1. Innovation networks in industries and sectoral systems: an introduction

Franco Malerba and Nicholas S. Vonortas

1. NETWORKS AS MAJOR PARTS OF INDUSTRIES AND SECTORAL SYSTEMS

The contributions in this book concentrate primarily on networks in industries and sectoral systems, reflecting a belief that some of the most important analytical and policy questions related to networks must fully consider the industry level (including the very structure of industries), the role of networks in different sectoral systems of production and innovation, and the delineation of real industry boundaries. Indeed, an extensive literature has developed around networks at various levels of analysis, but the bulk of these studies focus on single organizations and single networks, or are done at the macro, aggregate level. There has been little analysis at the industry and sectoral levels. We are convinced that a relevant and useful way to examine networks is one that takes industry and sectoral systems into consideration and, therefore, allows us to examine diversity in network emergence, structure and evolution, and to evaluate the differential effects of networks on firms and industry growth and performance.

In addition to the previous objective, a second goal of this book is to open up to the reader the tremendous opportunities for significant study in the areas of industry structure, firm strategy and public policy through the use of network concepts and indicators as well as to highlight the complexities and challenges involved. We strongly believe that, although extensive, the literature on networks has just scratched the surface in terms of concepts, models and indicators that can be used to address challenging strategy and policy questions.

Why focus on the industry and sectoral levels in the analysis of networks? The evidence on inter-organizational technological agreements is already very rich, pointing at their importance for fast-changing environments where flexibility is highly prized. We would argue that the existing
empirical literature can constitute the basis for an “appreciative theory” that links the self-organization of research and development (R&D) networks to the rate and the direction of technological progress, to the actors involved in the innovative process and, more generally, to the evolution of industries. The formation of R&D networks is a self-organizing process because such networks are the result of uncoordinated choices of organizations over time in response to technological factors and socio-economic conditions. In turn, such factors and conditions are affected, over time, by that same network, so that the dynamics of the system are characterized by several feedbacks, mostly positive (self-reinforcing) in nature.

A useful starting point for framing the contributions in this book is to consider that networks of various types are in sectoral systems of innovation that differ to a great extent in terms of knowledge, actors and institutions. These differences greatly affect the extent, structure and dynamics of networks of agents active in a sector. This discussion can be tied into the significant efforts that have been undertaken in recent years to provide a multidimensional, integrated and dynamic view of sectors, related to the concept of sectoral systems of innovation and production (Malerba, 2002 and 2004). The basic analytical foundations underlying the notion of sectoral systems of innovation follow the traditions of evolutionary theory (Dosi, 1988; Nelson, 1995) and systems of innovation theory (Edquist, 1997). The sectoral systems approach concerns all the stages of industry evolution, from inception to maturity. This approach has both quantitative and formal (with the development of history-friendly models of industry evolution) elements, as well as qualitative and “appreciative” elements, highlighted by aspects such as learning, the knowledge base, competencies, and relationships among agents. In general, the basic elements of a sectoral system can be identified in the knowledge base and the basic technologies, products, agents (including both firms and other organizations such as universities, financial institutions, etc.), demand and institutions.

Within sectoral systems, heterogeneous agents are connected through networks that include both market and non-market relationships. On this issue, it is possible to identify different types of relationships, linked to different analytical approaches. These relationships, however, are not limited to just agents involved in the processes of exchange, competition and command. They concern also formal cooperation or informal interaction among firms or among firms and non-firm organizations, ranging from tacit or explicit collusion, to hybrid governance forms, to formal R&D cooperation. The evolutionary approach and the innovation systems literature have paid much attention to the wide range of formal and informal avenues of cooperation and interaction among firms. According to this perspective, in uncertain and changing environments networks emerge
not because agents are similar, but because they are different. In this way networks may integrate complementarities in knowledge, capabilities and specialization (see Lundvall, 1992; Edquist 1997; Nelson, 1995; Teubal et al., 1991). In addition, the literature has examined the role of the relationships between firms and non-firm organizations (such as universities and public research centres) as a source of innovation and change in several specific sectors, such as pharmaceuticals and biotechnology, information technology, and telecommunications (Nelson and Rosenberg, 1993).

In this framework, network structures emerge in a self-organizing process from the initial conditions of a specific industry, the characteristics of the relevant technologies, and the norms and institutional factors that help generate rules that guide firm behaviour. Behavioural rules and network structure are linked in an interactive relationship: as rules generate the structure of the network, network structure influences subsequent behaviour. The emergent structure dissuades rule-breaking behaviour. “The dynamic between internal capabilities, ensconced in specific identities and organizational structures, and the external knowledge in the market (network) drives a co-evolution between the emergent properties in the firm and the network” (Kogut, 2000; p. 412).

Using this conceptual framework as background, the book is divided into three parts. The first part, Chapters 2–3, is methodological in nature and discusses concepts and measurements of networks. The second part, Chapters 4–8, examines empirically the structure and features of various types of networks across different sectoral and scientific domains. Finally, the third part, Chapters 9–10, introduces the public policy aspect and uses ICT as a case-study sector in which to examine policies favouring networks of research and of diffusion.

2. NETWORKS IN INDUSTRIES AND SECTORAL SYSTEMS: AN INITIAL DISCUSSION

As stated earlier, the first part of this book discusses the main methodological problems associated with concepts and measurements, and places the empirical discussion into an industrial framework that takes into account the fact that industries and sectoral systems evolve over time.

