Infusion

▶ Network Management and Governance

Innovation

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▶ Social Networking for Open Innovation

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▶ Entrepreneurial Networks

Innovator Networks

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Synonyms

Interorganizational collaborations; Inventor networks; R&D (Research and Development) collaborations

Glossary

Architectural control	Refers to innovation in high-technology systems and measures how the control over the architecture of the final product is concentrated within the hand of one (or few) agents (Prybeck et al. 1991). A concentrated architectural control can be found, for instance, in a high-tech industry where a dominant standard interface incorporates proprietary elements, such as telecommunications networks
Heterogeneity	Relationships in an Innovation System span across very different kinds of agents, ranging from firms to scientists. In addition, each agent is endowed with specific features and a unique knowledge base
Innovation system (IS)	An analytical framework aimed at understanding how innovation is produced in a complex system of interacting agents. The IS approach, introduced by Lundvall (1985), is now especially used to study innovation at national or regional level
Separability of innovation	Applies to product systems and indicates the degree to which components and/or processes are independent and innovation activities can be performed by separate agents. Separable innovation systems are associated with a higher community activity (Baldwin and Clark 2000)
Technological dynamism and uncertainty	In a rapidly changing technology environment where knowledge often has a tacit component and is strongly distributed over agents, collaborations become a central component of the innovation strategy (Tushman and Rosenkopf 1992). Moreover, collaborations mitigate uncertainty about the direction

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of technological change. Innovators share risks when they collaborate which allows for more flexibility and more investments in future opportunities as compared to an isolated state

Definition

From the perspective of innovation economics evolving institutions, innovating entrepreneurs, technological change, and creative destruction are the driving force of economic growth (Schumpeter 1942). To mitigate the uncertainty involved in the creation of new processes, products, or business models, innovation exhibits an intrinsic collaborative nature. Innovator networks form through formal and informal collaborations between different agents, including firms, institutions, universities, state agencies, inventors, and other stake-holders of the innovation system. Being embedded in a network enables these agents to coordinate innovative efforts, as well as to pool and jointly create knowledge (Kratzer et al. 2009; Raab and Kenis 2009).

Introduction

To cope with the variety of agents in innovator networks, their analysis can be abstracted in a network approach where nodes represent the innovating entities and links represent their collaborations. A large body of literature in this field has focused on collaborating firms (Allen 1983) as the fundamental units in creating innovations, which is in line with recurrent theoretical arguments such as Schumpeter's idea of innovation as a recombination process, or the resource-based view of the firm. Firm-related data sources, such as databases on strategic alliances, offer the possibility to construct large and often longitudinal networks, allowing extensive empirical studies. Hence, innovator networks in this article refer mainly to networks of collaborating firms.

Key Points

Collaboration between innovators is not a new phenomenon; however, the 1980s and 1990s witnessed an unprecedented growth of strategic alliances aimed at research and development (R&D) activities (Hagedoorn 2002). This has been investigated by two different streams of empirical literature (see Ebers 1997; Veugelers 1998; Walker 2005, for a more extensive overview).

A body of work has studied the salient features of empirically observed collaboration networks (see e.g., Fleming et al. 2007; Powell et al. 1996; Roijakkers and Hagedoorn 2006). These studies have found that collaboration networks exhibit a small-world topology characterized by short path lengths and high clustering. In addition, these networks tend to be highly heterogeneous and centralized, although there exist some differences across industries (Powell et al. 2005; Rosenkopf and Schilling 2007), as we show below. The study by Tomasello et al. (2014) further investigates the drivers behind the formation of interfirm R&D alliances and presents a model to reproduce the observed "small-worldliness" of R&D networks.

Another body of work has studied the network position of firms in relation to their performance and the role of link density in knowledge diffusion. It is of interest whether dense interconnections are more conducive than weak bridging ties between separate communities (Granovetter 1983). Indeed, clusters of densely connected firms foster collaboration efforts by generating trust, punishment of opportunistic behaviors, and common practices (as shown by Ahuja 2000; Walker et al. 1997). Conversely, by creating a structural hole in the network, firms have access to different sources of knowledge spillovers, economizing on the costs of direct collaborations (Burt 1992). Other works (Gulati and Gargiulo 1999; Rosenkopf and Padula 2008) have analyzed the mutual feedback between a firm's position in the network and its knowledge base. As it has been found by Cohen and Levinthal (1990) and Lazer and Friedman (2007), two agents should not be too similar nor too different in their knowledge bases in order to engage in a collaboration.

