# Network topologies to manage the globalization of innovation

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**Abstract:**
Organizations are bounding together in collaboration networks, yet, without acknowledging the challenges generated by network-structures. Collaboration networks financed by German ministries between 2007-2014 and producing social, radical and incremental innovations were analyzed to characterize these networks. The findings contribute to the understanding of the interrelationship between network topologies and innovation.

**Keywords:** Collaborative innovation networks, Network topologies, Innovation management.

## INTRODUCTION

Innovation is a complex dynamic process and it becomes more complex when innovation is performed within network environments. In both, cooperation and collaboration scenarios, large numbers of agents engage repeatedly in local interactions, giving innovation as a result. The use of synergy potentials, the reduction of time and cost, the sharp specialization, the reached efficiency through reduction of overcapacities, the product quality, the distributed risks and the generation of new sources of profit are some of the arguments explaining cooperative and collaborative initiatives (Gassmann et al. 2010, Hemphälä and Magnusson, 2012).

The globalization of innovation stresses the complexity of the innovation process by intensifying the externalization of innovation activities. Two clearly behaviors are observable within organizations reacting to these dynamics. First, innovation as by definition implies that something new is generated and accepted by a defined market. However, to build that 'something new', different knowledge-units have to come together to solve the deficiencies or fulfill the expectations of that defined market. Thus, framed by the globalization of innovation, within innovation networks, knowledge is playing both, the input and output role of the innovation process. Organizations are already aware of the advantages brought by the globalization of innovation regarding the acquisition, creation and exchange of knowledge. Therefore, they are starting to be more explorative and are linking themselves with other agents targeting the acquisition and at last the absorption of new knowledge (Archibugi and Iammarino, 2002; Gassmann et al. 2010). Organizations are reaching knowledge and competences not just from

agents in their vertical and horizontal ties, but also they are feeding the innovation process through "diagonalization", leveraging knowledge from external industries. Second, organizations are gradually incorporating digital solutions within products and production systems and as a result, new sources automatically engendering information that could be transformed in new kinds of industrial knowledge are emerging.

The globalization of innovation offers advantages like the access to high qualified knowledge and competences without having spatial barriers (Cohen and Levinthal, 1990), but at the same time challenges organizations to absorb the external knowledge. Although knowledge will not hold longer competitive advantages, the first to absorb it will have the chance to delineate future developments. Therefore the globalization of innovation is requesting major flexibility in the process of innovation, the organizations' internal structures and the arrangements of networks.

Hence, to support the last one the structure of innovation networks has to be defined. Scholars have centered their focus of research on the importance of performing innovation within network environments (Choi et al. 2010; Zeng et al. 2010; Hemphälä and Magnusson, 2012; Dodourova and Bevis, 2014). However, there is still a lack of research on the influence that networks structures have in the generation of innovation (Hemphälä and Magnusson, 2012). Now the question is whether distinct networks topologies are adopted to achieve the goals of innovation. Some works have explored the relationship between innovation and network connectivity through the analysis of the agents centrality and nodes adjacency (Burt 2004; Choi et al. 2010; Hemphälä and Magnusson, 2012). Nonetheless, neither a proper categorization of networks nor a defined topology has been outlined to carry out innovation.

Recognizing preconditions of networks could help organizations to better set up the working groups and in advance, be aware of potential changes in their organizational structures. The reviewed literature suggests that (1) networks can be modeled, (2) a topology can be defined to describe those invariant arrangements formed by organizations during the execution of the innovation process and (3) once the topology has been established, not only the intrinsic characteristics can be measured, but also it is possible to better identify agents and create strategies to improve the performance of the innovation network from the very moment of its conception. The following contribution attempts to formulate a first approach to define the topology of innovation networks. Information collected from innovation projects worked out within networks environments and financed by different German ministries during 2007 and 2014 were analyzed to acknowledge divergent arrangement structures of networks while executing innovation. Likewise, a characterization of the elements of innovation networks is presented and further research questions related to this topic are going to be pointed out.

