DEPARTMENT OF ENVIRONMENTAL STUDIES

Network analysis:

social, ecological, and social-ecological approaches

FSS:ENSb1315 (Spring 2025)

Yanhua Shi & Harald Waxenecker

Feb 27; U44

Course objectives

This course introduces the students to qualitative and quantitative network analysis and its interdisciplinary applications in institutional analysis, political economy and ecology, social-ecological economics, international relations, among others.

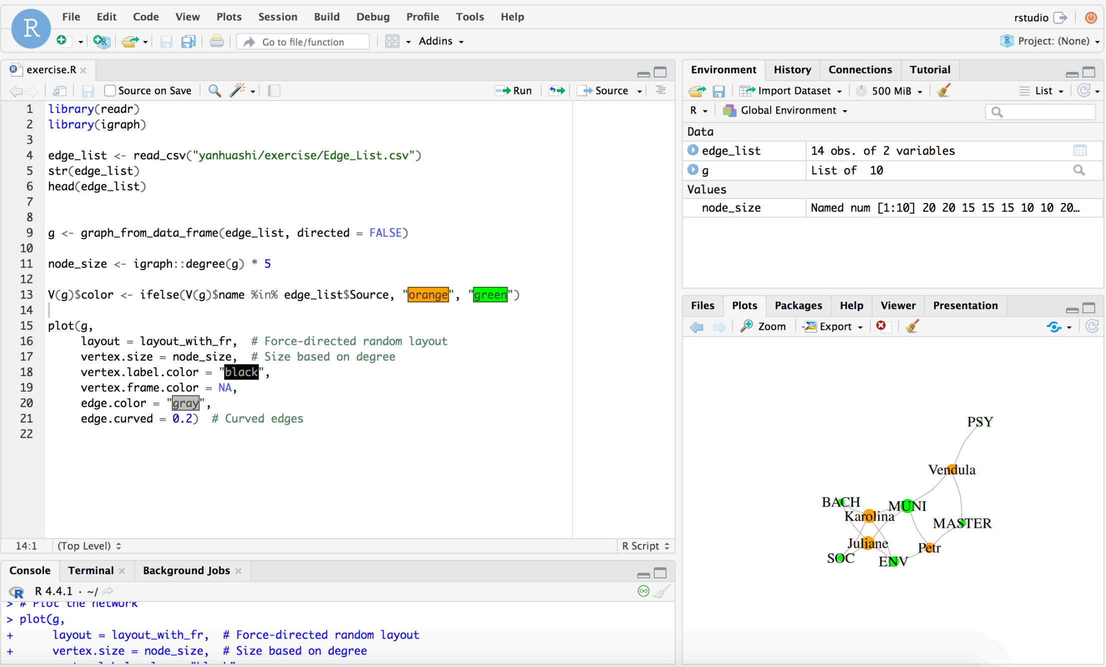
Social Network Analysis (SNA), Ecological Network Analysis (ENA) , and Social-Ecological Network Analysis (SENA) will be introduced. The students will understand the basics of network analysis across disciplines and be prepared to transfer parts of the acquired knowledge to cases of their own interest.

When?	What?
27.2.	Course introduction, basic network-related concepts
6.3.	Introduction of situation-centered institutional analysis
13.3.	Basic network analysis in R – Part I
20.3.	Basic network analysis in R – Part II
27.3.	Social Network Analysis: history, theory and application
3.4.	Ecological and social-ecological networks
10.4.	Network of Action Situations – Part I
17.4.	Network of Action Situations – Part II
24.4.	Students presenting paper ideas and discussions
1.5.	Holiday
8.5.	Holiday
15.5.	Students presenting their papers

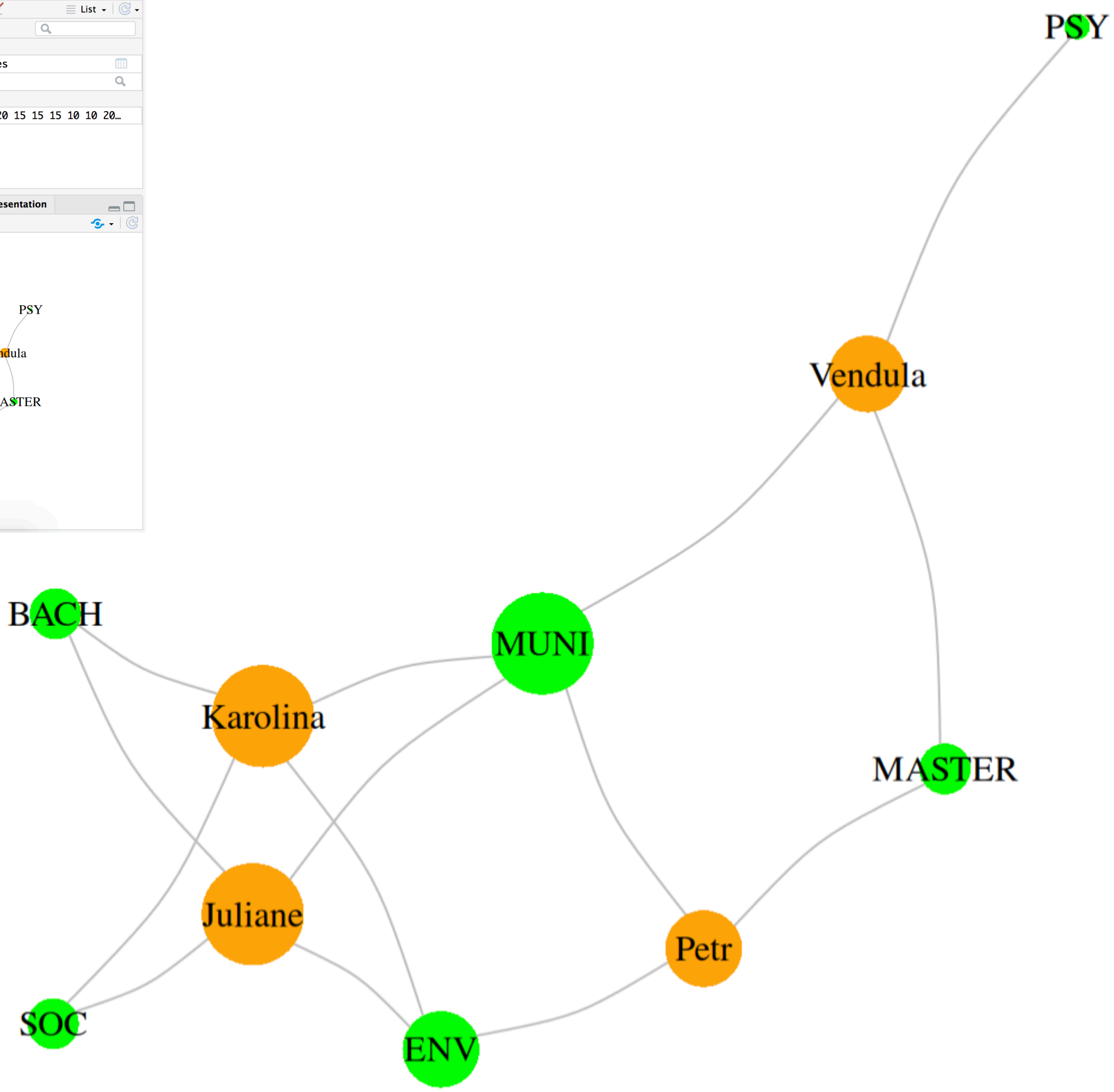
Who are we?

…previous knowledge about the course topics?
…your studies and interests?
…etc.

	Careers			Studies		University	
	ENV	PSY	SOC	BACH	MASTER	MUNI	INTERNSHIP
Karolína	1		1	1		1	
Juliane	1		1	1		1	
Petr	1				1	1	
Vendula		1			1	1	



exercise.R
library(readr)
library(igraph)
edge_list <- read_csv("yanhuashi/exercise/Edge_List.csv")
str(edge_list)
head(edge_list)
g <- graph_from_data_frame(edge_list, directed = FALSE)
node_size <- igraph::degree(g) * 5
V(g)$color <- ifelse(V(g)$name %in% edge_list$Source, "orange", "green")
plot(g,
layout = layout_with_fr, # Force-directed random layout
vertex.size = node_size, # Size based on degree
vertex.label.color = "black",
vertex.frame.color = NA,
edge.color = "gray",
edge.curved = 0.2) # Curved edges
Environment History Connections Tutorial
Global Environment
Data
edge_list 14 obs. of 2 variables
g List of 10
Values
node_size Named num [1:10] 20 20 15 15 15 10 10 20…
Files Plots Packages Help Viewer Presentation
Console Terminal Background Jobs
R 4.4.1 · ~/
> plot(g,
+ layout = layout_with_fr, # Force-directed random layout
+ vertex.size = node_size, # Size based on degree



PSY
Vendula
BACH
MUNI
Karolina
MASTER
Juliane
Petr
SOC
ENV

The course

First section

When?	What?	Who?
27.2.	Course introduction, basic network-related concepts	Yanhua Shi
13.3.	Basic network analysis in R – Part I	Harald Waxenecker
20.3.	Basic network analysis in R – Part II	Harald Waxenecker
27.3.	SNA, ENA, SENA – Part I	Harald Waxenecker
3.4	SNA, ENA, SENA – Part II	Harald Waxenecker

Second section

When?	What?	Who?
27.2	Situation-centered institutional anlaysis	Yanhua Shi
10.4	Network of Action Situations – Part I	Yanhua Shi
17.4	Network of Action Situations – Part II	Yanhua Shi
24.4	Discussion of paper ideas	Yanhua Shi Harald Waxenecker
15.5	Paper presentations	Yanhua Shi Harald Waxenecker

Evaluation

Course attendance: 80%

March 20: network analysis in R (individual exercise)

April 24: Presenting your paper ideas (individual)

May 15: Paper presentations

End of May: essay (individual)

- A musthave: network perspective applied to a topic of your interest
- Outlining a research proposal…
- Introducing a case study…
- Analyzing existing data…
- Etc.

Individual consultation

- Related to your individual essay: topics, analysis, discussion
- Book an appointment with one of the lecturers during the semester

Get started with thinking about your essay topic!

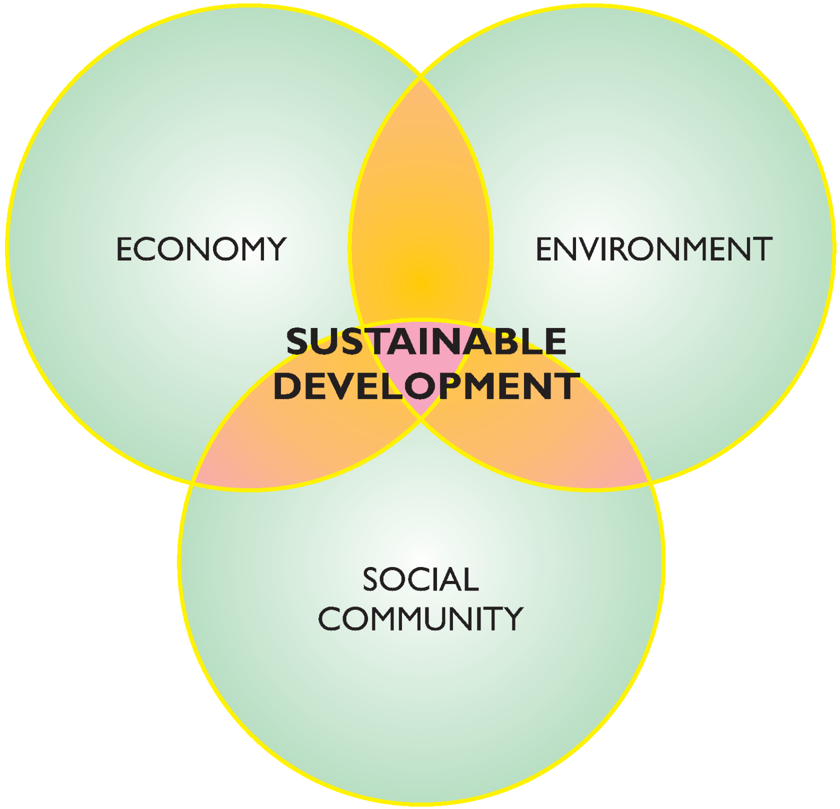
- A social, ecological, or social-ecological problem of your interest
- Or you can choose and analyze publicly available network datasets, e.g.,
  - National, regional, and global trade data: Input-Output Table: EORA (https://worldmrio.com/); EXIOBASE (https://www.exiobase.eu/); GLORIA (https://ielab.info/analyse/gloria)
  - Procurement data in Europe: https://opentender.eu/all/start
  - Open ownership data: https://www.openownership.org/en/
  - Datasets from publications, e.g., Ocelík et al. (2022)

Relation society – nature

How network perspective can be utilized?

