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Social Network Analysis in Regional Science

Tom Broekel

Outline

🌐 Networks?

- 🌐 Terminology?

- 🌐 Examples?

🌐 Why networks?

- 🌐 Networks & agglomeration

- 🌐 Networks & spatial dependencies

- 🌐 Networks & spatial interaction

🌐 Conclusion

Networks: Terminology

- Increasing importance in Regional Science & Economic Geography in the last 10-15 years
 - Google Scholar: 3.440 articles (search terms: „social network analysis“ AND „economic geography“)
 - Web of Science: 207 articles (search terms: „social network analysis“ AND „economic geography“)

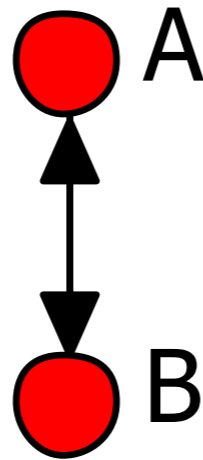
Networks: Terminology

Nodes

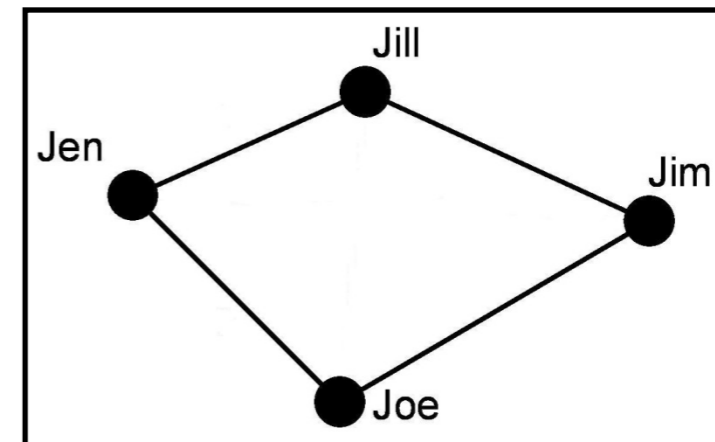
- Node (ICT)
- Vertex (Physics)
- Actor (Sociology)

Links

- Link (ICT)
- Edge (Physics)
- Tie (Sociology)

