DEPARTMENT
OF ENVIRONMENTAL
STUDIES

Network analysis:

social, ecological, and social-ecological approaches

FSS:ENSb1315 (Spring 2024)

Yanhua Shi & Harald Waxenecker

Course objectives

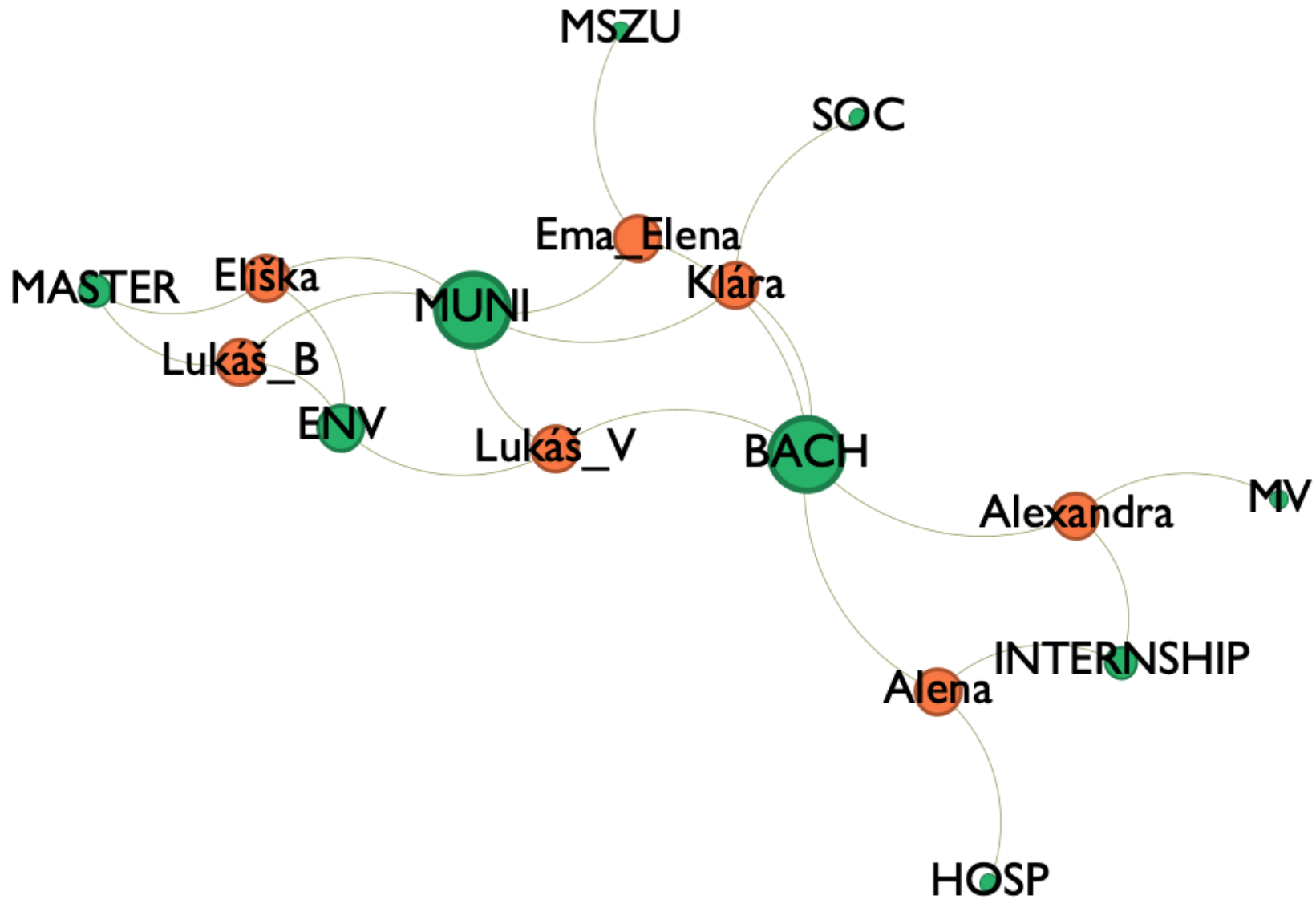
This course introduces the students to qualitative and quantitative network analysis and its interdisciplinary applications in institutional analysis, political economy and ecology, social-ecological economics, international relations, among others Social Network Analysis (SNA), Ecological Network Analysis (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?
23.2.	Course introduction, basic network-related concepts
1.3.	Basic network analysis in R – Part 1
8.3.	Basic network analysis in R – Part 2
15.3.	Social Network Analysis (SNA)
22.3.	Ecological Network Analysis (ENA) and Social-Ecological Network Analysis (SENA)
5.4.	Institutional Analysis and Development (IAD) framework
12.4.	Network of Action Situations I: A Multilevel Social Network Perspective
19.4.	Pitch and groups
26.4.	Network of Action Situations II: Applications to Game Theory and Agent-Based Modeling
28.4.	Social-Ecological Systems Frameworks: IAD-SES; SE-AS
3.5.	Case study
10.5.	Case study
17.5.	Paper discussion in groups

Who are we?

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

	Careers					Studies		University	
	ENV	MSZU	SOC	HOSP	MV	BACH	MASTER	MUNI	INTERNSHIP
Alexandra					1	1			1
Lukáš_B	1						1	1	
Ema_Elena		1				1		1	
Eliška	1						1	1	
Klára			1			1		1	
Alena				1		1			1
Lukáš_V	1					1		1	


MSZU
SOC
Ema_Elena
MASTER
Eliška
MUNI
Klára
Lukáš_B
ENV
Lukáš_V
BACH
MV
Alexandra
INTERNSHIP
Alena
HOSP

The course

First section

When?	What?	Who?
23.2.	Course introduction, basic network-related concepts	Yanhua Shi Harald Waxenecker
1.3.	Basic network analysis in R – Part 1	Harald Waxenecker
8.3.	Basic network analysis in R – Part 2	Harald Waxenecker
15.3.	SNA, ENA, SENA – Part 1	Harald Waxenecker
22.3.	SNA, ENA, SENA – Part 2	Harald Waxenecker

Second section

When?	What?	Who?
5.4.	Institutional Analysis and Development (IAD) framework	Yanhua Shi
12.4.	Network of Action Situations I: A Multilevel Social Network Perspective	Yanhua Shi
19.4.	Pitch and groups	Yanhua Shi Harald Waxenecker
26.4.	Network of Action Situations II: Applications to Game Theory and Agent-Based Modeling	Christian Kimmich
28.4.	Social-Ecological Systems Frameworks: IAD-SES; SE-AS	Yanhua Shi
3.5.	Case study: Danube east of Vienna	Yanhua Shi
10.5.	SNA, (embodied) ressources and sustainability	Christina Prell
17.5.	Paper discussion in groups	Yanhua Shi Harald Waxenecker

Evaluation

Course attendance: 80%

March 22: network analysis in R (individual exercise)

April 19: pitches (individual)

May 17: group discussion

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

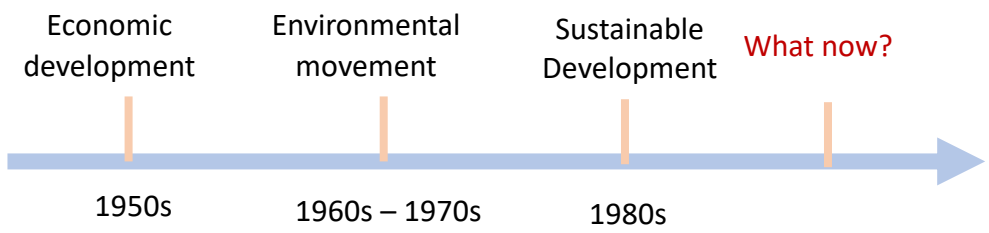
- Related to your individual essay: topics, analysis, discussion
- Book an appointment with one of the lecturers during the semester

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

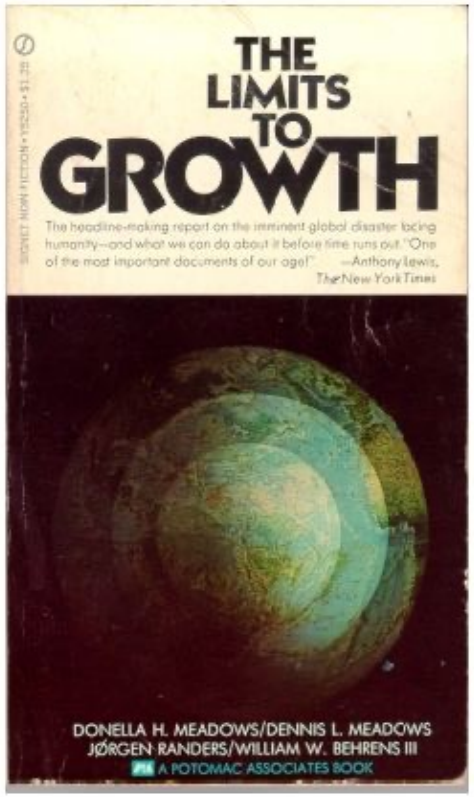
From economic development to sustainable development



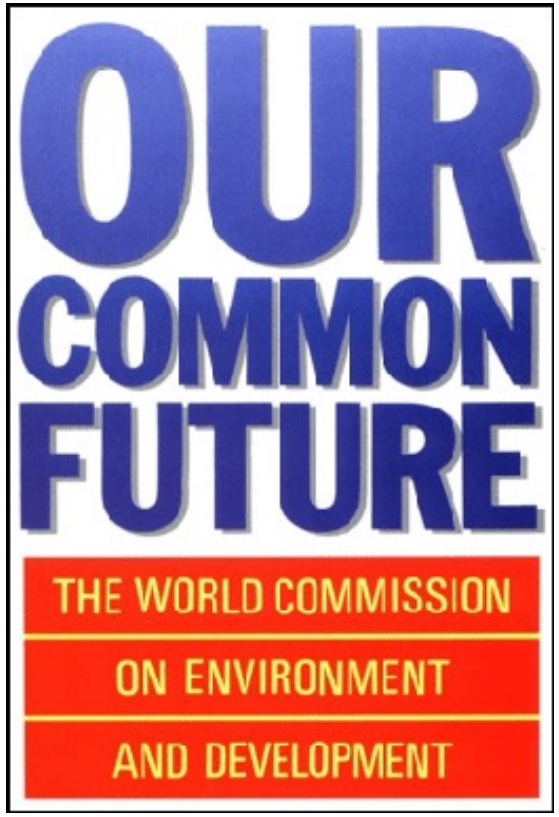
- *'Silent Spring' (Carson, 1962);*
- *'The Population Bomb' (Ehrlich, 1968);*
- *'A Blueprint for Survival' (The Ecologist, 1972)*
- *'Limits to Growth' (Meadows et al. 1972)*

"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

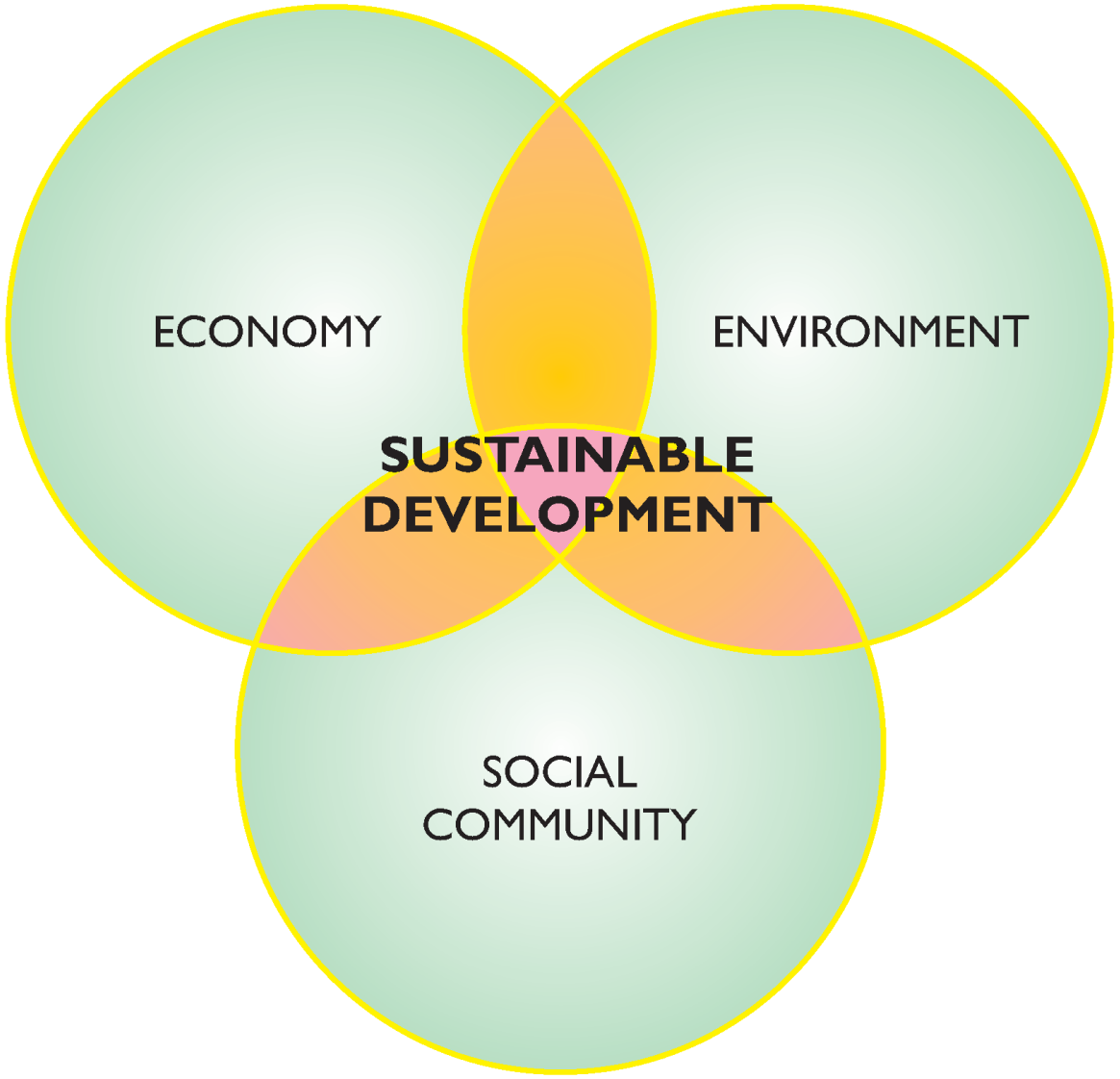


The limits to Growth, 1972
"world system…that is sustainable"