# THEORETICAL CONSIDERATIONS

## Assessing innovation networks

A network encloses at least two elements: nodes or agents and links. The amount of agents and the links connecting each agent define the complexity of the network. The complex network approach adds to these two elements the degree of distribution, signaling the amount of links connected to each agent. The globalization of innovation increases automatically the complexity of the network, since at least two organizations will join forces to accelerate innovation. An innovation network has to be perceived then, as an interactional system, where exchanges are triggered by a set of relationships between participating organizations or organizational units

(Sydow and Windeler, 2003). Moreover, innovation networks can have formal and informal structures. Formal structures are known as clusters. Agents within these structures are often part of the same industry and are usually following long term goals. Informal networks are project-oriented, where agents bound temporarily together to solve a defined problem (Dodourova and Bevis, 2014). Specifically, innovation networks are connecting agents related to knowledge generation, dissemination and absorption. In this sense, an agent will have network-characteristics and will be considered part of the innovation network only if its participation contributes, in a direct or indirect way, to reach the network's goals of producing innovation.

Consequently, innovation networks should have at least: (1) interconnectivity between the network's agents, meaning that they should be related to at least one agent in the same network and be fulfilling the same purpose. Those relations will give (2) structure to the network and meanwhile, every agent of the network will have to give a contribution, helping to reach the network's common goal. This contribution is going to be the (3) function of each agent within the network. Moreover the combination of interconnectivity, structure and function, will define the (4) behavior of the network; embodying the strategies followed by the network to meet its goals.

## Characterizing the agents of innovation networks

Innovation networks can be formed from different types of agents. In an industrial context, innovation networks might be conformed by organizations, associations, research centers, universities and even funding and governmental bodies (Freeman 1987; Edquist and Hommen, 1999; Freel 2003, Johnson et al. 2004). However the motivations to come together may have distinctive roots and can be defined by different variables, namely: competence of the agent, topic of research, type of innovation to be developed, the market in which the participants are having influence. Defining the agents of the network has been one of the challenges within this field of study. Some authors suggest that the formation of a complex network follows the "rich gets richer" or the "fitness" pattern (Barabasi and Frangos, 2014). In innovation networks this behavior is characterized by agents usually tightening up linkages with (1) renowned agents within the system or (2) specialized agents or newcomers with disruptive perspectives.

## Unfolding the linkages between agents in innovation networks

Links are the formal and informal representations of the relationship of two agents. The literature regarding links in complex networks refers to the importance of the strength of the link. Granovetter (1983) suggested that the strength of the link curiously resides in identifying 'weak' links. This means that in order to find superior input, those weak links are more important than the already established 'strong' relations between agents. In innovation networks, agents outside the system or even outside the main industry represent those weak links. When it comes to innovation production within network environments, cooperative and collaborative initiatives are defining the strength and function of the linkages. Usually the definition of the link is influenced by the cooperative and collaborative composition of the network. Most scholars do not properly distinguish between cooperation and collaboration activities towards innovation. Moreover, these two terms are commonly used in the literature as synonyms (Ingram and Hathorn, 2004; Abbasi et al. 2011). Since the outcomes of innovation can be expressed in terms of knowledge (Bellantuono et al. 2013), the clarification of these two concepts will be made to emphasize the difference of the outcomes through cooperative and collaborative learning activities.

On one hand, cooperative learning activities imply that agents will share the same goals, however each agent accepts defined tasks to be completed, in most of the cases, by each agent alone. On the other hand, collaboration seeks to achieve a common goal through the mutual engagement of the participants. Networks established to collaborate gain more understanding from other perspectives (Cunningham 1992) and are more willing to create new insights (Henri 1992) through combination of knowledge. Ingram and Hathorn (2004) suggested that outcomes from collaboration practices are usually different from what any individual could produce alone. Moreover, those outcomes have greater potential to be innovative (Argote and Ingram, 2000).