From economic development to sustainable development

"...development that meets the needs of the present generation without compromising the ability of future generation to meet their own needs"
Our Common Future, 1987

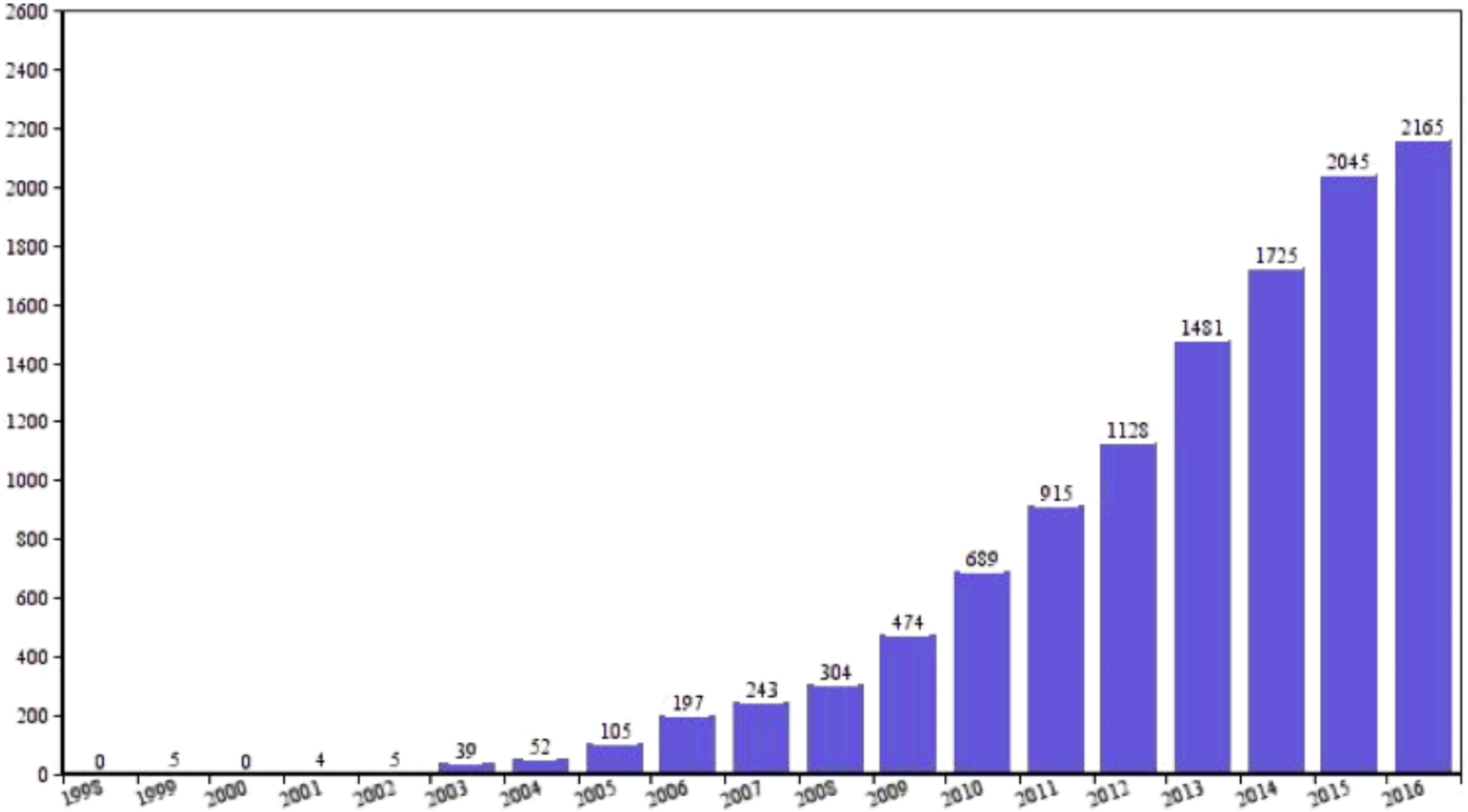


Three pillars of SD

Our Common Future/United Nation's Brundtland Report, 1987

Social-Ecological Systems

Fig. 2. Publications related to social-ecological systems, covering the years 1998–2016. Source: Based on data in the Scopus database, accessed 20 August 2017.



Colding, J., and S. Barthel. 2019. Exploring the social-ecological systems discourse 20 years later. *Ecology and Society* 24(1):2. https://doi.org/10.5751/ES-10598-240102

Synthesis

Exploring the social-ecological systems discourse 20 years later

Johan Colding [1,2,3] *and Stephan Barthel* [1,3]

Social-Ecological Systems (SES)

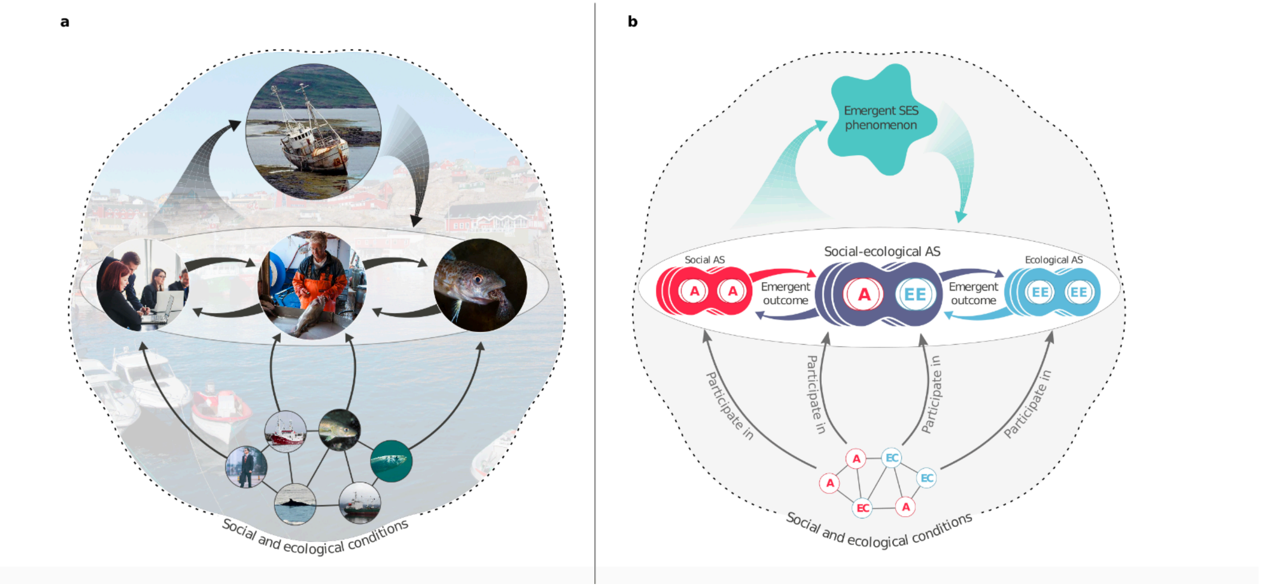
- “Social-ecological systems (SES) are complex adaptive systems (CAS) that are constituted by interactions between diverse people and elements of diverse ecosystems (Berkes and Folke 1998, Folke et al. 2016).” (Schlüter et al. 2019)

- How to conceptualize and analyze Interactions (or links, connections, relations, etc) between human and nature?

- Why do we care about social-ecological interdependence?

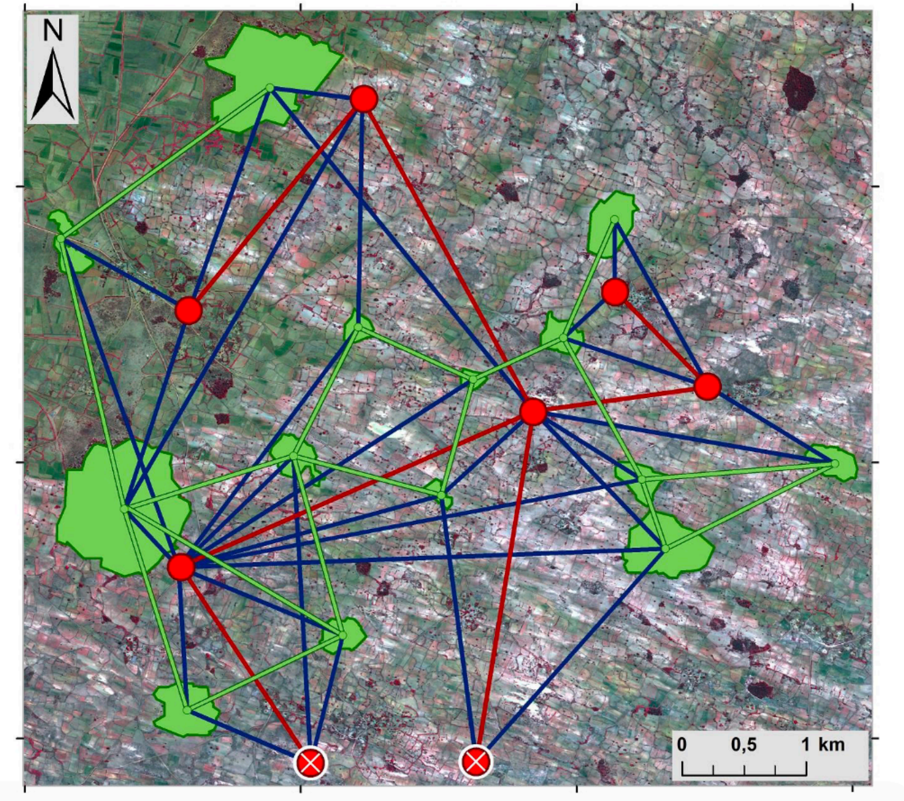
Network perspective to study SES

Fig. 1. The emergence of a social-ecological phenomenon (emergent SES phenomenon) from social-ecological interactions. (a) The collapse of a fishery (a type of regime shift, top picture) emerges from interactions between fishers and the fish through fishing (middle circle), policymakers that devise incentives and regulations (left circle), and different fish and other species that interact through a food web (right circle). The framework is used to abstract these action situations from the many relations and interactions between actors and ecosystem components in a given SES, represented by the network of actors and ecological entities at the bottom of the figure. Emergent outcomes from one AS, such as regulations, affect interactions in another AS, e.g., fishing. (b) The generic SE-AS framework. The eclipse in the middle represents a configuration of AS that are hypothesized to have generated the emergent SES phenomenon of interest. There can be multiple social, social-ecological, and ecological AS in a configuration. This configuration is developed by identifying those social-ecological, social, and ecological AS from the many interactions in the SES (network in the bottom) that are considered relevant from a theoretical or empirical perspective. The emergence of the phenomenon results from a continuous process of local interactions that shape emergent outcomes to which they subsequently adapt (green arrows).



Schlüter et al. (2019)

Fig. 3. Social-ecological network of forest patches, clans, and their different interrelationships in an agricultural landscape in southern Madagascar. The red nodes represent clans residing in the landscape, and the green nodes forest patches. The tiers between clans represent various forms of social relations, the ties between clans and forest patches represent use and managerial responsibilities, and the ties between the forest patches represent seed dispersals (figure from Bodin and Tengö 2012).