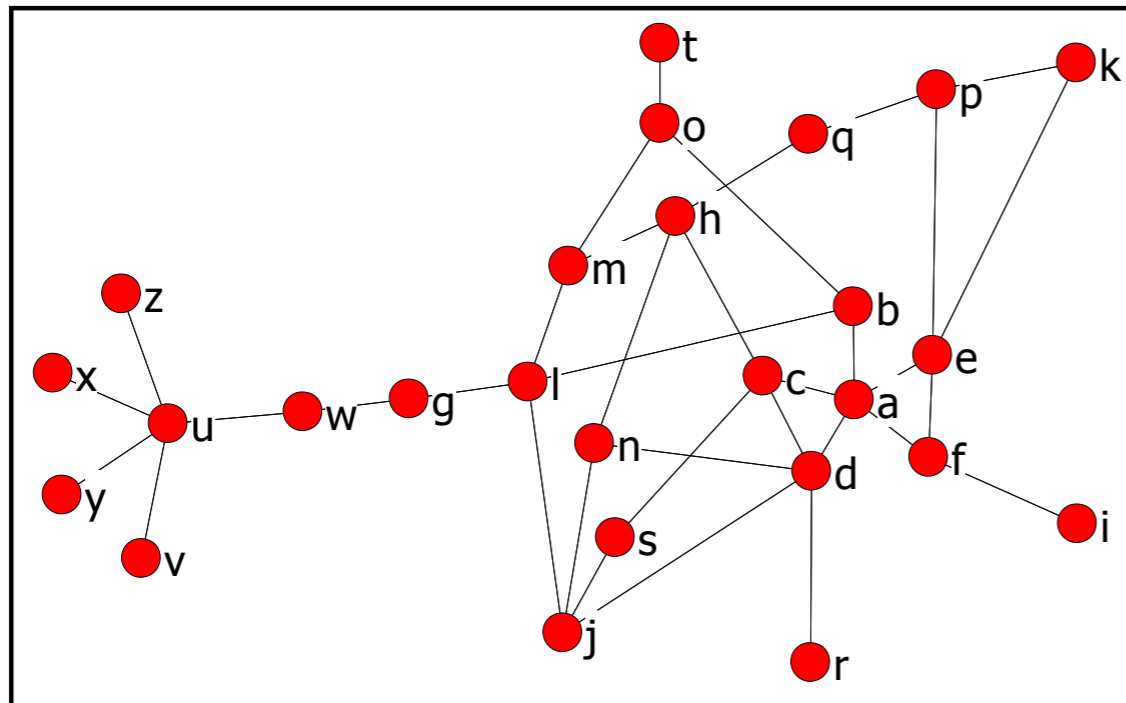


- Graphs visualize existence and values of links



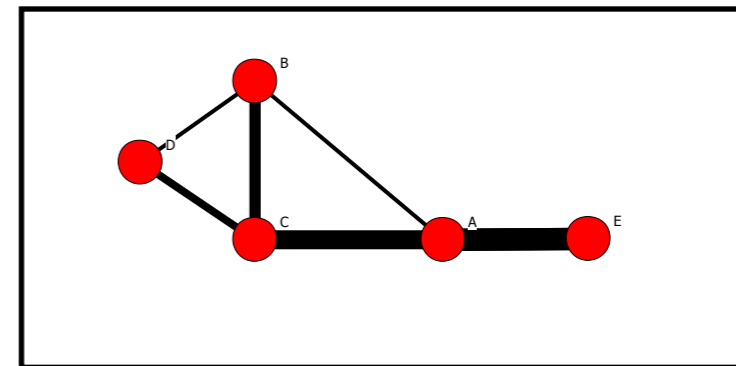
Networks: Terminology

Binary graph



Link exists „1“ or „0“ if not existing

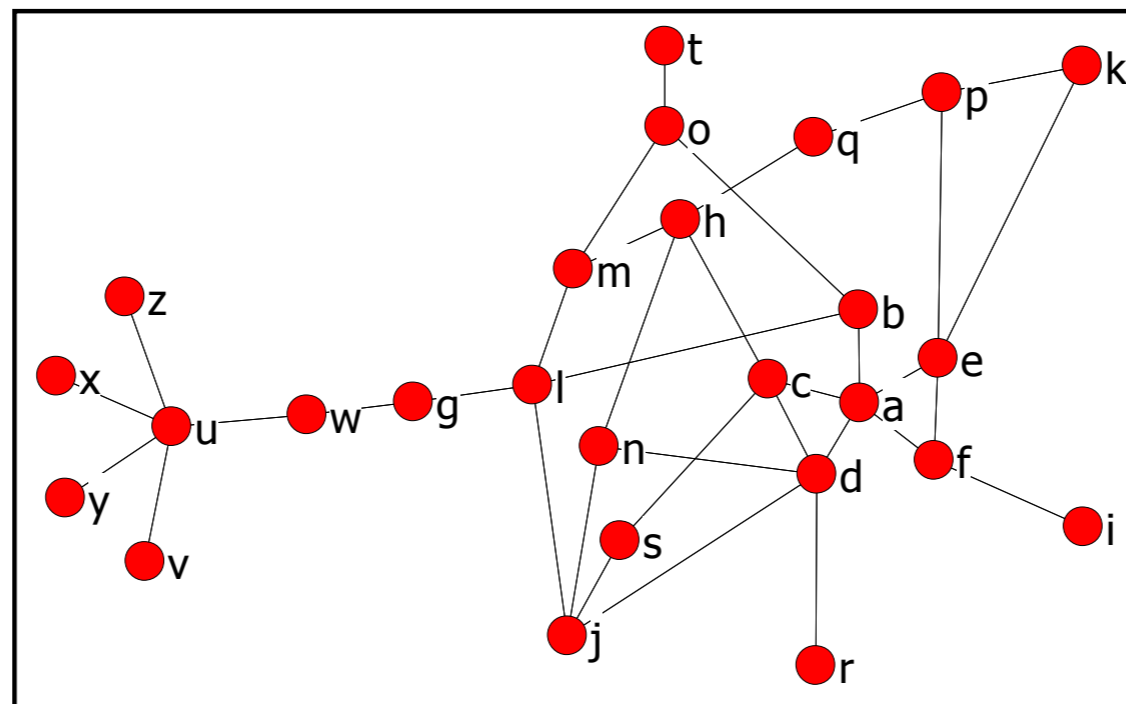
Valued graph



Link has value:
(e.g. distance, strength, frequency
of relation, ...)

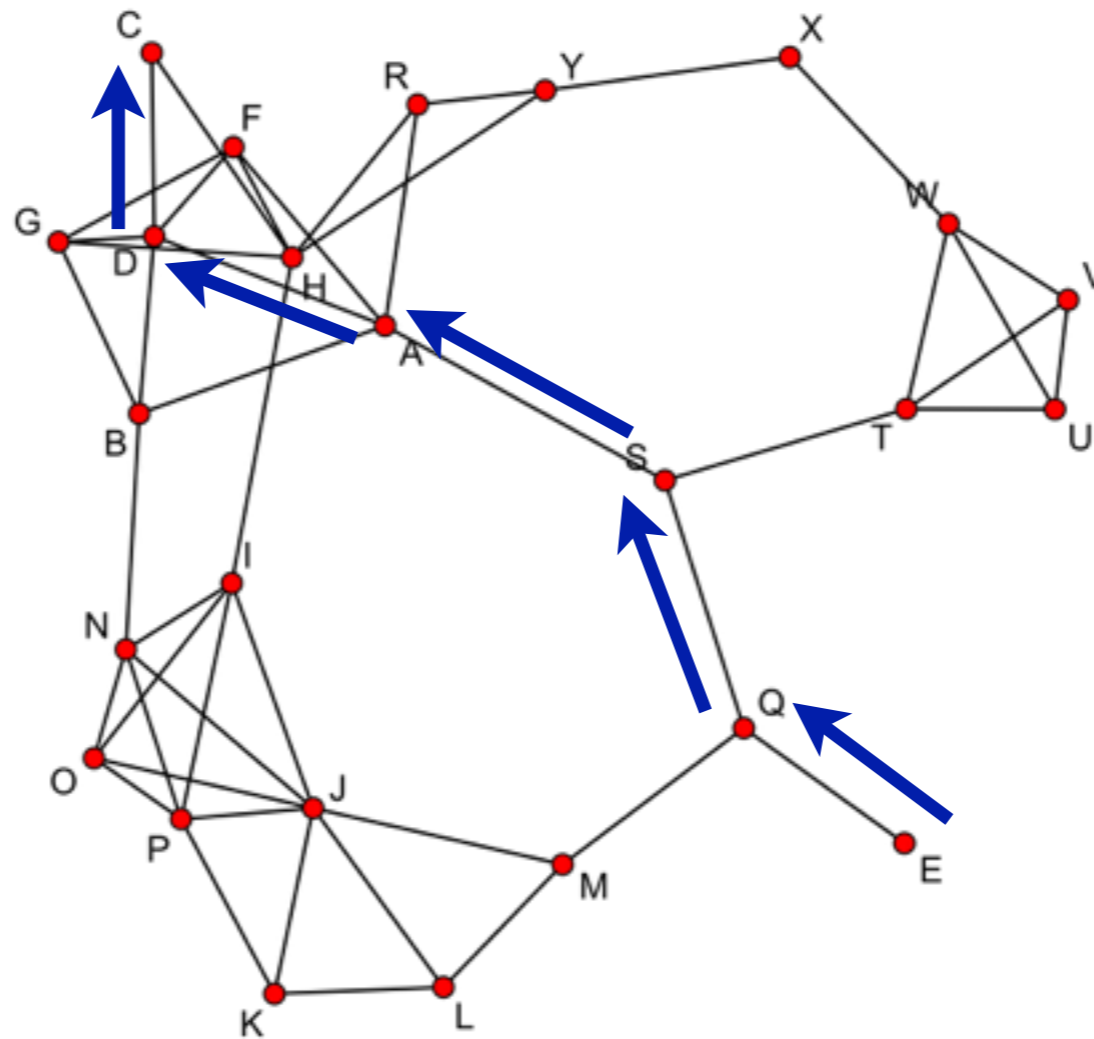
Networks: Terminology

- Position within graphs and length of links (usually) uninformative
- Estimated to maximize visibility



Networks: Terminology

🌐 Geodesic distance / shortest path



Networks: Terminology

- Social network analysis: *„the process of investigating social structures through the use of network and graph theories“* (Wikipedia 2016)
 - „Social“ refers to heritage of analysis
 - 3 levels of analysis
 - **Nodes:** Importance of nodes (individuals, firms, regions) & impact, ...
 - **Links (dyad / pair of actors):** Link importance & impact, determinants of link formation, ...
 - **(Complete) network:** Description / change / impact of network (system) structure ...


