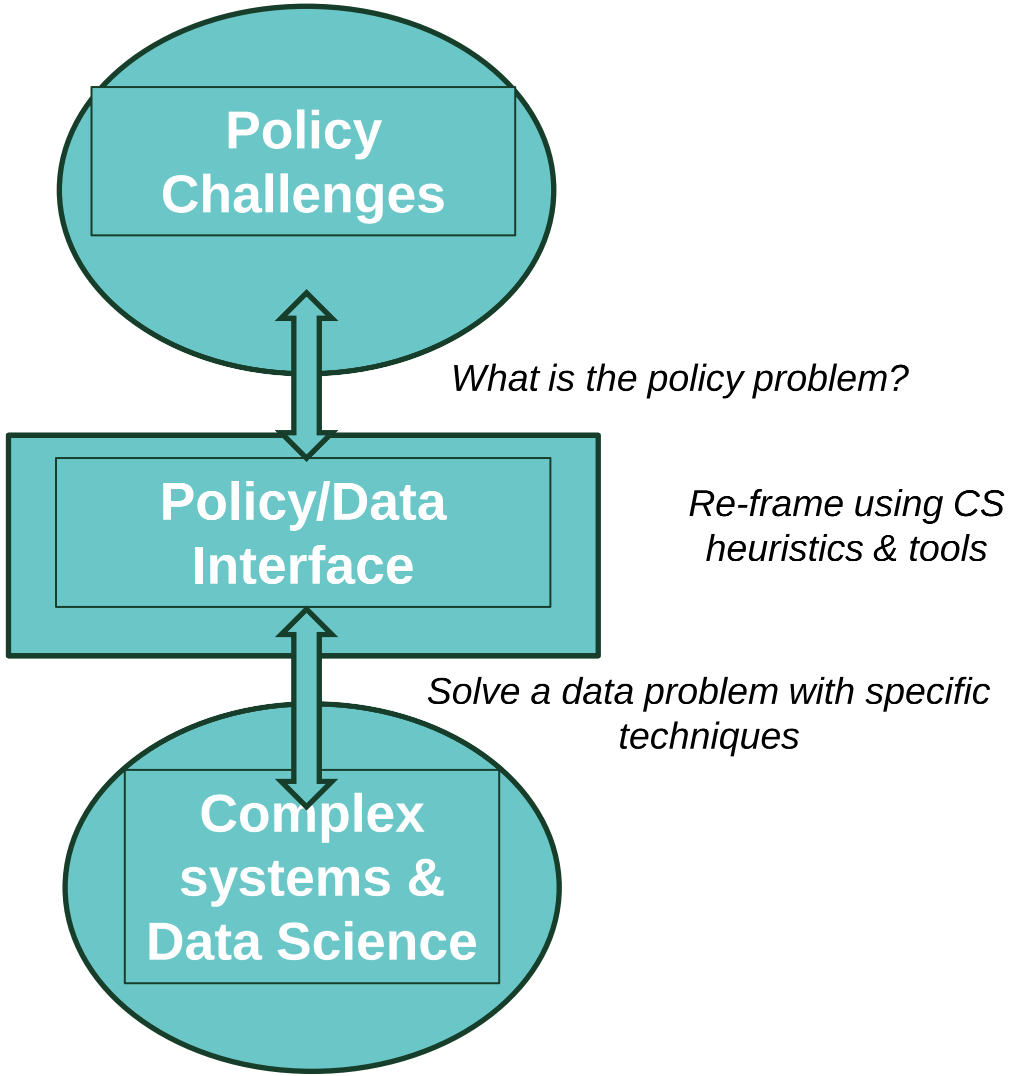
Closeness



Eigenvector



Degree

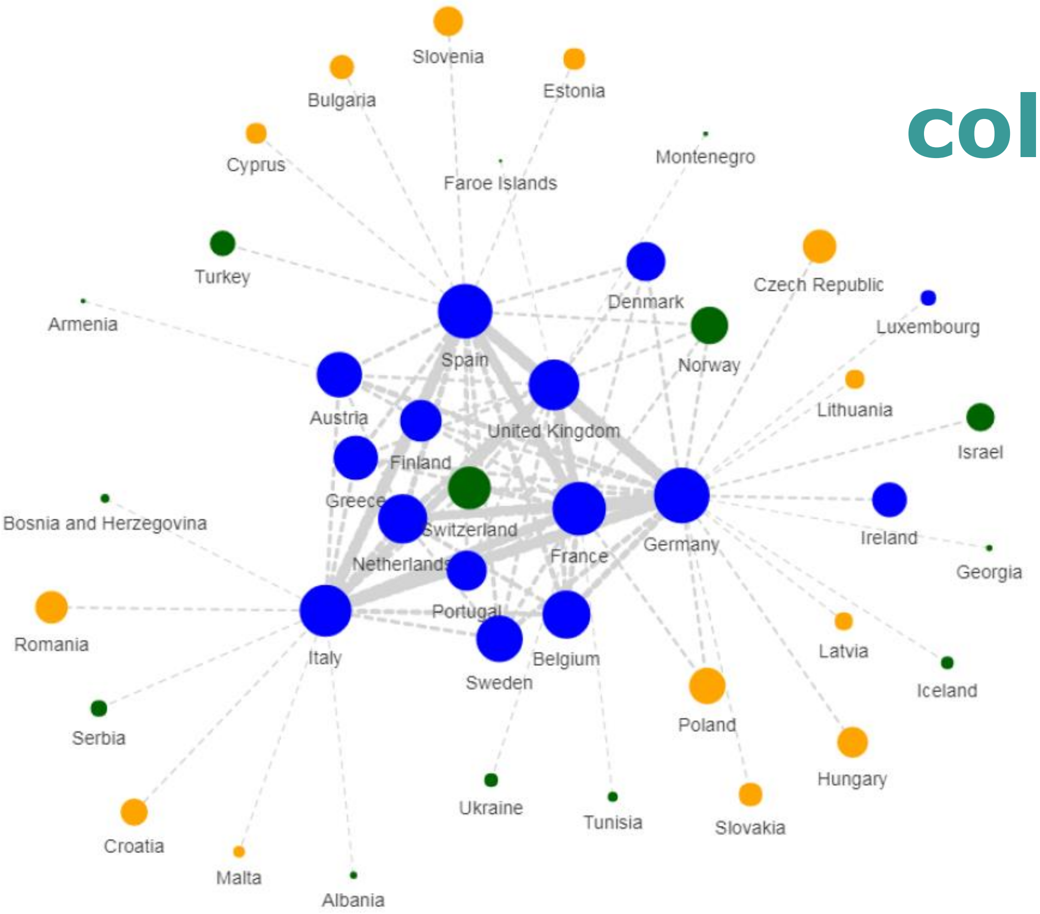

Policy Challenges
What is the policy problem?
Policy/Data Interface
Re-frame using CS heuristics & tools
Solve a data problem with specific techniques
Complex systems & Data Science

Linking to policy

Monitor and fix **innovation system failures** (detect system failures, monitor system performance, target specific links)

