Oliver Som
Eva Kirner *Editors*

Low-tech Innovation

Competitiveness of the German Manufacturing Sector

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Chapter 1
Introduction

Oliver Som and Eva Kirner

Abstract Shedding light from various research perspectives on the phenomenon of non-R&D-performing and non-R&D-intensive innovators is the aim of this anthology. A variety of different empirical approaches ranging from macroeconomic considerations to microeconomic analysis address open questions related to the role of non-R&D-performing and non-R&D-intensive sectors as well as firms in developed economies like Germany. The editorial highlights the research motivation of this anthology and outlines the structure of every book chapter.

During the previous several decades, research and development (R&D) activities have received the greatest degree of study in attempts to explain the levels of innovation and competiveness of enterprises, specific economic sectors and entire economies (Teece 1986; Brown and Eisenhardt 1995; Freeman 1994a, b; Freeman and Soete 1997; Rosenthal 1992; Saviotti and Nooteboom 2000; Stock et al. 2002; Santamaría et al. 2009; Raymond and St-Pierre 2010). Subsequently, the terms "innovation" and "R&D" have been increasingly used in the mainstream literature to describe the levels of R&D in and innovativeness of firms and economies. This prevailing focus on R&D on a macroeconomic level is prominently rooted in the works of Solow (1956, 1957) and those of subsequent scholars of endogenous growth theory (Romer 1986, 1990; Lucas 1988). These authors have explained economic growth and competitive advantage in international markets by positing the endogenous and intentional R&D activities of firms as the most important source of technological progress. The relationship between technological progress and economic growth is thereby characterised as a linear, steady-state growth pattern that can be adjusted relatively easily by "turning the knobs of the R&D process" (Verspagen 2005).

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There is a vast amount of empirical literature that supports the importance of firm-internal, institutionalised R&D activities as the primary source of many productivity-enhancing, technological innovations for improving competitiveness, particularly those of fast-growing industries, such as pharmaceuticals, automobiles, computers, communications, instruments, and machinery (Freeman 1994a; Freeman and Soete 1997). "There is ample empirical evidence supporting the hypothesis that R&D expenditures are a sine-qua-non for the firm's level of innovation activities" (Shefer and Frenkel 2005), which has resulted in broad agreement among economists that innovations resulting from R&D are the critical source, the "engine" (Pessoa 2010), of growth in a developed economy (Arnold 1997; Kuznets 1973; Grossman and Helpman 1994; Sandven et al. 2005). The application of R&D to the production of technologically advanced products for export can also improve the terms of trade on a national level. In addition, R&D activities create a demand for highly skilled and qualified human resources, which provides an impetus to develop and improve educational systems and leads to potential benefits throughout an economy (Huang et al. 2010). Empirical studies also indicate that a high level of technology in an economy results from high levels of innovation as a result of R&D, which in turn result in higher production of new goods and greater use of new production techniques (Fagerberg 1987).

However, certain empirical studies have shown that a significant number of firms do not invest in R&D. For example, a study of large U.S. firms by Cohen et al. (1987) revealed that 24 % of such firms did not invest in formal R&D. Similarly, a study by Bound et al. (1984) indicated that 40 % of U.S. firms did not report R&D expenditures, and an analysis by Galende and Suarez (1999) of firms headquartered in Spain revealed that 71 % of the surveyed companies did not undertake formal R&D. Based on data from the Community Innovation Survey (CIS), Arundel et al. (2008) concluded that slightly over half of all innovative firms in Europe do not perform R&D.

Based on these empirical findings regarding R&D, it is even more surprising that previous analyses did not reveal any differences in the economic performance between innovative firms with and without in-house R&D, as measured by profit development. Most recently, Rammer et al. (2011) lent support for this idea in the form of findings from manufacturing in Germany. Their analyses revealed that approximately 44 % of all innovative manufacturing firms (i.e., firms that introduced new products or processes during recent years) did not engage in internal R&D. Moreover, they could not identify significant differences in the economic outcomes between non-R&D-performing innovators and their R&D-performing counterparts. Kirner et al. (2009a, b) and Som (2012) reported that German manufacturing firms engaging in low levels of R&D are able to obtain at least the same or even slightly higher levels of productivity than are R&D-intensive firms.

Therefore, firms that do not invest in regular in-house R&D activities but nevertheless manage to survive in market competition over long periods of time pose a major challenge to neoclassical mainstream innovation theory because a lack of R&D or low R&D intensity is usually associated with the stagnation or decline of firms.[1] This challenge to mainstream theory becomes all the more pronounced as firms with low or zero R&D intensity are increasingly observed holding significant market shares of various industries in the manufacturing sector, even those industries that are usually associated with high levels of R&D, such as medical engineering or process measurement and control technologies (Kirner et al. 2009a; Som 2012). Thus, there is a relevant group of manufacturing firms that perform little or no in-house R&D and whose innovation strategies, competitive advantage and economic success cannot be explained sufficiently using the dominant R&D-focused approaches of mainstream innovation analyses.

Following Nelson and Winter (1982), theorists of the evolutionary tradition in economics have criticised this R&D paradigm. These theorists suggest that capabilities for innovation are more likely to be based on firm-specific routines and heuristics rather than mere single, homogeneous R&D-based innovation strategies. One of the key arguments of evolutionary economics is that enterprises display considerable heterogeneity in their innovative behaviour and strategies even within similar framework conditions of sectors or innovation systems (Srholec and Verspagen 2008; Nelson 1991). Following the large strand of theory labelled the "resource-based view of the firm" (Barney 1991; Wernerfelt 1984; Peteraf 1993), which also originates from an evolutionary perspective, this heterogeneity is related to the various routines, capabilities, skills and experiences of firms (Nelson and Winter 1982; Nelson 1991; Christensen 2002; Teece et al. 1997; Massini et al. 2005). The innovativeness and economic success of firms thus do not stem from a reliance on high technology or high R&D expenditures. R&D-focussed approaches often overlook the possibility that a major portion of a firm's innovation does not necessarily originate from institutionalised internal R&D activity but rather from new combinations of existing in-house or externally available solutions and technologies (Kline and Rosenberg 1986; Fagerberg 2005; Nelson 1993; Hansen and Serin 1997; Bender et al. 2005).

In addition to technological R&D-based innovation, non-technological dimensions or "modes of innovation" (Jensen et al. 2007), such as services, marketing, organisational innovation, and experience-based sources of knowledge, are also increasingly recognised as distinct types of innovation that contribute to a firm's economic success (Damanpour and Evan 1984; Womack et al. 1990; Piva and Vivarelli 2002; Totterdell et al. 2002; Smith 2005). These dimensions of innovation correspond to Schumpeter's broad definition of innovation, which besides new products also includes the development of new product-related services, the use of innovative organisational or marketing concepts, and the use of innovative manufacturing technologies at an early stage (Schumpeter 2006). Tidd and Bessant

[1] "(A) sustained high rate of growth depends upon a continuous emergence of new inventions and innovations, providing the basis for new industries whose high rates of growth compensate for the inevitable slowing down in the rate of invention and innovation, and upon the economic effects of both, which retard the rates of growth of older industries. A high rate of overall growth in an economy is thus necessarily accompanied by considerable shifting in relative importance among industries, as the old decline and the new increase in relative weight in the nation's output" (Kuznets 1959).

(2009) reported the use of such strategies in the German firm Würth, which is the largest manufacturer of screws and other fasteners, such as nuts and bolts, in the world. Despite low-cost competition from China, the company has managed to stay ahead of its competitors through product and process innovation across a supplier network similar to the model used by Dell computers (Financial Times 2008). In the first half of 2010, Würth achieved a total income of 4.2 billion euros.[2] Another example is the German fashion company Gerry Weber,[3] which belongs to the textile sector and is thus a typical non-R&D-intensive "low-tech" industry. However, the firm is currently investing strongly in process technologies, such as computer-aided design (CAD), new information and communication technologies in sales and distribution and the use of radiofrequency identification (RFID) chips to enhance logistics (VDI Nachrichten 2010).

These insights have barely been incorporated into new standard indicators, although the latest edition of the OSLO Manual (OECD 2005) shows indications of certain promising improvements regarding innovation sources other than those related to R&D. Currently, the majority of scholarly research and policy documents regarding innovation still focus almost entirely on discrete, dedicated expenditures on R&D and ignore other, embedded methods that firms use to innovate (Becheikh et al. 2006). Evidently, the empirical academic study of innovation has not managed to overhaul its linear science-push model of innovation (Arundel 2007). This failure is partly due to a belief that non-R&D innovators are either rare or have little to offer and that most productivity improvements and performance outcomes are attributable to more advanced innovations that emerge from R&D efforts (Arundel et al. 2008). According to Arundel et al. (2008) and Cuervo-Cazurra and Un (2010), if only R&D indicators are used to measure innovative capabilities, innovation by certain firms will not be captured adequately and many will be classified as non-innovative or even be excluded from innovation studies. Consequently, many firms that do not engage in formal R&D have been largely neglected by academic research and the policy community.

For these reasons, non-R&D-performing firms are still regarded as a type of a "black box" in scientific, managerial, and particularly current public and political discussions. As a result, the majority of current innovation and technology policies based on neoclassical models of mainstream innovation research still aim to increase industrial R&D activities in certain selected fields of high technology. However, because little is known regarding the complex interplay between R&D-intensive and non-R&D-intensive manufacturing sectors and the underlying individual innovation strategies of non-R&D-intensive firms, innovation and technology policies may risk disregarding important competitive potentials of other innovation paths aside from R&D. Contemporary innovation and technology policy needs to develop greater appreciation of the innovation strategies of non-R&D-performing firms to be able to increase the innovation capabilities of firms and the

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[2] See: http://www.wuerth.de/web/de/awkg/unternehmen/portraet/portraet.php

[3] See: http://www.gerryweber-ag.de/

economy in general instead of only focusing on the specific niche of R&D as the alleged "one best way" to generate innovation.

This book aims to open this "black box" of non-R&D-performing firms by presenting recent scientific insights obtained via empirical research conducted at the Fraunhofer Institute for Systems and Innovations Research (ISI) during the past several years.[4] It seeks to enhance scientific knowledge regarding the competitive and innovation strategies of non-R&D-performing and non-R&D-intensive firms in manufacturing. Therefore, it seeks to increase the awareness of innovation researchers and students, business practitioners and open-minded policy makers regarding the often overseen but nevertheless highly relevant group of industries and firms with no or low R&D intensity and their particular levels of innovation, strategic behaviour, and management challenges.

Please note that the empirical findings from these projects have been updated with the most recent data available and, at certain points, present completely novel insights that have not been published previously.

1.1 Defining the Key Concepts

Because all the chapters in this book address the notions of "non-R&D-intensive" and "non-R&D-performing" firms and industries (compared to "R&D-intensive" or "very R&D-intensive" ones), these groups of industries and the exact meaning of R&D should be defined.

Parallel with the rise of neoclassical growth theory, the measurement of scientific and technological advancement also emerged in the early 1950s with the U.S. government taking the lead (Godin 2001b). Following the concept and definitions of the U.S. National Science Foundation (NSF), the OECD decided to produce the first methodological manual containing research and development statistics in 1963, called the "Frascati Manual" (OECD 1963).[5] Since then, this document has been revised several times,[6] and its 6th edition was published in 2002. To establish an international standard of coherent science and technology measurement, this manual proposes precise definitions and classifications of the concepts and activities to be measured and recommends the types of data and

[4] These projects are titled "Innovationsmanagement für Lowtech-Hightech Innovationskooperationen (Low2High)" Bundesministerium für Bildung und Forschung (BMBF), 2008–2011/ „Innovation ohne FuE", Expertenkommission Forschung und Innovation des Deutschen Bundestages (EFI), 2011/„Zukunftspotenziale und Strategien nicht-forschungsintensiver Industrien in Deutschland", Büro für Technikfolgenabschätzung beim Deutschen Bundestag (TAB), 2010.

[5] For an excellent overview of the history of indicators of scientific and technological advancement, see Godin (2001b).

[6] Revised editions of the OECD Frascati Manual were published in these years: 1963 (1st edition), 1970 (2nd edition), 1976 (3rd edition), 1981 (4th edition), and 1993 (5th edition).

indicators to present (Godin 2006). The primary purpose of these R&D indicators is to measure and illustrate the science and technology endeavours of a country, demonstrate its strengths and weaknesses and follow its changing character with the aim of providing an early warning of events and trends that may impair its ability to meet the country's needs.

The OECD defines R&D as "... creative work undertaken on a systematic basis to increase the stock of knowledge, including knowledge of man, culture and society and the use of this stock of knowledge to devise new applications" (OECD 2002: 30). Thus, R&D covers both formal R&D in dedicated R&D units or laboratories and informal or occasional R&D performed in other units of an organisation (OECD 2002).

The term "systematic" refers to purposeful effort rather than accidental discovery (Arundel et al. 2008). As Godin (2001a) discusses, the essential idea of systematicity pervades most of the twentieth-century's definitions of R&D in dictionaries or international conventions. Originally, the systematicity requirement referred to the processual aspects of scientific regularities, the use of scientific methods, the intersubjectivity of the applied methodology, and logical consistency (in terms of objectivity, reliability, and validity). However, over time, the meaning of the term "systematic" in definitions of research has shifted from an emphasis on the scientific method to an emphasis on institutionalised research (Godin 2001a). R&D must be properly structured, which means it must meet the minimum requirements of a systematic activity: the persons performing R&D must work a significant number of hours per year, and there must be a programme of work for which certain financial resources (R&D expenditures) are earmarked. In turn, diffuse or scattered R&D activities (e.g., activities performed sporadically or from time to time within the various services or functional areas of an organisation) are not taken into account (Messman 1977). In fact, the concept of systematic research had considerably more influence than another innovation that appeared at approximately the same time, namely, the concept of "scientific and technical activities" (STA), which was conceived of in Canada and was used for a time by the NSF (Godin 2001b).

The Frascati Manual (OECD 2002) divides R&D into three types of activities:

– ***Basic research:*** Experimental or theoretical work performed primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts without any particular application or use in view.
– ***Applied research:*** Original investigation undertaken to acquire new knowledge. It is, however, directed primarily toward a specific practical aim or objective.
– ***Experimental development:*** Systematic work that draws on existing knowledge gained from research and/or practical experience and is directed to producing new materials, products or devices, to installing new processes, systems and services, or to substantially improving those already produced or installed.

As described in more detail in the Frascati Manual, basic research is performed with the aim of analysing properties, structures and relationships with the goal of formulating and testing hypotheses, theories or laws. Thereby, the reference to "no particular application in view" is crucial because the purpose of this type of research activity is only to generate new scientific knowledge and is not prompted by a concrete practical problem or goal that needs to be solved. Basic research can be oriented or directed toward certain broad fields of general interest with the explicit goal of developing a broad range of applications in the future (Rosenberg 1990). This orientation implies that the results of basic research are not generally sold but are usually published in scientific journals or are circulated among interested colleagues. Basic research is expected to occur primarily in institutions of higher education (e.g., universities), the government sector, or private non-profit research organisations, such as the Max Planck Society or Helmholtz Society (Specht and Beckmann 1996). In contrast to the definition presented in the Frascati Manual, the NSF has blurred the boundaries between basic and applied research in its modified definition of basic research to account for the empirical observation that basic research is also performed within certain industrial firms (Rosenberg 1990).[7] However, commercially oriented private firms usually do not engage in basic research (Specht and Beckmann 1996) because its results are generally characterised as public goods, which means that other individuals or competitors practically cannot be prevented from using them.[8] Thus, basic research corresponds to the element of publically available technological knowledge in Endogenous Growth Theory that diffuses through spillover processes among the economic actors and stimulates them to transform this public knowledge into commercial products or commercially advantageous production methods via applied research.

Thus, applied research is performed either to explore possible uses for the findings provided by basic research or to determine new methods or ways of achieving specific and predetermined objectives (OECD 2002; Rosenberg 1990). Typically, researchers draw on available stocks of knowledge and extend them to solve particular problems. Therefore, the results of applied research are primarily useful only for a single or limited number of products, operations, methods or systems. This type of research is clearly most closely associated with the term "industrial" or "private sector" research, as it is performed with the intent of generating a new commercial product, process, or method that helps the enterprise overcome a certain economic problem or unsatisfactory situation that could not be solved using existing knowledge (Grupp 2008; Dreher 1997). In this context, R&D conducted in the private sector is commonly directed toward concrete problems and the direct applicability of the solutions and the quick market exploitation of the newly generated knowledge (Burr 2004).

[7] "To take into account industrial goals, NSF modifies this definition for the industry sector to indicate that basic research advances scientific knowledge not having specific commercial objectives, although such investigations may be in fields of present or potential interest to the reporting company" (Rosenberg 1990).

[8] Burr (2004) discusses certain arguments for why firms of the private sector may be motivated to engage in basic research and how they may be able to appropriate at least some of its results (e.g., first-mover advantages, strong market power, or by-products; or the accidental luck of basic research may generate specific problem solutions, as basic research is a necessary precondition for successful applied research in certain fields).

The category of experimental development[9] became more and more relevant when industrialists, consultants and academics in business schools began to study industrial and applied research (Godin 2006). Into this category these thinkers place all elements of innovation that address the improvement, troubleshooting, or technical control of process and quality. Moreover, this category corresponds to the work by research divisions in firms and organisations that define themselves as research and development (Godin 2006). Thus, development was first described as a series or a list of activities before it came to be identified as a subcategory alongside basic and applied research. Finally, it became a separate category identified by its well-known abbreviation “R&D”.

The Frascati Manual (OECD 2002) describes two indicators by which R&D activities can be measured as innovation input of firms: monetary expenditures devoted to R&D during a specific period and the personnel working in R&D. The manual advises that “all persons employed directly on R&D should be counted, as well as those providing direct services such as R&D managers, administrators, and clerical staff” (OECD 2002). These employees are measured either in terms of full-time equivalents (FTEs) or person-years spent on R&D (OECD 2002).

The basic measure of monetary R&D expenditures consists of “intramural expenditures”, meaning “all expenditures for R&D performed within a statistical unit (e.g., the firm) or sector of the company” (OECD 2002). Another measure, referred to as “extramural expenditures” on R&D, is defined as payments for R&D performed outside the statistical unit (e.g., external partners or contractors outside the firm) or sector of the economy during a specific period (OECD 2002). “R&D expenditure data should be compiled on the basis of performers’ reports of intramural expenditures” (OECD 2002). Moreover, to assess the extent to which R&D plays a central role in a firm in the sense of an institutionalised activity characterised by constantly used routines and capabilities, the indicator can be deployed regardless of whether the firm conducts R&D on a continuous basis OECD 2009).

R&D indicators are frequently classified based on multiple criteria. Beyond the mentioned distinction between basic research, applied research, and experimental development, R&D data are often structurally classified based on their sector of performance (business enterprise, government, higher education, private non-profit), their sources of financing (domestic, international), and more content-oriented indicators, for instance, their socio-economic objectives or fields of research (Bronwyn et al. 2010; Smith 2005). While such detailed classifications

[9] “Since the 1970 edition of the Frascati Manual, the OECD suggests adding the adjective ‘experimental’ to ‘development’ to avoid, so it is argued, a confusion between development, a phase of R&D, and the same term in economics, and to use the same term as eastern European countries and UNESCO” (Godin 2006: 73; note #34).

are usually not considered by researchers, the R&D intensity of firms, industries or countries is one of the indicators most widely used by researchers, policy analysts and policy makers (Smith 2005). The R&D intensity is defined as the ratio of R&D expenditures to some measure of output. For a firm, it is usually the ratio of R&D expenditures to sales.

For an industry or a country, it is the ratio of business expenditures on R&D (often known as BERD) to total production or value added. For a country, it is the gross expenditure on R&D divided by the gross domestic product (GDP) (Smith 2005; Legler and Frietsch 2007).[10] In contrast to this classification on the industry level, there is no common definition of non-R&D-intensive or non-R&D-performing firms on the firm level.

Therefore, most studies define non-R&D-intensive firms based on their sector affiliation; firms that are located in the OECD classification of low- or/and medium-low-tech industries are summarily defined as non-R&D-intensive. Other studies instead apply sectoral classifications of low-, medium-, and high-tech sectors at the firm level by building a firm-level taxonomy from the firms' individual shares of R&D expenditures on total sales (e.g., Kirner et al. 2009a, b).

In the sectoral definition and in the firm-level definition based on sectoral classifications, non-R&D-intensive firms may still have R&D expenditures. However, it is questionable whether it is truly reasonable to assume that a firm that spends less than 2.5 % on R&D is less R&D-intensive than a firm with 3 % R&D expenditures. The critical decision for firms regarding R&D is not so much the intensity of R&D (e.g., whether 2.5 % or 3 % of total sales will be invested in R&D), but rather whether or not to engage in formal in-house R&D at all. Accordingly, authors such as Rammer et al. (2009), Barge-Gil et al. (2008), Arundel et al. (2008), Huang et al. (2010), and Som (2012) decided to select their subsamples of non-R&D performers by applying a zero-level condition of R&D intensity at the firm level.

To develop a comprehensive picture, the empirical findings presented in this book address all three dimensions. The macroeconomic findings regarding economic relevance are clearly based on the sectoral classification (Chaps. 3 through 5), whereas the chapters regarding innovation strategies, innovation activities and management issues (Chaps. 6 through 10) will address both "non-R&D-intensive firms" with a less than 2.5 % share of R&D expenditures based on sales and "non-R&D-performing firms" with zero R&D expenditures. Figure 1.1 below shows a comprehensive overview of the various levels of R&D intensity of sectors/industries and firms and the criteria for the definition used in this book.

[10] For a detailed discussion of R&D indicators, see Grupp (1997).

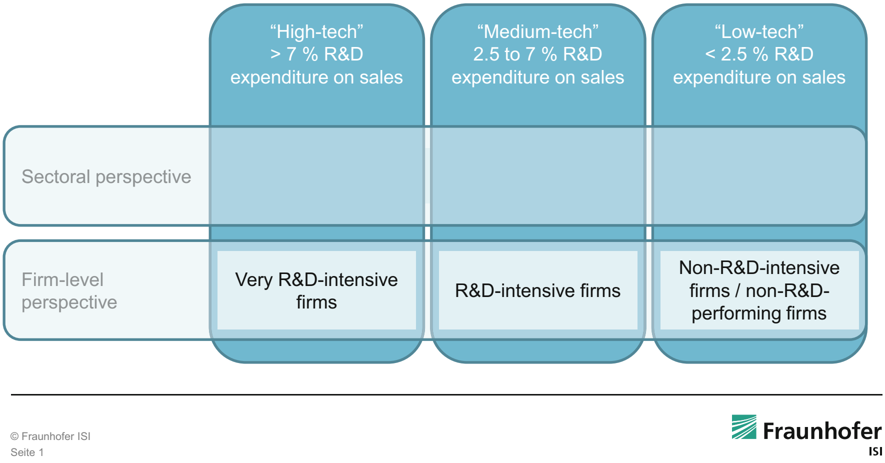

Fig. 1.1 Overview of the concepts and criteria of "non-R&D-intensive" and "non-R&D-performing" firms and industries/sectors (Illustration by the authors)

1.2 Contents of the Book

Based on these preliminary points, the editors are very glad to present in this book a compilation of a great variety of research results regarding the innovativeness and performance of firms with little to no R&D investment that will hopefully contribute to opening the "black box" of firms that do not actively engage in R&D and understanding their role in advanced economies, such as the German economy. We would like to thank the authors of the various chapters for their high-quality contributions and the efforts they expended to make this book a reality. Moreover, we are particularly grateful to Brigitte Mastel and Kristina Schiefer for their valuable support in publishing this book.

The book's chapters are arranged such that they begin on the macroeconomic and sectoral levels and then successively move "down" to the microeconomic, firm level of analysis with increasing specificity. The analytical Chaps. (3 through 10) are based on an overview of the previous 10 years of research presented in Chap. 2, and the implications of the research in terms of policy are presented at the end of the book (Chap. 11).

This book aims to answer the following research questions:

1. How great is the economic relevance of non-R&D-intensive firms and sectors in Germany? How strongly do they contribute to the development of the national economy, employment and qualifications?
2. How innovative are non-R&D-intensive sectors of the economy and non-R&D-intensive technological fields with regard to patenting activity?

3. In which markets are non-R&D-performing and non-R&D-intensive firms active? What are their most important competitive factors?
4. How innovative are non-R&D-performing and non-R&D-intensive firms with regard to product, service, and technical and organisational process innovations?
5. Which forms of internal and external knowledge sources are most important for non-R&D-performing and non-R&D-intensive firms? Where do their relevant external innovation impulses come from, and how are they assimilated?
6. What are the specific requirements for innovation management in non-R&D-performing and non-R&D-intensive firms?

