Chapter 1
Introduction

At its heart, economic theory is about individuals and their interactions on markets or other social systems.
(James J. Heckman 2000)

Abstract Without a doubt, the twentieth century saw some of the most notable innovations in world history and the laser can certainly be counted among them. The aim of this study is to contribute to an in-depth understanding of collective innovation processes by analyzing R&D cooperation and innovation networks in the German laser industry. Following the neo-Schumpeterian tradition, it employs interdisciplinary analytical concepts and draws upon a unique longitudinal dataset from the laser industry that covers more than two decades of observations. The first chapter provides a general introduction to the subject and is structured as follows: Sect. 1.1 starts with a brief introduction of the laser and its roots in Germany. In Sect. 1.2 we raise awareness of the importance of R&D cooperation and innovation networks in science-driven industries. In Sect. 1.3 the overall research questions underlying this study are presented. And finally, the research design and the plan of the book are outlined in Sect. 1.4. In short, our aim with this study is to contribute to the existing body of literature by exploring how and why firm-specific R&D cooperation activities and network positions, large-scale network patterns, and evolutionary network change processes affect the innovative performance of laser source manufacturers in Germany.

1.1 The Laser and its Beginnings

The twentieth century saw some of the most notable innovations in world history. Many of these innovations led to the emergence of entirely new technological fields which have affected our lives and habits in a remarkable way. For instance, the development of novel means of transportation has enabled the world to grow closer together and has paved the way for trade between nations. The development of the transistor has revolutionized the field of electronic engineering and enabled pocket

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calculators, personal computers and countless other electronic devices to be developed. New information and communication technologies, such as the Internet and other mobile communication devices, have changed the way people interact in their private and professional lives. This small selection of examples illustrates how tremendously new ideas can influence the social and economic life of individuals in modern societies.

The invention of the laser in the late 1950s can also be included in the list above. The acronym *laser* was originally coined by Gordon (1959) and stands for *"Light Amplification by Stimulated Emission of Radiation"*. At the onset of laser research several competing research groups were working under extreme pressure to secure their supremacy in this vibrant research field. Only one year after Gould's seminal article was presented at the *"Ann Arbor Conference on Optical Pumping"*, Maiman (1960) commenced operation of the first stable laser device.

Almost instantly the commercial sector took notice of the new technology and numerous laser source manufacturers (LSMs) entered the scene, not only in the United States but also in Germany. In the early 1960s, the Siemens Group, whose headquarters were located in Munich at that time, started to play a dominant role in the development and manufacturing of lasers in Germany. Shortly afterwards, an entire industry started to emerge that was characterized by its high number of micro and small businesses (Buenstorf 2007). Expertise in electrical engineering, physical and technical skills as well as access to cutting-edge technologies and new sources of scientific knowledge are essential for LSMs to keep pace with competitors. As a consequence, the demand began to increase for both applied and basic research into novel laser operating principles, gain media and laser components. Numerous public funding initiatives were launched to promote research in this field (Fabian 2011). New laser-related research facilities were founded and entered the German research landscape. Physics departments at universities and other publicly funded research organizations (PROs) started to intensify their efforts with regard to laser research. When Germany was reunified in 1989, the leading laser research facilities in the former German Democratic Republic (GDR) were integrated into the German laser innovation system. All in all, these efforts led to substantial refinements in the initial laser devices and were accompanied by groundbreaking technological advances in modern laser research carried out over the past half-century.

Today, laser applications can be found in nearly every walk of life. Their output power range from 1 to 5 milliwatt (10^{-3} W) for DVD-ROM drives and laser pointers, to 1–5 kW lasers (10^{3} W) commonly used for industrial laser cutting and petawatt lasers (10^{15} W) used for experiments in plasma and atomic physics. The economic potential of laser technology has increased significantly over the past decades. In 2006 the revenue of German producers of laser sources and optical components amounted to approximately EUR 8 billion and about 45,000 people were employed in the industry (Giesekus 2007, p. 11).