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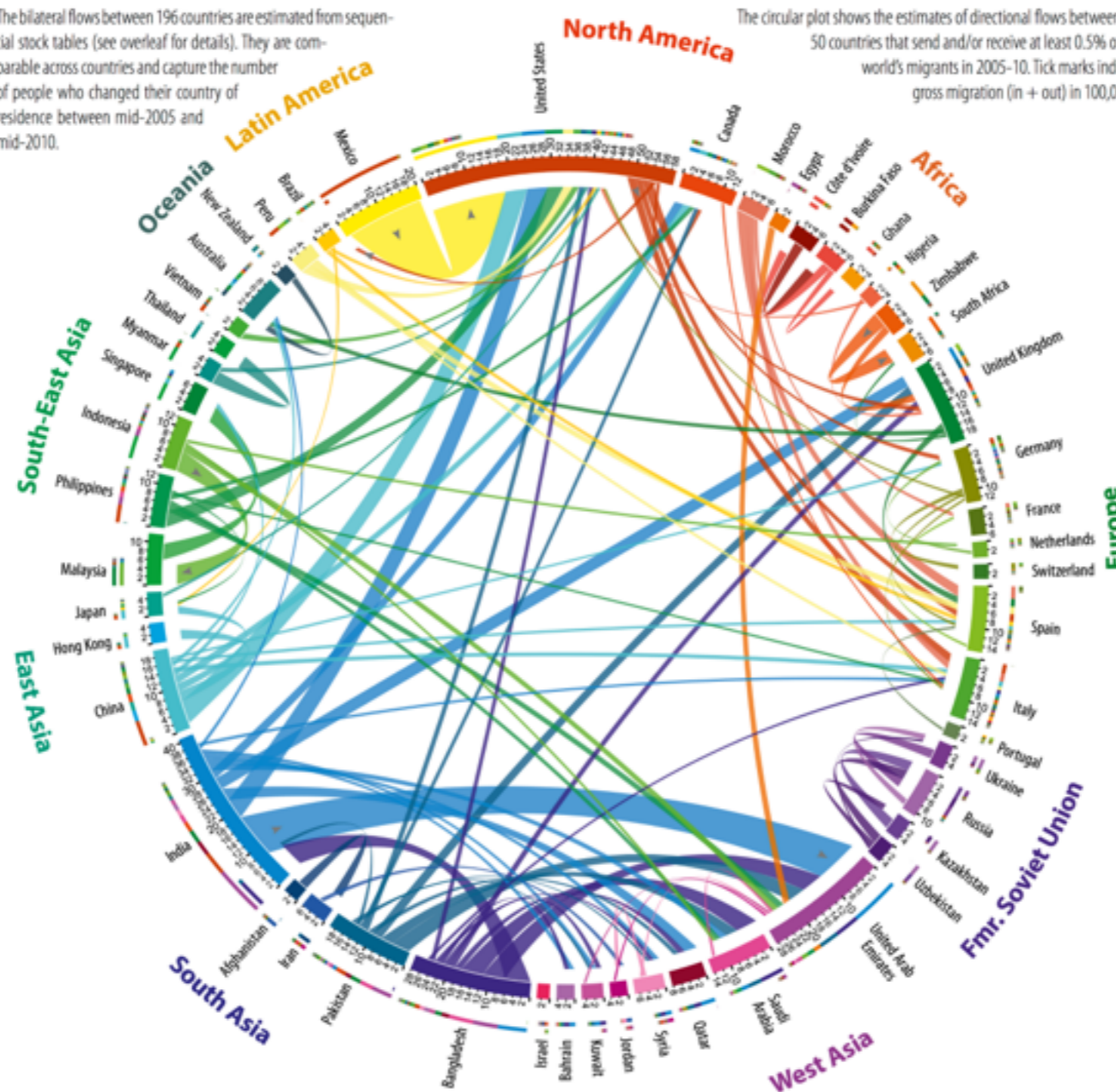
Networks: Examples



Networks: Examples

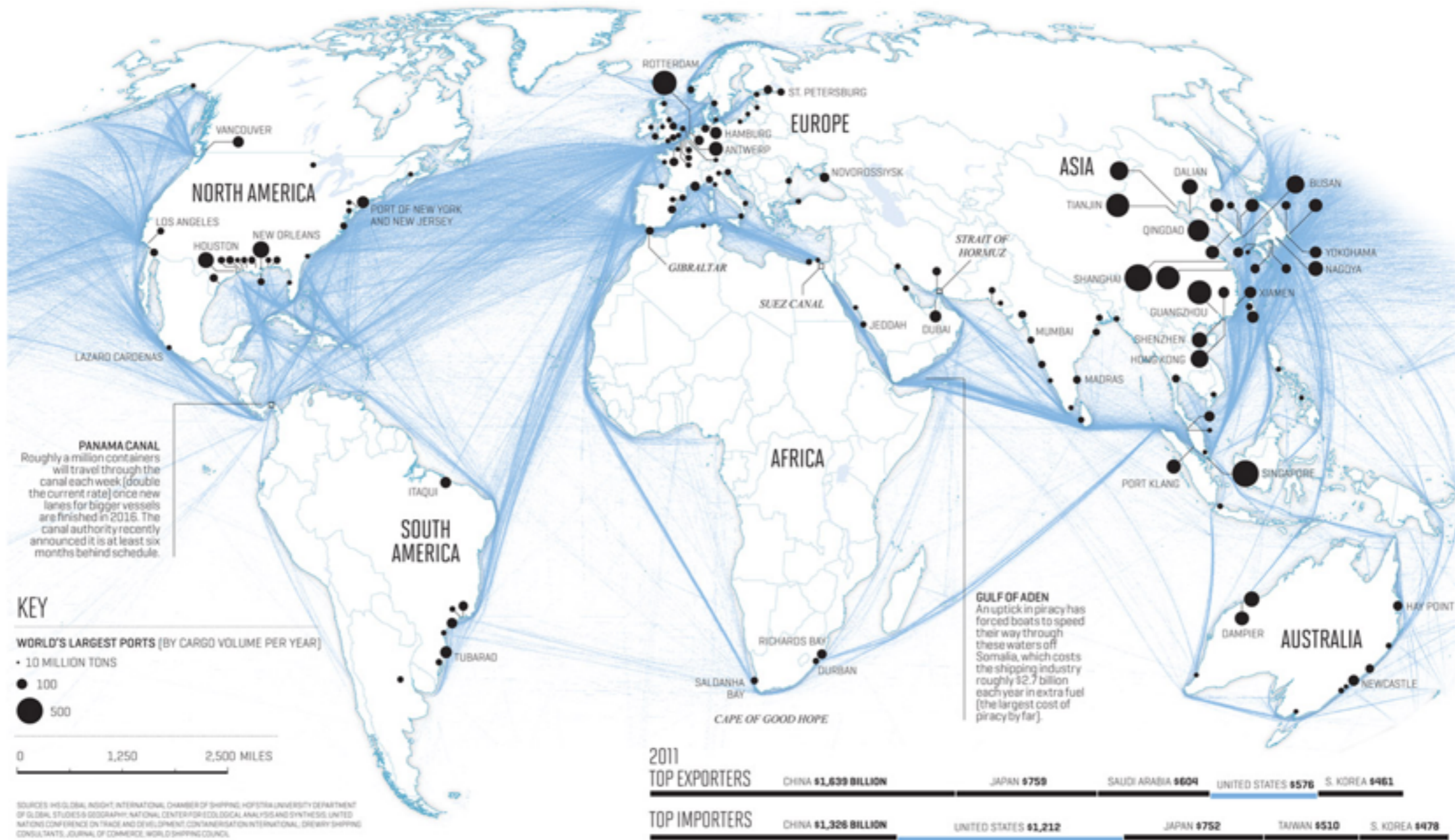
The bilateral flows between 196 countries are estimated from sequential stock tables (see overleaf for details). They are comparable across countries and capture the number of people who changed their country of residence between mid-2005 and mid-2010.

The circular plot shows the estimates of directional flows between the 50 countries that send and/or receive at least 0.5% of the world's migrants in 2005-10. Tick marks indicate gross migration (in + out) in 100,000's.