Historical Background

Following the wave of empirical research, various theoretical models have explored the dynamics of collaboration networks and their impact on innovation. This literature on network formation is basically divided in two strands (Schweitzer et al. 2009). In the dynamic random network approach, mainly developed by mathematicians and physicists, networks are formed either through a purely stochastic process or through some other statistical algorithms (see e.g., Ehrhardt et al. 2006). In the strategic network approach, mainly developed by economists, strategic interaction decides about the link formation: agents may follow different strategies (see e.g., Jackson and Wolinsky 1996; König et al. 2011) to decide about – and interact with – their counterparts; therefore, this approach is also called "games on networks." While the random network approach gives insights into *how* networks form, the strategic network approach tries to explain *why* networks form.

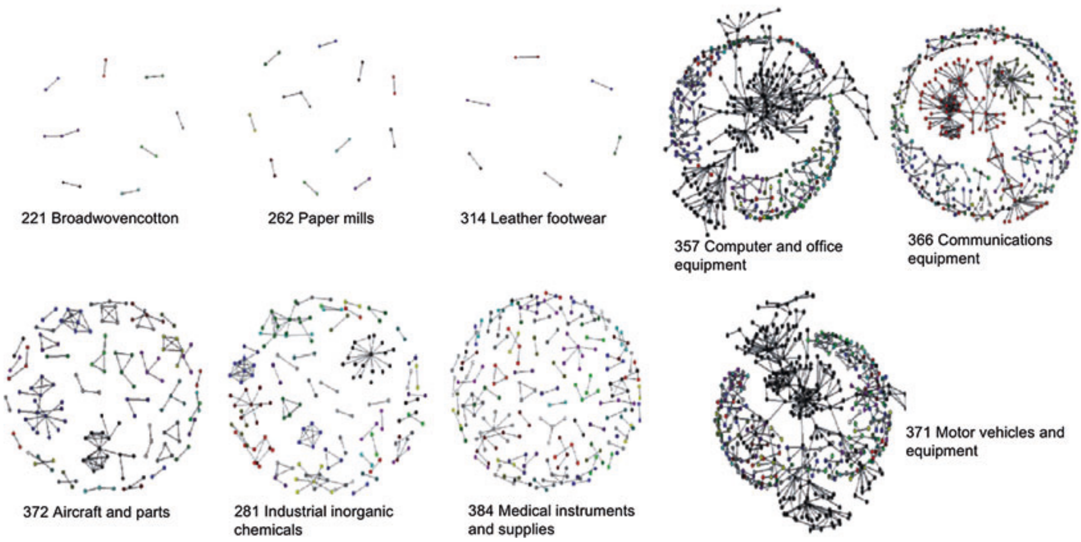
In the "games on networks," the network is usually static and taken as given, and the focus is on how the network structure impacts on outcomes and individual decisions. In particular, some works (Ballester et al. 2006; Goyal and Joshi 2003) show that the centrality of an agent in the network predicts its innovation efforts and outcomes.

Other works combine a dynamic approach with games on networks. For instance, König et al. (2008) and (2012) examine the theoretical efficiency of a given network in terms of total profits maximization, showing that the most efficient network structure depends on collaboration costs. When the marginal cost is low, the efficient collaboration network is fully connected, while a high marginal cost implies a sparse efficient network, with a core-periphery structure. In another work combining strategic agents' decisions with a dynamical network evolution (Tomasello et al. 2015, 2016b), the effect of R&D alliances on the firms' technological positions is studied through an agent-based model. The study uses real patent data for a precise quantification of every firm's knowledge position, and shows that effective policies for an optimized collaboration network would promote shorter R&D alliances and higher interfirm knowledge exchange rates (e.g., by including rewards for quick co-patenting by allied firms).

Illustrative Examples

We present here two illustrative examples of innovation networks, from the empirical literature. In the first example (Rosenkopf and Schilling 2007), the comparison of alliance networks across industries highlights how technology relates to network structures. The alliance network for 32 industrial sectors has been analyzed in terms of size, connectivity, centralization, small-world properties, and other indicators. As shown in Fig. 1, the networks exhibit different structures across industries, depending on their technological features. Technological dynamism and separability of innovation are positively related to the number of firms participating in alliances (the size of the network) and to the average number of alliances formed by each firm (the average degree). The concentration of architectural control is instead correlated to the asymmetry in the degree distribution (number of alliances per firm) and to the appearance of small-world architectures in the network (high clustering and short path lengths).