1.2 Why Study Innovation Networks?

The previous reflections illustrate the enormous economic potential of new and innovative ideas. One of the first scholars to recognize the importance of innovations for economic welfare was Schumpeter (1912, 1939, 1942). He emphasized the role of entrepreneurs and their innovative ideas as the driving forces behind economic change processes in capitalist societies. Nowadays, it is widely accepted that technological progress is fundamental to economic growth and the prosperity of nations (Graf 2006). In this context at least one central question arises that also constitutes the initial starting point for this book: *what are the factors that affect a firm's ability to generate novelty and innovate over time?*

The search for an answer to this question is anything but new. Over the past decades scholars of economics and related disciplines have addressed this question (cf. Sect. 2.2). Previous research on the very nature of innovation processes (cf. Sect. 2.3) teaches us that the innovation process itself is neither linear in nature nor is it limited to the individual efforts of single economic entities. Instead, it is characterized by small incremental steps and accompanied by multiple feedback loops. The generation of novelty is a highly uncertain and, in most cases, collective process which is characterized by multiple interactions of independent but heterogeneous economic actors with different capabilities, goals and strategies. Neo-Schumpeterian scholars (Freeman 1988; Lundvall 1988, 1992; Nelson 1992) explicitly addressed the collective nature of innovation processes by introducing the concept of "national innovation systems". Since then, several refinements to the originally proposed concept have been discussed in the literature (cf. Sect. 2.3). The common ground shared by all systemic concepts is that: **(I)** they involve creation, diffusion and use of knowledge, **(II)** feedback mechanisms are inherently built in, **(III)** they can be fully described by a set of components and relationships among these components, and **(IV)** the configuration of components, attributes, and relationships is constantly changing (Carlsson et al. 2002).

The overlapping of systemic concepts and network concepts is obvious. However, the systemic approach can be seen as a broader and more general approach that inherently entails innovation networks. It has been argued that innovation is the outcome of the interaction between a wide range of heterogeneous economic actors (Pyka 2002, 2007). These actors are, in many cases, connected through formal agreements[1] such as cooperation in research and development (R&D) (Brenner et al. 2011, p. 1). Innovation networks allow organizations to exchange existing information, knowledge and expertise (Cantner and Graf 2011, p. 373). At the same time, innovation networks provide the basis to commonly generate new knowledge which can be embodied in new products, services or processes (ibid).

The aim of this book is to analyze innovation networks in the German laser industry from various angles. More precisely, the investigations below seek to

[1] It is important to note that informal cooperation is not a subject of this investigation. Others have addressed this mode of cooperation in detail (Pyka 1997).

contribute to the existing body of literature about innovation networks by exploring how and why firm-specific cooperation activities, structural network patterns, strategic network positioning, and network evolution affect the innovative performance of firms at the micro-level.

1.3 The Current State of Scientific Research and Research Questions

The initial starting point for every research project is to conduct a comprehensive literature review. We carried out a bibliometric analysis[2] to gain an overall picture of previous theoretical and empirical contributions in the field of alliances and networks. In an initial step, we systematically screened various databases in order to identify all of the relevant articles on cooperation, alliances and networks. We identified a total of 3,694 publications between 1937 and 2014 from 242 academic journals. In a second step, we excluded all publications in which alliances and networks were used in another context or only mentioned in passing. We ended up with a collection of 2,103 scientific publications for the period between 1980 and 2013.[3] In a third step, we explored the bibliometric data from various angles. The results of this analysis revealed some interesting insights. Figure 1.1 provides a general overview of alliance and network research over the past three decades.

The solid black line illustrates the full set of empirical and theoretical publications that focus on interfirm or interorganizational alliances, networks and other collaborative forms. Hence, this category also includes publications that deal with a wider range of hybrid organizational structures, such as joint ventures, licensing or franchising agreements. The dotted black line represents publications that concentrate mainly on interfirm and interorganizational networks in the narrow sense. This category also includes a small number of publications on complex cooperation structures like, for instance, core-periphery and small-world patterns at the overall network-level. The solid gray line represents all of the publications that focus primarily on dyadic strategic alliances or bilateral partnerships. Finally, the dotted gray line represents publications with a clear emphasis on firm-specific networks like, for instance, ego networks, alliance constellations, multi-partner alliances and alliance portfolios.

