Inventor networks in emerging key technologies: information technology vs. semiconductors

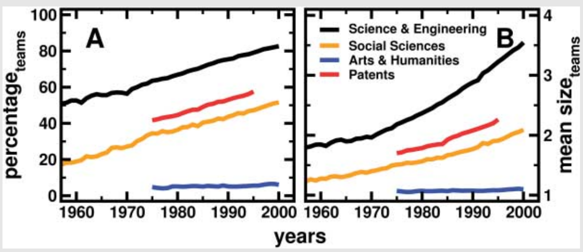
Holger Graf
Friedrich-Schiller University Jena

Evolutorischer Ausschuss des VfS
Jena, July 3, 2009

Motivation and research questions

Motivation

- Changes in the organization of innovative activities
- General trend: increasing team size in research



Source: Wuchty, Jones, and Uzzi (2007)

- increasing capital intensity
- lower costs of communication
- increasing labor mobility
- increasing specialization
- increasing division of labor

Research questions

- Refine existing explanations taking an evolutionary perspective
- Dynamic relationship between knowledge base and inventor networks

Theoretical building blocks I

Innovation and technology – dynamics of knowledge generation

- Cumulativeness of innovation (Dosi 1982)
- Changing technological opportunities (Malerba and Orsenigo 1997)
  - ➟ Opportunities diminish within a specific field but arise from new combinations
- Knowledge relatedness (Nesta and Saviotti 2005)
  - ➟ Key technologies at the center of the knowledge base

First step

1. Map the knowledge base to identify 'interesting' technologies

Theoretical building blocks II

Organization of the innovation process – network dynamics

- Social proximity as explanation for spillovers (Breschi and Lissoni 2003, 2009, Singh 2005)
- Co-authorship networks, inventor networks (Balconi et al. 2004, Fleming et al. 2007)
- Increasing team size (Wuchty et al. 2007)
- Formation of large components (Fleming and Frenken 2007)

Second step

2. Analyze the structure of inventor networks

Hypothesis

Knowledge base

- Direction of the search process influences the position of a technology within the knowledge base
- Opportunities in knowledge . . .

  . . . *deepening* activities ⇒ stable position within the knowledge base
  . . . *widening* activities ⇒ move towards center of the knowledge base

Consequences for innovation process / networks

- Individual capabilities not sufficient for widening activities

⇒ Need for interdisciplinary teams in fields that connect to other fields

Hypothesis

Technologies which become more central to the knowledge base are also characterized by a higher connectedness of the inventor network

Construction of the knowledge base

- Patents are assigned to technological classes (IPC)
- Concordance (FhG-ISI, OST, SPRU) ➟ 30 technologies

$$P_{ik} = \begin{cases} 1 & \text{if patent } k \text{ is assigned to technology } i \\ 0 & \text{otherwise} \end{cases}$$

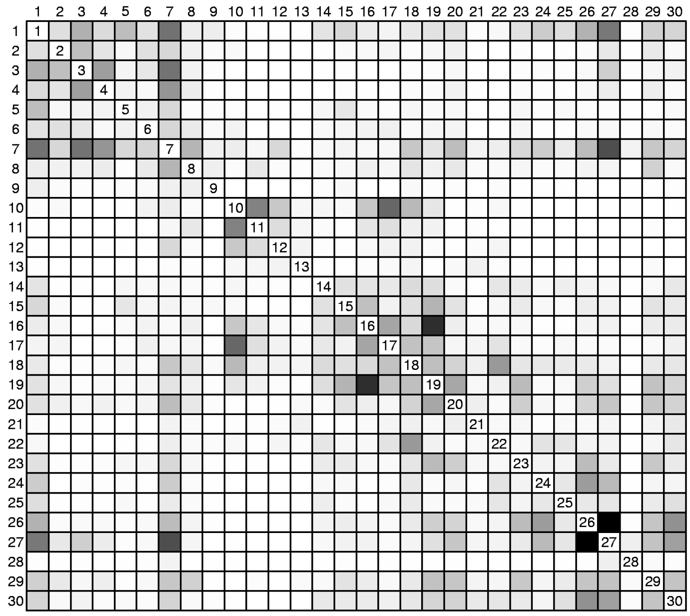
- Co-occurences

$$J_{ij} = \sum_k P_{ik} P_{jk}$$

- Knowledge base

$$\mathbf{\Omega} = \begin{pmatrix} J_{11} & \cdots & J_{1j} & \cdots & J_{1n} \\ \vdots & \ddots & & & \vdots \\ J_{i1} & & J_{ij} & & J_{in} \\ \vdots & & & \ddots & \vdots \\ J_{n1} & \cdots & J_{nj} & \cdots & J_{nn} \end{pmatrix}$$