The second work (Tomasello et al. 2016a) extends the investigation of R&D networks to the temporal dimension, by employing a longitudinal dataset (from 1986 to 2009) of alliance formation in several manufacturing sectors. The study has found that most network properties are not only invariant across sectors (as shown in Fig. 2) but also independent of the scale of aggregation at which they are observed (i.e., in the aggregated global R&D network versus the individual sectoral R&D networks). Remarkably, many properties of R&D networks are characterized by a peculiar rise-and-fall dynamics with a peak in the mid-1990s, driven by mechanisms of *accumulative advantage*, *structural homophily*, and *multiconnectivity* (see Powell et al. 2005). In particular, the *multiconnectivity* hypothesis states that partners allowing a firm to reach many other firms through multiple independent paths in the network are the most attractive alliance partners. The study has found that the change from the



Innovator Networks, Fig. 1 The structure of the collaboration networks in nine distinct industrial sectors. Some sectors (industrial codes 221, 262, and 314) exhibit *disconnected* networks, consisting mainly of pairs of allied firms with no bridging ties. Other sectors (codes 372, 281, and 384) display networks of moderate size, defined *hybrids*, with many separate clusters of nodes, but no main component dominating the graph. The last sectors (codes 357, 366, and 371) show large *spider-web* networks, consisting of a main component and several peripheral components (See Rosenkopf and Schilling (2007) for more details)

"rise" to the "fall" phase is indeed associated to a structural break in the importance of multiconnectivity as driving mechanism behind the strategic choice of alliance partners.

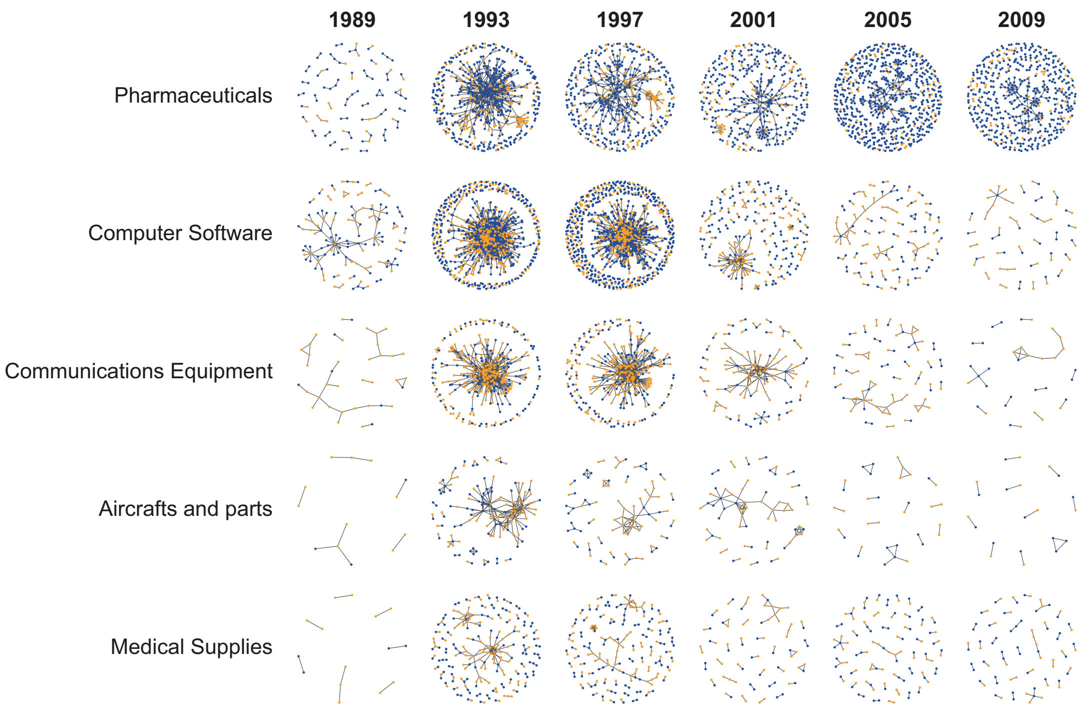
Key Applications

One prominent application in the field of innovator networks is the use of agent-based models to not only reproduce the characteristics of the observed networks but also to predict their formation and evolution, and to possibly optimize some indicator of actual knowledge production and diffusion. In this respect, the study by Tomasello et al. (2014) develops an agent-based model of strategic link formation, to explain the emergence of such structures observed in real collaboration networks. Similarly to the previous illustrative example, the study is inspired to the four fundamental link creation mechanisms identified by Powell et al. (2005) – *accumulative advantage*, *homophily*, *follow-the-trend*, and *multiconnectivity* – and to the stylized facts reported in Rosenkopf and Padula (2008), showing the presence of distinct clusters (or communities) in a real R&D network. By incorporating a set of appropriate link formation rules into an agent-based model, Tomasello et al. (2014) are able to reproduce the emergence of network clusters (see Fig. 3), as well as other additional network indicators, including the distributions of degree, local clustering, path length, and size of the network components.