Hence, cooperation activities represent the 'fast-track' of innovation. They are oriented to achieve product development and are set to carry out mainly incremental innovations. In contrast, collaboration activities aim attention at generating new knowledge. Both, cooperation and collaboration activities are usually present in the industrial context. Motivations to cooperate tend to be related to the reduction of risks and costs while collaboration activities are more associated with substituting technologies, developing new technologies or changing customer requirements (Sydow and Windeler, 2003). To ensemble an innovation network, linkages are defined by the type and characteristics of the agent and by the nature of the formalization of their relationship.

## Defining the degree of distribution in innovation networks

Different to the strength of the link, the degree of distribution of a network is determined by the amount of links attached to an agent. In the innovation context, agents are motivated to link themselves with the most striking ones. The degree of distribution of an agent can increase due to, among others, an agent's popularity, defined by its position in the market, its financial muscle, its knowledge specialization; the incentives within a defined market and the policies surrounding the framework of the innovation system. However, since the goal of this work is to formulate the topology of innovation networks, the representation of the network will be simplified to identify basic network structures. The degree of distribution of an agent in the system is not going to be considered; yet agents-units could coexist in the same topology and these cases are going to be addressed.

# PROPOSED FRAMEWORK

## General considerations and data structure

The data collection used to perform this study has been extracted from the 'funding catalog' database and comprises information from completed and ongoing projects worked out within networks and financed by different German ministries during 2007 and 2014. The type, size and economic activities of the organizations participating in this kind of actions were counteracted with the data in the regional chambers. The main data indicates among others: (1) the type of innovation; (2) the investment made by the public body; (3) the project's coordination unit; (4) the characteristics of the organizations involved in the project; (5) the topic of research and (6) the cost and duration of each project. 4.062 innovation networks involving the participation of 5.380 different organizations or organization-units respectively are considered.

Some considerations regarding the data are: (1) the data corresponds to innovation networks financed by public bodies. Some incentives are set to increase the participation of SMEs in the generation of country's innovation. (2) Public bodies have characterized, in concordance with the

industry, the topics relevant for the German innovation system. Therefore the topics are not randomly generated; casually innovations are not expected. (3) Hence, all networks are conceived as innovation projects that could have cooperative and collaborative characteristics.

## Steps for defining the topology of innovation networks

Since innovation has specificities that have to be addressed before assuming the generalities of the network analysis, the next steps are going to be followed:

*Step 1. Identify the intrinsic characteristics of innovation networks:* The most basic representation of innovation networks has to be achieved to identify those specificities brought by performing innovation in network environments. Agents' (a) type, (b) size, (c) industry and (d) location represent its degree of attractiveness in a network. Also a characterization of the links and the agents' degree of distribution in the innovation network has to be identified.

*Step 2. Recognize and visualize the identified networks:* Since this paper aims to identify the topology of innovation networks, a simplified representation of those innovation networks has to be achieved. Therefore, the data will be clustered taking into consideration the following variables: type of innovation, size of the network and the type of agents taking part of innovation activities. By means of NetworkD3 package of R (Gandrud et al. 2015), network structures are going to be roughly analyzed. The clusters will be represented as network structures and for each; the type of agents and their relationships will be analyzed in depth.

*Step 3. Identify the behavior of innovation networks:* The function and dynamics of the network are pulled by their links. In the innovation context, cooperative and collaborative ties define linkages and the degree of distribution is associated to the coordination of the process of innovation. Moreover, the type of innovation to be developed pulls the association between agents. These characteristics will be assessed to each identified structure.

*Step 4. Formulate the typology of innovation networks:* Based on the identification of the agents' interconnectivity and the type of relations created between them, the simplified network structures are going to be characterized and the topology is going to be depicted. The function of the agents in each type of structure and the possible behavior of each arrangement are going to be suggested. However, the dynamics between agents accordingly to their function in each structure are going to be subject of further research.