In Chapter 2, “Innovation networks in industry”, Nicholas Vonortas provides a methodological discussion of evaluating networks in industry, and attempts to link the terminology in the networks field proper to core concepts in the field of industrial economics. The chapter draws on recent developments regarding the concepts of social capital/network resources, information/learning, network governance, network emergence, and
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network structure to discuss their influence on firm strategy in industrial sectors characterized by rapidly changing technologies. Distinct from human capital – or, equivalently, organization-specific attributes/capabilities – social capital (or network resources for organizations), is understood as a set of social resources embedded in relationships and associated norms and values. The build-up of human capital and organization-specific capabilities requires investment, as does the build-up of social capital and network resources. However, the type of required investment is different. Network resources translate into informational and control benefits generated through network ties and positioning. These network resources are influenced very much by the conditions of the specific industry, the characteristics of the relevant technologies, and associated norms and institutional factors. A network balance emerges that allows both for stability, when it proves advantageous, and for a recombination of information and network renewal. This is not very different from the traditional market analysis in economics: (network) entry and barriers to such entry become key factors for network structure and its rejuvenation, exactly as they do in markets where entrants dilute the strongholds of incumbents. Similarly to achieving optimality in markets, achieving balance in networks is complex and varies across activity areas (e.g. sectors). Vonortas concludes that in order to determine the incentives (net benefits) of a firm to participate in a network one needs to address network structure optimality and the firm’s positioning in the network, which, in turn, requires addressing the relationship between industry (activity) characteristics and firm strategy. Vonortas argues that this reflects the fact that networking is only a part of the more general strategy orientation of the firm, which itself is influenced by the characteristics of the economic activity in which the firm is engaged. By implication, the utility of network analysis increases if it is combined with more traditional investigations of market structure, technological advance, competitive behaviour, and company performance in different industrial environments.

In Chapter 3, “The dynamics of networks and the evolution of industries: a survey of the empirical literature”, Lorenzo Zirulia reviews the empirical literature on inter-firm technological agreements. Several databases exist that track the developments in such agreements, using public announcements as the unit of analysis. While these kinds of data are subject to several biases – related to language, characteristics of announced agreements, and so forth – they all point to a number of stylized facts indicating that: alliances have increased greatly in the past two to three decades; they tend to be of a contractual nature and not involve significant investment by the parties involved; and they are overwhelmingly concentrated in high-tech activities. The incentives for forming them vary widely – even among
members of the same alliance – but tend to include some form of access to market and/or resources, risk mitigation, and technology intelligence. Following a discussion of the main analytical findings in the relevant literature regarding the influence of alliances on performance and capabilities, the author turns to the relationship between technological agreements and industry evolution. He suggests that inter-firm technological agreements and related networks can be viewed as structural elements in the evolution and dynamics of industries. He proposes three interrelated themes that define the relationship between technological collaborations, R&D networks and industry evolution. The first is path dependency in collaboration and the first mover advantages it might offer to early entrants in a nascent industry environment. The second theme centres on the role of networks as both a mechanism of technological knowledge diffusion for firms within the network and an exclusionary mechanism for firms outside the network. If no firm possesses all the relevant technological capabilities to innovate, the network will act as the “locus of innovation”, increasing competition within it but excluding those outside it. The network may be composed of different cohesive sub-groups, so that competition occurs among groups, rather than at the firm level, and might explain differences in exit rates, growth, economic performance and innovativeness. Finally, a third theme describes the role of networks in affecting the “collective” direction of technological change in industries.

3. THE FEATURES AND STRUCTURES OF NETWORKS IN DIFFERENT INDUSTRIES AND SECTORAL SYSTEMS

A central conclusion of this book is that the features and structures of networks differ from industry to industry and, consequently, from sectoral system to sectoral system. This is the result of the specificity of the knowledge base, the relevant learning processes, the basic technologies, the characteristics of demand, the key links, and the dynamic complementarities that characterize an industry and a sectoral system. For example, in pharmaceuticals, think of the change in the underlying knowledge base in the switch from old drug discovery to modern biotechnology. This change has created new types of networks and relationships among firms (large pharmaceutical companies and new biotech firms), and among firms, non-firm organizations (such as universities and venture capitalists) and institutions (such as regulations). Now compare pharmaceuticals with the knowledge base of the machinery production sector, which reflects completely different types of networks and relationships between firms
Innovation networks in industries (users and suppliers), non-firm organizations (such as local banks and industry associations and government) and institutions (local trust). Or consider the type of knowledge and networks in an industry such as software. Within this perspective, one common aspect affecting the evolution of different networks is the learning environment in terms of technological regimes defined in terms of various degrees of technological opportunity, appropriability of innovation, cumulativeness of technical advance, and the properties of key knowledge bases and learning processes (Malerba and Orsenigo, 1996; Breschi et al. 2000).

This background brings to mind questions regarding what kind of networks are present in different industries. We explore this issue by examining different types of networks for innovation in industries such as pharmaceuticals, electronics, instrumentation and chemicals. Networks are examined in terms of content and in terms of actors and organizations. In the first case we distinguish three broad classes of networks: scientific networks, knowledge networks and alliance networks. In the second case, we discuss universities and research organizations, companies and individuals. Of course, the categories of content and actor-based networks are strictly related in various ways.

Networks are multidimensional concepts that cut across different types of actors, different types of scientific, technology and knowledge realms, and may touch on R&D, production and marketing. In this vein, this book is one of the first to analyse networks by applying different measures to disparate industries: scientific publications to assess scientific networks; patent citations to identify knowledge networks; technological partnerships (joint ventures, formal alliances, licences) to identify partnership networks; and the movement of researchers across organizations to identify researcher mobility networks.

Often, the focus of the analysis is not the organizations within, or the physical structure of, the network, but the collaborative exchange in predefined industrial sectors; that is, the activity of the organization. That is to say, the examined scientific, knowledge, partnership or mobility networks are not the complete networks of the organizations that can be classified in the predefined sectors on the basis of their production. Rather, they are the inter-organizational networks constructed on the basis of the knowledge and collaborative activities of these organizations.

