Agent-based models of social networks

Mitchell Centre Seminar Series - The University of Manchester

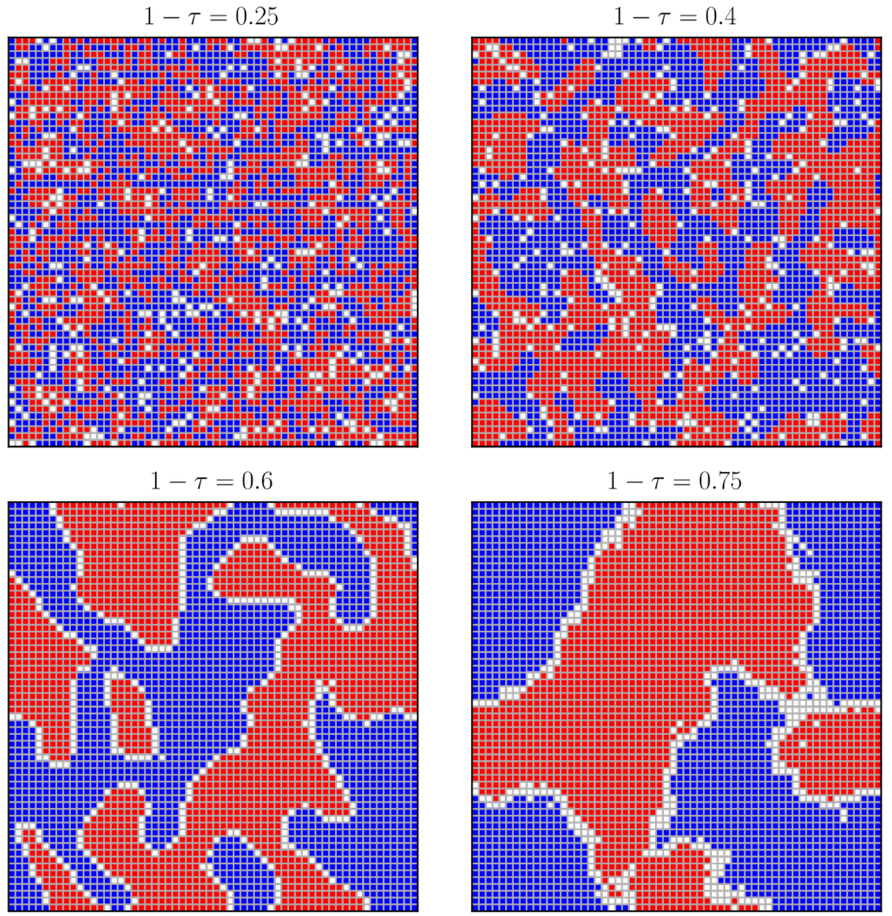
Federico Bianchi

Behave Lab
Department of Social and Political Sciences
University of Milan, Italy

Oh, no! Another modelling technique

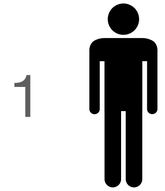
Yes… and no

- Agent-based modelling (ABM) has been around since at least the 1990s (Macy & Willer, 2002; Bianchi & Squazzoni, 2015)
- **Formal models** of a population of **interdependent**, **autonomous agents**, **(inter)acting** upon some behavioural rules within environmental (structural, institutional…) constraints (Gilbert & Troitzsch, 2005)
- So far, little application to studying the formation/emergence/evolution of social networks (e.g., Hummon, 2000)



ABMs are models of social interaction

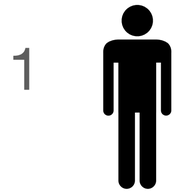
Time *t*

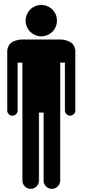


Age = 35
Gender = F
politics = left

Age = 47
Gender = F
politics = **right**

Time *t + 1*





Age = 35
Gender = F
politics = left

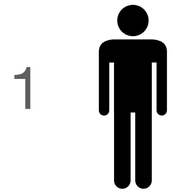
Age = 47
Gender = F
politics = **left**

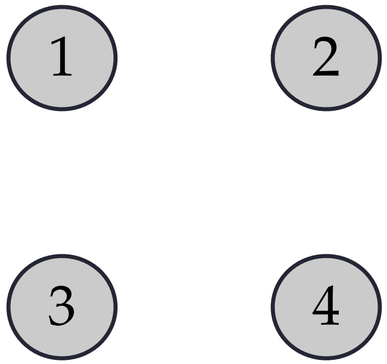
	Age	**Gender**	**Politics**
1	35	F	left
2	47	F	right
...			
n			

"From factors to actors"
(Macy & Willer, 2002)

ABMs can model social networks

Time *t*

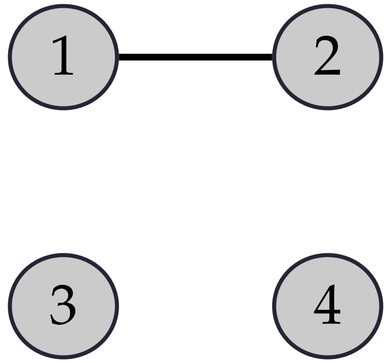




Age = 35
Gender = F
Neighbours = ( )

Age = 47
Gender = F
Neighbours = ( )