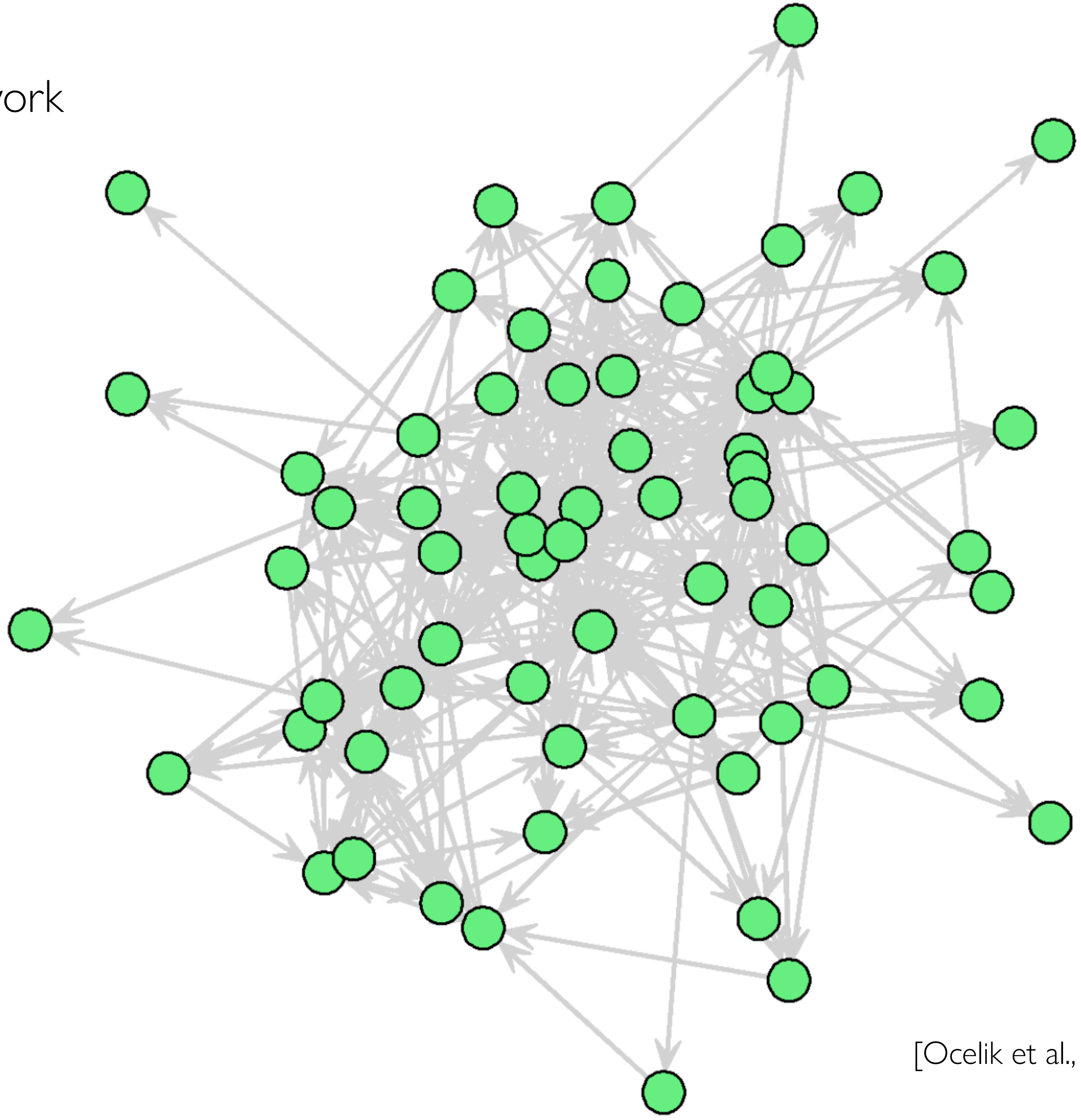
Bodin et al. (2016)

Networks

…concepts from graph theory

Social networks

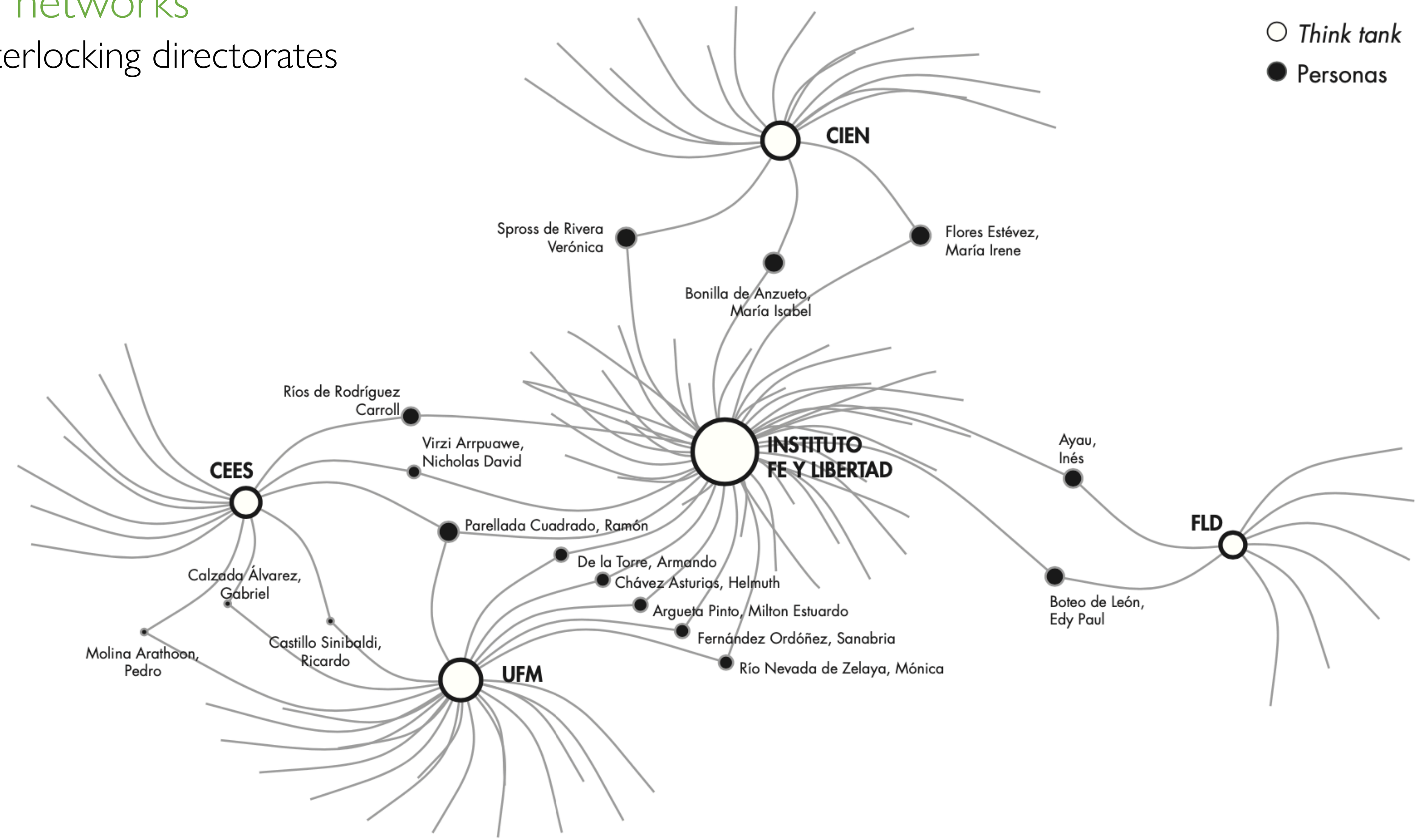
e.g., political collaboration network



[Ocelik et al., 2022]

Social networks

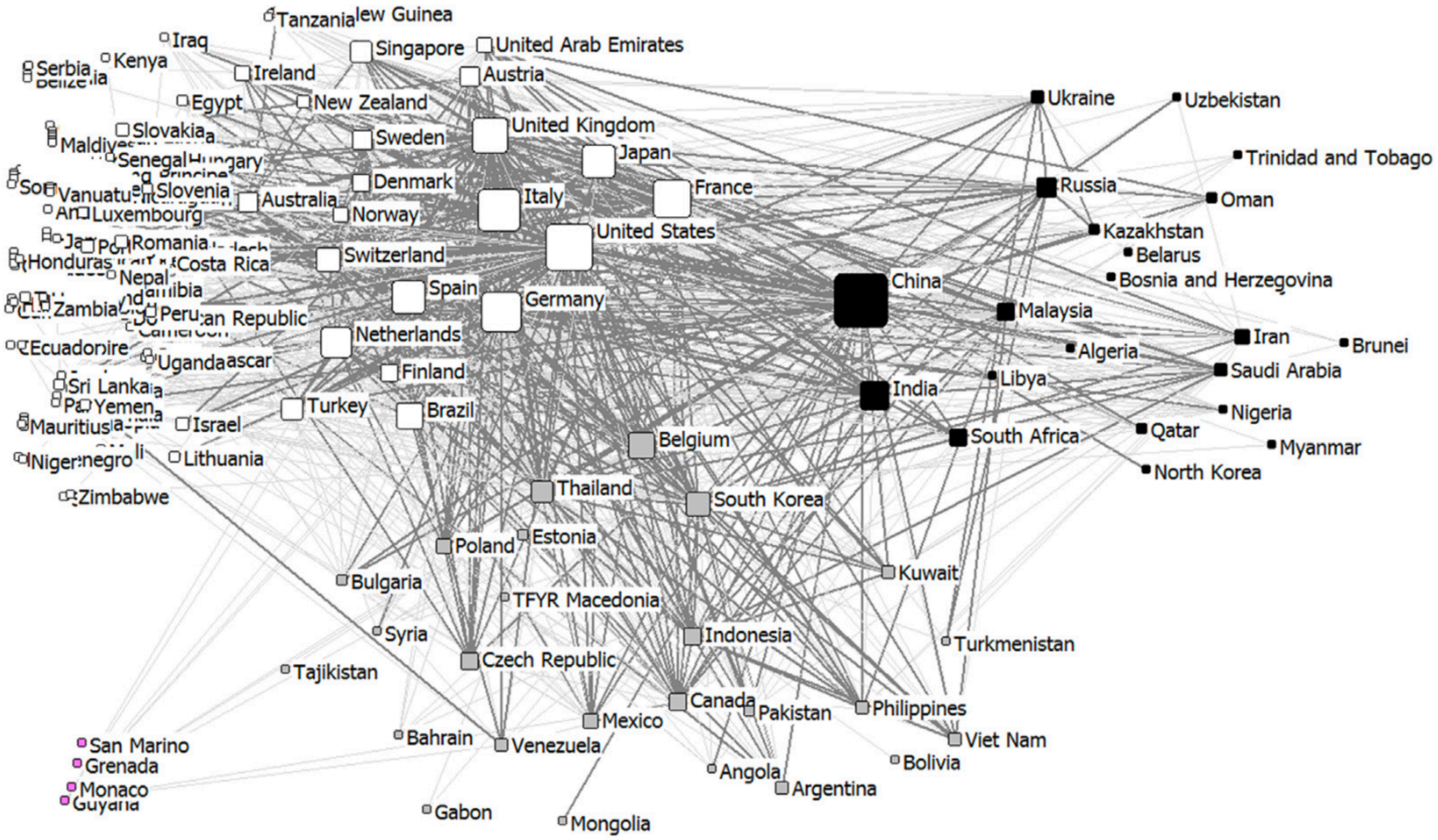
e.g., interlocking directorates



[Fischer & Waxenecker, 2020]

Social networks

e.g., trade network



Year 2010

[Prell & Feng, 2016]