# TOPOLOGY OF INNOVATION NETWORKS

## Identify the intrinsic characteristics of innovation networks

Innovation networks in the industrial context are limited in size. Formal and informal links are bounding different types of organization to leverage the most of the outcomes of innovation efforts. This behavior is accentuated in countries with defined innovation systems and even more in countries where the industry is actively innovation oriented. Organizations involved in the production of innovation have different characteristics. They are represented basically by organizations part of the academia, research centers, public bodies and the industry. While most radical innovation are being developed by academic organizations, incremental innovations are performed mostly by the industry. Radical Innovations are barely part of large organizations and the efforts of producing radical innovations, although few are more frequent in Small and Medium Enterprises (SME). Social innovation on the other hand, are more scattered in the

organizations horizon. Some incremental innovations carried out are supplementing social innovations. This means that social innovations are in most cases incremental innovations, yet dedicated to solve social concerns i.e. climate change, soil management and food secure, among others.

## Recognizing and visualizing the identified networks

Since the attributes of innovation can be mirrored with the attributes embedded in the definition of 'Project Management' (Barczak et al. 2009), most scholars agree in describing innovation in the form of "project". Due to the independent character of innovation within collaborative environments, portraying innovation as a project helps agents to delimit and assume better their functions within the created network. Yet, one of the main characteristics of a project is its temporality, meaning that objectives associated to a defined timeline are expected. Although innovation involves a degree of uncertainty, this behavior emphasizes that the process of innovation do not usually produce unexpected outcomes. A first look into the data shows that different network structures coexist in the whole system. Both formal and informal structures (Dodourova and Bevis, 2014) are in this case delimited by the means of innovation projects. Moreover, since this approach simplifies the network structure associated with innovation production, contrary as has been shown (Choi et al. 2010; Delre et al. 2010; Hemphälä and Magnusson, 2012) there are isolated networks formed by agents less popular in the system.

## Identify the behavior of innovation networks

Organizations are taking advantages from alliances and the acquisition of knowledge from external sources. However, coming to the process of innovation production, the pattern followed by organizations tends to be 'semi-open'. Ties are created based mainly on trust and specialization (Dodourova and Bevis, 2014). In order to avoid network distortion, networks are being formed basically by tying links between organizations part of the same national innovation system. The participation of external newcomers is rather inexistent. Moreover, analyzing the size of the networks and their correlation with innovation production, the data shows that while incremental and social innovations accept the dynamics between large numbers of agents, radical innovations are performed rather in controlled environments. Nonetheless, most innovations independent of their type are executed in networks with less than 10 nodes. Hence, innovation is executed under coordinated environments. In order to avoid desegregation and reduce the risk of the globalization of innovation, the formation of complex networks is rather avoided by the industry. The strength of the link in this case is being defined by the coordination and the amount of participation in the development of the innovation.

## Defining the topology of innovation networks

Most innovation networks found in the literature have suggested that innovation networks could generate fully connected structures (Choi et al. 2010; Delre et al. 2010, Zeng et al. 2010; Hemphälä and Magnusson, 2012; Dodourova and Bevis, 2014). However, after assessing the data and identifying the possible innovation networks structures, none of the identified networks were interconnecting the nodes altogether. Moreover, five different structures have being identified.

*Agent-to-Agent*: Figure 1 depicts the structures formed by two agents coming together. This is the most frequent type of structure established to generate innovation. Usually agents are cooperating to reach the goals of innovation and are mutually accepting the responsibility of the whole process. In Figure 1 *(a)* none of the participants is influenced by the associated characteristics of the other organization. Each participant is able to carry out their tasks based on the requirements of the innovation and both are slightly to none biased by externalities in terms of management. On the other hand, Figure 1 *(b)* shows the structure assembled by innovation networks, where one of the participating organizations assumes the coordination of the process of innovation and defines the management strategy used to carry out the innovation. In these cases, the work made by the secondary organization is going to by highly biased by the interests of the coordination unit. Agent-to-Agent networks are used to perform more radical than social or incremental innovations. The innovation process is complex itself and its complexity increases by the high uncertainty typically found in radical innovations. Therefore, in this type of innovation agents tend to reduce the risk by controlling other variables that could increase the complexity of the process. In this means, most radical innovations are carried out within networks with reduced complexity. Also the strength of the linkages is accentuated. Most networks are having just one coordination unit, trying to manage better the anomalies present in cooperative environments.

