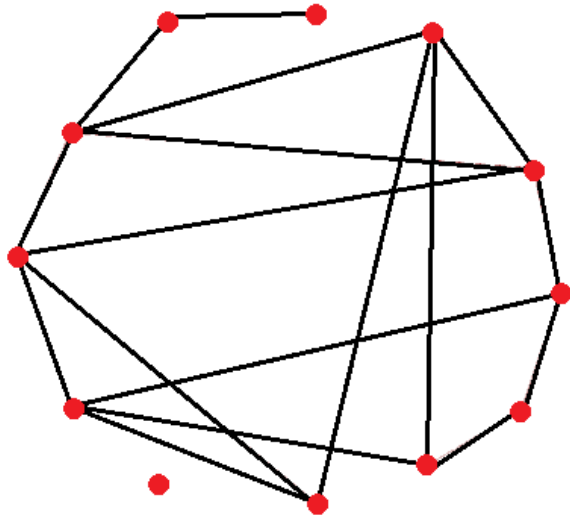


The Strength of Weak Ties as a Strategy to Allocate Research Funds: Making a Bioenergy Research Network More Productive

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Background: Small-World Principle



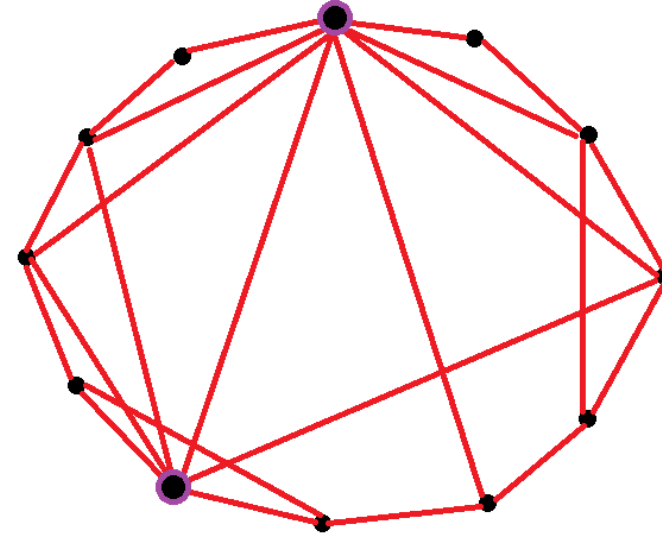
Random network

Hubs are about the same size as other nodes

Average degree = 2.833

Average shortest path length = 2.109.

Clustering coefficient = 0.167



Small-world network

Hubs are bigger than other nodes

Average degree = 3.833

Average shortest path length = 1.803.

Clustering coefficient = 0.522

A network that exhibits a strong small-world property can enhance information transmission among the network actors.

Prior Literature

- Major works on the problem of how networks are affected – and affect - research outcomes and the structure of scientific fields.
 - Powell, W. W., Koput, K. W., & Smith-Doerr, L. (ASQ 1996)
 - Powell, W. W., White, D. R., Koput, K. W., & Owen-Smith, J. (AJS 2005)
 - Rawlings, C. M., McFarland, D. A., Dahlander, L., & Wang, D. (Social forces, 2015)
 - Ayoubi, C., Pezzoni, M., & Visentin, F. (Res. Pol. 2019)
 - Baruffaldi, S., Visentin, F., & Conti, A. (Res. Pol. 2016)
 - Ayoubi, C., Pezzoni, M., & Visentin, F. (Sci&Publ. Pol., 2021)
 - Kim, L., Smith, S., Dahlander, L., & McFarland, D. A. (Social Networks, 2022)
- Can we target *researcher pairs* as opposed to *researchers* for funding?

Social Networks to Facilitate Knowledge Transfer

- By funding researcher pairs, can we increase the likelihood that collaborations would be productive and successful if they were funded based on how effectively scientists tap into their networks of professionals?
- Main purposes of the study are to:
 - Examine to what extent strategic funding helps the structure of the collaboration network resemble the *small-world network* structure.
 - Examine the stimulative effect of different funding strategies on the evolution of the structure of collaboration network of scientists on their research *productivity* and *connectivity*.

Data

- Data collected from survey of 20 top researchers in black liquor gasification field, collectively responsible for the near universe of all publications in this topic area.
- Exhaustive data on publication, date, coauthors, recruitment of new coauthors entering the network through a particular paper, etc. recorded.
- Each paper tied to research projects (if any), information on project funding, and funding per paper calculated.
- Final dataset on a total of 126 publications, published in 40 peer-reviewed journals by 127 researchers from 60 institutions.

