Knowledge in socio-economic systems

Insights from collaboration, mobility, and data-driven models

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Knowledge in our world

- Knowledge assets reflect the market value of many leading firms
- The creation of new knowledge makes the way to scientific progress
- Knowledge is increasingly an outcome of collaborative efforts:
  1. rise of R&D alliances
  2. dominance of teams in scientific production
  3. Big Science (LHC, LIGO, EHT)

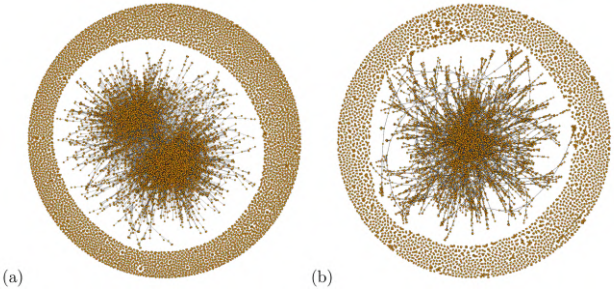
Key drivers

- social and technical capitals $\rightarrow$ R&D alliances among firms
- scientists' expertise and "their (social) centrality" $\rightarrow$ scientists' productivity and impact

OECD, (2013); Kuhn (1962); Wuchty et al., (2007); Hagedoorn, J. (2002); Walsh (1935); Mincer (1958); Schultz (1989); Stewart and Ruckdeschel (1998); Walker et al, (1997), Gulati and Gargiulo (1999), Stuard and Podolny (1996)

Unified vision: Collaboration networks in Industry and Science

- (a) **R&D alliances** and
  (b) **co-authorship activities** are different processes …
- but they share similarities:
  - emergent network structures
  - knowledge is encoded:
    firms → patents
    scientists → publications

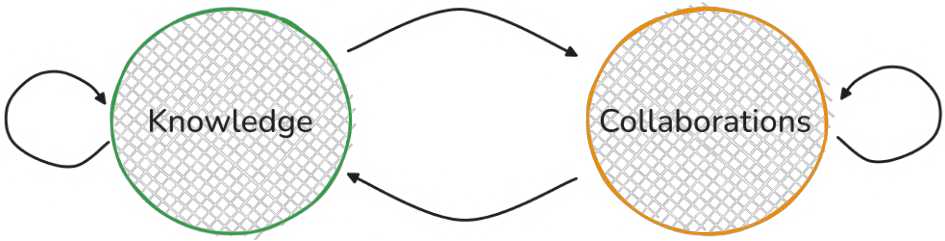


Key ingredients

- Agents form networks
- Co-produced knowledge artifacts

Tomasello, M. V., Vaccario, G., & Schweitzer, F. (2017). Data-driven modeling of collaboration networks: A cross-domain analysis. *EPJ Data Science*

Feedback loop between knowledge and collaboration

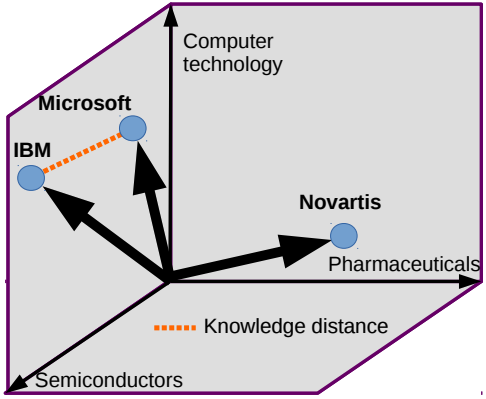


Questions

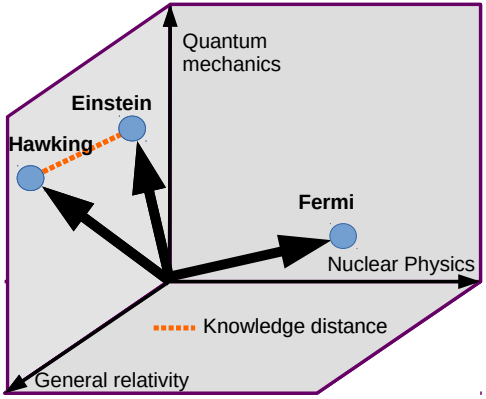
1. How does **knowledge** influence **collaborations**?
2. How do **collaborations** influence **knowledge**?
3. How do collaborations influence new collaborations?
4. How does existing knowledge influence new knowledge?