On the basis of this discussion, the chapters (4–8) in Part II of the book address questions such as:

- What are the main features of scientific, knowledge and partnership networks across industries?
- Are there broad differences between these networks?
Do such networks establish effective channels of knowledge communication of different intensity across sectors?

- How do companies position strategically in these networks and how do they differ across sectors?
- What is the search process of companies in these networks?
- What are the main features of networks of mobile inventors?

In Chapter 4, “Measuring the corporate web of science: research and partnership networks within the European pharmaceutical industry”, Robert Tijssen uses research cooperation data within the pharmaceutical sector to examine the scientific networks in pharmaceuticals in which at least one partner is an industrial company. The results that emerge from this study of ten European pharmaceutical companies enable a certain degree of aggregate-level benchmarking. The indicators produce a one-year snapshot of the combined firm-level research partnership profiles, in which several interesting features are observed. Most striking is the degree of similarity between the research partnership profiles of these ten companies. This shows that the distributive characteristics of the ten firms are again remarkably similar, suggesting that these research cooperation patterns within the large companies are predominantly sector-specific, rather than company-specific, and are dependent on the type of knowledge base that characterizes the sector.

However, the international orientation of the two Swiss companies in the sample, Novartis and Roche, both of which have many labs outside their home countries, highlights the impact of corporate strategies for locating R&D centres in many other countries. This outcome raises questions on how or why these firm-level research partnership profile features come about. Are they mainly determined by global, sector-specific R&D processes, by competitive pressures impacting on corporate R&D strategies, or are they still very much rooted in the traditional practice of proximity-driven preferences for partners? Can these internally driven partnering mechanisms be redirected and made more effective by introducing additional incentive systems and imposing new collaborative frameworks from the outside? Even though these partnership indicators and statistics produce a novel and unique window of research cooperation within the European pharmaceutical industry and help unravel the web of research networks involving pharmaceutical companies, a convincing interpretation of these findings requires a global perspective and sector-wide frame of reference, which cannot be provided here. Future research must be designed to answer questions such as: what does it mean for a specific European company to be near the bottom of a ranking, or to have an average score, in terms of participation in co-authored research articles?
Providing answers to such questions not only requires technical expertise on the ins and outs of the information sources and an in-depth understanding of the underlying metrics and statistical properties of the data, but, above all, accurate comprehension requires a thorough grasp of the relevant economic environments and geo-political contexts in which these European multinational companies operate. We still know little about the detailed and hard-to-observe mechanisms and organizational conditions that are driving these research partnerships. It stands to reason that the various types of linkages are driven by differing environmental conditions, which are strongly affected by the prevailing R&D objectives and constraints, intellectual property rights (IPR) and knowledge appropriation regimes. Moreover, each type of research partnership and network is likely to operate according to its own managerial models and organizational structures, including different milestones and deliverables that affect incentives at the firm and network level.

In Chapter 5, “Knowledge search and strategic alliance: evidence from the electronics industry”, Stefano Breschi, Lorenzo Cassi and Franco Malerba go in depth within the knowledge and partnership networks of electronics firms and inquire empirically about the existing trade-off between strategies of “local” search, which builds cumulatively on a firm’s established knowledge base, and strategies aimed at recombining ideas and knowledge, drawing on areas relatively distant from a firm’s current technological base and competencies. The analysis is related to firms’ R&D collaborations. The chapter combines patent citations and strategic alliances data for a sample of 272 publicly traded companies operating in the electronics industry in the 1990s. In particular, patent co-citation data are used to investigate the extent to which the pattern of search for new knowledge overlaps across companies.

The authors argue that processes of competition and collaboration have to be taken into account when exploring the impact on innovative performance of different search strategies. On the one hand, competition from other firms building on a firm’s knowledge base may hamper innovation by that firm, thereby reducing the effectiveness of a local and cumulative search strategy and increasing the attractiveness of a recombination strategy. On the other hand, forming alliances with competitors is a means of internalizing the potential negative effects arising from competitors exploiting a firm’s knowledge base. In this case, R&D alliances are formed among partners that perform searches in the same knowledge base and along similar lines, rather than among companies searching in different directions. The chapter shows that search strategies based on the cumulative exploitation of a firm’s own stock of knowledge are positively related to the firm’s rate of innovation. But results show also that this positive
effect is moderated by the negative effect arising from competition from other organizations trying to exploit the same knowledge base of the focal firm. Finally, the results show a possible solution to this problem: joining an R&D collaboration by a firm that has its knowledge set crowded by too many competitors searching in its technological space reduces the intensity of competition and, in this way, increases its rate of technological innovation.

In Chapter 6, “Partnership networks and knowledge networks in five sectors”, Koichiro Okamura and Nicholas Vonortas examine two different types of networks – knowledge and technology partnership – in five industrial sectors: pharmaceuticals, plastics, computers, electronics, and instruments. Their findings point to three sets of results that require further attention. First, there is an apparent difference in the networking behaviour in pharmaceuticals vis-à-vis networking behaviour in computers, electronics and instruments. Second, there is an apparent difference between knowledge and partnership networks across all sectors in terms of their effectiveness as channels for knowledge communication. Third, there is an apparent difference in the competitive positioning of European firms and firms from the United States and Japan in the knowledge networks across the examined industrial sectors. In general, all five knowledge networks are found to be highly connected. That is to say, there are paths connecting the identified companies to each other in a given sector in the form of inter-linking patent citations. These paths tend to be short: on average, a company can find any other in less than three steps. There are, however, differences between sectors in terms of the nature of this connectivity. For instance, the knowledge network in pharmaceuticals appears to be the most broadly connected, whereas the knowledge network in instruments seems to depend more on gatekeepers and information hubs for its connectivity.