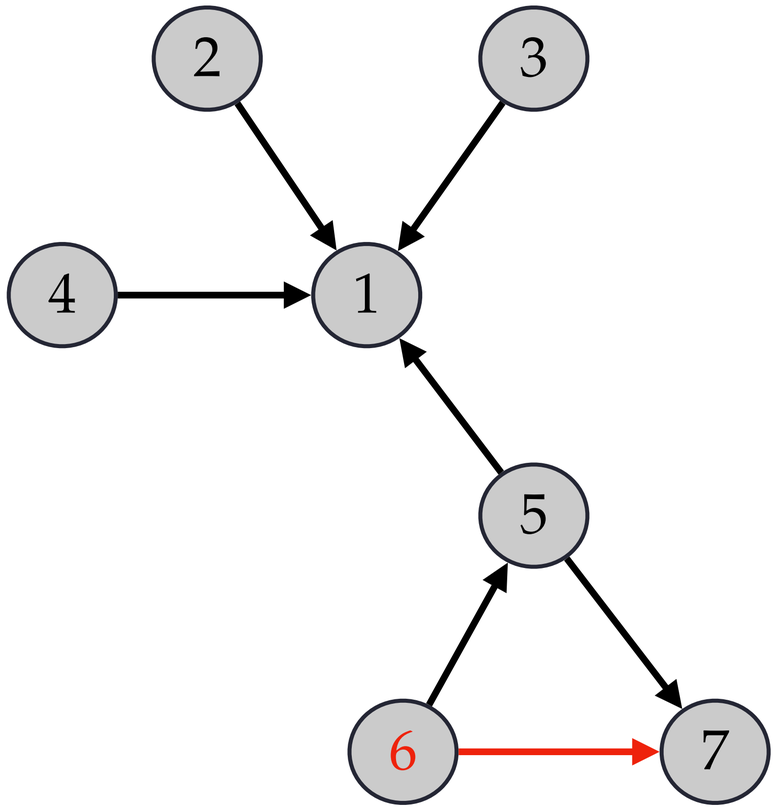
Time *t + 1*



Age = 35
Gender = F
Neighbours = (2)

Age = 47
Gender = M
Neighbours = (1)

Nodes are agents



Simple behaviour

If you're lying on a 2-path, then close the triad with some probability *p*

More complex behaviour

If you haven't asked anybody in the last *m* steps, then ask an agent who's not being asked by many agents

Sounds like SIENA!

Yes… and no

SAOMs (Stochastic Actor-Oriented Models) are a particular kind of ABMs (Snijders *et al.*, 2010), constrained by a set of assumptions on agents' decision-making and environmental constraints because

