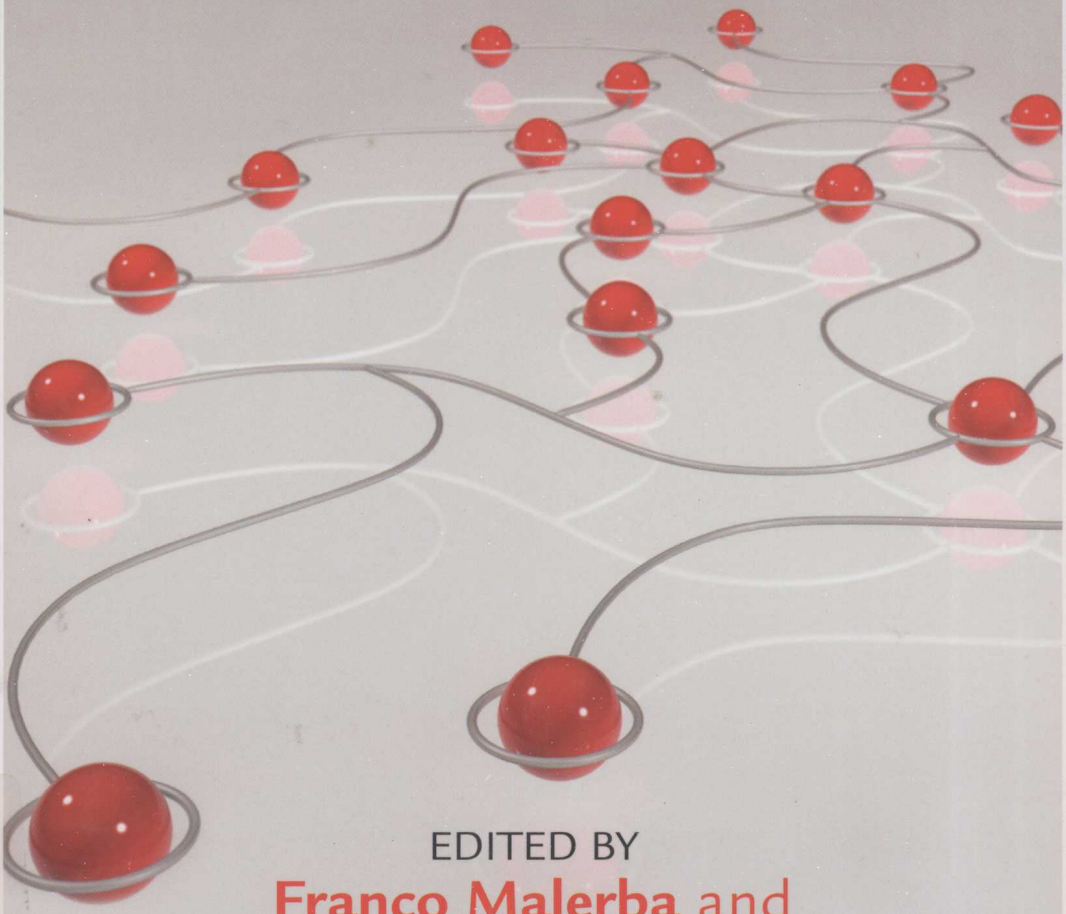
INNOVATION NETWORKS IN INDUSTRIES



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Edward Elgar
Cheltenham, UK • Northampton, MA, USA

Published by
Edward Elgar Publishing Limited
The Lypiatts
15 Lansdown Road
Cheltenham
Glos GL50 2JA
UK

Edward Elgar Publishing, Inc.
William Pratt House
9 Dewey Court
Northampton
Massachusetts 01060
USA

A catalogue record for this book
is available from the British Library

Library of Congress Control Number: 2009928596

ISBN 978 1 84720 376 2 (cased)

Printed and bound by MPG Books Group, UK

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Preface

At the turn of the millennium, the European Commission released the communication, "Towards a European Research Area".[1] This statement of goals has come to underline European strategic thinking regarding the role of the Commission, as well as that of national and regional governments of member states, in science and technology policy. The prospect of a European Research Area has provided the basic foundation for the sixth Framework Programme for Research and Technological Development and is expected to continue doing so for the seventh Framework Programme.