The macroeconomic section of the book begins with a positioning of the German industrial sectors and their average R&D intensity in an international framework in Chap. 3. The economic analysis hereby extends to the determination of the domestic added value generated in non-R&D-intensive sectors and their export intensity and closes with a detailed input-output calculation of direct and indirect employment and production effects triggered by additional demand in these sectors. Chapter 4 looks at the patenting activity of non-R&D-intensive sectors and technological fields to assess their innovativeness. The contributions of non-R&D-intensive sectors to overall national employment and to qualification development are analysed in detail in Chap. 5. Chapter 6 focuses on the specific market environment and the primary competitive factors of non-R&D-performing and non-R&D-intensive firms and identifies the primary structural characteristics of these firms. The innovation ability and innovation performance of non-R&D-performing and non-R&D-intensive firms are the focus of Chap. 7. Based on the latest available firm-level data, their products/services and process innovativeness are analysed from the perspectives of inputs and outputs. Chapter 8 looks at the specific knowledge sources of innovation that these firms tend to access and use. A detailed analysis of the relevance of each of the various internal and external knowledge sources for different innovation fields is provided. Furthermore, the collaboration patterns of non-R&D-performing and non-R&D-intensive firms are identified. These firms' absorptive capacities as a special form of external knowledge access and assimilation is the primary focus of Chap. 9. Therefore, various types of knowledge and their relevance depending on the particular strategic focus of the firms are distinguished. Finally, Chap. 10 discusses the specific innovation management challenges of non-R&D-performing and non-R&D-intensive firms and presents certain practical managerial implications derived from best-practice cases of successful innovative non-R&D-intensive firms.

On behalf of all the contributing authors, the editors wish you a stimulating and inspiring read.

Oliver Som and Eva Kirner

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Chapter 2
Innovation in Low-Tech Industries: Current Conditions and Future Prospects

Hartmut Hirsch-Kreinsen

Abstract This paper deals with an industrial sector that will be referred to as "low-technology" or non-research-intensive and that comprises mostly mature industries. In recent years, a growing body of innovation literature has dealt with the relevance and prospects of low- and medium-technology (LMT) in advanced economies. This research focus is above all motivated by criticism of the mainstream of innovation debate with its high-tech focus. However, LMT research can instructively show that non-research-intensive industries are surprisingly innovative and play an essential role for the development of modern economies. Following the literature, the industrial LMT sector holds forward-looking innovation potential based on both the intelligent modification of available technologies and existing knowledge and their combination with new high-tech components. Therefore, the research findings outlined here culminate in the thesis that "hybrid" innovations open up promising development perspectives for traditional industries. Hybrid innovations are understood to be innovations based on distinct market-oriented modifications of available technologies and of existing knowledge as well as especially on their combination with new high-tech components. The methodological base of the argumentation is a systematic analysis of LMT industry research results from approximately the last 10 years.

2.1 Introduction

In recent years, a research field has been established in international innovation research dealing with industries that do not conduct R&D. The main focus of this research is on manufacturing sectors and firms. These industries can also be termed non-research-intensive and mature industries because they are well advanced in their life cycles. The key criterion of classification is R&D intensity, which indicates the ratio of a company's average investment in R&D activities to its revenue from sales. According to this criterion, industries with R&D intensity

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below 3 % are regarded as non-research-intensive industries. These sectors are also referred to as low-technology or medium-low-technology (LMT) in international usage. For instance, industries producing basic metals, rubber and plastic products, food products, beverages and tobacco, and furniture as well as wood, pulp and paper constitute this sector. By contrast, all sectors that have higher R&D intensity are classified as research-intensive or high-technology and medium high-technology (HMT) sectors. Examples of top-ranking sectors in this regard are office, accounting and computing machinery; medical, precision and optical instruments; and pharmaceuticals. The motor vehicle and trailer, machinery and equipment sectors also have above-average R&D intensity (OECD 1999).

The research interest in LMT industries is primarily motivated by criticism of mainstream innovation research and policy, according to which high investment in R&D and advanced technologies is the key driver of growth and prosperity. This assumption has led to an almost exclusive focus on economic sectors with high R&D intensity, with the economic importance and specific innovative ability of LMT industries being overlooked. By contrast, two research findings on LMT industries are particularly revealing (e.g., Robertson et al. 2009a). First, LMT industries are surprisingly innovative in terms of technology, and their relevance with regard to the innovation ability of the entire economy should not be underestimated. Second, the significance of research-intensive industries in terms of their contribution to employment and growth is greatly overestimated, whereas the importance of LMT industries remains undervalued. Thus, during the second half of the last decade (2006), 11.7 % of the labour force in the EU 27 were employed in LMT industries; in manufacturing alone, this figure rises to nearly two-thirds of all employees (Heidenreich 2009). Of course, this percentage varies greatly among different countries. In Germany, approximately 50 % of all industrial workers were employed in LMT sectors in 2006, and these sectors accounted for nearly 42 % of the total industrial added value. Moreover, there have been few structural shifts between sectors with varying R&D intensities in recent years (Som 2012).

This paper will summarise the research findings on innovation in LMT industries and discuss the development prospects of these industries in advanced societies. The aim is to highlight the specific innovative abilities of mature industries and their future innovation potential. The thesis is that the industrial LMT sector holds forward-looking innovation potential based on both the intelligent modification of available technologies and existing knowledge and their combination with new high-tech components. This innovation pattern will be referred to as 'hybrid innovations' in this paper. This thesis is organised as follows: in Sect. 2.2, the prevailing innovation pattern in LMT manufacturing industries will be analysed with regard to innovation areas, knowledge bases and predominant organisational forms; this analysis will be followed by a detailed definition of the term 'hybrid innovation' in Sect. 2.3; and in the concluding Sect. 2.4, the prospects of this innovation type will be discussed. The term 'innovation' will be understood based on innovation research that can be traced back to Schumpeter. Innovation is perceived as an activity that includes research and development activities, the development and successful marketing of new products, the introduction of new production technologies and the reorganisation of processes; hence, innovations involve both technical and non-technical elements. Therefore, this paper further differentiates between technical and organisational process innovations on the one hand and product and service innovations on the other hand. Marketing innovations involve all of these dimensions (Fagerberg 2005).

The methodological base of the following argumentation is a systematic analysis of LMT industry research results from approximately the last 10 years. These results include a large number of studies that examine the situation across the entire European Union from various perspectives and several studies that concern the German innovation system. Methodologically, either these studies follow a quantitative-statistical approach (Arundel et al. 2008; Heidenreich 2009; Kirner et al. 2009a; Rammer et al. 2011; Som 2012) or their findings are based on qualitative research findings primarily obtained within the scope of case studies (e.g., Palmberg 2001; Bender et al. 2005; Hirsch-Kreinsen et al. 2006; Lichtenthaler 2009). On the basis of this literature, the current study will elaborate on the situation of the LMT sector in the EU as a whole as well as the specific German situation. To identify characteristic LMT features, comparative data on HMT industries will also be used within the given scope of the paper.

2.2 Innovation Patterns of the LMT Sector

2.2.1 Innovation Areas

In the literature, it is undisputed that LMT industries must be regarded as innovative: it is assumed that at least half of all innovative companies in Europe have no in-house R&D capacities (Arundel et al. 2008; Huang et al. 2010). However, it is also shown that LMT firms are less innovative than HMT firms are. According to an analysis of data from the European Community Innovation Survey (CIS-4), more than one-third of LMT firms (37 %) were innovative between 2002 and 2004, whereas more than 55 % of all HMT firms were innovative during the same period (Heidenreich 2009). It is emphasised that the innovation activities of LMT companies are primarily directed at modifying and incrementally developing existing technologies (Arundel et al. 2008).

2.2.1.1 The Great Importance of Process Innovations

Regarding the main areas of innovation, the research findings can be summarised as follows: virtually all research concurs in referring to the particular importance of process innovations (Evangelista and Mastrostefano 2006; Heidenreich 2009; Kirner et al. 2009; Huang et al. 2010; Rammer et al. 2011). According to analyses of CIS data for 2004, these innovations are nearly twice as important for LMT companies as they are for HMT companies, at nearly 36 % versus 17 % of all innovating firms, respectively (Heidenreich 2009). However, 2009 data from German studies contradict this finding. These data show that the intensity of technology use does not correspond to the degree of in-house R&D intensity and that LMT companies are largely capable of adopting new production technologies for their purposes. This capability applies particularly to the introduction of established and mature technologies. However, it is evident that advanced and modern process technologies are used by HMT enterprises to a greater degree (Som et al. 2011; also Rammer et al. 2011). Nonetheless, only a small minority of innovating LMT firms can be characterised as pure technology adopters of new, ready-to-use process technologies. Rather, the large majority of these enterprises engage in far-reaching activities of integrating and adapting new technologies into their manufacturing processes (Huang et al. 2010).

There are often close links between technical process innovations and innovations in given organisational structures, such as the introduction of new forms of company or work organisation or new logistics concepts. Organisational innovations are often intrinsically and functionally linked to the technical innovation of processes. However, organisational innovations can secure a competitive edge for companies, as they are difficult to imitate by competitors because of their immaterial character. These innovations are also drivers of new marketing strategies, which are of utmost importance for LMT companies (see below). As the available data show, organisational process innovations are therefore given high priority by LMT companies as a whole, and in this respect, they differ little from research-intensive enterprises. In fact, the data show that 61 % of all LMT companies in the manufacturing sector were concerned with organisational innovations in 2009 versus nearly 59 % of research-intensive companies (Som 2012).

These technical-organisational process innovations have been characterised as 'process specialization' strategies or 'technical process specialist' strategies in LMT research (Hirsch-Kreinsen 2008; Som 2012). As the research results show, this innovation type is often found in sectors in which standardised products are manufactured with a high degree of automation. Examples can be found in the food and furniture industries and in rubber and plasticware production. Two factors are cited for the relevance of process innovations in both the technical and organisational dimensions. First, process innovations can largely be conducted relatively smoothly even without R&D competencies because these innovations are generally performed by technology suppliers. The adoption of new machinery or of a single machine necessitates adaptation efforts on the part of the innovating LMT firms, such as the integration of new technology into existing processes and organisation-wide employee reorientation and training (Rammer et al. 2011). These adaptation activities typically occur within the context of ongoing operations under the direction of production management (i.e., on the shop floor). Therefore, additional investments in in-house R&D activities are normally not required. Second, the prevailing strong cost competition in LMT industries exerts pressure on enterprises to concentrate their innovation efforts on their production processes, which allows them to reduce costs quickly, to improve their efficiency and to ensure their competitiveness (Cox et al. 2002; Heidenreich 2009; Kirner et al. 2009).

2.2.1.2 The Growing Importance of Product-Related Innovations

Product innovations are assigned similar importance to that of process innovations (Rammer et al. 2011). However, a comparison shows that product innovations are much more important for HMT industries than for LMT industries. According to CSI data, slightly more than 18 % of innovating LMT firms focus on product innovations, but more than 30 % of HMT firms do so (Heidenreich 2009; similarly: Arundel et al. 2008); data for Germany reveal similar connections (Rammer et al. 2011). The research literature offers little explanation for this finding. One can surmise, however, that product innovations (to a far greater extent than process innovations) demand the utilisation of new technologies (Huang et al. 2010). This circumstance calls for technology-oriented competencies and possibly also specialised R&D capacities, which LMT firms often do not have, or if they do, they have them only on a small scale.

Upon closer examination of product innovation, additional findings can be cited (Hirsch-Kreinsen 2008; Som 2012). First, innovation activities in the LMT sector are often limited to the continuous further development of given products. Product components are often improved incrementally in terms of their materials, function and quality to be consistent with changing customer demands. Therefore, this innovation strategy is referred to as 'step-by-step product development' (Hirsch-Kreinsen 2008), or these firms are characterised as 'low-innovative manufacturers' (Som 2012). Second, one can also detect product-oriented innovations that involve the fashion-oriented design of products and functional and technical product upgrades. These measures are closely associated with organisational and market-oriented process innovations. LMT firms that pursue this strategy are aiming for a rapid response to changing customer wishes and are attempting to take advantage of market niches by means of skilful branding strategies and expanded product-related service activities.

When one probes further into the significance of service innovations in the LMT sector, the available data initially show that only a limited number of firms introduced product-related service activities in 2009 (12 % of all companies). This finding is ascribed to the fact that the often simple products of traditional firms offer few opportunities for complementary service activities; for research-intensive companies, with their typically more complex products, the data show that a higher percentage of enterprises are active in this field (Som 2012). However, with respect to service innovations that are independent of technical products, it appears that these innovations were assigned a higher priority by LMT firms than by research-intensive firms in 2009. It is thus evident that LMT companies wish to expand their product portfolios (Som et al. 2011; similarly Rammer et al. 2011). The literature generally notes that many LMT companies regard service innovations as potentially important (Kirner et al. 2008; Rammer et al. 2011).

Correspondingly, the literature also highlights the importance of design and marketing in this innovation focus and refers to this focus as 'customer-oriented strategy' or to the firms as 'occasional business-to-customer product developers' (Hirsch-Kreinsen 2008; Som 2012). Basic features of the above-mentioned innovation strategy include not only the systematic and intelligent modification of available product technologies but also their enhancement with technical and non-technical components that are new to the respective companies and their sales markets.

2.2.2 *Knowledge Base*

Innovation research consistently highlights the important role of the available knowledge in each case for the course and success of innovations. Knowledge is a key resource on which companies must rely for innovations. However, knowledge is also simultaneously a source of information that can provide key impulses for innovations (Malerba 2005). On this point, the relevant literature presents instructive results that notably distinguish between in-house and external knowledge bases and their corresponding information sources (Nouman et al. 2011).

2.2.2.1 In-House Skills and Knowledge

As quantitative analyses of LMT innovations show, internal knowledge bases are of relatively great importance for a successful LMT innovation process. According to an analysis of CIS4 data for 20 EU countries, this internal information source is regarded as being of great significance for innovations by 40.6 % of all innovating LMT companies. However, in view of their internal R&D capacities, the significance of internal information sources remains considerably higher (55 %) for research-intensive enterprises (Heidenreich 2009). These research findings are also corroborated by analyses of other data for the EU-15 (Arundel et al. 2008; Huang et al. 2010) as well as for Germany (Rammer et al. 2011; Som 2012).

This finding is not surprising. Because of these firms' lack of internal R&D capacities, formalised knowledge generation and use play only a minor role in LMT firms (see below). Instead, innovation activities proceed in the form of 'practical and pragmatic ways by doing and using' (Tunzelmann and Acha 2005). Hence, the knowledge that is relevant for these enterprises can be regarded as application-oriented practical knowledge (Maskell 1998; Arundel et al. 2008; Hirsch-Kreinsen 2008). This term represents a complex bundle of different knowledge elements that comprise explicit, codified and formalised elements such as design drawing and requirement specifications for new products as well as, above all, implicit elements such as accumulated experience.

The relevance of this type of knowledge can be exemplified by referring to process innovation activities (Rammer et al. 2011): the enterprises considered here make use of engineering knowledge that is incorporated and codified in their production facilities and operating instructions, although specifications and ongoing intervention and adaptation measures are necessary. An indispensable precondition is the available knowledge on the shop floor (e.g., knowledge of the shortcomings of the production technologies that are already in use and the need for innovation). As shown above, process innovations generally occur in the context of ongoing operative processes; additionally, they are potentially initiated and always conducted by the staff who are responsible for ongoing functions, such as engineers, technicians, master craftsmen and even workers (e.g., Ghosal and Nair-Reichert 2009).

2.2.2.2 Essential External Knowledge

LMT research shows that a company's external knowledge base plays an even more crucial role in the innovativeness of LMT firms. The main reason for this importance is that LMT companies can compensate for their limited R&D resources by simply adapting externally generated knowledge (Bender and Laestadius 2005; Hauknes and Knell 2009). As shown by quantitative data from a number of sources (Grimpe and Sofka 2009; Heidenreich 2009; Rammer et al. 2011), market and marketing information from customers and competitors on the necessity of innovations plays the most important role for LMT companies. As Heidenreich shows on the basis of CIS4 data for 20 EU member states, these information sources—taken together—are considered highly important by more than 35 % of all innovating LMT firms (Heidenreich 2009). As more detailed studies show, customer input—not surprisingly—plays a large role in product innovations in particular. According to the CIS4 data, this source of information is of special importance for approximately 24 % of LMT companies (Heidenreich 2009). Obviously, functioning cooperative relationships between innovating companies and customers can be helpful in many cases; thus, more than 60 % of German LMT companies participated in innovation cooperation with customers in 2009 (Som 2012). Nevertheless, LMT companies differ little from research-intensive companies with regard to the significance attached to market and marketing information and cooperative customer relations, as customers and competitors play similar if not more important roles in these firms' innovations as well (Heidenreich 2009; Som 2012).

However, information and knowledge from suppliers are of significantly greater importance to LMT businesses than to research-intensive companies. This increased importance necessarily results from the great significance of process innovations for LMT companies (see Sect. 2.3; Cox et al. 2002; Som 2012). Nearly 25 % of all LMT companies from the EU 20 describe this information source as being highly important, whereas this statement holds true for only 18 % of research-intensive companies (Heidenreich 2009); data on German enterprises reveal similar relationships (Som 2012). Cooperative relationships with suppliers also prove to be highly important for the innovation capability of these companies. When introducing sophisticated manufacturing technologies in 2009, more than two-thirds of

LMT companies in Germany cooperated with suppliers (ibid.). As researchers note, the LMT sector can therefore be characterised as ‘supplier dominated’. The innovativeness of companies is largely based on their ability to adopt technical-organisational process components—an ability that is also referred to as embodied knowledge (Arundel et al. 2008)—and to adapt it to their own requirements.

Finally, scientifically generated, codified knowledge also plays a certain role in the innovation ability of LMT companies. The literature identifies a number of non-firm organisations, such as research institutions, consulting firms and trade fairs, that also act as sources of information. Thus, Santamaria et al. (2009) emphasise that the use of consultants, the hiring of personnel and external R&D are particularly significant external sources of innovation in LMT industries. In the case of product innovations, consultants are a significant factor for LMT firms, but not for HMT firms. However, LMT studies also show that compared with LMT companies, HMT companies make much more extensive use of these different information sources, particularly of scientific institutions such as universities and research institutes, as sources of inspiration for innovations (Grimpe and Sofka 2009; Kirner et al. 2009). According to Heidenreich’s analysis of the CIS data, 6.2 % of all innovating HMT companies, compared with only 3.2 % of all innovating LMT companies, referred to the scientific sector as an important source of information (Heidenreich 2009); data from German industries show similar ratios (Rammer et al. 2011; Som 2012). Cooperative relationships between LMT companies and external scientific institutions are therefore significantly less frequent than are those of research-intensive enterprises (ibid.).

2.2.3 Organisation and Management of Knowledge

What is of decisive importance for the innovativeness of LMT companies is the manner in which they use internally and externally available knowledge (i.e., how they organise the innovation process). In concrete terms, innovation research specifies the importance of routines, practices and company structures, the prevailing communication and cooperation forms, and the associated qualification and personnel structures (e.g., Cohen and Levinthal 1990; Henderson and Clark 1990).

2.2.3.1 SME-Shaped Practices

As the research results show, the innovation courses addressed here have been strongly shaped by the typical structures of small and medium-sized enterprises (SMEs); as the data show, LMT enterprises are predominantly SMEs. This statement holds true for the EU as a whole (CIS 2004) as well as for the German situation: in 2009, more than 60 % of all German LMT companies were SMEs with fewer than 250 employees (Som 2012). As a result, the prevailing structural pattern in these companies is characterised by a limited set of resources and capacities for strategic action. These companies have few resources in terms of capital, skills and know-how, and the degree of professionalisation of their management is often low. Furthermore, because of their limited R&D capacities, the technological capabilities of such companies are only rudimentary. Instead, innovation processes–as described above–occur at a strongly practice-oriented level and are generated by a small group of management representatives and technical experts.

Overall, the literature emphasises that the innovation courses and practices in LMT companies show a low degree of formalisation. Thus, it is reported that LMT enterprises employ systematic methods of innovation management much less frequently than HMT companies do. This tendency applies, for instance, to the use of innovation-oriented incentive schemes; the integration of innovation-related performance figures into target agreements; selective qualification measures; and the existence of innovation-promoting forms of work organisation, such as innovation circles, teamwork and temporary project teams (Rammer et al. 2011; Som 2012). This finding is not surprising, as enterprises from LMT industries have an above-average share of semi-skilled and unskilled workers and small proportions of skilled personnel (Abel et al. 2009). The large majority of employees of such firms work in production, with only a few in indirect areas such as engineering and design. Therefore, innovation activities are primarily embedded in centralised company and work organisation activities that are based on a marked division of labour.

Furthermore, the research findings show that these structural characteristics apply to the large majority of innovative LMT companies, largely irrespective of the types of innovation that they pursue. Divergent structures are observable only in exceptional cases, such as cases of innovators who, as process specialists, rely on particularly advanced manufacturing technologies. These companies are characterised by high levels of qualifications and holistically oriented forms of work organisation that allow regular workforces of skilled technical staff a great deal of leeway for decisions and room for the continuous innovation of process technologies. Ghosal and Nair-Reichert provide an impressive example from the pulp and paper production perspective: '. . . the typical worker in a pulp and paper firm can be quite technical . . . and these employees contribute to learning-by-doing gains in productivity, pointing out areas that need upgrading and modernization and various forms of incremental innovation. While these employees are hired to do routine work for the firm, they also contribute as "R&D workers" at the margin' (Ghosal and Nair-Reichert 2009).

2.2.3.2 Informal Cooperation

As noted previously, the relevance of external knowledge and information sources implies the great importance of LMT cooperation with external partners. The literature emphasises that the principle of 'connect and develop' is far more important for LMT enterprises than is the principle of 'research and develop' that often prevails in HMT industries (Huston and Sakkab 2006). Thus, the data on German industry for 2006 to 2008 show that in the case of product innovations, 15 % of all LMT companies and only 5 % of all research-intensive companies adopted externally developed innovations; for process innovations, these figures were 27 % for LMT enterprises and less than 10 % for HMT companies (Rammer et al. 2011). Furthermore, the above-mentioned data underline the great importance of cooperative relationships for LMT companies: For product innovations, nearly 30 % of all innovating LMT companies worked with other actors, particularly customers, whereas approximately 15 % of LMT enterprises fully adopted already developed products; for process innovations, cooperative relationships with suppliers dominated, as shown previously (ibid.).

However, it also becomes apparent that in comparison with research-intensive enterprises, LMT companies relatively seldom enter into formalised and contractually agreed upon cooperative relationships with external partners (e.g., Chen 2009; Santamaria et al. 2009). Thus, the data on German industry indicate that only approximately half of the cooperative relationships between LMT companies and other partners have a contractual basis. Conversely, one can infer that cooperative relationships in the LMT sector are largely informal and based on personal relationships (Rammer et al. 2011; Som 2012). Data on the food industry in Germany also show that informal contacts constitute the most frequent form of cooperation, whereas more formal ways are less frequently used (Menrad 2004). These findings are quite plausible for three reasons. First, informal cooperation practices are often a precondition for LMT enterprises to be able to identify the often unarticulated, tacit and unreliable knowledge of customers (Grime and Sofka 2009). Second, the predominance of SMEs plays a significant role, as these businesses are hesitant to engage in formal cooperation and prefer informal, personnel-based relationships. Third, the low qualification levels of LMT companies impede rather than promote official and formal cooperation with external partners. By contrast, research findings indicate that companies with considerably better qualified personnel or with their own R&D departments more often formally cooperate with external partners (ibid.).

2.3 The Relevance of ‘Hybrid’ Innovations

In summarising the research findings, one can identify a specific innovation pattern that is termed ‘hybrid’ innovations. This concept is used to describe those innovations in LMT companies that are characterised by a combination of different innovation activities. These innovations comprise technical and non-technical components and are strongly oriented towards external knowledge sources as well as the sales market. Empirically, this pattern applies to the above-mentioned innovation strategies of process specialisation and to the customer-oriented strategy or ‘occasional business-to-customer product developer’. Additionally, studies note that LMT innovations often extend beyond incremental improvements and do not focus on only one core activity, such as process or product innovation (Tunzelmann and Acha 2005). According to the available data, up to 40 % of innovating enterprises in the German manufacturing sector conducted such innovation activities, which are also termed 'complex' innovations, in the 2006–2008 period (Rammer et al. 2011). Furthermore, researchers emphasise that this specific type of innovation is considerably increasing. LMT firms are increasingly combining design-oriented product innovations with both organisation and technology process improvements, and most importantly, they are introducing new business models that are strongly oriented towards market demands and the needs of specific customer groups (Improve 2011). Above all, researchers highlight the importance of a market-oriented layout of both processes and product design as pivotal and critical drivers of LMT innovations (Arundel et al. 2008; Santamaria et al. 2009).

However, as the research results demonstrate, this innovation type hinges on two key conditions. First, LMT companies must be able to manage the described variety of external knowledge resources, also referred to as the 'distributed knowledge base' in the literature (Robertson and Patel 2007). This base comprises the different forms of knowledge possessed by actors who are independent of one another and who often come from different sectors and technology fields. The empirical findings suggest that the main source for the knowledge generation of LMT companies lies here. This information source applies to processes of knowledge and technology transfer between LMT and high-tech sectors, which are credited with playing a rapidly growing role in the innovative abilities of LMT companies (Mendonça 2009; Potters 2009). Second, the research results highlight the importance of specific capabilities that enable LMT enterprises to identify valuable knowledge in their environments, to integrate this knowledge into their existing knowledge stocks and to utilise it for successful innovation. This ability can be regarded as the key prerequisite, especially for successful process innovations. The key actors often include a small circle of management representatives and technical experts. From a broader perspective, research following the approach of dynamic capabilities (Teece and Pisano 1994) conceptualises this feature as 'transformative capability' (Bender and Laestadius 2005), which can be regarded as a core competence of LMT industries and which refers to the transfer of generally available knowledge to an individual LMT firm's innovation process. Mendonça (2009) emphasises this point, stating that low-tech firms '... demand some degree of endogenous capabilities in order to understand, procure and interact with the partner-suppliers to facilitate the production of renewed traditional goods'. According to the author, these capabilities result in the hitherto often overlooked yet highly dynamic development of LMT industries because this specific ability to integrate new technologies must be constantly developed further in view of general technological changes.