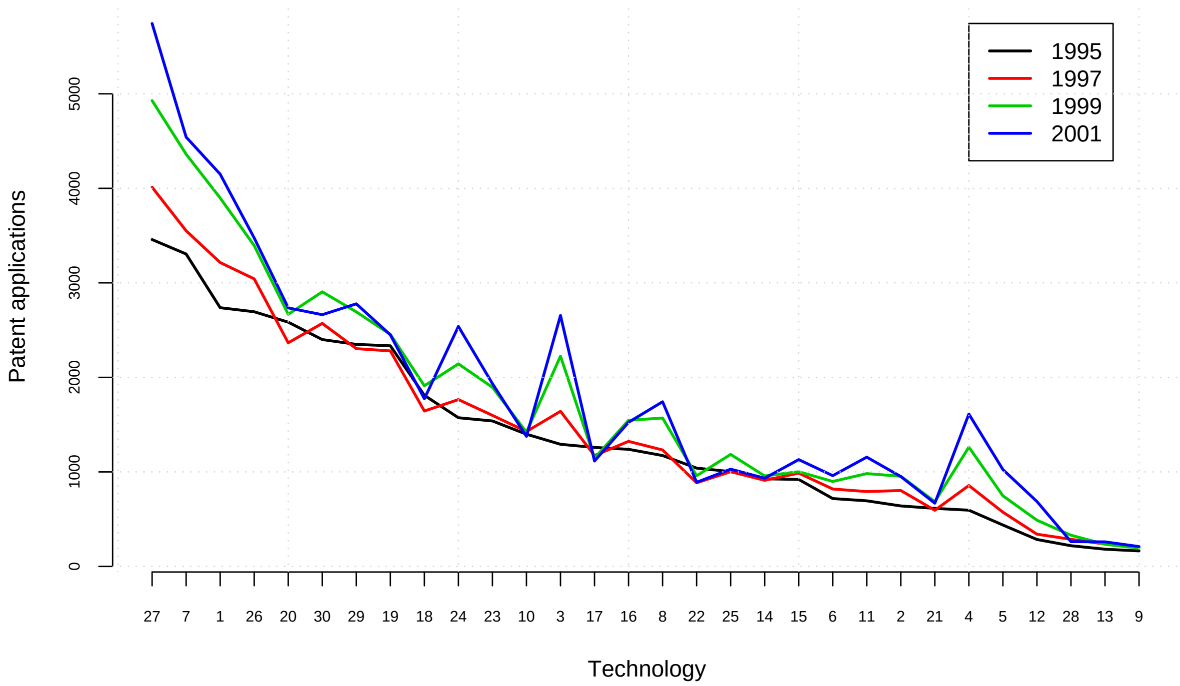
German knowledge base 1995–2001



- **Key technologies**: analysis, measurement (7), electrical machinery (1)
- Related fields: Electronics (1 – 7), large scale chemistry and process engineering (14 – 19), mechanical elements and transport (26 – 27)