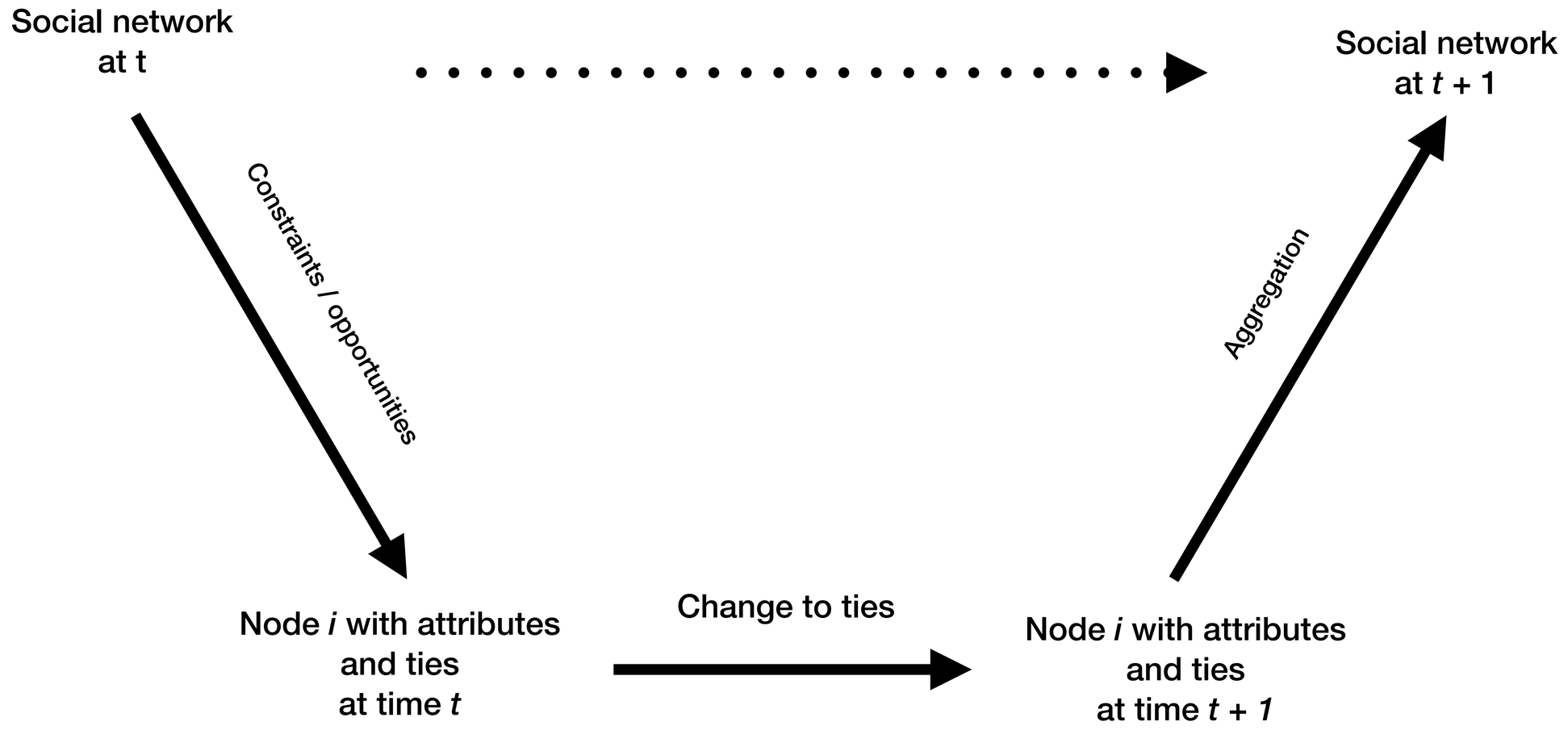
SAOM

- Agents optimize preferences based on expected utility at time *t + 1*
- Agents choose among an alternative set of options
- Agents form/destroy ties according to the same decision-making process (**homogeneity**)
- Agents have **information on the whole network**
- **Markov chain**: one change at a time
- Agents cannot coordinate (no collective action)

General ABM

- Broad range of behaviour, including learning, strategic forward-looking rationality, complex cognitive heuristics
- Agents can choose upon any kind of heuristics
- Agents can be **heterogeneous** in terms of decision-making
- Agents can have **limited information**
- **Simultaneous events** are possible (critical events / threshold-like processes)
- Agents can coordinate (communicate, negotiate…)

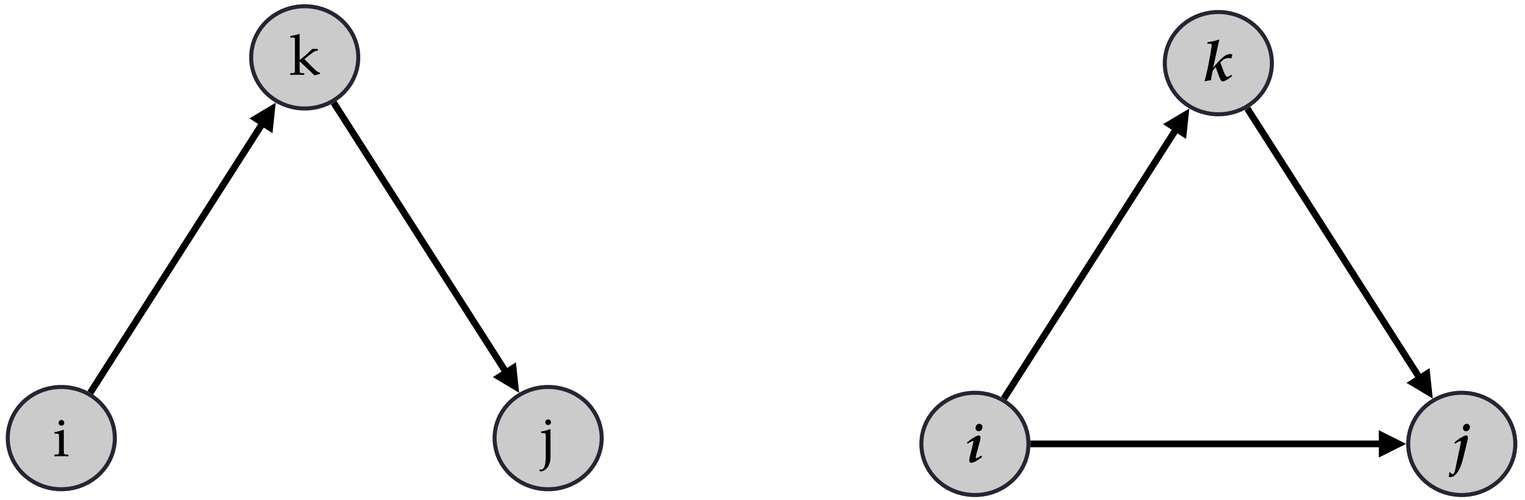
Why would we need more complexity?



Network processes vs. mechanisms

Reciprocation

- Complying to a norm prescribing reciprocation OR
- Instrumentally investing in a cooperative relationship to reap long-term benefits



Transitivity

- More likely to meet if we share a friend OR
- More likely to be similar if we share a friend OR
- Avoiding unpleasant emotions linked to imbalance

Relationships are not of the same kind

SAOM assumptions

- Agents have **information on the whole network**
- Agents form/destroy ties according to the same decision-making process (**homogeneity**)
- Agents choose among an alternative set of options
- Agents optimize preferences based on expected utility at time *t + 1*

What about…

- Advice-seeking in a competitive environment?
- Networks larger than very small *n*?
- Status-based relationships?
- Cognitive relational states (trust, liking, etc.)
- Friendship?

Case 1:
Analysis of counterfactual scenarios

Solidarity as byproduct of collaboration

Contents lists available at ScienceDirect

Social Networks

journal homepage: www.elsevier.com/locate/socnet

Solidarity as a byproduct of professional collaboration: Social support and trust in a coworking space

Federico Bianchi, Niccolò Casnici, Flaminio Squazzoni*

Department of Economics and Management, University of Brescia, Via San Faustino, 74/B, 25122 Brescia, Italy

ARTICLE INFO

Article history:

Keywords:
Solidarity
Social support
Trust
Collaboration
Multivariate ERGM

ABSTRACT

This article investigates solidarity arising from economic exchange, by studying a multiplex network of collaboration, trust and social support. After a qualitative pre-study, we performed a full-network survey on a group of independent professionals sharing a coworking space and occasionally collaborating with each other. By running multivariate Exponential Random Graph Models, we showed that successful collaboration might not determine expectations of social support. However, these relationships were related to business-based trust ties, which were predicted by collaboration. Our results suggest that solidarity can emerge as a byproduct of peer economic exchange when trust mediates between professional relationships and expressive ties.