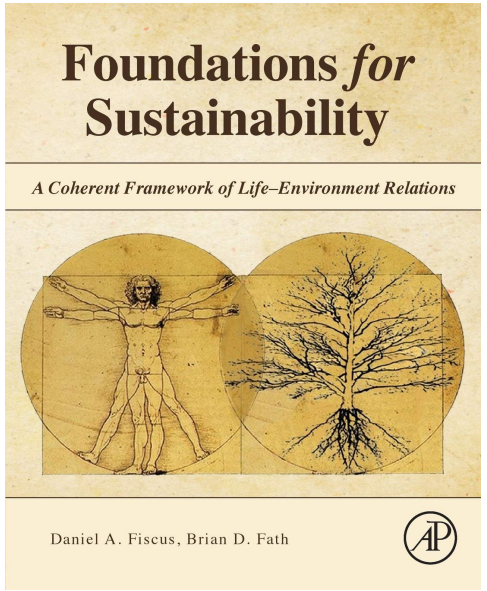


Our Common Future/United Nation's Brundtland Report, 1987

Three pillars of SD



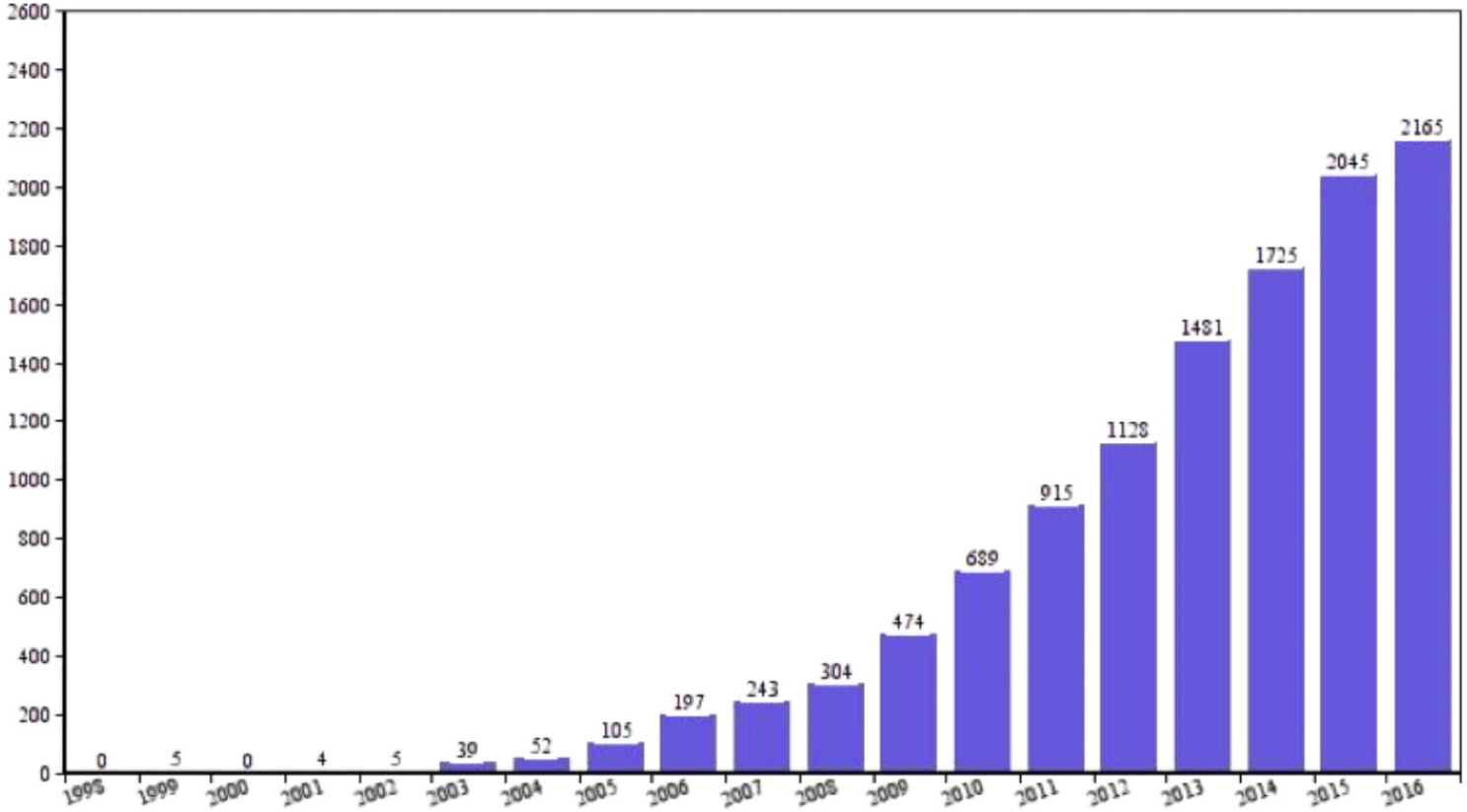
Sustainable development v.s. Sustainability



Source: Fiscus and Fath, 2018

A long history of understanding human environment interactions as coupled 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

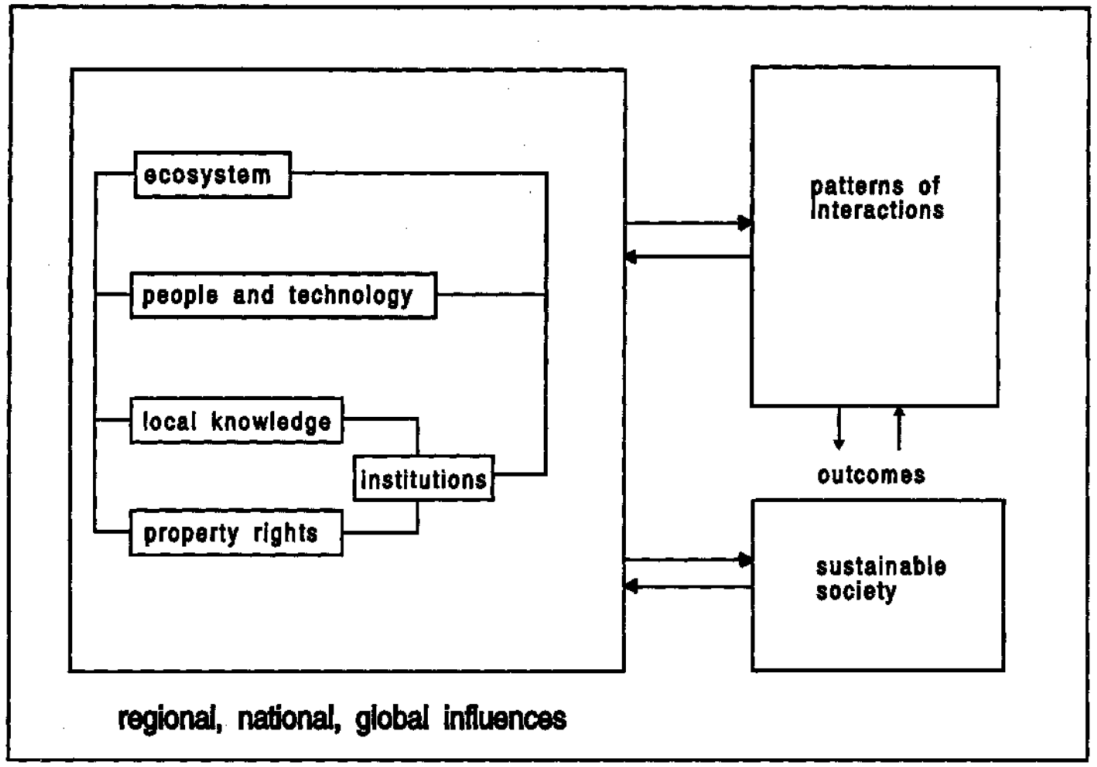
Synthesis

Exploring the social-ecological systems discourse 20 years later

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

Intertwined social and ecological systems

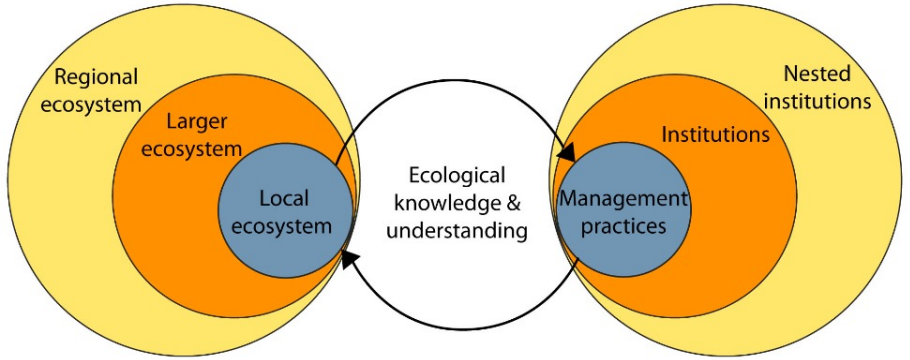
Figure 1. A framework for analyzing the link between social and ecological systems for resilience and sustainability



Berkes F, Folke C (1994) Linking Social and Ecological Systems for Resilience and Sustainability. Beijer Discussion Papers

"[t]he challenge is to find ways to match the dynamics of institutions with the dynamics of ecosystems for mutual social-ecological resilience and improved performance." (Folke and Berkes, 1998; p.4)

Fig. 1. A conceptual framework for the analysis of linked social-ecological systems. Ecological knowledge and understanding is a critical link between complex and dynamic ecosystems, adaptive management practices, and institutions. Source: Based on and modified from Folke and Berkes (1998).



Social-ecological systems as complex adaptive systems

- How dynamic interactions among and between human and non-human elements of a SES gives rise to system-level patterns, which in turm affects local interactions (Levin et al. 2013; Folke et al. 2016).

- A systematic approach that looks at processes and interactions of the social-ecological phenomenon

	Empirical phenomenon of interest	SES phenomenon of interest	Research question	Key literature
1	Collapse of the Baltic Sea cod populations	Regime shift	How did social factors and processes in the cod fishery contribute to the cod collapse?	Lade et al. 2015
2	Persistent poverty in the Pamir Mountains	Social-ecological trap	How did the introduction of a new seed by a donor organization contribute to the creation of a social-ecological trap?	L. J. Haider, W. J. Boonstra, A. Akobirshoeva, and M. Schlüter, *unpublished manuscript*
3	Collapse of the Newfoundland cod fishery	Regime shift	Which social and social-ecological interactions have maintained unsustainable harvesting and led to the collapse of cod?	Mason 2002
4	Restoration of lake Ringsjön, southern Sweden	Regime shift	How do social and ecological processes interplay to determine the restoration time of a tipping lake?	Martin and Schlüter 2015 R. Martin, M. Schlüter, T. Blenckner, *unpublished manuscript*
5	Small-scale fisheries in Mexico	Trap	Which microlevel mechanisms lead to a dominance of patron-client relationships in the fishery?	Lindkvist et al. 2017
6	Dryland agriculture in Tanzania	Social-ecological trap	What feedbacks maintain the trap and what leverage points for escaping the trap exist?	Enfors 2013
7	Spread of Avian influenza	Cascading crisis	What are possible social-ecological feedbacks that may precipitate an epidemic?	Galaz et al. 2011

Source: Schlütler et a;l. 2019; p.9)