The sectoral partnership networks investigated here are much smaller than the knowledge networks. They are also more fragmented than knowledge networks in all five sectors. Among partnership networks, the pharmaceuticals network seems to be the least closely connected and depends more than the other sectoral partnership networks on a few hubs for its connectivity. The knowledge network is robust to the random removal of nodes across all industrial sectors but quite vulnerable to the removal of the most connected nodes. The same is true for the partnership networks in pharmaceuticals and electronics. In fact, the partnership network in pharmaceuticals disintegrates more quickly than its knowledge network, indicating that it is more dependent on a few highly connected firms. The apparent difference in networking behaviour between pharmaceuticals and other sectors is an important finding that requires further attention in
future investigations. Drug company networking behaviour seems to be different in patenting and in strategic partnering. Note that pharmaceuticals as an industry has different technology domain characteristics from computers, electronics and instruments.

The authors did find a major contrast between knowledge and technological partnerships. All five knowledge networks appear to be effective channels for knowledge flow between the participating organizations: they can all be characterized as “small worlds”. The examined technological partnership networks cannot be characterized as such, even though their largest components come much closer to the small world phenomenon. This difference between knowledge and partnership networks is the second potentially important result of this study, and requires further investigation as the partnership data used in this exercise were relatively thin.

A third important result of the chapter points out differences between European firms and their American and Japanese counterparts. European firms tend to position in less crowded partitions of the examined sectoral knowledge networks. They dominate the “technology broker” partitions of the sectoral graphs, where less crowded positions are combined with high status. They also appear in large numbers in the “technology isolate” partitions, where less crowded positions are combined with low status. In contrast, Japanese firms tend to reside mostly in the partitions of “technology leaders” and “technology followers”, where more crowded positions are combined with high status and low status, respectively. US firms tend to lie somewhere in between, their distribution among the four partitions resembling somewhat more that of the Japanese firms.

The dominating presence of European firms in the “technology brokers” partition across all examined industries can have two explanations. It could imply a bright future for European firms in that they are getting equipped with new, desirable technologies. Though this benefit might be tempered by the possibility that their early-stage research may not be followed with equal success in commercializing the resulting technological advancements as Japanese and US firms dominate the technology leaders’ partition and capture the associated rents. Alternatively, it could be argued that EU firms tend to stick to unsuccessful technologies that die out sooner rather than later. In contrast, Japanese firms seem to follow a “fast-second” approach, keeping close to the forefront of technology but not as brokers or isolates/entrepreneurs. When they find promising technologies, Japanese firms will concentrate their R&D efforts on pushing the technology forward and reaping the benefits from commercialization. As for the American firms, their relatively more even spread in the graph indicates capabilities to follow diversified strategies. They maintain solid capabilities as technology leaders in all examined industries, including the
occupation of significant positions as isolates in drugs, plastics and instruments. Unexpectedly, however, they appear relatively weak as technology brokers. Significant numbers of US firms were also found in the followers’ partition across all industrial sectors. To conclude, we should add that, while characterizing the nature of the examined inter-organizational networks and the strategic positioning of companies in them has proven quite rewarding, for a fuller picture, network analysis should be complemented with the more traditional approaches in the economics and management/strategy fields dealing with the competitive behaviour of individual companies and their market success.

In Chapter 7, “What do you mean by ‘mobile’? Multi-applicant inventors in the European biotechnology industry”, Francesco Laforgia and Francesco Lissoni focus on networks among companies through the mobility of inventors that move from one company to another. Laforgia and Lissoni propose a taxonomy of the phenomena of multi-applicant inventorship, defined as inventors that patent in multiple organizations, thus creating de facto links among these organizations. By making use of information on the identity and history of those applicants, they propose a taxonomy of the phenomena behind multi-applicant inventorship, which could be distinguished between true job mobility, mobility as a result of mergers and acquisitions (M&As) and residuals cases. They rely on the EP-Cespri database of patenting activity at the European Patent Office (EPO), covering the time period of 1978–2003, from which they have extracted data on all the inventors with more than one patent application signed in biotechnology-related fields and associated with a European address. Within that sample, they focus on all inventors associated with two or more patent applications, and no less than two different applicants. Job mobility turns out not to stand as the dominant source of multi-applicant inventorship. However, not all the phenomena behind “multi-applicant” inventorship may be equated to genuine job mobility creating mobility networks among different organizations. By applying their taxonomy to EPO patent data in biotechnology, the authors found that both the existence of markets for inventions and M&A activity contribute to multi-applicant inventorship, even though the existing literature has lumped all of these explanatory phenomena under the single label of mobility. Laforgia and Lissoni emphasize that it is important to identify all the various phenomena behind multi-applicant inventorship because these phenomena bear different consequences in terms of knowledge diffusion. The authors show that firm networks generated by truly mobile inventors are very different from those created by M&A-induced, multi-applicant inventorship. It is likely that the findings signal the capacity of mobile inventors to connect more firms and institutions than can other
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categories of inventors, therefore providing a powerful mechanism of net-
worked knowledge diffusion.