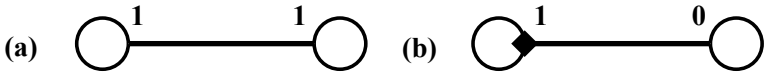


*Figure 1 - Representation of Agent-to-Agent innovation networks*

*Star*: Figure 2 portrays the network structure, where just one of the participating organizations is assuming the coordination role, but the network is having at least three participants. The additional agents, usually located in the periphery, are acting as secondary organizations in the network. However, this does not mean that their tasks towards innovation accomplishment are less important, nor that they cannot be related one another. In this type of structures, the main organization acts as a 'hub' receiving the developments executed by the other participants and enables the assembling of the innovation itself. Although this structure allows achieving better control, the outcomes of the network are highly influenced by the coordination unit. Therefore communication management strategies are key to assure the consecution of the innovation goals in this type of structures. Agents in the same industry or working in innovation networks dedicated to generate and transform specialized knowledge are mostly adopting this type of structure. Nonetheless, it is the less frequent structure among all types of innovation.

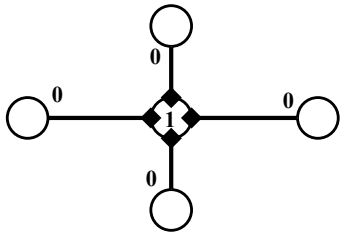


*Figure 2 - Representation of a star innovation network*

*Tree*: in networks agglomerating greater numbers of agents, tree-innovation-networks are the most selected structures. Figure 3 shows an example of this type of network structures, where up to 2 coordination units are expected. Conflict of interests between organizations assuming

coordination roles are often emerging. Project management strategies especially during assembling the final stages of innovation are highly recommended to avoid the disintegration of the outcomes. This structures present dense ties in the center and agents in the periphery are frequently known partners by the associated coordination unit. Likewise, agents located in the periphery of the network avoid direct ties among them.

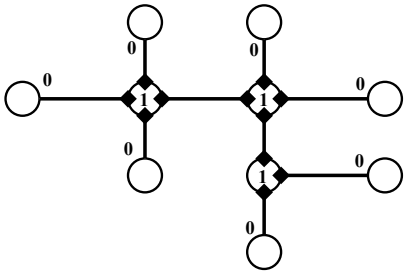


*Figure 3 - Representation of a tree innovation network*

*Collaboration*: Collaborative innovation networks, as represented in Figure 4, tend to work as a unit. Innovation networks, taking this form are in most cases conceived as an independent body in an industrial context. This independence can be either (1) physical creating a temporary agent to carry out the innovation; or (1) virtual, where agents are assigning dedicated resources to perform the innovation (Winkler 2009). In these structures, ties between agents are stronger and are usually oriented to develop product and services new to the involved organizations. Therefore, more radical than incremental innovations are being carried out under this type of structures.

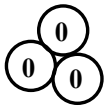


*Figure 4 - Representation of a collaboration innovation network*

*Cascade or line*: The more complex the project, the more control has to be addressed. As shown in Figure 5, the tasks regarding innovation are produced almost separately and each agent coordinates the production and its outcomes. Outcomes can be worked out in parallel or in series depending on the structure of the innovation process itself. Conflicts of interest are emerging between agents, especially while assembling the individual productions. Also communication management strategies are highly important in this type of networks, since in most cases the knowledge is highly specialized to an extent that other agents possess slight to inexistent experience handling that type of knowledge. This type of innovation network is mostly used in small networks working out complex topics or focused on transforming specialized knowledge.