Conclusion

In conclusion, this paper addresses the question regarding the extent to which the outlined innovation pattern can be considered sustainable and whether LMT companies can thus not only secure but also expand their activities in their original business locations in advanced countries such as Germany. This question can be answered positively in view of the available research findings: researchers concur in highlighting the surprising economic stability of the LMT sector. Thus, although the research-intensive sector had markedly higher output in past years, growth rates in the LMT sector were likewise astonishingly high in the past decade. This finding applies to German industry in particular and to large areas within the EU. The innovativeness of many companies from the LMT sector is credited with this success (Kaloudis et al. 2005; Robertson et al. 2009a). Furthermore, the sustainability of many enterprises from the LMT sector depends on a number of additional factors. First, knowledge transfer processes—especially within research-intensive sectors—play a major role. As has been shown, studies emphasise the importance of the use of advanced machinery for both product and process innovations in LMT firms (Potters 2009; Santamaria et al. 2009). However, these transfer processes do not occur in only one direction; relevant innovation impulses are also transferred in the reverse direction—from low-tech to high-tech. These impulses result from the simple but often overlooked economic fact that profits from the sales of new technologies are vital for the amortisation and continuation of R&D investments by research-intensive enterprises. Furthermore, additional impulses result from companies' technical and economic specifications of new technology application requirements (Robertson and Patel 2007; Hansen and Winther 2011). These conditions often influence the development trajectory of new technologies if the requirements of individual users coincide with those of as many other users as possible, and thus, from the manufacturer's perspective, a broad application field for complex products opens. One can therefore speak of a high level of technological complementarity between LMT and high-tech industries that is central to the industrial innovativeness of the entire economy. In other words, low-tech industries 'are continuously creatively incorporating, adapting and transforming the key technologies of the current industrial revolution' (Mendonça 2009).

Second, these transfers between the different knowledge resources can potentially lead to the emergence of new technological sectors. By adapting new global knowledge, LMT companies not only enhance the performance of existing products but also extend the range of technological opportunities (Freddi 2008, 2009). This process can be conceptualised as 'technology fusion', which creates a new body of knowledge based on the integration of previously independent technologies. An example of this process is the creation of the technology field 'mechatronics', a blend of mechanics,

(continued)

electronics and informatics that is essential to further industrial development. Mechatronics is regarded as a key example of technology fusion because the interdependency between the different technologies is so great that a new body of knowledge actually emerges as a result of the fusion of previous knowledge bases (Freddi 2008). Third, a recent study of knowledge-based corporate activities reveals numerous opportunities for companies from the LMT sector to develop sustainable innovation strategies, to open new market segments and to stimulate new customer preferences. A key prerequisite is the systematic use of high-tech knowledge bases and their blending with existing company and sector-specific knowledge.

Finally, these findings can be linked to the debate in innovation research on ‘frugal innovation’. This term refers to simple and effectively developed but also ambitious innovations (e.g., Wooldridge 2011). Originally, this debate addressed the requirements of the rapidly growing markets of the new middle classes in rapidly developing countries such as China, India and Brazil. However, the debate has recently also turned to the market potential of highly developed countries. Thus, the focus is on growing market segments with customer groups who have only dwindling or insecure incomes or who, for various reasons, are becoming less willing to generally and exclusively purchase high-technology products for status reasons, for example. It is argued that this opportunity reveals increasingly significant markets for innovations that were originally developed for markets in newly industrialised countries. However, to date, only products from major international corporations have been cited as examples of successful innovations of this type, such as easy-to-use medical devices or technologically trimmed-down cars that were originally manufactured for developing countries but surprisingly also found a market in developed countries (e.g., Simon 2011).

It could be reasoned that this development also reveals new horizons for LMT enterprises in advanced countries. The specific features of the outlined LMT innovation patterns greatly resemble the characteristics of the concept of frugal innovation: both are geared towards the specific and intelligent combination of new technological components at the levels of processes and products. In view of rapidly changing income structures and customer preferences, previously overlooked sales potentials are emerging, especially in situations in which customer proximity and reliable delivery capacity are essential. Given the global market interdependencies and the resulting pricing pressures, this potential cannot assuredly be generally accessed by all LMT producers. Nonetheless, an increasing number of new opportunities are emerging, for example, for design-intensive and customised consumer goods or for the reliable and flexible supply of standardised but also technologically advanced components within differentiated production chains. The key condition for LMT companies to succeed in this field is their innovation ability.

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Chapter 3
Economic Relevance and the Future Potential of Non-R&D-Intensive Industries

Sven Wydra and Michael Nusser

Abstract This book chapter focuses on non-R&D-intensive industry sectors and analyses their economic importance for Germany. Therefore we compare non-R&D-intensive industry sectors with R&D-intensive-industry-sectors and service sectors regarding R&D activities, domestic value added and import intensity, production, employment and skills. In order to not only include direct effects for these indicators we also analyze indirect effects via input-output (I/O) analysis by simulating the potential effect additional 1 billion euros demand impulse in the various sectors. On the one hand, our results show that the dynamics of non-R&D-intensive industries is less than that of the R&D-intensive industrial sectors. Moreover, R&D-intensive industries are found to contribute more to the employment of highly skilled professionals. On the other hand, our potential analyses show that non-R&D-intensive industries are of significant economic importance to Germany. This importance is evident based on a number of macroeconomic indicators: non-R&D-intensive industries are associated with strong indirect employment effects that also include qualified personnel. Overall, the analysis shows that the consideration of indirect macroeconomic effects is important to con-ducting an appropriate analysis of the role of non-R&D-intensive industries. Non-R&D-intensive companies have profound effects on upstream economic sectors through their spending on intermediate inputs (including business-related services and engineering). Policymakers should consider those linkages in determining an adequate selection of measures.

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3.1 Introduction

As a highly developed country with a shortage of raw materials, the German national economy's development potential depends heavily on knowledge- and research-intensive industries. Germany has little choice but to rely on innovation to be able to compete internationally. Promising innovative economic sectors are opening new markets and competitively reorganising traditional industries. Developing, producing and commercialising innovative products, processes and services creates new jobs and secures existing jobs. For decades, Germany, as in other industrialised countries, has thus focused on the promotion of domestic high-technology sectors to foster innovation, growth and employment. Companies in these sectors receive significant government support (e.g., via subsidies or tax breaks) due to the expectation of higher growth rates and lower offshoring activities in developing countries in these sectors.

By contrast, the potential of non-R&D-intensive industries for Germany has typically been given only minor (political) importance. However, developments in recent decades have shown that neglecting non-R&D-intensive sectors cannot be justified from an economic perspective. Non-R&D-intensive sectors are closely interconnected with other sectors in supply chains or as collaboration partners (Hirsch-Kreinsen 2008). Thus, these sectors contribute to innovation output and employment throughout the entire economy.

This book chapter focuses on non-R&D-intensive industry sectors (sectors with less than 3 % of R&D expenditures on sales) and analyses their potential for innovation, growth and employment. The analysis includes the direct and, especially, the indirect contributions of these sectors towards strengthening innovation and business in Germany. The overall economic importance of non-R&D-intensive sectors is measured for different steps in the innovation chain by analysing the following:

- R&D activities,
- domestic value added and import intensity,
- production, and
- employment and skills.

Therefore, it must be considered that the usual indicators of direct economic output (e.g., employment, value added, production) insufficiently measure the effect of industry on the national economy. Non-R&D-intensive companies also add value through their spending on intermediate inputs (e.g., business-related services). This spending leads to indirect production and employment effects in the upstream supply sectors. Hence, in addition to some key indicators for direct economic effects and comparisons with other countries, potential spillover effects via an input-output (I/O) analysis for Germany are calculated.

The remainder of the article is structured as follows. We first analyse the development of R&D intensity over time in various sectors to test life-cycle theories. Subsequently, the results for the individual macroeconomic indicators for specific sector groups and for individual non-R&D-intensive sectors are presented in more detail. First, sectoral developments in value added over time and in comparison to other countries are analysed. Second, the results of potential I/O analysis for production, employment and skills are presented. In the final section, overall conclusions are drawn.

3.2 Sectoral R&D Intensity

First, we analyse an important question to help us characterise non-R&D-intensive industries over time. Is R&D intensity connected to the industrial life cycle, and therefore, does it typically decline over time, e.g., because of a dynamic increase in turnover that exceeds R&D growth rates? In that case, low R&D intensity would be an indicator of maturity and not necessarily an indicator of weak economic impulses.

Some theories (e.g., industrial life-cycle theory) postulate that R&D intensity depends on the development stage. The growing maturity in the processes, products or services that are developed may decrease the need for R&D activities. Moreover, strong growth in value added and turnover during this phase may increase the denominator, surpassing R&D growth. Those developments would result in lower R&D intensity. By contrast, it is also conceivable that new technological possibilities allow for the development of new processes, products or services in a sector and stimulate additional R&D activities to exploit these opportunities. In this case, R&D intensity may increase.

To analyse the development of R&D intensity over the long term, sectoral R&D intensities for Germany and major countries are calculated for the 1975–2006 period based on the OECD database. Contrary to the definitional demarcation of R&D-intensive sectors, R&D intensity is determined here by the gross value added as the denominator rather than production value. The reason for this choice is that production value depends significantly on input intensity, which has increased significantly over time in some sectors. In addition, in the case of strong production value growth, the rate tends to decline (Rammer 2009).

The sectoral R&D intensities shown in Table 3.1 highlight strong differences between individual sectors. For example, the R&D intensity for air and spacecraft in Germany is constant and greater than 30 %, whereas for print and paper, it is less than 0.5 %. The development of sectoral R&D intensity over time is mixed. In some sectors, R&D intensity is stable over time, whereas in other sectors, strong variation (e.g., other transport equipment) or temporal trends arise. For example, in the pharmaceutical industry, R&D intensity increased significantly over the period studied. However, there are no major changes in the ranking of sectors according to their R&D intensity. Although it cannot be observed directly in Table 3.1, additional analyses show that no sectors evolved from non-R&D-intensive industries into R&D-intensive industry sectors or vice versa. Hence, there are no clear indications of the developments suggested by industry life-cycle theory.

Table 3.1 Sectoral R&D intensity (R&D expenditures/value added) in Germany and selected other countries between 1975 and 2006 (in %) (Source: OECD STAN database [the other 7 OECD countries are Italy, Japan, Korea, Canada, the US, France and the UK])

	Germany				7 other OECD countries			
Sector	1975	1985	1995	2006	1975	1985	1995	2006
Manufacturing	3.5	5.7	6.8	7.6	4.7	7.3	7.0	9.4
	Non-R&D-intensive industry sectors							
Food and tobacco	0.2	0.7	0.6	0.8	0.7	1.1	1.3	2.0
Textiles and leather	0.2	0.6	1.5	2.6	0.4	0.5	0.7	1.4
Wood	0.1	2.0	0.4	0.3	0.7	0.7	1.0	0.6
Paper and publishing	0.1	0.3	0.4	0.4	0.6	0.6	0.9	1.4
Coke, refined petroleum and nuclear fuel	1.3	2.0	3.3	1.2	4.2	6.3	4.0	1.8
Rubber and plastic processing	1.0	2.5	2.1	3.2	1.2	2.5	2.8	4.2
Glass and ceramics	0.5	1.9	1.5	1.8	1.5	3.0	2.0	2.2
Basic metal	–	1.9	1.7	1.8	–	3.0	2.5	2.2
Metal processing sectors	–	2.4	1.1	1.1	–	1.2	1.1	1.1
Building of ships	–	3.4	5.4	3.5	–	1.4	3.0	3.5
Furniture	–	–	1.4	1.5	–	–	0.7	1.6
	R&D-intensive industry sectors							
Chemicals	–	11.2	11.1	10.1	–	9.4	8.0	7.9
Pharmaceutical industry	–	15.2	16.7	23.9	–	19.5	24.1	37.0
Machinery	2.5	4.7	5.6	5.8	–	3.6	5.3	7.2
Office machinery and equipment	4.0	8.2	26.4	14.9	5.8	39.8	22.3	61.5
Electrical machinery	6.2	6.7	7.1	3.5	2.6	8.1	10.4	9.8
Radio, television and communication equipment	27.2	38.4	36.0	28.8	10.1	27.8	19.1	26.2
Medical, precision and optical instruments	2.3	2.8	13.4	13.6	–	12.6	25.7	32.7
Motor vehicles	4.8	7.8	13.1	17.4	5.9	9.3	13.2	16.8
Aircraft and spacecraft	–	51.6	–	32.9	–	50.9	42.6	25.9
Other transport equipment	–	3.9	18.8	8.9	–	9.2	8.7	29.8

In the seven other OECD countries observed, the sectors with the highest R&D intensity are the same as those in Germany. Moreover, a rather similar temporal development of sectoral R&D intensities emerges. Only in some sectors does the development in Germany (e.g., textiles) surpass that of other countries. In several other sectors, the dynamic (e.g., electrical machinery) in Germany is weaker than in other countries.

3.3 Value Added

In this section, we analyse the economic importance of non-R&D-intensive sectors by considering the development of value added in different sectors. The real value added has increased significantly in all of the aggregated economic sectors between 1970 and 2007 (Fig. 3.1). For non-R&D-intensive sectors, there is a clear increase between the mid-1980s and the mid-1990s. However, between 1995 and 2000, the amount of value added declined. After 2000, the amount of value added again increased approximately to the level of the early 1990s. The temporal variations are similar to those observed in the R&D-intensive industries and service sectors; however, the latter industries and sectors grew more dynamically overall.

The development of individual sectors partly differs from these aggregate developments, but with the exception of office machinery, all of the R&D-intensive industries developed more dynamically than the non-R&D-intensive industries. In some non-R&D-intensive industries, the real value added actually decreased (e.g., textiles, tobacco, leather), whereas in other industries, the amount increased significantly (e.g., plastics, metals).

Because of the slower growth compared with the R&D-intensive industries and service sectors, the proportion of non-R&D-intensive industries to the overall value added declined from 55 % to 41 % between 1970 and 2007 (Fig. 3.2). This decrease occurred rather continuously, with a few interruptions between 1975 and 1980 and in the early 1990s. However, the non-R&D- intensive industries still contributed a significant proportion (41 %) of industry value added. Moreover, these non-R&D-intensive sectors employ approximately 11 % of the total workforce in Germany.

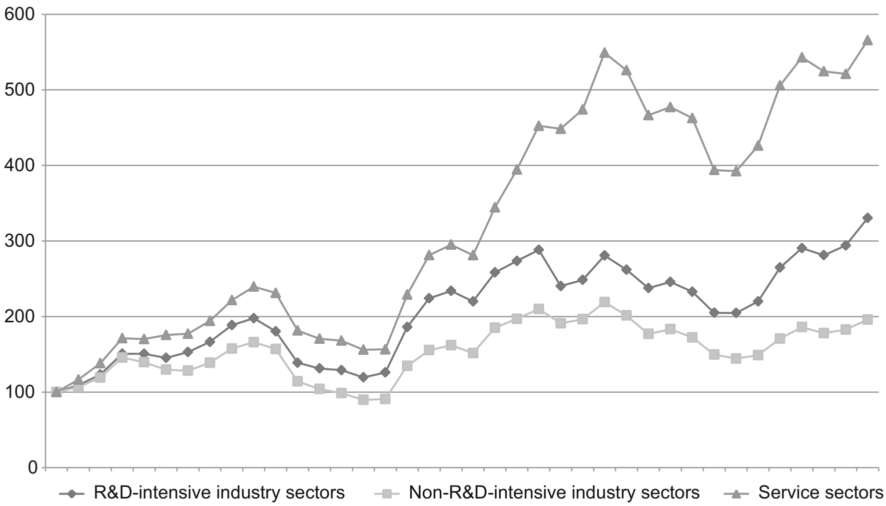

Fig. 3.1 Development of value added (in real prices) in Germany between 1970 and 2007 (Index 1970 = 100) (Source: Fraunhofer ISI [Data source: OECD STAN database])

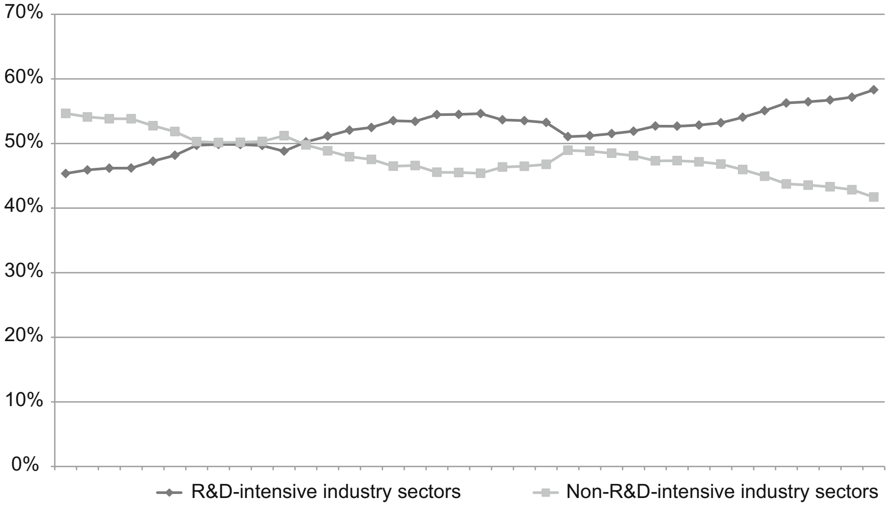

Fig. 3.2 Share of economic sectors in total value added in the manufacturing sector in Germany between 1970 and 2007 in % (Source: Fraunhofer ISI [Data source: OECD STAN 2010])

Table 3.2 The share of value added in industries in different countries (in %) (Source: Belitz et al. 2010 [Data source: EU-KLEMS])

	GER	USA	JPN	EU-14	EU-10	GER	USA	JPN	EU-14	EU-10
	1995					2007				
R&D-intensive industry sectors	51	46	45	36	27	58	47	49	27	34
Non-R&D-intensive industry sectors	49	54	55	64	73	42	53	51	73	66
Total industry	100	100	100	100	100	100	100	100	100	100

In comparison to other countries, Germany specialises in R&D-intensive industries regarding domestic value added (Table 3.2). The share of non-R&D-intensive sectors in value added is significantly lower than in the US, Japan and the EU. The primary reason for this difference is the traditionally high share of medium-high technologies in Germany (e.g., manufacturing equipment, automotive). Moreover, the decline in the share of non-R&D-intensive industries in other countries is lower than that in Germany between 1995 and 2007; in the EU-14, this share has even grown from 64 % to 73 %.

An important factor in domestic value added is import intensity (Table 3.3). The share of imports (imports as a percentage of domestic demand) in non-R&D-intensive industries in Germany was 41 % in 2007, which is lower than that in R&D-intensive industries (60 %). In the US and Japan, the import quota in non-R&D-intensive industries is significantly lower than that in Germany in 2007

Table 3.3 Imports of domestic demand in industries in different countries (in %) (Source: Belitz et al. 2010 [Data source: EU-KLEMS])

	GER	USA	JPN	EU-14	EU-10	GER	USA	JPN	EU-14	EU-10
	1995					2007				
R&D-intensive industry sectors	50	25	18	62	35	60	39	19	80	77
Non-R&D-intensive industry sectors	34	13	15	31	15	41	21	15	56	37
Total industry	41	18	16	43	21	50	28	17	67	53

(21 % and 15 %, respectively). However, in the EU-14 countries, the quota is significantly higher, at approximately 56 %.

3.4 Input-Output Potential Analysis for Production, Employment and Skills

The described developments in value added do not consider indirect effects. However, non-R&D-intensive companies also add value via their spending on intermediate inputs (e.g., business-related services, engineering). This spending leads to indirect production and employment effects in the upstream supply sectors. Hence, in addition to some key indicators for direct economic effects and comparisons with other countries, potential spillover effects via an I/O analysis for Germany are calculated.

3.4.1 Methodology

This study used the Fraunhofer ISIS I/O model to determine those indirect effects. The ISIS model is a static, open Leontief model based on the I/O tables of the German Statistisches Bundesamt for 2006. In these I/O tables, the German economy is divided into 71 economic sectors and different final demand sectors. The core of this I/O model is a matrix showing the interrelationships of goods and services among the 71 economic sectors (see Annex 3.1). Moreover, the Fraunhofer ISIS model contains additional modules to analyse the effects of various economic conditions on the level of employment, on required qualifications and working conditions, on the regional structure and on the environment, all within a consistent framework. The employment and qualification modules are particularly relevant to this analysis, and they are based on data from the German micro-census.

Based on this I/O model, potential analyses are conducted to measure the effects of certain economic impulses (e.g., rising consumer demand, production increases). With these I/O potential analyses, the relevance of non-R&D-intensive industries, especially for employment, domestic production and skills, can be estimated more comprehensively than by focusing only on direct economic indicators. The potential analysis is conducted for those indicators by simulating a permanent domestic sectoral demand increase in the amount of 1 billion euros: this demand impulse indicates the extent to which the considered indicator (e.g., indirect employment, domestic production) increases when the final domestic demand permanently increases by 1 billion euros in the sector concerned. For example, additional demand growth in the amount of 1 billion euros in the plastics processing industry in 2006 triggered approximately 9,100 jobs in Germany. Approximately 5,100 of these jobs would be created directly in the plastics processing industry itself and approximately 4,000 created indirectly in upstream supply sectors.

A permanent increase in final domestic demand in the amount of 1 billion euros could be realised, e.g., by an increase in domestic consumer spending or by the increased competitiveness of domestic enterprises with a corresponding increase in exports. However, even temporary increased government spending to stabilise the economy may have potential transitional positive effects in Germany. Of course, some limitations of these I/O model simulations in providing informative value for policy making must be recalled. The usual criticism concerns the double-counting of effects (the indirect effects of one sector are the direct effects of others) and the simplicity of assumptions, such as a fixed input structure in each industry, constant returns to scale in production, and unlimited labour and capital availability at fixed prices (Gretton 2013). These simplifications often lead to overexpectations for the effects concerned. The possibility of those counterarguments and effects cannot be eliminated completely, but simulating the marginal effects of a 1 billion euro change renders these limitations as less severe: potential shortages on the supply side that lead to, for example, increasing prices are unlikely for such a small change in demand. Moreover, at least during times of economic crisis or slow growth, the supply of goods and labour is more elastic than usual.

The potential analysis is conducted for all sectors in the German I/O tables. The key results for non-R&D-intensive industries (with less than 3 % of R&D expenditure on production value) in total always refer to a size-weighted average of 22 sectors, those in the R&D-intensive industrial sectors refer to an average of 9 sectors and those in the service sectors to an average of 27 sectors (see Annex 3.1).[1] Because of significant time delays in the official publishing of I/O tables and major changes in industrial classifications in recent years, the analysis primarily refers to the year 2006. As shown by our additional analyses for developments between 1995 and 2006 to detect long-term trends, there are indeed some changes over time (e.g., because of productivity, outsourcing, offshoring) that affect the

[1] All results, including more in-depth analyses for individual sectors as well as additional indicators, can be found in the following: Som, O.; Kinkel, S.; Kirner, E.; Buschak, D.; Frietsch, R.; Jäger, A.; Neuhäusler, P.; Nusser, M.; Wydra, S. (2010): Zukunftspotenziale und Strategien nichtforschungsintensiver Industrien in Deutschland – Auswirkungen auf Wettbewerbsfähigkeit und Beschäftigung. Büro für Technikfolgen-Abschätzung beim Deutschen Bundestag. Berlin, Arbeitsbericht Nr. 140, Chapter 2.

sectors differently; such developments typically occur slowly over time. Hence, the primary results are likely to persist over quite a long time.

3.4.2 Production

Additional domestic demand in the amount of 1 billion euros in the non-R&D-intensive industries induced an effective direct domestic production of approximately 750 million euros on average (Fig. 3.3). These effects are higher than the effects in R&D-intensive industries (approximately 650 million euros) but smaller than those in the service sectors (approximately 975 million Euros). The greatest effects among the non-R&D-intensive industries occurred in recycling (approximately 1,000 million euros) and printing (approximately 950 million euros). Low domestic direct production effects arise in leather (approximately 250 million euros) and apparel (approximately 300 million euros). In these areas, high production capacity has been shifted abroad in the last two decades, and import intensities are high.

Regarding the indirect effect on production in the upstream supply sectors, the resulting effects are greatest in the non-R&D-intensive industries at approximately 700 million euros on average. By contrast, in R&D-intensive industries, an effect of only 500 million euros of indirect production arises; in the service sectors, the effect is approximately 525 million euros. One reason for this result is that dependence on imports from abroad in non-R&D-intensive industries throughout the entire value chain is lower than that in R&D-intensive industries. Considering individual sectors, high domestic indirect production effects arise in basic metals (1,550) and food and beverages (950).