In conclusion, the early period between 1980 and 1990 is characterized by a very small number of relevant publications. In the mid-1990s alliance and network

[2] This exploration does not claim to be complete or exhaustive. Instead it aims to uncover general trends in the literature. Appendix 1 provides an overview of bibliometric data sources, a full list of the evaluated academic journals and a brief description of the applied conventions and search methods.

[3] We restricted the time period for two reasons: (I) research on alliances and networks before 1980 is rare, and (II) due to the time of evaluation, data for 2014 was incomplete.

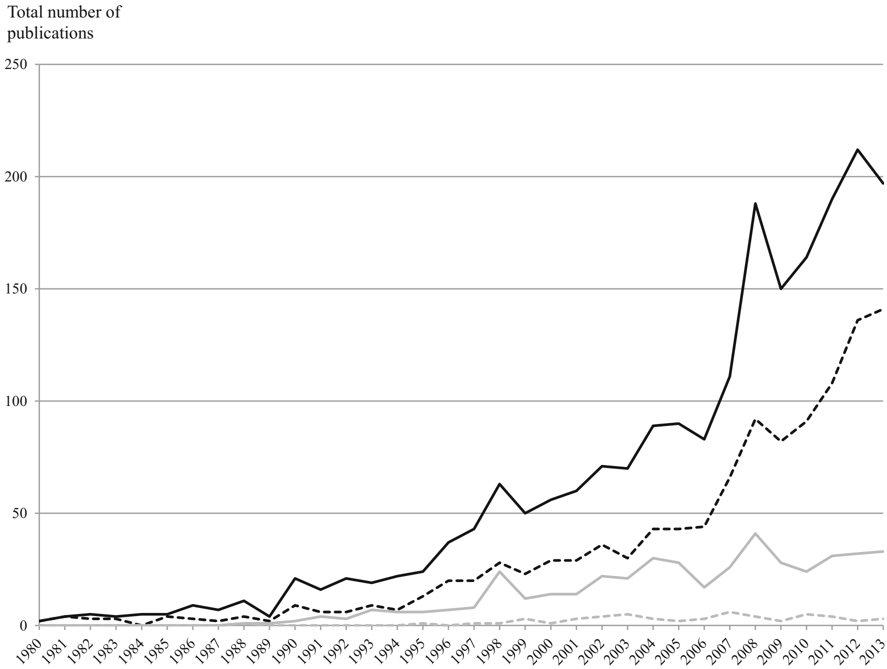

Fig. 1.1 Alliance and network research, 1980–2013 (Source: Author's own illustration)

research starts gaining momentum. This trend is set to continue over the next decades. Figure 1.1 clearly shows that the total number of publications has increased significantly in all areas of alliance and network research. Over the last few years we observe a strong increase, especially in network-related publications.

Our next analysis (cf. Fig. 1.2) explores alliance and network research broken down by scientific field. Our initial bibliometric exploration is based on three periods: 1980–1993; 1994–2003; 2004–2013. Figure 1.2 illustrates our findings for each of the three observation windows. In addition, particular attention was paid to the exploration of scientific publications over the entire observation period between 1980 and 2013 (results are reported using a log-scale and in percentage terms).

In the early phases of alliance and network research (cf. Fig. 1.2, dotted black line, solid gray line), we only found a relatively small number of papers in mainstream economics, economic geography, international business, marketing and entrepreneurship literature. Not surprisingly, we found a relatively high proportion of cooperation and network-related articles in typical sociological journals. The majority of publications fall into three groups: management science, organization science and innovation economics.