*Figure 5 - Representation of a cascade or line innovation network*

## DISCUSSION AND FURTHER RESEARCH

Whether organizations accept it or not, innovation production is accelerated by their participation in cooperative/collaborative activities. The globalization of innovation is present in

all industries and the phenomenon will be accentuated in the coming years. Organizations are not innovating randomly and distinctive structures are serving the goal of innovation. This work has presented five different network structures assembled to enhance the process of innovation. Recognizing the structure of the innovation network can help defining better management strategies to carry out the innovation process in network environments. Networks with dense ties at the center are more likely to produce incremental or social innovation, i.e. Networks having 'star', 'tree' structures or a defined strong coordination unit. However, when it comes to radical innovations, most of the networks are reducing the complexity by accepting fewer agents within the same network. Conceiving networks with few participants, but holding specialized knowledge will help reducing the risks intrinsic to this type of innovation; i.e., networks with distributed ties are more likely to produce radical innovations. The strength of the link is mostly explained by the coordination role of the organization in the production of innovation. Further analysis aiming the recognition of the 'weak' agents can help addressing the dynamics exposed by Granovetter (1983) in the context of innovation network topologies.

Innovation networks are often defining at least one coordination unit. Most of the innovations are assuming project forms and 'project management' strategies are defined before starting the innovation process. The extent to which these strategies are embedded in innovation networks is not clear, but it could be subject of research towards risk reduction of these kinds of activities. Especially in 'tree' structures, where coordination agents are in charge of coupling the innovation, the correlation between communication strategies and successful rates are worth to be analyzed. The behavior between coordination agents and agents in the periphery could be exceled by defining management strategies oriented to blend the results obtained by each agent in the network. The characterization of networks in the innovation context can help identifying critical arrangements for future innovation structures. Further analysis regarding network topologies in innovation networks may lead to augment the knowledge regarding the interrelation between weaknesses and strengths of innovation networks and their design features. It could provide a first approach to help organizations preparing their innovation process and could even suggest, which internal structures should be adjusted to assume the challenges of the globalization of innovation.

Finally, two additional behaviors are worth pointing out, since they can represent further paths of research.

First, innovation networks in an industrial context are being shaped by the dynamics of the industry itself. The process of innovation production tends to remain 'efficient' and networks are assembled based on efficiency rates. However, innovation networks conceived as an independent body in an industrial context although more flexible are hardly dynamic (Winkler 2009); once the network is established, new organizations are barely going to be welcomed. Organizations formalize their ties for a period of time, in which innovation is the main goal of the network. Therefore, the dynamism happens in the internal structures of the participating organizations. Organizations are affected in at least two points during the network's lifespan: (1) at the formation of the network, and (2) at the dissociation of the network.

Second, studies have shown that SMEs excel considerably their innovation by participating in network structures (Gassmann and Keupp, 2007; O'Regan and Kling, 2011). This work confirms this behavior and even places SMEs as vital interlockers and oilers to guarantee innovation production in an industry. The knowledge produced by SMEs tends to support radical innovation and be highly specialized. Additional research oriented to unfold the amount of the further transformation cycles needed by the SMEs produced knowledge could help to better define the role SMEs can assume within innovation networks.

# BIBLIOGRAPHY


Abbasi, A., Hossain, L., Uddin, S., and Rasmussen, K.J., 2011. Evolutionary dynamics of scientific collaboration networks: multi-levels and cross-time analysis. *Scientometrics*, **89** (2), 687–710.

Archibugi, D. and Iammarino, S., 2002. The globalization of technological innovation: definition and evidence. *Review of International Political Economy*, **9** (1), 98–122.

Argote, L. and Ingram, P., 2000. Knowledge transfer: A basis for competitive advantage in firms. *Organizational behavior and human decision processes*, **82** (1), 150–169.

Barabasi, A. and Frangos, J., 2014. *Linked: The New Science Of Networks Science Of Networks*. Basic Books.