Finally, in Chapter 8 “Science as a communications network: an
illustration of nanoscale science research”, Caroline Wagner and Susan
Mohrman present the results of a network analysis of the American
Department of Energy (DOE) national laboratories in their role of pro-
moting research and development in nanoscale science. Network analysis
was used to uncover the structure of social relationships within the specific
research community on the basis of the assumption that these relation-
ships transmit and diffuse information. This chapter analyses the roles and
positions of the nodes within and around the DOE laboratories with sig-
nificant investment in nanoscale science and technology capabilities. Six of
the DOE labs established centres dedicated to nanoscale science, called the
Nanoscale Science Research Centres (NSRCs), in a highly interdiscipli-
nary and unstructured research design. Wagner and Mohrman analyse the
network in which the labs and the centres operate (locally and globally),
and the centres of excellence to which they connect around the globe. The
analysis is presented over time to correlate with the time that the forma-
tion of the NSRCs was announced through the National Nanotechnology
Initiative (NNI) in the United States and their charters were being negoti-
ated. In the earlier years, the parent laboratory is the point of reference for
the network analysis, either because the NSRCs were not yet created or
because the smaller centres cannot be seen in the network at a particular
level of aggregation. Whenever possible, emphasis is given to the NSRCs
as they emerge from within the operations of the parent laboratories.

The analysis suggests that at least two of the DOE labs are in an excellent
position within the global network to trade knowledge. The DOE contract
research laboratories are shown to have been key players in the nanoscale
sciences even before the announcement of the creation of new interdis-
ciplinary research centres under the NNI. An interesting observation is
that during the years of investigation (2002–06), the NSRCs emerged
from within their parent laboratories, drawing strength from the robust
networks built by these DOE laboratories over more than 15 years of
nanoscale research and collaborations with other institutions from around
the world. As the NSRCs formed their own networks, in some cases they
appear to draw off collaborators from the parent labs’ networks, actually
reducing the strength of the parent network in the global system while not
building up the small centres into highly attractive nodes – at least not in
a visible way in 2007. In other words, the creation of a spin-off research
centre may actually have a short-term negative effect on the positions of
both the parent and the spin-off institution while social networks catch
up with the prior positions held by the parent labs. This may mean that,
during the time when the spin-offs are being created and the parent labs are regaining their position, the research centres actually lose power and influence in the network as a result of the reorganization. While this may be a short-term loss, it may also mean a loss of ability to contribute to regional or national innovation for some period of time, perhaps as much as two years, as new connections are made.

All of these chapters in the second part of the book point to some general conclusions about networks in different industries and, consequently, in different sectoral systems:

- Major differences are observed in networks of R&D and knowledge flows across industries, reflecting differences in the knowledge base and sectoral systems.
- However, scientific networks pertaining to a single industry show broad similarities.
- In an industry, search strategies by companies within networks can be quite different and may involve either local search or innovative recombination of quite different types of knowledge.
- Also, in the same industry, the extent of competition within and across networks could be relevant.
- Networks among companies and other organizations involve linkages that include also the mobility of researchers that takes various forms and has various effects on innovative performance.
- The emergence of new important units within central nodes of a scientific network may disrupt the global connectivity of the parent organizations for some time and reflect a tendency for more local activity by the new units for some time at least.

4. NETWORKS AND PUBLIC POLICY IN THE ICT SECTORAL SYSTEM

The final part of the book reviews policies supporting networks in a key, broad sectoral system: information and communication technology (ICT). Here, social network analysis and direct field research examine the effectiveness of public policies addressing the development of networks for the creation and diffusion of new technology.

In Chapter 9, “European policy favouring networks in ICT”, Stefano Breschi, Lorenzo Cassi, Franco Malerba and Nicholas Vonortas advocate the use of social network analysis to evaluate aspects of public programmes supporting research and development, especially as these aspects relate to the “behavioural additionality” of the programmes under investigation.
Appraisals of R&D expenditures have tended to concentrate either on the resources added by public funding into the system (input additionality) and/or on the extra private and social returns resulting from public funding (output/outcome additionality). The methodology employed in this chapter concentrates on the sustainable effects beyond the infusion of resources and/or the extraction of outputs that such investments create. Sustainable effects include improving the competencies, capabilities, organizational structures and strategies of firms (behavioural additionality). The authors draw on a recent study that appraised the partnership and knowledge networks created around the R&D activities of the Information Society and Media Priority of the Sixth Research Framework Programme (FP6) of the European Community. In an effort to address questions of knowledge network effectiveness, the authors apply a novel, quantitative methodological framework for assessment of inter-organizational networks established by IST-RTD programmes in comparison with global networks developing independently of Community funding. The results of the quantitative analysis are enriched with more qualitative information obtained through a series of expert/practitioner interviews. The analysis demonstrates the applicability of social network concepts and analytical tools in appraising the relative global positioning of public funding networks and the effectiveness of the specific networks in creating leading knowledge hubs in selected technological domains. The examined programmes are found to have played an important role in generating and diffusing knowledge by attracting key industry actors and by creating and increasing network connectivity. Hubs are effective in producing and diffusing knowledge. Gatekeeper organizations – simultaneously global hubs and IST-RTD hubs – are the most effective in terms of both enriching the network with new knowledge and facilitating the dissemination of knowledge among network members. It is argued that public policy should try to facilitate the development of more European organizations that can be characterized as global network hubs and to draw larger numbers of the most technologically dynamic small and medium-sized enterprises (SMEs) into these programmes.