The dotted gray line (Fig. 1.2) represents the total number of scientific publications in the most recent period between 2004 and 2013. The findings confirm most

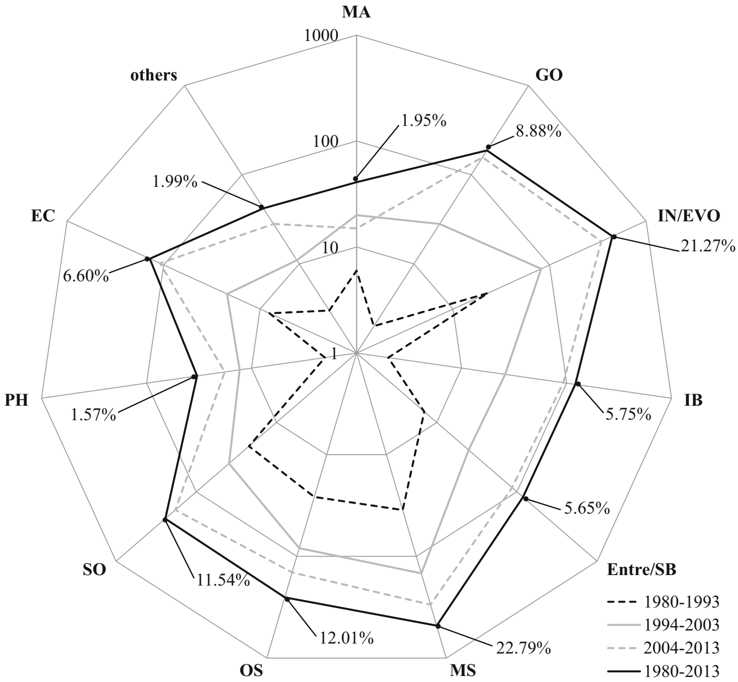

Fig. 1.2 Interdisciplinarity of alliance and network research (Source: Author's own illustration)

of the patterns identified before. However, there are at least two notable exceptions. Firstly, we observe a decreasing number of alliance and network-related publications in the field of marketing research. Secondly, there is a growing interest in alliances and networks in the field of mainstream economics and economic geography.

Finally, a closer look at percentage terms for the entire observation period between 1980 and 2013 reveals some interesting insights (cf. Fig. 1.2, solid black line). Alliance and network-related publications in the field of management science make up the largest percentage in our sample at about 23 %. The proportion of publications in the field of innovation economics, organization science, and sociology was 21.3 %, 12.0 %, and 11.5 %, respectively. About 8.8 % of all alliance and network-related papers were published in typical geographical journals and only 6.6 % of all papers appeared in mainstream economic journals.

Our final analysis explores how many of these publications address dynamic or evolutionary issues. Figure 1.3 illustrates the results of this exploration. As before, the solid black line represents the full set of papers on alliances, networks and other collaborative forms. The dotted black line illustrates the proportion of publications that focus explicitly on dynamic or evolutionary issues.

What do these initial investigations tell us? Firstly, alliance and network research is a vibrant and still growing field of research. Nonetheless, papers with