Social networks

e.g., policy instrument preferences

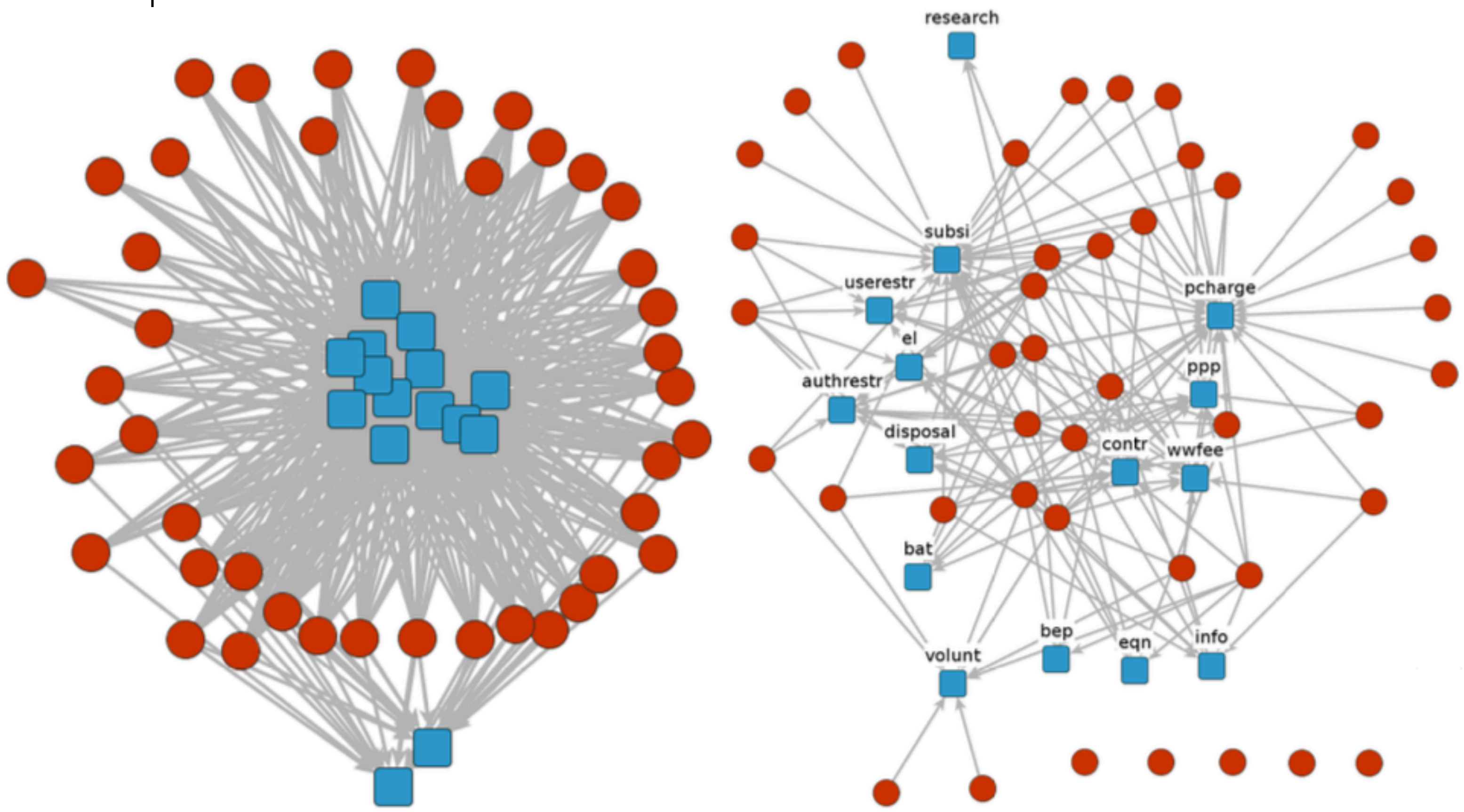


Figure 3. Two-mode network of policy instrument preferences.
Note: Support network ("agree somewhat" or "strongly agree") on the left; rejection network ("disagree somewhat" or "strongly disagree") on the right. Circles = actors, squares = policy instruments, ties = preferences in the form of support or rejection.

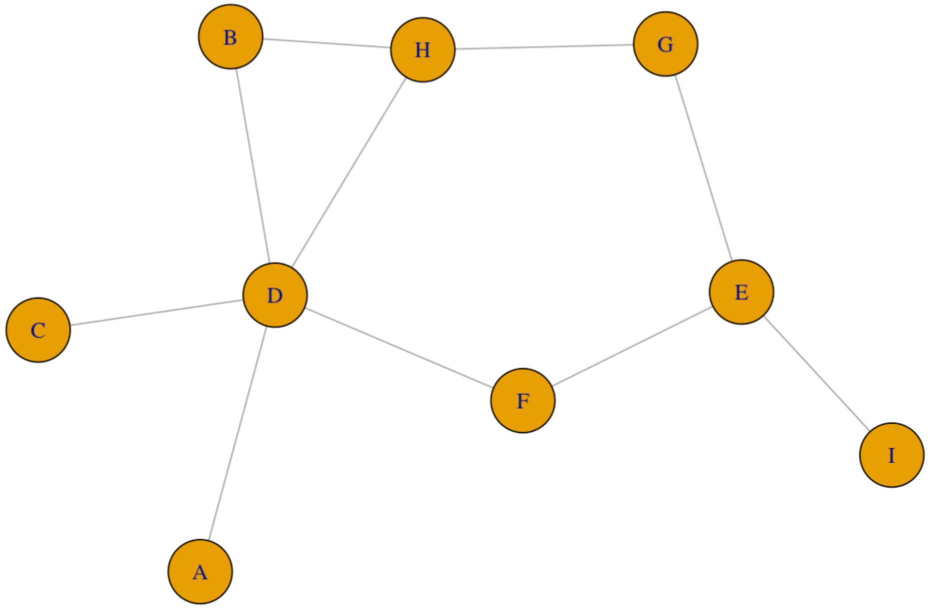
[Metz et al., 2018]

What is a network?

…an interconnected system of a set of vertices and edges

G(V, E)

G = graph [network]
V = vertices [nodes]
E = edges [ties, relations]

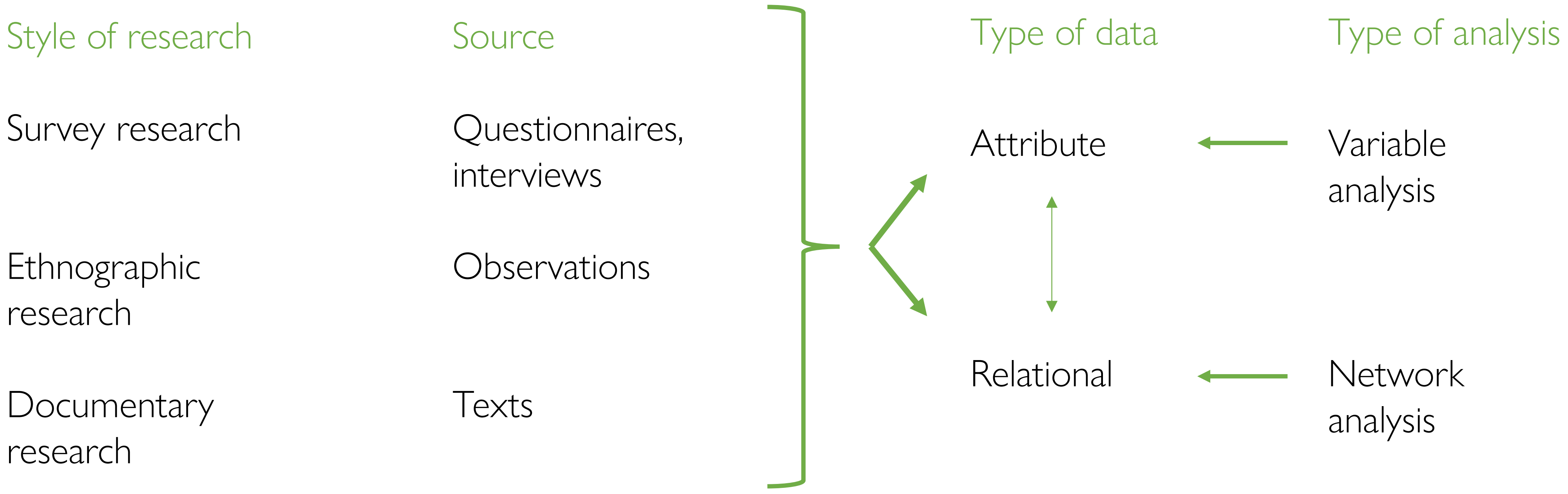


"The most general characteristic of social science data is that they are rooted in cultural values and symbols. Unlike the physical data of the natural sciences, social science data are constituted through meanings, motives, definitions and typifications. […] The principle type of data can be referred to as 'attribute data' and 'relational data'."

[Scott, 2013: 3]

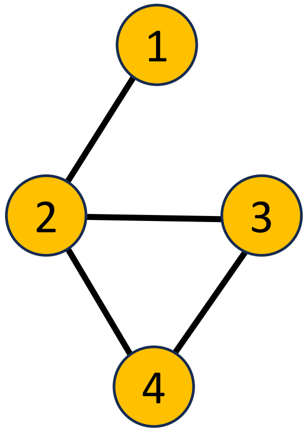
We need relational data!!!

What about the class graph we draw earlier?



[Based on Scott, 2013]

[graph]

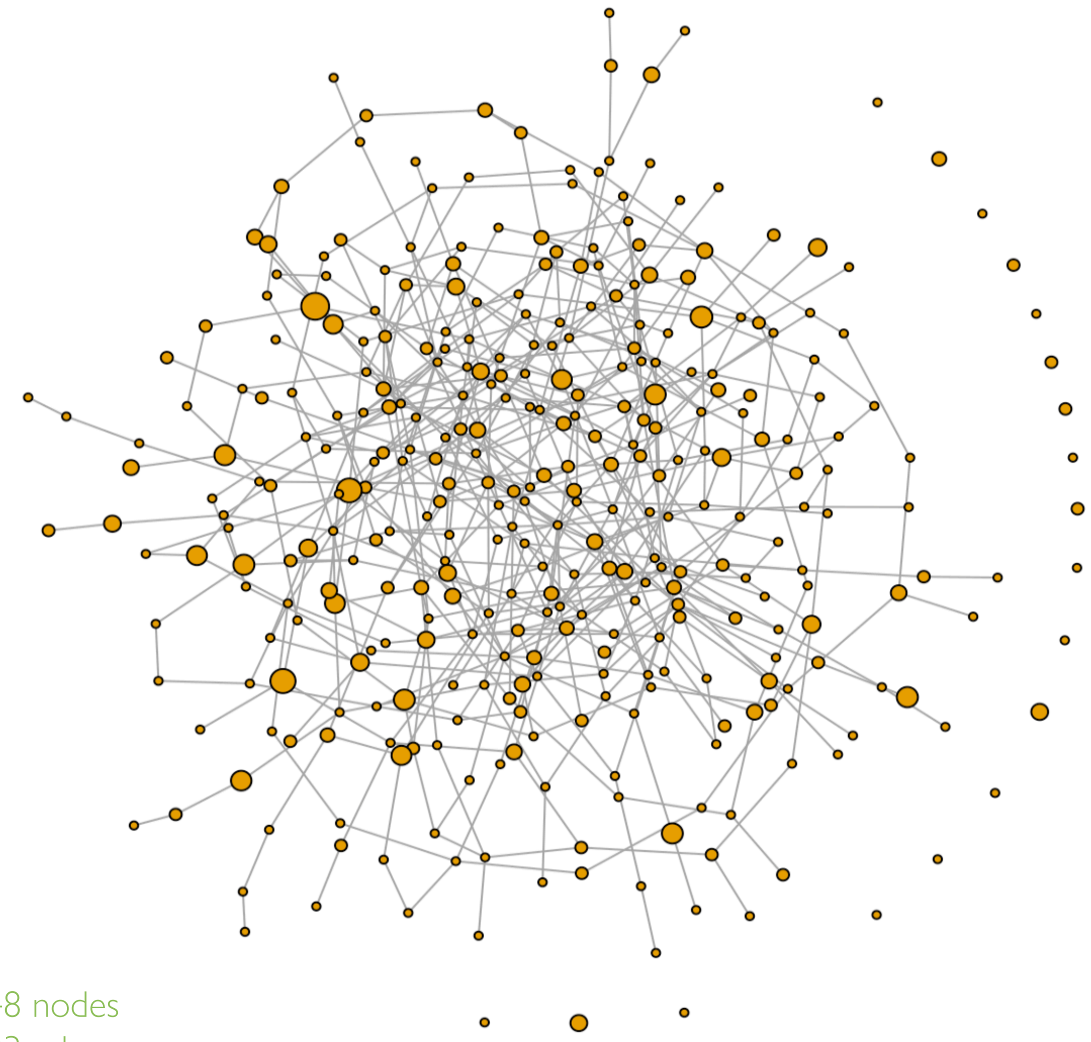


[matrix]

	1	2	3	4
1	0	1	0	0
2	1	0	1	1
3	0	1	0	1
4	0	1	1	0

[edgelist]

	A	B
1	Column1	Column2
2	1	2
3	2	3
4	2	4
5	3	4
6		
7		



348 nodes
523 edges
Graph density: 0.009

Describing a network…

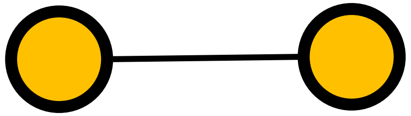
One-mode network
Binary
Undirected

Number of vertices (nodes)
Number of edges (ties)