In total, the additional demand in non-R&D-intensive industries in the amount of 1 billion euros induced an effective domestic total production (direct plus indirect at

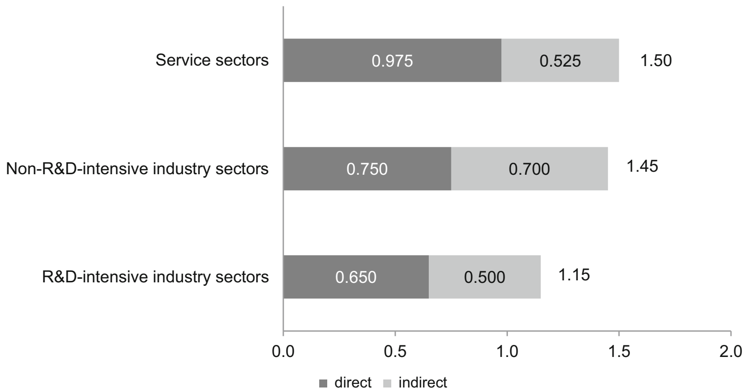

Fig. 3.3 Domestic total production (in billions of euros) per 1 billion euros demand impulse in Germany (Source: Calculations from Fraunhofer ISI)

the suppliers) in the amount of approximately 1.45 billion euros, on average (Fig. 3.4). This effect is greater than that in the R&D-intensive industries (approximately 1.15 billion euros) and is almost as large as that in the service sectors (approximately 1.5 billion euros). The non-R&D-intensive sectors with the greatest effects are basic metals (approximately 2.45 billion euros) and recycling (approximately 2.25 billion euros); the smallest effects are observed in leather (approximately 450 million euros) and apparel (approximately 550 million euros).

Another way to highlight the importance of an industry to the entire value chain is to calculate production multipliers. A production multiplier can be calculated by dividing the total domestic production (direct plus indirect) by the direct production. A production multiplier of 2 therefore indicates that each euro in direct domestic production induces an additional euro in domestic production for domestic suppliers. A high production multiplier indicates that large domestic indirect effects are generated by domestic production. The results show that the non-R&D-intensive industries have a production multiplier value of 1.88, which is on the same level as that of the R&D-intensive industries (1.85) and which lies above the value for the service sectors (1.55).

Development from 1995 to 2006
The production effects per 1 billion euros in demand decreased considerably between 1995 and 2006. In the non-R&D-intensive industries, the direct effect of domestic production decreased by approximately 50 million euros, from 800 million euros in 1995 to approximately 750 million euros in 2006. The cause for the decreasing direct effects on domestic production are rising import quotas resulting from the increasing international division of labour.

3.4.3 Employment

In the following, the direct and indirect effects on employment and the resulting overall employment effects are presented.

Additional domestic demand in the amount of 1 billion euros induced direct effects on employment in the non-R&D-intensive industries for an average of approximately 4,050 workers (Fig. 3.4), thus significantly exceeding the average direct employment effects in R&D-intensive industries (2,450 employed). One reason for this result is the generally higher labour productivity in the primarily capital-intensive R&D-intensive industries. However, the effects in the non-R&D-intensive industries are considerably smaller than those in the labour-intensive service sectors (approximately 14,300 in employment). Among the non-R&D-intensive industry sectors, the effects are relatively strong for printing (approximately 10,100), fabricated metals (approximately 6,350) and publishing (approximately 5,950). In those sectors, which have widely conducted outsourcing and

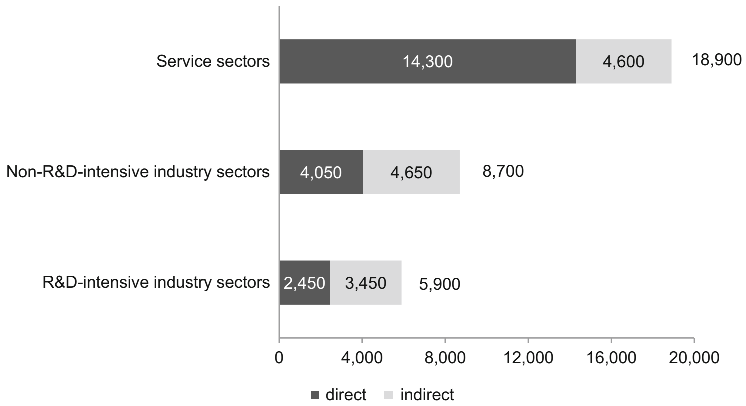

Fig. 3.4 Domestic employment per 1 billion euros demand impulse in Germany (Source: Calculations from Fraunhofer ISI)

automation in recent decades, namely, leather and textiles, the direct employment effects are considerably lower (under 2,000 for each).

Regarding the indirect employment effects, the additional demand in non-R&D-intensive industries in the amount of 1 billion euros induced an indirect effect on employment in the upstream supply sectors amounting to approximately 4,650 workers on average. This effect is larger than that observed in the R&D-intensive industries, in which average indirect employment effects amounting to approximately 3,450 workers were observed, but the effect is approximately the same as that in the service sectors (approximately 4,600 persons employed). The greatest indirect effects occurred in food and beverages (approximately 9,500) and publishing (approximately 7,500), whereas the smallest indirect effects were observed in apparel (approximately 1,750) and leather (approximately 1,450).

From direct and indirect employment, the results show the following total employment effects: an additional domestic demand in the amount of 1 billion euros in 2006 in the non-R&D-intensive industries induced a total employment effect of approximately 8,700 workers on average. This effect is significantly larger than the average total employment effect in R&D-intensive industries (approximately 5,900) but smaller than the effect in the highly labour-intensive service sectors (approximately 18,900). Among the non-R&D-intensive industries, the greatest total employment effects occurred in printing (approximately 15,350 jobs), and the lowest were observed in leather (approximately 3,450) and apparel (approximately 3,700).

Similar to production, the employment multiplier (indirect effects divided by direct effects) is often used to highlight the spillover effects in domestic upstream sectors. The non-R&D-intensive industrial sectors have, on average, a similar employment multiplier as in the research-intensive industries (1.6 vs. 1.7, respectively). This effect is significantly larger than that in the service sectors (approximately 0.8).[2]

Developments between 1995 and 2006

Concerning the development between 1995 and 2006, the employment effects per 1 billion euros (real prices in 2006) significantly declined. The total employment effects of an additional demand impulse of 1 billion euros in 1995 induced, depending on the sector, employment of approximately 5,500-8,800 more workers than in 2006. These declines in employment effects resulted from productivity gains and higher import quotas because of the stronger international division of labour.

In the non-R&D-intensive sectors, the direct employment effect of the additional demand decreased from approximately 7,500 in 1995 by approximately 3,450 to approximately 4,050 employed in 2006. In R&D-intensive industries, the direct employment effect of approximately 5,350 workers in 1995 decreased by approximately 2,900 to approximately 2,450 employed in 2006. The decrease in indirect effects was on a similar level.

3.4.4 Skills

In addition to total employment, the effects on high-skilled jobs are of high informative value. The market diffusion of innovation requires a workforce of individuals who have learned how to use technological knowledge in products and processes. A country must have a sufficient number of highly qualified employees and jobs to be able to transfer R&D knowledge to internationally competitive products and processes. A nationwide lack of highly qualified employees or jobs for such individuals may lead to a long-term competitive disadvantage. For example, other countries may be able to use technological knowledge gained from national R&D relatively quickly; meanwhile, the pace of struggling countries can never be sufficient to import foreign technological know-how. To realise the potential of highly skilled workers, it is also crucial to have the demand to absorb them.

According to our potential analysis, an additional domestic demand in the amount of 1 billion euros in the non-R&D-intensive industries induced approximately 300 jobs for academic graduates, which is below the comparative values for the R&D-intensive industrial sectors (approximately 450) and the service sector (approximately 2,100) (Fig. 3.5). This result is hardly surprising, as the average

[2] However, as the results in Figure 3.4 show, a small indirect effect on employment in terms of low multipliers is not synonymous with the low importance of the sector to the overall economy. In the labour-intensive service sectors, the total employment effects are typically high because of the (very) high direct employment. The latter also implies that the indirect employment multipliers are low.

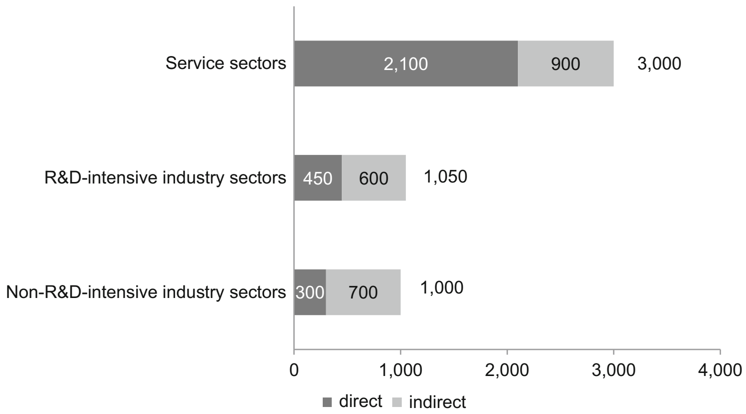

Fig. 3.5 Domestic academic graduate employment per 1 billion euros demand impulse (Source: Calculations from Fraunhofer ISI)

quota of academic graduates in the total workforce in non-R&D-intensive sectors is rather low. Again, the sectors with the largest effects are publishing (approximately 1,400) and printing (approximately 800); by contrast, the effects are negligible in the leather sector (approximately 100).

In contrast to the rather weak direct effects, the non-R&D-intensive sectors contribute heavily to the employment of academic graduates via demand for investment goods and intermediates from upstream supply sectors (e.g., R&D-intensive industry sectors or knowledge-intensive service sectors). Additional domestic demand in the non-R&D-intensive industries in the amount of 1 billion euros induced indirect employment effects of approximately 700 jobs for academic graduates on average (e.g., in supply firms from machinery and equipment manufacturing). This indirect skill-specific effect is greater than that in the R&D-intensive industrial sectors (600) but is slightly weaker than that in the service sectors (approximately 900). The average effect of the non-R&D-intensive industries is particularly influenced by publishing (approximately 1,500), tobacco (approximately 1,200) and recycling (approximately 1,150).

Primarily because of the large indirect employment effects in the supply sectors, non-R&D-intensive industries substantially contribute to the creation and protection of (highly) skilled jobs in Germany. An additional domestic demand impulse of 1 billion euros in the non-R&D-intensive industries induced total employment effects amounting to approximately 1,000 jobs for academic graduates. Thus, the overall effects are approximately the same as in R&D-intensive industries (approximately 1,050) but are significantly below those in the service sector (approximately 3,000) because of the smaller direct effects. The non-R&D-intensive sectors with the strongest effects are publishing (approximately 2,850 academic graduates) and printing (approximately 1,500); those with the weakest effects are apparel (approximately 350) and leather (approximately 250).

Development between 1995 and 2006
Between 1995 and 2006, the direct effects for academic graduate jobs per 1 billion euro decrease significantly. Depending on the sector, there are approximately 200 to 350 fewer jobs in 2006 compared to 1995. This result is primarily driven by the considerable productivity increases and import-related declines in direct employment effects between 1995 and 2006. These effects exceed the intensification of knowledge work (the share of academia in total employment) that can be observed in many sectors. Similarly, the indirect effects declined, e.g., in the non-R&D-intensive sectors, from 925 jobs for graduates in 1995 to 700 jobs in 2006.

Additional Analysis for Female Academic Graduates
Germany fails to sufficiently take advantage of the capabilities, skills, knowledge and innovation potential of women, according to various reports on technological competitiveness. Women's qualification levels are exceedingly high. In Germany, approximately 50 % of the graduates of tertiary education are women. However, the share of women in ongoing professional development (e.g., doctoral degree, university research, professorship, leading positions in the economy) is decreasing. To be open to new potential economic innovations, Germany must increase its share of women in the workforce, especially in the advanced professional phases of development. Using the capabilities, knowledge and skills of women is an investment in Germany's innovation potential. Thus, how do non-R&D-intensive industries perform with regard to employing highly qualified women? The results show that 1/3 of directly and indirectly employed graduates in the non-R&D-intensive companies are women. This proportion is higher than in the R&D-intensive industries. Therefore, non-R&D-intensive industries frequently use the capabilities, knowledge and skills of women as an investment in Germany's innovation potential.

Conclusion
The overall economic importance of certain activities and, in particular, the dynamics of non-R&D-intensive industries is less than that of the R&D-intensive industrial sectors, as shown in this contribution through the time development of value added. Moreover, R&D-intensive industries are found to contribute more to the employment of highly skilled professionals. However, our analysis highlighted important macro-economic characteristics of non-R&D-intensive sectors: they do not simply represent mature sectors at the end of the industry life-cycle, with declining R&D intensities and decreasing output. Rather, the non-R&D-intensive sectors are particular long-existing industries with a stable and significant output in terms of value added. Moreover, our potential analyses show that non-R&D-intensive industries are of significant economic importance to Germany. This importance is evident based on a number of macroeconomic indicators: non-R&D-intensive

(continued)

industries are associated with strong indirect employment effects that also include qualified personnel. Every additional 1 billion euros demand impulse permanently created in Germany generates approximately 8,700 jobs (see Fig. 3.5). Approximately 4,050 of these jobs represent direct employment. Upstream economic sectors generate 4,650 indirect jobs, and 600 of these indirect jobs are occupations for highly skilled personnel.

Overall, non-R&D-intensive industries are more oriented towards domestic value chains than R&D-intensive industrial sectors on average and hence are of significant importance to domestic production and value added. However, non-R&D-intensive sectors are not a homogenous group of sectors, and significant differences can be observed between single sectors. For example, publishing, printing and recycling are connected to long domestic value chains and significant employment in the economy, whereas demand impulses for leather and apparel have small effects on the domestic economy.

Overall, consideration of indirect macroeconomic effects is important to conducting an appropriate analysis of the role of non-R&D-intensive industries. Traditional industry reference numbers, such as sales or direct production and employment, fail to capture an industry's full economic significance. Non-R&D-intensive companies have profound effects on upstream economic sectors through their spending on intermediate inputs (including business-related services and engineering). Policymakers should consider those linkages in determining an adequate selection of measures.

Annex 3.1. Sectoral aggregation of German input-output tables for 2006, sorted by R&D intensity

Non-R&D-intensive industry sectors
9 Food (inc. feed)
10 Beverages
11 Tobacco
12 Textiles
13 Wearing apparel, dressing and dyeing fur
14 Leather
15 Wood and wood products
16 Pulp, paper and paper products
17 Articles of paper and paperboard
18 Publishing
19 Printing (incl. reproduction of recorded media)
20 Coke and refined petroleum products
23 Rubber
24 Plastics

(continued)

25 Glass
26 Ceramics, processed stone and clay
27 Basic iron, steel and tube
28 Precious and non-ferrous metals
29 Casting of metals
30 Fabricated metal products
38 Furniture, jewelery, musical instruments, sports articles and toys
39 Recycling
R&D-intensive industry sectors
21 Pharmaceuticals
22 Chemicals
31 Machinery and equipment
32 Office machinery and apparatuses, data processing equipment
33 Electrical machinery and apparatus
34 Radio, television and communication equipment and apparatus
35 Medical, precision and optical instruments, watches and clocks
36 Motor vehicles, trailers and semi-trailers
37 Other transport equipment
Service sectors
45 Sale, maintenance and repair of motor vehicles and motorcycles
46 Wholesale trade and commission trade
47 Retail trade
48 Hotels and restaurants
49 Transport via railways
50 Transport via pipelines and other transport
51 Water transport
52 Air transport
53 Supporting and auxiliary transport activities
54 Post and telecommunications
55 Financial intermediation
56 Insurance and pension funding
57 Activities auxiliary to financial intermediation
58 Real estate activities
59 Renting of machinery and equipment without operator
60 Computer and related activities
61 Research and development
62 Other business activities
63 Public administration and defence
64 Compulsory social security activities
65 Education
66 Health and social work
67 Sewage and refuse disposal, sanitation and similar activities
68 Activities of membership organisations
69 Recreational, cultural and sporting activities

(continued)

70 Other service activities
71 Activities of households
Other sectors
1 Agriculture and hunting
2 Forestry and logging (incl. related services)
3 Fishing, operation of fish hatcheries and fish farms
4 Extraction of coal and lignite
5 Extraction of crude petroleum and natural gas (incl. related services)
6 Extraction of uranium and thorium ores
7 Extraction of metal ores
8 Extraction of stone, sand, clay and other mining
40 Production and distribution of electricity and long-distance heating
41 Extraction of gas, distribution of gaseous fuels through mains
42 Collection, purification and distribution of water
43 Construction: Site preparation, complete constructions and parts thereof
44 Construction: Building installations and completion

Source: Fraunhofer ISI (Based on I/O tables from the Federal Statistical Office of Germany)

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Chapter 4
Patent Activities in Non-R&D-Intensive Technology Areas

Peter Neuhäusler and Rainer Frietsch

Abstract Intellectual property protection via patenting can be regarded as an indispensable means to stay competitive at the national and international levels, also in non-R&D-intensive technology areas. As patents can be used as output indicators of innovation, we aim to shed light on the technological output of non-R&D-intensive sectors with the help of in-depth patent analyses. In addition to investigating the absolute numbers and shares of patent filings compared with the high-technology areas, we examine the positioning of non-R&D-intensive sectors within the innovation chain and assess their internationalisation trends within Germany over the last decade.

The results of our analyses, which are based on the "EPO Worldwide Patent Statistical Database" (PATSTAT), show that the non-R&D-intensive technology areas are an integral part of the development of research and technology within the world economy. Patents from the non-R&D-intensive areas constitute approximately 40 % of worldwide transnational filings, although the size and importance of the non-R&D-intensive technology areas is highly dependent on national idiosyncrasies and industrial structures. The internationalisation trends reveal that the non-R&D-intensive technology areas are even more strongly targeted toward international markets than high-level technologies, although technologies from non-R&D-intensive are largely positioned at the end of the innovation chain, providing rather downstream or market-oriented inventions.

4.1 Introduction

Patents are among the most important indicators for the output of R&D processes and are frequently used to assess the technological performance of firms, technology fields, and entire economies (Freeman 1982; Griliches 1990; Grupp 1998). Thus, the key assumption is that patents reflect the knowledge capabilities or

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knowledge stocks of the patenting entities (mainly companies but also universities or public research institutes and single inventors) and – from a wider perspective – entire nations (Frietsch and Schmoch 2006). Although a patent may have no direct value for a firm or innovation system, it is at least a part of a technological trajectory from which a firm expects to generate economic or strategic value.

Because patents are used as output indicators of innovation, they fit into a system of several additional indicators to describe scientific and technological competitiveness and to analyse innovation systems. From this perspective, patents are an intermediate measure because they cover the output of R&D systems for which expenditures or human capital are the input. At the same time, patents can be regarded as an input into additional market activities, which are reflected by foreign trade, turnover, or qualified labour.

At its core, a patent is a legal intellectual right granted by an authorised government entity (patent office) to exclusively protect an invention from unauthorised use for a certain period of time (Frietsch et al. 2010), which is coupled with a disclosure requirement. Thus, all information that is covered by the respective patent must be disclosed after a given time period. Therefore, the patent system offers a temporary monopoly to inventors in exchange for their early disclosure of new technologies.

An invention, however, does not necessarily translate into an innovation. An invention is "[. . .] a research and development driven initial technical realisation of a new problem-solving mechanism" (Pleschak and Sabisch 1996). This definition implies that an invention only represents technical information, which may have an economic value in the future. An innovation "[. . .] is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations" (OECD and Eurostat 2005). In many cases, an invention can be viewed as an initiator for an innovation. Because the innovation process encompasses all stages, including planning, research, invention, commercialisation and implementation, an invention alone is not sufficient to qualify as an innovation (Schubert et al. 2011). Only the result of a full innovation process, (e.g., a new product or new process can be viewed as innovation) (Grupp 1998). However, the successful completion of the innovation process alone is not a sufficient condition to obtain the expected benefits from innovation because firms must appropriate these benefits (i.e., to prevent its competitors from imitating their results) (Hanel 2008). This result can be achieved not only by patenting or other intellectual property rights (IPRs) but also by informal appropriation mechanisms, such as keeping an invention secret or utilising lead-time advantages (Blind et al. 2006; Neuhäusler 2012).

The growth of the world economy and increasing globalisation have led to a rapid expansion of access to information and new markets for inventors and resulted in greater international competition and new forms of organisation, which makes intellectual property protection increasingly important (OECD and Eurostat 2005). However, intellectual property protection via patents is not only a phenomenon of high technology. A large share of inventions originates from the non-R&D-intensive technology areas, which makes intellectual property protection via patenting indispensable to stay competitive at the national and international levels.

Furthermore, not all technological output of non-R&D-intensive industries can be considered non-R&D-intensive technology; instead, it may be medium- or even high-tech. Sectors are rather heterogeneous agglomerations of companies, which may themselves be heterogeneous in terms of products, services, or even R&D intensity. A non-R&D-intensive sector is defined as the share of total R&D expenditures over turnover below an average threshold of 2.5 %. Some companies may conduct research regardless of this threshold, and some companies may even invest greater than 2.5 % shares in R&D. However, we must stress the distinction between non-R&D-intensive sectors/industries and non-R&D-intensive technology fields or areas.

In summary, we aim to shed light on the technological output of non-R&D-intensive sectors with the help of patent indicators. In addition to investigating the absolute numbers and shares of patent filings compared with the high-technology areas, we will examine the positioning of non-R&D-intensive sectors within the innovation chain and assess their internationalisation trends within Germany over the last decade.

4.2 Data and Methodology

The patent data for this study were extracted from the "EPO Worldwide Patent Statistical Database" (PATSTAT), which provides information regarding published patents collected from 83 patent authorities worldwide. To differentiate technology fields according to their research intensity and International Patent Classification (IPC), a list of research-intensive industries and goods (NIW/ISI/ZEW-Lists 2012) is employed, where a distinction between low- and high-technology areas is established (Gehrke et al. 2013). High-technology sectors are defined as technologies for which an average investment in R&D of greater than 2.5 % of the turnover is required. Additionally, high-technology sectors are differentiated by high-level and leading-edge technologies. Whereas the high-level sector includes technologies that require R&D expenditures between 2.5 % and 7 %, the leading-edge area covers technologies that are beyond 7 % investment shares. The remaining technology fields are defined as non-R&D-intensive.

At the core of the analysis, the data applied follow the concept of transnational patents suggested by Frietsch and Schmoch (2010), which can overcome the home advantage of domestic applicants, thus enabling a comparison of the technological strengths and weaknesses beyond home advantage and unequal market orientations. In detail, all filings via the Patent Cooperation Treaty (PCT) at the World Intellectual Property Organisation (WIPO) are counted regardless of whether they are transferred to the European Patent Office (EPO) or not. Furthermore, the analysis includes all direct EPO applications without precursor PCT application, excluding double counts. All patents in our analyses are counted according to their year of first worldwide filing, which is commonly known as the priority year. The priority year is the earliest registered date in the patent process and is therefore closest to the date of invention.

Furthermore, the method of fractional counting by (inventor) countries and technology fields is applied to consider cross-classifications of patent filings within the IPC. If a patent is assigned three IPC codes of which two would fall into the category of high-level technologies and one to the category of non-R&D-intensive technologies, it would be counted as two thirds for the high-level technologies and one third for the non-R&D-intensive category.

Additionally, some of the patent statistics are differentiated by the type of patent applicant (i.e., if the applicant is a small or medium-sized enterprise (SME), large enterprise (LE), or academic applicant (university or public research institute)) (Frietsch et al. 2011). The company identifier (e.g., Inc., Corp., GmbH, AG) in the name of the patent applicants indicates whether it is a company. Single inventors, universities, and public research institutes were classified manually. In correspondence to the German SME definition (Günterberg and Kayser 2004), applicants with more than 500 employees and more than three patent filings in a 3-year time window between the priority years of 1996 and 2008 were classified as LEs. The remaining applicants that have less than three patent filings in the given time window and less than 500 employees were classified as SMEs.

4.3 Results

4.3.1 General Structures

First, we consider the technological perspective and compare R&D-intensive and non-R&D-intensive technologies. Technological innovation is a prominent phenomenon in non-R&D-intensive technology areas. Nearly 40 % of all transnational patent filings can be classified as non-R&D-intensive technologies (Fig. 4.1), whereas the remaining 60 % of patent filings in 2010 are classified as leading-edge (approximately 28 %) and high-level technologies (approximately 34 %). In absolute terms, the non-R&D-intensive technology areas account for more than 84,000 transnational patent filings in the year 2010. Aside from the major decrease in patent filings during the recent economic crisis, which has affected all of the technology areas to a similar extent, the absolute number of patent filings has been increasing over the years. Nevertheless, a slightly decreasing trend in the shares of patent filings in non-R&D-intensive technology areas for total filings can be observed since the year 2000. This trend is mainly due to an increase in the shares of patents from high-level technologies – which is especially prominent in the year 2010 - that leads to declining shares of filings from the leading-edge and non-R&D-intensive technology areas.

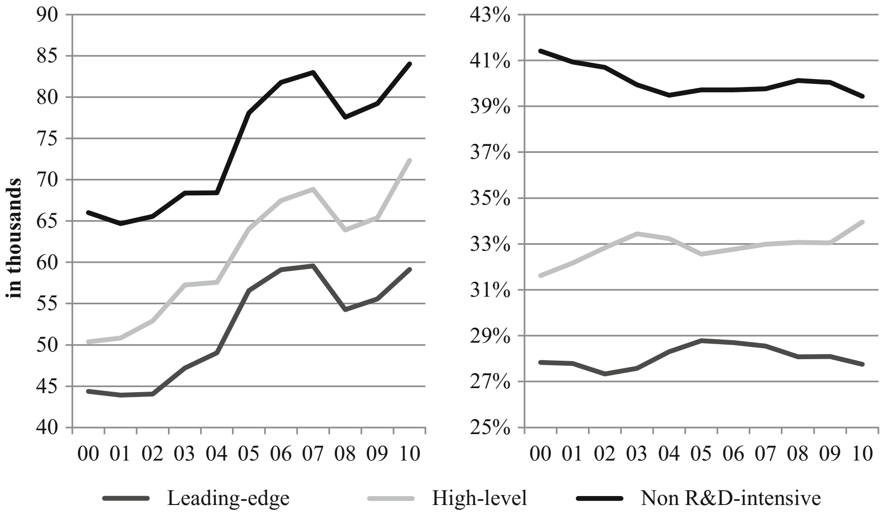

Fig. 4.1 Absolute numbers and shares of transnational patent filings by technology areas, 2000–2010 (Source: EPO – PATSTAT; Fraunhofer ISI calculations)

However, these trends become clearer when reviewing them by country (Fig. 4.2). Two BRICS countries, namely, South Africa and Brazil, have the highest shares of transnational patents in non-R&D-intensive technologies. In most European countries (e.g., Germany, France, Great Britain, Austria, Switzerland, and the Netherlands), the shares of patents from the non-R&D-intensive technology areas are slightly above the world average of 39.4 % (bold line). However, most Scandinavian countries have shares slightly below the worldwide average.

