Social network analysis 3 + 4

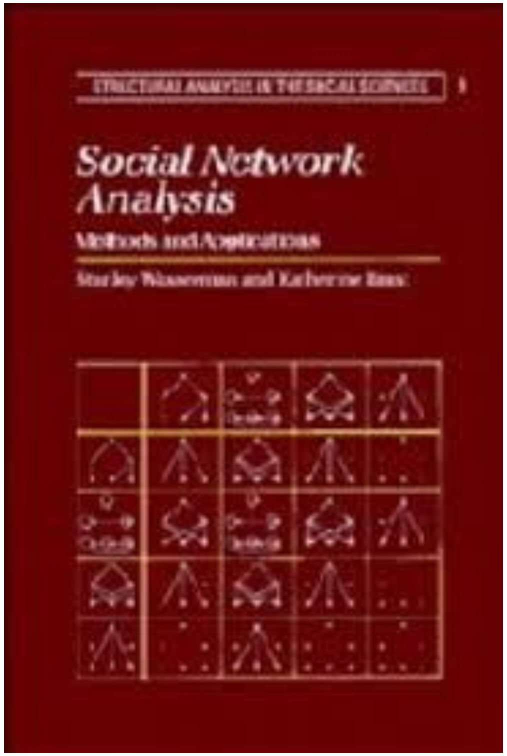
Petr Ocelík

Outline

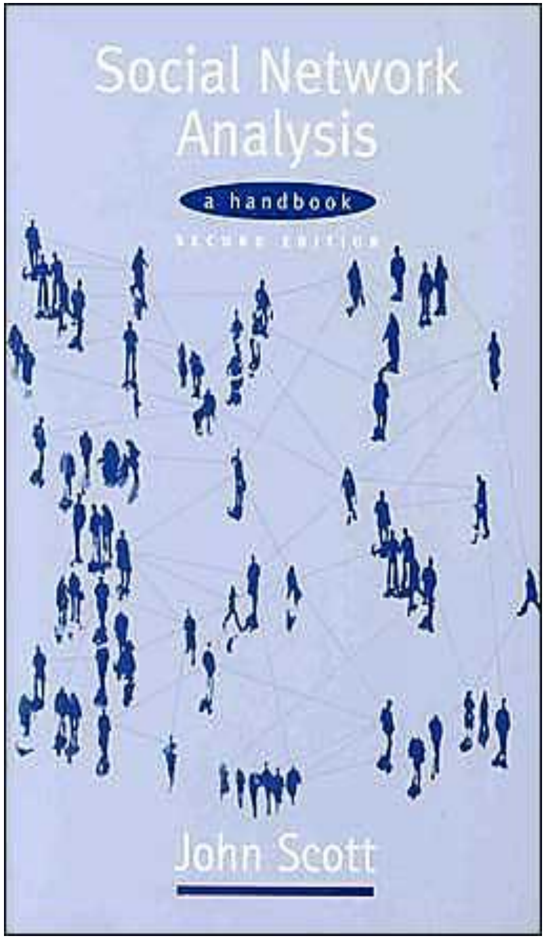
- Centrality and centralization
- Dyads and reciprocity
- Triads and transitivity
- Segments
- R: SNA mini-case

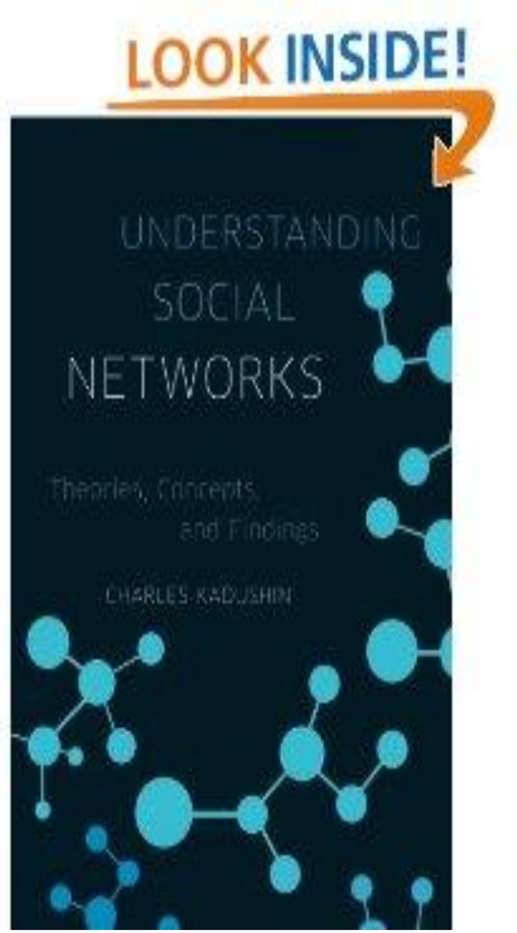
“Red bible”

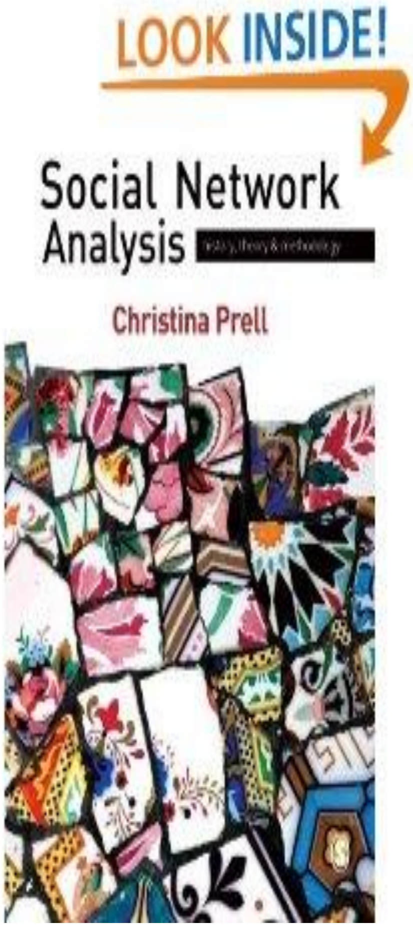
- Stanley Wasserman and Katherine Faust (1994): *Social Network Analysis: Methods and Applications*. Cambridge University Press.


STRUCTURAL ANALYSIS IN THE SOCIAL SCIENCES 8
Social Network Analysis
Methods and Applications
Stanley Wasserman and Katherine Faust

Introductory sources




LOOK INSIDE!
UNDERSTANDING SOCIAL NETWORKS
Theories, Concepts, and Findings
CHARLES KADUSHIN



Graph theory

- **Network topology** is defined by two main concepts: connectivity and centrality.
- **Connectivity** describes interconnectedness of nodes in network (focus on **flows**).
- **Centrality** describes location of nodes in network (focus on **positions**).

Graph theory: notation

- G = graph/network
- N = # of nodes in network, n = individual node
- e = edge, g = geodesic
- i, j, … = indices (labels for selected elements)
- gij = geodesic between nodes i and, ni = node i
- k = # of selected elements (typically nodes)
- Cd’(G) = ’ indicates that the measured value is standardized
- Upper case: global measures
- Lower case: local measures
- cd(ni) = node i degree centrality
- Cd(G) = graph G degree centralization

Centrality

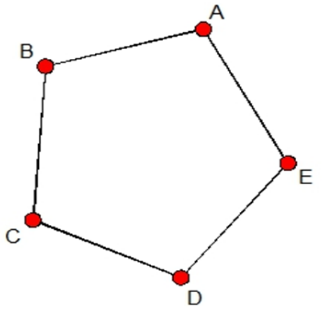
- **Local measure:** characterizes position of a particular node within a network.
- Different measures for different network classes! (e.g. bipartite networks, directed or weighted ties).
- Simplest case: undirected binary network.
- Different types of centralities:
  – Degree centrality
  – Closeness centrality
  – Betweenness centrality

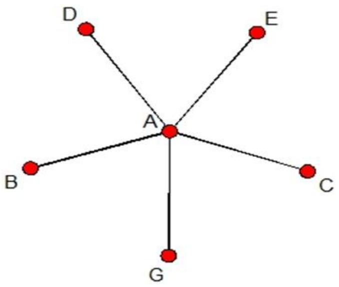
Centralization

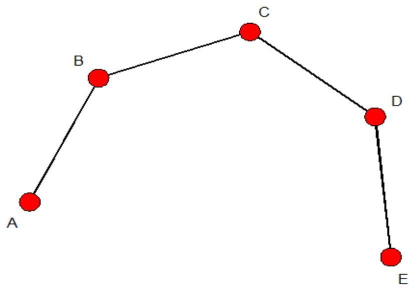
- **Global measure:** characterizes extent to which a certain local feature prevails in a network.
- **Centralization** is measured as a difference of all centrality values from the highest centrality value.
- Again, we need to consider the network class.
- Analogically, there are different types of centralizations.
- **centralization =/= centrality**

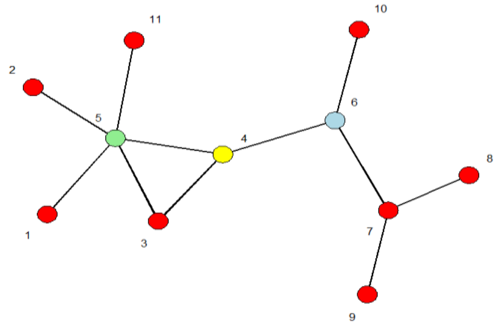
Degree centrality

- Nodes with most connections.
- **Theoretical importance:**
  - Most powerful actors in network.
  - Indication of prestige (in-degree centrality).
  - Indication of influence (out-degree centrality).
  - *Depends on tie conceptualization*.
  - *Limited only to adjacent nodes (neighborhood)*!









Degree centrality

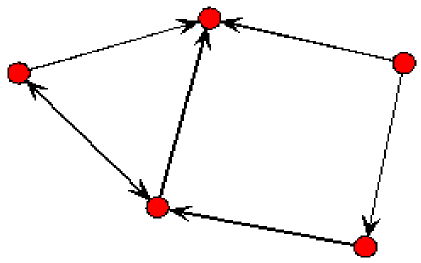
- **Undirected graph:** # of connections of a node.

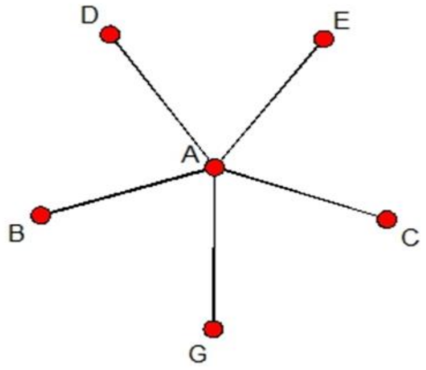
$$c_D(n_i) = d(n_i)$$

- **Standardization:** division by # of all possible connections (# of all nodes - 1).

$$c_D'(n_i) = d(n_i) / (N - 1)$$

- **Directed graph:** # of connections from/to a node.
  - In-degree centrality
  - Out-degree centrality





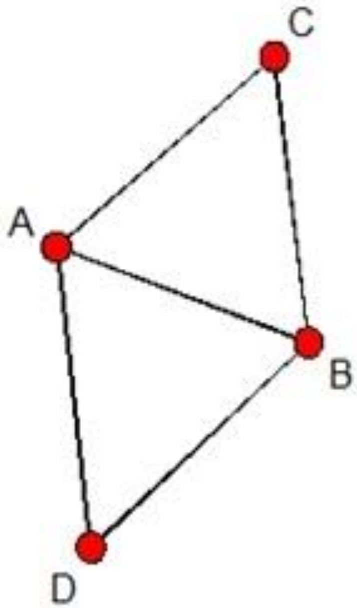
Degree centrality

$c_D(n_i) = d(n_i)$

$c_D(n_A) = d(n_A) = 3$

$c_D'(n_i) = d(n_i) / (N - 1)$

$c_D'(n_A) = 3 / 3 = 1$



Degree centralization

1. # of connections of each node (degree centrality).
2. Differences of centralities from the highest centrality value.
3. Summation of differences.

$$C_D(G) = \sum (c_D(n_{MAX}) - c_D(n_i))$$

4. Standardization: division by (N – 1) * (N- 2)

$$C_D'(G) = \sum (c_D(n_{MAX}) - c_D(n_i)) / (N - 1) * (N - 2)$$

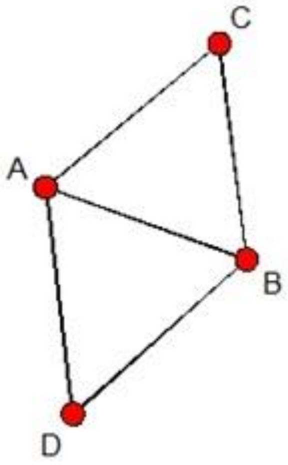
Degree centralization

$C_D(G) = \sum (c_D(n_{MAX}) - c_D(n_i))$

$C_D(G) = (0 + 0 + 1 + 1) = 2$

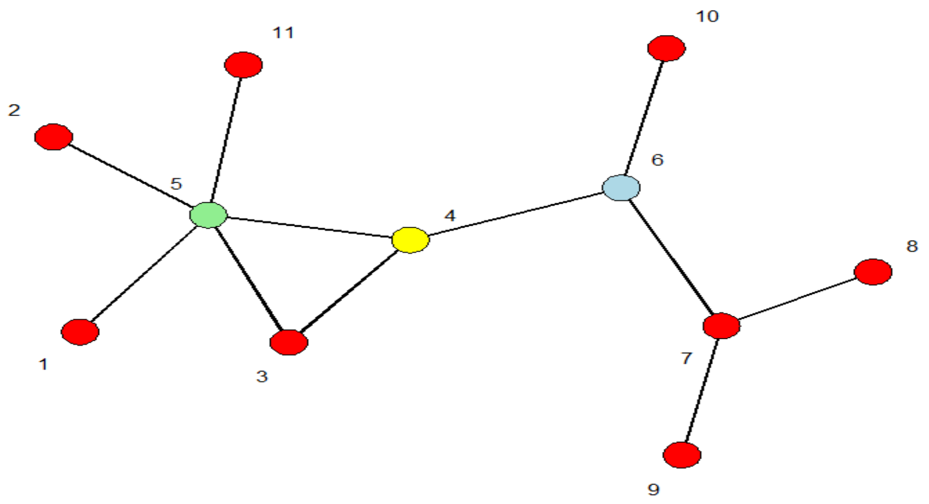
$C_D'(G) = \sum (c_D(n_{MAX}) - c_D(n_i)) / (N - 1) * (N - 2)$

$C_D'(G) = 2 / (4 - 1) * (4 - 2) = 2 / 6 = 0.33$



Closeness centrality

- Nodes with shortest average path length.
- Node is closer to more actors than any other node.
- **Theoretical importance:**
  - Shorter path lengths = quicker and more efficient access to sources.