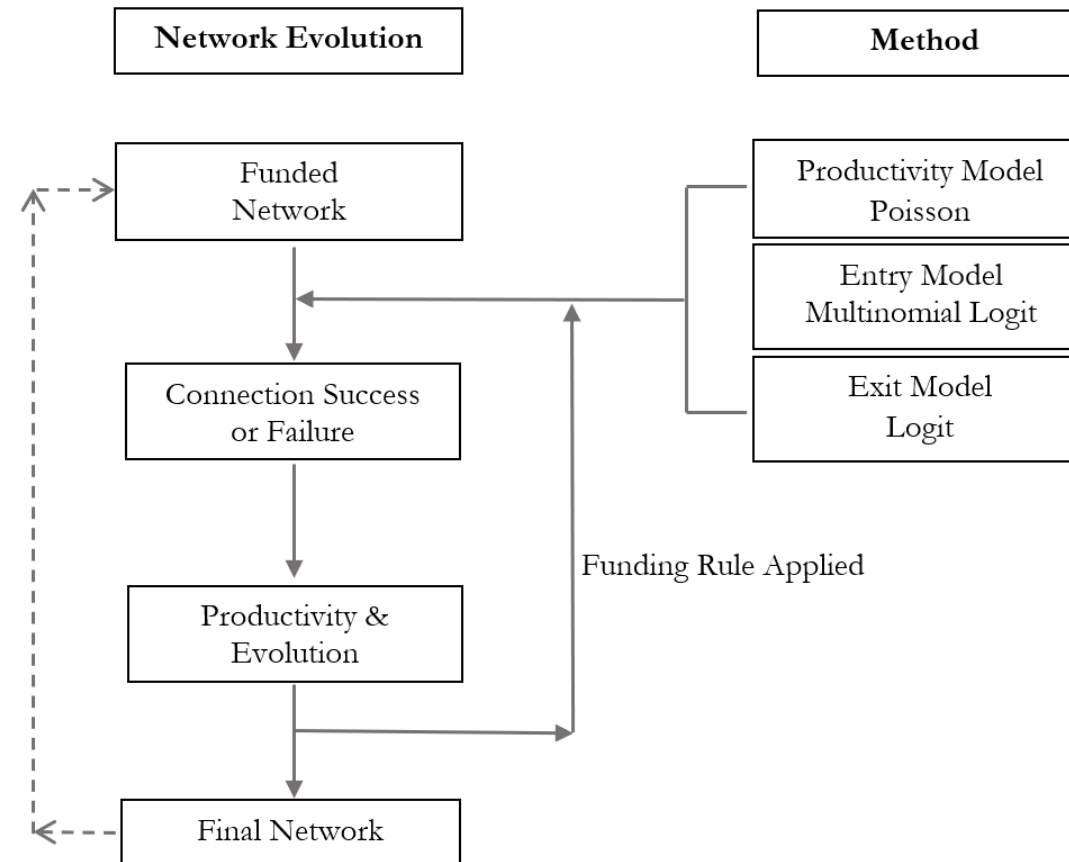
Why Black Liquor Gasification?

- Black liquor gasification offers significant improvements in energy efficiency, environmental performance and economic benefits.
 - Promising field – currently BL *boiled* to produce ~3% of total US domestic electric supply; can double if *gasified* instead.
 - Boilers were established in the 70s and 80s and need to be replaced soon.
 - Small network – allows us to collect an almost exhaustive list of researchers that ultimately allows us to represent all collaborations as a social network.
- Continued strategic funding is needed to stimulate research and innovation, and ultimately contribute to the development of this environmental-friendly energy source.

Rules for Network Evolution

- Poisson regression is used to estimate the productivity for a connection.
 - With the probability from the regression, we simulate the *number of publications* for the whole network in each period.
- Multinomial logit is used to estimate the probability of a new permanent entrance into the network.
 - With the probability of entry for each pair of cells, we simulate how many *new cells* will *enter* the system.
- Logit regression is used to estimate how people exit a network. First, we find the probability of whether a connection is broken or not. Second, if this connection is broken, we find which author in the connection exits the system.
 - With the probability of exit for each pair of cells, we simulate how many *cells* will *exit* the system.