Vaccario, G. (2019). The structure, exchange, and transfer of knowledge in socio-technical systems. *PhD Thesis*

Embedding Firms and scientists in a knowledge space



- 14K firms & 6 Million patents
- filed in 35 **ISI-OST-INPI fields**



- 100K scientists, 300K publications
- classified with 67 **PACS codes**

Vaccario, G., Tomasello, M. V., Tessone, C. J., & Schweitzer, F. (2018). Quantifying knowledge exchange in R&D networks. *Journal of Evolutionary Economics*
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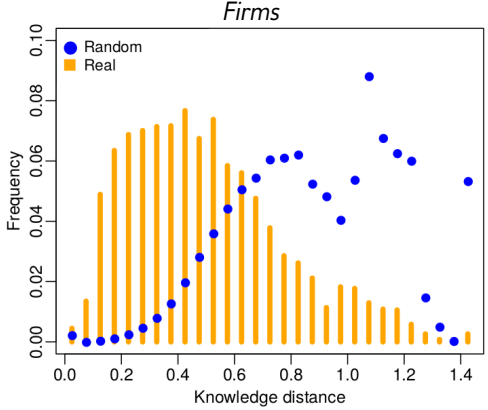
Knowledge influences collaborations differently across domains



- *Firms* prefer collaborators around an *optimal knowledge distance*

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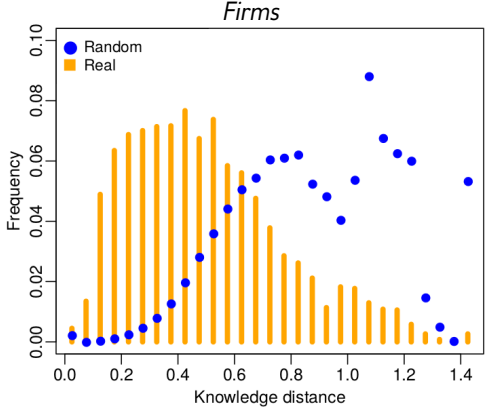

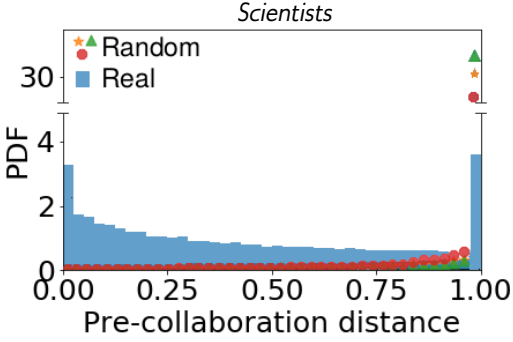

- *Firms* prefer collaborators around an *optimal knowledge distance*
- *Scientists* prefer collaborators with either very *similar* or very *different knowledge*

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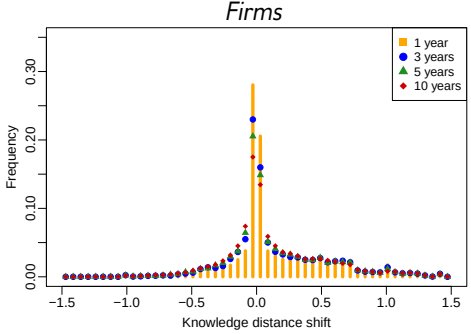
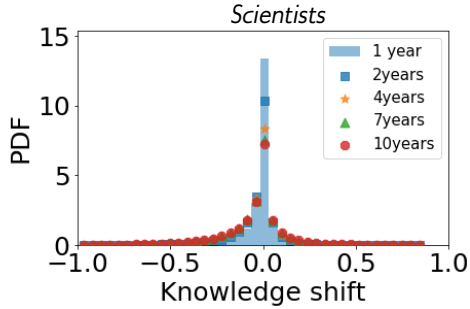
Collaborations influence knowledge in unexpected ways