North American countries (i.e., the USA and Canada, as well as Israel, which is technologically oriented toward the U.S. market) and Asian countries (i.e., Japan, Korea, and China) have comparably low shares of patents in non-R&D-intensive technology areas. Aside from Russia, which is located in the middle ranks with an above-average value, the BRICS countries have rather distinct technological strategies. Whereas South Africa and Brazil are highly patent-active in the non-R&D-intensive areas, China and India have the lowest shares of patents in these areas.

It is not only important to consider the shares within the technology fields but from a sectoral perspective (i.e., to determine which types of technologies are actually produced by firms from the non-R&D-intensive industries). Thus, aside from the technological view, a second perspective considers non-R&D-intensive sectors. Instead of classifying the patents/technologies according to their R&D intensity, we now use the sector classification (NACE) of the patent applicants and assign each company to one of these groups. Using a cross-tabulation of sectors and technologies enables us to observe whether companies in non-R&D-intensive sectors only file patents that are classified as non-R&D-intensive patents or whether they are active in high technology patenting as well. The shares of patents can also be calculated from non-R&D-intensive technology areas in high-technology sectors.

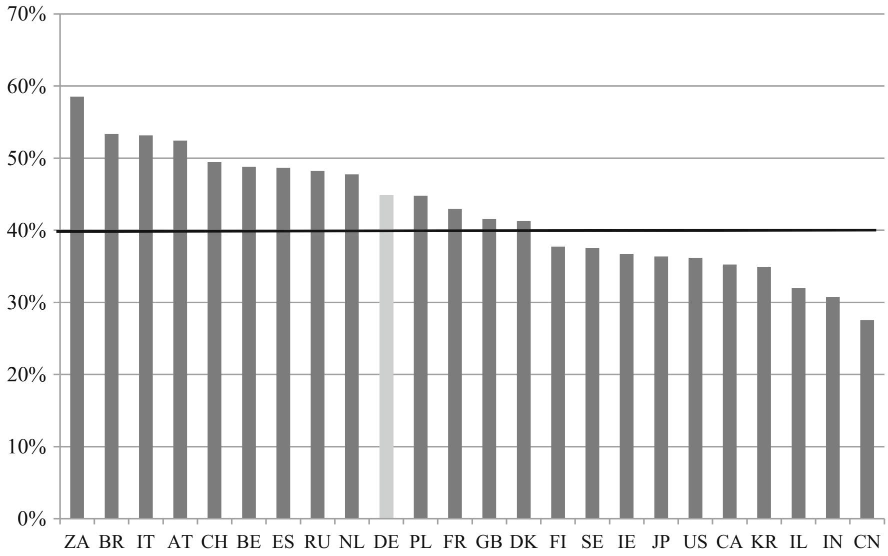

Fig. 4.2 Country-specific shares of transnational patent filings in non-R&D-intensive technology areas, 2010 (Source: EPO – PATSTAT; Fraunhofer ISI calculations)

However, it is difficult to combine the sectoral and technological perspectives because patents are classified based on their technological content according to IPC, which does not correspond to industry definitions (e.g., by NACE codes). Therefore, a concordance between industries and technology fields is required. To reach this concordance, a probability matching of German patent applicants with company names from the *Hoppenstedt* database of German companies (www.hoppenstedt.de) was applied. This matching allows for a combination of the two data sources at the micro-level of companies/patent applicants, through which patent filings can be assigned to individual sectors of the economy,[1] and enables us to calculate the shares of patents in non-R&D-intensive (manufacturing) industries by technology field. The non-R&D-intensive manufacturing sectors are defined according to their R&D intensity and are based on the sector lists by Gehrke et al. (2013) at the level of 3-digit NACE (Rev. 2) codes.[2] The results are displayed in Fig. 4.3.

[1] Our matching algorithm, which is based on a Levenshtein distance, covers 93 % of all transnational filings and 81 % of patent applicants in the year 2010 and reaches a precision of 0.91 and a recall of 0.53.

[2] From the manufacturing sectors (NACE Rev. 2, 10-33), the following 3-digit NACE codes are defined as leading-edge industries: 20.2, 21.1, 21.2, 25.4, 26.1, 26.2, 26.3, 26.5, 26.6, 26.7, 30.3, and 30.4. High-level technology industries are defined as follows: 20.1, 20.5, 22.1, 26.4, 27.1, 27.2, 27.4, 27.5, 27.9, 28.1, 28.3, 28.4, 28.9, 29.1, 29.3, 30.2, and 32.5. The remaining 66 3-digit NACE codes define the non-R&D-intensive manufacturing industries.

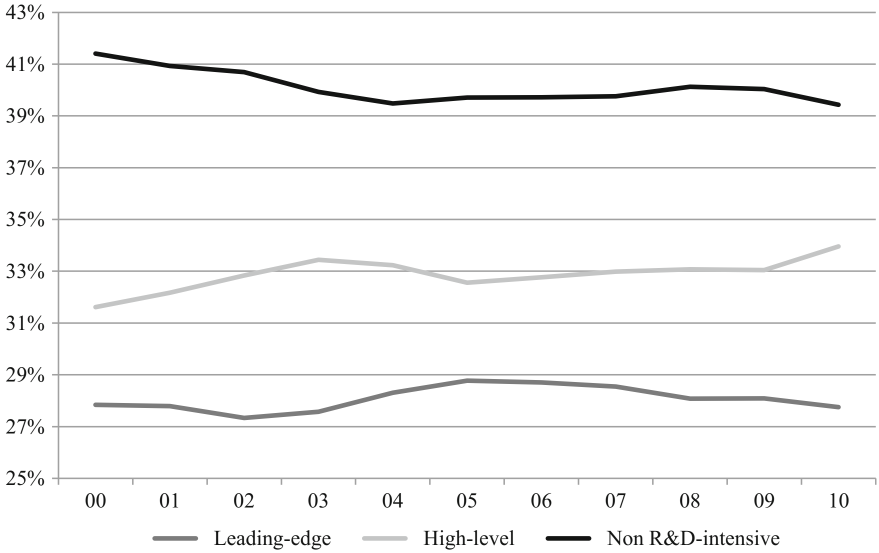

Fig. 4.3 Shares of transnational patent filings from non-R&D-intensive manufacturing industries (NACE Rev. 2) by technology field, German applicants (Source: EPO – PATSTAT; Hoppenstedt; Fraunhofer ISI calculations)

Approximately 65 % of all patent filings from German companies in the non-R&D-intensive sectors are filed in technology fields that are defined as non-R&D-intensive. However, approximately 7 % of their filings are classified as leading-edge technologies and 28 % are classified as high-level technologies. A comparison of the trends over time indicates that since 2006, patents from the non-R&D-intensive sectors are increasingly filed in high-level and leading-edge technologies. Thus, firms from the non-R&D-intensive industries have increasingly entered the high-technology scene in terms of patenting in recent years, and they increasingly rely on R&D-intensive technologies in their daily business.

As stated above, we can view the argument from the inverse perspective and consider the shares of patent filings from high-level and leading-edge manufacturing industries in non-R&D-intensive technology areas (Fig. 4.4). The companies from high-level sectors have a higher share of patent filings in non-R&D-intensive technology areas than companies from leading-edge sectors. Over the years, the shares for the high-level sectors have increased, implying that not only companies from non-R&D-intensive industries are increasingly entering the high-technology scene, but also that more patents in non-R&D-intensive technology areas are filed by companies from the high-level technology sectors. For the leading-edge sectors, the share of patents in non-R&D-intensive technology areas remains relatively stable over the entire time period, with only a slight increase of 2 % points between the years 2000 and 2010.

To gain a complete perspective of the trends in patenting in non-R&D-intensive technology areas, we review the shares of patent filings differentiated by the type of

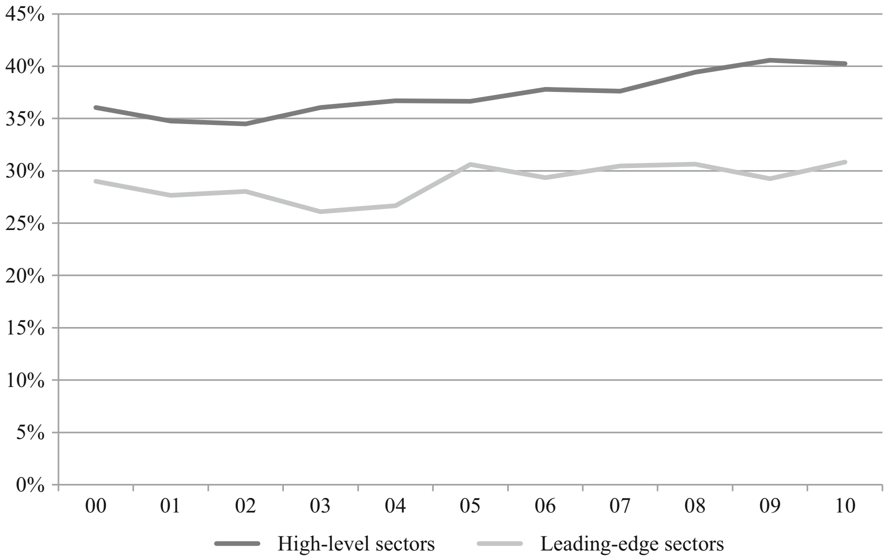

Fig. 4.4 Shares of transnational patent filings from high-level and leading-edge manufacturing industries (NACE Rev. 2) in non-R&D-intensive technology areas, German applicants (Source: EPO – PATSTAT; Hoppenstedt; Fraunhofer ISI calculations)

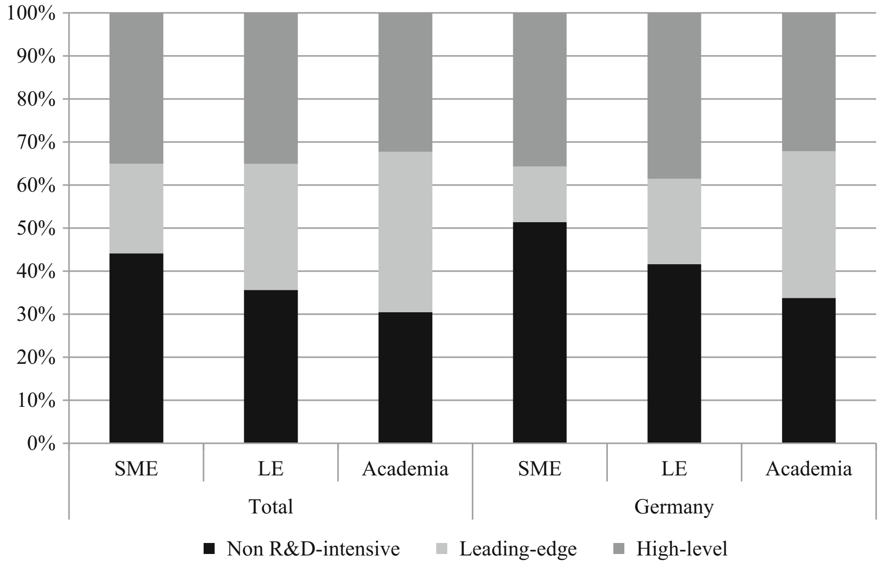

Fig. 4.5 Applicant-type specific shares of transnational patent filings by technology area, in Germany and total, 2010 (Source: EPO – PATSTAT; Fraunhofer ISI calculations)

patent applicant (i.e., SMEs, large enterprises, and academia, including both universities and public research institutes). In addition to the worldwide average, the trends for Germany are displayed in greater detail (Fig. 4.5).

Although large enterprises are responsible for the largest number of filings in non-R&D-intensive areas, the shares of SME filings in these areas are higher (i.e., 45 % of all SME filings are categorised as non-R&D-intensive). As expected, academia has the lowest shares of patents in non-R&D-intensive technology areas. Thus, the focus is clearly on research in leading-edge technologies. No clear specialisation can be observed for large enterprises. All three technology areas are nearly equally represented in their patent filings.

The figures for Germany are slightly different than those for the worldwide scale. Although the basic trends across the types of patent applicants are similar (i.e., SMEs have the largest shares of non-R&D-intensive patents in their portfolio, whereas the smallest shares can be found for academia), the general focus on non-R&D-intensive technology areas is greater in Germany than in the world average. This result resembles the country-specific trends shown in Fig. 4.2, where Germany has an above-average number of filings in non-R&D-intensive technologies. However, this greater focus on non-R&D-intensive technology areas mainly comes at the expense of a smaller focus on leading-edge technologies. High-level technologies, of which most mechanical engineering sectors belong and for which Germany is has its technological strengths, are slightly over-represented in the German technology portfolio, which can mainly be attributed to the large share of filings in high-level technologies from large enterprises.

We will now change our focus and review the internationalisation trends in the respective areas and then assess the non-R&D-intensive sectors' positioning within the innovation chain.

4.3.2 Internationalisation of Non-R&D-Intensive Technology Areas

The analysis of transnational filings offers the opportunity to assess trends beyond home advantage effects, national idiosyncrasies, and different market orientations. We can develop statements regarding the international orientation of countries for specific technologies or technological areas by relating the number of transnational filings to the total number of filings that are targeted toward a national market. Because patent filings via the EPO or PCT system are more expensive than purely national filings, we can assume that the patent applicant is expecting to sell products that incorporate the protected invention at an international scale (i.e., at several international markets). Thus, the ratio of transnational filings to national filings provides an estimate of how many inventions will be commercialised internationally.

To construct our indicator, we count all patent filings that are filed at the German Patent and Trademark Office (GPTO), whether they were filed directly at the GPTO via the EPO system or PCT system, excluding double counts. This method of counting patents is associated with the assumption that all PCT filings and patents granted by the EPO are forwarded to the GPTO, which is true for the majority of patents, at least when German inventors are named on the patent application. Thus, we limit the analysis to patents filed by German inventors.

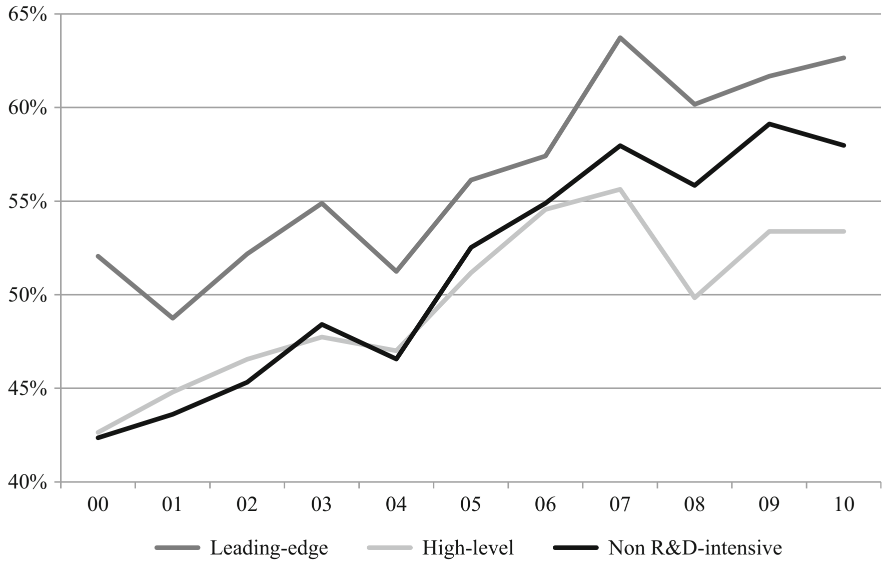

Fig. 4.6 International orientation of German patent filings by technology area, 2000–2010 (Source: EPO – PATSTAT; Fraunhofer ISI calculations)

By relating the number of transnational filings to the number of patents that are targeted toward the German market, differentiated by technological areas, we can estimate the internationalisation trends within these areas, which is plotted over time in Fig. 4.6. The orientation toward international markets has increased over the study period for all technology areas. Additionally, there was a strong decline in the share in transnational filings during the crisis of the new economy in 2003 and 2004 as well as during the recent economic crisis due to the cost-saving IP-strategies of firms within these periods (Neuhäusler et al. 2014).

A review of the different technological areas demonstrates that leading-edge technologies are most strongly oriented toward international markets across the entire time period. Approximately 63 % of all filings from leading-edge technologies targeting the German market are filed via the PCT or EPO system. The trends for the high-level technologies and non-R&D-intensive areas are even more interesting. Whereas R&D-intensive areas were slightly less internationalised than high-level technologies at the beginning of the century, the high-level technologies lost some ground until 2007. In addition, the effect of the economic crisis is considerably more pronounced in the high-level technologies because non-R&D-intensive technology areas are approximately 5 % higher in internationalisation on this indicator than the high-level technologies. Between 2009 and 2010, the shares decreased slightly in the non-R&D-intensive technology areas, which may imply a convergence of the numbers in the near future.

4.3.3 Position in the Innovation Chain

Citation-based measures were applied to assess the non-R&D-intensive sector's position in the innovation chain. Citations are provided by either the patent applicant or patent examiner and listed on a patent document. They reflect references that are made to prior art, most commonly to other patents, but also to scientific literature.

Citations can be counted from both forward-looking and backward-looking perspectives. The number of citations a patent receives from subsequent patent filings (i.e., the forward-looking indicator) is commonly referred to as patent forward citations. The basic assumption is that the number of forward citations measures the degree to which a patent contributes to further developing advanced technology and is an indicator of basicness, novelty, or technological significance of a patent in terms of spill-over effects (Carpenter et al. 1981; Trajtenberg 1990). However, patent backward citations refer to previous patents that are mainly used as an indicator of technological breadth and can provide hints on the scope of a patent (Harhoff et al. 2003). Additionally, patent backward citations can be interpreted as a measure of "originality": Patents with a large number of backward citations can be assumed to build on a larger given pool of already existing knowledge, whereas patents with only a few backward citations have a small existing knowledge stock on which to build (Rosenkopf and Nerkar 2001). In addition to previous patents, patent applicants and patent examiners have the option of citing scientific publications. These references to non-patent literature (NPL) can be used to indicate the closeness of a patent applicants' R&D activities to science or basic research (Deng et al. 1999). A large number of references made to scientific literature implies that the patent builds upon a comparably large scientifically used knowledge stock.

By building on these indicators of the *spill-over potential*, *originality*, and *scientific linkage*, we gain a deeper understanding of the non-R&D-intensive technology areas compared with high-technology and gain insights on their positioning within the innovation chain.

The average number of forward citations (in a 4-year time window) and backward citations by technology area is presented in Fig. 4.7. The leading-edge technologies are the most highly cited and thus have the highest spill-over potential. In addition, patents within this technology area cite the smallest number of previous patents and can thus be regarded as quite original. Patents from the non-R&D-intensive areas are at the other side of the scale. They build on a rather large pool of existing knowledge as indicated by the patent backward citations, and are cited less frequently (i.e., less subsequent patents are building on those technologies). High-level technologies are located between leading-edge and non-R&D-intensive areas. Although these patents receive a comparably large number of citations on average, they cite a larger number of previous patent applications.

Before we reach a final conclusion regarding the positioning in the innovation chain of the different technology areas, we review the scientific linkage as indicated

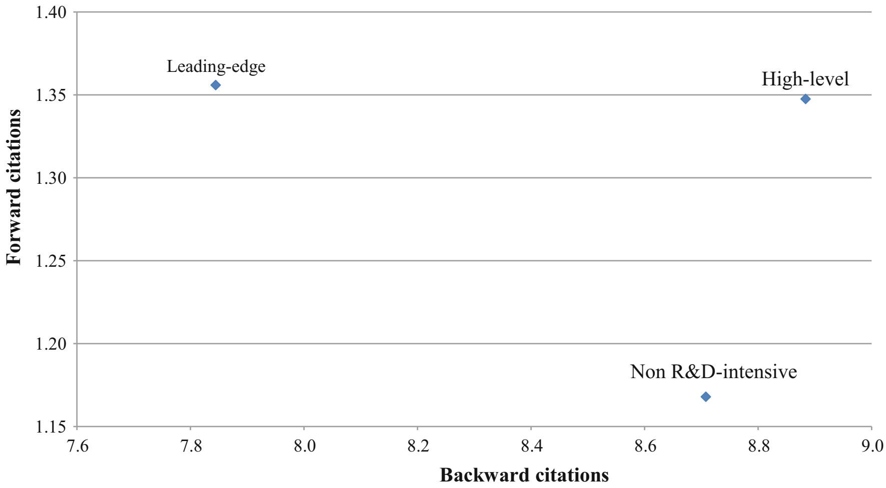

Fig. 4.7 Average number of forward and backward citations by technology area, 2006 (Source: EPO – PATSTAT; Fraunhofer ISI calculations)

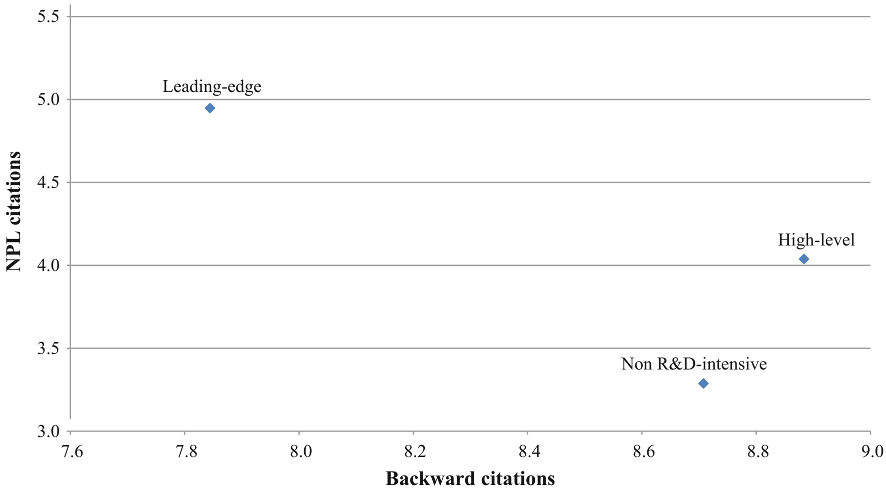

Fig. 4.8 Average number of NPL citations and backward citations by technology area, 2006 (Source: EPO – PATSTAT; Fraunhofer ISI calculations)

by the average number of NPL citations, which is shown in Fig. 4.8 and is compared to the number of patent backward citations. Patents from the leading-edge areas are most heavily citing scientific literature and have therefore can be said to have the largest science linkage. The science linkage of the non-R&D-intensive technology areas is rather limited, although approximately three scientific publications are cited in those patents on average. Patents from high-level technologies cite an average of four scientific publications and thus are located in the middle between the leading-edge and non-R&D-intensive technology areas.

In summary, leading-edge areas provide the innovation system with the most upstream-oriented technologies, which are characterised by a close link to science and a high-potential for further inventions to build on the knowledge generated within this area. Thus, these technologies position themselves on an early stage within the innovation chain. Additionally, high-level technologies have a rather high potential for spill-over effects. However, within this area, inventions build on a relatively large pool of existing knowledge and can thus be considered less original in nature. The non-R&D-intensive areas are mainly positioned at the end of the innovation chain (i.e., they provide rather downstream or market-oriented inventions). The patents originating from these areas are less linked to science and are building on rather large pools of existing knowledge.

Conclusions

The non-R&D-intensive technology areas are an integral part of the development of research and technology within the world economy. Nearly 85,000 transnational patent filings originated from non-R&D-intensive technologies in the year 2010. However, although the share of patents from the non-R&D-intensive areas has declined slightly over the study period, mainly due to the increasing share of filings from the high-level technologies, patents from the non-R&D-intensive areas still constitute approximately 40 % of all transnational filings. Yet, the size and importance of the non-R&D-intensive technology areas is highly dependent on national idiosyncrasies as well as the industrial structure and field specific specialisations within different countries. Whereas the non-R&D-intensive technology areas play a relatively large role in Europe, they are less important in North America and Asia. Interestingly, the BRICS countries have rather distinct national profiles. Whereas South Africa and Brazil are highly patent-active in the non-R&D-intensive areas, China and India have the lowest shares of patents in non-R&D-intensive technologies and are more highly specialised in high-level and leading-edge technologies.

From a sectoral perspective (i.e., looking at which types of technologies are actually produced by firms from the non-R&D-intensive industries), the non-R&D-intensive industries produce more than only patents that are classified as non-R&D-intensive; approximately 7 % of filings from non-R&D-intensive industries are classified as leading-edge technologies, and 28 % are classified as high-level technologies. Because these shares have increased over time, firms from the non-R&D-intensive industries have increasingly entered the high-technology scene in terms of patenting. In addition, the share of patents in non-R&D-intensive technology areas filed by companies from the high-level technology sectors has increased in the last decade.