A robustness framework of SES

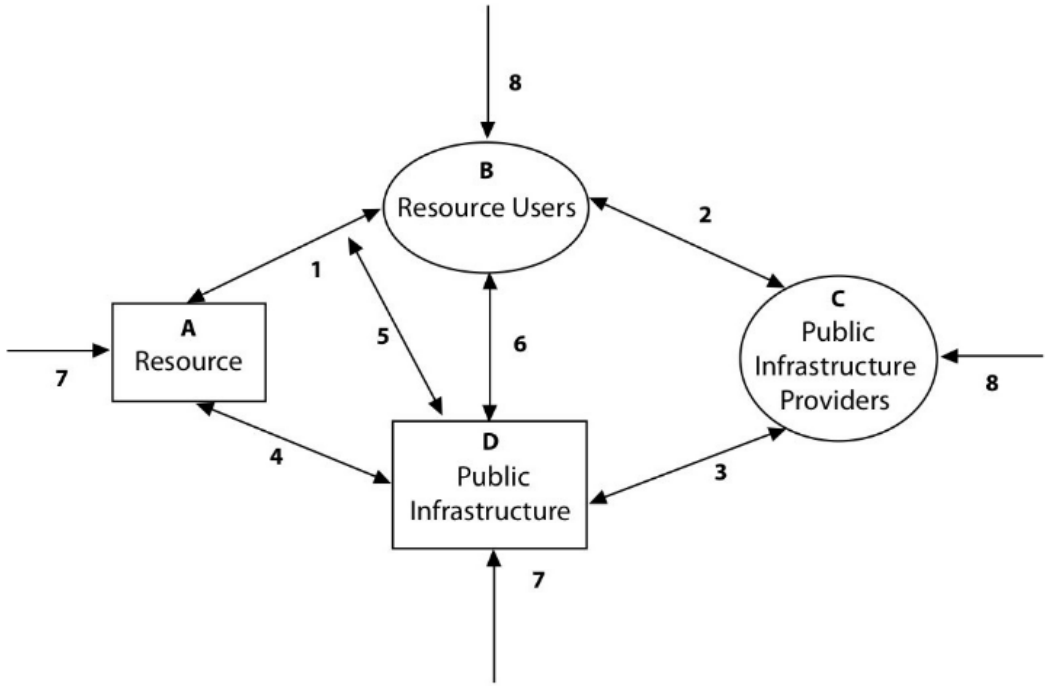
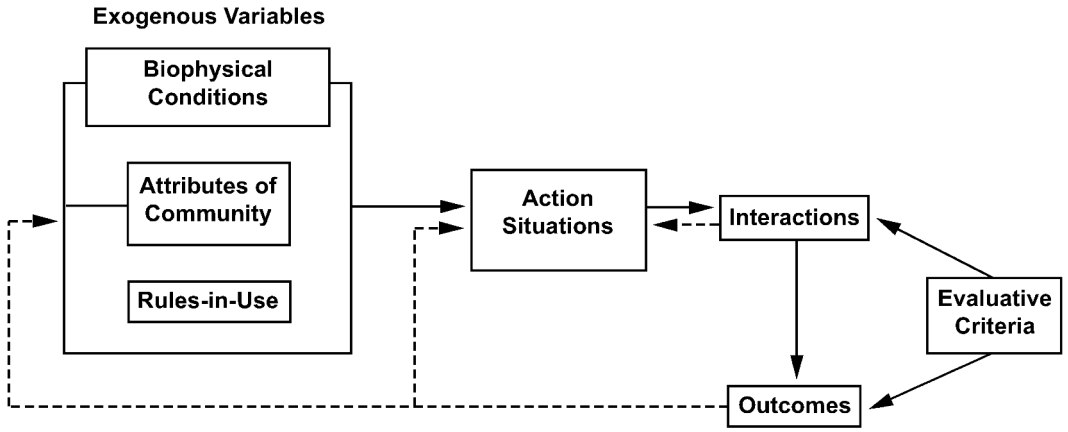


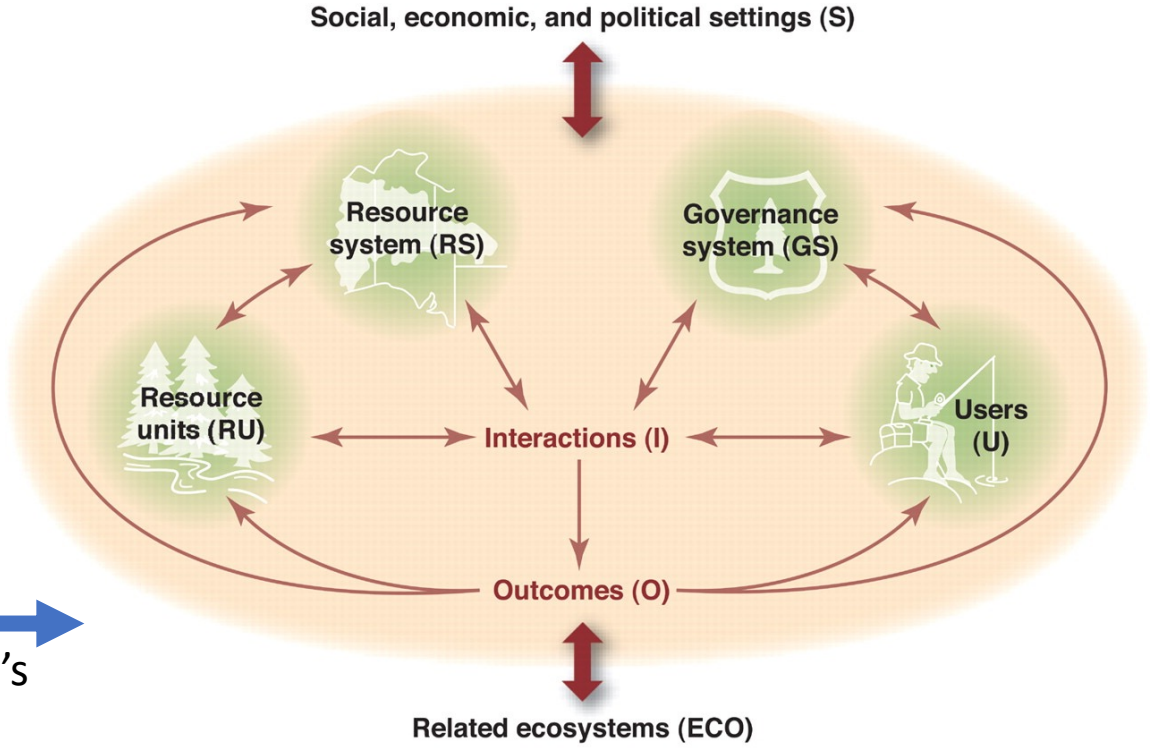
Fig. 3. Basic feature of a social-ecological system model. The resource (A) is used by resource users (B) and public infrastructure providers (C). Public infrastructure (D) refers to physical capital (i.e., any engineered works such as dikes, irrigation canals, etc.) and social capital (i.e., the rules used by those governing, managing, and using the system including monitoring and enforcement of these rules). In the examination of robustness, external disturbance (Arrow 7) can be addressed (i.e., biophysical disruptions such as floods, earthquakes, landslides, and climate change) as well as socioeconomic changes (Arrow 8), e.g., population increases, economic and major political changes that impact on the resource users (B) and the public infrastructure providers (C). Arrow numbers in the figure signify interaction as follows: (1) between resource and resource users; (2) between users and public infrastructure providers; (3) between infrastructure providers and public infrastructure; (4) between public infrastructure and resource; (5) between public infrastructure and resource dynamics; (6) between resource users and public infrastructure; (7) external forces on resource and infrastructure; (8) external forces on social actors. Source: Anderies et al. 2004.

Ostrom's A multitier framework of SES



A framework for institutional analysis. *Source:* Adapted from E. Ostrom, Gardnerm and Walker 1994, 37.

1990's → 2010's



The SES framework. *Source:* Ostrom (2009)

A SES is a system composed of:

(1) A focal resource system (RS);

(2) One or more resource units (RU) that exist within or affect this RS

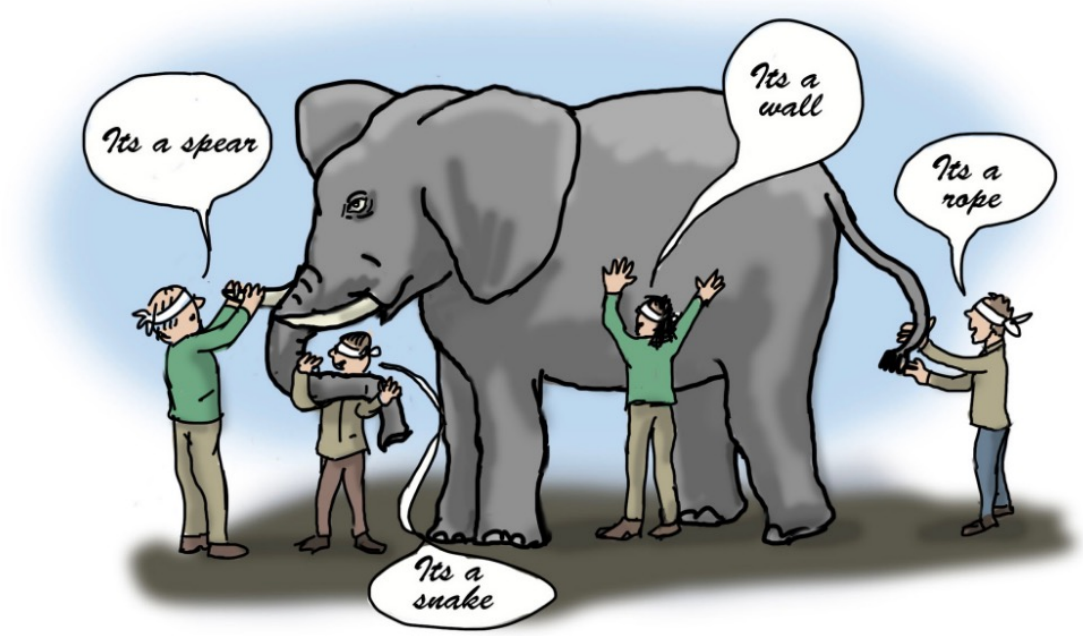
(3) A focal governance system (GS);

(4) One of more actor groups (U) that interact within this governance system

Source: The Bloomington school of institutional analysis (seminar on Institutional Theory – Fall 2023)

A common analytical framework needed

Fig. 5. The lack of a common analytical framework of social-ecological systems (SES) is a significant challenge for the field of SES to develop and communicate with other social and natural science fields. Artwork by Jonas Adner.



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Synthesis

Exploring the social-ecological systems discourse 20 years later

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A lack of a unifying definition of SES

"We hold the view that social and ecological systems are in fact linked, and that the delineation between social and natural systems is artificial and arbitrary." (Folke and Berkes, 1998; p.4)

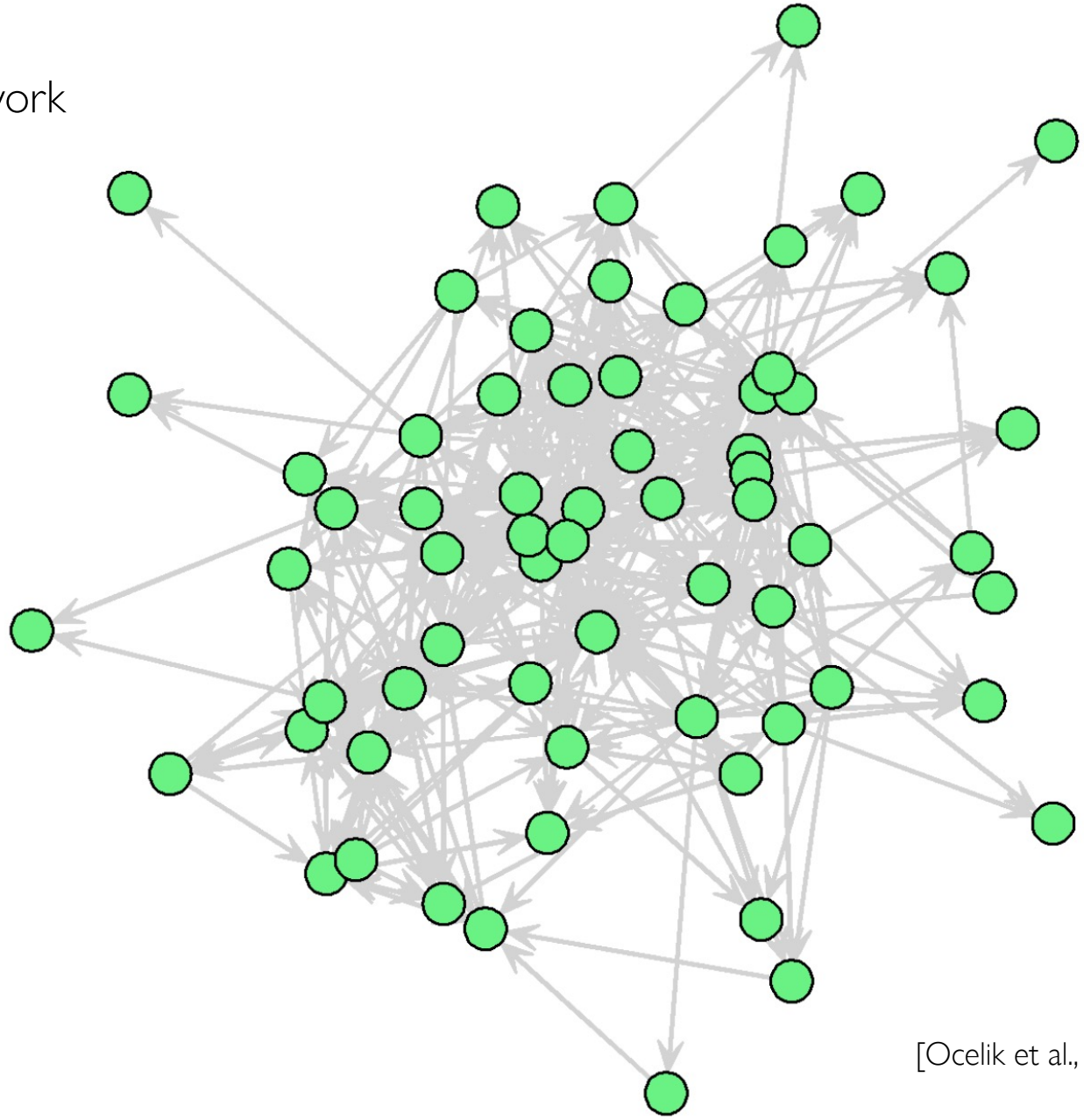
"A clearer definition would for sure avoid the 'blind elephant analogy' that runs the risk of circumscribing the SES concept" (Colding and Barthel, 2019; p.9)