Networks linking scientists, research institutes, universities and firms are a pillar of the envisioned European Research Area. The communication from the Commission emphasizes the need for better coordination between national and European research centres. It also calls for more consistency in foresight exercises, science and technology watch, socio-economic intelligence, science and technology options at the national and European levels, and benchmarking exercises. It makes a plea for improved statistics and indicators at a European level, particularly the kind of indicators that address important features of the knowledge-based society.

This book traces its origins to a research project, "Network Indicators: Science, Technology and Innovation"[2] (STI-NET) funded by the European Commission to start tackling the issue of network indicators. The main objective of STI-NET was to identify, construct and analyse network indicators for European science, technology and innovation. The consortium partners studied network formation and structure and derived relevant indicators from three large longitudinal databases of European patent citations, scientific co-publications and inter-firm cooperative agreements. By creating "connectivity indicators" (i.e. combinations of indicators showing relationships among agents in various knowledge-creating functions) the study made a significant contribution in terms of constructing datasets and deriving the network tools that can be used to study both the achievements of past European RTD policy and the prospective foci of the next Framework Programme. In addition, various research papers also explored the feasibility of using such indicators to address analytical questions with clear policy implications.

This book, however, contains much more than work originating in

STI-NET. In the course of the years, researchers at KITeS-Cespri, Bocconi University, as well as at other centres in Europe and the United States, have been involved in other research regarding networks, such as: "Evaluation of Progress Towards a European Research Area for Information Society Technologies";[3] Networks of Innovation in Information Society: Development and Deployment in Europe[4] concerning ICT; and KEINS – Knowledge-Based Entrepreneurship: Innovation, Networks and Systems[5] – concerning knowledge intensive entrepreneurship. This book reflects these efforts. In particular, Chapters 3 and 7–10 are contributions from researchers and studies beyond STI-NET.

We have had two main objectives in putting this material together. One has been to open up to the reader the tremendous opportunities for significant work on policy and strategy using network concepts and indicators as well as to highlight the complexities and challenges involved. The other objective has been to tackle the network issue from a perspective that has been relatively disregarded in the extant literature but which, we feel, deserves a lot of attention: namely, the perspective of industry and of sectoral systems. This contrasts with the typical perspective of the individual organization on which the literature has tended to focus. We believe that some of the most important policy questions of our times lie at the sectoral system level (including the delineation of industry boundaries that are getting increasingly blurry). Correct as this argument about systems and boundary ambiguity might be, it also reflects the frustration of analysts in fitting a radically new global environment into the confines of old definitions and concepts. Could industries be defined more accurately in terms of sectoral systems, and therefore of both the nature of the output as well as the inter-organizational relationships rather than just the former?

A lot of people in addition to the authors have worked to make this book happen. While we cannot thank all of them here, we certainly extend our warmest thanks to Fabienne Corvers, Frank Cunningham, Vincent Duchene, Peter Johnston, Pia Laurila and Ugur Muldur, who – as officials of the European Commission – have provided guidance, feedback and support in various stages and through several research projects that built the underlying material for this book. We are also obliged to Jeff Williams at the George Washington University who worked diligently with us in editing and preparing the manuscript.[6]

NOTES

1. Commission of the European Communities, "Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the

Committee of the Regions: Towards a European Research Area", Brussels, 18 January 2000, COM (2000) 6.

2. STI-NET Network Indicators: Science, Technology and Innovation (1 February 2001–31 January 2005) Contract n°HPV2-CT-2001-00014 – DG Research Directorate M Unit M2. Partners: CWTS and MERIT.
3. Evaluation of Progress towards a European Research Area for Information Society Technologies (1 January–31 December 2005). Contract n. 30302 – DG Information Society and Media.
4. Networks of Innovation in Information Society: Development and Deployment in Europe (23 December 2005–22 December 2006). Contract n. 30-CE-0039054/00-44 DG Information Society and Media.
5. KEINS – Knowledge-Based Entrepreneurship Innovation, Networks and Systems (1 September 2004–28 February 2008). Project n. CT2-CT-2004-506022.
6. In the final preparation of their chapters, Franco Malerba, Stefano Breschi, Nicoletta Corrocher and Lorenzo Cassi acknowledge the financial support of the Italian Ministry for Education, Universities and Research (FIRB, Project RISC – RBNE039XKA: "Research and entrepreneurship in the knowledge-based economy: the effects on the competitiveness of Italy in the European Union").

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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

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

(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