- **Knowledge shifts = knowledge distance after collaboration - knowledge distance before**
  - **Positive** values → collaborators have more **different** knowledge
  - **Negative** values → collaborators have more **similar** knowledge





- **More negative** values → Majority of collaborators share more similar knowledge
- **However**, still many collaborations lead to more different knowledge

Tomasello, M. V., Tessone, C. J., & Schweitzer, F. (2015). The effect of R&D collaborations on firms' technological positions. *IFKAD*.
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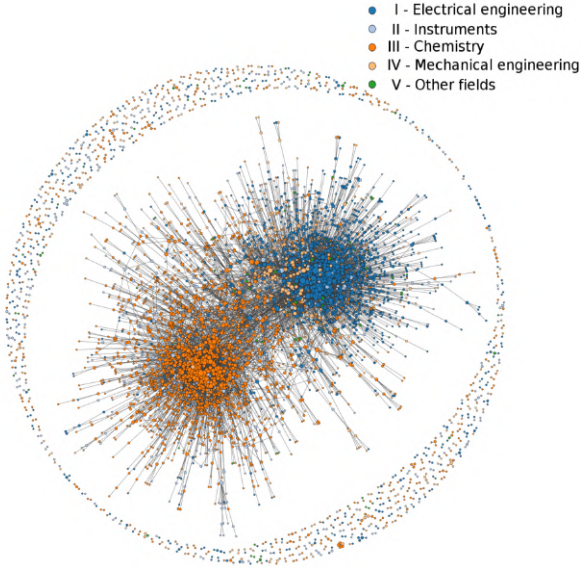
How to model the interplay between knowledge and collaborations

- **Data-driven agent-based model** to reproduce co-evolution
  - **formation** of the R&D network
  - **knowledge exchange**
- **Network perspective**
  - firms → nodes
  - collaborations → links



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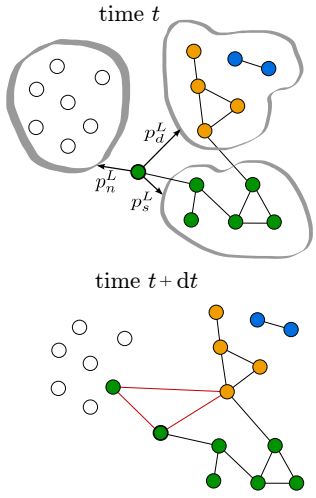
Old collaborations influence new ones: Label propagation model

- Existing collaborations define
  - firm's social capital
  - and influence new collaborations

- Firms $\rightarrow$ N agents
  - Firm's social capital $\rightarrow$ label
  - new collaboration $\rightarrow$ link formation
  - link formation probabilities depend on labels
    - with same label: p_s^L
    - with different label: p_d^L
    - with no label: p_n^L



Tomasello, M. V., Perra, N., Tessone, C. J., Karsai, M., & Schweitzer, F. (2014). The Role of Endogenous and Exogenous Mechanisms in the Formation of R&D Networks. *Scientific Reports*

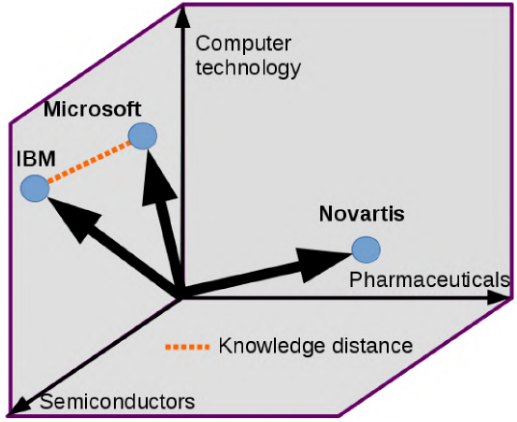
Tomasello, M. V., Burkholz, R., & Schweitzer, F. (2017). Modeling the formation of R&D alliances: An agent-based model with empirical validation. *Economics*