Networks

…concepts from graph theory

Social networks

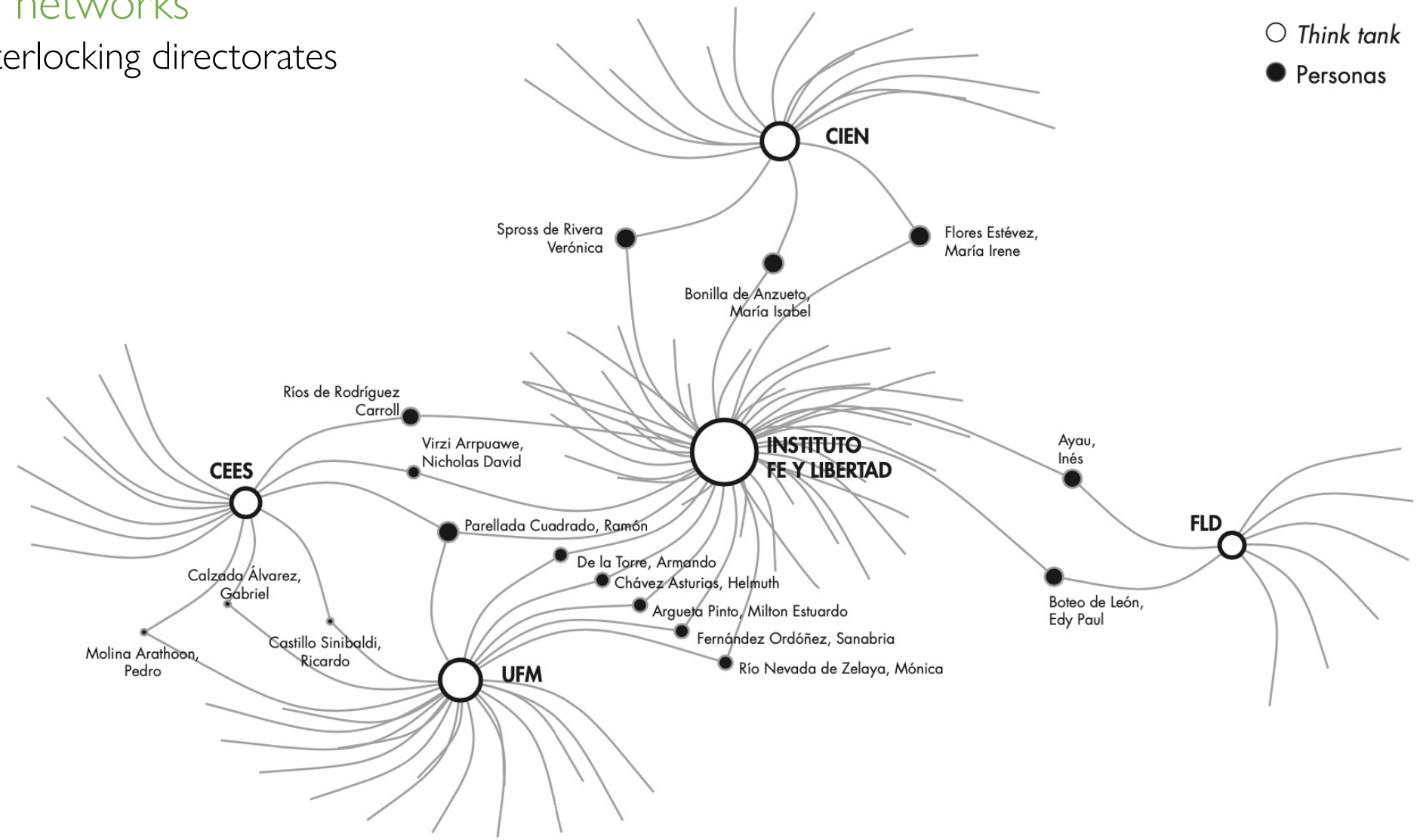
e.g., political collaboration network



[Ocelik et al., 2022]

Social networks

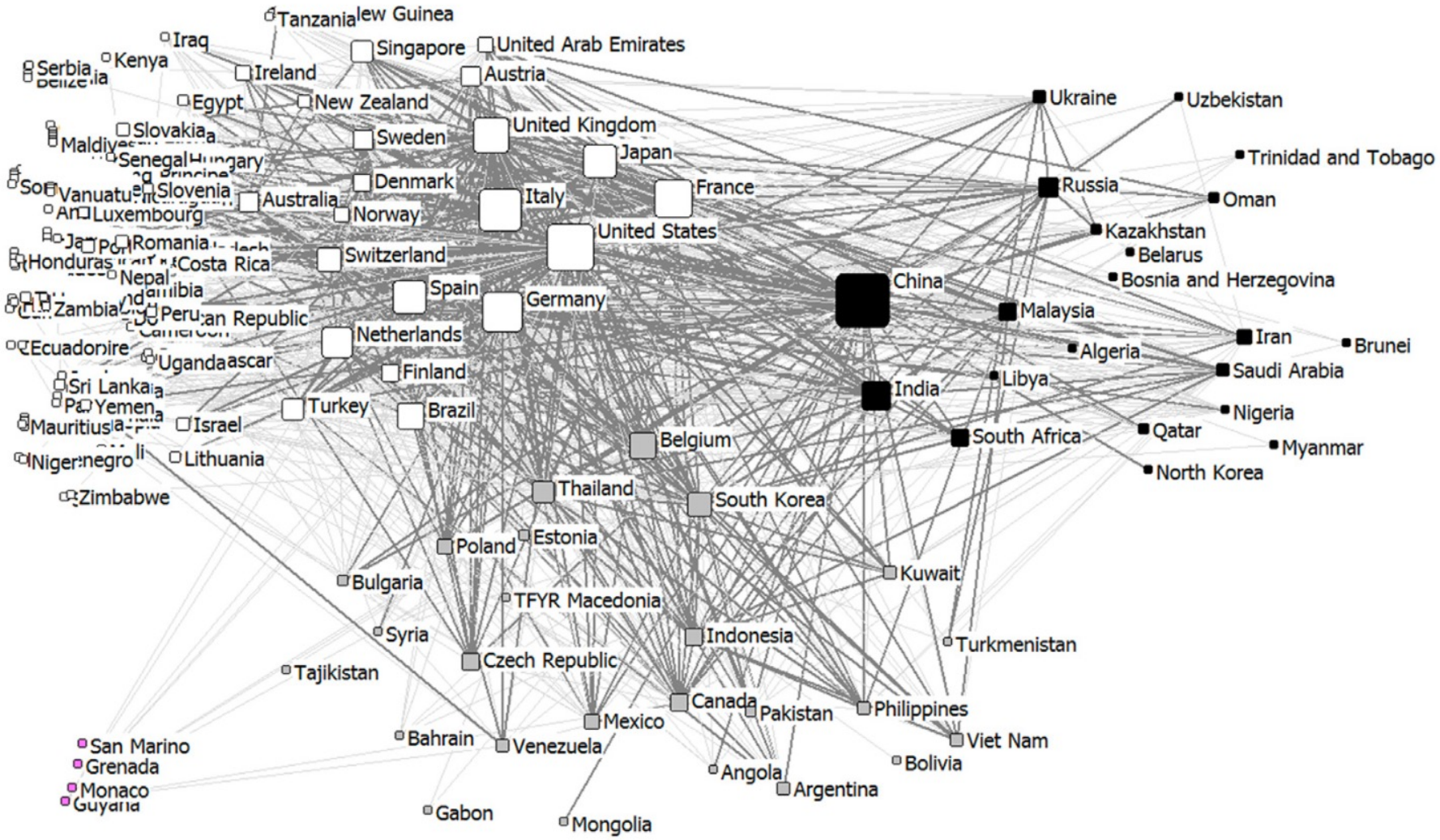
e.g., interlocking directorates



[Fischer & Waxenecker, 2020]

Social networks

e.g., trade network



Year 2010

[Prell & Feng, 2016]

Social networks

e.g., policy instrument preferences

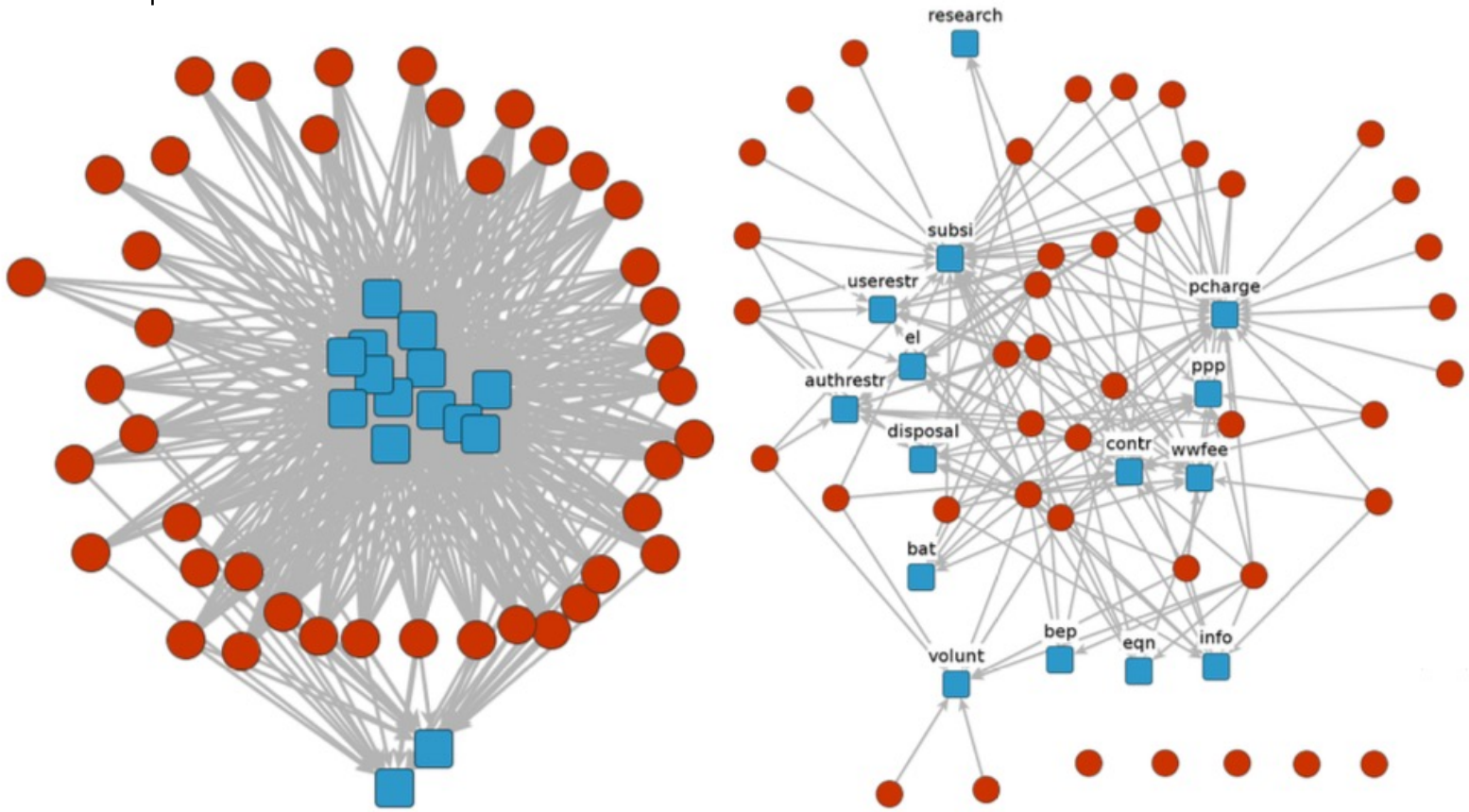


Figure 3. Two-mode network of policy instrument preferences.
Note: Support network ("agree somewhat" or "strongly agree") on the left; rejection network ("disagree somewhat" or "strongly disagree") on the right. Circles = actors, squares = policy instruments, ties = preferences in the form of support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

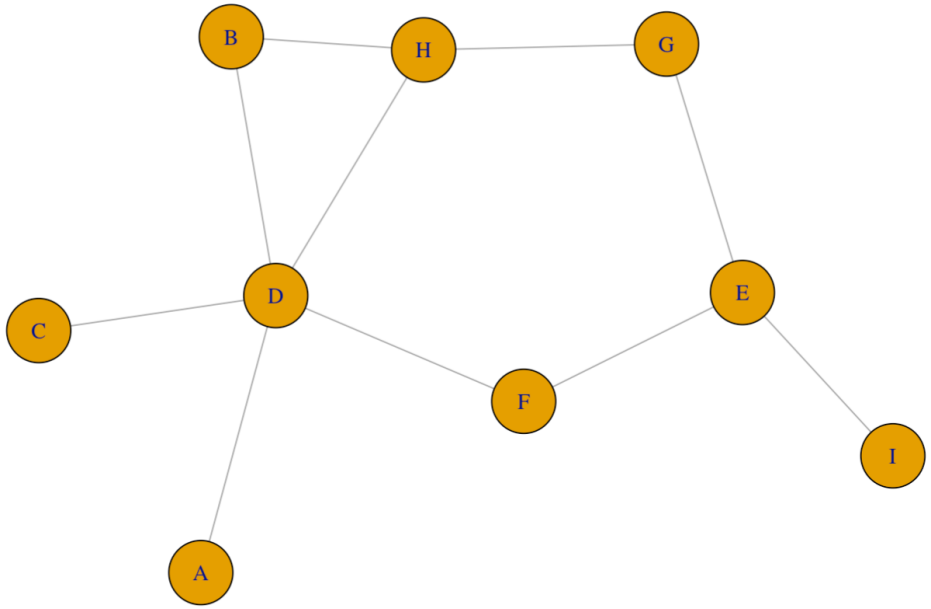
[Metz et al., 2018]

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]

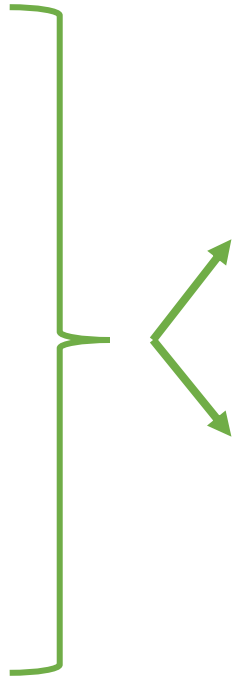


"The most general characteristic of social science data is that they are rooted in cultural values and symbols. Unlike the pysical data of the natural sciences, social science data are constituted through meanings, motives, definitions and typifications. […] The principle type of data can be referred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

[Scott, 2013: 3]

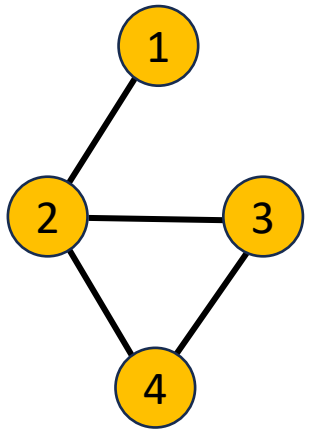
We need relational data!!!