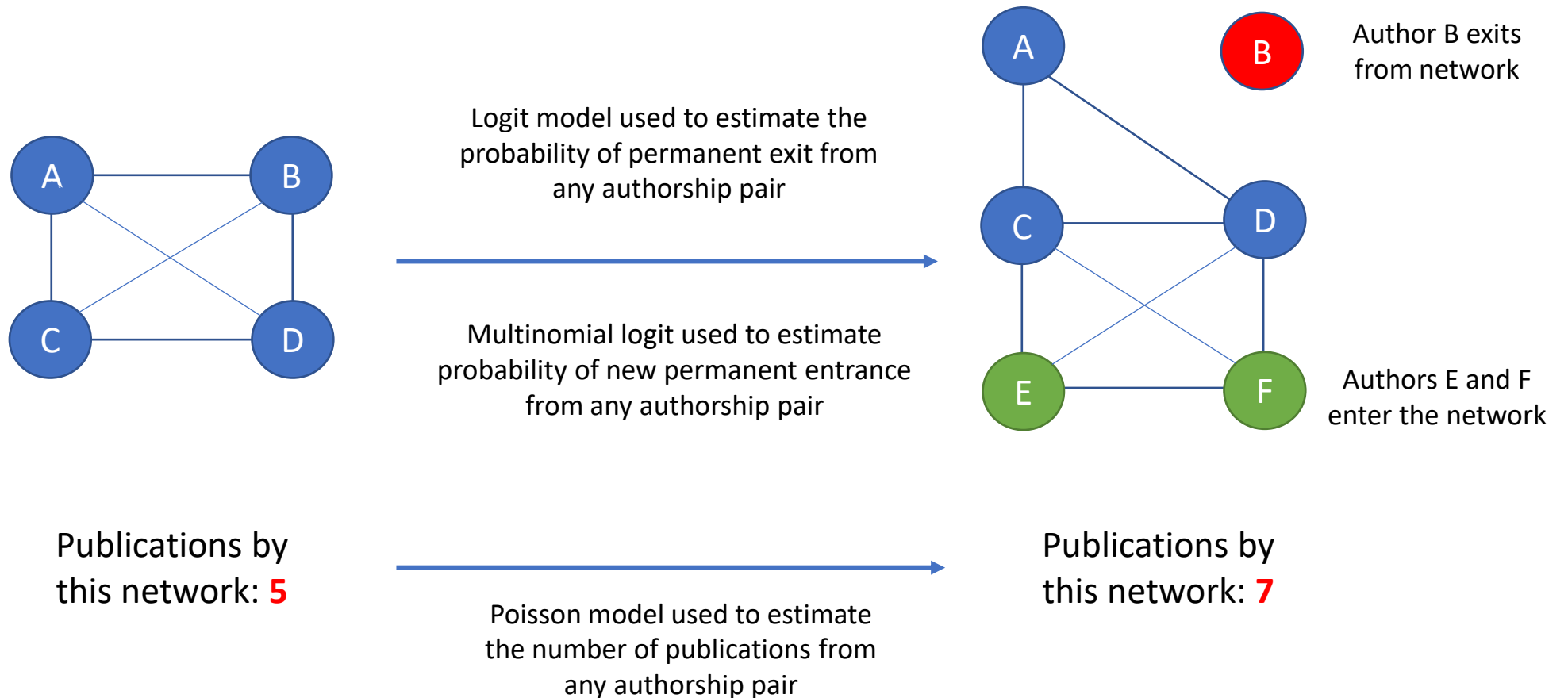
Illustration: Network Evolution



Funding Rules to Stimulate Network Evolution

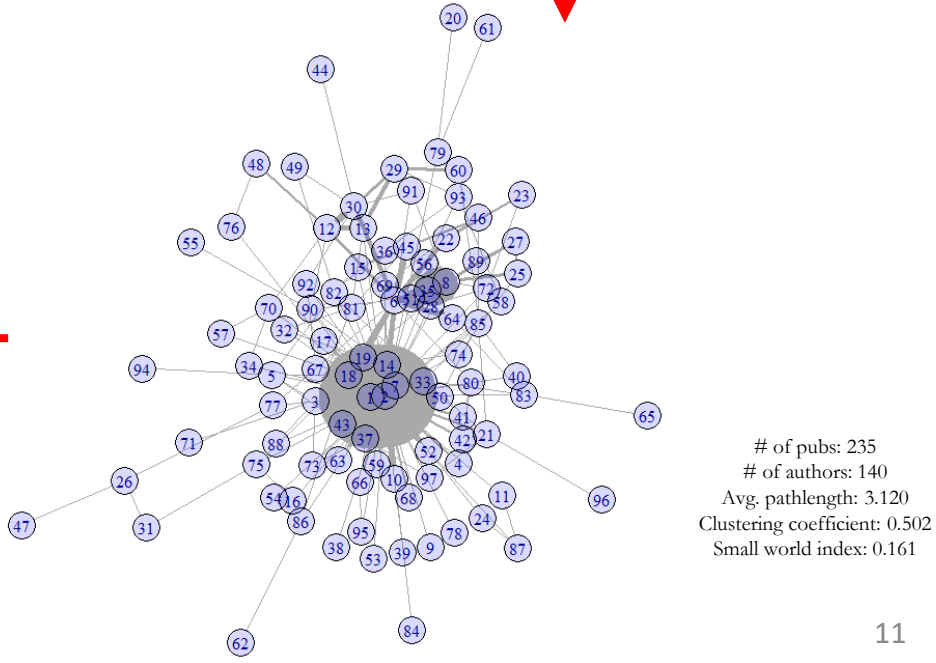
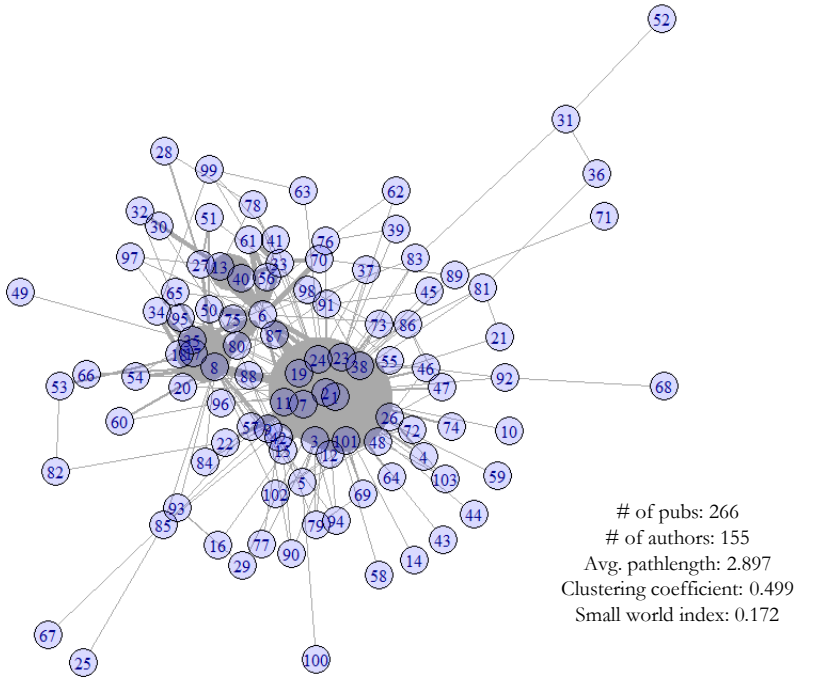
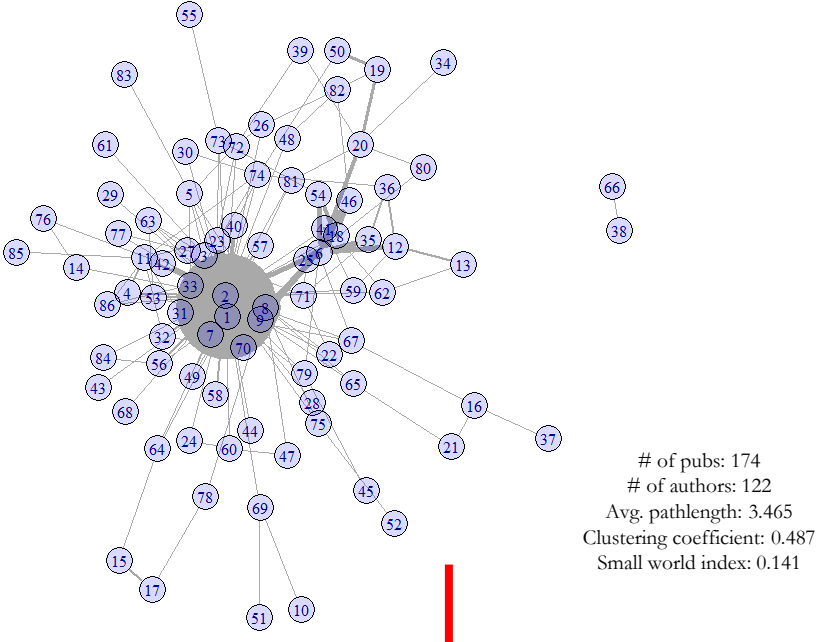
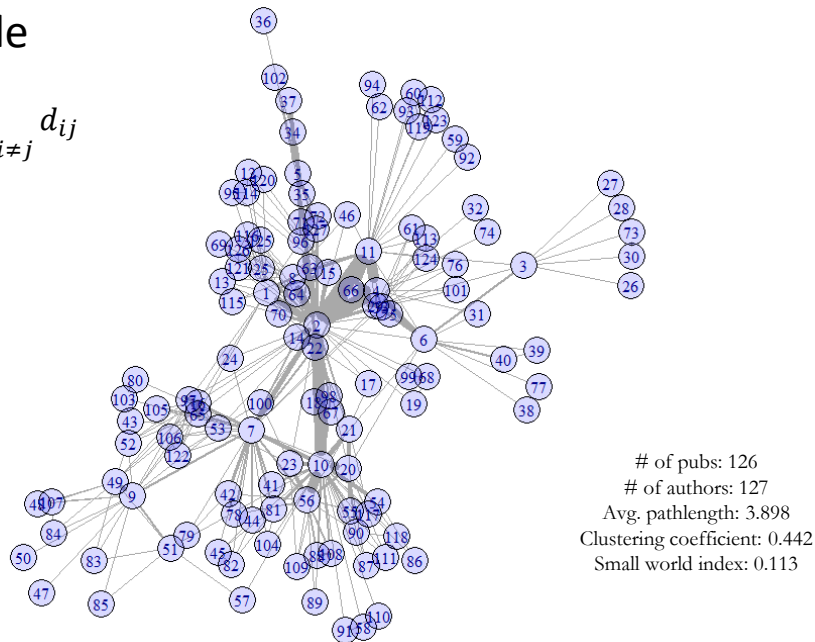
- Three funding rules tested:
 1. Fairness Rule: fund author pairs with shortest average pathlength.
 2. Direct Optimization: fund author pairs with highest number of expected publications.
 3. Smart Small World: fund author pairs with highest number first degree connections.
 4. No Funding: no injection of funds.