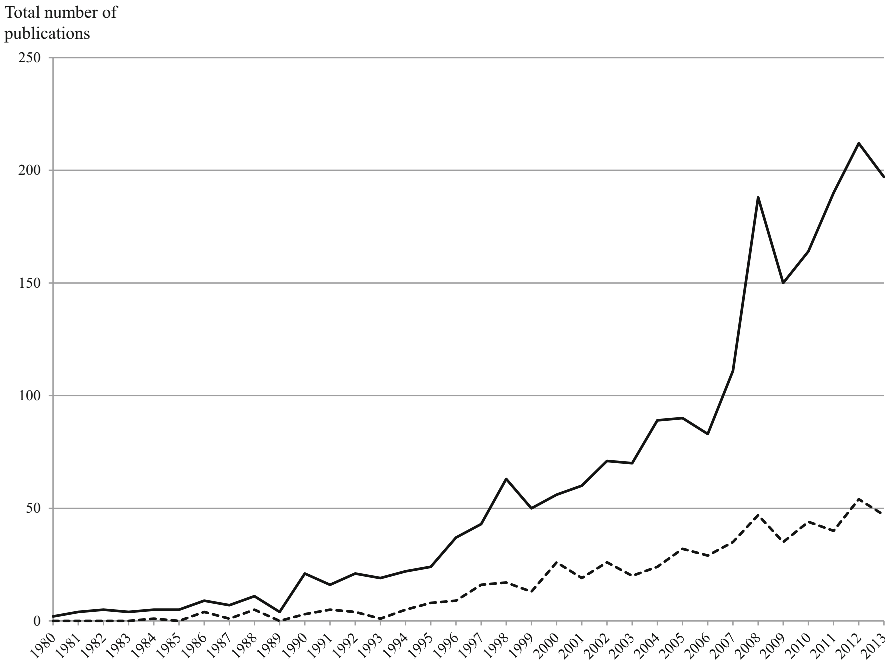

Fig. 1.3 Static versus dynamic contributions (Source: Author's own illustration)

a clear emphasis on firm-specific ego networks and on large-scale network properties are still rare. Secondly, alliance and network research is a highly interdisciplinary area. To illustrate this point, a notable number of relevant publications can be found in more than ten scientific disciplines and about 1.6 % of all relevant publications between 1980 and 2013 were published in typical physical journals. Finally, we found a large amount of papers that focus on interfirm or interorganizational networks. However, publications that explicitly address evolutionary or dynamic issues are clearly underrepresented in alliance and network research. Despite these interesting findings, a closer look at the literature is needed to identify research areas in the field that are still widely unexplored.

We will start by addressing the most general issues. By now, it is well recognized that a firm's position in the network affects its innovative performance in various ways. Previous studies have explored the important role that structural network characteristics play in a firm's innovation generating process (Shan et al. 1994; Podolny and Stuart 1995). These early studies did not directly examine the role of strategic positions in the network structure as predictors of firm-level innovation output. Over the past few years, scholars have started to analyze how a firm's innovative performance is impacted by the various types of network positions in interfirm or interorganizational network structures (Powell et al. 1996; Ahuja 2000; Stuart 2000; Baum et al. 2000; Gilsing et al. 2008). However, it is important to note that the type of network positioning that matters for a firm in its efforts to innovate can differ significantly from industry to industry. Accordingly, we reviewed the alliance and network literature that specifically focused on optical or laser-related technologies. We found very few publications that have explicitly analyzed the relatedness between network positioning and innovative performance in the optical industry. For instance, Ouiment and his colleagues (2007) have explored the relationship between a firm's network position and its innovativeness in small Canadian optics and photonics clusters. Lerch (2009) has investigated network dynamics in the optical cluster in the Berlin-Brandenburg region in Germany. Similarly, Sydow et al. (2010) have studied path dependencies in a network context in the Berlin-Brandenburg optics cluster. Joshi and Nerkar (2011) have analyzed the performance consequences of participating in patent pools, a unique form of R&D consortia, in the global optical disc industry. They found that patent pool participation decreases both the quantity and quality of patents of participating firms.

Even less research has been conducted on interorganizational networks in the laser industry. In a very early piece of work, Noyons et al. (1994) explored the science and technology interface by addressing inventor-author relations in laser medicine research. Shimizu and Hirao (2009) have analyzed interorganizational networks in the semiconductor laser industry in North America, Europe and Asia between 1975 and 1994. The two latter studies build upon patent data and bibliometric data, respectively. The results of both analyses are exploratory in nature. In summary, to the best of our knowledge, there is currently no longitudinal empirical study that has analyzed the collective nature of innovation processes in the German laser industry over a time span of two decades.