Barczak, G., Griffin, A., and Kahn, K.B., 2009. Perspective: trends and drivers of success in NPD practices: results of the 2003 PDMA best practices study*. *Journal of product innovation management*, **26** (1), 3–23.

Bellantuono, N., Pontrandolfo, P., and Scozzi, B., 2013. Mapping the Knowledge Supply Chain to Foster Innovation. *International Journal of Information Systems and Social Change (IJISSC)*, **4** (4), 9–25.

Burt, R.S., 2004. Structural holes and good ideas1. *American journal of sociology*, 110 (2), 349–399.

Choi, H., Kim, S.-H., and Lee, J., 2010. Role of network structure and network effects in diffusion of innovations. *Industrial Marketing Management*, **39** (1), 170–177.

Cohen, W.M. and Levinthal, D.A., 1990. Absorptive capacity: a new perspective on learning and innovation. *Administrative science quarterly*, 128–152.

Cunningham, D.J., 1992. Beyond educational psychology: Steps toward an educational semiotic. *Educational psychology review*, **4** (2), 165–194.

Delre, S.A., Jager, W., Bijmolt, T.H.A., and Janssen, M.A., 2010. Will It Spread or Not? The Effects of Social Influences and Network Topology on Innovation Diffusion. *Journal of Product Innovation Management*, **27** (2), 267–282.

Dodourova, M. and Bevis, K., 2014. Networking innovation in the European car industry: Does the Open Innovation model fit? *Transportation Research Part A: Policy & Practice*, **69**, 252–271.

Edquist, C. and Hommen, L., 1999. Systems of innovation: theory and policy for the demand side. *Technology in society*, **21** (1), 63–79.

Freel, M.S., 2003. Sectoral patterns of small firm innovation, networking and proximity. *Research policy*, **32** (5), 751–770.

Freeman, C., 1987. Innovation Process Imparts Uneven Ripple Effects. *Agricultural Engineering*, **68** (6), 16–17.

Gandrud, C., Allaire, J.J., Russell, K., Lewis, B.W., Kuo, K., Sese, C., Ellis, P., Owen, J., and Rogers, J., 2015. *networkD3: D3 JavaScript Network Graphs from R*.

Gassmann, O., Enkel, E., and Chesbrough, H., 2010. The future of open innovation. *R&d Management*, **40** (3), 213–221.

Gassmann, O. and Keupp, M.M., 2007. The competitive advantage of early and rapidly internationalising SMEs in the biotechnology industry: A knowledge-based view. *Journal of World Business*, **42** (3), 350–366.

Granovetter, M., 1983. The strength of weak ties: A network theory revisited. *Sociological theory*, **1** (1), 201–233.

Hemphälä, J. and Magnusson, M., 2012. Networks for innovation–but what networks and what innovation? *Creativity and Innovation Management*, **21** (1), 3–16.

Henri, F., 1992. *Computer conferencing and content analysis*. Springer.

Ingram, A.L. and Hathorn, L.G., 2004. Methods for analyzing collaboration in online. *Online collaborative learning: Theory and practice*, 215–241.

Johnson, B., Edquist, C., and Lundvall, B.-Å., 2004. Economic Development and the National System of Innovation Approach. Available at: https://smartech.gatech.edu/handle/1853/43154 (Accessed 20 Nov 2015).

O'Regan, N. and Kling, G., 2011. Technology outsourcing in manufacturing small-and medium-sized firms: another competitive resource? *R&d Management*, **41** (1), 92–105.

Sydow, J. and Windeler, A., 2003. Knowledge, trust, and control: Managing tensions and contradictions in a regional network of service firms. *International Studies of Management & Organization*, **33** (2), 69–100.

Winkler, H., 2009. How to improve supply chain flexibility using strategic supply chain networks. *Logistics Research*, **1** (1), 15–25.

Zeng, S.X., Xie, X.M., and Tam, C.M., 2010. Relationship between cooperation networks and innovation performance of SMEs. *Technovation*, **30** (3), 181–194.