Illustration: Researcher Recruitment & Exit



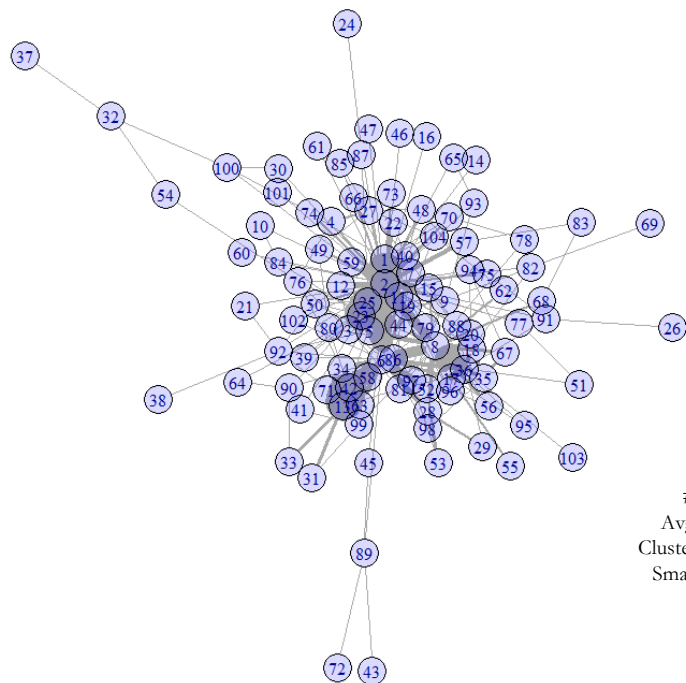
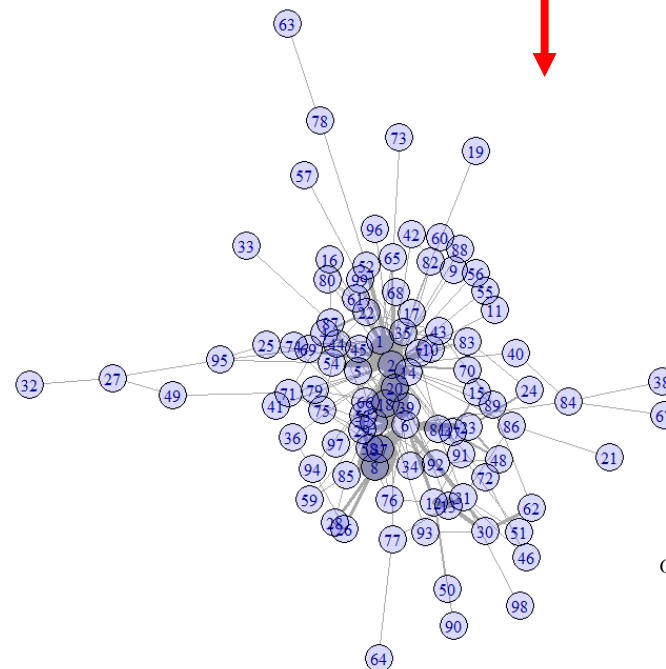
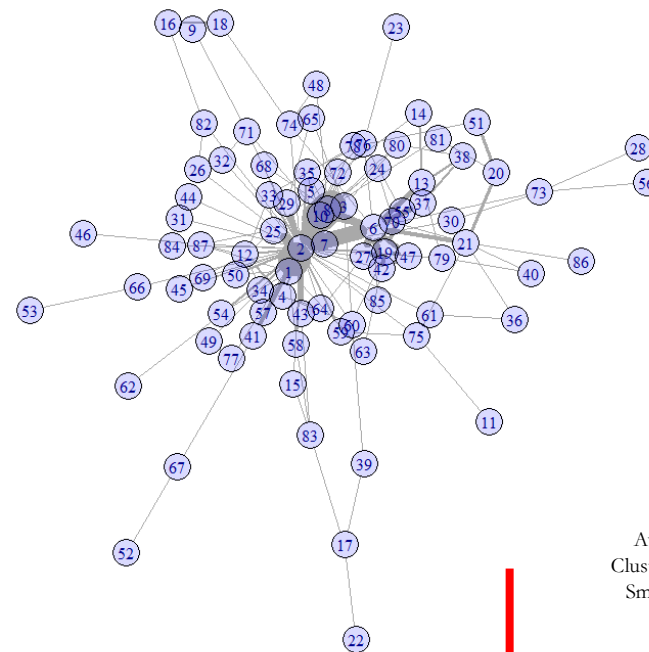
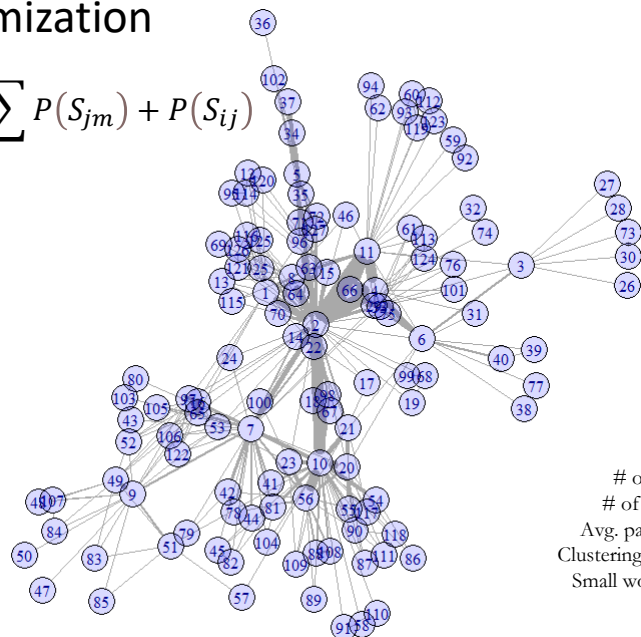
Fairness Rule