Closeness centrality

- **Distance:** ∑ geodesics of a node to all other nodes.
- **Closeness:** inverse concept → 1 / distance:

$$c_C(n_i) = 1 / \sum g(n_{i,} n_j) \;\mathbf{=}\; c_C(n_i) = [\; \sum g(n_{i,} n_j) \;]^{-1}$$

- Standardization: multiplication by # of nodes - 1.

$$c_C{}'(n_i) = [\; \sum g(n_{i,} n_j) * (N - 1) \;]^{-1}$$

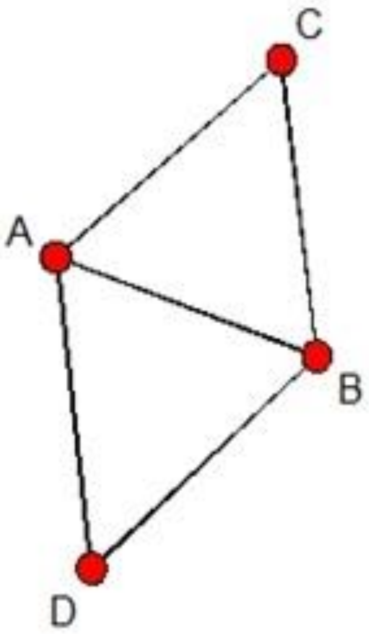
Closeness centrality

$c_C(n_i) = [\ \sum g(n_i, n_j)\ ]^{-1}$

$c_C(n_A) = [\ (1 + 1 + 1)\ ]^{-1} = 0.33$

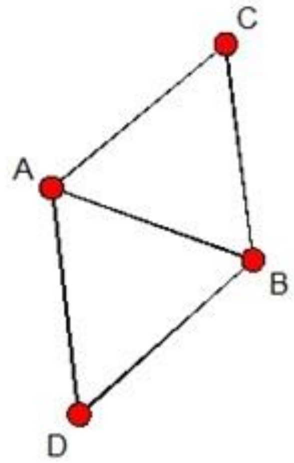
$c_C{'}(n_i) = [\ \sum g(n_i, n_j) * (N - 1)\ ]^{-1}$

$c_C{'}(n_A) = 0.33 * (4 - 1) = 1$



Closeness centralization

1. **Standardized** closeness centrality values for each node.
2. Differences of centralities from the highest centrality value.
3. Summation of differences.



$$C_C'(G) = \sum (c_C'(n_{MAX}) - c_C'(n_i))$$

4. Standardization: (N – 1) * (N- 2) / (2N – 3)

$$C_C'(G) = \sum (c_C'(n_{MAX}) - c_C'(n_i)) / [\,(N - 1) * (N - 2) / (2N - 3)\,]$$

Closeness centralization

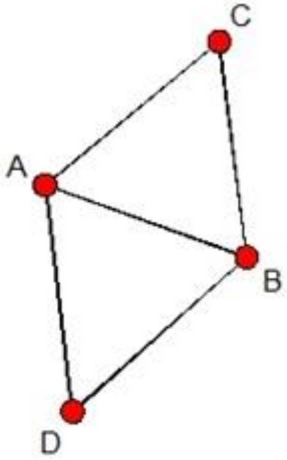
$$C_C'(G) = \sum (c_C'(n_{MAX}) - c_C'(n_i))$$

$$C_C'(G) = \sum (1 - 1) + (1 - 1) + (1 - 0.75) + (1 - 0.75)$$

$$C_C'(G) = \sum (c_C'(n_{MAX}) - c_C'(n_i)) / [(N - 1) * (N - 2) / (2N - 3)]$$

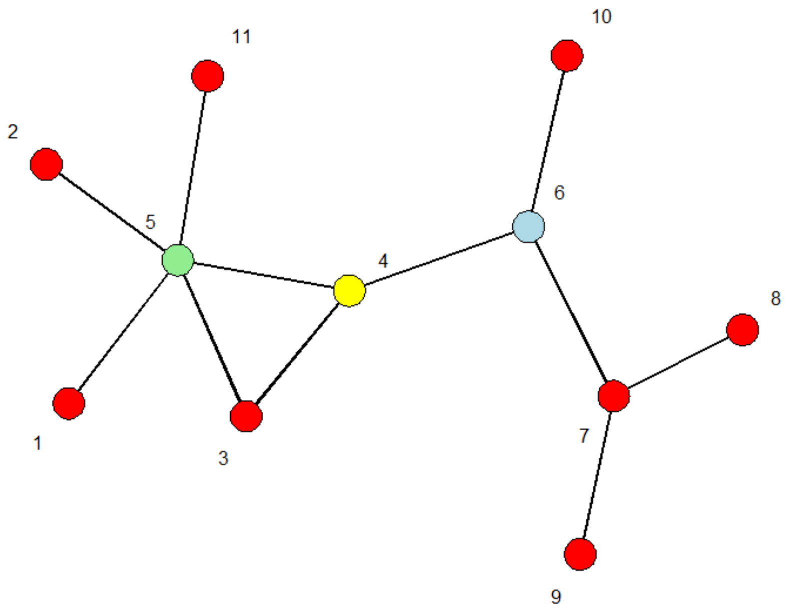
$$C_C'(G) = \sum (1 - 1) + (1 - 1) + (1 - 0.75) + (1 - 0.75) / [(4 - 1) * (4 - 2) / (8 - 3)]$$

$$C_C'(G) = 0.5 / (12 / 5) = 0.5 / 1.2 = 0.42$$



Betweenness centrality

- Nodes which are most in-between other nodes.
- **Theoretical importance:**
  - Crucial for flow control (gatekeepers, brokers).
  - Bridges to otherwise weakly connected parts of network (access to sources).



Betweenness centrality

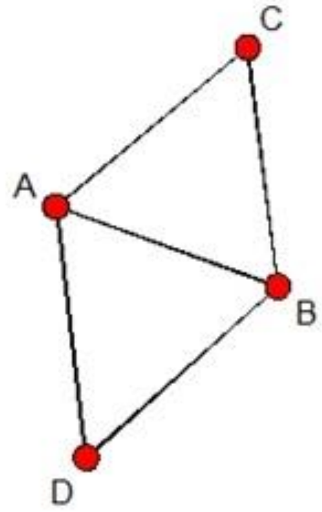
- **Betweenness:** ratio of geodesics upon which a node lies to all geodesics in network.

$$c_B(n_i) = \sum g_{jk}(n_i) / g_{jk}$$

- Standardization: division by # of all possible geodesics upon which node can lie.

$$c_B{}'(n_i) = [\, \sum g_{jk}(n_i) / g_{jk} \,] / [(N - 1) * (N - 2) / 2 \,]$$

Betweenness centrality



$c_B(n_i) = \sum g_{jk}(n_i) / g_{jk}$

$c_B(n_A) = 0.5 / 3 = 0.17$

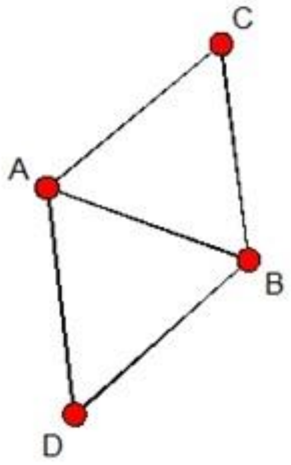
$c_B'(n_i) = [\sum g_{jk}(n_i) / g_{jk}] / [(N - 1) * (N - 2) / 2]$

$c_B'(n_A) = 0.17 / [((4 - 1) * (4 - 2)) / 2] = 0.17 / 3 = 0.06$

Betweenness centralization

1. Betweenness centrality values for each node.
2. Differences of centralities from the highest centrality value.
3. Summation of differences.

$$C_B{}'(G) = \sum (c_B(n_{MAX}) - c_B(n_i))$$



4. Standardization: (N – 1)^2 * (N- 2) / 2

$$C_B{}'(G) = \sum (c_B(n_{MAX}) - c_B(n_i)) \,/\, [\ (N-1)^2 * (N-2) / 2\ ]$$

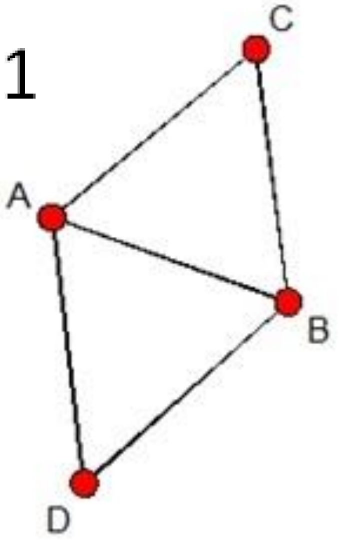
Betweenness centralization

$C_B{'}(G) = \sum (c_B(n_{MAX}) - c_B(n_i))$

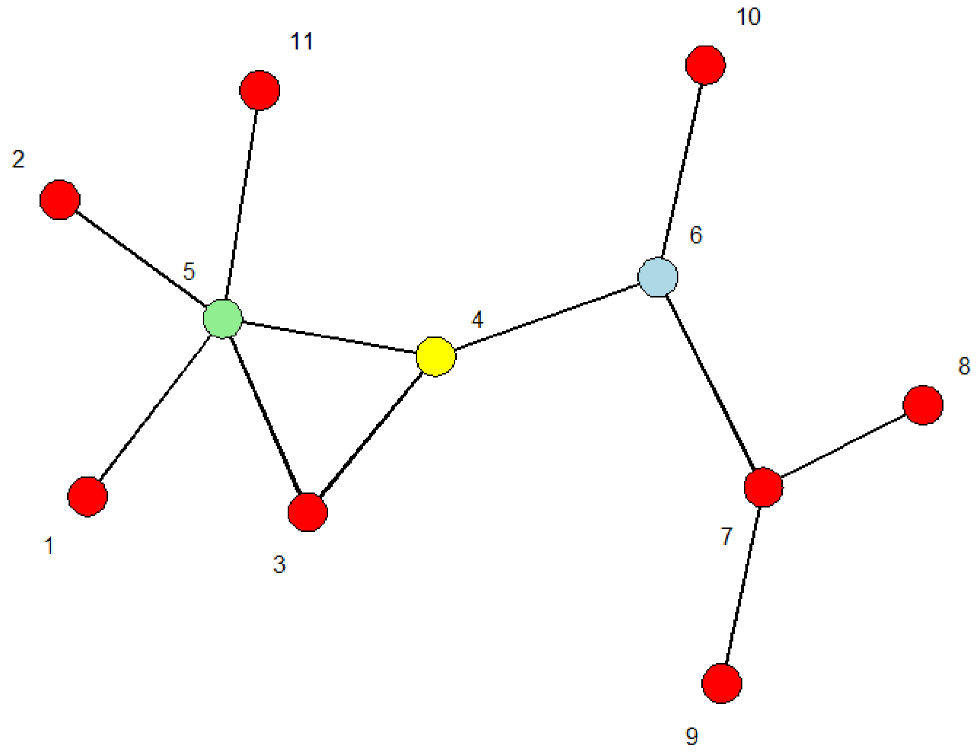
$C_B(G) = \sum (0.5 - 0.5) + (0.5 - 0.5) + (0.5 - 0) + (0.5 - 0) = 1$