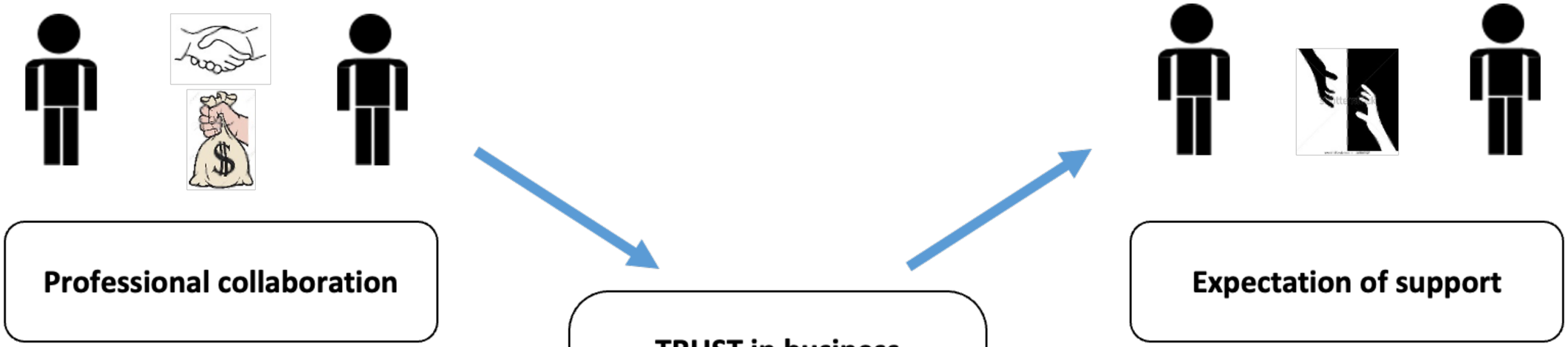
Can solidarity emerge from economic exchange?

?

Economic exchange
Bilateral transfer of benefits upon a negotiated agreement

Solidary behaviour
providing support (= costly help) to anoher individual

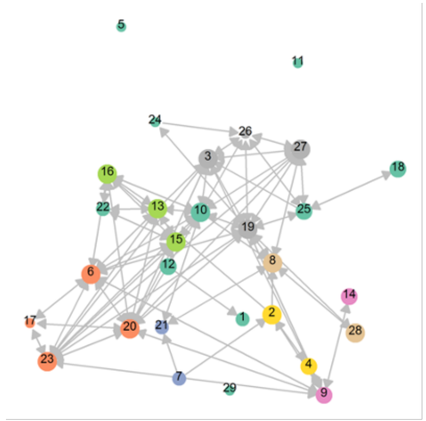
Reciprocity theory of solidarity



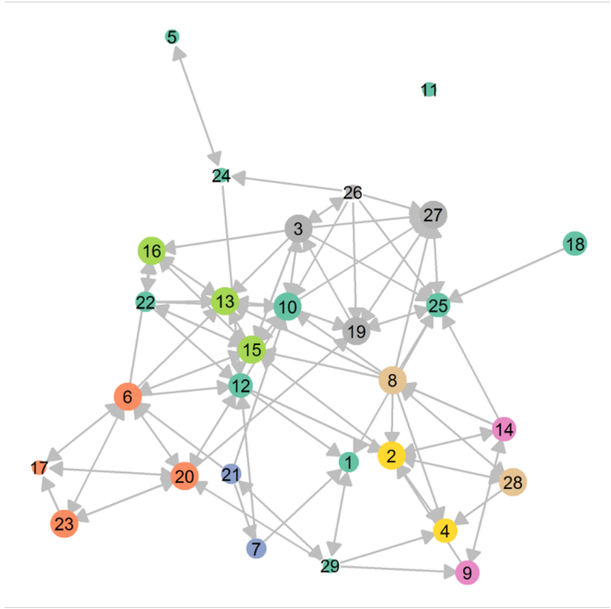
- Solidarity needs trust (of reciprocation)
- Economic exchanges involve agreements
- Agreements minimize risk
- Lack of risk prevents trust to develop

(Molm, 2003, 2010; Molm et al., 2006, 2007, 2009)