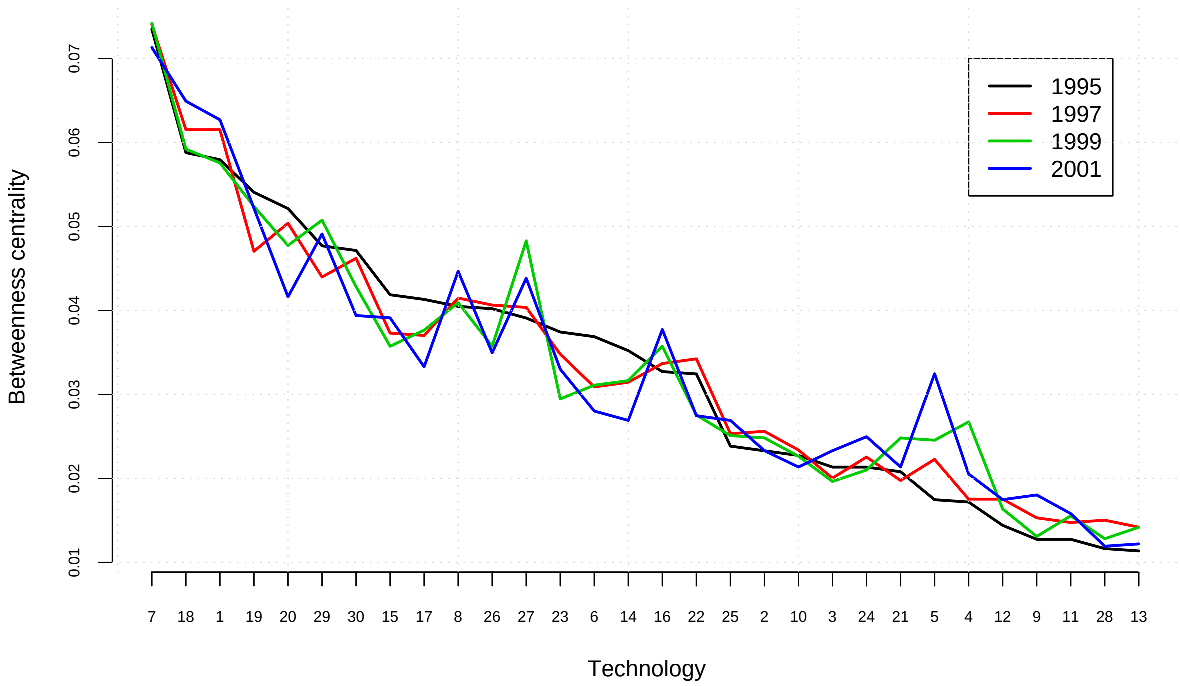
Co-occurences of technologies i and j

Patenting dynamics



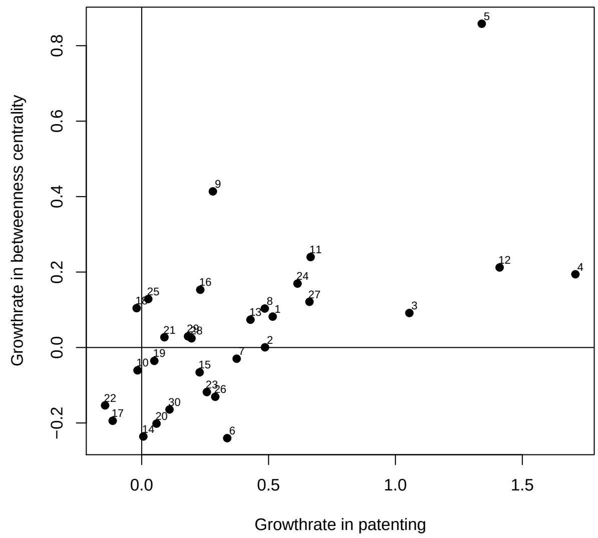
- Ranking according to the number of patents in the first period
- Importance of technology for the innovation system

Key technologies – betweenness centrality



- Ranking according to betweenness centrality in the first period
- Importance of technology for the knowledge base

Patent growth vs. betweenness growth



- Growth rates between 1995 and 2001
- Information technology (4) shows highest patent growth
- Semiconductors (5) shows highest betweenness growth

Hypothesis

Technologies which become more central to the knowledge base are also characterized by a higher connectedness of the inventor network

➠ Semiconductors should be characterized by a higher connectedness of the inventor network than IT

Co-inventorship networks

Social network analysis with patent data

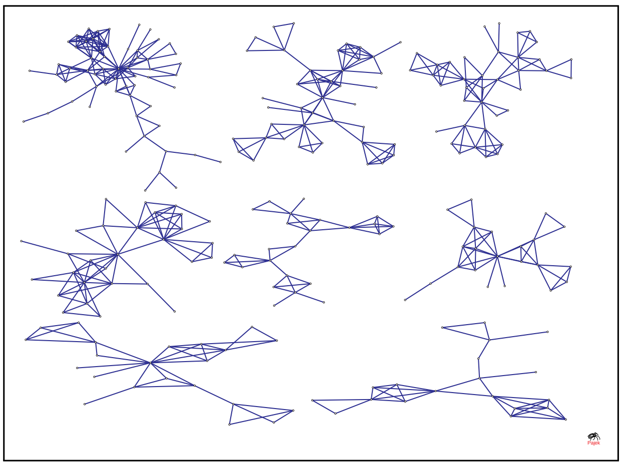
- Social proximity explains knowledge flows (Breschi Lissoni 2009)
- Analysis of networks to...
  - study organization of innovation process
  - explain performance
  - test hypothesis on formation
  - identify key actors
  - ...