(continued)

Additionally, the differentiation by the type of the patent applicant indicated that although large enterprises are responsible for the largest number of filings in non-R&D-intensive areas, SMEs file the largest number of patents in these areas on average. Academia has the lowest shares of patents in non-R&D-intensive technology areas and is highly focused on leading-edge technologies.

The internationalisation trends reveal that the non-R&D-intensive technology areas are more strongly targeted toward international markets than high-level technologies, although leading-edge technologies are still the most strongly internationally oriented. Regarding the position in the innovation chain, the patent citation indicators demonstrate that inventions generated within the non-R&D-intensive technology areas are less commonly linked to science and generally build on a large pool of existing knowledge. In addition, inventions from the non-R&D-intensive areas are less frequently the basis for further technological developments. Thus, the non-R&D-intensive sectors are largely positioned at the end of the innovation chain (i.e., they provide rather downstream or market-oriented inventions).

In summary, the non-R&D-intensive technology areas are an important and highly dynamic sector at the international scale that is mainly building on the R&D that has been performed in the high-technology areas and typically provides downstream innovations for directly marketable applications.

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Chapter 5
The Development of Qualification and Employment Structures in Non-R&D-Intensive Industry Sectors–The Case of Germany

Rainer Frietsch and Peter Neuhäusler

Abstract In the course of changes within the economic structure in many modern economies, there has been a trend towards more knowledge-, research- and innovation-intensive sectors. These changes were very much in favour of highly skilled employees, while the share of employment of less qualified personnel has decreased. Within this chapter, we aim to provide empirical evidence for the structural changes in the German economy that have occurred since the mid-1990s and try to shed some light on the current and future demand for highly qualified labour, especially in non-R&D-intensive sectors.

With the help of data from the German *Microcensus*, we performed a structural decomposition ("shift-share analysis") of the employment changes among highly skilled workers in Germany.

Although there has been a shift in employment towards the service sectors over the years, 22 % of the German workforce remains in the manufacturing sectors, with the majority of people being employed within non-R&D-intensive parts of the industry. Employment in non-R&D-intensive manufacturing industries has slightly decreased over the years, while there has been increasing demand for highly qualified personnel, which is especially true for university graduates. The non-R&D-intensive sector is increasingly dependent on highly skilled workers to maintain or even increase its innovative potential, which is critical with regard to its competitiveness.

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5.1 Introduction

Within economic innovation research, the ability to innovate has long been considered a key factor in long-term competitive advantage. However, this ability to innovate, or innovative capacity, cannot be considered separately from the people who perform innovative activities in the form of new or improved products or processes and thereby contribute to the development of new markets, increased market share or cost reduction.

Innovation is, first of all, the transfer of ideas to products, services or processes. The generation of ideas, as well as the transfer of these ideas to the market, are mainly driven by knowledge and creativity. Codified knowledge is one aspect of knowledge that surely plays an important role: "know-what" is the foundation. However, tacit knowledge—or, in other words, "know-how"—is at least as important as codified knowledge (Berg Jensen et al. 2007; Foray 1997; Foray 2004; Nonaka and Takeuchi 1995; Tödtling et al. 2009). In fact, tacit knowledge only exists in the brains of people, and it is difficult or even impossible to codify.

In addition to knowledge creation and dissemination itself, another important factor is the complexity of current products, processes and services. Of particular importance is the necessary division of labour and tasks that accompany this complexity (Frietsch and Grupp 2007). This division of labour makes economic activity more efficient because, due to specialisation, it is not only possible to use more in-depth knowledge in certain areas but also to benefit from scale effects in the use of knowledge. All of these aspects make people, their knowledge and their skills among the most important—if not the most important—resource in modern economies.

The economic structure has changed in the past, and there has been a trend towards more knowledge-, research- and innovation-intensive sectors in many modern economies (Frietsch 2011; Frietsch and Gehrke 2006; Hanushek and Wößmann 2007). This trend can be perceived as a between-sectors effect: in innovation-oriented economies, the share of sectors with high price competition and low qualification structures has decreased, while the share of innovation-oriented and quality competition-based sectors has increased. In addition, the literature has also revealed that within the sectors, a trend towards higher qualifications has been visible, i.e., there has been a shift on the demand side, implying that a structural change has occurred in the sectors themselves. At the same time, the supply of highly qualified personnel has also increased in recent decades in most of the industrialised countries, which has made these structural changes possible.

All of these changes have been summarised using the term "skill-biased technological change," which has been and remains the subject of many analyses and both empirical and theoretical work (Card and DiNardo 2002; Greiner et al. 2004; Machin 2001; Machin 2003). This term implies that the technological changes of the past (and also the present) were very much in favour of highly skilled employees, while the share of employment of less qualified personnel has decreased.

In this context, human capital, i.e., people's educations and skills, has thus played a key role because human capital equipment can be regarded as a basic factor of productivity. Therefore, analysis of the present and future endowments of these factors remains a very important task for innovation research. This is true not only for high-technology areas but also for non-R&D-intensive sectors. A potential future shortage of well-trained and qualified staff could be seen as a barrier to R&D projects and thus to overall economic development (Leszczensky et al. 2010; OECD 2011; OECD 2012).

This chapter seeks to provide empirical evidence for the structural changes in the German economy that have occurred since the mid-1990s. Moreover, it also attempts to shed some light on the demand for highly qualified labour, especially in non-R&D-intensive sectors rather than the high-tech areas that are most often the scope of such types of analyses and discussions. The chapter addresses two basic questions. First, we examine what type of formal qualifications are needed in non-R&D-intensive industries in Germany, and how the demand for personnel has evolved over the last decade, allowing us to estimate future developments. Second, in this context, it is highly relevant to assess the demand for especially highly skilled workers in non-R&D-intensive sectors because such an assessment could lead to important conclusions for both the educational system and the labour market.

To answer these questions, the sections of this chapter first provide an overview of the data and classifications used for our analyses. Next, we offer some descriptive statistics on the employment trends in German industry, followed by a shift-share analysis, which disentangles the different structural trends and facilitates an understanding of the contributions and effects of overall economic trends relative to the structural changes within and between sectors. The final section concludes the chapter.

5.2 Data and Classifications

To analyse the qualification and employment structures, data from the German *Mikrozensus*, from the years 1996 to 2006, are employed.[1] The focus for our analyses is only on employed persons, as defined by the concept of employment used by the International Labour Organization (ILO) (Eurostat 1999; International Labour Office 1990; Schmidt 2000).[2] In addition, we look more deeply at employment only within the commercial economy, i.e., non-profit organisations and public

[1] The *Mikrozensus* constitutes the official representative statistics on population and the labour market in Germany. One percent of all German households participate in each wave of the survey. The selection of surveyed households is conducted using a single-stage stratified sample. In 2006, for instance, a total of 370,000 households and all related persons (820,000) were interviewed.

[2] According to the concept of the ILO, all persons between the ages of 15 to 64 are regarded as employed if they are working for at least one hour per week.

Table 5.1 R&D- and non-R&D-intensive sectors in the manufacturing industry (Source: NACE, Rev. 1.1, own compilation)

Name	NACE	Category
Manufacture of food products and beverages	15	Non-R&D-intensive
Manufacture of tobacco products	16	
Manufacture of textiles	17	
Manufacture of wearing apparel; dressing and dyeing of fur	18	
Tanning and dressing of leather; manufacture of luggage, hand-bags, etc.	19	
Manufacture of wood and of products of wood and cork, except for furniture	20	
Manufacture of pulp, paper and paper products	21	
Publishing, printing and reproduction of recorded media	22	
Manufacture of coke, refined petroleum products and nuclear fuel	23	
Manufacture of chemicals and chemical products	24	R&D-intensive
Manufacture of rubber and plastic products	25	Non-R&D-intensive
Manufacture of other non-metallic mineral products	26	
Manufacture of basic metals	27	
Manufacture of fabricated metal products, except for machinery and equipment	28	
Manufacture of machinery and equipment n.e.c.	29	R&D-intensive
Manufacture of office machinery and computers	30	
Manufacture of electrical machinery and apparatus n.e.c.	31	
Manufacture of radio, television and communication equipment and apparatus	32	
Manufacture of medical, precision and optical instruments, watches and clocks	33	
Manufacture of motor vehicles, trailers and semi-trailers	34	
Manufacture of other transport equipment	35	
Manufacture of furniture; manufacturing n.e.c.	36	Non-R&D-intensive
Recycling	37	

administrations are excluded. Finally, we focus on the manufacturing sector within our analyses and differentiate between R&D- and non-R&D-intensive industries. Nevertheless, in the course of the analyses, we compare our figures to total employment, as well as to employment within the service sector. The non-R&D-intensive sectors are defined according to their R&D and knowledge intensities, as defined by Legler and Frietsch (2007), using 2-digit NACE (Rev. 1.1) codes. An overview of the analysed industries, as well as their categorisations according to their R&D intensity, can be found in Table 5.1.

5.3 Qualification and Employment Structures

Within this section, we first provide an overview of the general structures of qualification and employment in the German economy to obtain an impression of the size of the relevant sectors, as well as their demand for especially highly skilled personnel.

Starting with employment, Fig. 5.1 shows that approximately 23 % percent of the German workforce is employed within the non-commercial economy, i.e., public administration or non-profit organisations. Consequently, 77 % of all employees are located within the commercial economy, which is the focus of the subsequent analyses. In 2006, 68 % of all of the employees within the commercial economy belonged to the service sector. This percentage has increased continuously over the years. However, this increase has resulted in a slight decrease in the proportion of employees in the manufacturing sector over the years. In 2006, approximately 22 % of the German workforce was located within the manufacturing sector or in traditional industries. Within the manufacturing sector, 58 % of employment can be attributed to non-R&D-intensive areas, which corresponds to a share of 13 % of the total German workforce. The R&D-intensive areas, on the other hand, employed approximately 9 % of the total German workforce (42 % of employment within the manufacturing sector). Over the years, employment in the non-R&D-intensive manufacturing industries has slightly decreased, while the proportion in R&D-intensive sectors has increased.

As previously stated in the introduction, it is important to assess the demand for highly skilled workers within non-research-intensive sectors because such an assessment could lead to important conclusions for the educational system, as well as for the labour market. Figure 5.2 therefore provides us with a first impression of the sectoral qualification structures within the German economy. Because we focus on highly skilled personnel, as well as university graduates (as a subgroup of highly skilled employees[3]), both groups are reported separately in this graph. University graduates include all persons who hold a university degree or PhD.

The data show that the proportion of highly skilled employees within the total workforce ranged from 23 % in 1996 to 25 % in 2006. With regard to university graduates, this proportion ranged from 14 % to 16 %, with slight growth over the entire observation period. The largest proportion of highly skilled personnel in Germany can be found in the non-commercial sector (36 %). In the service sector, the proportions of highly skilled personnel and graduates were greater than average, at approximately 27 % and 18 %, respectively, while a less than average share of highly skilled employees was engaged in the manufacturing sector. However, this proportion can be attributed mostly to the non-R&D-intensive manufacturing sectors, in which the share of highly skilled personnel was clearly less than average, with a value of approximately 16 %. The percentage of highly skilled employees in R&D-intensive sectors, in contrast, was greater than average, reaching 27 %.

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[3] In addition to university graduates, individuals who have acquired a degree at a technical school belong to the group of highly skilled employees.

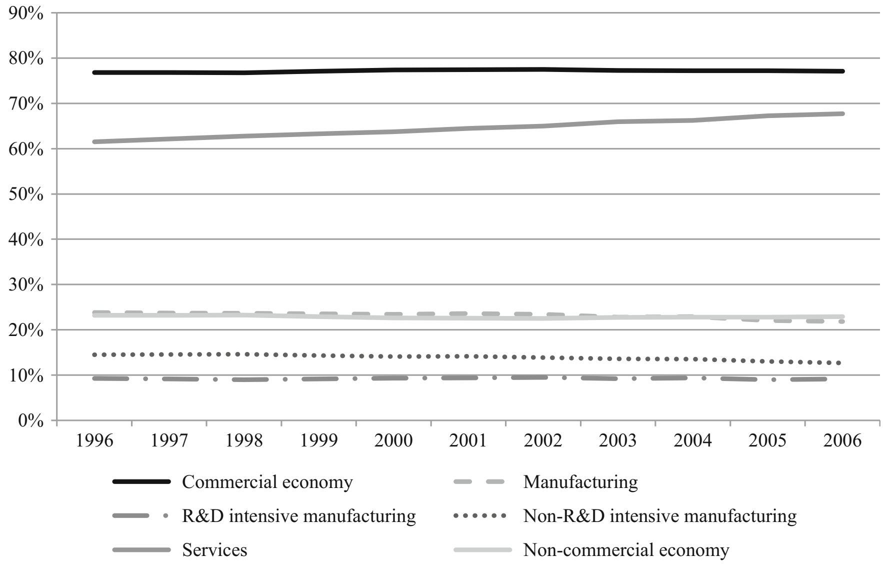

Fig. 5.1 Shares of employees by sectors, 1996–2006 (Source: German Mikrozensus 1996–2006, own calculations)

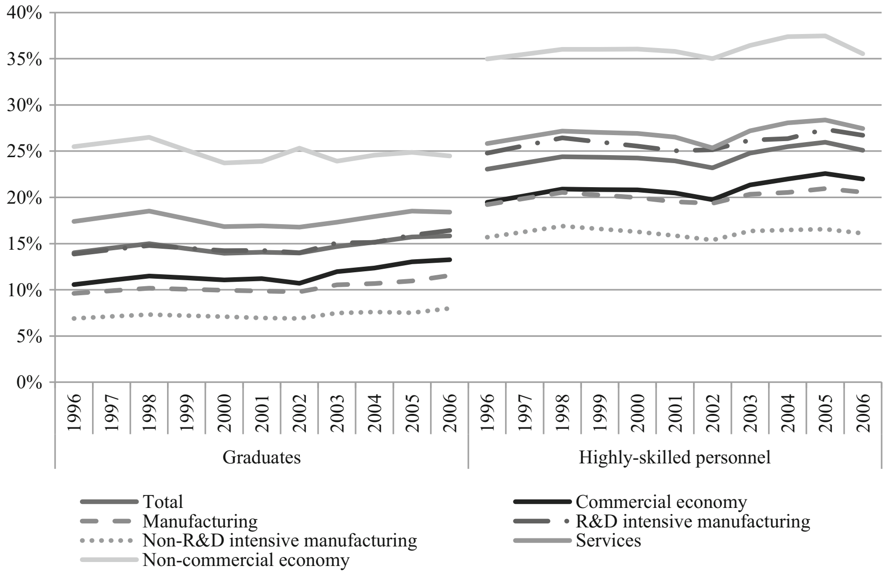

Fig. 5.2 Proportions of academics and highly skilled personnel among total employees, 1996–2006 (Source: German Mikrozensus 1996–2006, own calculations)

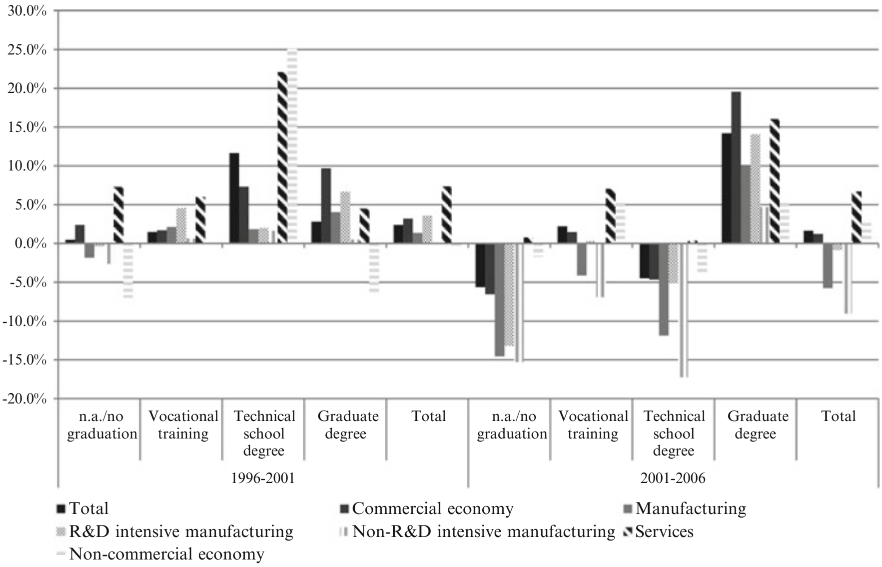

Fig. 5.3 Percentage changes in the employment structure by educational attainment between 1996 and 2001 and 2001 and 2006 (Source: German Mikrozensus 1996–2006, own calculations)

To draw a complete picture of the qualifications required across sectors, the changes in the employment structure by educational attainment over two time periods (1996–2001 and 2001–2006) are depicted in Fig. 5.3.

In particular, employment in the service sector has grown over the years. Between 1996 and 2001, the additional labour demand within this sector was mostly focused on employees with technical school degrees. Between 2001 and 2006, however, the demand for graduates rose within the service sector. With regard to manufacturing, we can also observe additional demand for labour between 1996 and 2001, especially in the case of academics. However, this growth can mostly be attributed to the R&D-intensive manufacturing sector. The demand for labour in the non-R&D-intensive sectors stagnated during this time period. For the period between 2001 and 2006, a slightly decreasing demand for labour within the manufacturing sector can be observed because the demand for employees with technical school degrees in particular decreased in the non-R&D-intensive manufacturing sectors. However, the demand for employees with university degrees increased in these industries.

5.4 Structural Decomposition—Shift-Share Analysis

To qualify these findings and further analyse the changes in the employment structure, especially for highly skilled personnel, this section performs a structural decomposition of the employment changes among highly skilled workers through a Shift-Share Analysis. Shift-Share Analysis allows for decomposition of the growth rates between two points of time. Specifically, the overall change within the sectors is divided into three components, namely: a) the general *trend effect*, b) the *structural effect* and c) what is called the *intensification effect* (see, for example, Casler 1989; Dinc and Haynes 1999; Gehrke and Legler 2007; Leszczensky et al. 2009; Ray and Harvey 1995; Stevens and Moore 1980).

The trend effect reflects the change in the demand for highly skilled personnel between two points in time, which can be attributed to the general change in employment within the German economy as a whole. In other words, the trend effect encompasses the growth that one would expect if the proportion of highly skilled workers developed in parallel to the changes in total employment, given a constant sectoral structure and a constant demand for specific human capital. The structural (or inter-sectoral) effect isolates the proportion of the change in the demand for highly qualified personnel that is caused by the structural changes in a given sector. If employment increases (or decreases) within a given sector, then the share of highly qualified personnel employed within this sector also increases (decreases). This effect thus provides evidence of changing trends in the development of sectoral employment structures, as well as information about specific qualification requirements. The intensification (or intra-sectoral) effect, in contrast, reflects the change in the demand for highly skilled personnel, based on the actual sector-specific need for these skills. This indicator becomes positive when a sector, independent of the general trend or structures within the economy, demands more highly skilled personnel. In other words, the specific requirements for given skill levels within a given sector grow.

The formulae used for the calculation of the three effects are as follows:

$$\mathrm{Trend}_{es}^{t} = \mathrm{HQ}_{es}^{t-1} * \left(\frac{\mathrm{HQ}_{e}^{t}}{\mathrm{HQ}_{e}^{t-1}} - 1\right)$$

$$\mathrm{Structure}_{es}^{t} = \mathrm{HQ}_{es}^{t-1} * \left[\left(\frac{\mathrm{HQ}_{es}^{t}}{\mathrm{HQ}_{es}^{t-1}}\right) - \left(\frac{\mathrm{HQ}_{e}^{t}}{\mathrm{HQ}_{e}^{t-1}}\right)\right]$$

$$\mathrm{Intens}_{es}^{t} = \mathrm{HQ}_{es}^{t-1} * \left[\left(\frac{\mathrm{HQ}_{es}^{t}}{\mathrm{HQ}_{es}^{t-1}} - \frac{\mathrm{HQ}_{es}^{t}}{\mathrm{HQ}_{es}^{t-1}}\right)\right]$$

$$\mathrm{Total}_{es}^{t} = \mathrm{Trend}_{es}^{t} + \mathrm{Structure}_{es}^{t} + \mathrm{Intens}_{es}^{t}$$

where HQ = Highly-qualified personnel, e = Employees, s = Sector and t = Time.

In summary, for further discussion of the results, it is important to note that

- the trend effect reflects the general change in employment within the German economy;
- the structural effect reflects the role of the change in sectors; and
- the intensification effect reflects the changes in the demand for highly skilled personnel within a given sector.

The results of the structural decomposition of the changes in the employment structure from 1996 to 2001 and 2001 to 2006 can be found in Table 5.2. Concerning the first period, we observe a total growth of 6.27 % in the employment of highly

Table 5.2 Percentage change in the employment of highly skilled personnel by components (Source: German Mikrozensus 1996–2006, own calculations)

	Percentage change (1996–2001)				Percentage change (2001–2006)			
Sector	Total	Trend effect	Structural effect	Intensification effect	Total	Trend effect	Structural effect	Intensification effect
Total	6.27	2.38	−0.42	4.31	6.52	1.65	0.21	4.66
Commercial economy	8.60	2.38	0.81	5.41	8.59	1.65	−0.43	7.37
Manufacturing	2.93	2.38	−1.01	1.56	−0.75	1.65	−7.42	5.02
R&D-intensive manufacturing	4.59	2.38	1.11	1.09	3.79	1.65	−4.24	6.38
Non-R&D-intensive manufacturing	0.46	2.38	−2.86	0.93	−7.83	1.65	−10.28	0.80
Services	10.27	2.38	4.99	2.90	10.39	1.65	5.07	3.67
Non-commercial economy	1.98	2.38	−2.68	2.28	2.45	1.65	1.47	−0.67

skilled personnel within the German economy, of which 2.38 % can be attributed to the trend effect. With regard to the structural effect, we find a negative value in total; however, this result must be interpreted in light of the trend effect, i.e., a positive sign indicates that a given sector has grown more rapidly than the economy as a whole, whereas a negative sign indicates slower growth. Thus, positive values reflect increasing demand for highly skilled personnel within a given sector.

A highly positive value, even exceeding the trend effect, can be found in the service sector. However, the R&D-intensive manufacturing sector also shows a positive indicator, which suggests that this sector has grown compared to others. The value for the non-R&D-intensive sectors has a negative sign, indicating a relative decline in the sector. However, the intensification effect, or the intra-sectoral effect, is positive for the non-R&D-intensive industries during this time period. The intensification effect is also the most interesting indicator because it allows for inferences beyond the general trend and structural effects about the demand for highly qualified labour within the respective sectors. Despite the structural changes within the non-R&D-intensive sectors, which cause the demand for highly qualified personnel to decrease, we can nevertheless state that the actual sector-specific demand for highly qualified labour increased between 1996 and 2001.

A similar picture can be drawn for the period between 2001 and 2006. Nevertheless, we identified total growth in the demand for highly skilled personnel. The trend effect was smaller than during the previous time period, whereas the structural effect showed more extreme negative values, especially in the manufacturing sector. However, the intensification effect was more positive in manufacturing. Thus, although inter-sectoral shifts in the demand for highly qualified labour between the sectors could be observed, e.g., between manufacturing and services, the sector-specific demand for highly qualified labour increased within manufacturing. This change was especially prominent in the R&D-intensive manufacturing sectors. However, the non-R&D-intensive sectors also showed increased demand for highly qualified labour, beyond the general trend.

In summary, we can state that although we observe a major structural shift in the demand for highly qualified personnel from the manufacturing to the service sectors, both the R&D- and non-R&D-intensive sectors showed intensified demand for highly qualified personnel.

Conclusions

In this chapter, we have provided an overview of the qualification structures and employment trends in non-R&D-intensive business sectors in Germany. Because human capital equipment can be regarded as a basic factor of productivity, it is important to know which types of formal classifications are needed in German non-R&D-intensive industries, especially in the case of highly qualified personnel with regard to innovative activities.

The results of the analyses showed that, although there has been a shift in employment towards the service sectors, approximately 22 % of the German

(continued)

workforce remains in the manufacturing sector or traditional industries. The majority of this 22 % is employed within non-R&D-intensive manufacturing sectors. However, employment in non-R&D-intensive manufacturing industries has slightly decreased over the years, while the proportion of employment in R&D-intensive sectors has increased. Furthermore, there has been increasing demand for highly qualified personnel in non-R&D-intensive sectors, although this demand has been lower than in R&D-intensive industries. Thus, it is interesting to note that the demand for university graduates in particular has increased, whereas the demand for employees with technical school degrees has decreased.

When decomposing the change in the employment of highly skilled personnel into three components, it becomes obvious that although there was a structural shift in the demand for highly qualified personnel from the manufacturing sector to the service sector, both the R&D- and non-R&D-intensive sectors showed increased demand for highly qualified personnel over time. This outcome leads to the conclusion that the non-R&D-intensive sector is increasingly dependent on highly skilled workers to maintain or even increase its innovative potential, which is critical with regard to its competitiveness.

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Chapter 6
The Market Environment and Competitive Factors of Non-R&D-Performing and Non-R&D-Intensive Firms

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Abstract Following the analysis of the specific characteristics of non-R&D-intensive industries on the macroeconomic level in the previous chapters, the next three chapters provide a detailed analysis of non-R&D-intensive firms on the microeconomic level. This chapter examines firm-level data on the market and competitive environment of non-R&D-intensive firms. The aim is to locate these firms within their industrial competitive environment, clarify their structural characteristics, and obtain information about their most relevant competitive factors and future expectations.