Empirical test in a coworking space

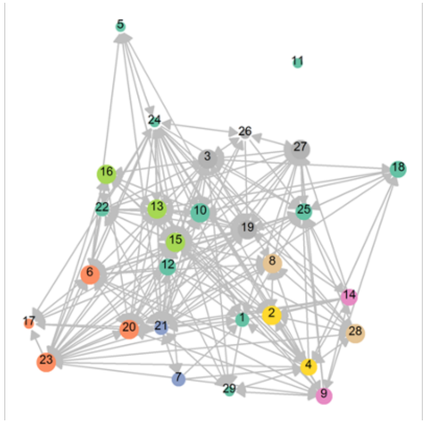


Successful collaboration



Support expectations

+



Trust

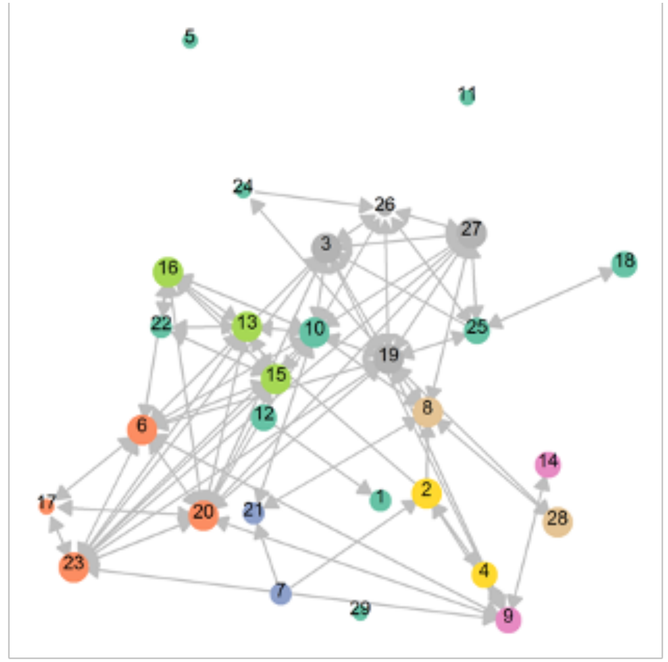
+

ERGM for multiplex networks
(Pattison & Wasserman, 1999;
Wang et al., 2006)

Caveats (idiosyncratic nature of empirical case)

Table 1: Participant demographics

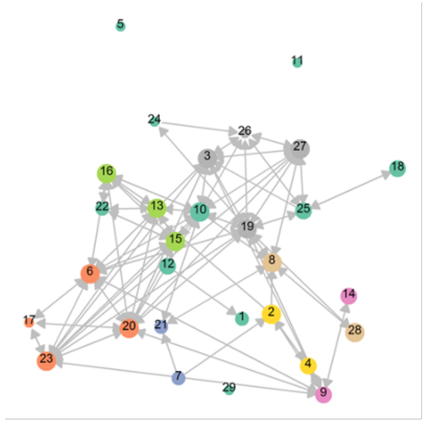
Number of coworkers	29
Gender	Male = 24, Female = 5
Age	31.83 (6.04)
Family status	Single = 4
	In a stable relationship = 6
	Cohabitant with partner = 11
	Married = 8
Seniority in coworking space (months)	29.34 (14.26)
Educational degree	Middle school or vocational training = 2
	High school = 10
	Bachelor = 7
	Master = 10



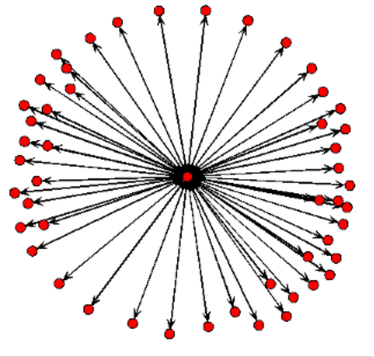
- Estimated effect is conditioned on professional collaboration network (exogenous factor)
- Collaboration network is relatively decentralised
- Skills are homogeneously distributed

What if..?

- …Distribution of resources worth for collaboration had been more uneven?
- Collaboration network would have been more centralised
- Would trust and solidarity networks have developed differently?
- Did support emerge from collaboration because of low competition for the best collaboration partners?



Successful collaboration



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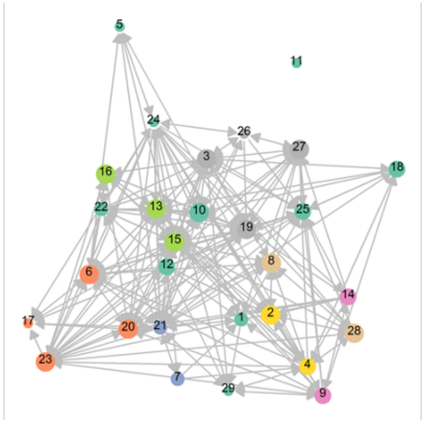
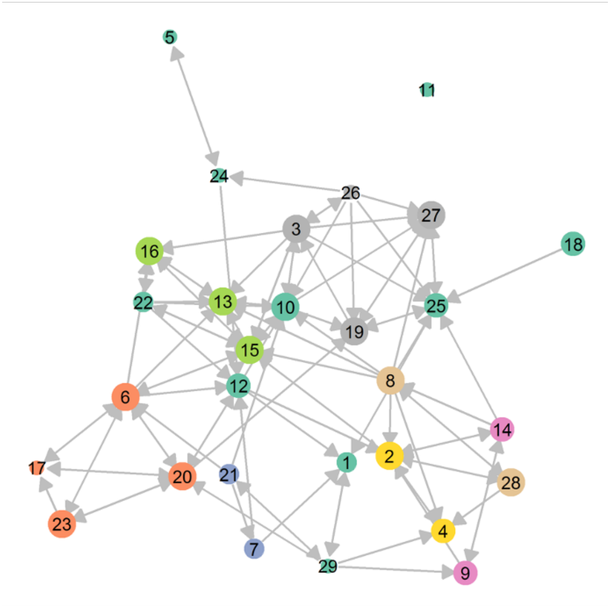


Trust

\+



Support

Solidarity from collaboration under competition

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Solidarity in collaboration networks when everyone competes for the strongest partner: a stochastic actor-based simulation model

Federico Bianchi [a], Andreas Flache [b], and Flaminio Squazzoni [c]

[a]Department of Economics and Management, University of Brescia, Brescia, Italy; [b]Department of Sociology/ICS, University of Groningen, Groningen, The Netherlands; [c]Department of Social and Political Sciences, University of Milan, Milan, Italy

ABSTRACT

This article examines the emergence of solidarity from interactions between professionals competing for collaboration. Research on multiplex collaboration networks has shown that economic exchange can elicit solidarity when mediated by trust but did not consider the effect of competition. To fill this gap, we built an agent-based model that simulates the evolution of a multiplex network of collaboration, trust, and support expectations. Simulations show that while resource heterogeneity is key for collaboration, competition for attractive collaboration partners penalizes low-resource professionals, who are less connected and highly segregated. Heterogeneous resource distribution can trigger segregation because of preferential selection of resourceful peers and reciprocity. Interestingly, we also found that low-resource professionals can reduce their marginalization by building in-group mutual support expectations.