Knowledge distances decrease: Modelling knowledge exchange

- **knowledge position**
  - patent portfolio
- Collaborating firms exchange knowledge

$\Rightarrow$ **approach** in the knowledge space

$$\dot{\mathbf{x}}_i(t) = \mu \sum_{j \in \mathcal{N}_i(t)} [\mathbf{x}_j(t) - \mathbf{x}_i(t)]$$



Tomasello, M. V., Tessone, C. J., & Schweitzer, F. (2016). A model of dynamic rewiring and knowledge exchange in R&D networks. *Advances in Complex Systems*
Vaccario, G., Tomasello, M. V., Tessone, C. J., & Schweitzer, F. (2018). Quantifying knowledge exchange in R&D networks. *Journal of Evolutionary Economics.*

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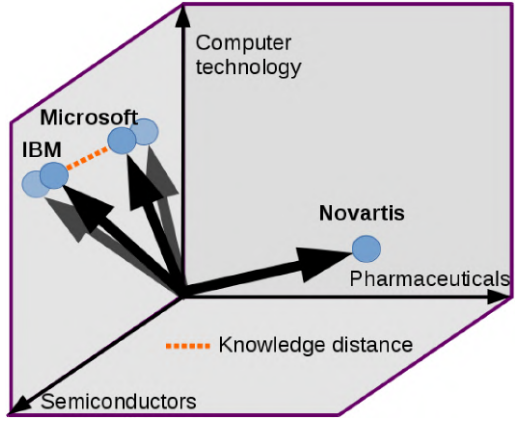

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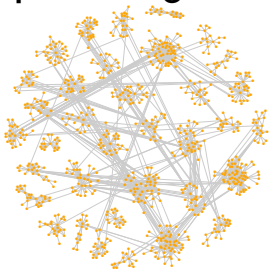
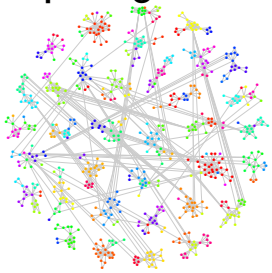
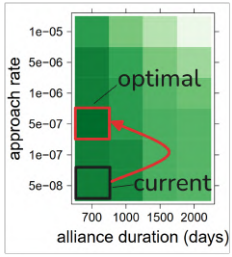
Reproducing, learning, and proposing interventions



empirical



simulated



what-if analysis

Data-driven agent-based models

- **Reproduces** the empirical network and positive and negative knowledge shifts
- **Learns** about the current state using interpreting parameters values
- What-if analysis →**Proposes** interventions to improve current state

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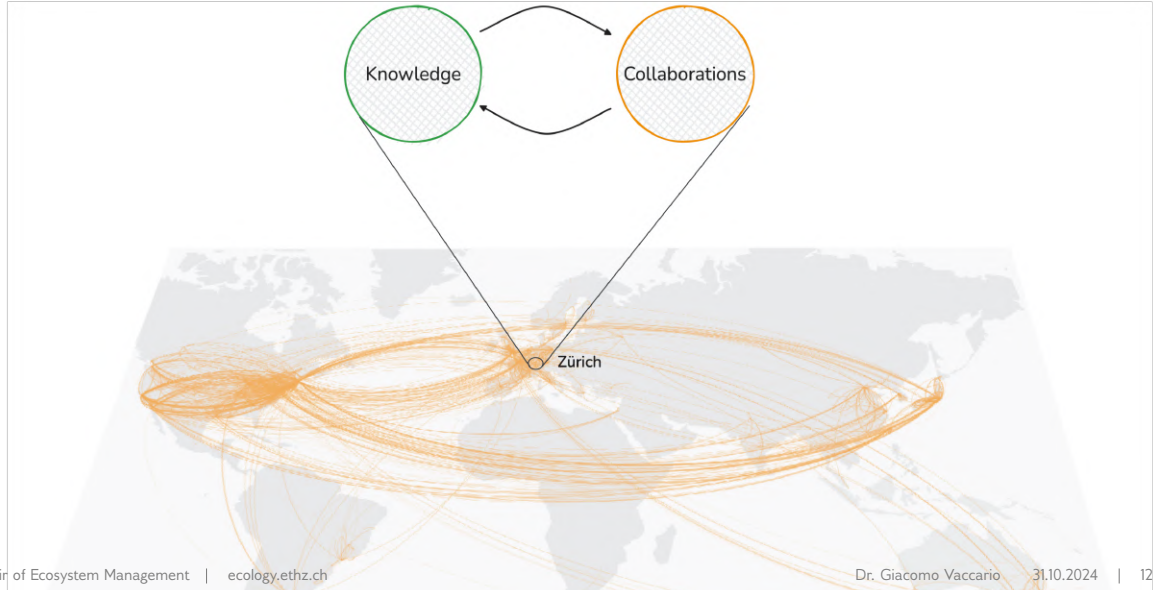
Collaborations and knowedge in the geographic space