Chapter 10, “Evaluating the links between research and deployment networks of innovation in information society in Europe”, Lorenzo Cassi, Nicoletta Corrocher, Franco Malerba and Nicholas Vonortas use network analysis to examine the structure of collaborative networks and of knowledge transfer between research, innovation and deployment activities in the field of information and communication technology (ICT) for the European Union as a whole and for several European regions. In particular, this chapter analyses the linkages between the research networks built through the sixth Framework Programme funding in the
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thematic area, “Applied IST Research Addressing Major Societal and Economic Challenges”, and the diffusion networks built through EU programmes (eTen, eContent) and regional programmes. Research networks are found to complement diffusion networks by providing additional links and by increasing the number of organizations involved in sharing and exchanging knowledge. Two types of actors are key players in these networks: hubs and gatekeepers. Hubs maintain the bulk of ties in the networks and help the smaller and more isolated members remain connected. Gatekeepers bridge research and diffusion networks. Such organizations naturally offer greater policy leverage in establishing a European knowledge infrastructure. Moreover, strengthened inter-network connectivity among research and diffusion activities (deployment) is projected to raise the effectiveness of European research in terms of accelerating innovation. Hubs and gatekeepers partially overlap and include both research organizations (universities, research institutes) and business firms. Multinational corporations and some small and medium-sized firms play key roles in these networks. Thus, multinationals participating in research networks and in large-scale projects that link research and diffusion allow smaller organizations to access critical knowledge, technical and/or market resources, while smaller firms are effective in the deployment of specific applications. A clear policy implication follows from this analysis: if a European knowledge infrastructure is considered important and the connectivity among organizations focusing on research and innovation is a way to strengthen this infrastructure, then the connections between research networks and diffusion networks must be strengthened and the role of gatekeepers nurtured.

5. THE ROAD AHEAD

Clearly, more work is needed to develop a comprehensive analytical framework and an associated typology of partnerships and the networks that link them to the main features of industries and sectoral systems. For example, we need further in-depth analysis of research publication data, conclusive information from other sources on inter-organizational research networks, and illustrative case studies to R&D objectives and business strategies that drive and shape these partnerships. Further statistical analysis of the underlying relational patterns within the joint research publications of these firms might also disclose more details about how they organize.

Building on the premises that networks (a) differ across industries and sectoral systems, and thus across knowledge, technology and production
space; (b) reflect social norms and institutional factors; and (c) evolve through time and as a result of changing technology, firm, and industry characteristics, the chapters in this book present a range of exploratory methodological and analytical work based on extensive network data. Methodological results have implications regarding the use and correct interpretation of network data based on scientific publications, patents and patent citations, and inter-organizational partnerships. Analytical results have direct implications for policy and were summarized in the previous section of this chapter.

Network data also can prove very useful for helping to address a much wider variety of analytical questions than can be tackled in a single book. Below, we provide a menu that, although by no means exhaustive, illustrates the possibilities of further research in this area. In the spirit of this book, all of these issues and dimensions of investigation should be examined both in a general way as well as in their relationship with the specificity of the technology, industry and sectoral system. In fact, it is highly likely that networks differ from one industry to another and, consequently, from one sectoral system to another in several respects:

- **Frequency of network formation.** Inter-organizational networks are increasingly regarded as a core governance mode in the knowledge-based economy. Economic success in knowledge-intensive industries depends on the commercialization of technologies that require constant organizational learning and the integration of a wide variety of know-how, skills and capabilities. These technologies have become so complex they can often only be innovated by complex organizational networks, rather than by individual firms. Can it be hypothesized that networks will be formed much more frequently around complex technologies than around simple technologies?

- **Types of networks.** Technological/organizational complexity might suggest that networks formed around complex technologies will be of a different nature than the networks formed around simple technologies. For instance, if we assume that the knowledge base of a technology (for example, information and communication technologies) is more complex and more dynamic than the knowledge base of another technology (for example, bulk chemicals), this argument would imply that an information technology network may have more members and different types of ties among those members than does a chemical network. Such a hypothesis would lead to an examination of the linkage between the type of network and the type of technology.
Lock-ins in networks. A firm’s network(s) is a source of both opportunities and constraints. Strategic networks potentially provide a firm with: access to information, resources, markets and technologies; advantages from learning, scale and scope economies; and opportunity to achieve objectives such as sharing risks and outsourcing. Networks may also lock firms into unproductive relationships and preclude partnerships with more viable partners. Thus, the firm’s network might assume greater importance as the economic environment becomes more competitive. To what extent is that true across broad technology areas? What factors account for prospective differences?

Cross-network differences in performance. Network scholars propose that the concept of similarity in relational space – which differs from the concept of similarity in attributes (e.g. scale, scope, technology) – is an important way to think about competition patterns and profitability differences between firms in an industry. Therefore, do groups defined in terms of attributes overlap with groups defined in terms of relational similarities? Is firm conduct and performance contingent on these different ways of grouping?

Competition, positioning and networking. Recent research has indicated that the location of a firm in a network is an important element of competition. Competition is seemingly more intense for actors that occupy similar locations relative to others but is mitigated if actors are tied to each other. Assuming an overall objective of achieving a sustained, rapid rate of technological advance in a highly risky environment, is it advisable to allow similarly positioned organizations in a network to create cooperative relationships with each other? What factors should influence the decision?

The value of networks as a key resource. The resource-based view of the firm has underlined the potential for enduring benefits from a collection of resources that is inimitable and not readily substitutable. Network scholars now argue that a firm’s network of relationships can create inimitable and non-substitutable value themselves and allow access to unique resources and capabilities, including network resources and social capital. To what extent does this phenomenon differ across sectoral systems? Is it more important for large, diversified firms or for smaller firms? If so, why?

Repeated collaborations. It is easy to imagine that a company would confront prohibitive transaction costs should it be obliged to engage in multiple alliances with partners that it does not somehow know well, control, or trust. To mitigate the problem, firms depend on networks built on repeated interactions between
members and on verifiable member reputations. It has been a researchable proposition in the business literature that membership in tight and persistent networks provides deep knowledge and a strong lever of combined trust and control over other members, thus lowering the transaction costs of collaboration in situations of incomplete contracts. Contract incompleteness is prevalent when firms experiment with new technologies and when high market and technological uncertainties are present. Does this factor alone provide a sufficiently strong argument for repeated collaboration in these circumstances? Could it be that tests between controlled populations of firms similar in all other respects except networking activity would show systematic performance differences one way or the other?