Style of research	Source	Type of data	Type of analysis
Survey research	Questionnaires, interviews	Attribute	Variable analysis
Ethnographic research	Observations		
Documentary research	Texts	Relational	Network analysis



[Based on Scott, 2013]

[graph]

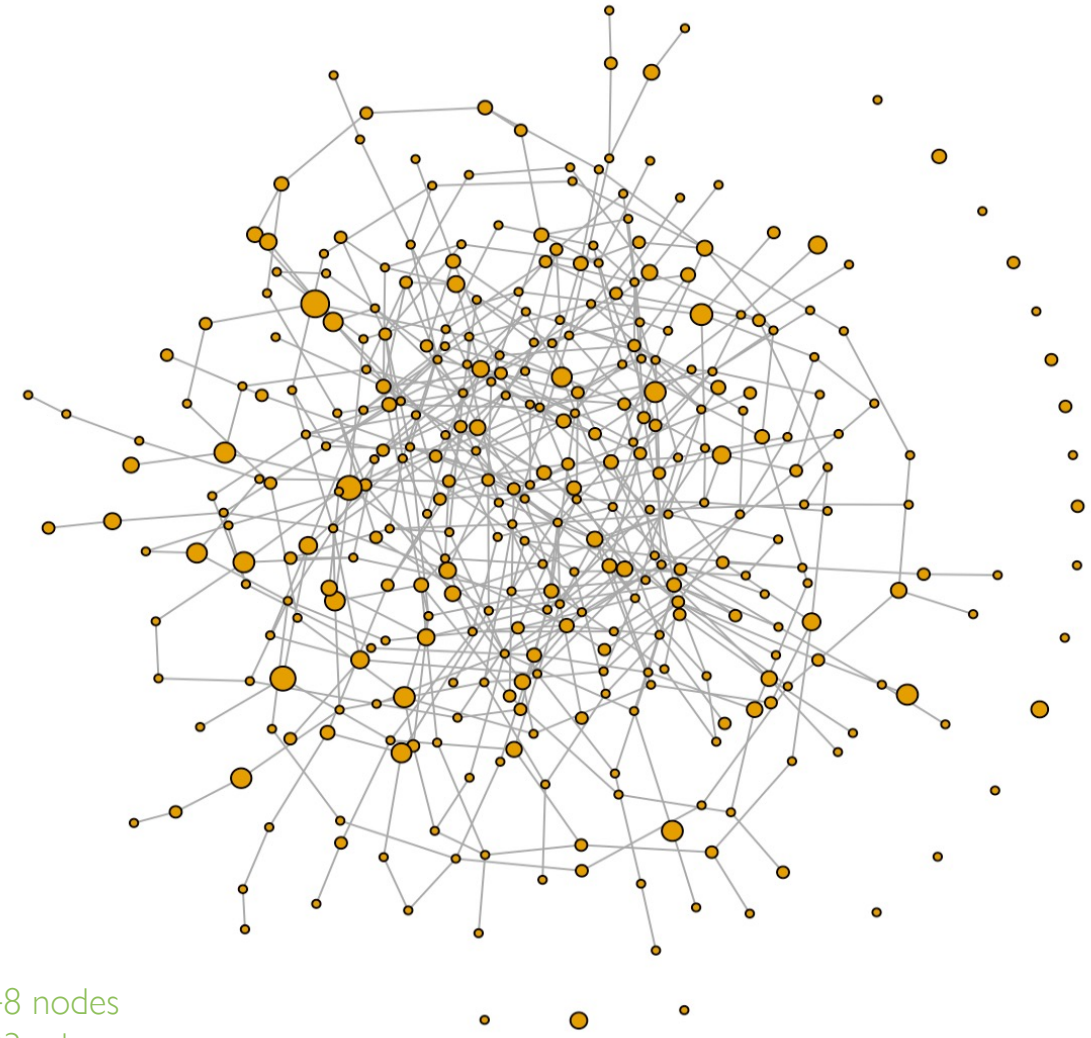


[matrix]

	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

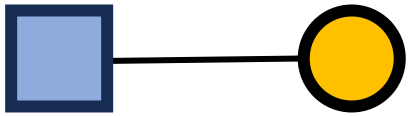
Number of vertices (nodes)
Number of edges (ties)

Graph density

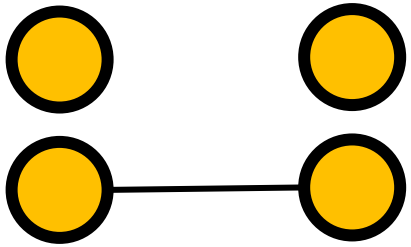
Describing a network…

One-mode network

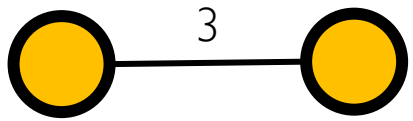
Two-mode network



Binary [0, 1]

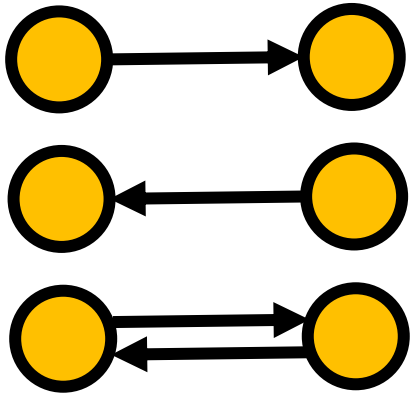


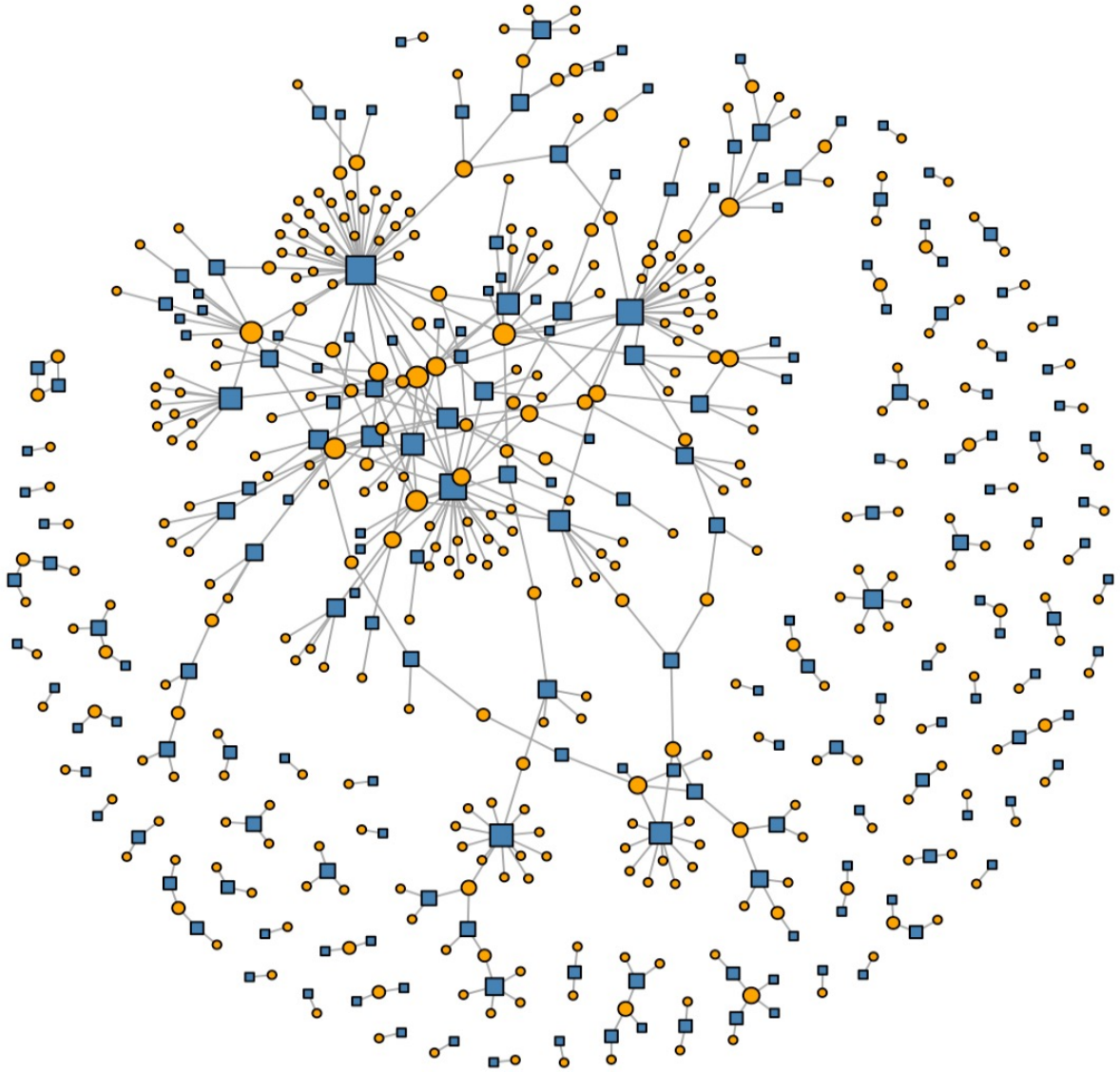
Wheighted



Undirected

Directed





Two types of nodes

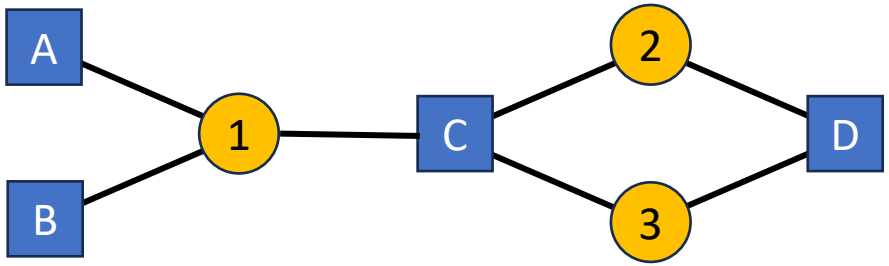
Mode 1 (set 1)

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

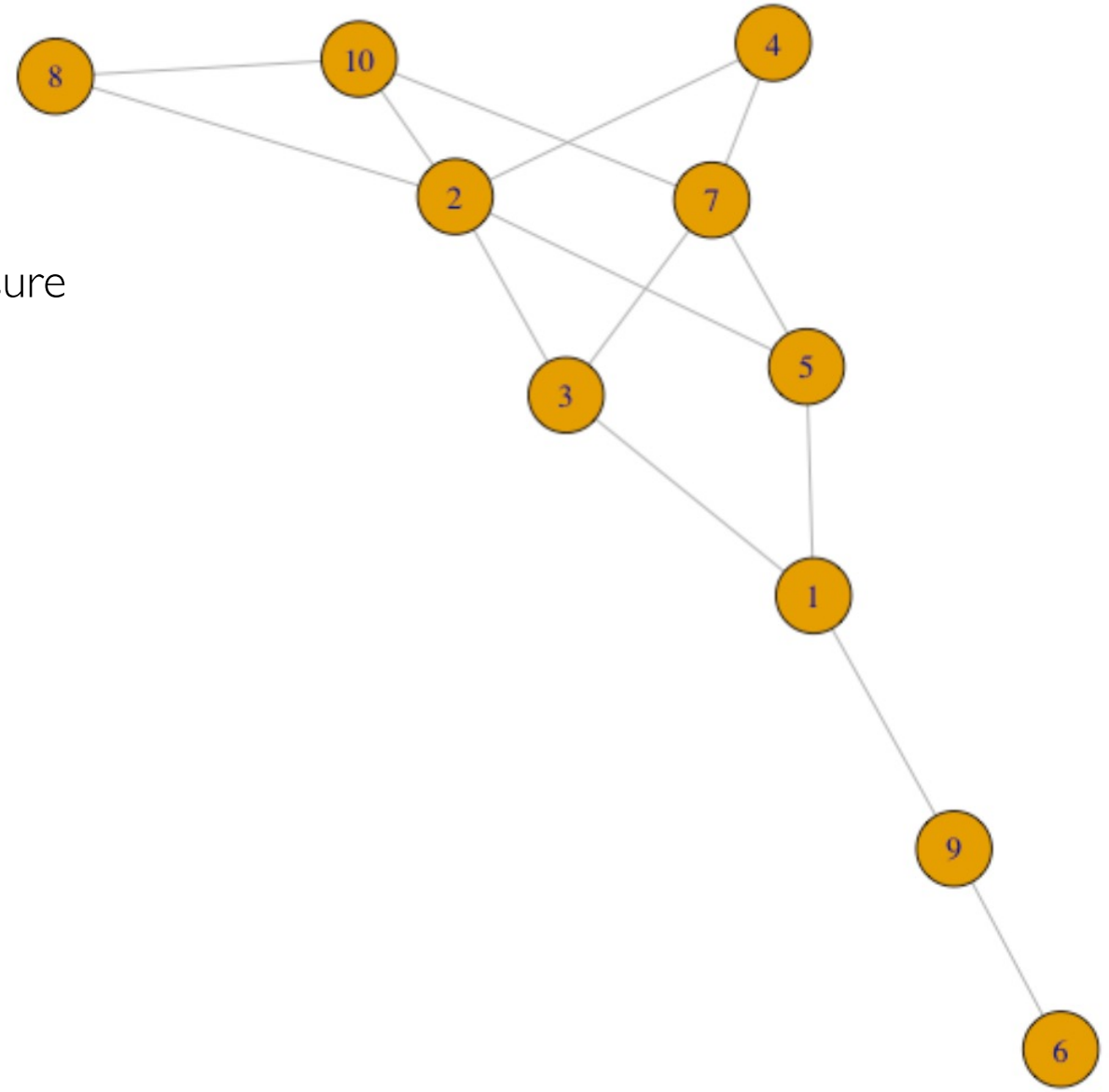
[edgelist]