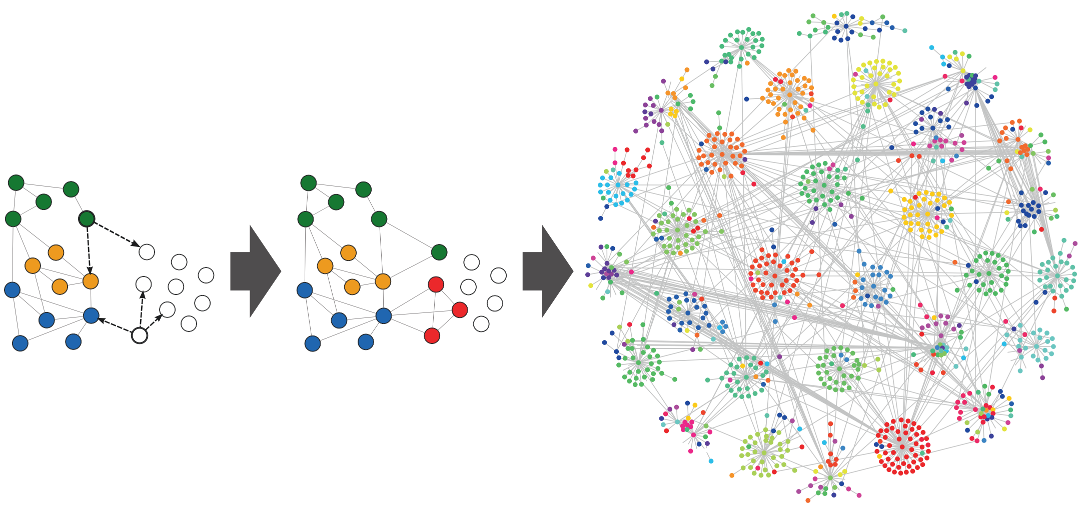
Finally, by estimating the link probabilities towards newcomers and incumbent firms from the data, the study has found that the alliance formation process is dominated by network endogenous mechanisms. In other words, the existing network structures (i.e., social capital) are more important than the firms' own characteristics (i.e., technological and commercial capital) in selecting new R&D partners.

Future Directions

Empirical evidence suggests that innovator networks are not designed, but emerge endogenously.



Innovator Networks, Fig. 2 Snapshots in the years 1989, 1993, 1997, 2001, 2005, and 2009 for five selected sectoral R&D networks: Pharmaceuticals, Computer Software, Communication Equipments, Aircrafts and parts, Medical Supplies. *Blue* nodes represent the firms strictly belonging to the examined sector, while *orange* nodes represent their alliance partners belonging to different sectors. The peculiar rise-and-fall trend is visible in all sectoral networks shown



Innovator Networks, Fig. 3 The formation of an interfirm innovator network, captured through an agent-based model. The figure depicts a representative example of strategic link formation and community building in a collaboration network. The result is a network whose synthetic communities (represented by different colors) exhibit a remarkable overlap with the empirical ones (represented by different locations in the plot area) (See Tomasello et al. (2014) for more details)

Agents pursue self-interested goals when forming and dissolving relationships, and thereby create an evolving network that affects all the agents in its turn. Although some models are already able to capture several empirical observations, a comprehensive theory to explain the features of real-world innovator networks is still missing. A complete study should be able to reproduce similarities and differences across the large variety of observed innovation systems, and at the same time unveil the complex interdependencies between the network position of the innovators and their intrinsic knowledge characteristics.

Besides, substantial potential for future work lies in the study of performance, optimization, and resilience of real innovator networks. The exercise of defining and maximizing a performance indicator, so far limited to the field of R&D networks (see Tomasello et al. 2016b), could be extended to other domains. The ultimate goal would be to assess innovator networks in real time, and design policies to make them more resilient and more conducive to knowledge transfer.

Cross-References

- ▶ Actor-Based Models for Longitudinal Networks
- ▶ Collaboration Patterns in Software Developer Network
- ▶ Entrepreneurial Networks
- ▶ Interorganizational Networks
- ▶ Network Games
- ▶ Networks of Practice
- ▶ R&D Networks

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Instant Message

► Microtext Processing

Instant Messaging for Detecting Dynamic Ego-Centered Communities

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Synonyms

Community evolution; Dynamic community detection; Temporal analysis; Temporal networks

Glossary

Dynamic Community	a community that changes over time
Ego-Centered Community	a community based on a targeted node called *ego*
Instant Messaging Networks	a social network communication built based on the content of instant messaging
Instant Messaging	an online chat that offers real-time text transmission over the Internet
Spatiotemporal Network	a social network that is built based on individuals, their interaction, and their location over the time

Definition

The development of online social media has created many opportunities to communicate, access, and share information from anywhere and at anytime. The kind of application such as *Viber*, *WhatsApp*, *Imo*, *Line*, as well as *Facebook* affords