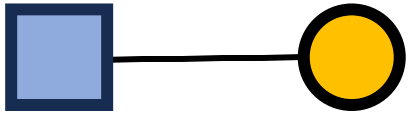
Graph density

Describing a network…

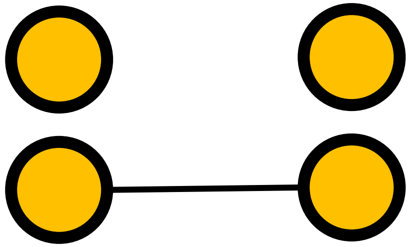
One-mode network



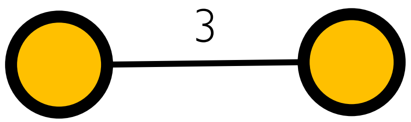
Two-mode network



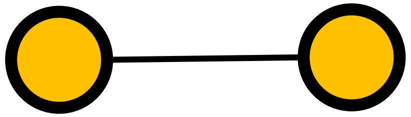
Binary [0, 1]



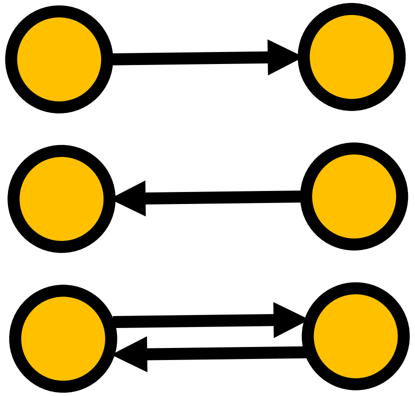
Wheighted

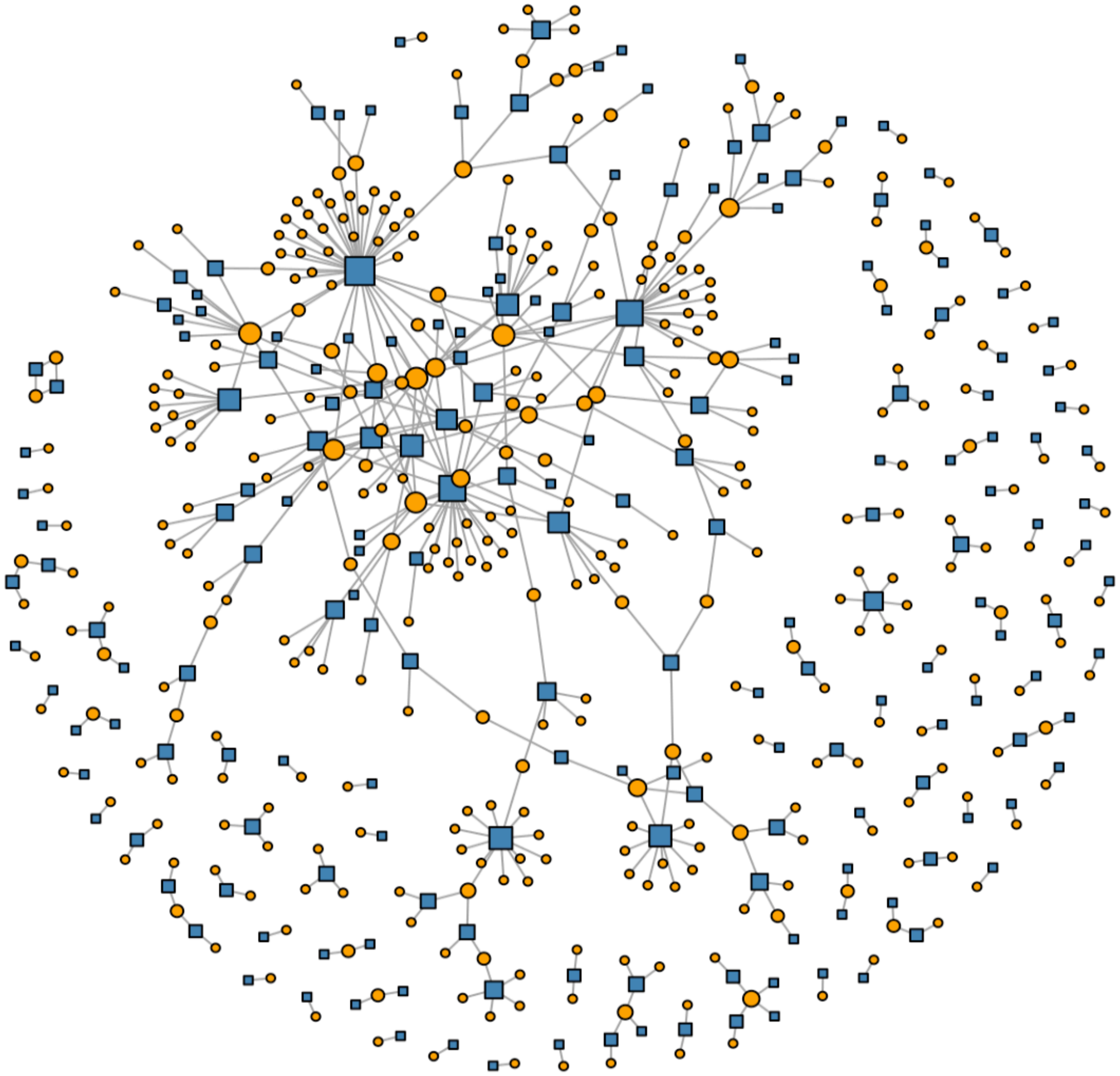


Undirected



Directed





Two types of nodes

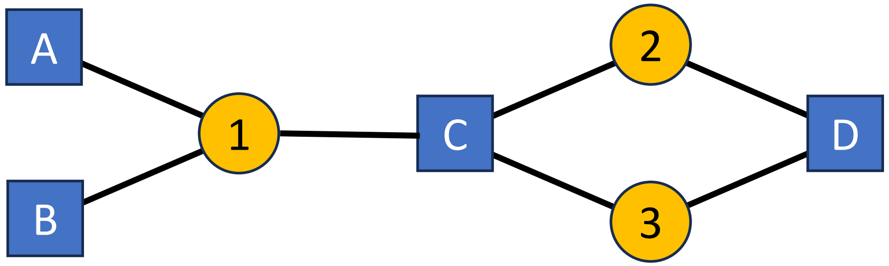
Mode 1 (set 1)

Mode 2 (set 2)

edge

= bipartite or two-mode network

[graph]



[matrix]

Second node set

First node set

	1	2	3
A	1	0	0
B	1	0	0
C	1	1	1
D	0	1	1

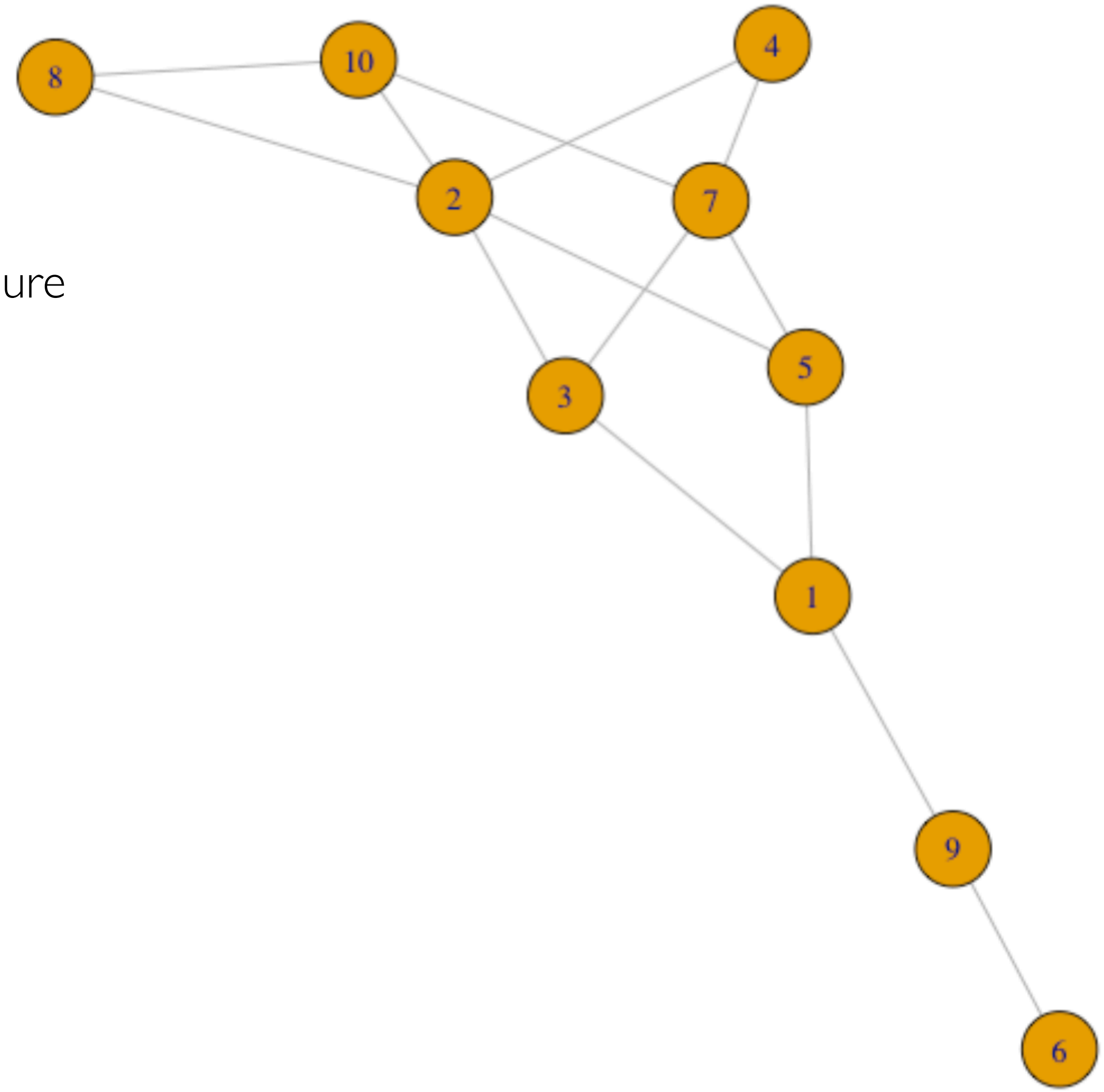
[edgelist]

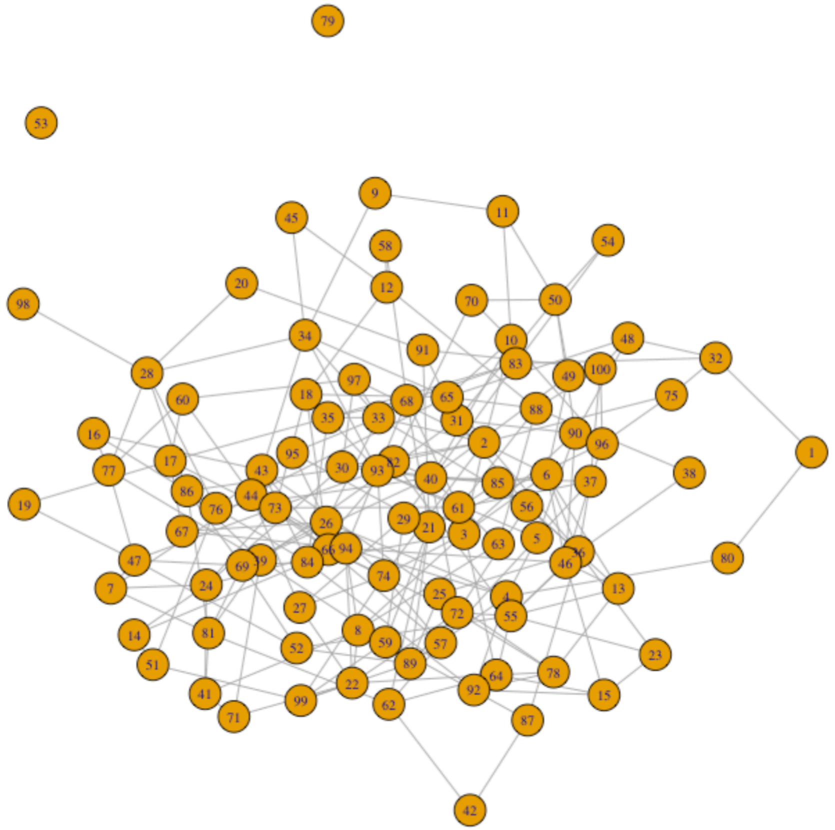
	A	B
1	First mode	Second mode
2	A	1
3	B	1
4	C	1
5	C	2
6	C	3
7	D	2
8	D	3
9		