Global migration network
@ Tom Murphy, 2014

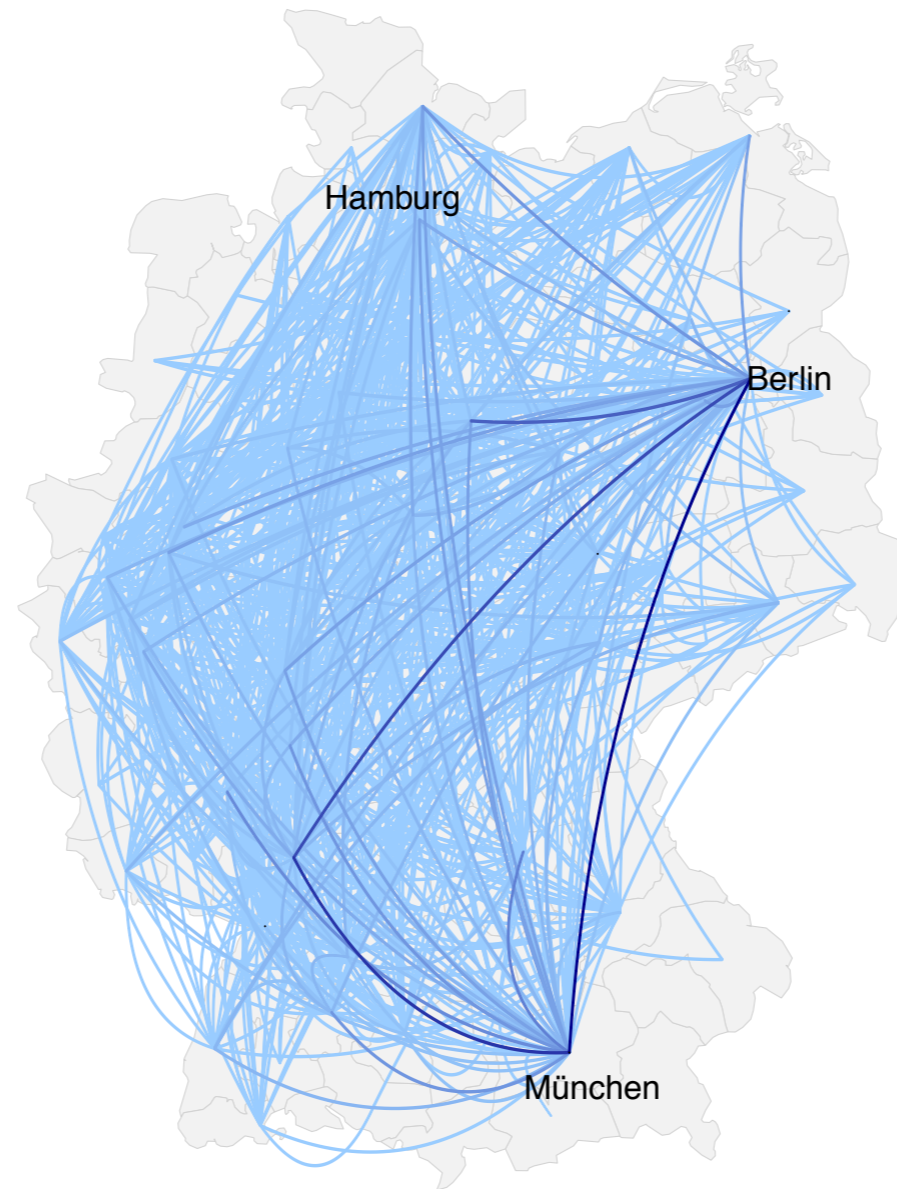
Networks: Examples



Global shipping network
@ Nicolas Rapp, 2012

Networks: Examples

Domestic subsidized R&D cooperation biotech, 2003–2005



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Networks & Agglomeration: Intro

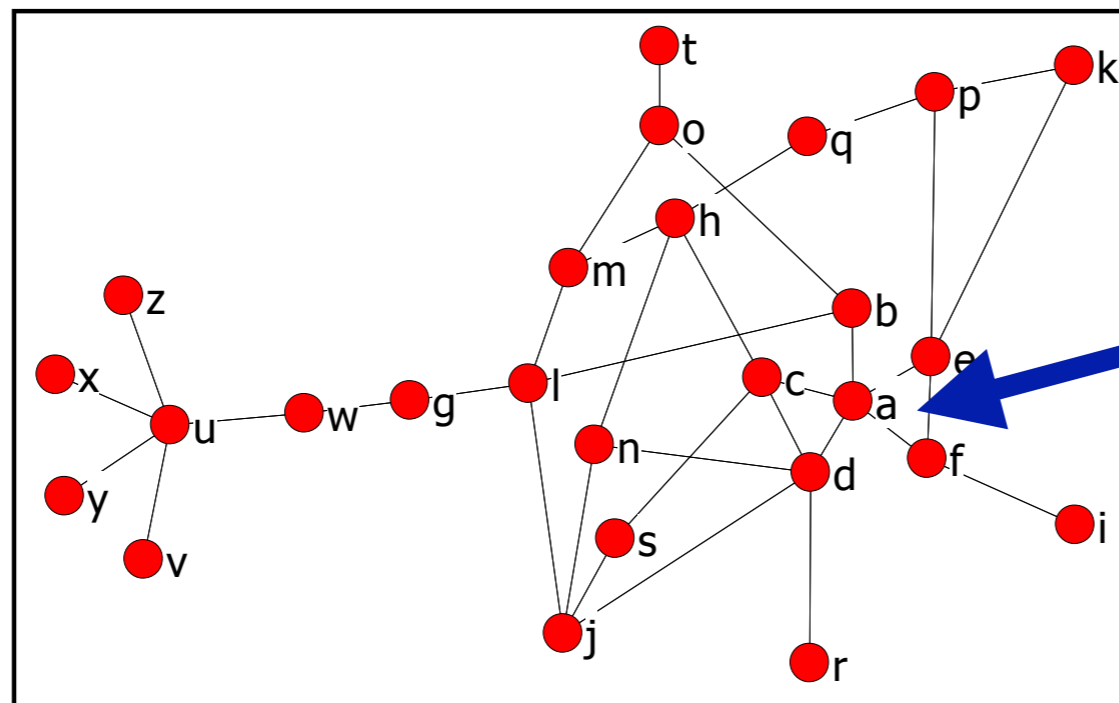
- Castells (1996), Ter Wal & Boschma (2009)
 - *"being in the right place is what counts" vs "being part of a network is crucial"*
- Opening the black box of regions & agglomeration (Giuliani & Bell 2005, Ter Wal & Boschma 2007, Plum & Hassink 2011, Broekel & Boschma 2012, ...)
 - Traditional RS analysis equates agglomeration with participation in local interaction (spillover, labor market, resource sourcing, ...)
 - Network analysis zooms into agglomeration and looks at actual interaction

Networks & Agglomeration: SNA approach

- **Aim:** Analyze interactions between actors within same region (extended to inter-regional links)
- **Data:** primary (interviews) or secondary (patents, labor flows, ...)
- **Approach:** static and dynamic
- **Central methods**
 - Description & qualitative analysis
 - Quantifying actors' network positions to construct variables for regression analyses ➔ networks & spatial dependencies
 - Comparison of network structural characteristics (few attempts)

Networks & Agglomeration: SNA approach

- Degree centrality = number of links
 - Strong „local“ embeddedness: high exposure to local flows
 - Robust embeddedness: resilient against shocks / change in network