$C_B{'}(G) = \sum (c_B(n_{MAX}) - c_B(n_i)) / [(N - 1)^2 * (N - 2) / 2]$

$C_B(G){'} = 1 / [(4 - 1)^2 * (4 - 2) / 2] = 1 / 9 = 0.11$

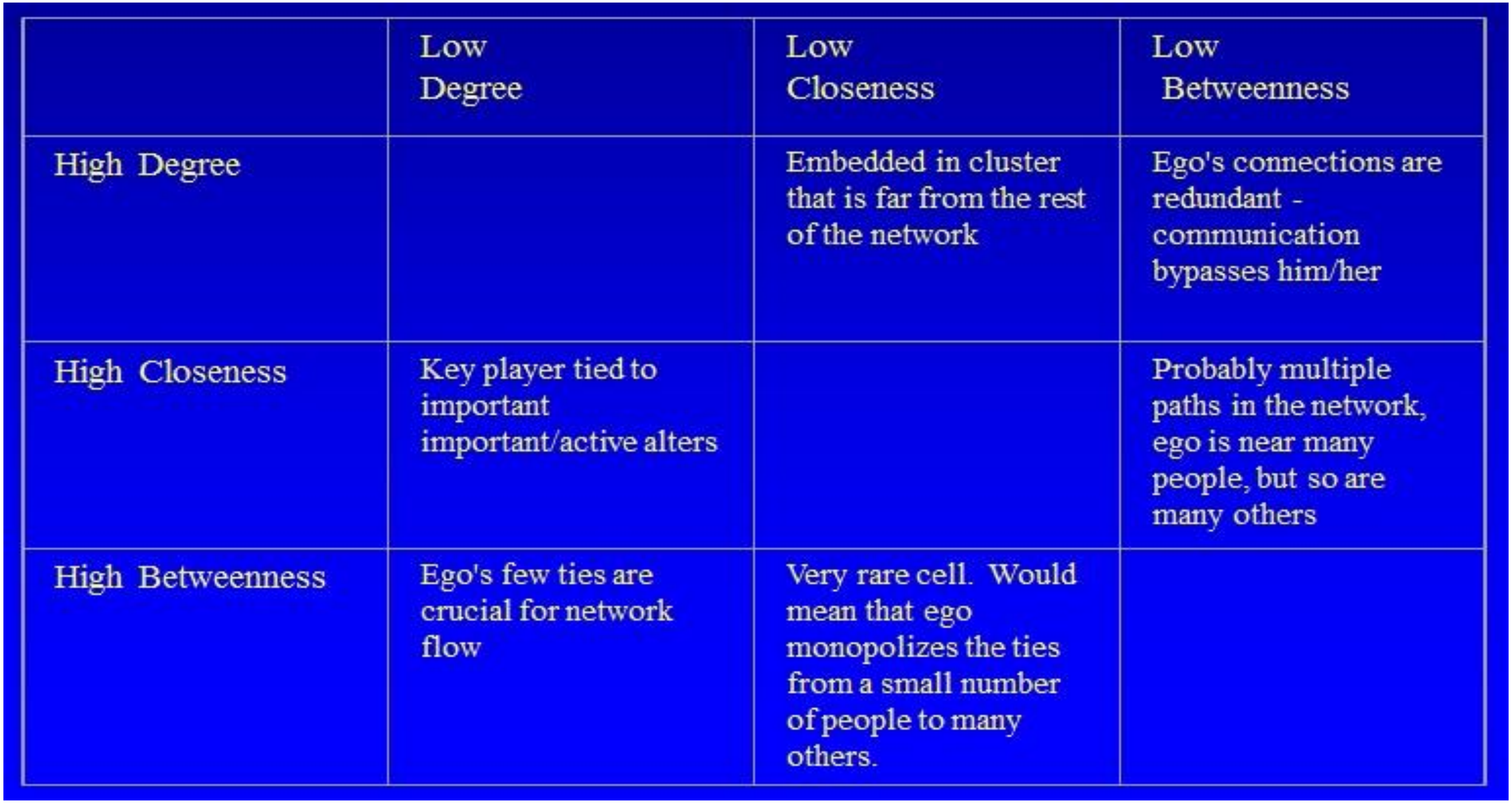


Degree vs. closeness vs. betweenness



	1	2	3	4	5	6	7	8	9	10	11
degree	1	1	2	3	5	3	3	1	1	1	1
closeness	0.33	0.33	0.42	0.53	0.48	0.5	0.4	0.29	0.29	0.34	0.33
betweenness	0	0	0	50	48	54	34	0	0	0	0

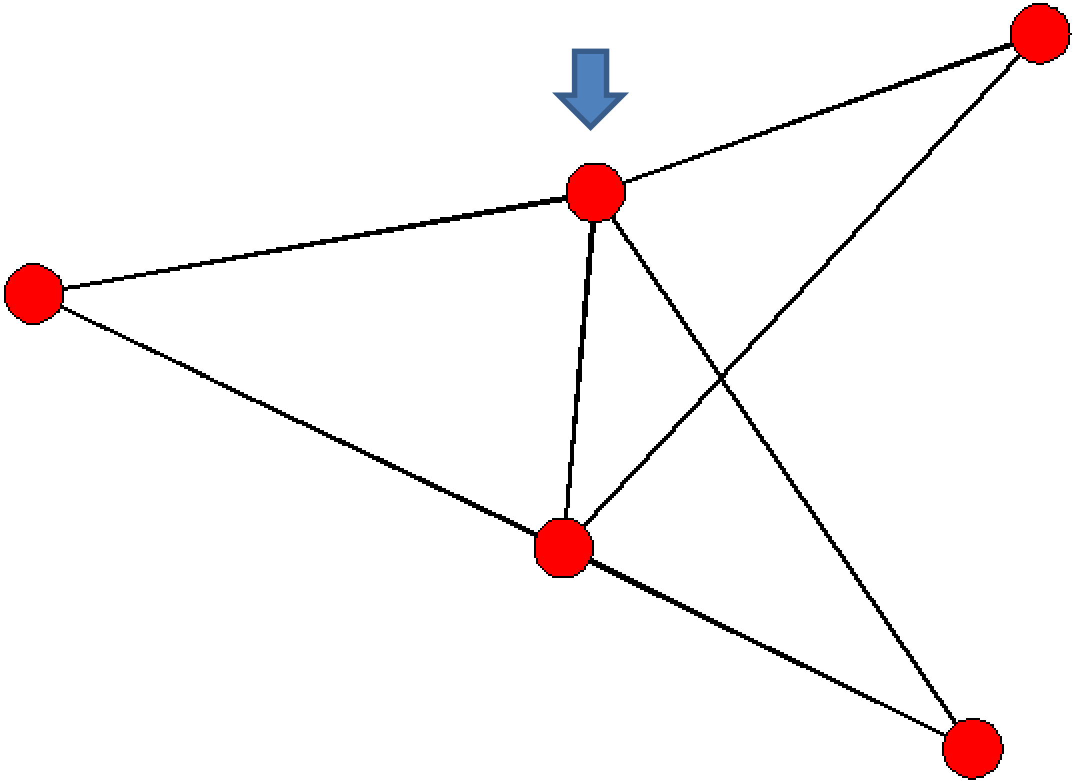
Centrality classification (Moody)



	Low Degree	Low Closeness	Low Betweenness
High Degree		Embedded in cluster that is far from the rest of the network	Ego's connections are redundant - communication bypasses him/her
High Closeness	Key player tied to important important/active alters		Probably multiple paths in the network, ego is near many people, but so are many others
High Betweenness	Ego's few ties are crucial for network flow	Very rare cell. Would mean that ego monopolizes the ties from a small number of people to many others.	

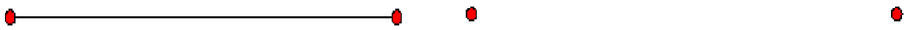
Exercise

- Calculate degree and closeness centrality of a given node. What is degree centralization?

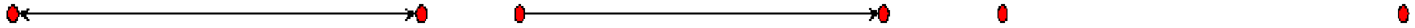


Dyads

- Dyad: a most basic relational unit.
- 2 dyads for undirected graphs:



- **Isomorphism:** structural interchangeability of nodes, edges or their configurations.
- 3 isomorphic dyads for directed graphs.
- **MAN: M:** mutual, **A:** asymmetric, **N:** null:



Reciprocity (Wasserman & Faust 2009)

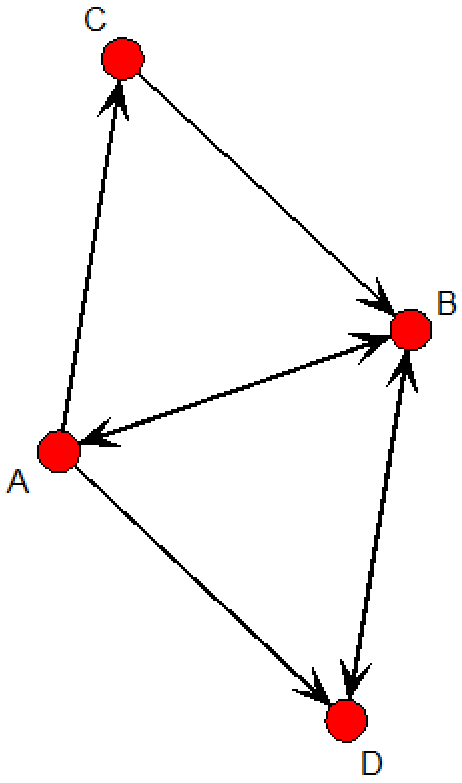
- **Reciprocity:** there is a bidirectional (mutual) tie between two nodes.

- Reciprocity in graph is given as a ratio of reciprocal (**m**utual) dyads to total number of connections (mutual + **a**symmetrical dyads).

$$R(G) = 2M / (2M + A)$$

Reciprocity

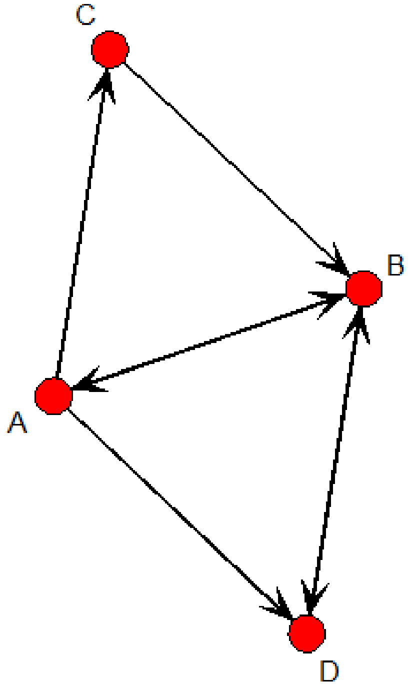
$R(G) = 2M / (2M + A)$



Reciprocity

$$R(G) = 2M / (2M + A)$$

$$R(G) = 2*2 / (2*2 + 3) = 4 / 7 = 0.57$$



- R default

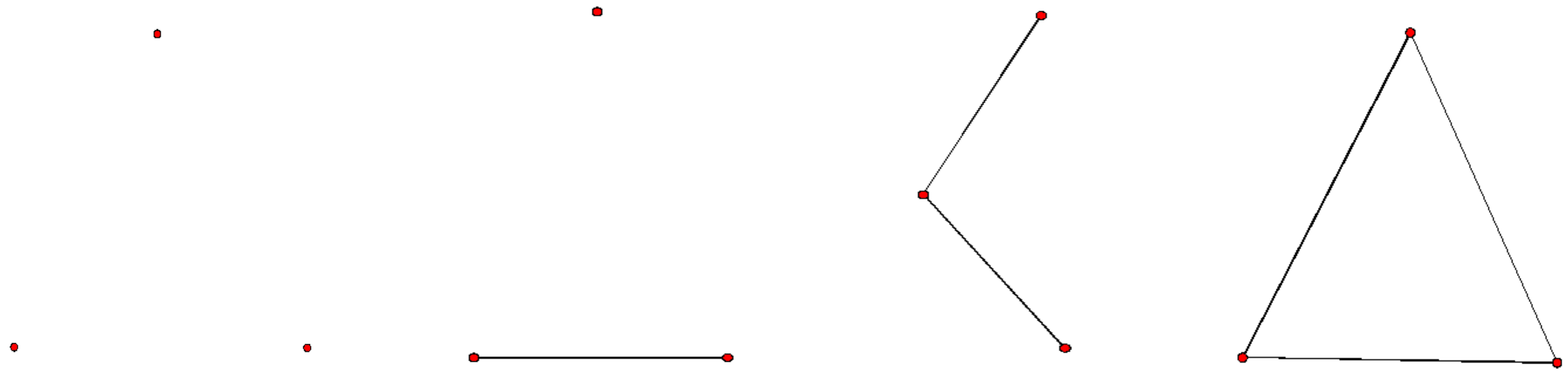
$$R(G) = M / (M + A + N) = (1 + 1) / ((1 + 1) + (1 + 1 + 1) + 1)) = 2 / 6 = 0.33$$

- R dyadic.nonnul

$$R(G) = M / (M + A) = (1 + 1) / ((1 + 1) + (1 + 1 + 1)) = 2 / 5 = 0.4$$

Triplets and triads in undirected graph

- Triad as **a basic unit of social organization**.
- triplet = empty triad
- In undirected graph: 2^3 = 8 combinations of triads with preserved identity (anisomorphic).
- 4 isomorphic triads:



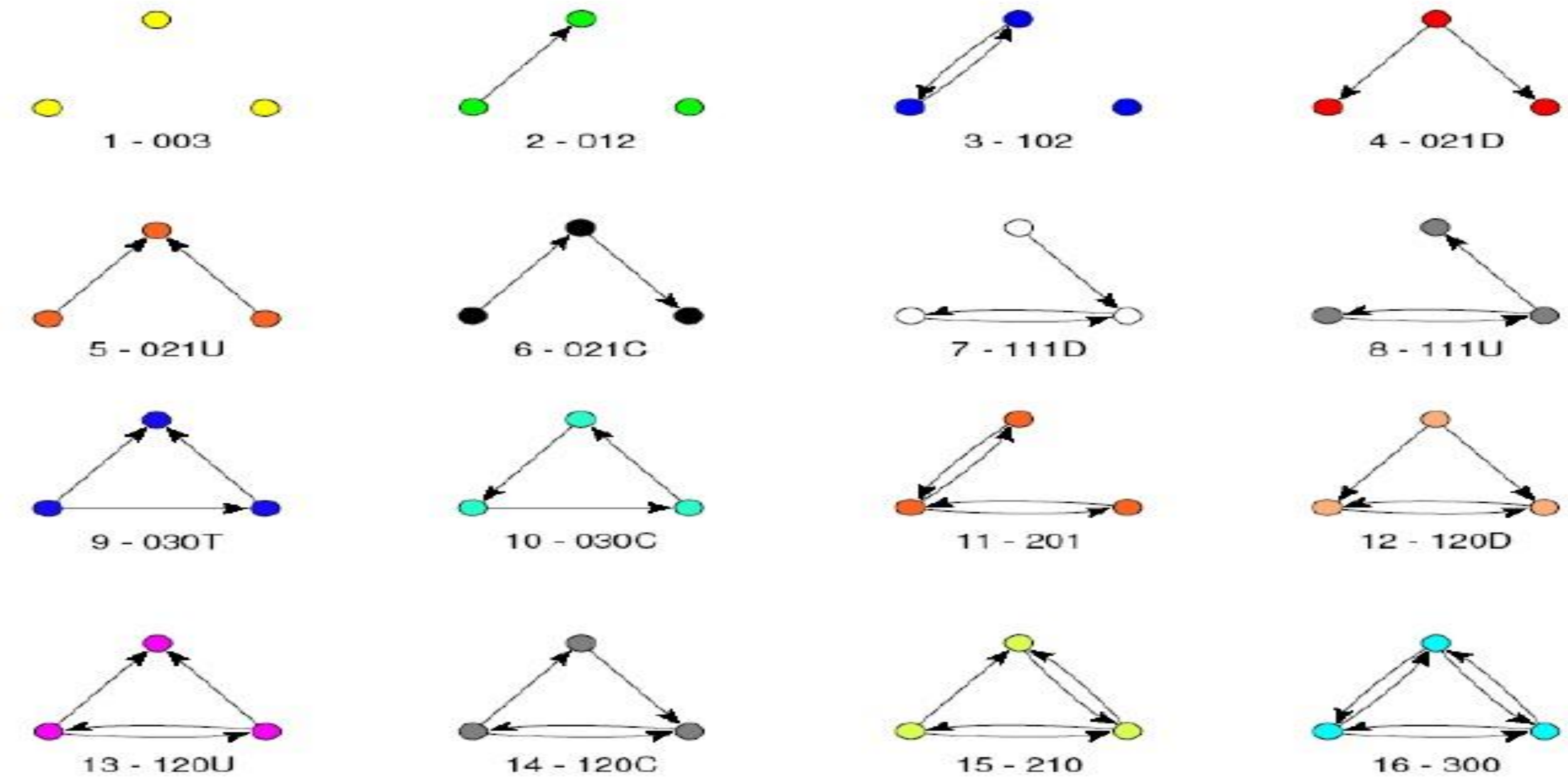
Triplets and triads in directed graph

- There is a 6 combinations of triplets: (a, b, c); (a, c, b); (b, a, c); (b, c, a); (c, a, b); (c, b, a).
- Thus: 2^6 = 64 combinations of anisomorphic triads.
- If we neglect node identities, we get 2^4 = **16 isomorphic triads = triadic census**.
- # of isomorphic triads in directed graph is given by:

$$\sum T_u = N! / (k! * (N - k)!)$$

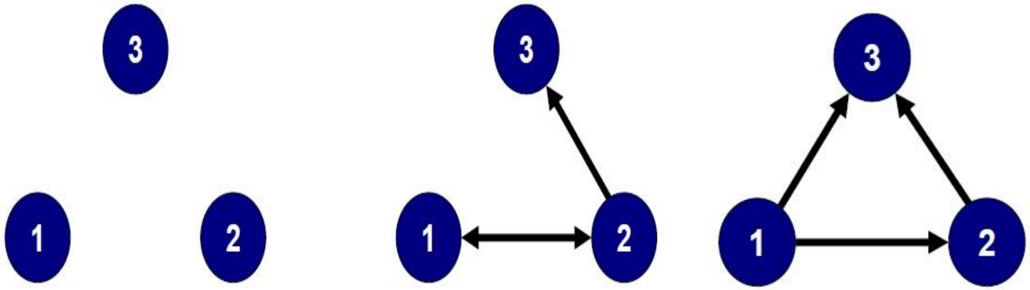
Triadic census

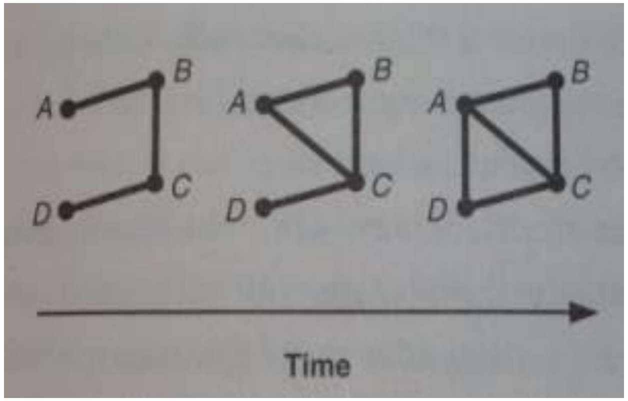
- MAN (**M**utual-**A**symmetric-**N**ull), tie direction (**U**p/**D**own), transitivity (**T**) vs. cycle (**C**)



Transitivity

- Transitivity: *a friend of my friend is my friend*.
- Triadic closure:



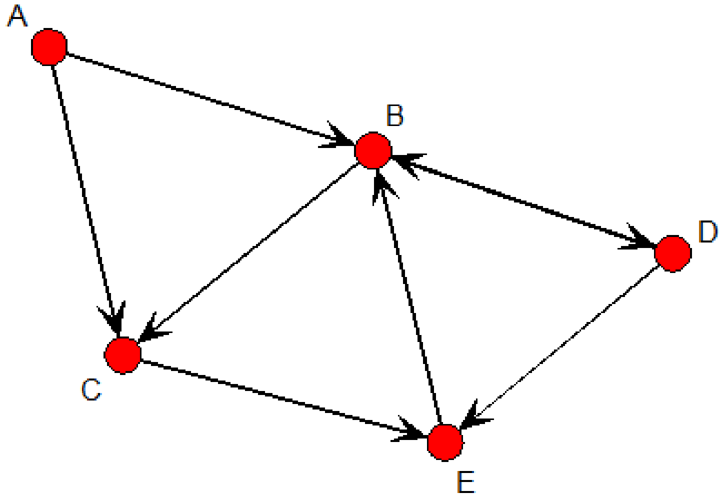


Thurner 2012

- **Measure:** # of transitive triads over # of all triads. $T(G) = \sum_{ijk} e_{ij}, e_{jk}, e_{ik} / (N! / (k! * (N - k)!)$

Transitivity

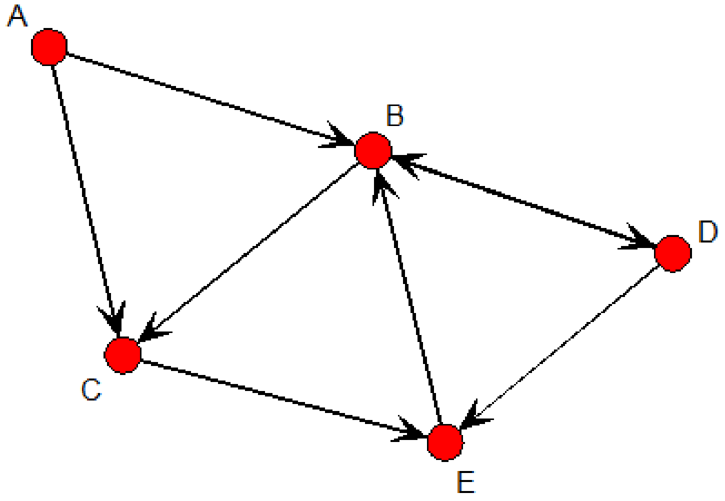
$T(G) = \sum_{ijk} e_{ij}, e_{jk,} e_{ik} / (N! / (k! * (N - k)!))$



Transitivity

$$T(G) = \sum_{ijk} e_{ij}, e_{jk,} e_{ik} / (N! / (k! * (N - k)!))$$

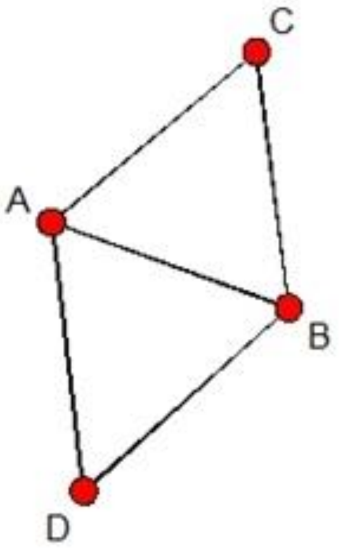
$$T(G) = 1 / (120 / 6 * 2) = 1 / 10 = 0.1$$



Local clustering coefficient

- Measures level of a given node’s neighborhood’s interconnectedness.
- Measure: # of interconnections of adjacent nodes over # of all possible interconnections of adjacent nodes.

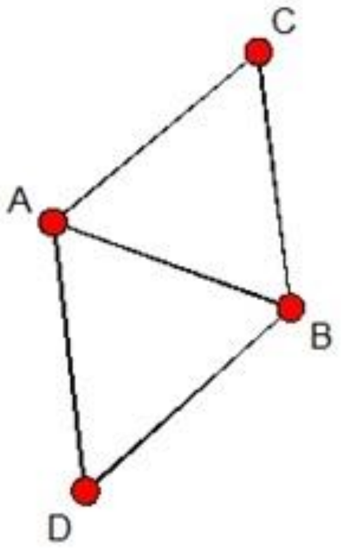
$$cc_i = e_{jk} / (n_{jk} * (n_{jk} - 1) / 2)$$



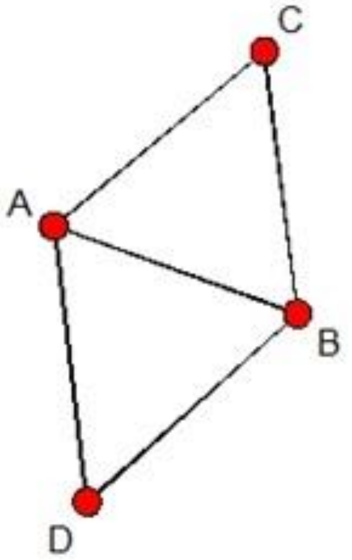
Local clustering coefficient

$cc_i = e_{jk} / (n_{jk} * (n_{jk} – 1) / 2)$

$cc_A = 2 / ((3 * 2)/2) = 2 / 3 = 0.67$



Clustering coefficient



- Global measures:
- (1) **global cluster coefficient (GCC):**
  - – # of closed triads / # all connected triads
- (2) **average cluster coefficient (ACC):**
  - – Arithmetic mean of local cluster coefficient values.

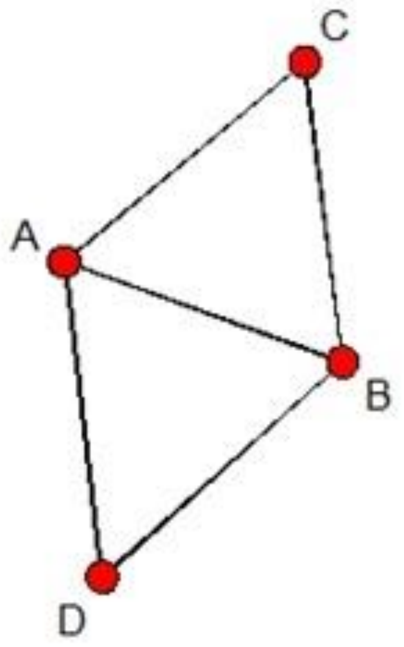
$ACC(G) = \sum cc_i / N$

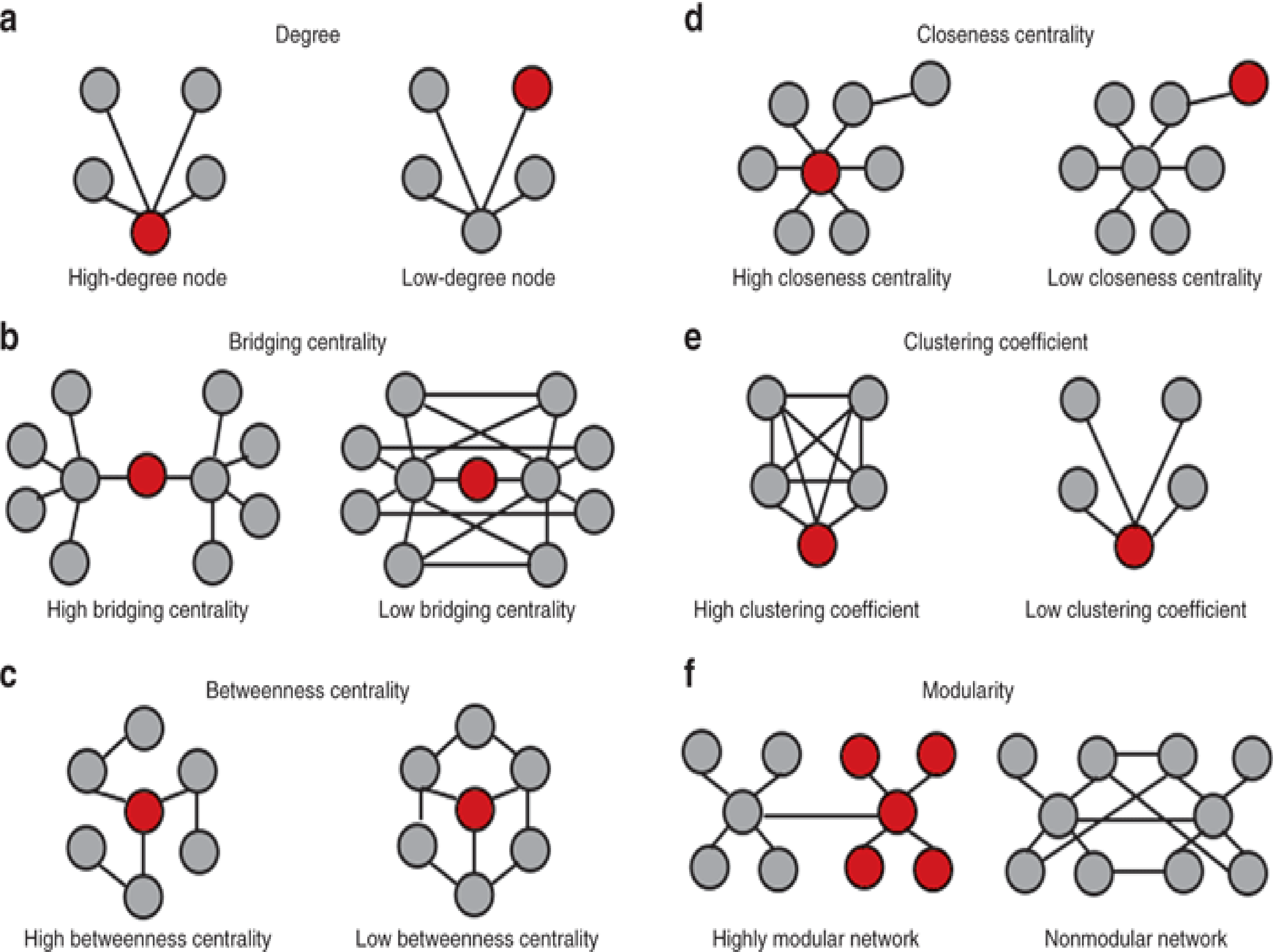
Clustering coefficient

$ACC(G) = \sum cc_i / N$

$ACC(G) = \sum(0.67 + 0.67 + 1 + 1) / 4 = 3.34 / 4 = 0.835$

$GCC(G) = 2 / 4 = 0.5$




a
Degree
High-degree node
Low-degree node
d
Closeness centrality
High closeness centrality
Low closeness centrality
b
Bridging centrality
High bridging centrality
Low bridging centrality
e
Clustering coefficient
High clustering coefficient
Low clustering coefficient
c
Betweenness centrality
High betweenness centrality
Low betweenness centrality
f
Modularity
Highly modular network
Nonmodular network