Data

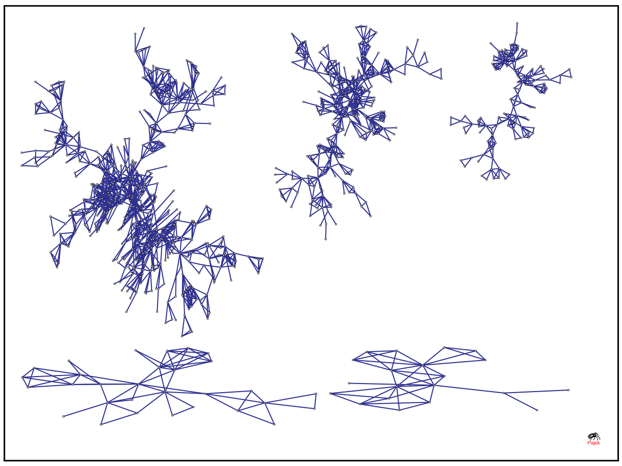
- Patents in IT and semiconductors to construct inventor networks
- Three-year moving windows ➟ 5 periods
- Comparable sizes (patents, actors)
- Overlap in applicants: Siemens, Bosch, Infineon, Philips, Daimler, and Fraunhofer among top 10 in both

Inventor networks

Information technology
(high patenting growth)



Semiconductors
(high betweenness growth)



Components with $n \geq 20$ for the last period (1999–2001)

Dynamics of inventor networks in IT and semiconductors I

	1997	1998	1999	2000	2001
Information technology (high patenting growth)					
Nodes	2946	3430	4146	4584	5287
Share in main comp.	**0.95%**	**3.12%**	**2.10%**	**1.16%**	**1.12%**
Share of isolates	**26.61%**	**27.76%**	**27.45%**	**27.75%**	**26.08%**
Mean degree	**1.9579**	**2.0093**	**2.0014**	**2.0414**	**2.1865**
Semiconductors (high betweenness growth)					
Nodes	2122	2394	2694	2849	3107
Share in main comp.	**3.68%**	**10.69%**	**10.80%**	**11.72%**	**15.29%**
Share of isolates	**14.47%**	**14.24%**	**13.47%**	**13.93%**	**13.00%**
Mean degree	**2.9161**	**3.1997**	**3.2858**	**3.5114**	**3.5558**

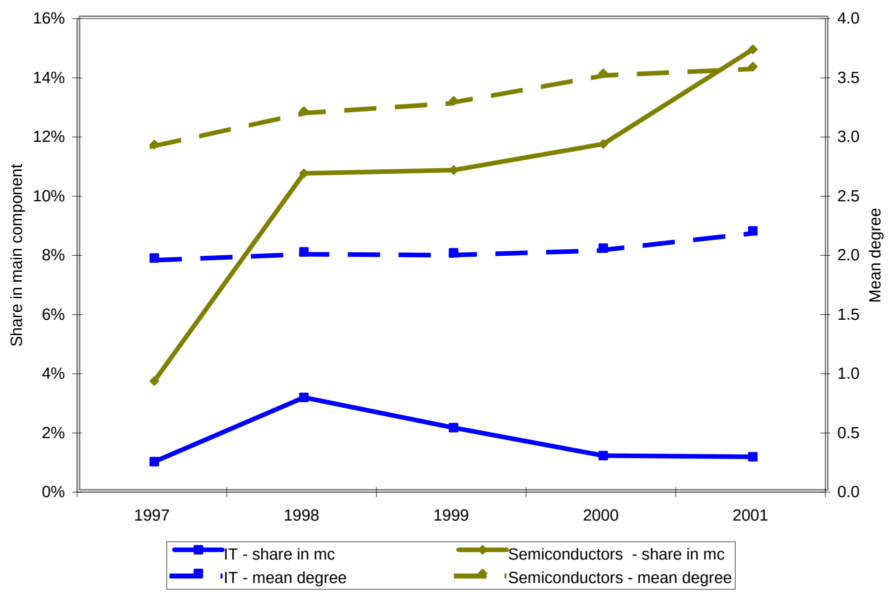
Measures of connectedness

Share in main comp. Share of actors who are member of the largest connected part of the network