Degree centrality

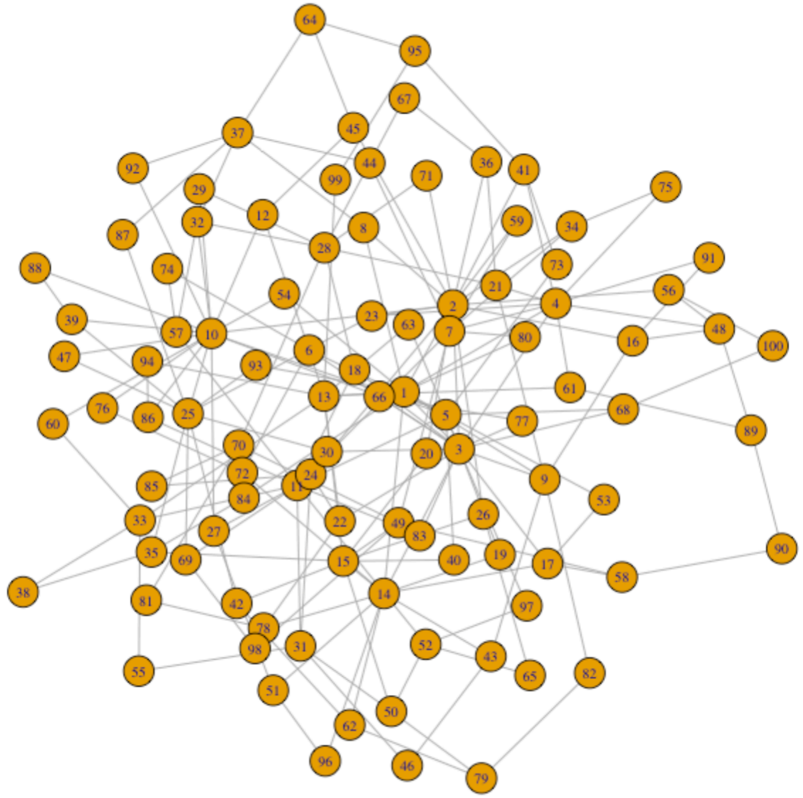
- How many actors is one directly tied to?
- In social theory, high degree tends to be a measure of popularity for undirected graphs.
- Which actor(s) appear to have more degree centrality?

$$C_{deg(i)} = \sum_{j=1} X_{ij}$$

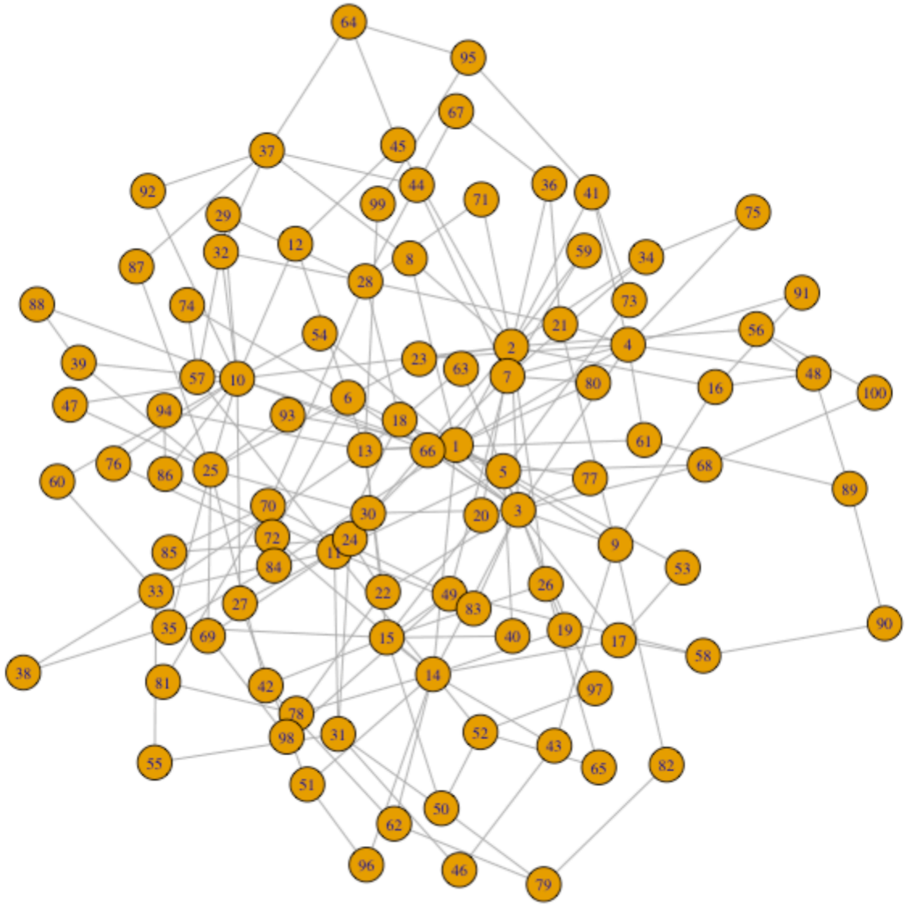




100 nodes
243 edges
Graph density: 0.049

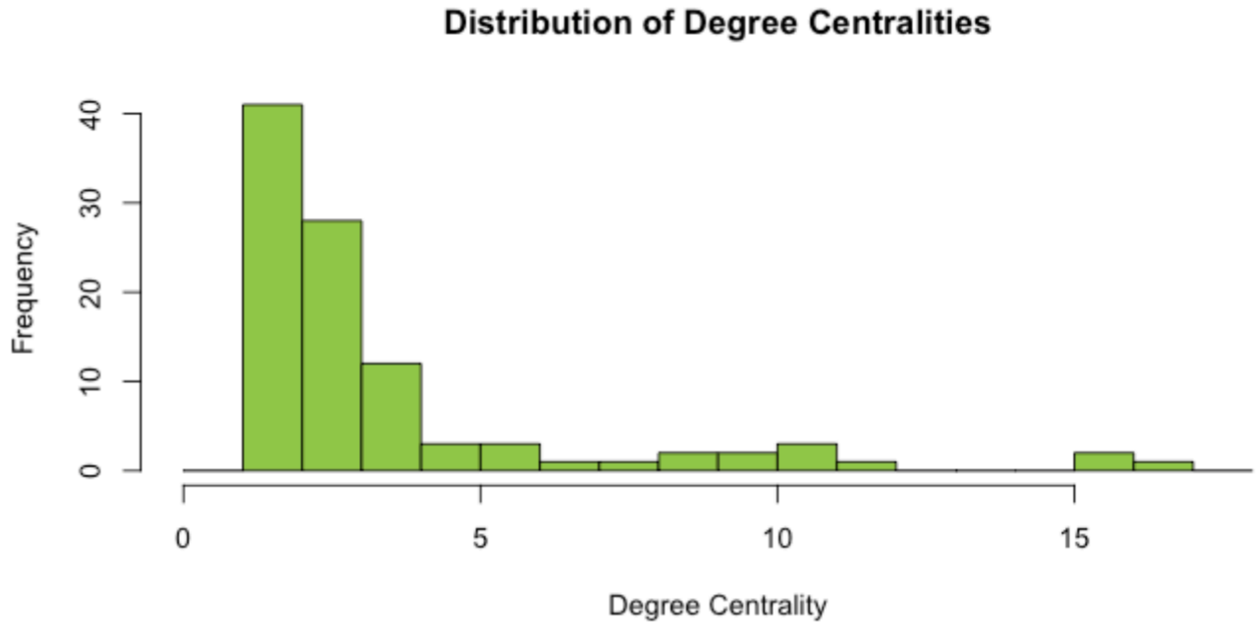


100 nodes
197 edges
Graph density: 0.039

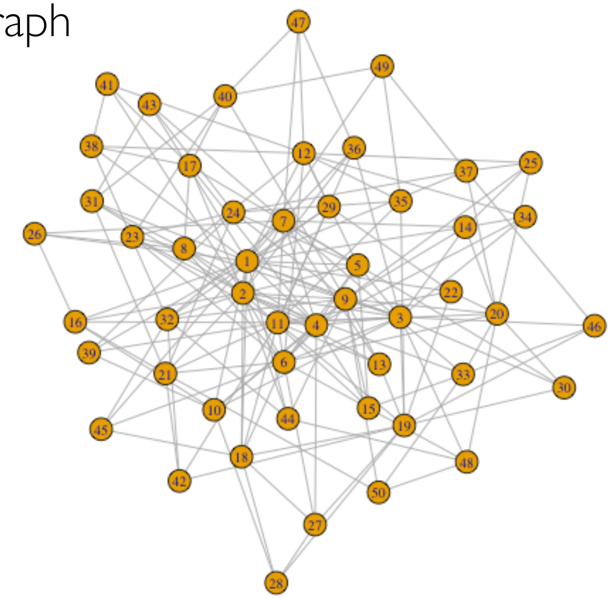


Scale-free network: a network in which a few actors hold a high degree centrality, and the majority of actors have a low degree centrality.

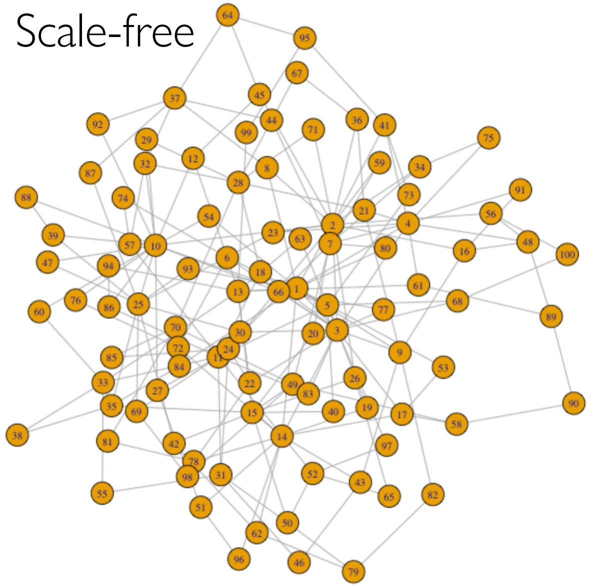
Such a distribution of ties resembles a 'power-law'. Many empirical networks have this property, to some extent.