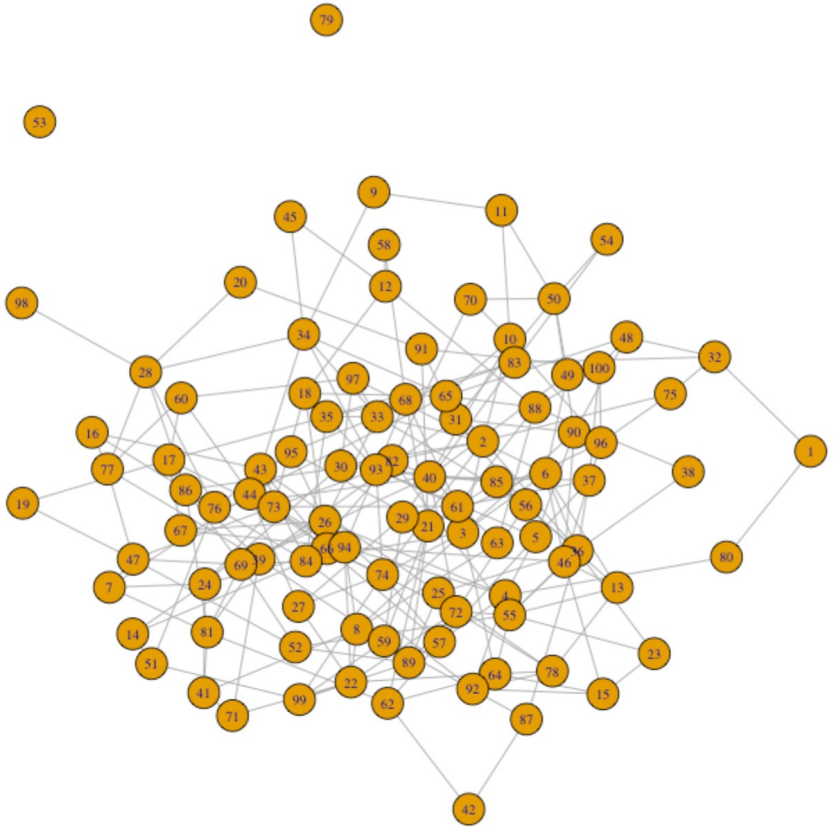
	A	B
1	First mode	Second mode
2	A	1
3	B	1
4	C	1
5	C	2
6	C	3
7	D	2
8	D	3
9		

Degree centrality

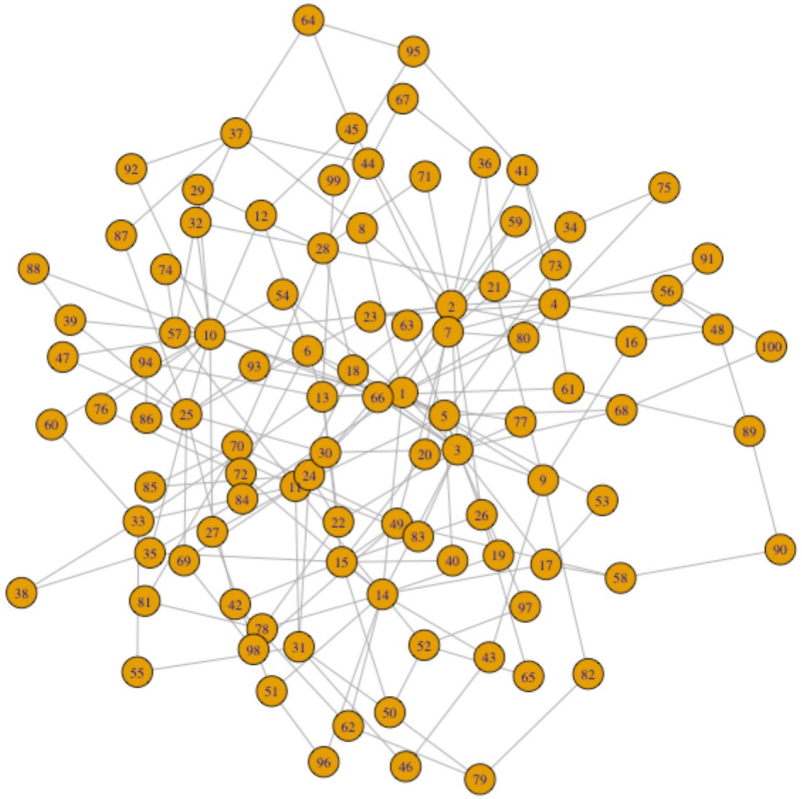
- How many actors is one directly tied to?
- In social theory, high degree tends to be a measure of popularity for undirected graphs.
- Which actor(s) appear to have more degree centrality?

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

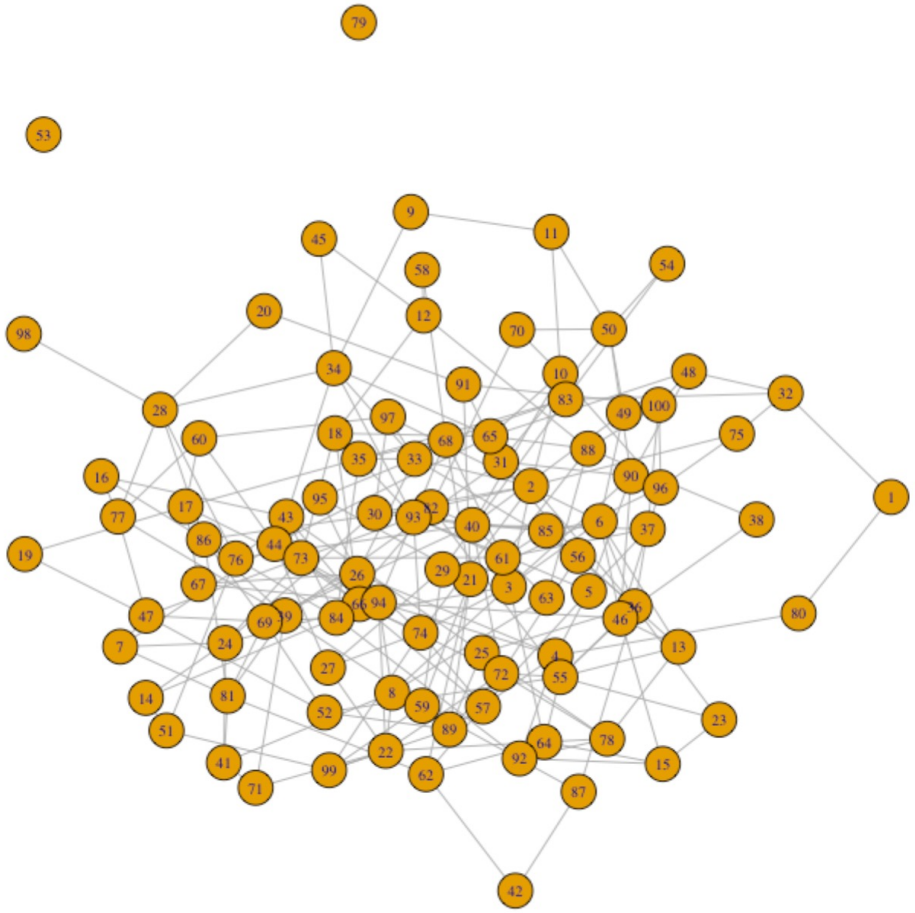




100 nodes
243 edges
Graph density: 0.049

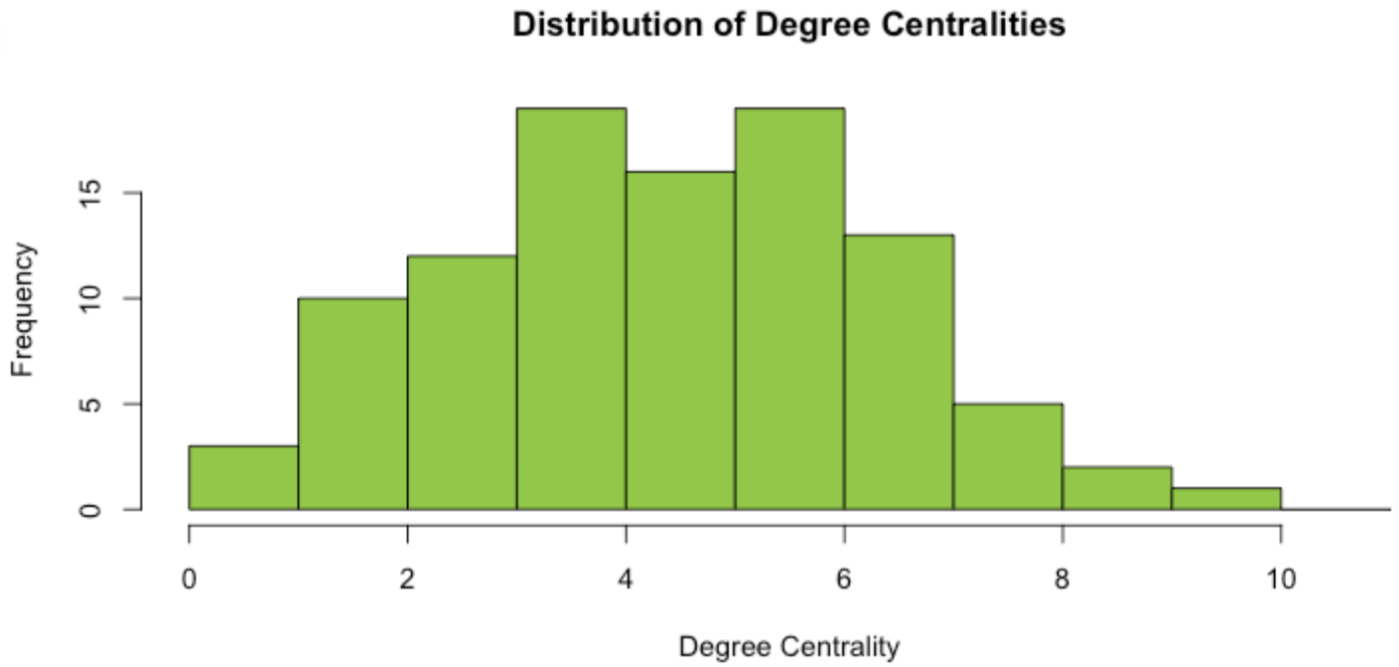


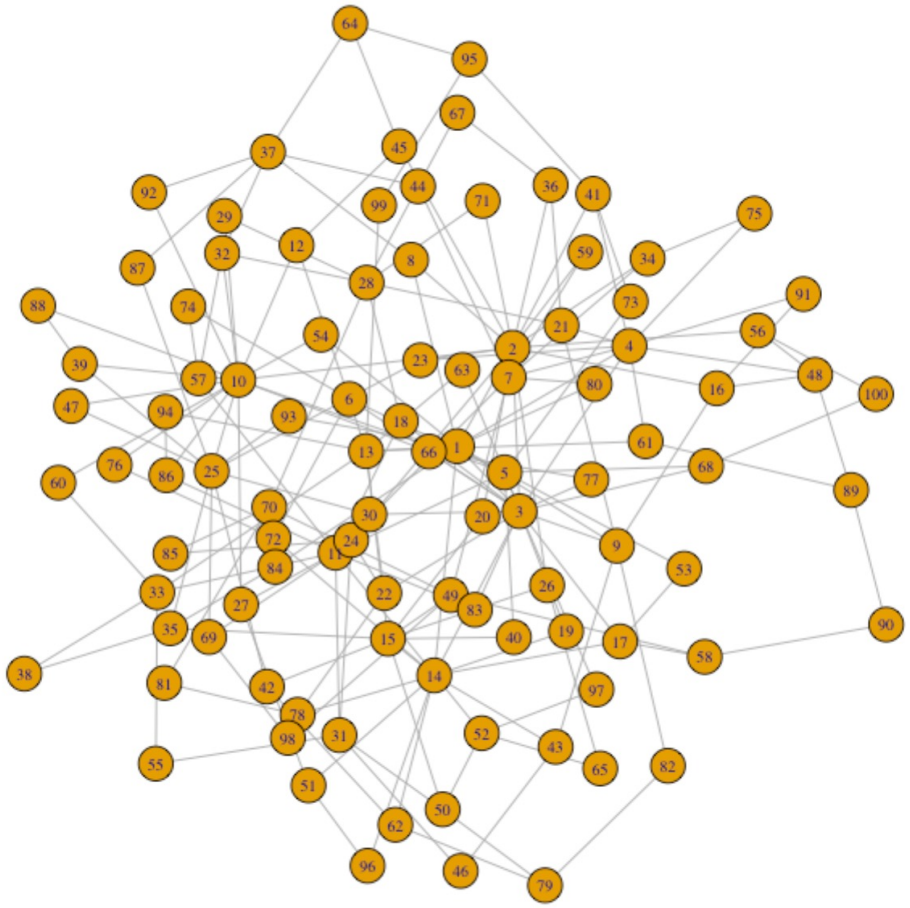
100 nodes
197 edges
Graph density: 0.039



Erdös-Renyi

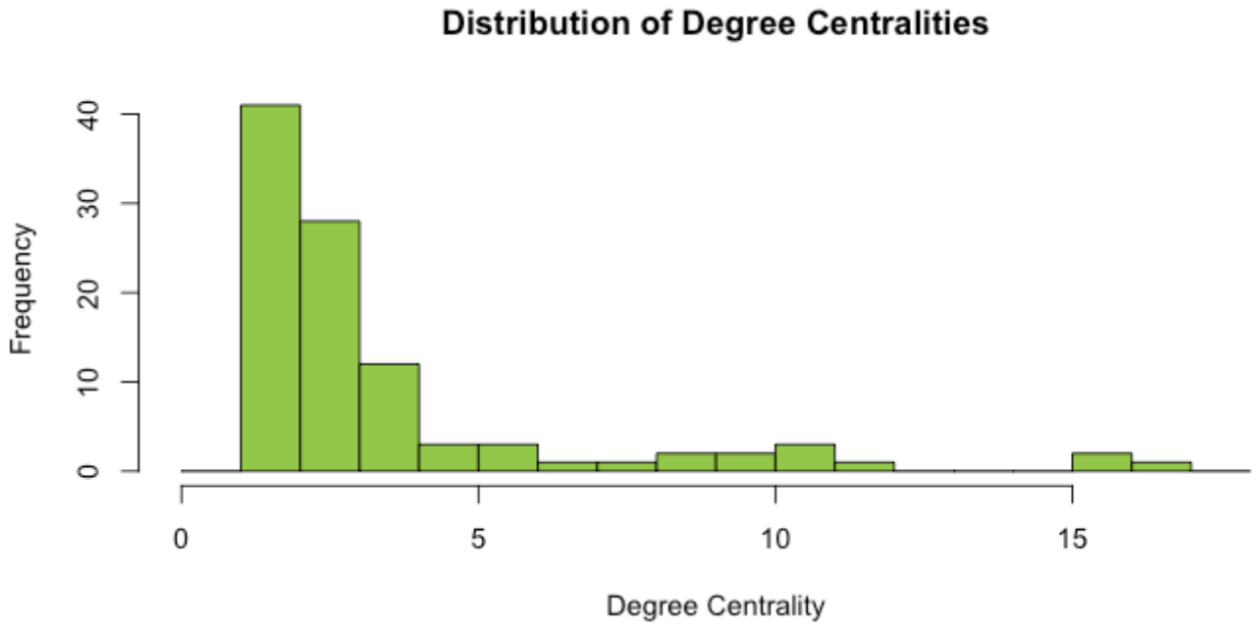
Erdős-Rényi graphs provide a simple model for studying random networks and serve as a baseline for comparison with more complex network models.