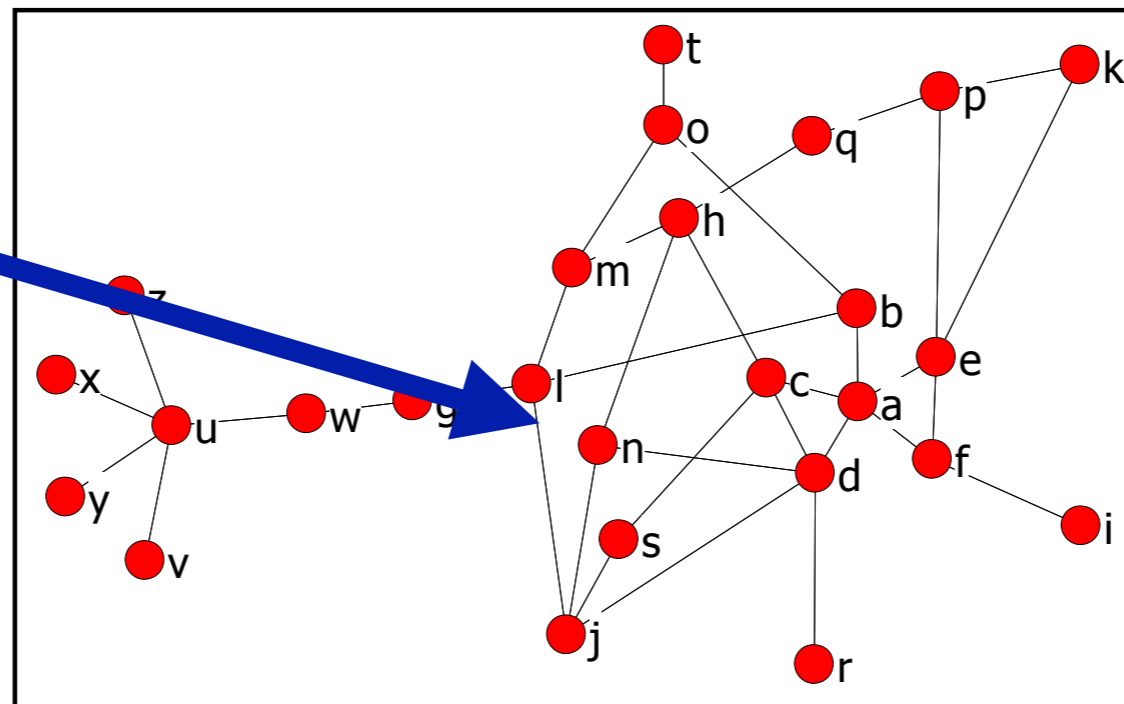
Highest degree
centrality
 $C_D(n_i) = d(n_i)$

Networks & Agglomeration: SNA approach

- Betweenness centrality = number of shortest paths through nodes
 - Strong „global“ embeddedness: high exposure to global flows
 - Brokerage position gives control over global flows (e.g. gatekeeper)

Highest betweenness centrality

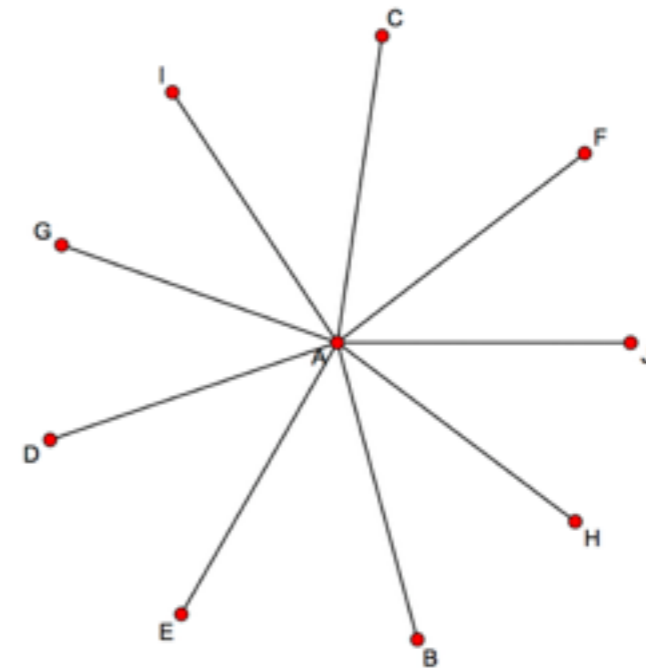
$$C_B(n_i) = \sum_{j < k} \frac{g_{jk}(n_i)}{g_{jk}}$$



Networks & Agglomeration: SNA approach

System level analysis

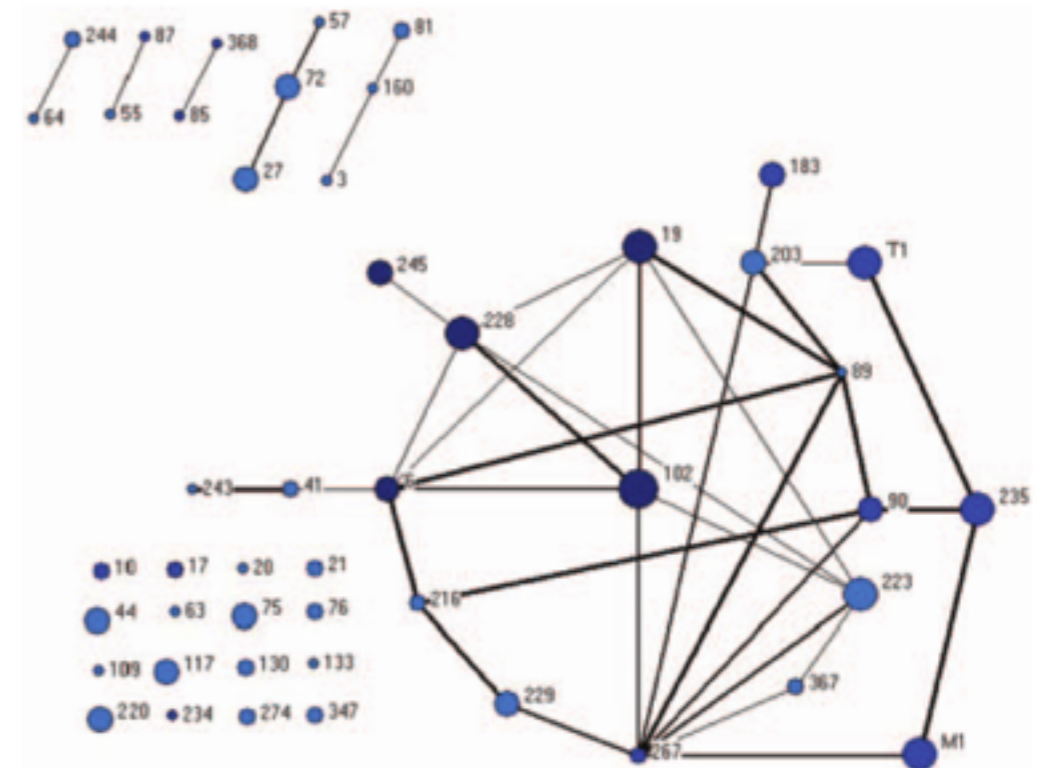
- Centralization (degree, betweenness, ...)
- Dominance of actors in network
- Ease of flows in networks
- Resilience of networks to shocks
- ...



Networks & Agglomeration: Findings

Central findings (Powell et al. 1995, Ter Wal & Boschma 2007, Graf & Henning, 2009, Maggioni et al. 2014)

- Agglomeration \neq interaction
- Strong heterogeneity in local embeddedness
- „Position“ in local networks matter
- Structure of networks varies between agglomerations



The size of the nodes denotes size of the enterprises (allocated to categories)
The thickness of the lines denotes "the importance of the network links for innovation" as indicated by the enterprises themselves
The colours denote producers of the following footwear categories:

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Networks & spatial dependence: Intro

- Tobler's first law of geography: *„Everything is related to everything else, but near things are more related than distant things.“*
 - Organizations and regions embedded in spatial systems
 - Empirical observations not independent but spatially related
- Spatial regression analysis
 - Consideration of spatial lags and spatially correlated errors
 - Modeling of spatial dependencies through spatial weights matrices

Networks & spatial dependence: Problem?