- **Networks, idiosyncratic capabilities and the appropriability of innovations.** Networks have a paradox: on one hand, firms often join to access the know-how and capabilities of their partners; on the other, they want to protect their own proprietary assets. It is now argued that building relational capital helps achieve both objectives simultaneously by facilitating learning and curbing opportunistic behaviour. To what extent is the building of relational capital responsible for differing strategies within the same industry, where some firms find it beneficial to collaborate and some don’t?

- **Learning to collaborate.** Alliance networks involve costs in terms of managerial resources. It is now being established that firms learn to manage alliances as experience accumulates, and learn how to learn from their partners. It seems that these learning effects depend on firm-specific alliance capabilities. Can such learning effects be clearly quantified in terms of value? Does it mean that firms with more experience and higher social capital have permanent advantages over others? What does that mean for new companies in rapidly changing environments? Are there differences between broad technological areas?

- **Routines for absorbing knowledge in networks.** Scholarship suggests that organizations effective in learning establish routines that allow them to effectively develop, store and apply new knowledge systematically. Establishing such routines may also seem an appropriate thing to do in networks concentrating on the creation and dissemination of knowledge. Yet, we still lack a clear understanding of this issue. While recent research has pointed out the use of such effective routines in some of the most venerable industry networks, it leaves open the question of network structure. In particular, can effective learning routines be established in networks? How do these learning...
routines relate to the objectives of the network and its members? Do
learning routines co-evolve with network structure?

- **Networks for exploration and networks for exploitation.** One of the
  most interesting hypotheses in network research as it applies to
technological advance and innovation is whether highly connected,
strong-tie networks are better suited for the diffusion and exploita-
tion of existing knowledge while weak-tie networks are better suited
for the exploration of new knowledge. In particular, it is suggested
that the degree of uncertainty and the rapidity of rate of innovation
influence the appropriate network configurations, promoting strong
ties and dense networks in more stable environments. Such argu-
ments are rooted in earlier research on social networks regarding the
roles and advantages of strong and weak ties and strong and weak
structural embeddedness. Is this hypothesis supported in European
high-tech industries? How is it affected by different technological
characteristics and selection environments across sectors? To what
extent can one provide empirical support through European data to
recent theoretical assertions that network structure is emergent in the
initial conditions of the specific industry, reflecting the inherent
characteristics of the technologies as well as social norms and insti-
tutional factors?

- **Networks and firm evolution.** It has been argued that the effect of
alliance network composition may vary at different stages of evolu-
tion for a firm. For example, it has been shown that start-ups can
enhance their early performance by establishing an alliance network
and configuring it to provide efficient access to diverse information
and capabilities with minimum costs of redundancy, conflict and
complexity. A core hypothesis here is that, by forming alliances,
start-ups can potentially access social, technical and commercially
competitive resources that typically require years to acquire. How
generalizable are those results across various technological fields
and industries? What enables new firms to be accepted into net-
works given their lack of resources, prior results, and lack of social
capital?

- **The dynamics of network resources for a firm.** A firm’s stocks of (a)
technical capital (capabilities to create new technologies, products,
processes), (b) commercial capital (complementary assets required
to commercialize new technologies and obtain rents), and (c) social
capital (network resources emanating from prior relationships with
other organizations) qualify as resources. Each of these assets adds
value, is accumulated over time, and is difficult to trade across
markets. However, the relationship of these asset-stocks to the
alliance formation of a company may be non-linear. How are these resources defined empirically in high-technology sectors? How do companies perceive them? Does speed in the rate of evolution of an industry affect their relative importance? What factors may enable a firm to participate in a desired network even though it lacks one or more of these resources?

- **Network features in sectoral systems.** Various network features, such as network density, structural holes, structural equivalence, and core-versus-peripheral firms, have been identified as influencing the profitability of industries and firms. What role do they play in environments of fast technological advance? For example, is a network riddled with structural holes more suitable to situations of high risk and fast technological change than a very dense network where everybody is linked with everyone else?

- **Network structures and the actors of a sectoral system.** It has been argued that in exploring technological change in some industries the focus ought to be on the network of actors—the suppliers, customers, and complementors on whose capabilities and successes a firm often depends. Tightly knit networks can confer advantages when actors succeed and disadvantages when they don’t, as for instance, in the case of technological change that renders actors' capabilities obsolete. What may be the repercussions of this for network structure in the face of rapidly changing, high-risk industrial environments?

- **Types of networks and types of knowledge bases of a sectoral system.** Recent scholarship has argued that when the knowledge base of an industry is both complex and expanding and the sources of expertise are diffuse, the locus of innovation will be found in networks of learning, rather than in individual firms. These inter-organizational networks sustain fluid and evolving communities of different kinds of agents (e.g. firms, universities, research institutes) and different kinds of organizational practices to access the knowledge base of the community. Path-dependent cycles of learning may be supported in such networks. How have the characteristics of the knowledge base and the distribution of capabilities among actors influenced the emergence and density of networks across industries populated by complex or simple technologies in Europe? How far can one go in identifying path dependency and its effects in these networks?