6.1 Introduction

According to the market-based view, a firm's strategic positioning depends on the optimal competitive strategy available in light of the firm's specific product-market characteristics. Thus, a firm's competitive success is largely influenced by the specific industry and market structures in which the firm is embedded, and its business success is determined by the firm's chosen strategic market positioning. Firms choose their strategic positioning by considering the five main competitive forces proposed by Porter (1985, 1999): the bargaining power of buyers, the bargaining power of suppliers, the threat of substitute products/services, the threat of new market entrants, and the existence of rivalry among existing competitors. Further, firms select the best possible competitive strategy, which can be a strategy of differentiation, a strategy of cost leadership, or a niche strategy (Porter 1997). The choice of one of these competitive strategies is believed to be crucial for

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successful market positioning. A firm's primary goal is hence to achieve the best possible positioning in the market according to the characteristics of the existing market. Thus, the market-based view posits that a firm's strategic positioning is largely determined by already existing external circumstances and is mainly a reactive or adaptive move for the firm.

Despite its merits, the market-based view can also be criticised because it pays little attention to firm-specific competences, which might equally lead to successful market positioning, largely independent of existing competitive forces. Additional important criteria might exist for the choice of a particular competitive strategy, which cannot be solely attributed to the external market environment. According to the resource-based view (Burr 2004, Teece et al. 1997, Welge and Al-Laham 2008), a firm's internal factors can also account for the choice of a successful competitive strategy. If every firm is assumed to possess a unique combination of different assets and competences, a firm can gain a competitive advantage from having a superior combination of firm-specific competences. If a firm succeeds in developing and offering competences that are valuable for customers yet that are difficult for other firms to copy and imitate, it can achieve a sustained competitive advantage (Foss and Knudsen 2003). Therefore, it is important for firms not only to possess relevant resources and assets but also to be able to creatively combine and apply their resources and assets to changing their demands (Moldaschl and Fischer 2004). Not all firm-specific resources fulfil these criteria; thus, not all resources are equally relevant for a firm's competitiveness. Core competences (Prahalad and Hamel 1990), which are central to firms' long-term competitiveness, cannot be exchanged or bought by firms. They are developed through time and consist of a bundle comprising a firm's experiential knowledge, harmonised internal (technical and organisational) processes, and internalised routines, which are highly context-dependent and thus offer a "natural" protection against imitation by competitors.

Thus, to take a comprehensive strategic approach, a firm would consider both strategic approaches (i.e., the market-based view and the resource-based view) and both acknowledge the characteristics of the market and develop a unique bundle of internal resources and capabilities (Porter 1996).

To analyse the competitive environment of non-R&D-intensive firms, the following chapter will present the latest available firm-level empirical findings related to the structural, competitive and market characteristics of non-R&D-performing and non-R&D-intensive firms and will examine the expected future developments in this area. The empirical analysis is largely based on data from the latest German Manufacturing Survey 2012. This survey is conducted by the Fraunhofer Institute for Systems and Innovation Research (ISI) and is part of the European Manufacturing Survey (EMS), which comprises surveys in 13 countries rooted in a network of research institutions from 18 countries. The objective of this regular, questionnaire-based postal survey that is conducted in Germany is to systematically monitor manufacturing industries. The survey addresses firms with 20 or more employees from all manufacturing sectors (NACE Rev 2: 10–33). The eight-page questionnaire includes questions on innovative manufacturing technologies, organisational innovations, cooperation, relocation, performance indicators, products, and services, as well as general company data. The German Manufacturing Survey was first launched in 1993 and is conducted regularly every 3 years. In 2012, 15,420 manufacturing firms in Germany were asked to complete the questionnaire, and 1,594 returned useable replies, which amounts to a response rate of 10 %. The dataset represents a cross-section of the manufacturing sector. Manufacturers of machinery and equipment represent 17 % of the total sample, manufacturers of metal products 23 %, manufacturers of electrical and optical equipment 11 %, and producers of chemical and rubber and plastic products 14 %. The remaining answers come from other sectors, such as paper and publishing, wood and woodworking, food processing, textiles, and transport equipment. The variety of firms in the industries in terms of firm size (number of employees) is also well represented in the sample. Firms with fewer than 100 employees constitute 65 % of the firms, mid-sized firms with fewer than 1,000 employees constitute 32 %, and larger firms with 1,000 employees and more account for 3 % (Jäger and Maloca 2013).

6.2 The Market Environment of Non R&D-Performing and Non-R&D-Intensive Firms

If the sectoral definitions of low-, medium-, and high-tech sectors by Legler and Frietsch (2007) are applied to the firm level, it becomes evident that so-called low-, medium-, and high-tech sectors comprise firms with different levels of R&D intensity (Fig. 6.1). The sectoral classification thus only partially reflects the actual R&D intensity of the firms belonging to these sectors. Further, we observe substantial intra-sectoral heterogeneity regarding firms' R&D intensity, which is not adequately acknowledged by the sectoral grouping alone. Over 50 % of firms in medium- and high-tech sectors are not classified as medium- or high-tech firms.

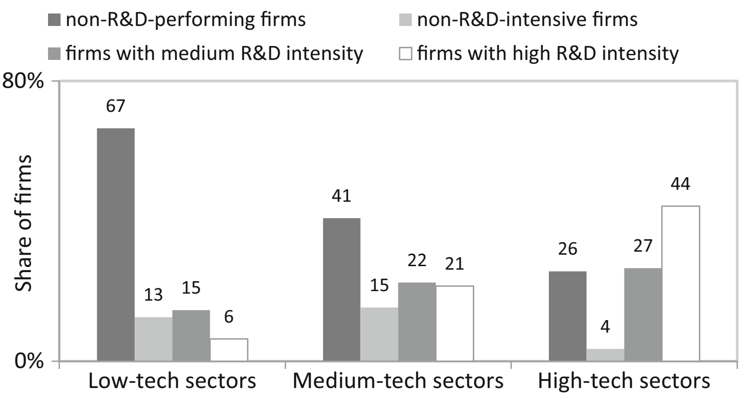

Fig. 6.1 Distribution of firms with different levels of R&D-intensity within low-, medium-, and high-tech sectors (Source: *German Manufacturing Survey 2012*)

Medium-tech sectors largely (more than 50 %) comprise non-R&D-performing and non-R&D-intensive firms, whereas roughly one-third of the firms in high-tech sectors are non-R&D-performing or non-R&D-intensive firms. Thus, any analysis of the effect of R&D intensity on market competitiveness and (innovation) performance needs to be conducted on the firm level rather than on the sectoral level to obtain meaningful results.

According to latest available firm-level German data, firms without any R&D expenditures compose the largest group within low-tech and medium-tech sectors and compose a large group within high-tech sectors. This finding indicates that firms without any R&D activities play a relevant role in the industrial value chain of research-intensive sectors, perhaps even a crucial one. A more detailed analysis of the composition of single industrial sectors regarding firms' R&D intensity reveals that although typical low-tech sectors, such as *food* and *textiles*, are clearly dominated by non-R&D-performing and non-R&D-intensive firms and although typical high- and medium-tech sectors, such as *computer, electronic, and optical products*, are relatively dominated by R&D-intensive firms, a considerable number of firms in each sector nevertheless belong to the opposite R&D intensity category. The share of non-R&D-intensive and non-R&D-performing firms differs in each industrial sector, but these firms are still relevant in each sector, even in classical high-tech sectors. The share of non-R&D-intensive and non-R&D-performing firms ranges from about one-third to over 80 %, depending on the sector. These results show that even in R&D-intensive industrial sectors, such as *computer, electronic, and optical products*, roughly one-third of all firms are either non-R&D-performing firms or non-R&D-intensive firms without substantial R&D expenditures. Nevertheless, these firms manage to succeed in a strongly R&D-driven sector, most likely by contributing specific experience-based knowledge and strongly customer-focused competences (see also chapter 8 in this book).

Regarding firm size, the empirical results confirm the clear dominance of non-R&D-performing firms among small and medium-sized enterprises (SMEs) in general, while all four categories of R&D intensity are distributed almost evenly among large firms (Fig. 6.2). Thus, a lack of investment in R&D is clearly common among SMEs. Given that SMEs form the backbone of every economy, the present and future competitiveness and innovativeness of firms with no or only low R&D expenditures is of general interest. These results confirm once again the previous findings regarding the central role of non-R&D-intensive firms within the German industrial landscape and industrial value chains, indicating that they play a crucial role in the economic landscape (Kirner et al. 2009).

With regard to firm size, non-R&D-intensive firms are predominantly SMEs. Given that SMEs compose the majority of all firms in all economies, non-R&D-intensive firms are a widespread phenomenon and form the backbone of developed economies. However, slightly more than half of all large manufacturing firms can be characterised as non-R&D-intensive. They either have no R&D expenditures (nearly 30 % of all large firms) or belong to the group of low-tech firms with only small investments in R&D (about one-quarter of all large firms). Apparently, not only the vast majority of SMEs but also a substantial share of large firms are able to

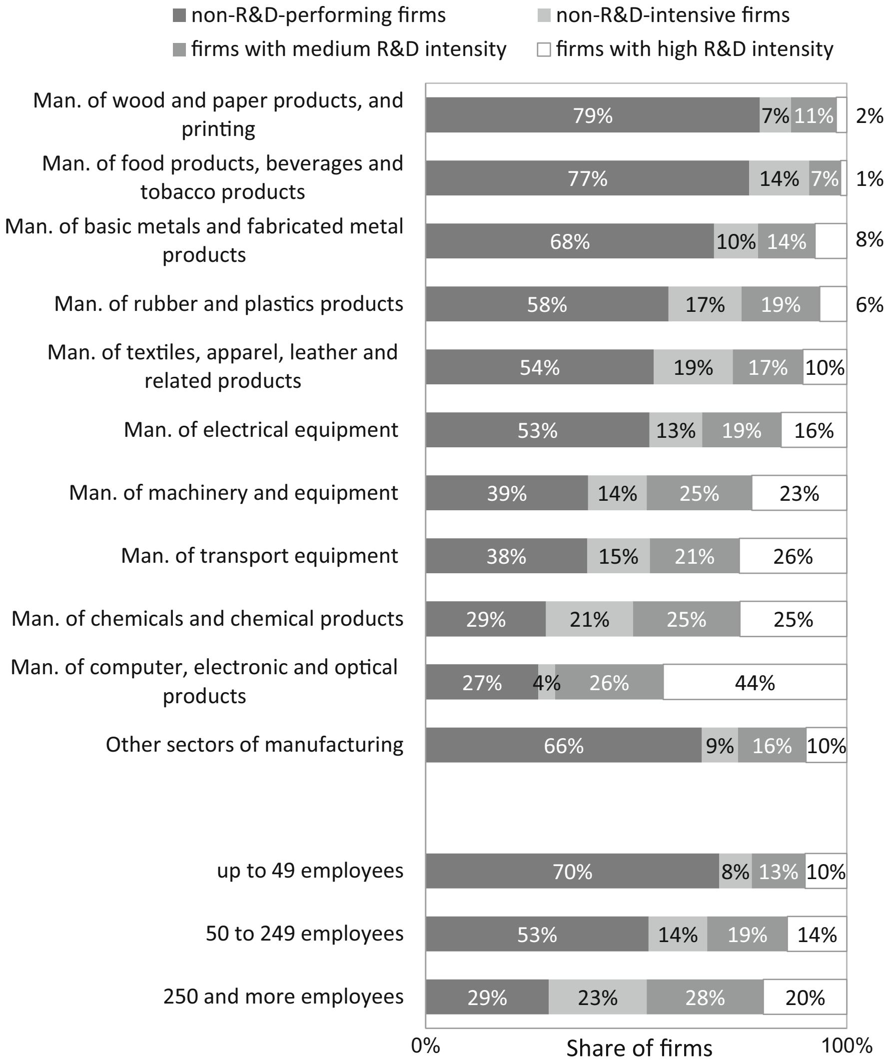

Fig. 6.2 Distribution of firms with different levels of R&D intensity by sector and firm size (Source: *German Manufacturing Survey 2012*)

survive and remain competitive even in a highly developed economy such as Germany with no or little R&D expenditures. These firms seem to be able to remain competitive and successful with competitive strategies that obviously do not rely on R&D-based innovations.

Regarding the age and mortality rates of firms with different levels of R&D intensity, previous analyses have demonstrated that non-R&D-intensive firms are distributed equally among all categories of firm age, including mature as well as newly founded firms (Kirner et al. 2010; Rammer et al. 2011; Som 2012). There are no detectable differences among firms with different levels of R&D intensity with respect to their market stability over time or their potential for start-up and entrepreneurial activity.

6.3 Strategic Positioning of Non-R&D-Performing and Non-R&D-Intensive Firms

Another interesting question regarding the strategic position of non-R&D-performing and non-R&D-intensive firms relates to their position in the value chain. Firms lacking relevant R&D investments may be argued to be suppliers of R&D-intensive firms because they might lack the capacity to develop own products that are sufficiently innovative to end customers. Our empirical analysis, however, shows that non-R&D-performing and non-R&D-intensive firms are clearly not suppliers of R&D-intensive firms only. Indeed, there are no significant differences among firms with different levels of R&D intensity with respect to their position in the value chain. Roughly half of all firms are producers of finished goods, regardless of their level of R&D intensity. The other half are only suppliers, and a small share are both suppliers and end producers. These results indicate that non-R&D-performing and non-R&D-intensive firms are equally able to provide end customers with up-to-date products relative to their R&D-intensive counterparts. Their lack of R&D intensity does not automatically predispose them to a downstream supplier role within the value chain (Fig. 6.3).

The ability to provide up-to-date competitive products is also reflected in the firms' international activity. Regarding the level of internationalisation of firms with different levels of R&D intensity, the firm-level analysis offers a clear picture. Export intensity increases with firm size in all categories of R&D intensity. Among large firms, firms with different levels of R&D intensity do not differ in terms of their internationalisation. Large firms with no or little R&D are equally active in international markets relative to R&D-intensive firms. About half of the products of all large firms are sold abroad, regardless of their level of R&D intensity. Differences regarding internationalisation are more pronounced among SMEs. Among SMEs, the share of products sold abroad significantly differs among the firms, particularly between non-R&D-performing and R&D-intensive firms. Nevertheless, even small firms with no or little R&D expenditures are still able to sell a considerable share (between one-fifth and one-third) of their products abroad, which demonstrates their existing international competitiveness (Fig. 6.4).

Regarding the specific characteristics of the market environment of non-R&D-intensive firms, previous empirical results of a telephone survey among German

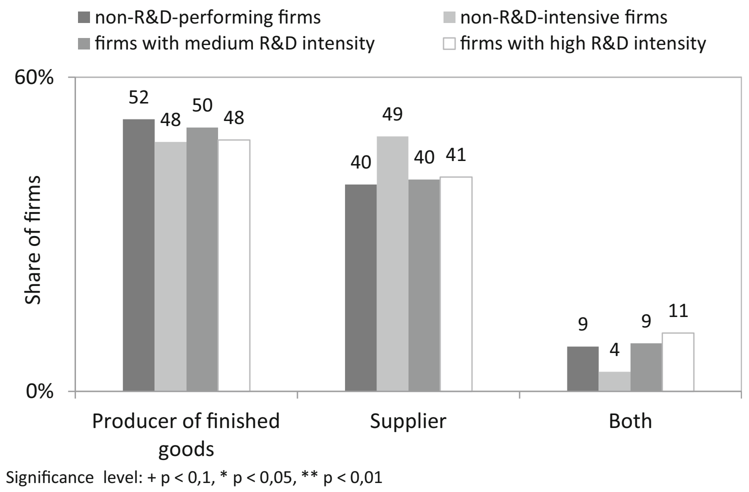

Fig. 6.3 Position of firms with different levels of R&D-intensity in the value chain (Source: *German Manufacturing Survey 2012*)

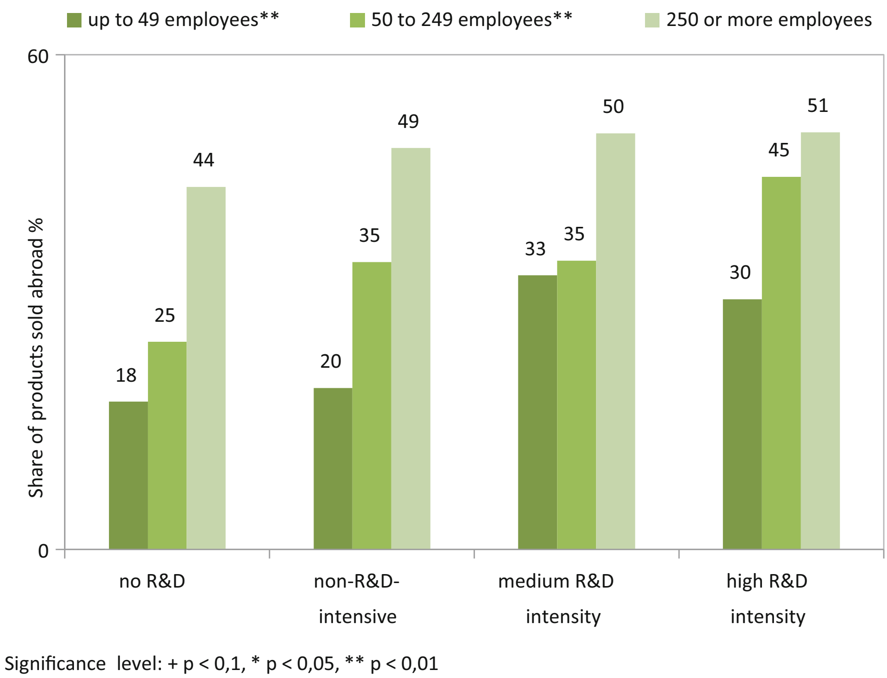

Fig. 6.4 Share of products sold abroad by firm size and R&D intensity (Source: *German Manufacturing Survey 2012*)

manufacturing companies from 2010[1] reveal that only 12 % of all surveyed non-R&D-intensive firms operate in shrinking markets, while the rest are active in either saturated or even growing markets. Further, 74 % of the non-R&D-intensive firms characterised their market as stable and not particularly threatened by new competitors. These results indicate that non-R&D-intensive firms are able to compete in saturated as well as expanding markets. They are quite successful in maintaining and defending their existing market position and in positioning themselves in growing markets. According to the results of the same survey, one reason for this success is that their markets tend to be protected by market entry barriers that are created by high investment costs and long-established networks. The relevance of high investment costs as a market barrier increases with company size and serves as a protection mechanism, particularly for larger non-R&D-intensive firms that operate expensive equipment. Overall, non-R&D-intensive firms seem to have a stable market position that is characterised by high investments in equipment and long-term relationships with suppliers and customers, which serve as important market entry barriers for new competitors (Som et al. 2010). Thus, a systematic structural weakness of non-R&D-intensive firms regarding their overall market competitiveness cannot be identified on the basis of these results.

The same previous empirical results also show that the majority of non-R&D-intensive firms are strategically independent with respect to the choice of their product offerings. More than half of the surveyed non-R&D-intensive firms only produce products that have been developed by themselves, an additional 23 % offer partially self-developed products and act partially as toll manufacturers for other firms simultaneously, and only one-quarter of the surveyed non-R&D-intensive firms act solely as toll manufacturers for other firms. Thus, the great majority of non-R&D-intensive firms are engaged in their own successful new product development, even though they lack relevant R&D investments. The majority of non-R&D-intensive firms are able to develop and introduce their own products to the market and therefore are able to remain strategically independent with respect to the product development activities of other firms. However, the survey results also show that the products of non-R&D-intensive firms are generally quite easy to substitute with rival products. The majority (65 %) of the surveyed non-R&D-intensive firms indicated that their products could be easily substituted by rival products, whereas 35 % of firms indicated that considerable effort would be required by customers to substitute their products and that substitution would therefore be unlikely (Som et al. 2010).

[1] The telephone survey was conducted in 2010, and the results comprise answers from 220 non-R&D-intensive companies (R&D expenditures $<$ 3 % of their sales) and 88 high-tech companies (R&D expenditures $>$ 7 % of their sales) about their market environment, competitive strategies, and structural characteristics. The results of this survey have been previously published by *Som, O., Kinkel, S., Kirner, E., Buschak, D., Frietsch, R., Jäger, A., Neuhäusler, P., Nusser, M., Wydra, S. (2010): Zukunftspotenziale und Strategien nichtforschungsintensiver Industrien in Deutschland – Auswirklungen auf Wettbewerbsfähigkeit und Beschäftigung. Innovationsreport TAB Büro für Technikfolgenabschätzung beim Deutschen Bundestag. Arbeitsbericht Nr. 140.*

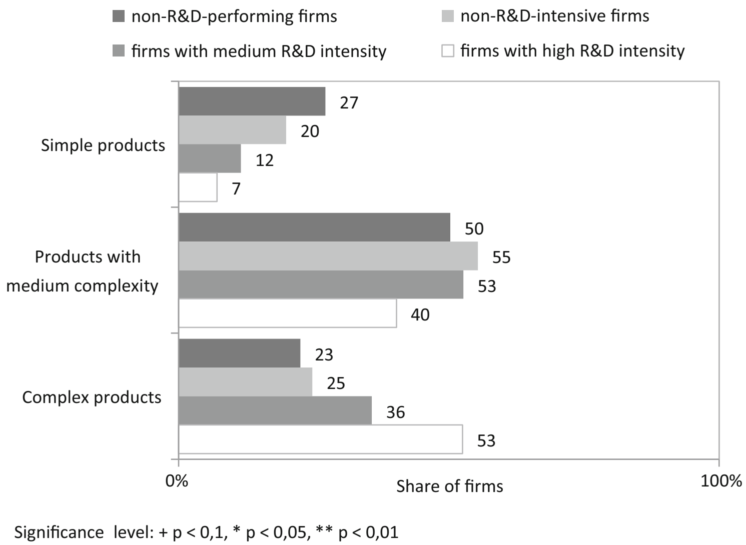

Fig. 6.5 Complexity of products offered by firms with different levels of R&D-intensity (Source: *German Manufacturing Survey 2012*)

These findings are not surprising considering that one-fifth of non-R&D-performing and more than one-quarter of non-R&D-intensive firms currently produce and sell products of low complexity (simple products); these shares are about three times that of R&D-intensive firms. Although the majority of non-R&D-intensive firms offer products of medium or high complexity (Fig. 6.5), a relevant number of them still face a higher overall risk of substitution. Given that less complex products tend to be generally easier to substitute than more complex products, some non-R&D-intensive firms structurally face a higher risk of substitution. Nevertheless, they seem to be able to maintain their overall market position despite this higher risk. In addition to their successful competitive strategy, long-established business networks could be an explanation for their ability to maintain their overall market position (Kirner et al. 2010). Non-R&D-intensive firms might be able to compensate for some of their structural disadvantages by focusing on competitive factors that are highly valued and honoured by their customers despite the existing threat of technologically equivalent competitors. A successful strategy can act as powerful protection against market competition induced by a lack of technological differentiation.

Regarding their most important competitive factor, 74 % of all surveyed non-R&D-intensive firms indicated product and process quality as the most important factor. The second most important competitive factor is product and process flexibility—the ability to adapt products and processes to customers' individual needs. This factor was mentioned by 60 % of the surveyed firms. Other competitive factors of non-R&D-intensive firms include short delivery times (47 %), a breadth of different product variants (31 %), company and brand image (30 %), and manufacturing costs (27 %). Only 10 % of the surveyed non-R&D-intensive firms indicated the degree of novelty of the offered products as one of the most important competitive factors (Som et al. 2010). These results show that non-R&D-intensive firms differentiate themselves from their competitors mainly through superior manufacturing quality and a high degree of flexibility, as well as *how* their products are offered but not necessarily what the products themselves are. Their products are generally of low or medium complexity and are comparably relatively easy to substitute; nevertheless, non-R&D-intensive firms are able to sustain a remarkably stable market position and competitive strength.

Their robust competitive position is also evident in their responses regarding their strategic plans for the coming years. Almost 80 % of the surveyed non-R&D-intensive firms indicated that they plan either to considerably expand their position in their current market or to enter entirely new markets. Only a minority (23 %) aim to simply maintain their existing market position without any expansion. More than half of the surveyed non-R&D-intensive firms plan to expand by developing new products, which indicates that the firms have great potential for innovation even without making any substantial investments in R&D. The largest expected investments in the future are planned in the areas of new equipment (36 %) and new distribution channels (27 %), followed by marketing activities (13 %). Plans to invest in R&D and plans to invest in staff received the lowest number of responses, with 11 % each (Som et al. 2010). The targeted market expansion seems to be largely driven by the improvement of production and delivery processes.

6.4 Summary

The empirical findings regarding the market environment and market position of non-R&D-performing and non-R&D-intensive firms clearly show that these firms compose a significant share of firms in every industrial sector, including so-called "high-tech" sectors. Non-R&D-performing and non-R&D-intensive firms are an integral part of every industrial sector in Germany and thus play a crucial role in the manufacturing value chain. However, these firms are by no means predisposed to take "only" a downstream position in the industrial value chain; rather, they are quite able to compete in national and international markets with their own products, even though their products are predominantly of low or medium complexity and thus at an increased risk of substitution. The robust competitive position of non-R&D-intensive firms is based on their strong customer orientation and superior process quality and flexibility, which provide a stable competitive advantage despite their lack of substantial R&D investments. Non-R&D-intensive firms are able to offer their customers qualitatively superior products that meet their individual needs.