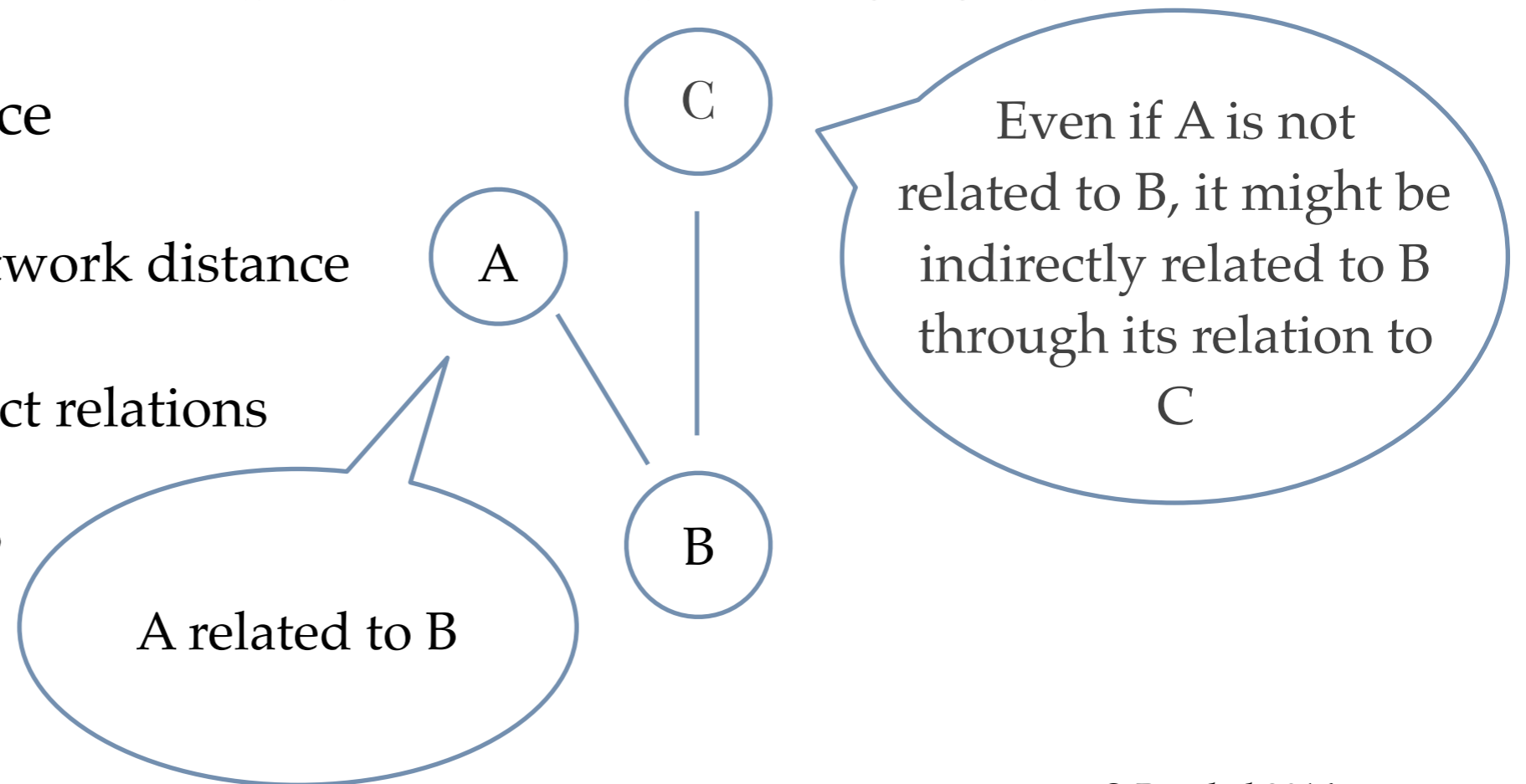
● Spatial dependence

- Spatial relation as „catch all“ relation
- Spatial dependence is **direct** proportional to pairwise geographic distance

● Network dependence

- Proportional to network distance
- Builds upon indirect relations

● Which one matters?