Another critical issue is that the majority of the network studies outlined above are static. The few longitudinal studies that are concerned with performance outcomes in evolving networks have quite contradictory findings. For instance, it is still unclear the extent to which network-hub positions or broker-positions are most beneficial in terms of performance outcomes (Rowley et al. 2000; Gargiulo and Benassi 2000; Burt 2005). Researchers from various disciplines have called for more dynamic-oriented alliance and network research (Parkhe et al. 2006; Cantner and Graf 2011; Ahuja et al. 2012). In general, networks are subject to change due to multiple network change processes at the micro-level (cf. Chap. 9). Tie formations or tie terminations as well as node entries or node exits affect the structural configuration of overall networks over time. These processes of "creative destruction" are clearly Schumpeterian in nature and provide the basis for explaining the evolution of networks (Boschma and Frenken 2010, p. 129). The dynamic nature of networks implies that a firm's structural positioning within such a network is by no means static. In other words, neither single cooperation events nor static network positions should be considered at given points in time but rather cooperation sequences or positioning paths should be taken into consideration in future research. This recognition brings us to one of the most crucial points in this section. A comprehensive analysis of how and why firm-specific cooperation activities, structural network patterns and network positions are related to innovative outcomes at the micro-level requires a dynamic research setting.

Keeping in mind the considerations above, we turn our attention now to more specific issues in order to stipulate our research questions. An in-depth evaluation of the literature[4] reveals some interesting findings and allows us to extract four widely unexplored research areas: **(I)** causes and consequences of evolutionary network change, **(II)** cooperation events, ego networks and firm innovativeness, **(III)** large-scale network properties and micro-level innovation outcomes, **(IV)** network proximity, geographical proximity and firm innovativeness.

Research area **(I)** addresses the dynamic nature of networks. The evaluation of the literature shows[5] that we still have a rather incomplete understanding of the drivers and mechanisms that cause evolutionary change in complex interorganizational networks. For instance, considerably little research has been conducted on network formation processes affected by both endogenous and exogenous factors. In addition, there is a strong bias in the literature towards the presence rather than the absence of relationships (Kenis and Oerlmans 2008, p. 299). To enhance our understanding of how and why networks change over time, we propose a conceptual network evolution framework and empirically analyze a still widely neglected facet of network dynamics, i.e. the propensity and timing of network entry processes. More precisely, we seek to answer the following two research questions:

How can we explain the network evolution process and its structural implications in a theoretical way? What are the endogenous or exogenous determinants affecting a firm's propensity and timing to cooperate for the first time and enter the industry's innovation network?

Research area **(II)** focuses on the innovative performance of firms and seeks to disentangle the relationship between cooperation events, ego network characteristics and firm innovativeness.[6] An essential question that arises in this context is whether the innovativeness of firms in the German laser industry is directly affected by individual R&D cooperation events or more indirectly by structure and structural change in firm-specific ego network characteristics over time. In other words, through which transmission channels do cooperation events affect a firm's subsequent innovative performance? This dual character of individual R&D cooperation events has been widely neglected in previous research on ego networks and constitutes the core of this investigation. Consequently, we address the following research questions:

[4] Each chapter in Part IV provides a comprehensive literature review for each of the four research areas.

[5] For a literature review on the dynamics of alliances and networks, see Sects. 9.1 and 9.2.

[6] A literature review on R&D alliances, networks and innovation output is provided in Sect. 10.2.1. Previous research on the relationship between ego network structure and innovation output is discussed in Sect. 10.2.2.

Can we identify a significant relationship between individual cooperation events (i.e. "direct effects") or ego network characteristics (i.e. "indirect effects") and firm innovativeness over time? How do individual cooperation events affect the structural configuration of the focal actor's ego network and which structural features affect its subsequent innovation output?

Research area **(III)** turns our attention to the overall network level. Contemporary research on large-scale network properties implies that the network topology itself is likely to affect the exchange of knowledge in innovation networks.[7] It is, however, important to note that the relationship between large-scale network properties at the macro-level and innovation outcomes at the micro-level have been widely neglected in the field of interorganizational alliance and network research. In this study we focus on small-world properties of large-scale industry networks. We propose a theoretical framework that draws upon a reconceptualization (Zahra and George 2002) of the absorptive capacity (Cohen and Levinthal 1990) in order to provide the missing link between overall network characteristics and a firm's innovative performance. More precisely, we raise the following research question:

Can we identify a significant relationship between distinct large-scale network characteristics (i.e. a "high degree of clustering" ***or*** "short average paths") or small-world properties (i.e. a "high degree of clustering" ***and*** "short average paths") and firm innovativeness over time?