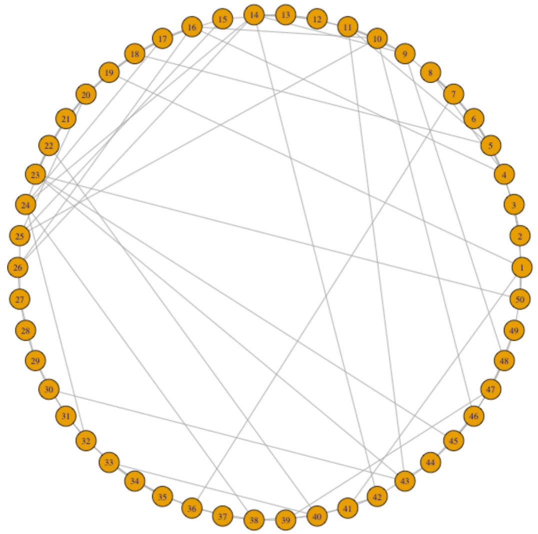
Core-periphery graph



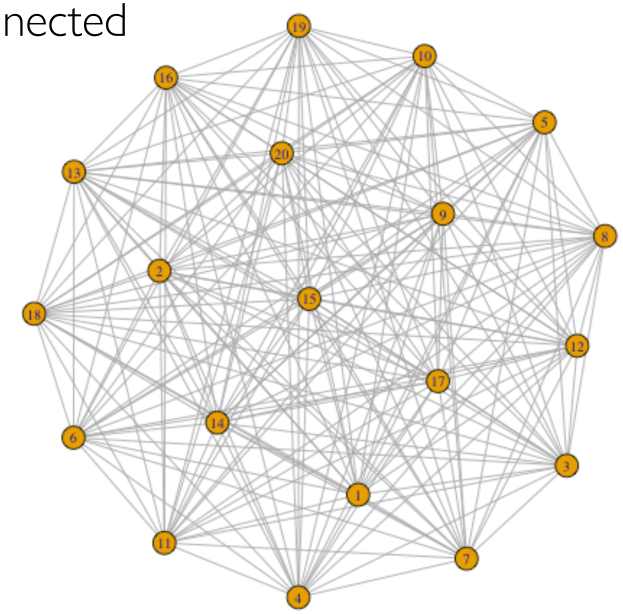
Scale-free



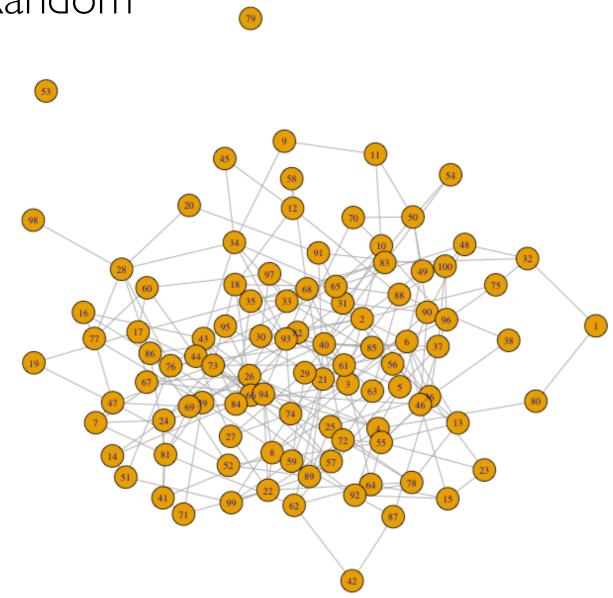
Small world



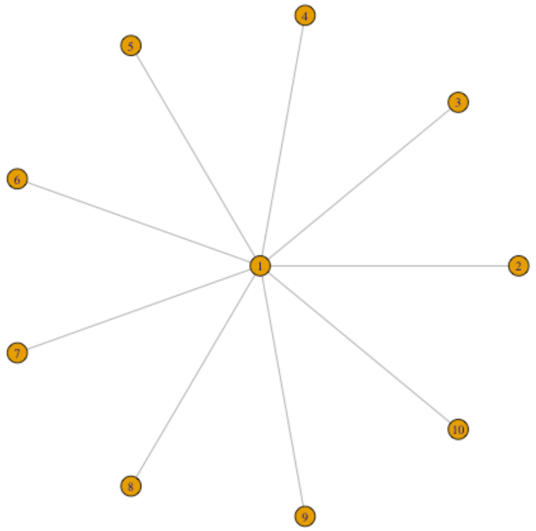
Fully connected



Random



Star



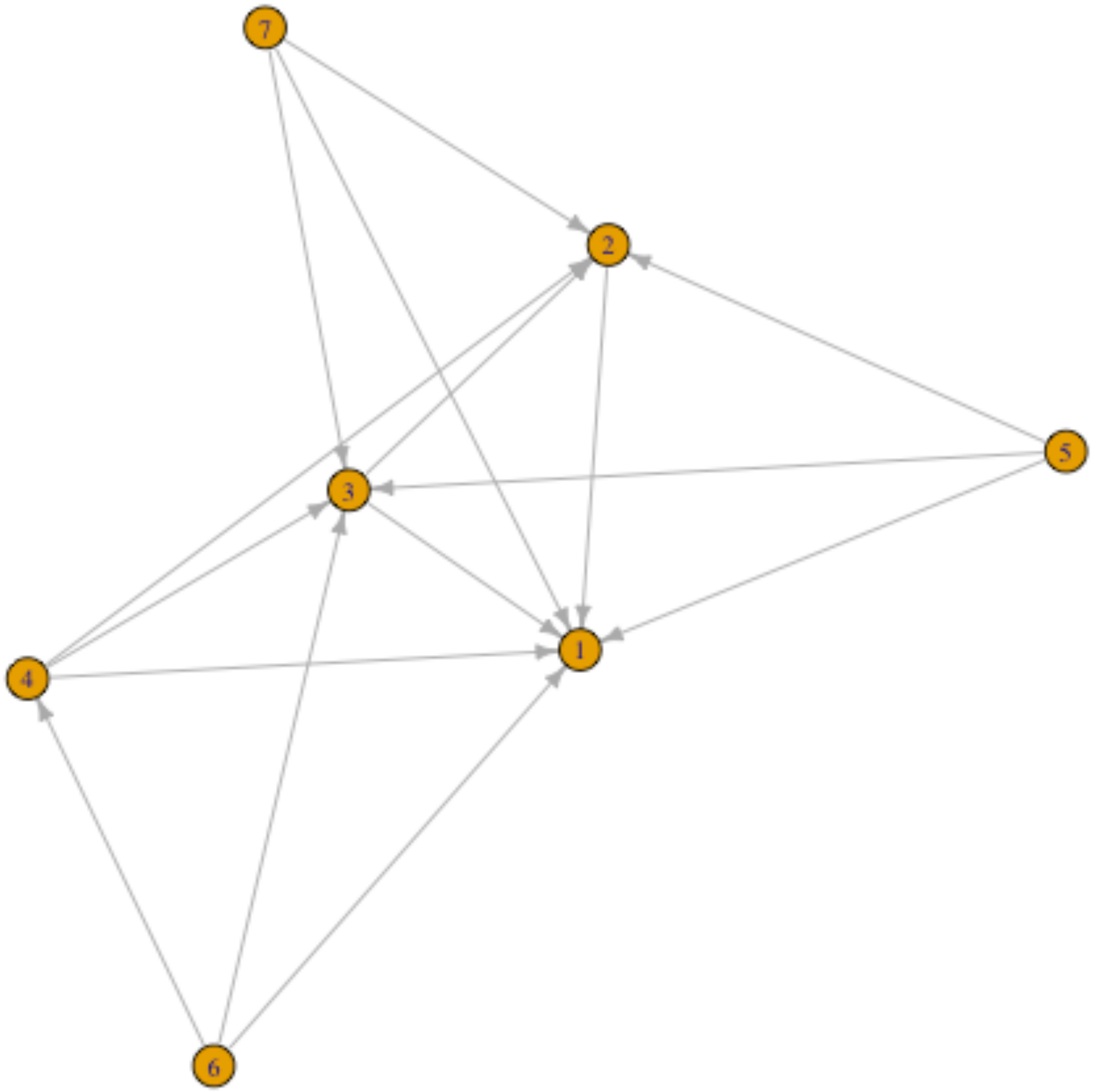
Degree centrality in a directed network

- Indegree = how many nominations one receives?
  - This is often seen as a measure of prestige, popularity, or importance.

$$C_{ideg(i)} = \sum_{j=1} X_{ji}$$

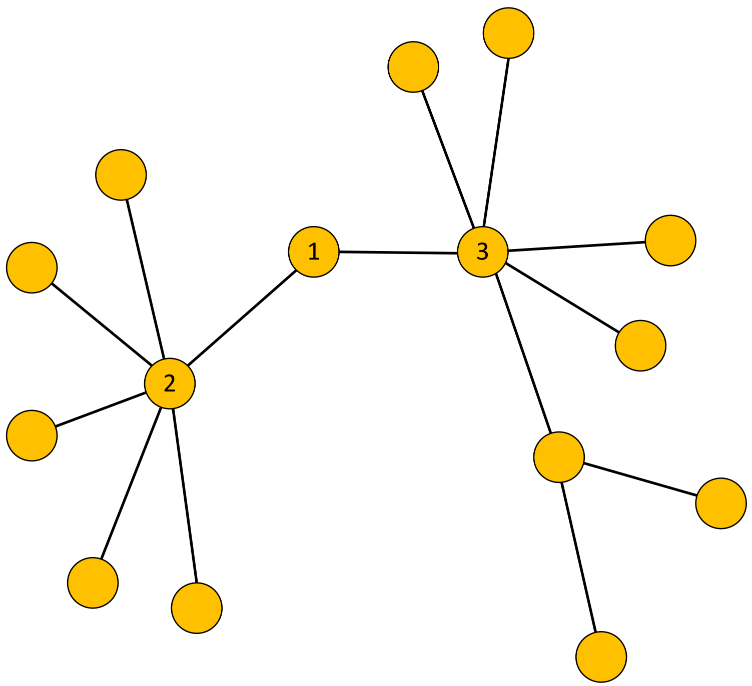
- Outdegree = how many nominations does one give?
  - Usually seen as indicating the extent to which one is dependent on others.
  - Linked to spreaders of gossip,
  - etc.

$$C_{odeg(i)} = \sum_{i=1} X_{ij}$$



Eigenvector

- This is an extension of degree centrality:
- How central are those to whom you are connected?
- Efficiency: rather than building your own ties, simply connect to those with high degree centrality.
- Dependence: you are dependent on the central others.



$$C_{eg(i)} = \sum_{i=1} X_{ij} C_{deg}(j)$$

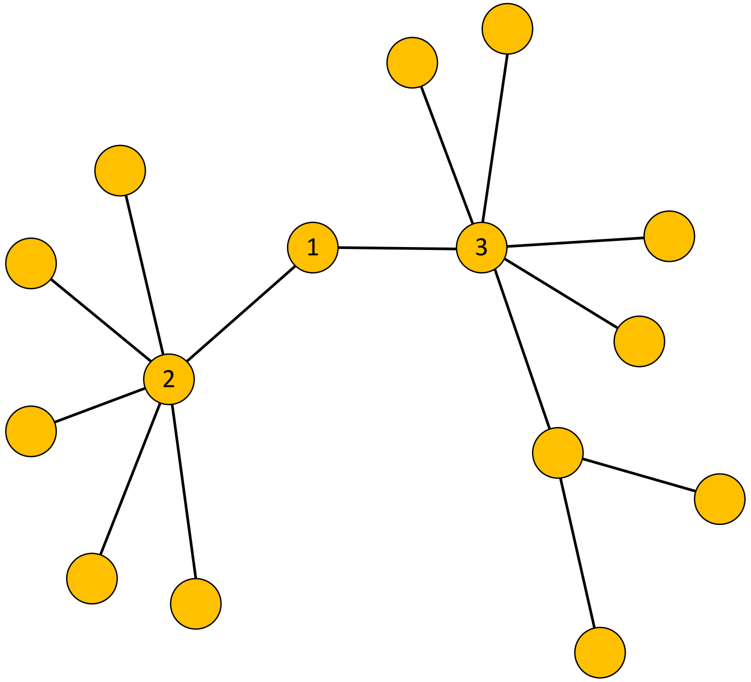
On a symmetric network:

For all ties for ego (Xij), what is the degree centrality of j?

The higher $C_{deg}(j)$, the higher is ego's eigenvector centrality $C_{eg(i)}$.