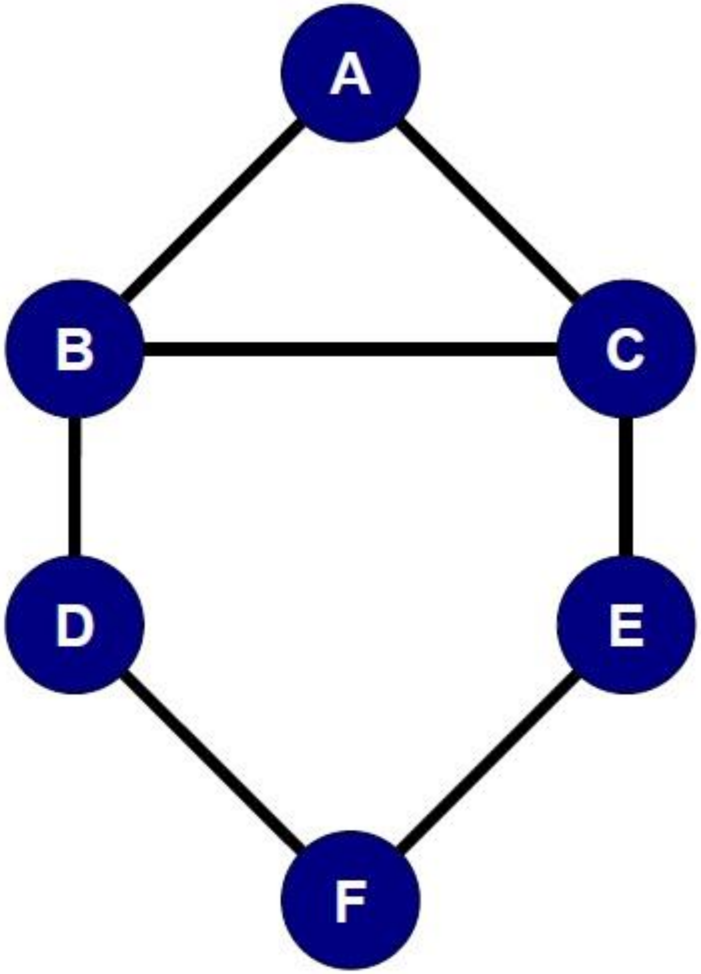
Segments

- SNA toolkit allows to describe larger parts of the graph than triads.
- The most used concepts for network segmentation measurement:
  - cliques / n-cliques
  - k-cores
  - … and many others

Cliques and n-cliques

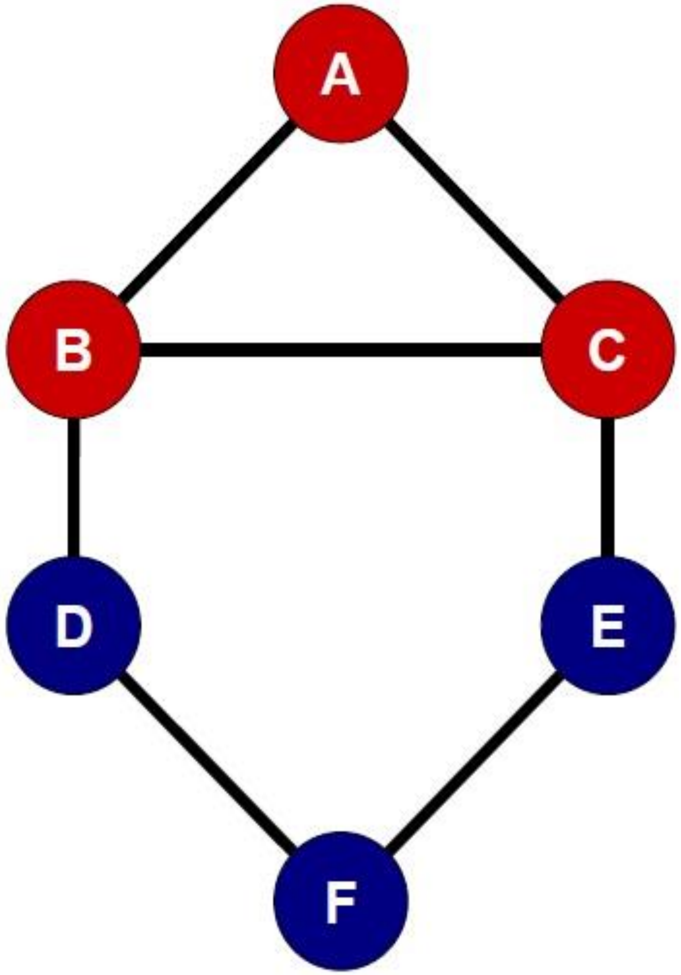
- **Clique** is a **maximal complete subgraph** that consists from three and more nodes.
- → each member of the clique has to be connected to all other members of the clique.
- Strong assumption → **n-clique**.
- N-clique is a maximal subgraph where **longest geodesic** between any two members is not greater than **n**.
- Thus in 2-clique every members is connected to all other members in 1 or 2 steps.

Cliques and n-cliques



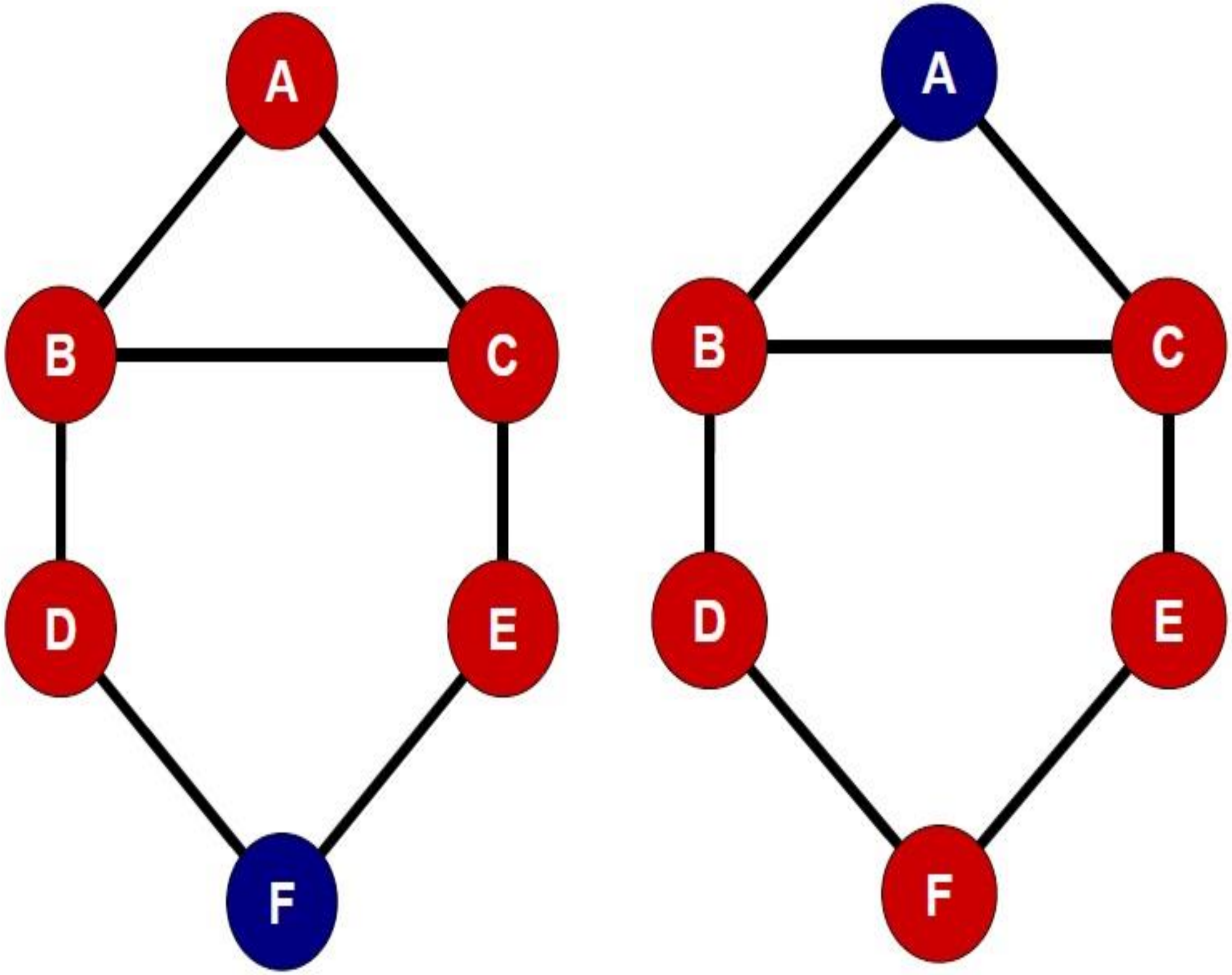
Thurner 2012

Cliques and n-cliques



Thurner 2012

Cliques and n-cliques



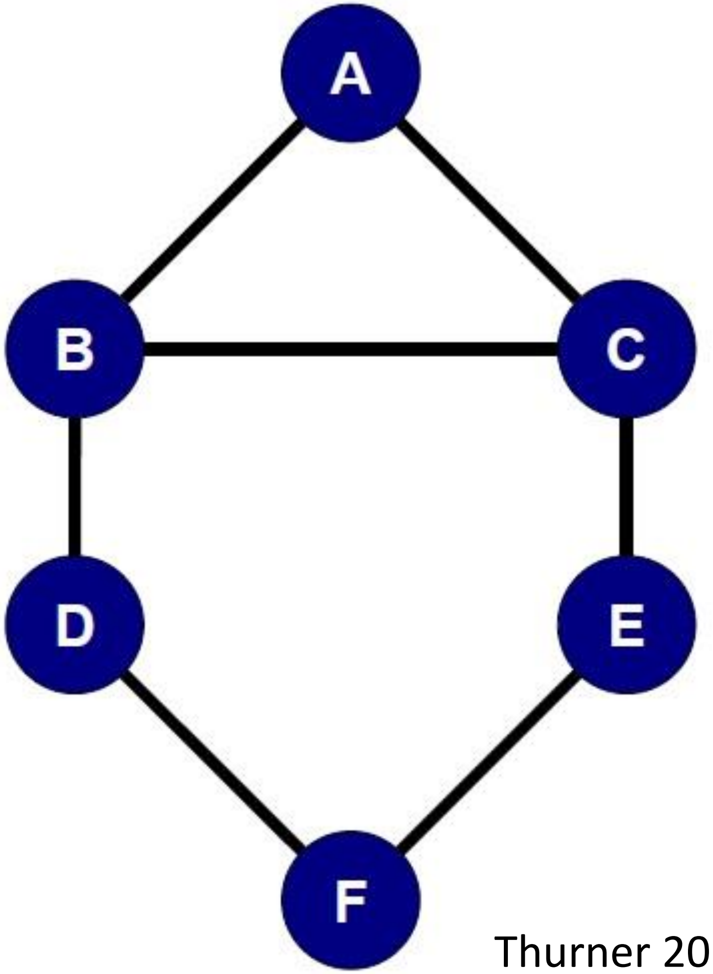
Thurner 2012

K-core

- **K-core** is maximal subgraph where all nodes are connected with specific (*k*) minimal # of nodes in the subgraph.
- Thus: ***k* indicates how many connections each member of the subgraph has to have.**
- Therefore: it is not important how many connections to other members is missing.