Research area (**IV**) addresses the fact that firms are concurrently exposed to various proximity dimensions. Boschma (2005, pp. 63–71) and Boschma and Frenken (2010, pp. 122–124) have proposed a theoretical concept that allows for an unambiguous definition and a clear-cut distinction of five proximity dimensions. In this study we seek to disentangle the relationship between network positioning, geographical co-location and firm innovativeness. The literature review reveals[8] that integrative research addressing both distinct and combined proximity effects remains rare. This is in line with the observation made by Whittington et al. (2009). Thus, we address the following research question:

Are firm-level innovation outcomes positively or negatively related to network positioning effects, geographical co-location effects or combined proximity effects; and if the latter case is true, are the combined effects substitutional or complementary in nature?

[7] For an overview of previous research on small world characteristics in an interorganizational context, see Sect. 11.1. Previous research on the graph theoretical foundations of the "small-world" phenomenon is discussed in Sect. 11.2.1.

[8] For a literature review and discussion of contemporary research in the field, see Sect. 12.2.

1.4 Research Design and Plan of the Book

The research design guides and structures the entire research process. Designing the research project requires some fundamental decisions at quite an early stage. The initial question that needs to be addressed is whether to apply a theory-building or a theory-testing strategy (De Vaus 2001, p. 5).

This book is governed by a deductive theory-testing approach. Deductive reasoning starts from a general theoretical framework and the theoretical considerations within this broader framework stipulate which observations are to be made (De Vaus 2001, p. 6). The underlying research logic implies a move from the general to the specific (ibid). The research process involves the deduction of testable hypotheses, data collection and hypotheses testing. The neo-Schumpeterian approach provides the general theoretical framework for all empirical parts in this book. This approach explicitly addresses the importance of knowledge, learning and innovation processes in complex socio-economic systems for the economic performance of economic agents at the micro and macro-level. Even though Schumpeter did not address cooperation or networks explicitly, his writings help to improve the understanding of how interorganizational connections among firms lead to new combinations and innovative endeavors (Dodgson 2011, p. 1142). We concretize our hypotheses by drawing upon theoretical concepts and arguments from economics and related disciplines.

At this point, it is important to note that the applied methods and data are irrelevant to the logic of the research design (De Vaus 2001, p. 8). The very nature of the phenomenon in question guides the selection of data and methods. Collective innovation processes are, as the name already suggests, not a static but rather a dynamic phenomenon. Consequently, this led to the decision in favor of a quantitative approach and a longitudinal data design. For the purpose of this study, multiple streams of archival raw data were exploited to create a comprehensive picture of cooperation and innovation activities for the entire population of German laser source manufacturers between 1990 and 2010. In principle, two strategies can be applied to conduct an empirical research project. A “descriptive approach” allows specific facts and patterns to be identified and explored, whereas an “explanatory approach” answers the question of how and why specific observations came to be the way they are (De Vaus 2001, pp. 1–3). We started with a descriptive analysis to gain a fundamental understanding of industry, firm, cooperation and innovation patterns in the German laser industry. De Vaus (2001, p. 2) notes that good descriptive analysis usually provokes questions for explanatory research. This was certainly also the case here, since many of the descriptive findings trigged several subsequent in-depth analyzes. This brings us to the main body of the book. Each of the four empirical sections explicitly addresses one of the four initially raised questions and draws upon a separate conceptual framework that schematizes the transition from the conceptual level to the empirical level. Finally, the ultimate goal of explanatory methods is to test whether a prediction is correct or incorrect and to support or reject the theoretical argument that underlies this particular hypothesis (De Vaus 2001, p. 7). We applied event history techniques and panel data count models to accomplish this task. Last but not least, the extraction of descriptive and exploratory results is necessary but not sufficient. Results have to be critically discussed and interpreted against the backdrop of a broader theoretical context. Accordingly, this book is divided into five parts and fourteen chapters whose contents are described in more detail below.