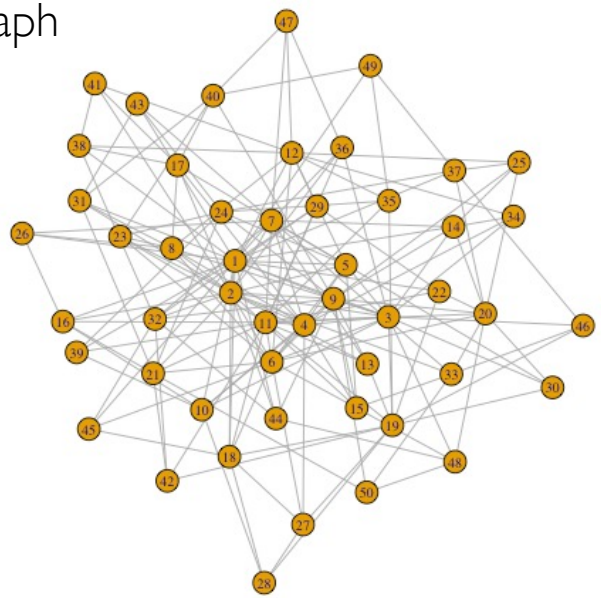


Scale-free network: a network in which a few actors hold a high degree centrality, and the majority of actors have a low degree centrality.

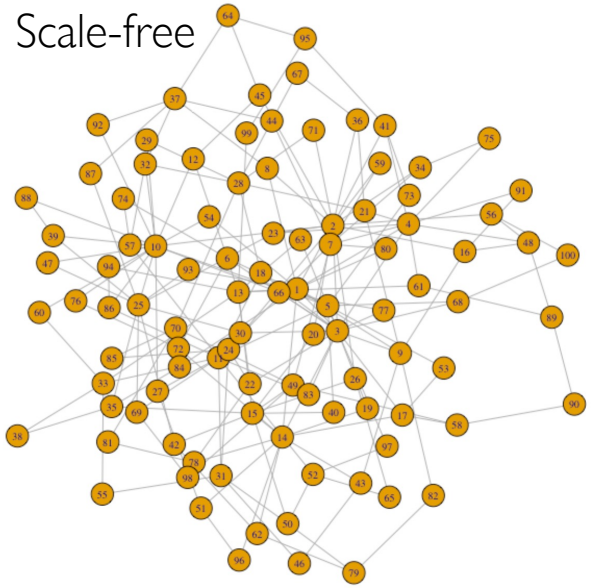
Such a distribution of ties resembles a 'power-law'. Many empirical networks have this property, to some extent.



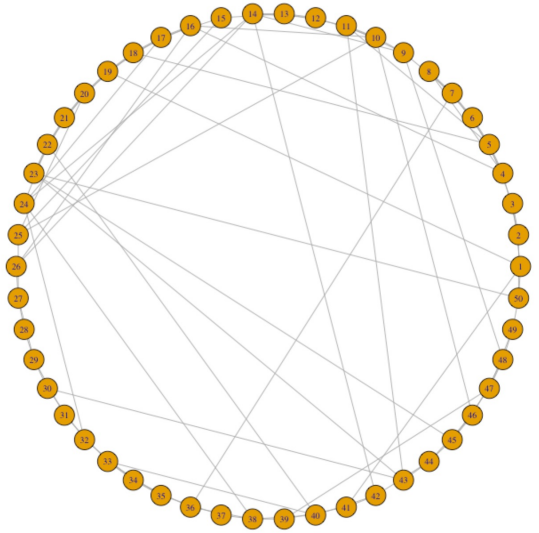
Core-periphery graph



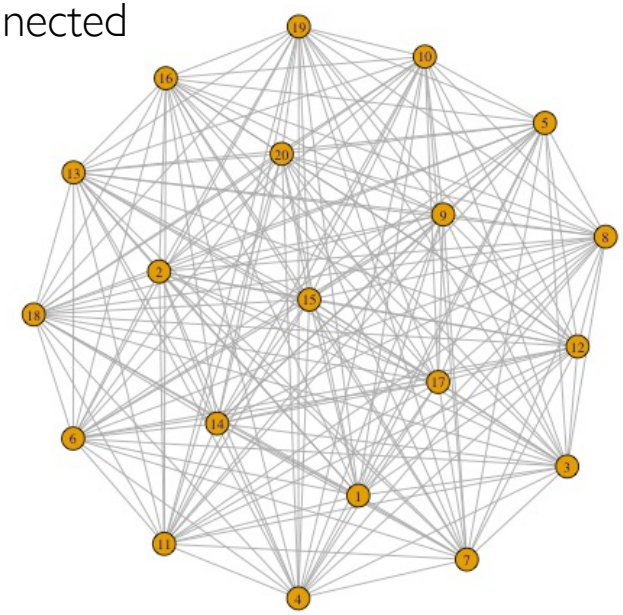
Scale-free



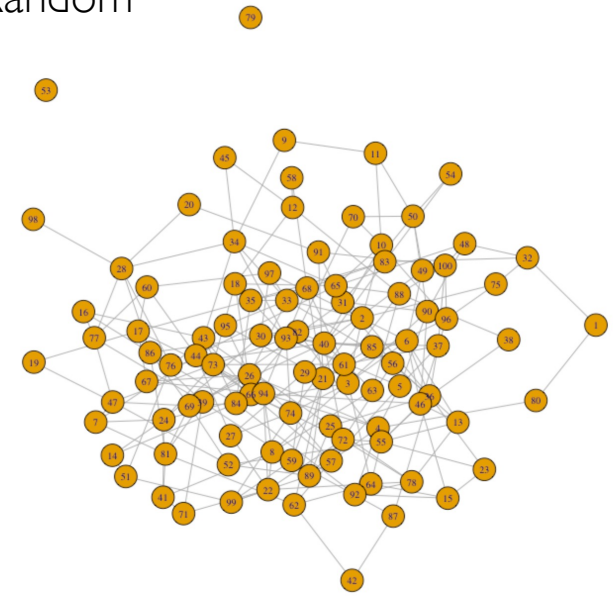
Small world



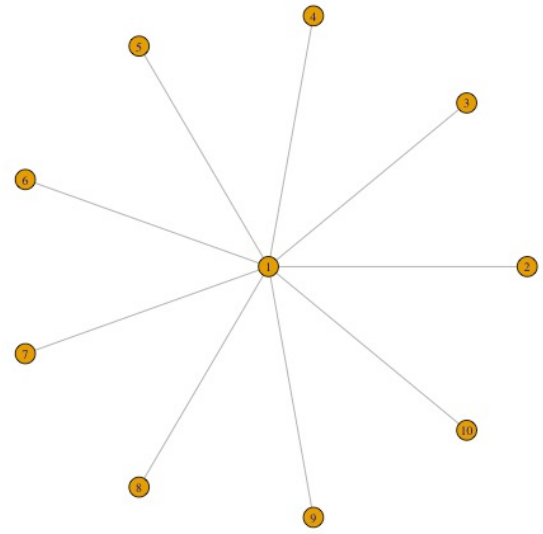
Fully connected



Random



Star



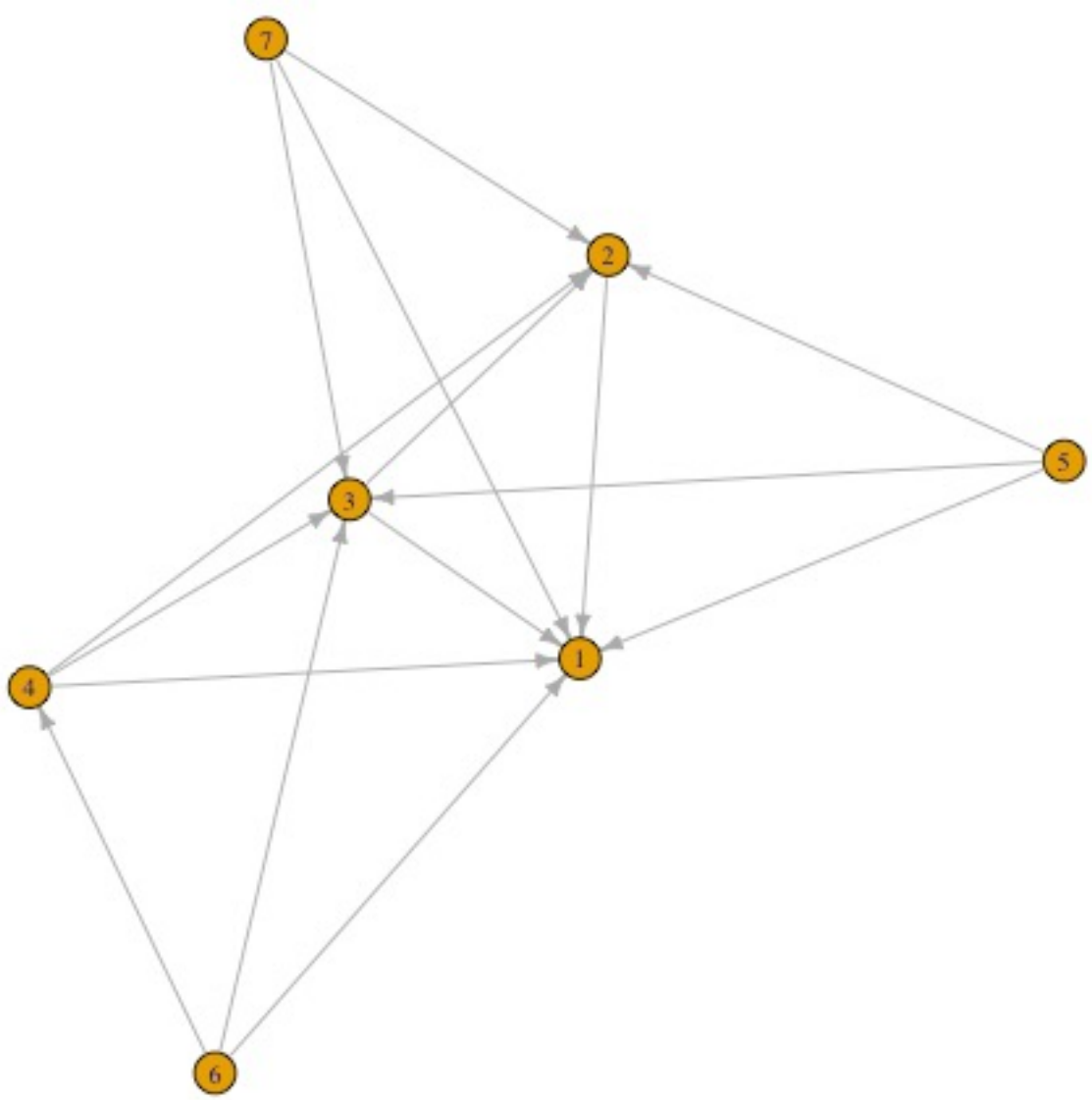
Degree centrality in a directed network

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

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

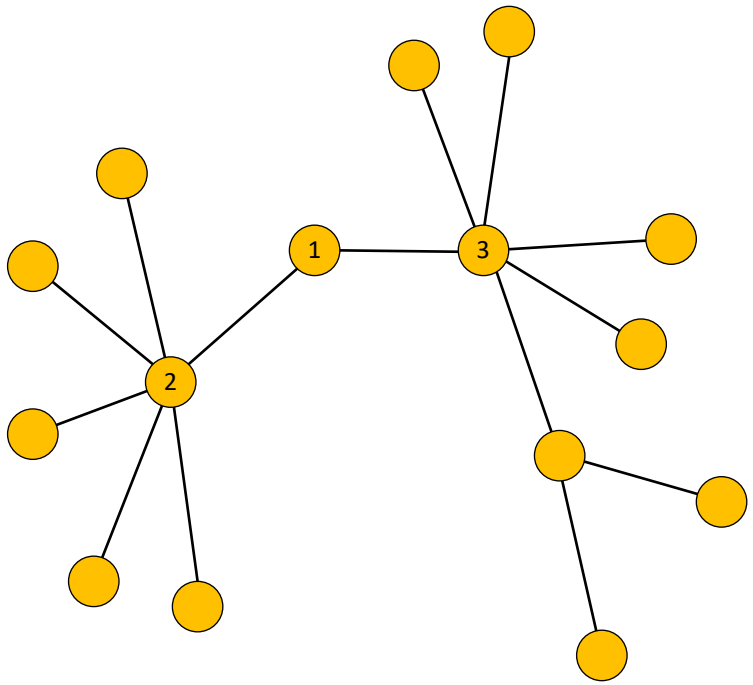
- Outdegree = how many nominations does one give?
  - Usually seen as indicating the extent to which one is dependent on others.
  - Linked to spreaders of gossip,
  - etc.