$$\text{Min } \frac{1}{n(n-1)} \sum_{i \neq j} d_{ij}$$



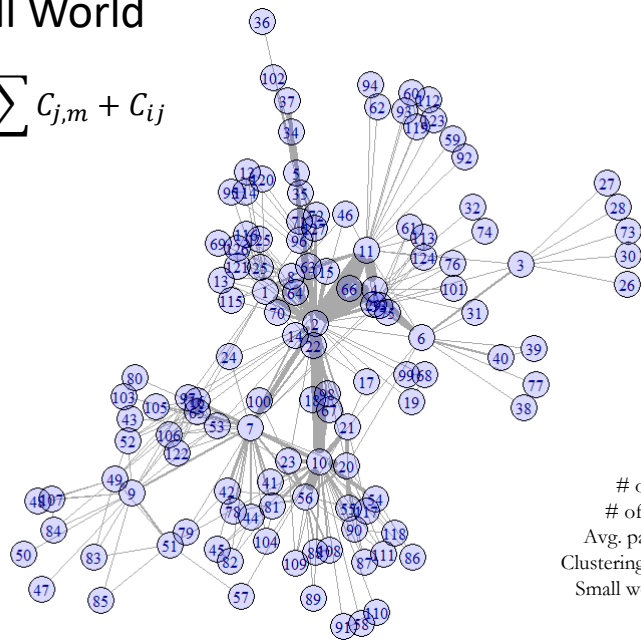
Direct Optimization

$$\text{Max} \sum P(S_{ik}) + \sum P(S_{jm}) + P(S_{ij})$$

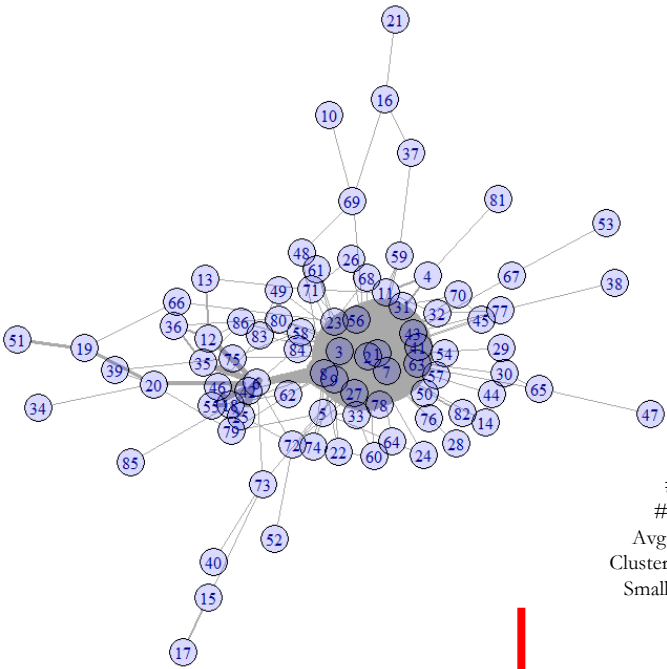


Smart Small World

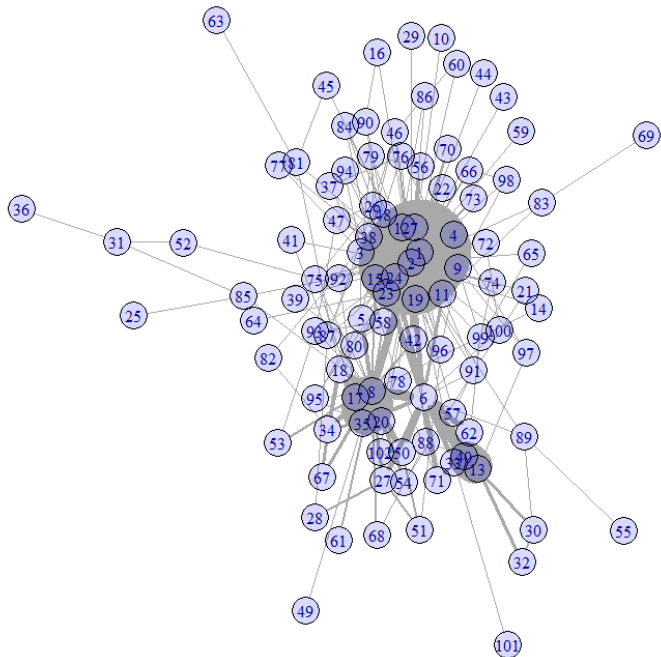
$$Max \sum C_{i,k} + \sum C_{j,m} + C_{ij}$$