ARTICLE HISTORY
Received 22 July 2019
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KEYWORDS
Solidarity; collaboration networks; competition; multiplex networks; agent-based model; stochastic actor-oriented model

ABM parameters

$$f_i^{(r)}(x) = \sum_k \beta_k^{(r)} s_{ik}^{(r)}(x)$$

$$p(\text{change in } x_{ij}) = \frac{\exp(f_i^{(r)}(\text{change in } x_{ij}^{(r)}))}{\sum_h \exp(f_i^{(r)}(\text{change in } x_{ih}^{(r)}))}$$

Collaboration	
Outdegree	-4
Resource popularity	3
Reciprocity	3
Association with Trust	1

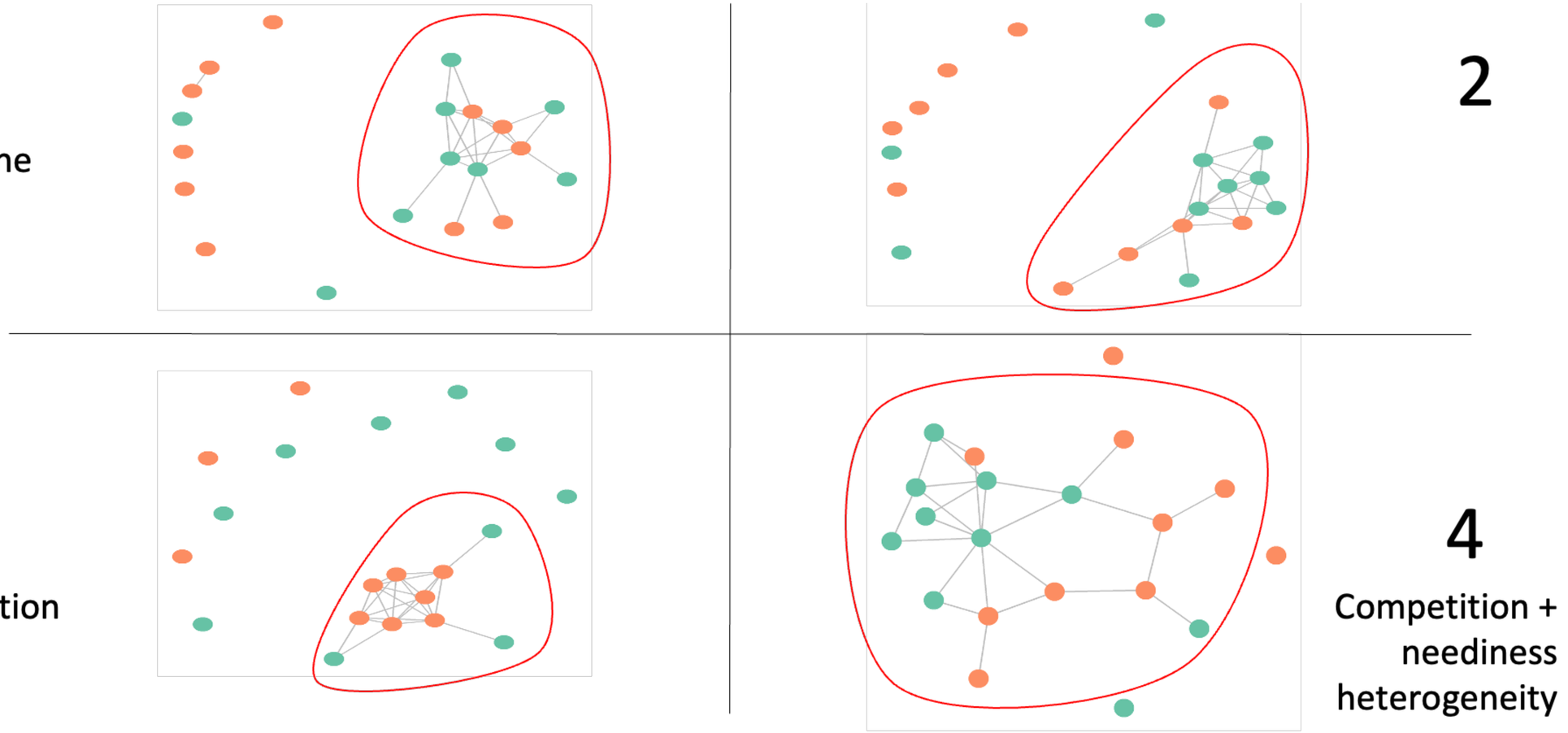
Trust	
Outdegree	5
Outdegree slope	-1
Reciprocity	1
Transitive triplets	0.5
Association with Collaboration	1

Expectation of support	
Outdegree	5
Outdegree slope	-1
Reciprocity	1
Transitive triplets	0.5
Association with Trust	1

Simulation design

		Neediness	
		Equal	2-class
Resources	Equal	Scenario 1	Scenario 2
	2-class	Scenario 3	Scenario 4