Share of isolates Share of actors who patent without any co-authors

Mean degree Average number of connections to other actors

Dynamics of inventor networks in IT and semiconductors II



- Information technology (4): no key technology ⇔ low connectedness
- Semiconductors (5): key technology ⇔ high connectedness

➟ Semiconductors are characterized by a higher connectedness of the inventor network than IT ⇒ in line with hypothesis

Conclusions

Knowledge base

- Technologies assume different and changing positions
- Changing opportunities seem relevant for these dynamics
- Betweenness centrality as a measure for key technologies

Inventor networks

- Inventor networks in IT and semiconductors show different dynamics
- Differences in technological opportunities as an explanation for increasing team size and the formation of large components

➟ Co-evolution of knowledge base and inventor networks

Limitations

- Opportunities are not exogenous
- Case study character can only provide anecdotal evidence

Thank you for your attention!

holger.graf@uni-jena.de

Literature

- Balconi, M., Breschi, S. & Lissoni, F. (2004), Networks of inventors and the role of academia: An exploration of Italian patent data, Research Policy, 33, 127-145
- Breschi, S. & Lissoni, F. (2003), Mobility and Social Networks: Localised Knowledge Spillovers Revisited, Cespri, 142
- Breschi, S. & Lissoni, F. (2009), Mobility of skilled workers and co-invention networks: an anatomy of localized knowledge flows, Journal of Economic Geography, 9, 4, 439-468
- Dosi, G. (1982), Technological paradigms and technological trajectories : A suggested interpretation of the determinants and directions of technical change, Research Policy, 11, 3, 147-162
- Fleming, L. & Frenken, K. (2007), The evolution of inventor networks in the Silicon Valley and Boston regions, Advances in Complex Systems, 10, 1, 53-71
- Fleming, L., King, Charles, I. & Juda, A. I. (2007), Small Worlds and Regional Innovation, Organization Science, 18, 6, 938-954
- Malerba, F. & Orsenigo, L. (1997), Technological regimes and sectoral patterns of innovative activities, Industrial and Corporate Change, 6, 1, 83-117
- Nesta, L. & Saviotti, P. P. (2005), Coherence of the knowledge base and the firm's innovative performance: evidence from the U.S. pharmaceutical industry, Journal of Industrial Economics, 53, 1, 123-142
- Wuchty, S., Jones, B. F. & Uzzi, B. (2007), The Increasing Dominance of Teams in Production of Knowledge, Science, 316, 5827, 1036-1039

Concordance between IPC and technology codes

	Industry Technology
I.	ELECTRICAL ENGINEERING
1.	Electrical machinery and apparatus, electrical energy
2.	Audiovisual technology
3.	Telecommunications
4.	Information technology
5.	Semiconductors
II.	INSTRUMENTS
6.	Optics
7.	Analysis, measurement, control technology
8.	Medical technology
9.	Nuclear engineering
III.	CHEMISTRY, PHARMACEUTICALS
10.	Organic fine chemistry
11.	Pharmaceuticals, cosmetics
12.	Biotechnology
13.	Agriculture, food chemistry
14.	Materials, metallurgy
15.	Surface technology, coating
16.	Macromolecular chemistry, polymers
17.	Chemical industry and petrol industry, basic materials chemistry
IV.	PROCESS ENGINEERING, SPECIAL EQUIPMENT
18.	Chemical engineering
19.	Materials processing, textiles, paper
20.	Handling, printing
21.	Agricultural and food machinery and apparatus
22.	Environmental technology
V.	MECHANICAL ENGINEERING, MACHINERY
23.	Machine tools
24.	Engines, pumps, turbines
25.	Thermal processes and apparatus
26.	Mechanical elements
27.	Transport
28.	Space technology, weapons
29.	Consumer goods and equipment
30.	Civil engineering, building, mining

Source: ISI OST INPI classification (update 2005).