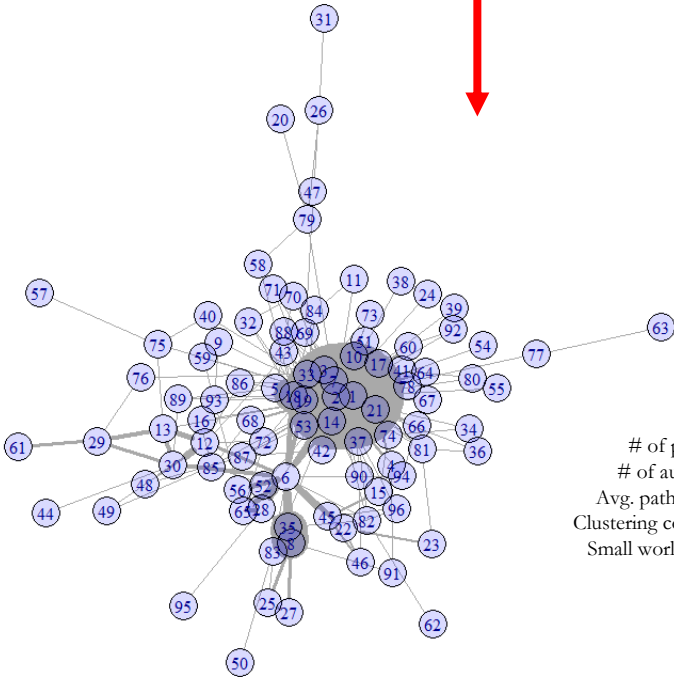
of pubs: 126
of authors: 127
Avg. pathlength: 3.898
Clustering coefficient: 0.442
Small world index: 0.113



of pubs: 179
of authors: 122
Avg. pathlength: 3.561
Clustering coefficient: 0.476
Small world index: 0.134