Results: segregated solidarity



Why ABM

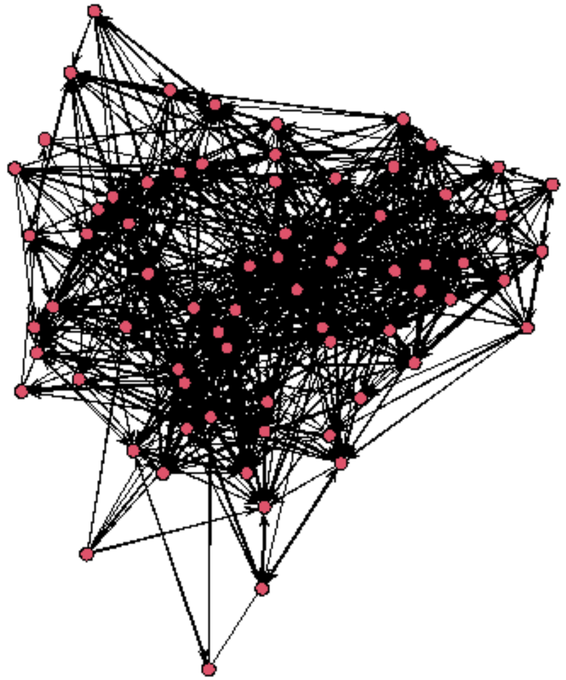
- Overcoming limits of case-based nature of observational studies in network research
  - Exploring counterfactual scenarios
  - Testing robustness of empirical studies by modelling unobserved (unobservable?) factors
- Similar to Steglich & Snijders (2022) but
  - ABM parameters are not estimated on the empirical data because we don’t want simulations to reflect idiosyncrasy of the data
  - More parsimonious (only generatively sufficient mechanisms)

Case 2:
Modelling generative mechanisms

(working paper co-authored with Francesco Renzini & Flaminio Squazzoni)

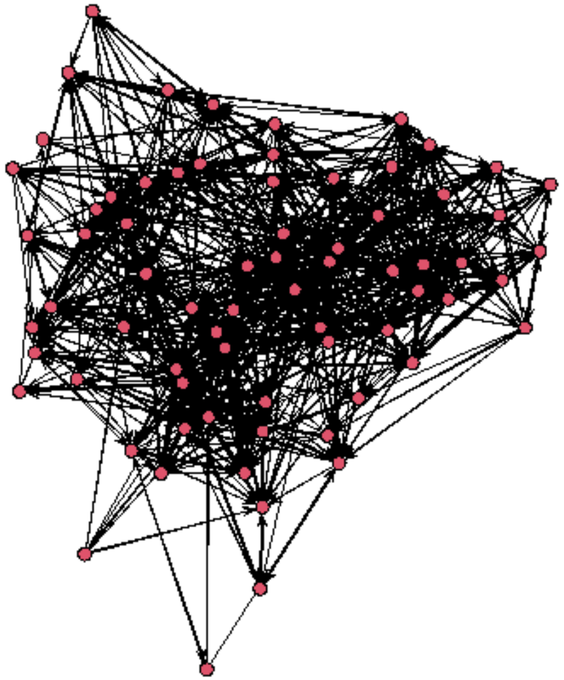
Explaining advice-seeking networks

- Lazega's classic advice-seeking network (Lazega, & Van Duijn, 1999; Lazega, 2001)
- Context: law firm in '90s New England (*n* = 71)
- High internal competition for status: different preferences based on status (unobserved)
- Lazega (2006, 2014): "cognitive overload" (time is valuable) (unobserved)
- No generalized triadic/popularity processes because information is limited (competition)



Fitting a SAOM?

- In principle, SAOMs are preferable to ERGMs because they are ABMs (Snijders & Steglich, 2015; Block *et al.*, 2019), therefore they model dependencies between data better
- SAOMs can be fitted to cross-sectional data (stationary distribution) (Snijders & Steglich, 2015)