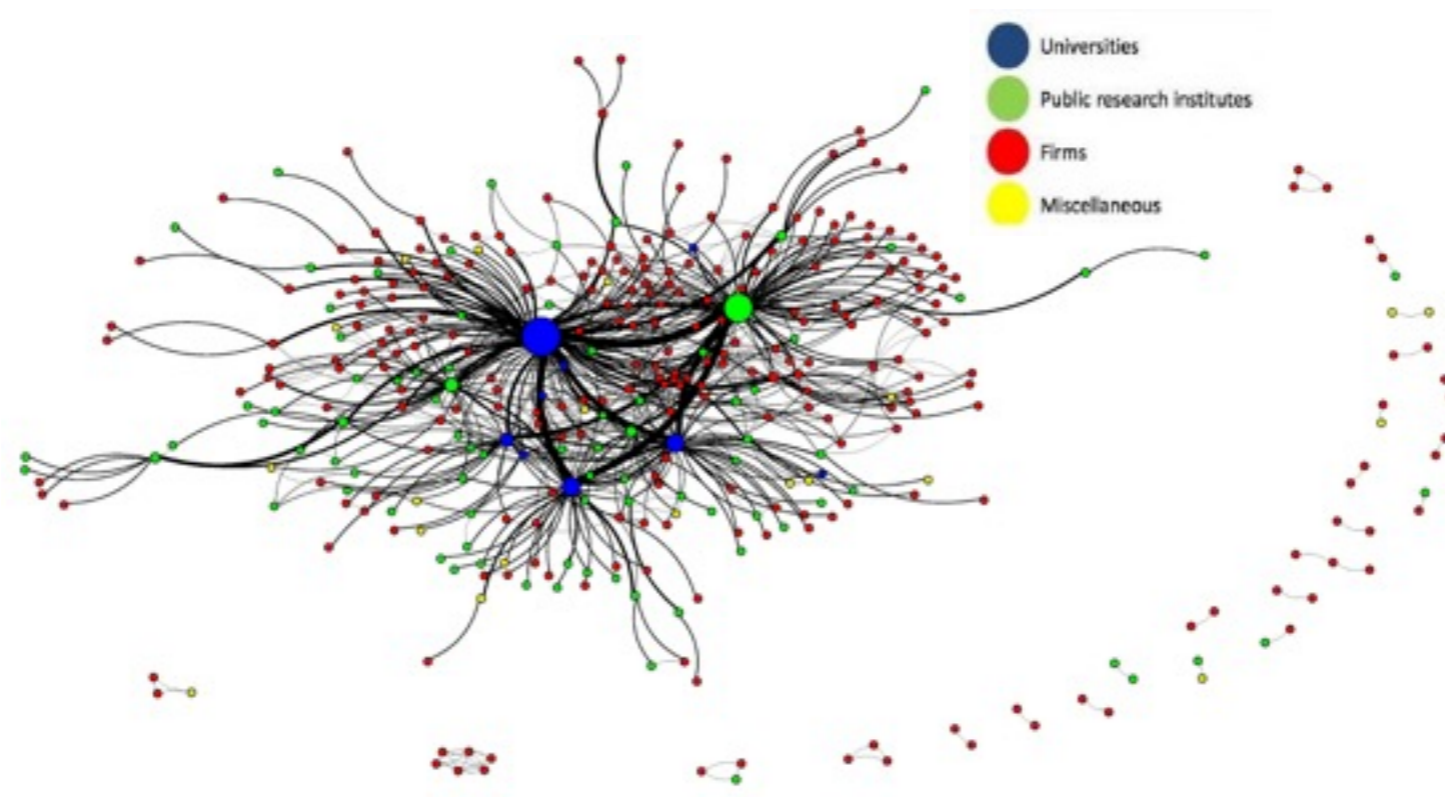


Networks & spatial dependence: SNA approach

- **Aim:** Disentangling spatial from network dependencies
- **Data:** Secondary (roads, collaboration, migration, ...)
- **Approach:** Static and dynamic (stronger focus on statics)
- **Central methods**
 - Construction of network variables (embeddedness, network structure)
 - Consideration of network dependencies in statistical analyses
 - Network autocorrelation regression (Leenders 2002)
 - Spatial regression models with extension of additional (network) weight matrix (Lacombe 2004, LeSage & Pace 2009)

Networks & spatial dependencies: Findings

- Central findings (comparatively little research) (Powell et al. 1995, Maggioni et al. 2014, Broekel et al. 2015)
 - Network dependencies appear weaker than spatial dependencies in context of knowledge networks and regional innovation
 - Position in inter-regional networks influences firms' and regions' performance



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Networks & spatial interaction: Intro

● Tobler's first law of geography

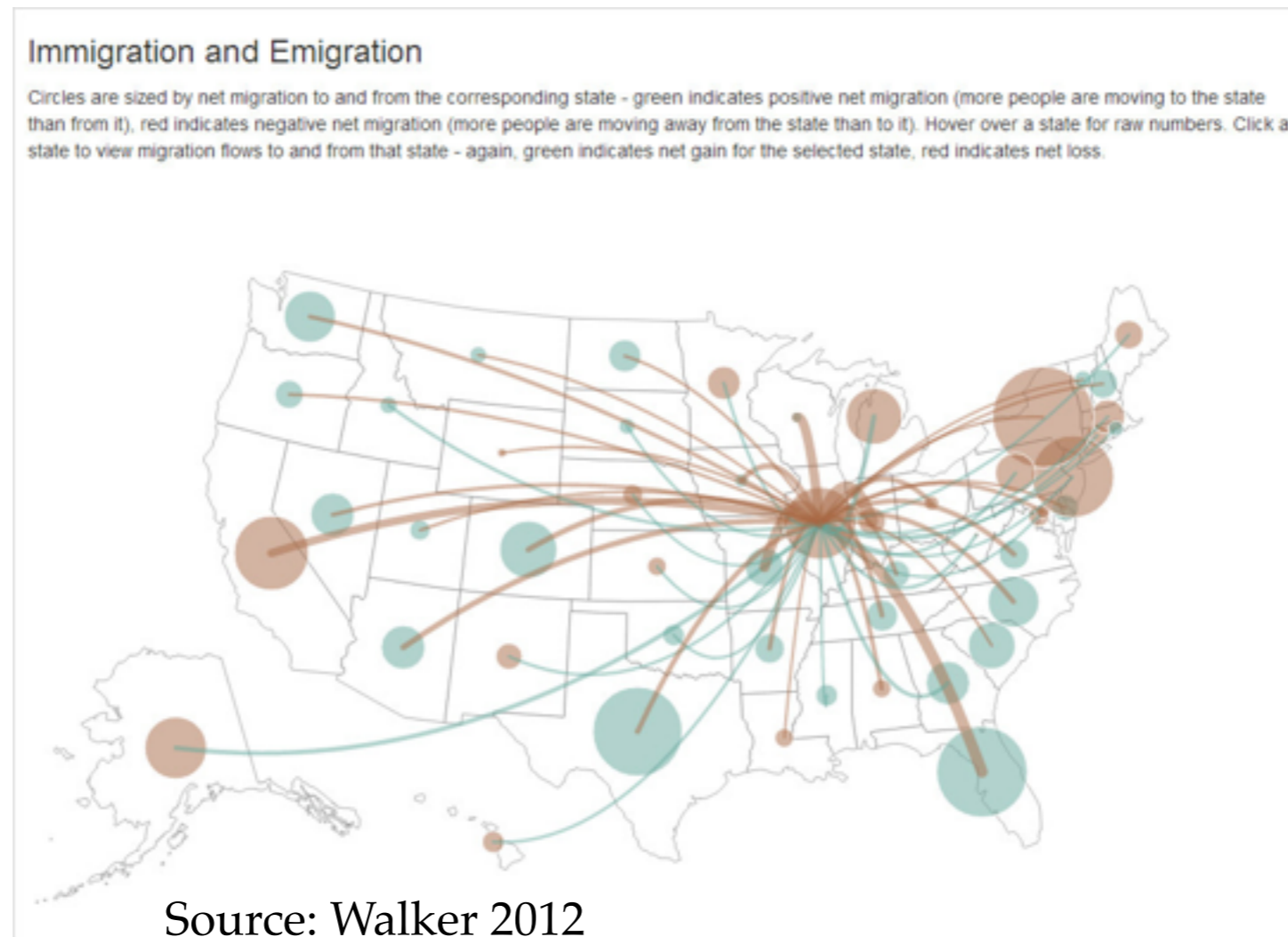
- *„Everything is related to everything else, but near things are more related than distant things.“*

● Boschma (2005)

- *„We argue that the importance of geographical proximity cannot be assessed in isolation, but should always be examined in relation to other dimensions of proximity [social, technological, institutional, ...]“*

Networks & spatial interaction: Intro

- What impacts the intensity of relations between individuals / organizations / regions in space?
- Impact of geography on interaction systems, e.g. trade, knowledge flows, migration, ...



Networks & spatial interaction: Problem?