Betweenness centrality

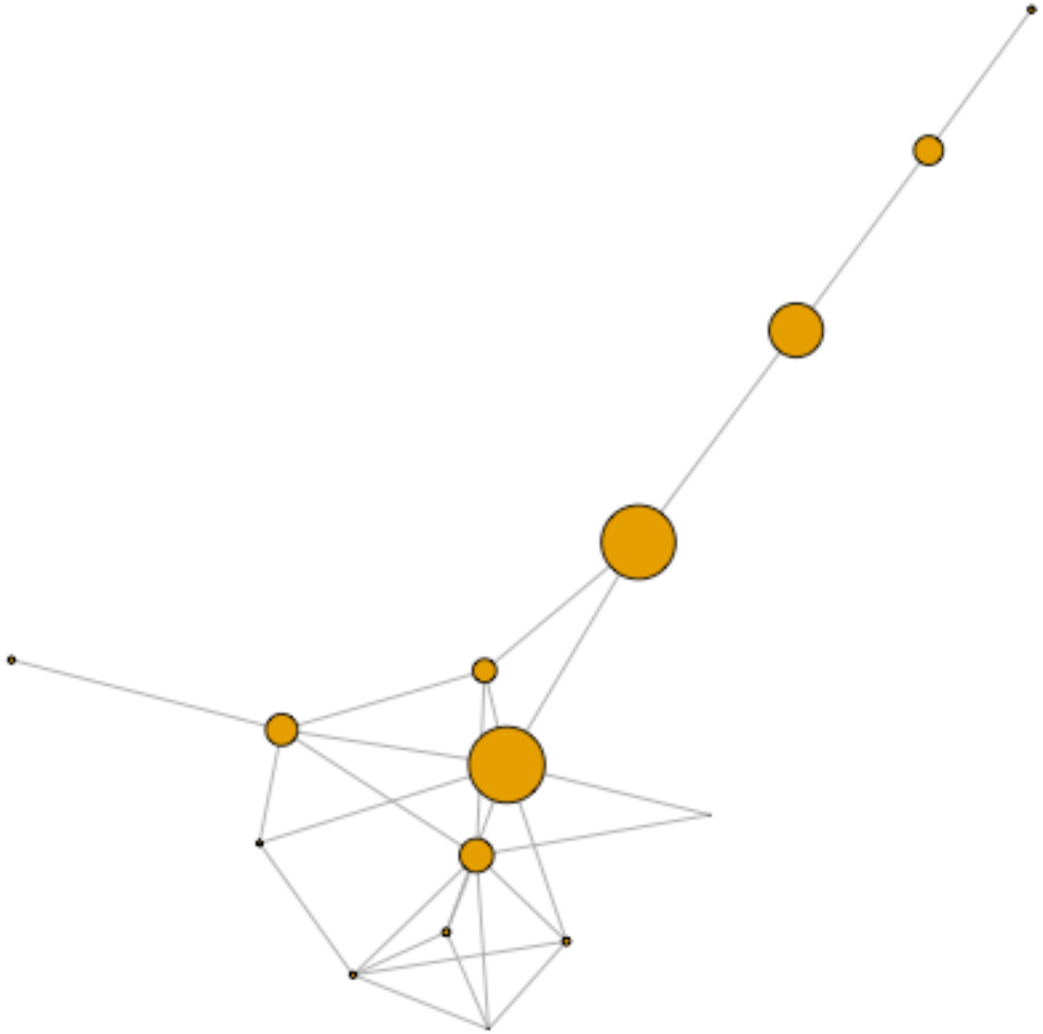
- The frequency of a node *(i)* lying on the shortest path between two actors (*s*,*t*) who are otherwise disconnected actors.
- A good measure for resource flows along relations.
- A common measure to capture the notion of a 'broker'



$$C_{bet(i)} = \sum_{s \neq t \neq i} \frac{\partial_{st}(i)}{\partial_{st}}$$

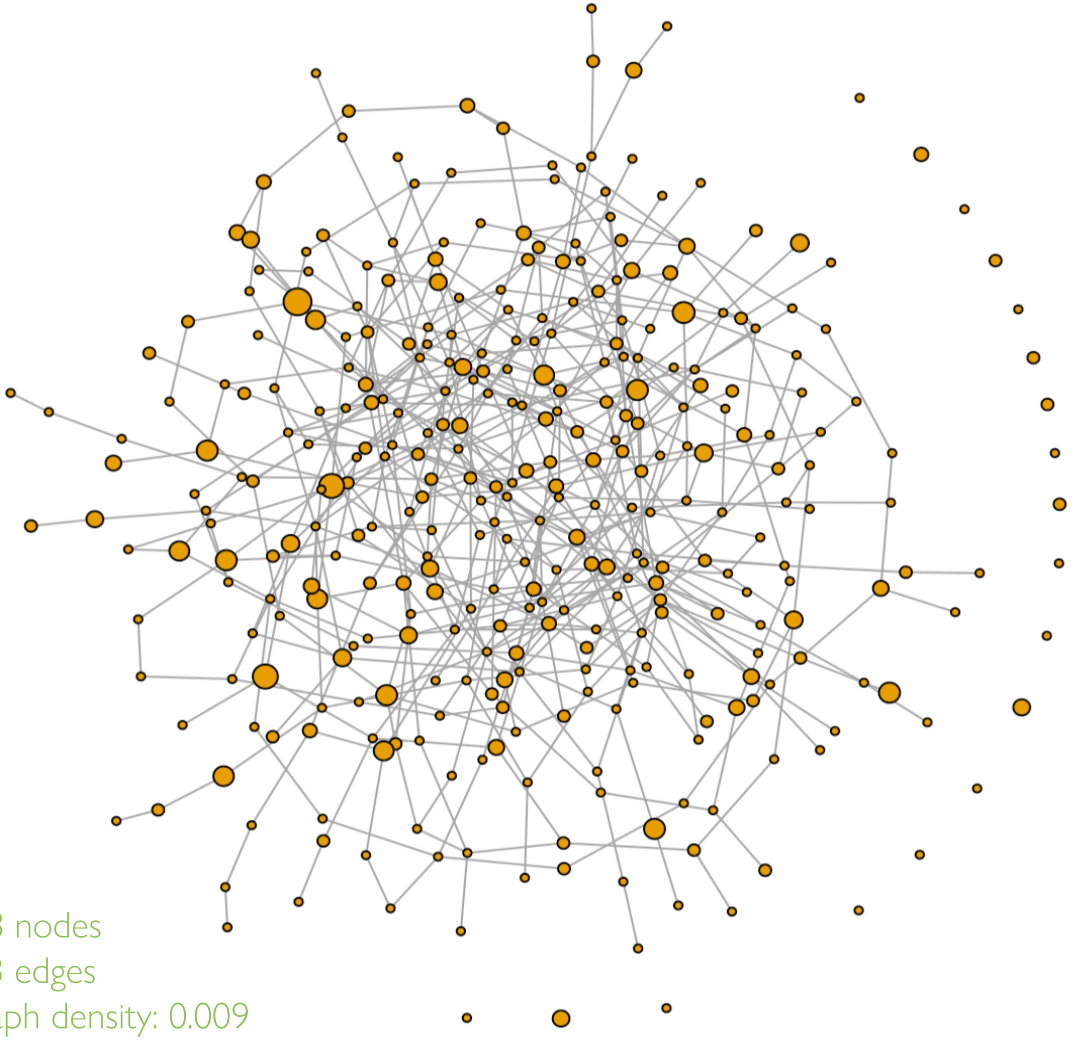
∂_{st} = shortest path linking s to t.

$\partial_{st}(i)$ = the number of shortest paths between s and t that actor i lies on.



	Node	BC
1	1	0.263736264
2	2	0.036996337
3	3	0.165750916
4	4	0.002747253
5	5	0.002197802
6	6	0.156043956
7	7	0.372710623
8	8	0.115750916
9	9	0.142857143
10	10	0.025641026
11	11	0.362637363
12	12	0.036996337
13	13	0.030219780
14	14	0.000000000
15	15	0.000000000

= normalized



348 nodes
523 edges
Graph density: 0.009
Mean degree: 3.0
Isolates: 18

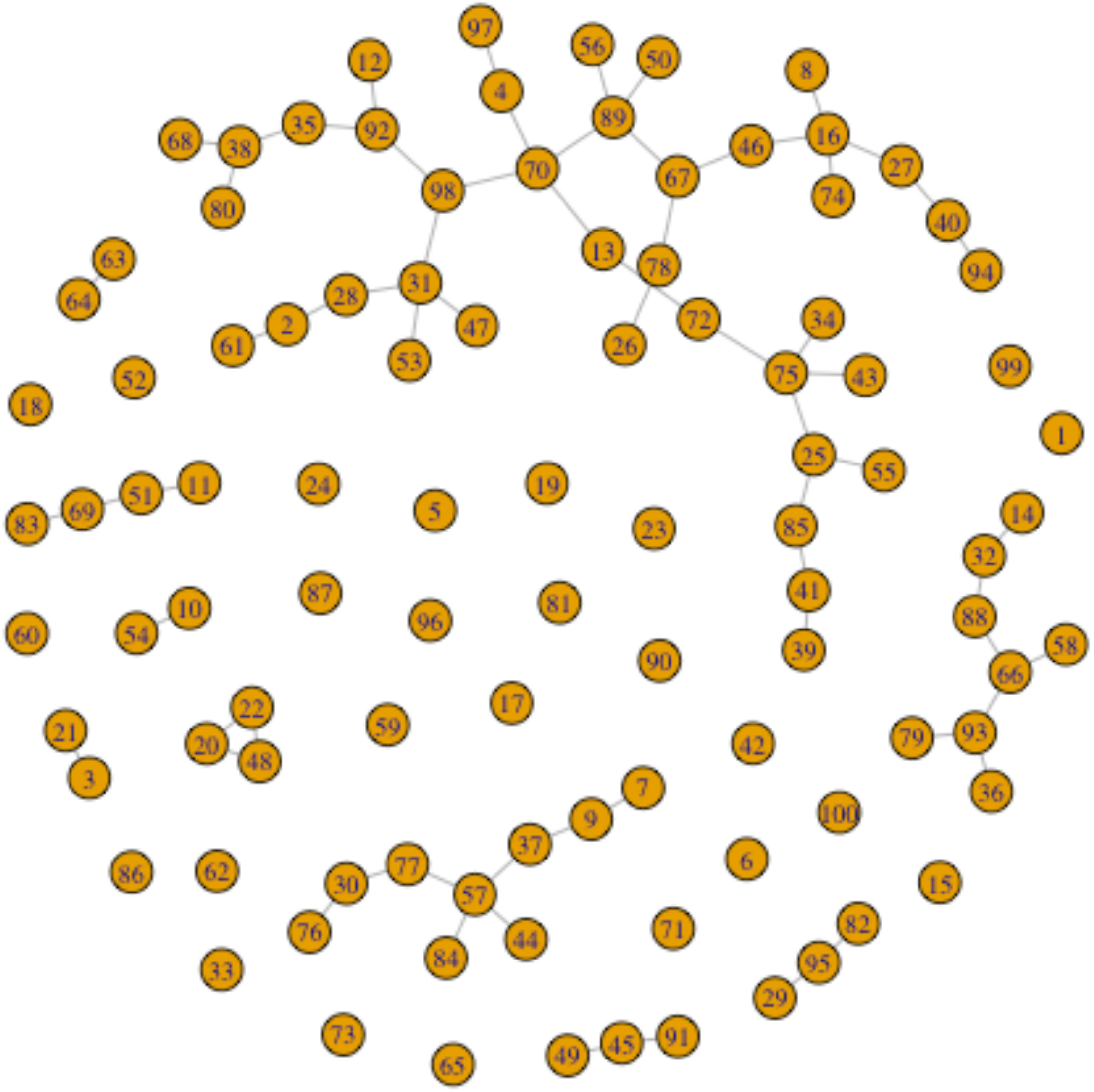
Describing a network…

One-mode network
Binary
Undirected
Number of vertices (nodes)
Number of edges (ties)
Graph density

Mean degree
Isolates

Components

Components



100 nodes
66 edges
Graph density: 0.013
Mean degree: 1.32
Component: 35

Summarising…

One-mode network / two-mode (bipartite) network
Types of networks (scale-free, small-world, star, etc.)
Binary / weighted
Undirected / directed
Number of vertices (nodes)
Number of edges (ties)
Graph density
Degree / Indegree / Outdegree
Eigenvector
Betweenness centrality
Isolates
Components

…In two weeks

Who has experience with R?

Install R and RStudio

Explore some tutorials

https://www.r-project.org

https://posit.co/download/rstudio-desktop/

…Next week

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15.5.	Students presenting their papers

References

Fischer, Karin y Waxenecker, Harald. (2020). Redes de poder: consideraciones sobre la elite neoliberal de poder y conocimiento en Guatemala. Revista CIDOB d'Afers Internacionals, 126, 89-115. https://doi.org/10.24241/RCAI.2020.126.3.89

Metz, F., Leifeld, P., & Ingold, K. (2018). Interdependent policy instrument preferences: A two-mode network approach. Journal of Public Policy, 39, 609–636. https://doi.org/10.1017/S0143814X18000181

OCELÍK, Petr, Tomáš DIVIÁK, Lukáš LEHOTSKÝ, Kamila SVOBODOVÁ a Markéta HENDRYCHOVÁ. (2022). Facilitating the Czech Coal Phase-Out : What Drives Inter-Organizational Collaboration? Society & Natural Resources. Philadelphia: Taylor & Francis, roč. 35, č. 7, s. 705-724. ISSN 0894-1920. doi:10.1080/08941920.2022.2065394

Prell C.L. & Feng, K. (2016.) The evolution of global trade and impacts on countries' carbon trade imbalances. Social Networks 46, p.87-100 http://dx.doi.org/10.1016/j.socnet.2016.03.001

Wasserman S. & Faust, K. (1994). Social Network Analysis: Methods and Applications. Structural Analysis in the Social Sciences. Cambridge University Press,. doi: 10.1017/CBO9780511815478.

Prell C.L. (2012). Social Network Analysis: History, Theory and Methodology.

Scott, J. (2013). Social Network Analysis. London: SAGE Publications, third edition.