Hypothesised mechanism violates SAOM assumptions

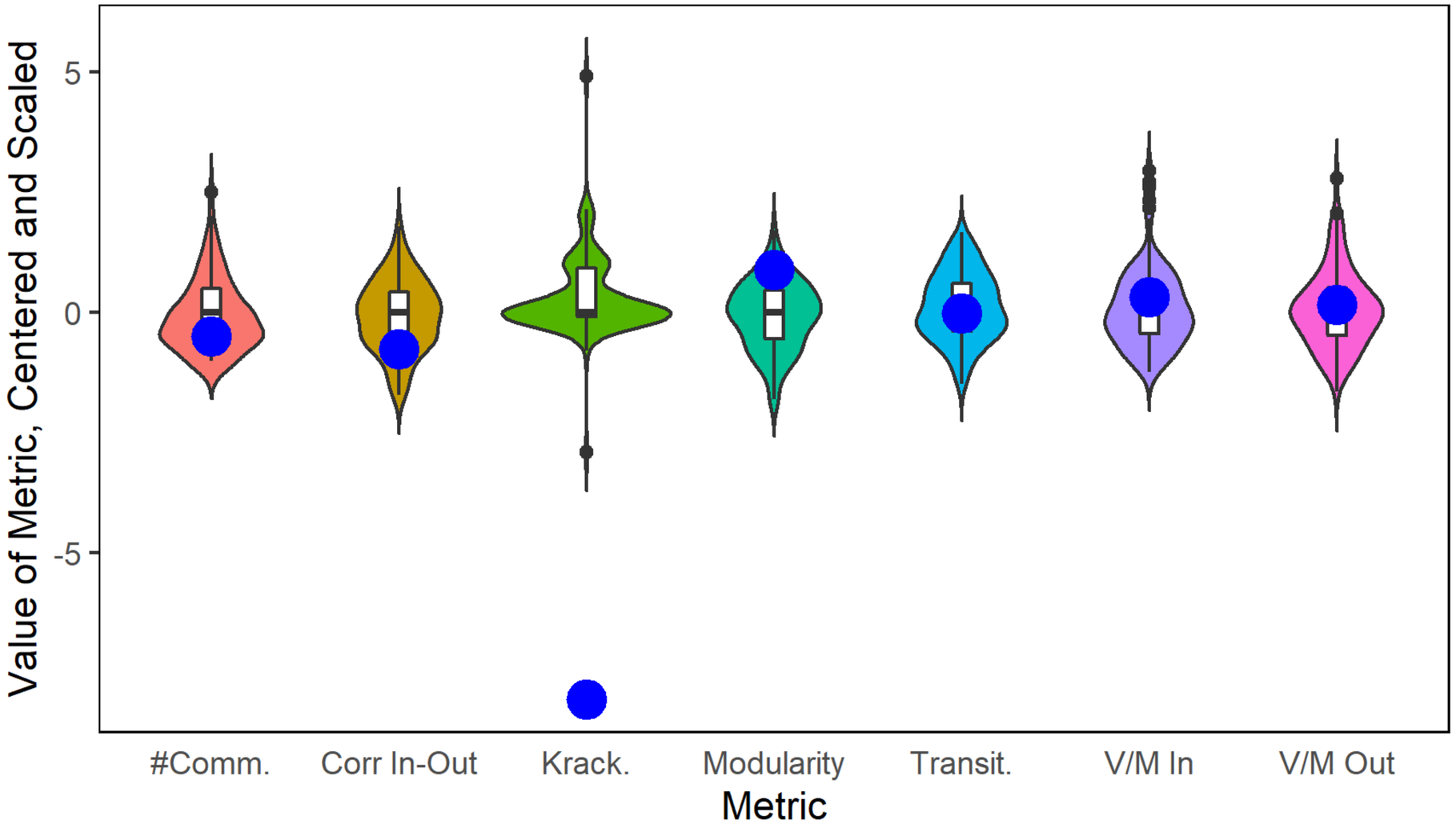
Our model

- Lower-status agents preferentially ask higher-status for advice, not viceversa —> different behavioural rules
- If number of requesting agents meets a threshold, lower-status ties reallocate their requests simultaneously
- In case of reallocation, lower-status choose according to simple heuristics of exploitation (reciprocation) and exploration (transitivity)

SAOM

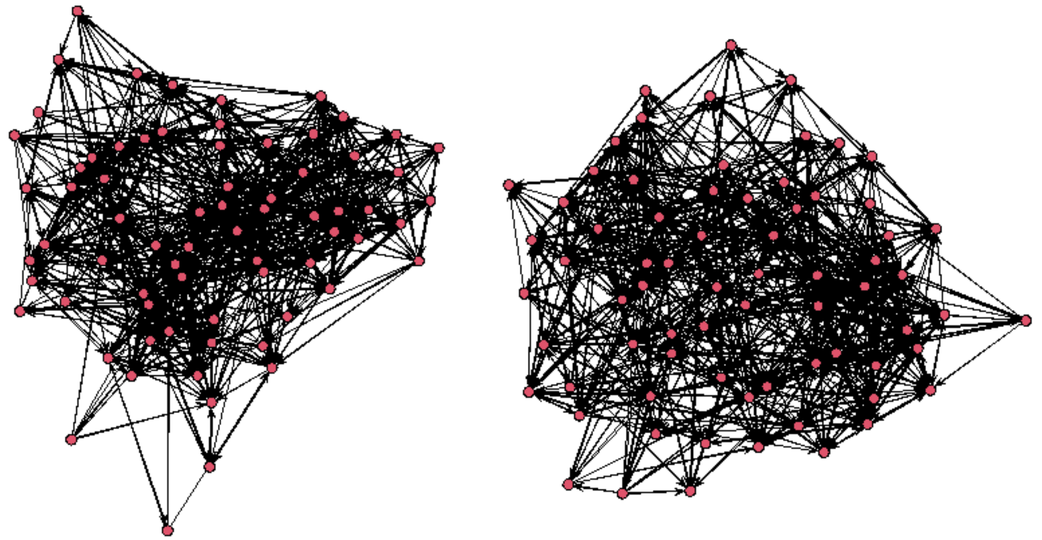
- No heterogeneity (same objective function for all agents
- No simultaneous events
- Information is not limited

Results


Value of Metric, Centered and Scaled
5
0
-5
#Comm.
Corr In-Out
Krack.
Modularity
Transit.
V/M In
V/M Out
Metric

Results

- Generative sufficiency of hypothesized mechanisms
- More realistic assumptions:
  - Limited information
  - Heterogeneous behaviour
  - Simultaneous events
- More parsimonious

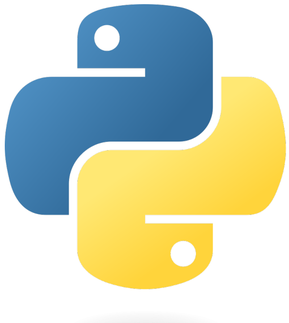


Why ABM

- More flexible modelling
  - More realistic decision-making heuristics
  - More realistic environment (limited information)
  - Heterogeneity of behaviour
- Generative sufficiency: Interest in middle-range theories
- Stochastic parameters can now be estimated

ABM is not difficult!

NetLogo



Python

Behave Summer School on ABM

federico.bianchi1@unimi.it
@federico_fb
@BehaveLab_unimi