Traditional analysis

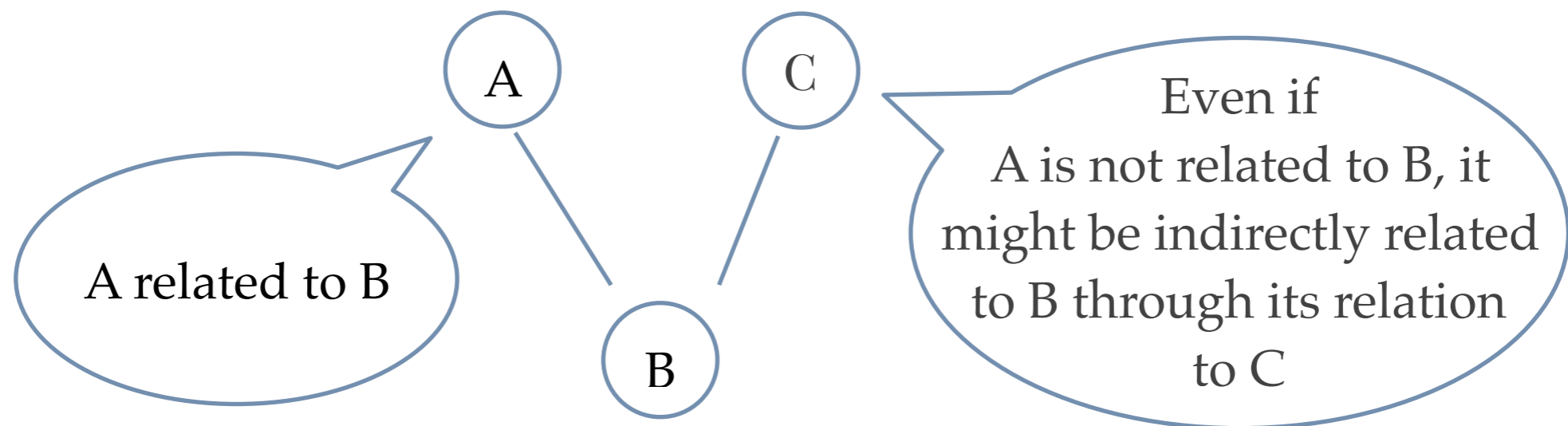
- Focus on variance & change of relations between individuals / organizations / regions (Ponds et al. 2007, Fratianni 2009, Scherngell & Barber 2009)
- Empirical approach inspired by Newton's gravity model
 - Application of spatial interaction models - regression analysis explaining existence of network links or their values
 - Characteristics of regions (attributional variables) and distances (relational variables) explain existence of and variance in relations
 - Limited possibilities to consider (network) structural dependencies**

Networks & spatial interaction: Problem?

Main structural dependencies

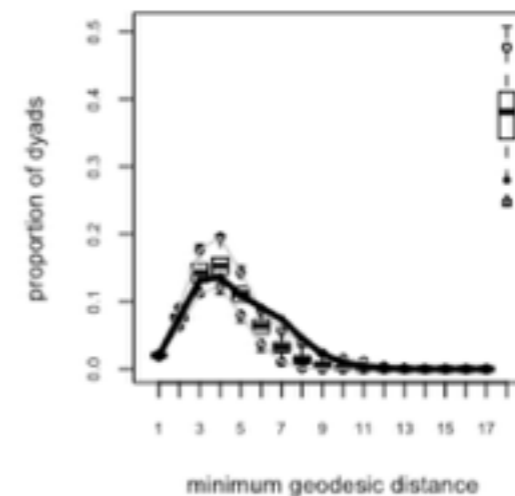
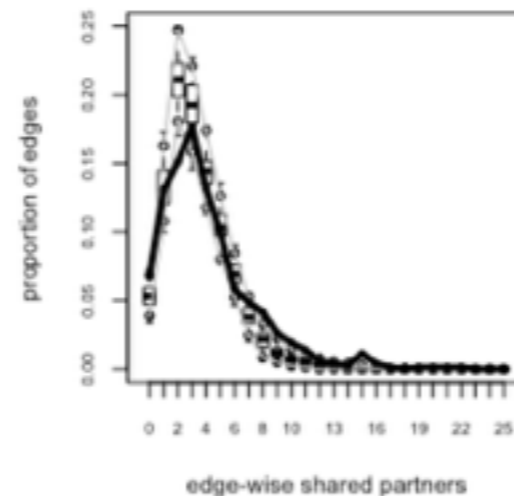
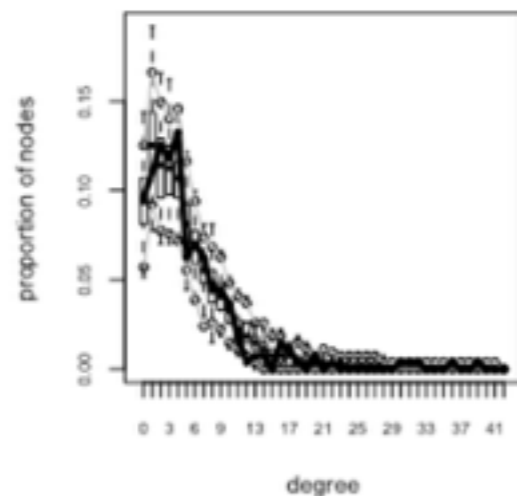
- **Triadic closure:** A intensifies relation with B because both are related to C
- **Preferential attachment:** A intensifies relation with B because B is central (local / global) in network
- **Multiconnectivity:** A intensifies relation with B because it is related to B in multiple (indirect) ways

● ...



Networks & spatial interaction: SNA approach

- **Aim:** Explain change in existence and intensity of relations
- **Data:** primarily secondary data (patents, publications, migration, trade,...)
- **Approach:** static and dynamic (focus on dynamics)
- **Methods**
 - ERGM (static), SAO & STERGM (dynamic)



Networks & spatial interaction: SNA approach

- Exponential random graph models (ERGM, STERGM), and stochastic actor-oriented models (SAOM) (Robins et al. 2007, Snijders et al. 2001)
 - Modeling of entire system (network) evolution as time continuous Markov chain dependences
 - Combination of regression and simulation techniques
 - Fitting of model reproducing dynamics to get from network in t to network in $t+1$
 - **Attribute** (node), **relational** (dyad), and **structural dependencies** (network / system) variables possible
 - **Co-evolution** of attribute variable (R&D intensity) with network structure

Networks & spatial interaction: Findings

- Central findings (Balland 2012, Ter Wal 2014, Broekel & Hartog 2012, Juhász & Lengyel 2016)
 - Structural dependencies highly relevant for network evolution (in particular triadic closure)
 - Differences between link formation and dissolution
 - Geographic distance (and other proximities) remain crucial even when controlling for structural dependencies



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- 🌐 What can network analysis do for regional scientists?
 - 🌐 **New perspective:** Opening spatial container
 - 🌐 **New variables:** Accounting for variance in spatial embeddedness
 - 🌐 **New level of analysis:** Investigating (spatial) systems of interaction
 - 🌐 **New dependencies:** Considering indirect relations
 - 🌐 **New methods:** Explaining interactions in space with superior methods
 - 🌐 **New figures:** Adding network visualizations

Conclusion

🌐 Crucial issues

- 🌐 Frequently just **descriptive** / visual
- 🌐 **DATA!** Lack and limitations of data: dominance of cross-sectional primary and longitudinal secondary (patent and joint projects) data, no official statistics
- 🌐 Economic **relevance?!**
- 🌐 **Methods** not (yet) fully developed
 - 🌐 Spatial & relational dependencies
 - 🌐 Change in relations & evolution of networks: Network evolution (valued networks!)
 - 🌐 Simultaneous consideration of multiple (spatial & network) dependencies
 - 🌐 Large networks (computational issues and statistics)

Conclusion

🌐 What is next?

- 🌐 Actual diffusion within networks?
- 🌐 Explanation for structural variance over time and space?
- 🌐 Impact of policy on networks?
- 🌐 Different types of networks and their relation?
- 🌐 Co-evolution of networks with spatial structures?

Thank you for your attention

Tom Broekel

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- Ter Wal & Boschma (2009) Applying social network analysis in economic geography: framing some key analytic issues. *Annals of Regional Science*, 43(3):739-756
 - Broekel & Balland & Burger & van Oort (2014) Modeling knowledge networks in economic geography: a discussion of four methods. *Annals of Regional Science*, 53:423-452