Chapter 2 provides the theoretical foundation for this book. We start from a classical-neoclassical perspective and discuss the role of knowledge and innovation in traditional economic approaches. Then we turn our attention to evolutionary approaches in economics and related disciplines. The neo-Schumpeterian approach in evolutionary economics constitutes the core of the theory chapter. Then we continue by introducing theoretical concepts at the firm level, i.e. the "structure conduct performance" (SCP) paradigm, the "resource-based view" (RBV), and the knowledge-based view (KBV), that seek to explain the sources of a firm's competitive advantage. Next, we draw upon interdisciplinary alliance and network research. We conclude the theoretical discussion by exposing how this research project relates to the previously outlined theoretical concepts.

Chapter 3 gives a short introduction of basic laser operating principles and outlines the most notable technological developments over the past 50 years. Subsequently, we focus our attention on the German laser industry and illustrate the configuration of the industry value chain.

Chapter 4 starts with a general discussion of methodological issues and provides a detailed description of the data sources used to construct a unique longitudinal laser industry database. This lays the ground for the analytical parts of this study. The laser industry database covers a time period between 1990 and 2010.

Chapter 5 presents some general graph theoretical concepts and introduces indicators and measures needed for the quantitative description of the industry and the industry's innovation network. Focus is on quantitative network analysis methods and geographical indicators.

Chapter 6 is divided into two sections. First two longitudinal datasets are presented. Then there is an overview and general discussion on estimation methods. In this context, event history analysis methods as well as techniques for analyzing longitudinal count data are addressed.

Chapter 7 reports descriptive findings at the industry level. We analyze geographical concentration patterns for three types of organizations, i.e. laser source manufacturers (LSMs), laser system providers (LSPs) and laser-related public research organizations (PROs). The subsequent explorations concentrate on LSMs which are considered to be at the core of the industry value chain.

Chapter 8 focuses on R&D cooperation and innovation networks. We start with summary statistics on publicly-funded R&D cooperation projects in the German laser industry. The next descriptive analysis explores the organization's involvement in these projects from various angles. Our data allows us to construct innovation networks on an annual basis for the entire population of LSMs and PROs in the German laser industry. This provides the opportunity to analyze basic node-related and tie-related network measures and reveals characteristic network change patterns over time. We supplement this initial longitudinal network exploration by conducting an in-depth analysis of the overall network topology. In the last descriptive analysis, we check for the existence of scale-free patterns, test for small-world properties and analyze the emergence of a core-periphery structure over time.

Chapter 9 focuses on the evolution of innovation networks. The aim of this analysis is to investigate the determinants of evolutionary change processes in innovation networks. We address one particular facet of the network evolution process in the empirical part of this chapter. More precisely, we conduct an event history analysis in order to disentangle the extent to which exogenous or endogenous determinants affect a firm's propensity and timing to cooperate and enter the industry's innovation network.

Chapter 10 points to the importance of firm-specific cooperation strategies. The goal of this investigation is to shed light on the relationship between individual cooperation events, firm-specific ego network characteristics and firm-level innovation outcomes. In short, by using a panel data count model, we explore how a firm's innovativeness is related to its cooperation events on the one hand, and the structural configuration and dynamics of its ego network on the other.

Chapter 11 raises awareness for large-scale network properties. Consequently, we switch the analytical level and turn our attention to systemic level properties. The aim of the third analysis is to understand how the structural network configuration at the macro-level is related to firm-level innovation outcomes at the micro-level. We use longitudinal network data and quantitative network analysis methods to quantify large-scale network properties and put the "small-world" hypothesis to the test in terms of which networks with a high degree of clustering and high reachability provide a superior environment for firm innovativeness.

Chapter 12 draws upon the proximity concept and points to the fact that firms are concurrently exposed to multiple proximity dimensions. We apply panel data methods to find out the extent to which distinct and/or combined effects between network proximity and geographical co-location are positively related to subsequent firm-level innovation outcomes.

Chapter 13 marks the completion of the research project. We summarize the findings and raise awareness of the limitations of our results.

Chapter 14 concludes with some final considerations and critical remarks. It includes suggestions for further research.

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