- Describe the structure of networks and identify key actors (monitoring)
- Link network indicators and innovation performance (impact evaluation)
- Explain (predict) link formation (strategy)

H2020 collaborations



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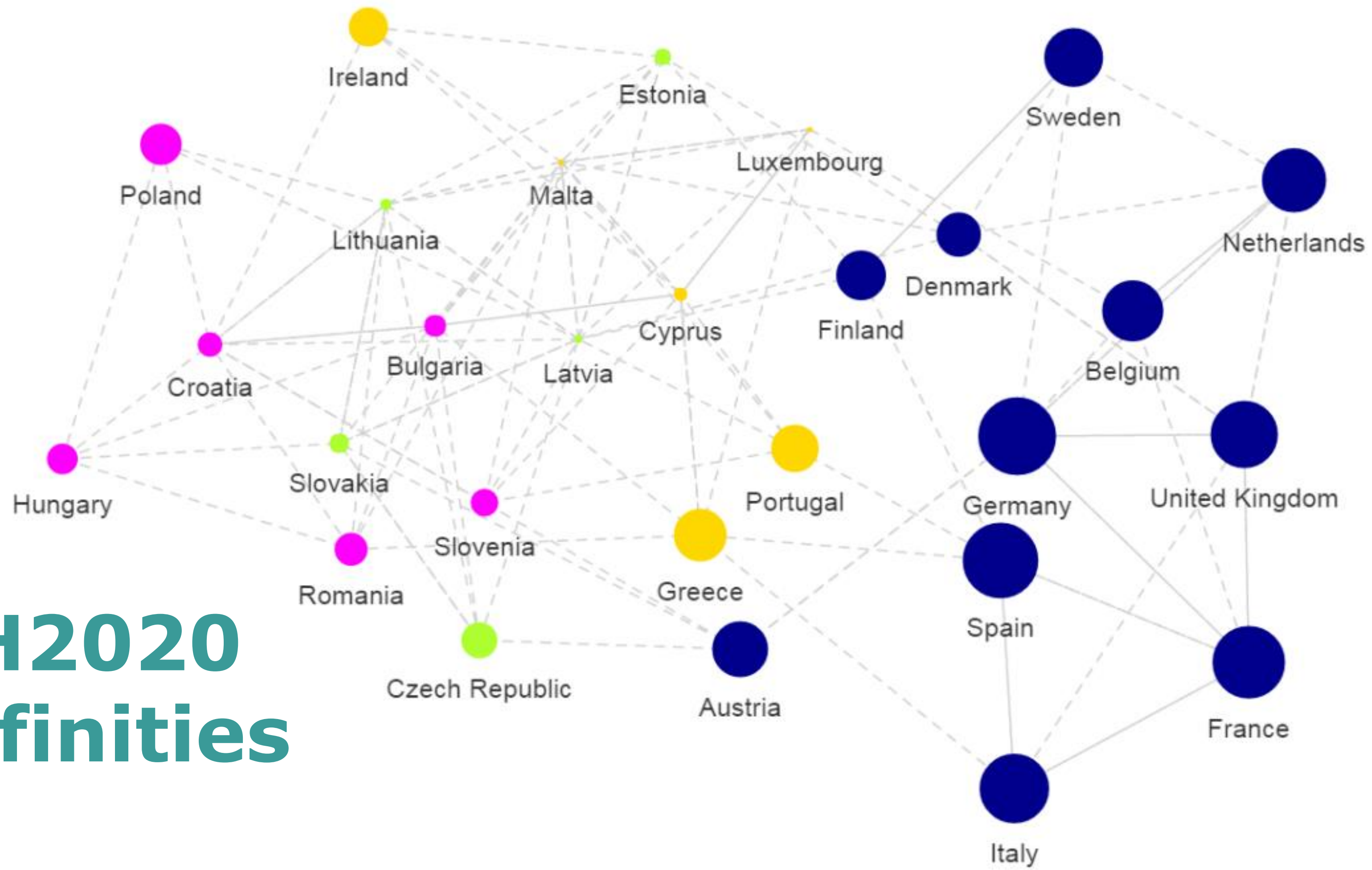

H2020 affinities

Balland, P.A., Boschma, R., and Ravet, J. (2019) - European Planning Studies, 27 (9)

YOUR POLICY CHALLENGES