K-core

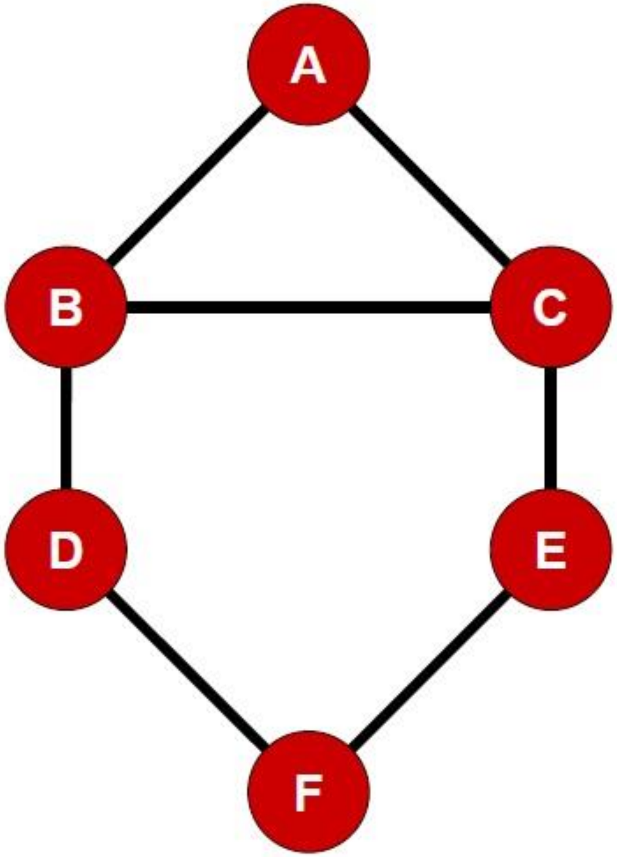
- Find 2-core and 3-core

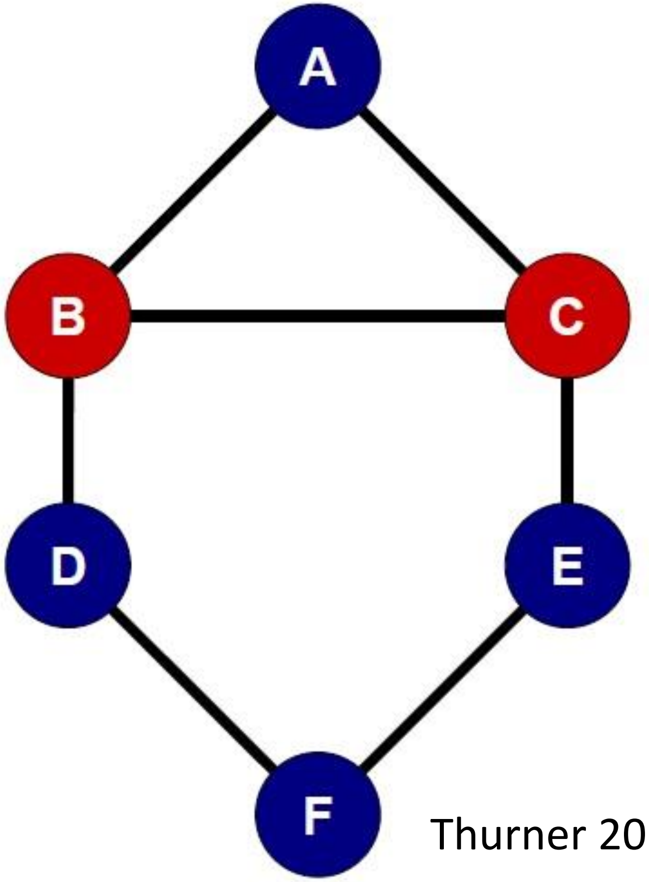


Thurner 2012

K-core

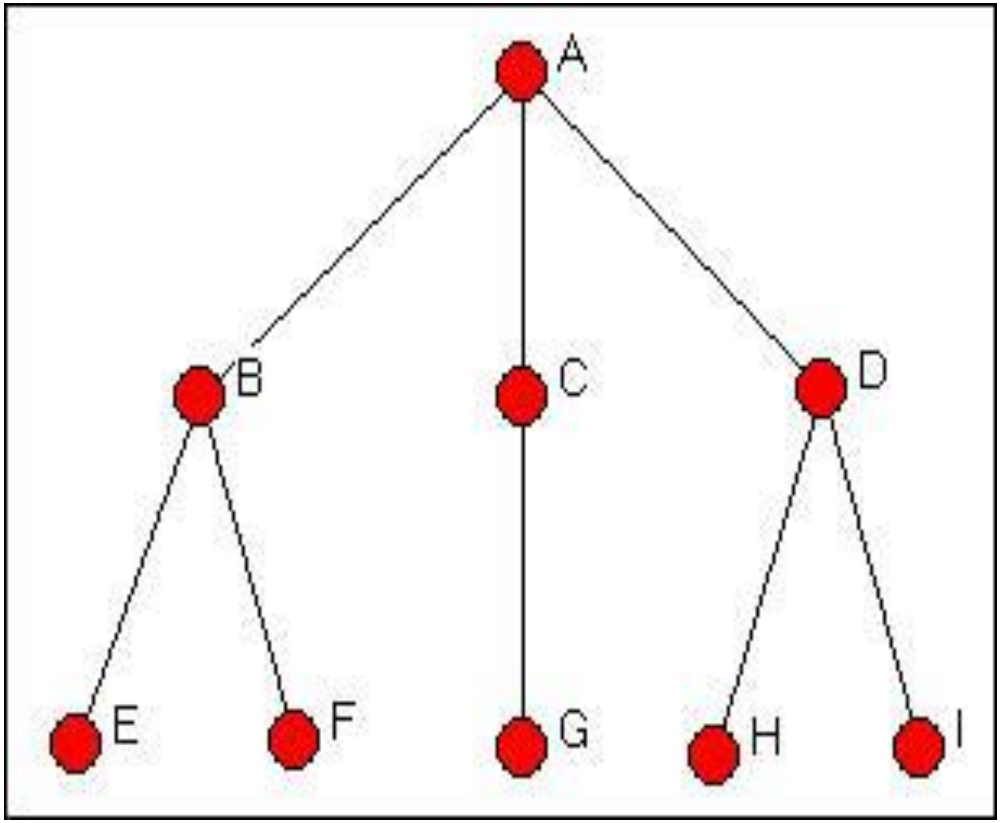
- Find 2-core and 3-core:





Thurner 2012

Structural equivalence



Hanneman & Riddle 2005

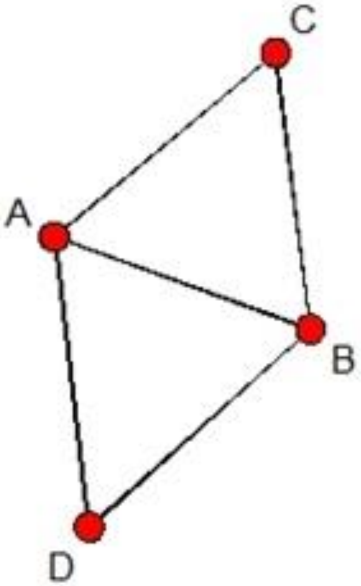
Structural equivalence

- **Social position:** similar ties to other nodes.
  - E.g. Ph.D. students at our department have similar ties to others (under/graduates, department members, supervisors, etc.) as Ph.D. students at other departments.
- **Social role:** pattern of ties to other positions.
  - E.g. professional ties with department members, competitive ties with other Ph.D., friendship ties with other students, etc.

Euclidean distance

- **Euclidean distance (ED):** is a distance of nodes i and j in relation to all other nodes in graph.
- ED of structurally equivalent nodes = 0.
- It is possible to classify nodes based on their ED.

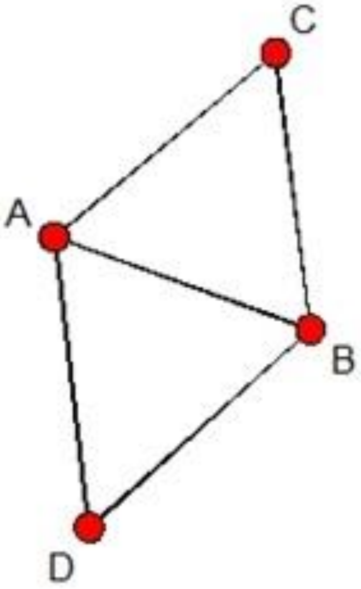
$$d_{ij} = \mathrm{sqrt}[\ \sum\sum\ [\ (n_{ik} - n_{jk})^2 + (n_{ki} - n_{kj})^2\ ]\ ]$$



Euclidean distance

- **(1):** differences of distances of i and j to all other nodes.
- **(2):** sum of squares of the differences (SSD).
- **(3):** square root of the result (SSD).

$$d_{ij} = \mathrm{sqrt}[\ \sum\sum\ [\ (n_{ik} - n_{jk})^2 + (n_{ki} - n_{kj})^2\ ]\ ]$$



Euclidean distance

$d_{ij} = \text{sqrt}[\ \sum\sum\ [\ (n_{ik} – n_{jk})^2 + (n_{ki} – n_{kj})^2\ ]\ ]$

$d_{ac} = \text{sqrt}[\ \sum\sum\ [\ (n_{ak} – n_{ck})^2 + (n_{ka} – n_{kc})^2\ ]\ ]$; $k = \{b, d\}$

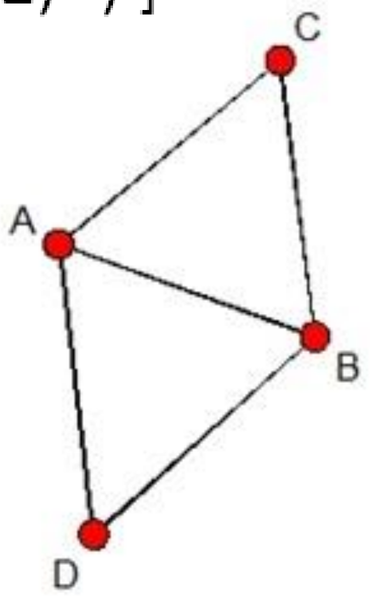
$d_{ac} = \text{sqrt}[\ (\ (ab – cb)^2 + (ba – bc)^2\ ) + (\ (ad – cd)^2 + (da – dc)^2\ )\ ]$

$d_{ac} = \text{sqrt}[\ (\ (1 – 1)^2 + (1 – 1)^2\ ) + (\ (1 – 2)^2 + (1 – 2)^2\ )\ ]$

$d_{ac} = \text{sqrt}(0 + 0 + 1 + 1) = \text{sqrt}(2) = 1.41$

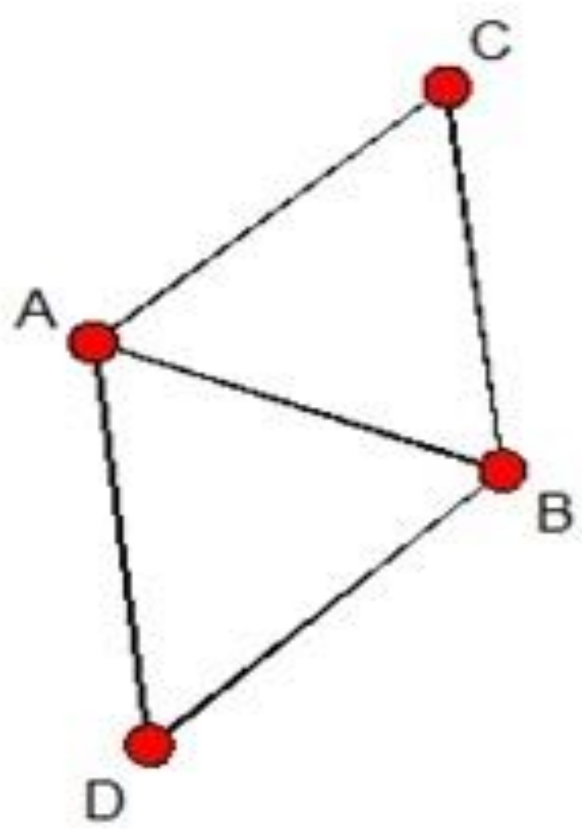
0	1	1	1
1	0	1	1
1	1	0	0
1	1	0	0

0	0	1.41	1.41
0	0	1.41	1.41
1.41	1.41	0	0
1.41	1.41	0	0



0	1	1	1
1	0	1	1
1	1	0	0
1	1	0	0

0	0	1.41	1.41
0	0	1.41	1.41
1.41	1.41	0	0
1.41	1.41	0	0



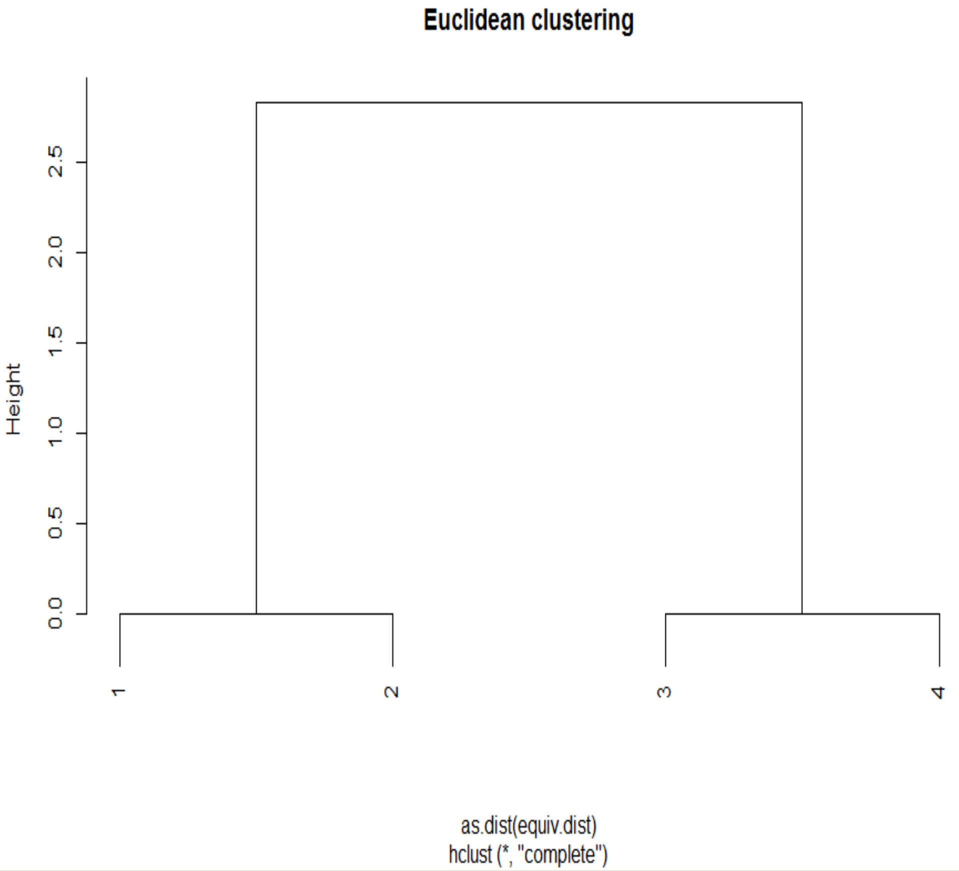


Illustration: energy interdependence

- **Research objective:**
  - Mapping energy interdependence relations at the European natural gas market (exploratory objective).
- **Research question:**
  - What is the level of energy interdependence at the European market?
- **Research importance:**
  - Collection of data and exploration.
  - Necessary step for explanatory research (liberal peace hypotheses).