Collaborations and knowedge in the geographic space

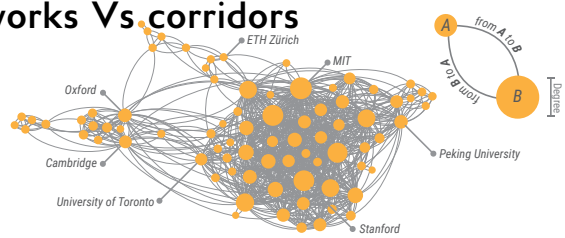
Verginer, L., & Riccaboni, M. (2020). Cities and countries in the global scientist mobility network. *Applied Network Science*
Verginer, L., & Riccaboni, M. (2021). Talent Goes to Global Cities: The World Network of Scientists' Mobility. *Research Policy*

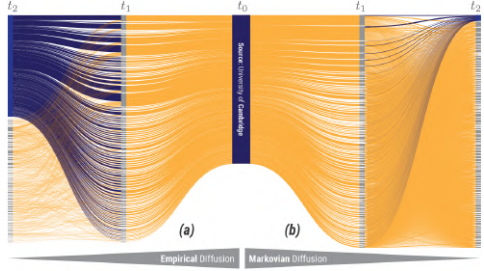
How tacit knowledge moves: Networks Vs corridors

- Scientists → Tacit knowledge

- **Networks**
  - **Freely move** between locations
  - From one starting node career trajectories go to every other nodes
  - Only true at **city** level

- **Corridors**
  - **Specific paths** connect locations
  - From one starting node career trajectories go to a few other nodes
  - At **institution** and **country** level





Scholtes, I. (2017). When is a Network a Network? Multi-Order Graphical Model Selection in Pathways and Temporal Networks. *SIGKDD*

Vaccario, G., Verginer, L., & Schweitzer, F. (2020). The mobility network of scientists: Analyzing temporal correlations in scientific careers. *Applied Network Science*

Reproducing mobility network: Data-driven agent-based model

Data

- MEDLINE: scientists' publications

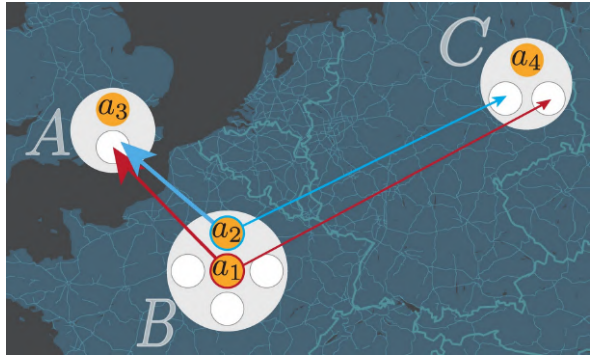
⇒ Career trajectories

Model entities

- **Scientists** prefer closer location with higher fitness
- **Locations** prefer scientists with higher fitness