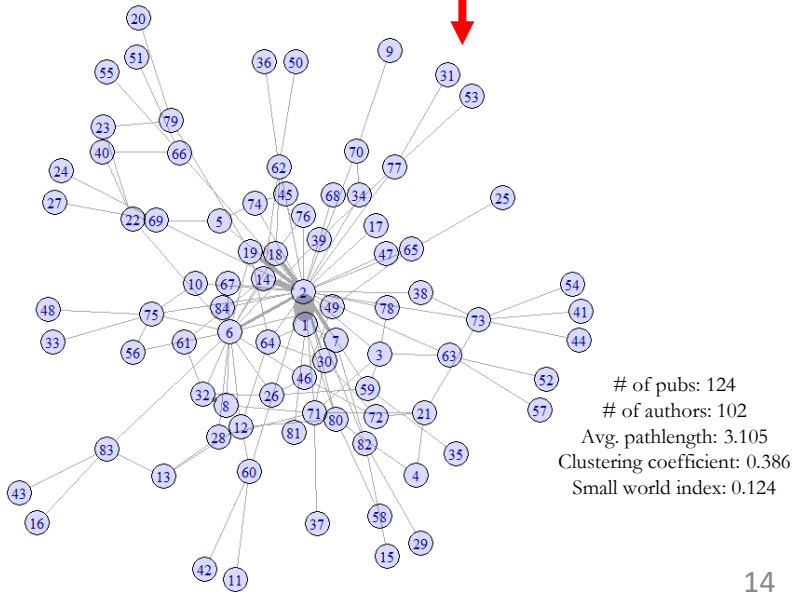
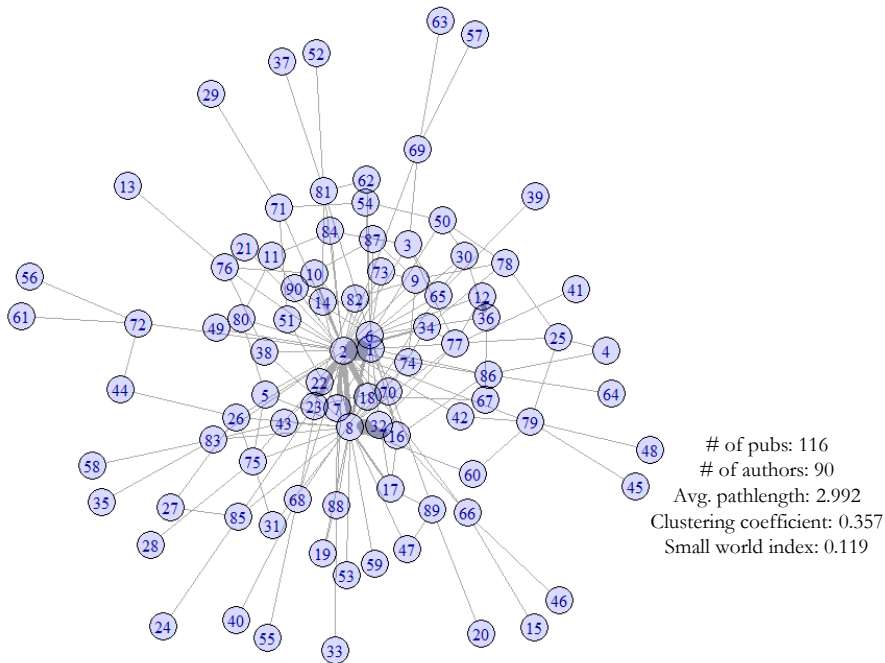
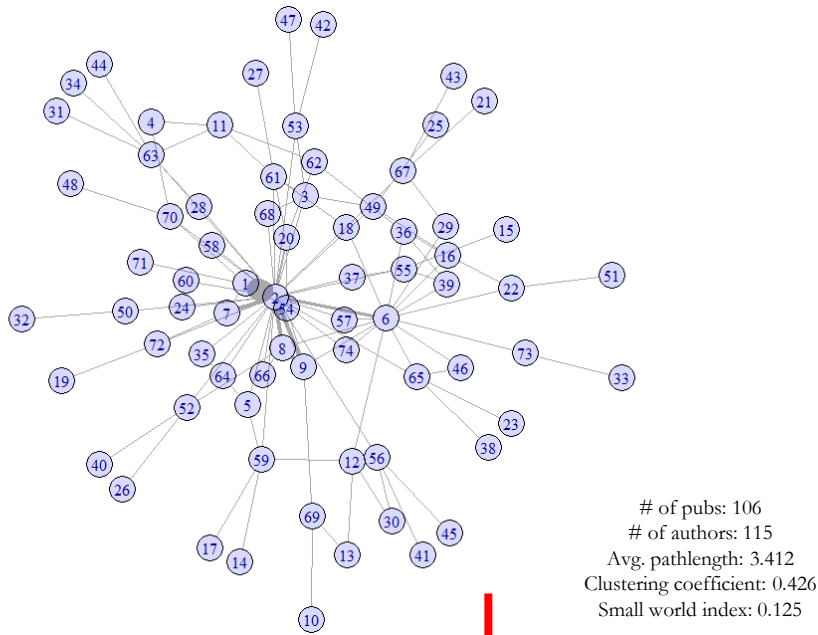
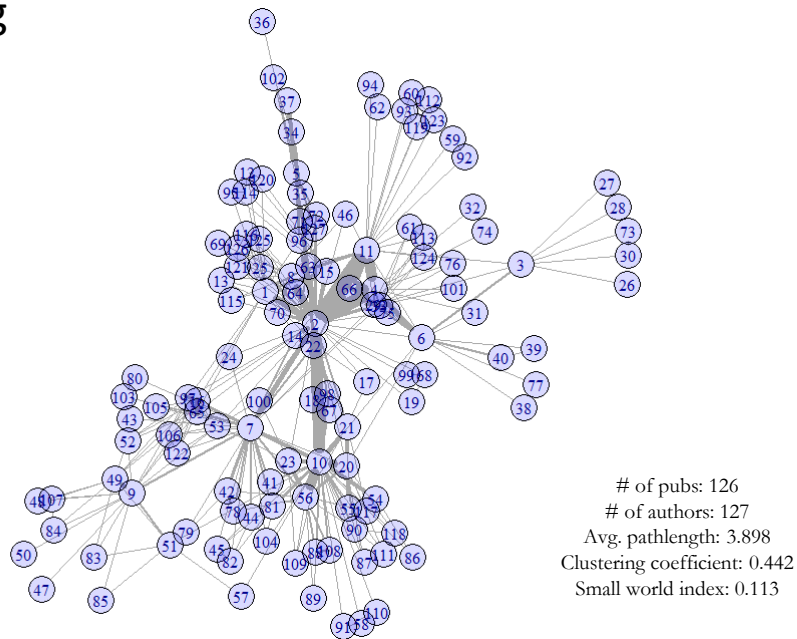


of pubs: 268
of authors: 150
Avg. pathlength: 3.073
Clustering coefficient: 0.500
Small world index: 0.163



of pubs: 242
of authors: 144
Avg. pathlength: 3.123
Clustering coefficient: 0.482
Small world index: 0.154

No Funding



Summary diagnostics

	Avg. # of publications	Avg. # of authors	Avg. shortest pathlength	Clustering coefficient	Small world index
Static Baseline	126	114	3.898	0.442	0.113
Fairness Rule	266	155	2.897	0.499	0.172
Smart Small World Rule	268	150	3.073	0.500	0.163
Direct Optimization	242	148	2.952	0.480	0.163
No Funding	116	90	2.992	0.357	0.119

Summary Results

- Adhering to a policy that provides **22%** more funding to the:
 - Most efficient collaborators could increase publication rates by **111%** and researcher recruitment by **22%** (Fairness Rule)
 - Most prolific researchers could increase publication rates by **92%** and researcher recruitment by **17%** (Direct Optimization)
 - Most prolific collaborators could increase publication rates by **113%** and researcher recruitment by **18%** (Smart Small World)
- Strategic funding help facilitate small-world network formation, stimulates publications and network cohesion