Network border delineation

- positional strategy of border delineation:
  - European NG consumers and their suppliers.
- sample ~ population :
  - EU28 + Norway, FYROM, Ukraine, Belarus, Turkey and its suppliers.

Conceptualization / operationalization

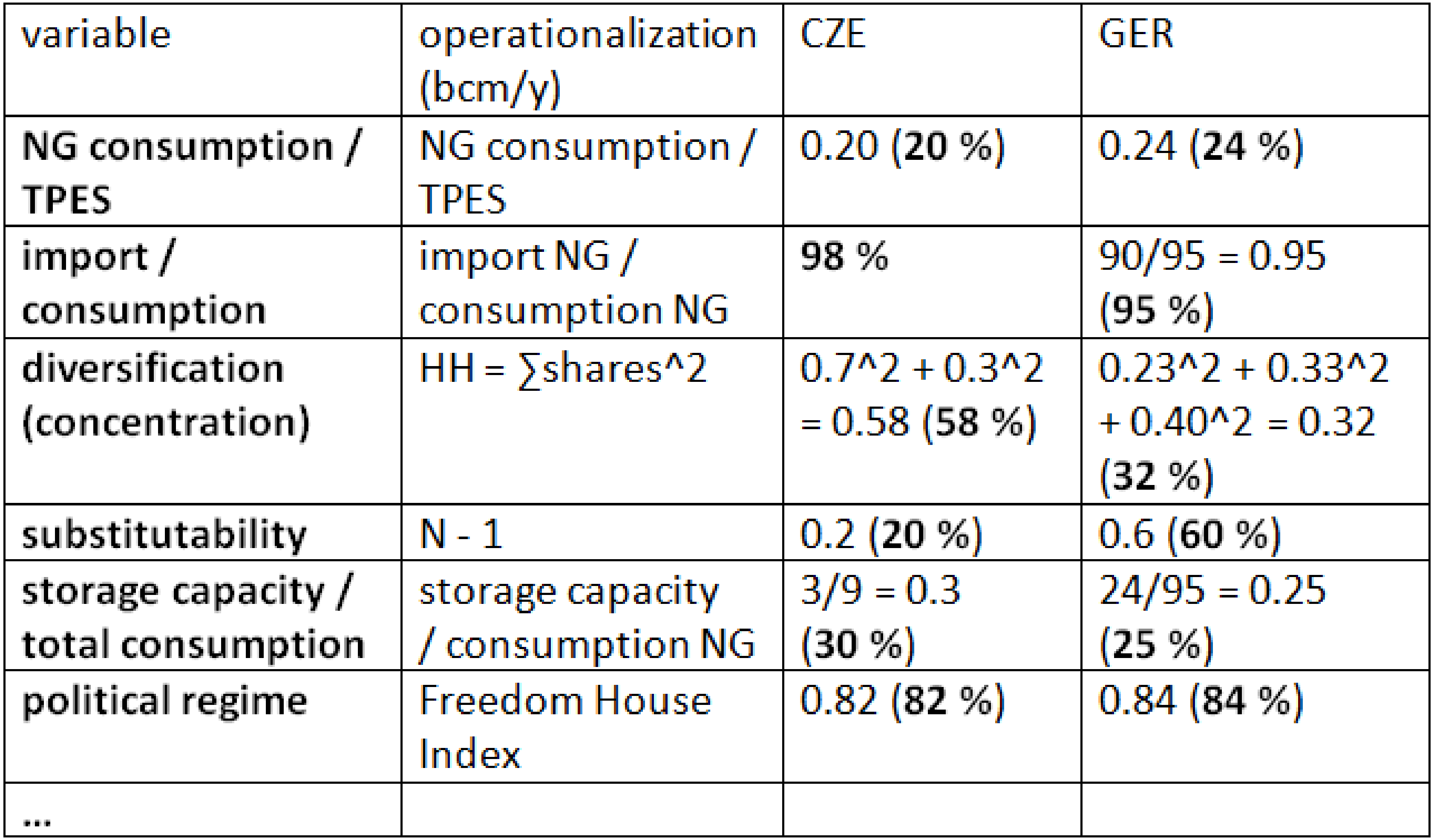
- Operationalization (Barbieri 1996):
  - Interdependence has two dimensions: saliency and symmetry.
  - **Trade share (TS):** bilateral trade flow over total trade flow
    - TS = tradeAB/tradeAW ; tradeBA/tradeBW
  - **Saliency (S):** trade shares product of A and B
    - S = sqrt(tradeAB/tradeAW * tradeBA/tradeBW)
  - **Symmetry (Y):** difference of trade shares of A and B
    - Y = 1 – abs(tradeAB/tradeAW – tradeBA/tradeBW)
  - **Interdependence (I):**
    - **I = sqrt(V * S)**
- Attribute variables:
  - exporter / importer
  - Composite Index of National Capability (CINC)

Interdependence: calculation

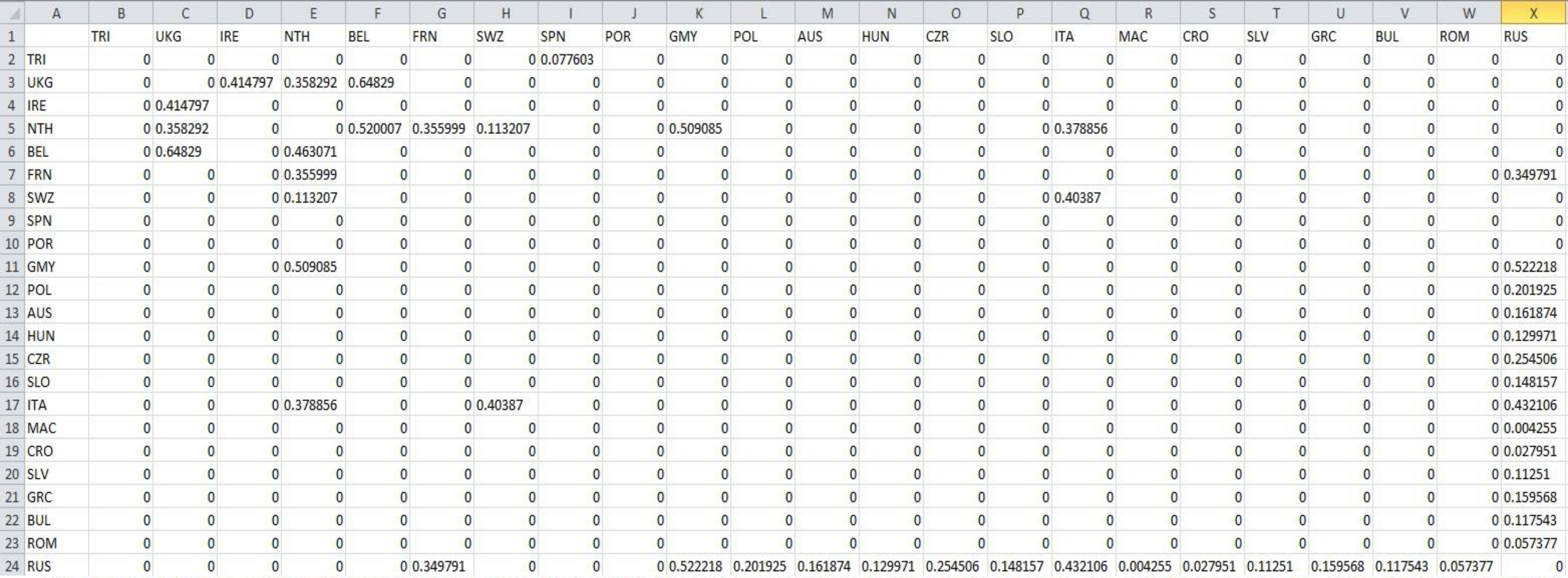
CZE-RUS	
share (bcm/y)	CZE: 7/9 = 0.77 (**77** %); RUS: 7/150 = 0.05 (**5** %)
saliency	sqrt(0.77*0.05) = 0.20 (**20** %)
symmetry	1 – abs(0.05 - 0.77) = 1 – 0.72 = 0.28 (**28** %)
interdependence	sqrt(0.20*0.28) = 0.24 (**24** %)
weighted interdependence	sqrt(0.24*sqrt(0.20*0.04)) = 0.15 (**15** %)

GER-RUS	
share (bcm/y)	GER: 40/85 = 0.47 (**47** %); RUS: 40/150 = 0.27 (**27** %)
saliency	sqrt(0.47*0.27) = 0.36 (**36** %)
symmetry	1 – abs(0.47 - 0.27) = 1 – 0. 2 = 0.8 (**80** %)
interdependence	sqrt(0.36*0.80) = 0.54 (**54** %)
weighted interdependence	sqrt(0.54*sqrt(0.24*0.04)) = 0.23 (**23** %)