- **The co-evolution of networks and sectoral systems.** Both exogenous and endogenous forces shape network evolution over time. A key research issue is to put networks in industry in a dynamic framework: that is, to examine industry evolution and network dynamics. This means that one must fully examine co-evolutionary processes.
In fact, changes in network structure, content and function are the result of co-evolutionary processes involving actors, knowledge, technology and institutions. These processes are sector-specific and often path-dependent. Here, local learning, interactions among agents, and networks may generate increasing returns and irreversibilities that in some cases may lock sectoral systems into inferior technologies. In general, one could say that changes in the knowledge base and in the relevant learning processes of firms induce deep transformations in the behaviour and structure of the agents and in their relationships among one another. These transformations may also be seen in the structure, content and function of networks. The convergence of industry boundaries in the information technology area, for example, has shaped the strategic networks that impact that sector. Partner decisions also affect how networks evolve. It is then conceivable to think of lock-in and lock-out situations that can be the result of network evolution. If it is not costless to shift instantaneously across groups, such evolution can be the source of differential returns. Choices made by actors early in the life of the network will affect future returns. By definition, evolution is faster in environments of rapid technological advance. How do technologies, industry boundaries and networks co-evolve? To what extent is this co-evolution in rapidly changing environments the result of firms using networks to reposition in new, higher profitability activities?

6. POLICY IMPLICATIONS

The set of analytical issues discussed above has direct and indirect policy implications in terms of the ability of network concepts and indicators to address some key policy issues and to allow for an evaluation of policies. Here we identify some implications for policy analysis.

- **Enhancing policy “intelligence”**. Network indicators can expand the ability of governments and of individual agents to predict accurately future developments in markets and technologies. In theory at least, governments can use network indicators to devise “early warning systems” to create intelligence concerning changes in the technological and industrial landscape, thus allowing governments to maximize gain, or mitigate loss, from the fallout of those changes.

- **Understanding cohesion**. The extensive mapping of inter-organizational networks through strategic technology alliances,
Innovation networks in industries

scientific co-publications, co-patenting and patent citations allows analysts to illustrate the extent to which the networks in which European organizations participate have been transformed from national/regional to pan-European and global in scope. The formation of strong innovation networks across Europe can be considered an indication of the emerging European Research Area.

- **Promoting competition.** An important benefit from the creation of inter-organizational networks can be the improved ability of members to create and exploit technology options and opportunities. The formation of complex and partly overlapping networks, however, also has a dark side of increased potential for anticompetitive behaviour. What are the potential policy trade-offs between the improved ability to create and exploit technology options for members of a network, and the increased potential for anticompetitive behaviour as a result of the formation of complex and partly overlapping networks?

- **Perceiving competing constellations.** It is argued frequently that competition in certain industries (particularly those involving information and communication technology) takes place between constellations of companies rather than between individual companies. If so, this raises important implications for competition and industrial policies.

- **Avoiding unproductive lock-in.** Strategic networks may lock firms into unproductive relationships and preclude partnerships with more viable partners. In the case of industry-wide networks, one may perceive a lock-in situation in a specific technology or technological standard. When does the government have a role in intervening to disrupt such situations? When should the market be left without policy intervention?

- **Avoiding harmful lock-out.** The creation of tight networks around particular technologies may make it difficult for new entrants to participate. This may be particularly severe for new technology-based firms that lack commercial capital and social capital. Indeed, these may be the firms that need networks the most in order to access necessary social, technical and commercial resources. Is there a role for the government in terms of making these firms more attractive as partners? For example, by increasing their social capital?

- **Promoting effective network structure.** Different network structures are expected to vary in degree of effectiveness depending on the environment. Highly connected, strong-tie networks may be better suited for the diffusion and exploitation of existing knowledge, whereas weak-tie networks may be better suited for the exploration
of new knowledge. How should a government structure incentives and criteria in programmes promoting new technologies in order to achieve the most effective network structures for experimentation and risk taking?

- **Benchmarking.** Inter-organizational networks are not new. Indeed, the literature has extensively discussed regional networks (clusters) in different parts of Europe. Rigorous network indicators can assist in the visualization and benchmarking of good practices for efficient communication and knowledge diffusion across geographical space.

- **Lowering management and coordination costs for new firms.** Alliance networks involve costs in terms of managerial resources. It is now being established that firms learn to manage alliances as experience accumulates. Conversely, the high expected costs for learning how to manage alliances may operate as a disincentive to inexperienced firms. Should this be a consideration for government agencies designing programmes targeting new technology-based firms and technology experimentation?

- **Promoting networks of learning.** When the knowledge base of an industry is complex and expanding and the sources of expertise are dispersed, the locus of innovation is expected to be found in networks of learning, rather than in individual firms. These inter-organizational networks sustain fluid and evolving communities of different kinds of agents including firms, universities and research institutes. Such a phenomenon points out the potential for differential policy approaches to complex and simple technologies. Alternatively, the characteristics of the knowledge base will affect the extent of success of policies promoting innovation networks in industry.

- **Additionality.** The additionality of a European Union effort to create and maintain inter-organizational networks in science, technology and innovation is always a concern. The answer will depend on the nature, characteristics and geographical spread of the supported networks. Significant additionality is expected when inter-organizational networks are increasingly international.

- **Labour market implications of network formation.** The growth and expansion of high-technology networks could have implications for labour market policies in various member countries. For instance, it is likely that worker mobility could be enhanced in the aftermath of network formation. Other concerns include whether firms have sufficient skills to join a network, and the role of skills development as a determinant of the performance of the network.
At the opening of this introductory chapter we argued that the proliferating literature on networks has just begun to address a multitude of challenging strategy and policy questions. We hope that this book adds a useful link in the long chain of policy-relevant network research.

NOTE

1. Complex technologies could be defined as related to products or processes that cannot be understood in full detail by an expert. Examples include aircraft and telecommunications equipment. These are contrasted with simple technologies that can be fully understood by an individual expert (e.g. chemicals, pharmaceutical compounds).

REFERENCES