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



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.



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

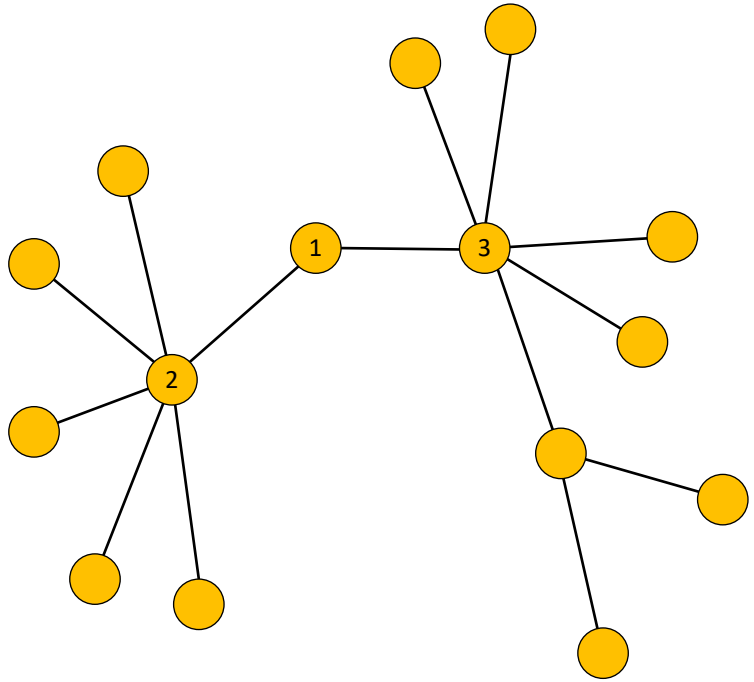
On a symmetric network:

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

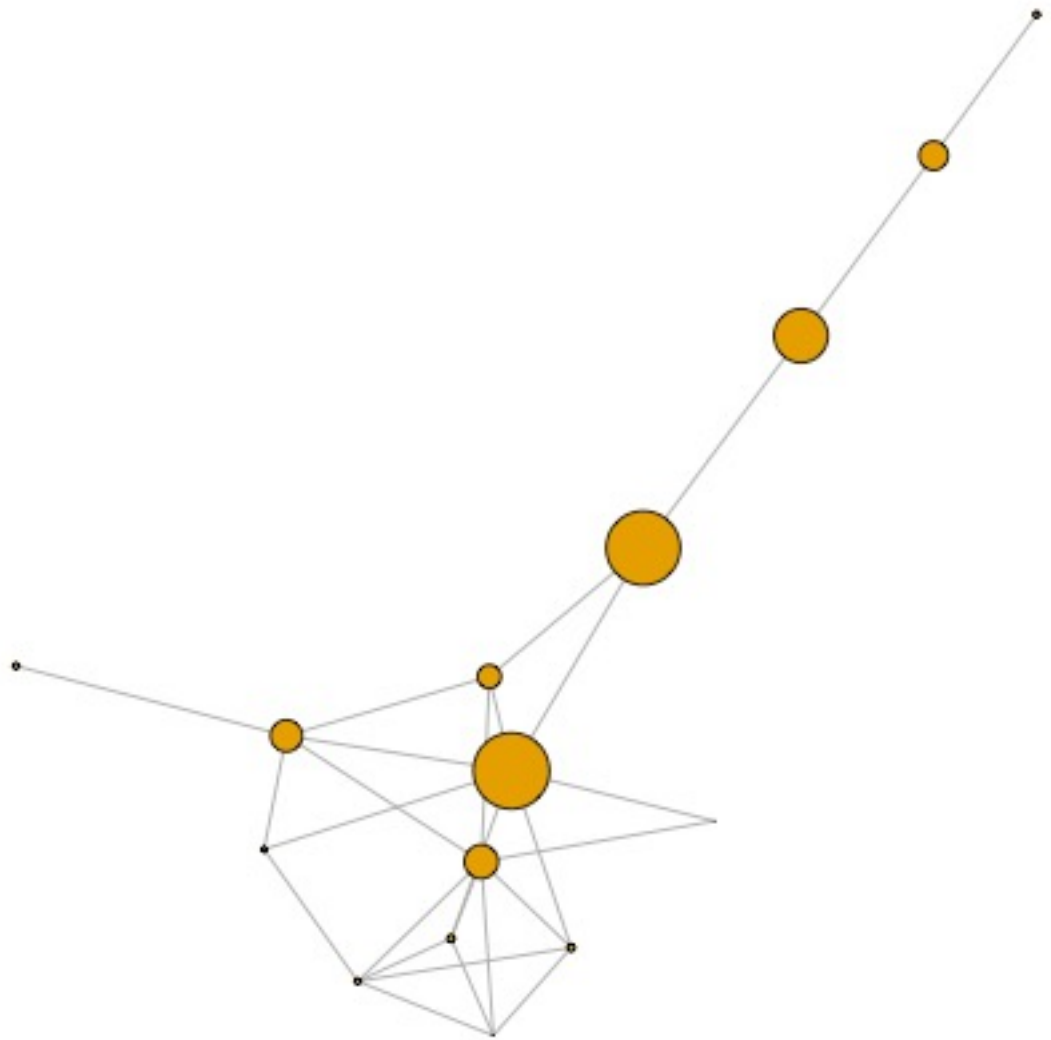
- The frequency of a node *(i)* lying on the shortest path between two actors (*s*,*t*) who are otherwise disconnected actors.
- A good measure for resource flows along relations.
- A common measure to capture the notion of a 'broker'



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

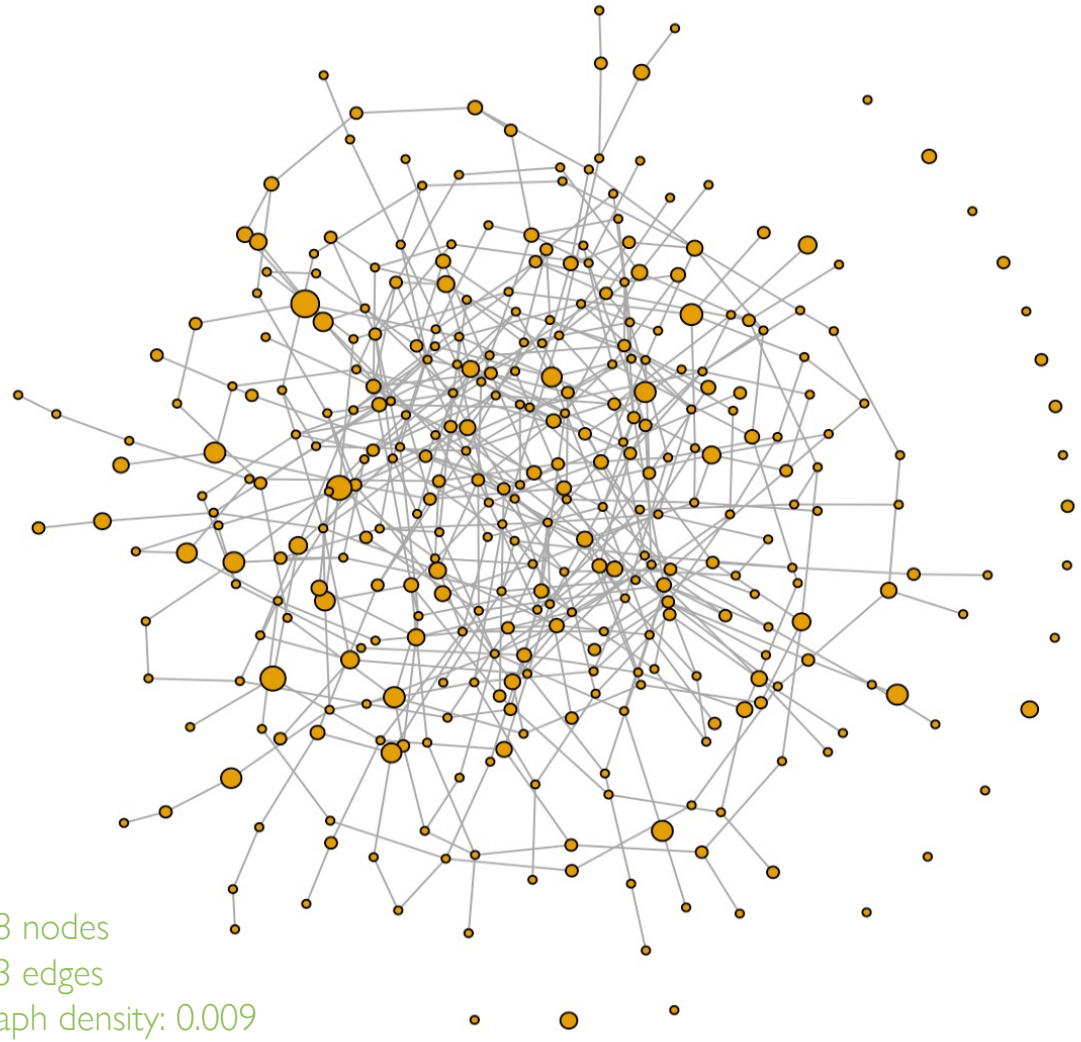
∂_{st} = shortest path linking s to t.

$\partial_{st}(i)$ = 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

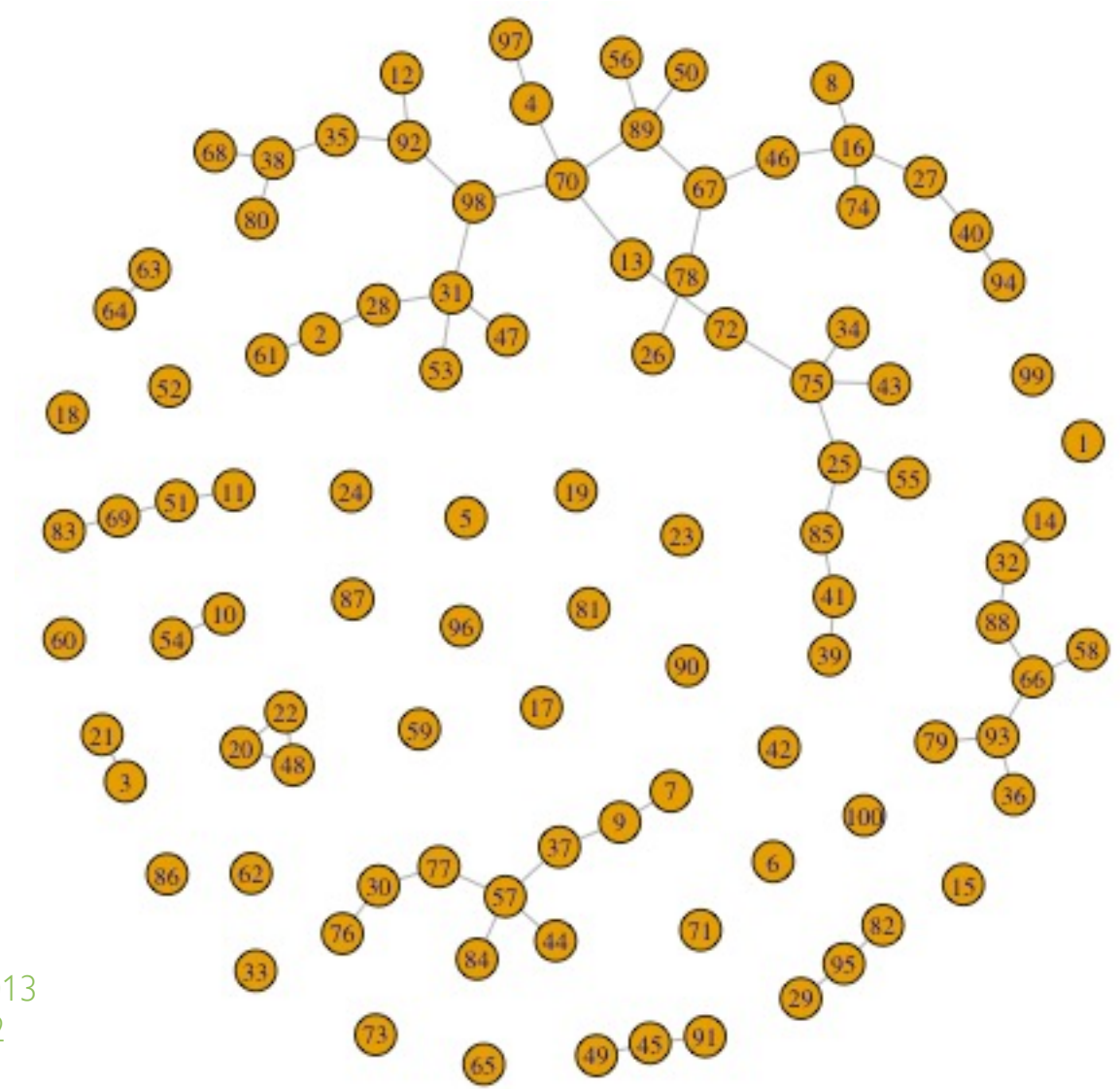
Describing a network…

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

…for next week

Who has experience with R?

Install R and RStudio

https://www.r-project.org

Explore some tutorials

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

References

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