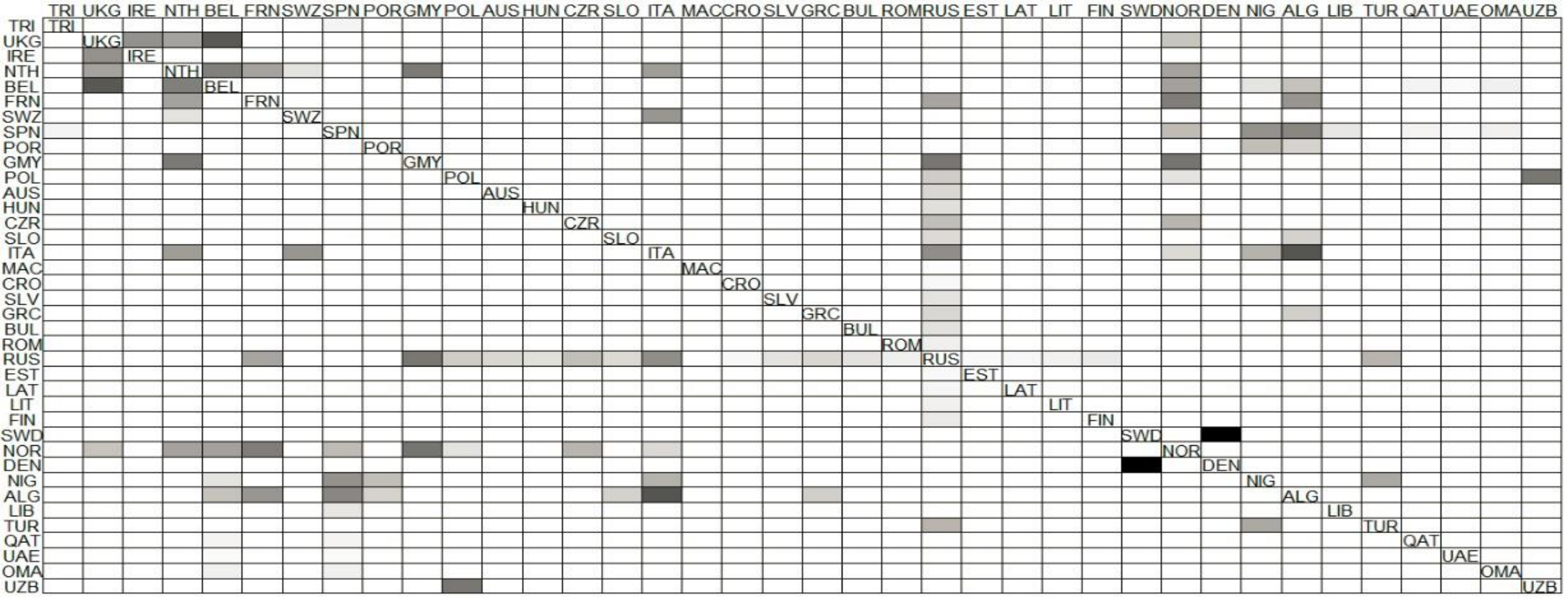
Attribute variables



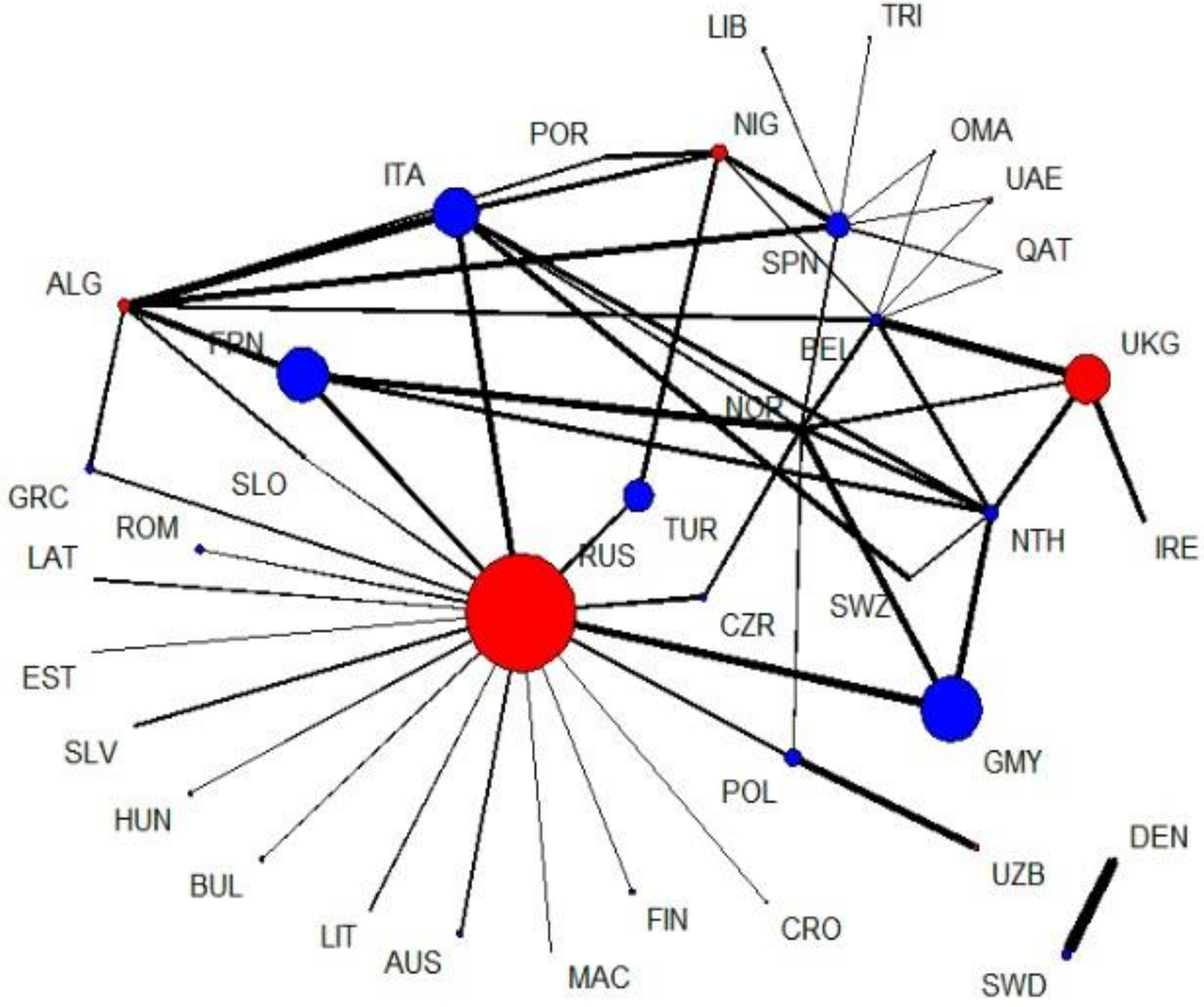
variable	operationalization (bcm/y)	CZE	GER
NG consumption / TPES	NG consumption / TPES	0.20 (20 %)	0.24 (24 %)
import / consumption	import NG / consumption NG	98 %	90/95 = 0.95 (95 %)
diversification (concentration)	HH = ∑shares^2	0.7^2 + 0.3^2 = 0.58 (58 %)	0.23^2 + 0.33^2 + 0.40^2 = 0.32 (32 %)
substitutability	N - 1	0.2 (20 %)	0.6 (60 %)
storage capacity / total consumption	storage capacity / consumption NG	3/9 = 0.3 (30 %)	24/95 = 0.25 (25 %)
political regime	Freedom House Index	0.82 (82 %)	0.84 (84 %)
...			



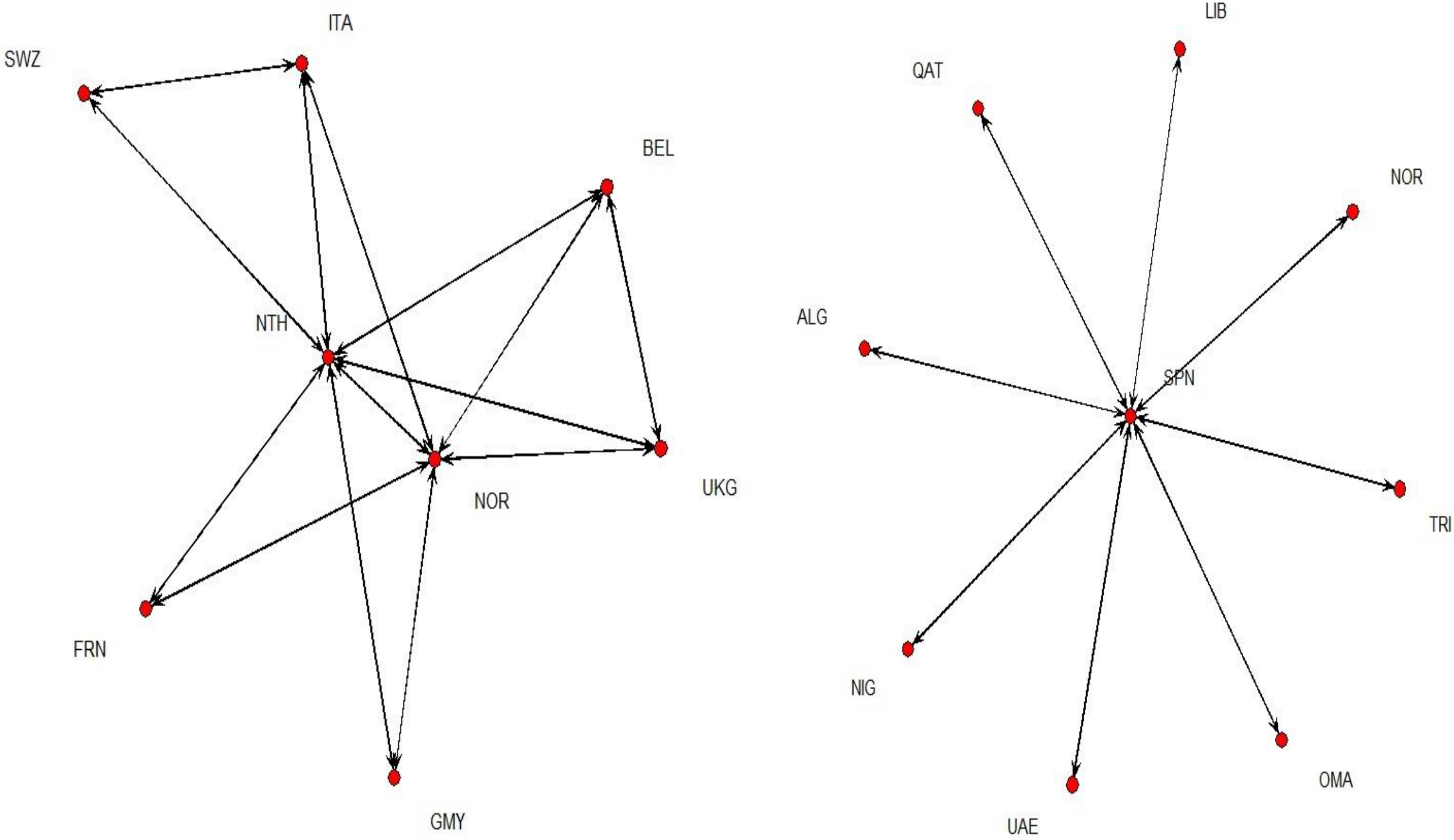
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
1		TRI	UKG	IRE	NTH	BEL	FRN	SWZ	SPN	POR	GMY	POL	AUS	HUN	CZR	SLO	ITA	MAC	CRO	SLV	GRC	BUL	ROM	RUS
2	TRI	0	0	0	0	0	0	0	0.077603	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	UKG	0	0	0.414797	0.358292	0.64829	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	IRE	0	0.414797	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	NTH	0	0.358292	0	0	0.520007	0.355999	0.113207	0	0	0.509085	0	0	0	0	0	0.378856	0	0	0	0	0	0	0
6	BEL	0	0.64829	0	0.463071	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	FRN	0	0	0	0.355999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.349791
8	SWZ	0	0	0	0.113207	0	0	0	0	0	0	0	0	0	0	0	0.40387	0	0	0	0	0	0	0
9	SPN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	POR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	GMY	0	0	0	0.509085	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.522218
12	POL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.201925
13	AUS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.161874
14	HUN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.129971
15	CZR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.254506
16	SLO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.148157
17	ITA	0	0	0	0.378856	0	0	0.40387	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.432106
18	MAC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.004255
19	CRO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.027951
20	SLV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.11251
21	GRC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.159568
22	BUL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.117543
23	ROM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.057377
24	RUS	0	0	0	0	0	0.349791	0	0	0	0.522218	0.201925	0.161874	0.129971	0.254506	0.148157	0.432106	0.004255	0.027951	0.11251	0.159568	0.117543	0.057377	0

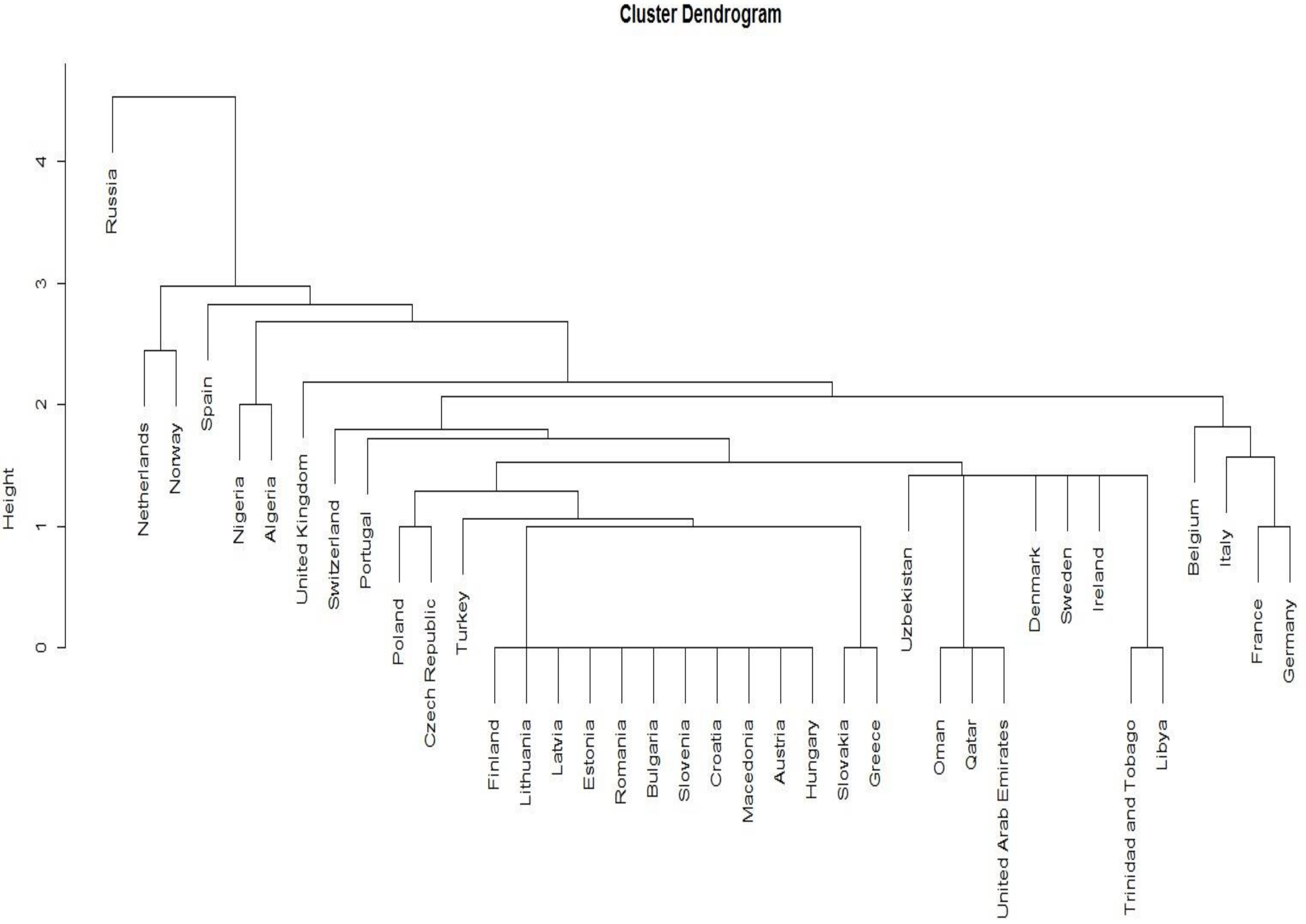


Interdependence network (European natural gas market (2001))



edge width: interdependence
node size: national capabilities
exporter (red), importer (blue)


ITA
SWZ
BEL
NTH
NOR
UKG
FRN
GMY
LIB
QAT
NOR
ALG
SPN
TRI
NIG
OMA
UAE


Cluster Dendrogram
Height
0
1
2
3
4
Russia
Netherlands
Norway
Spain
Nigeria
Algeria
United Kingdom
Switzerland
Portugal
Poland
Czech Republic
Turkey
Finland
Lithuania
Latvia
Estonia
Romania
Bulgaria
Slovenia
Croatia
Macedonia
Austria
Hungary
Slovakia
Greece
Uzbekistan
Oman
Qatar
United Arab Emirates
Denmark
Sweden
Ireland
Trinidad and Tobago
Libya
Belgium
Italy
France
Germany

Assignment 2

- Create a new script.
- Generate a random graph with 5 nodes.
- Calculate degree, closeness, and betweenness centrality.
- Calculate degree centralization.
- Visualize graph and report the centrality / centralization results.
- Bonus: display node size as a function of its degree centrality.