Constraints

- **Limited space** per location
- Scientists **propose** to move
- But locations **decide** to accept



Vaccario, G., Verginer, L., & Schweitzer, F. (2021). Reproducing scientists' mobility: a data-driven model. *Scientific Reports*

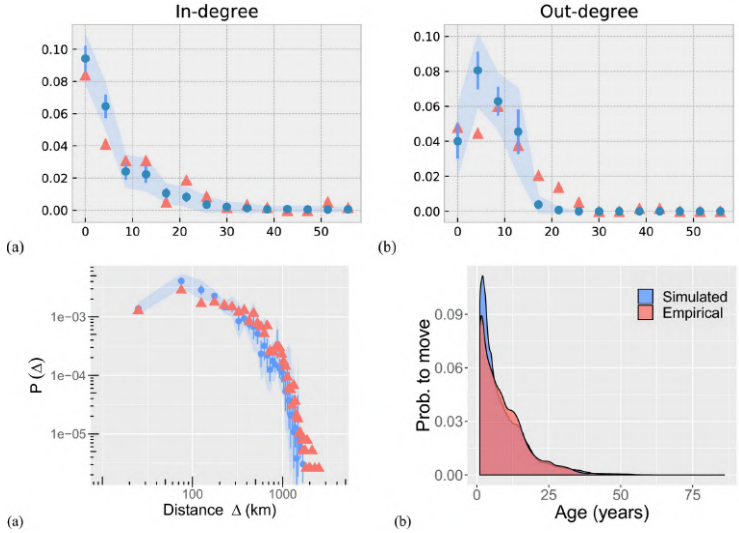
Reproducing mobility network: Data-driven agent-based model

Network level properties

- Degree distribution
- Clustering coefficient
- Path lengths
- …

Scientist level properties

- Traveled distance
- Academic age when moving



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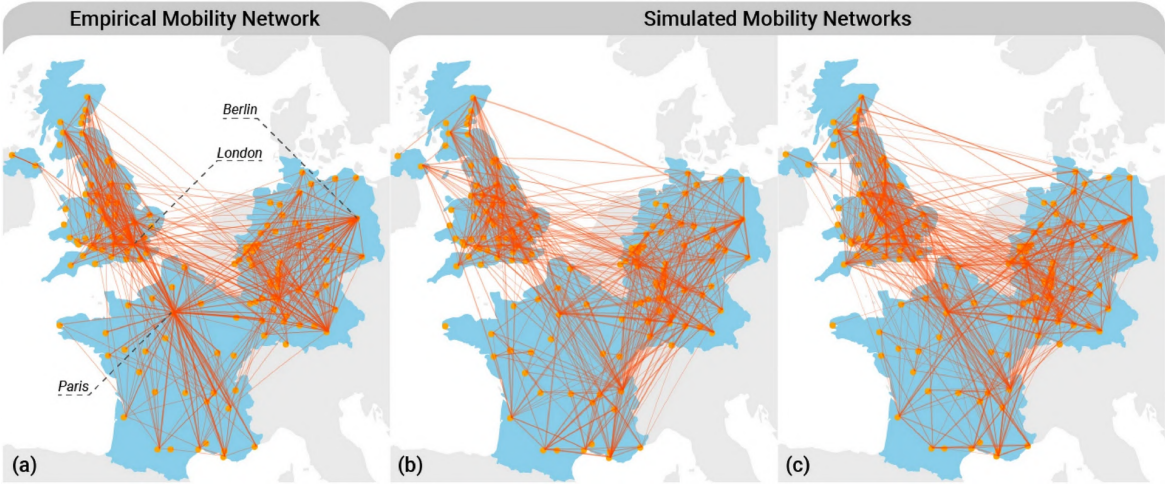

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Conclusions

- Knowledge and collaborations are interdependent
- A unified vision of collaborations across industry and science is possible thanks to network models
- Knowledge is constrained in the geographic space
- Data-driven agent-based models reproduce the interdependence between knowledge and collaborations