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Chapter 7
Innovation Strategies and Patterns of Non-R&D-Performing and Non-R&D-Intensive Firms

Eva Kirner, Oliver Som, and Angela Jäger

Abstract This chapter focuses on the innovation ability of firms with different levels of R&D intensity. Using the latest available firm-level data from Germany, we analyse the product and process innovation activities and the innovation performance of firms with different levels of R&D intensity on both the descriptive and the multivariate level. Based on a holistic understanding of firm-level innovation, the input and output activities of non-R&D-performing and non-R&D-intensive firms are highlighted across different innovation fields.

7.1 Introduction

Distinguishing between different types of innovation is crucial to measure firm innovativeness. According to the OECD's definition of innovation (OECD 2005), firms can follow different innovation paths to reach the goal of sustained business success. In addition to developing and introducing new products to the market, manufacturing firms can also develop and offer product-related services, implement innovative manufacturing technologies, and/or introduce innovative organisational concepts. Each of these types of innovation can be a source of competitive advantage in itself or in combination with another type of innovation. Because of the different possible modes and paths of innovation (Jensen et al. 2007; Damanpour and Evan 1984; Piva and Vivarelli 2002; Totterdell et al. 2002), their interdependent nature (Edquist 1997), and their embeddedness in innovation systems (Lundvall 1992), innovation does not merely occur in R&D-intensive sectors or firms. Given the close and reciprocal relationship between sectors with different

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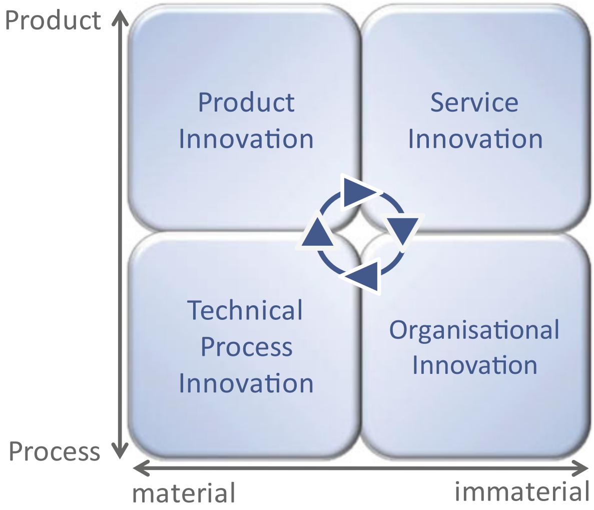

Fig. 7.1 Innovation fields in manufacturing firms (Adapted from Kinkel et al. 2004; Kirner et al. 2006)

levels of R&D intensity in developed economies (Robertson and Patel 2007; Hirsch-Kreinsen et al. 2005), innovations that are generated in high-tech sectors or firms diffuse into non-R&D-intensive sectors and firms. Moreover, non-R&D-intensive firms are involved in knowledge-creating activities in high-tech fields (see also Chap. 9 in this book).

If we look at the different possible fields of innovation, we can roughly distinguish product innovations from process innovations: whereas product innovations can consist of either physical (material) or intangible (immaterial) products, process innovations involve technological and organisational aspects that equally represent the physical and intangible dimensions of process innovations (Fig. 7.1). Product innovations are undoubtedly crucial for long-term business success. Service innovations also play an increasingly important role in manufacturing firms' competitiveness. The services that manufacturing firms provide are usually closely related to their products, and they may include different forms of maintenance, training, consulting, project planning, software development, or support for the initial set-up of machines and equipment. Innovative services can advance to become a major differentiating factor for firms against competitors in the market. Further, firms can generate product-service combinations, which offer complete solutions for customers and therefore create additional value for which customers are prepared to pay. The continuous advancement of manufacturing technology is another important driver of innovation for manufacturing companies. Technical process innovations can lead to major improvements even without new product development; however, often, their implementation is linked to newly developed products. Similarly, organisational innovations can substantially improve firms' overall process efficiency and quality with or without simultaneously occurring product innovations.

The innovativeness of non-R&D-performing and non-R&D-intensive firms can be further analysed from two different angles: the input side and the output side. Knowing which resources and framework conditions characterise manufacturing firms on the input side is crucial. However, it is even more important to determine the actual innovation performance of these firms on the output side. More detailed knowledge of innovation input factors allows us to better assess these firms' innovation capabilities, but actual performance measures are required to determine whether these firms actually manage to be successful innovators. The following empirical analysis is based on data from the German Manufacturing Survey from the year 2012[1] (Jäger and Maloca 2013).

7.2 Innovation Input and Innovation Activities of Non-R&D-Performing and Non-R&D-Intensive Firms

One of the most commonly used innovation input indicators is R&D investment. In this regard, non-R&D-performing and non-R&D-intensive firms have a structural disadvantage relative to other firms. They either do not invest in R&D at all or do not invest a relevant amount of resources in formal R&D, and they may lack an R&D department altogether. The distribution of employees across different business functions clearly shows that non-R&D-performing and non-R&D-intensive firms' low investment in formal R&D is also reflected in their low share of employees working in the field of R&D; this as expected. According to our firm-level data, only 3–4 % of employees work in the field of R&D in non-R&D-performing firms, whereas 7 % of employees in non-R&D-intensive firms and 12 %

[1] The German Manufacturing Survey 2012 is conducted by the Fraunhofer Institute for Systems and Innovation Research (ISI) and is part of the European Manufacturing Survey (EMS), which comprises surveys in 13 countries rooted in a network of research institutions from 18 countries. The objective of this regular questionnaire-based postal survey that is conducted in Germany is to systematically monitor manufacturing industries. The survey addresses firms with 20 or more employees from all manufacturing sectors (NACE Rev 2: 10–33). The eight-page questionnaire includes questions on innovative manufacturing technologies, organisational innovations, cooperation, relocation, performance indicators, products, and services, as well as general company data. The German Manufacturing Survey was first launched in 1993 and is conducted regularly every 3 years. In 2012, 15,420 manufacturing firms in Germany were asked to complete the questionnaire, and 1,594 returned useable replies, which amounts to a response rate of 10 %. The dataset represents a cross-section of manufacturing sectors. Manufacturers of machinery and equipment represent 17 % of the total sample, manufacturers of metal products 23 %, manufacturers of electrical and optical equipment 11 %, and producers of chemical and rubber and plastic products 14 %. The remaining answers come from other sectors, such as paper and publishing, wood and woodworking, food processing, textiles and transport equipment. The variety of firms in the industries in terms of firm size (number of employees) is also well represented in the sample. Firms with fewer than 100 employees constitute 65 % of the firms, mid-sized firms with fewer than 1,000 employees constitute 32 %, and larger firms with 1,000 employees and more constitute 3 %.

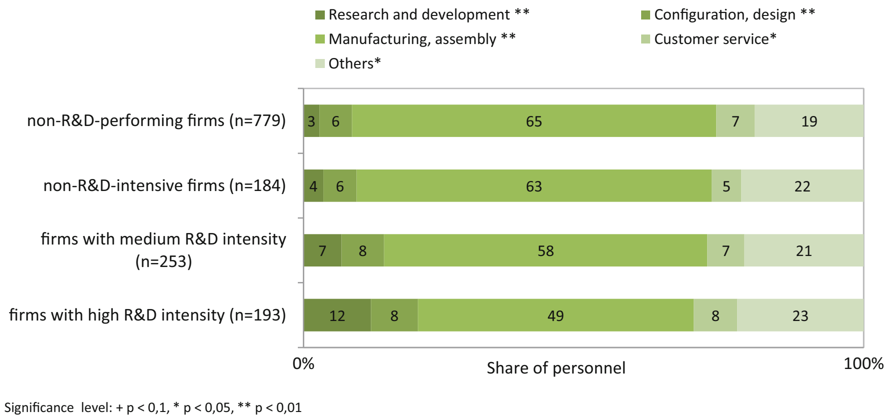

Fig. 7.2 Share of personnel working in different business functions (Source: *German Manufacturing Survey 2012*)

of employees in firms with medium or high levels of R&D intensity in the field of R&D; these differences are statistically significant. A relationship clearly exists between the level of R&D expenditures and the share of employees in the field of R&D (Fig. 7.2).

However, if we look at the share of employees working in the area of configuration/construction and design, the differences among firms with different levels of R&D intensity become smaller (6 % versus 8 %), though are still statistically significant. Configuration/construction and design can be considered innovation-related activities. Further, these activities are creative business functions because they mainly involve the customer-specific development and adaptation of products, which often require new and creative practical solutions to problems. Both non-R&D-performing and non-R&D-intensive firms can be assumed to rely more strongly on their incremental innovation capabilities, which are closely linked to customer-specific product development and product adaptation. These capabilities thus at least partially successfully compensate for these firms' lack of formal R&D capacity.

The share of employees directly working in manufacturing or assembly continuously decreases as a firm's R&D expenditures increase. Non-R&D-performing and non-R&D-intensive firms employ more personnel in the areas of manufacturing and assembly than their more R&D-intensive counterparts. These firms may employ more such personnel because their employees generally have a lower skill level (see also Chap. 4 in this book) and some of their processes have a higher labour intensity. Finally, small but still statistically significant differences are found between non-R&D-intensive firms and other firms regarding the share of employees working in customer service. The customer service orientation of non-R&D-performing and R&D-intensive firms is quite comparable; however, non-R&D-intensive firms have somewhat fewer personnel in this area. One explanation for this result could be that these average statistics do not adequately reflect the rather

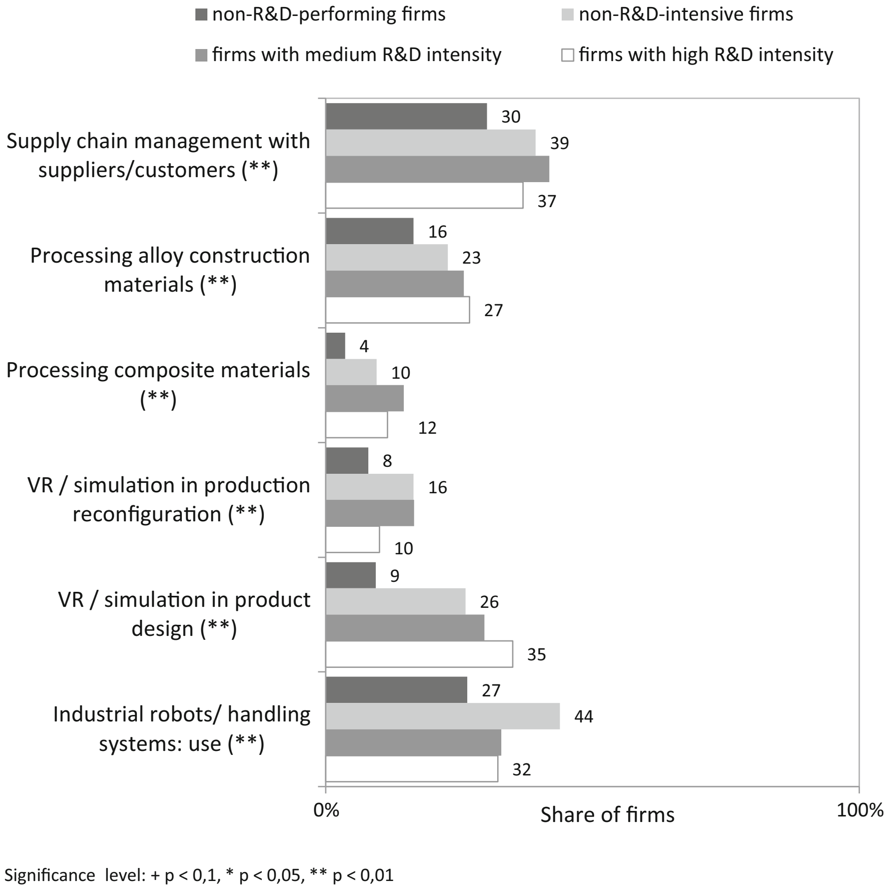

Fig. 7.3 Share of firms using innovative technological processes (Source: *German Manufacturing Survey 2012*)

different innovation paths pursued by non-R&D-intensive firms. Given that closeness to customers and a strong customer orientation are key competitive factors for many non-R&D-intensive firms (see also Chap. 6 in this book), these firms most likely do have a higher share of staff employed in the area of customer service. However, other non-R&D-intensive firms may focus less intensely on customer service with respect to their innovation and competitive strategy.

Looking at the innovation input side from a technological perspective, we can measure the use of different technical process innovations, e.g., the processing of composite materials, the integration of supply chain management with suppliers and/or customers, the application of different forms of simulation, or the use of industrial robots and handling systems (Fig. 7.3). The implementation of these process innovations may indicate the advanced innovation capabilities of a particular firm. Regarding the share of firms that have implemented these process innovations, there is a clear difference between the intensity of use among firms with different levels of R&D intensity, particularly between firms without any R&D expenditures and other firms. Interestingly, non-R&D-intensive firms use most of these process innovations almost as frequently as firms with medium or high levels of R&D intensity, with the exception of virtual reality and simulations in product design. Non-R&D-intensive firms' lower use of virtual reality and simulations is due to their overall lower level of product innovation activity, which is the main application field of this type of simulation, relative to R&D-intensive firms. Regarding the use of automatised equipment, such as industrial robots and handling systems, non-R&D-intensive firms actually considerably outperform firms with medium or high levels of R&D intensity. This result can be attributed to non-R&D-intensive firms' frequent high-volume production of simple parts (see also Chap. 6 in this book), for which automation is well suited because it generates quality and efficiency gains. These results show that although firms with and without R&D expenditures clearly differ with regard to the implementation of technical process innovations, the frequent use of technological process innovations is by no means limited to R&D-intensive firms. Many non-R&D-intensive firms and even some non-R&D-performing firms also use these technologies. Thus, advanced technical process capabilities are not a privilege of R&D-intensive firms only; rather, they can be attained and implemented by non-R&D-performing and non-R&D-intensive firms. Differences in the use of advanced manufacturing process technologies seem to arise when a firm has at least a minimum level of R&D activity. Non-R&D-intensive firms are considerably more frequent users of these technologies compared to non-R&D-performing firms. Once R&D activity is performed in any way by a firm, the firms seem to be more likely and able to use advanced manufacturing technologies.

In addition to firms' use of technological process innovations, firms' use of innovative organisational concepts can provide information about the non-technological input side of innovation to help assess the innovation capabilities of firms with different levels of R&D intensity.

Figure 7.4 shows firms' use of different advanced organisational concepts, such as shop floor segmentation, teamwork (in the narrow definition indicating that all team members are qualified for all tasks, which leads to job enrichment and increased autonomy in working teams with regard to task planning, execution, and quality), the implementation of systematic and continuous incremental innovations through methods for continuous improvement processes (CIP), and task integration through the definition of complete work tasks that include several work steps. The results show that non-R&D-performing, non-R&D-intensive firms, and R&D-intensive firms significantly differ in the implementation of all the selected innovative organisational concepts except teamwork. The differences are most pronounced between firms without any R&D and other firms. Once again, similarly to the use of innovative technologies, the differences between non-R&D-performing and non-R&D-intensive firms with regard to the implementation of innovative organisational concepts are quite pronounced. Once firms start to perform even a minimum level of R&D activity, the implementation of innovative organisational concepts seems to become more attractive.

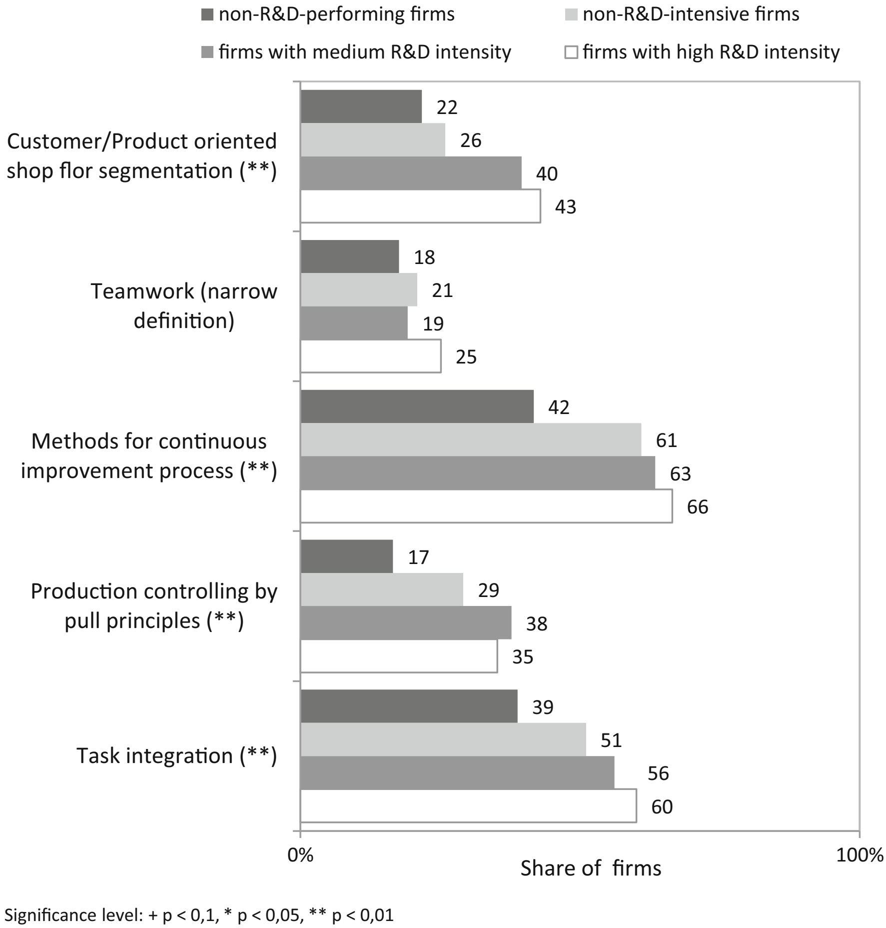

Fig. 7.4 Share of firms using innovative organisational processes (Source: *German Manufacturing Survey 2012*)

7.3 Innovation Output and Economic Performance of Non-R&D-Performing and Non-R&D-Intensive Firms

Different types of innovations lead to different types of results. Some results can be measured directly in monetary terms, whereas other results cannot be measured in monetary terms and thus need to be captured by other types of performance measures. The effects of product and service innovations can be most directly measured by the share of sales from new products and new services, respectively. These types of innovation results can easily be identified and quantified. However, determining the effects of technical and organisational process innovations is a much more difficult task. While product and service innovations usually have a direct monetary effect (even if it is often delayed by a time lag), process innovations usually do not have a direct effect on monetary performance measures. They primarily target process-related performance dimensions—mainly speed, efficiency, and quality—as competitive imperatives (Wheelwright and Clark 1992). For the empirical analysis, the following three indicators are used to measure process innovation results: the average lead time to introduce a new product as an indicator of speed, the firm's labour productivity measured as the value added (sales minus purchased parts, materials, and services) per employee to indicate efficiency, and the average percentage of products that need to be scrapped or reworked as an indicator of quality.[2]

7.3.1 *Product and Process Innovation Performance*

In a first step, the average product and process innovation performance of firms with different levels of R&D intensity is compared in a descriptive analysis (see Table 7.1).

The results show that firms with different levels of R&D intensity significantly differ with regard to their product innovation performance (measured by the share of the turnover of new products); however, no statistically significant performance differences are detected among non-R&D performing, non-R&D-intensive firms, and R&D-intensive (medium-tech and high-tech) firms with regard to their service innovation performance.

The weaker product innovation performance of non-R&D-performing and non-R&D-intensive firms compared to R&D-intensive firms is expected because the firms are distinguished based on their R&D expenditures. Given that there is a clear and robust relationship between a firm's R&D expenditures on the input side and the development of new products on the output side (Cassiman and Veugelers 2002; Becker and Dietz 2004; Dosi 1988; Acs and Audretsch 1988), these results are not surprising. Furthermore, earlier research related to product and industry life cycles shows that R&D intensity and product innovation rates tend to slow down as industries and products mature (Bos et al. 2013; Utterback and Suarez 1991; Suarez and Utterback 1991). Thus, product innovation rates are likely to be lower in non-R&D-performing and non-R&D-intensive firms because they tend to manufacture more mature products that already have well-established dominant designs. However, firms with very low or no R&D expenditures still generate on average approximately 13 % of their turnover from product innovations. This share of turnover is significantly lower than that of highly R&D-intensive firms (on average 20 %), but this result is nevertheless remarkable considering that

[2] See also Kirner et al. 2009 for a detailed discussion based on earlier data.

Table 7.1 Average product and process innovation performance of firms with different levels of R&D intensity

	non-R&D-performing firms		non-R&D-intensive firms		firms with medium R&D intensity		firms with high R&D intensity	
	N	Mean (S.D.)	N	Mean (S.D.)	N	Mean (S.D.)	N	Mean (S.D.)
Share of turnover with new products (%)**	331	**13.8** (15.3)	141	**12.4** (12.7)	221	**15.0** (14.5)	154	**20.0** (17.7)
Share of turnover with new services ("all firms")	739	**0.9** (3.7)	172	**0.6** (2.6)	246	**1.2** (3.2)	181	**0.8** (2.6)
Share of turnover with new service [%]	103	**6.4** (7.9)	34	**3.0** (5.3)	66	**4.6** (4.9)	33	**4.4** (4.7)
Labour productivity (turnover-input/employee) (000 Euro)**	623	**84.1** (54.1)	157	**99.8** (46.4)	189	**97.0** (51.8)	142	**106.7** (56.2)
Rework/scrap rate (%)	785	**3.0** (4.4)	177	**3.1** (5.9)	250	**3.7** (7.2)	185	**3.6** (5.5)
Production lead time (h)**	779	**22.5** (44.7)	178	**26.9** (54.7)	249	**30.0** (49.7)	192	**40.4** (58.7)

Source: *German Manufacturing Survey 2012*
Notes: One-way ANOVA
Significance level: + $p \leq 0.1$, *$p \leq 0.05$, ** $p \leq 0.01$)

these firms lack the relevant investment in R&D on the input side. Thus, non-R&D-performing and non-R&D-intensive firms are by no means excluded from the opportunity to pursue a successful product innovation path. These firms might compensate for their lack of R&D investments through other successful innovation management practices (Rammer et al. 2009).

Regarding the level of service innovations (measured as the share of turnover from new services), no significant differences are found among firms with different levels of R&D intensity—neither when all firms (regardless of their declared share of turnover from services) nor when only firms that explicitly provide information regarding their share of sales from innovative services are considered. These results indicate that a firm’s service innovation performance is not directly linked to its R&D intensity. Thus, non-R&D-performing and non-R&D-intensive firms can be just as successful in service innovations as R&D-intensive firms if they choose to follow this particular innovation path. They are equally able to provide their customers with continuously up-to-date product-related services that customers are prepared to pay for. These firms’ service innovation ability can also safeguard them firms against competition because high-quality services can differentiate them from otherwise technologically similar competitors (Kirner et al. 2007).

The analysis next moves from the performance indicators of product/service innovation to the performance indicators of process innovations. The results clearly show that non-R&D-intensive firms do not have any systematic disadvantage compared to their R&D-intensive counterparts in terms of quality and speed. By contrast, average production lead times are statistically significantly lower in less R&D-intensive firms compared to their R&D-intensive counterparts. The higher production lead times for R&D-intensive firms are partially due to the generally higher complexity of their manufactured products (see also Chap. 6 in this book). Nevertheless, on average, non-R&D-performing and non-R&D-intensive firms seem to have a clear advantage in terms of manufacturing speed. If shorter lead times are also linked to shorter delivery times, manufacturing speed can provide a substantial market advantage and high customer satisfaction. The greater manufacturing speed of less R&D-intensive firms may also be related to their generally lower product complexity, which allows for faster lead times. With regard to the quality dimension, no significant differences are found among firms with different levels of R&D intensity. They all have comparable rework/scrap rates, which serve as an indicator of the quality of their products and production processes.

Labour productivity as the chosen measure for overall efficiency in our analysis increases with increasing R&D intensity; however, only firms without any R&D investments have statistically significantly lower productivity compared to other firms. This result could be linked to the relatively lower labour intensity in other firms because of their more intense use of advanced technology, which might substitute for manual labour. Surprisingly, labour productivity does not significantly differ between non-R&D-intensive firms and highly R&D-intensive firms. Thus, even firms with low R&D investments are able to achieve the efficiency of R&D-intensive firms. However, labour productivity is a highly aggregated indicator; therefore, the measure might combine different effects that cannot be clearly separated and interpreted in a descriptive analysis. Hence, these results should to be interpreted with caution.

This initial descriptive analysis above has shown that R&D-intensive firms have a significant performance advantage over non-R&D-performing firms in terms of product innovation performance and labour productivity. However, no performance differences in terms of service innovation, quality, and speed are detected among firms with different levels of R&D intensity. In these aspects of performance, non-R&D-performing and non-R&D-intensive firms seem to perform equally well or even better than their more R&D-intensive counterparts. These results indicate the overall competitive strength of firms with no or little R&D expenditures, at least on a descriptive level.

Looking at the product innovation performance of firms in greater depth, we find that depending on firm size, between one-third and half of all the analysed firms without R&D expenditures are still product innovators (see Fig. 7.5). These firms have been able to successfully introduce a new product to the market within the past 3 years. Between one-tenth and one-third of these firms are even market innovators (introducing products that are new to not only the firm but also the market). These results show that product and market innovations do not necessarily require

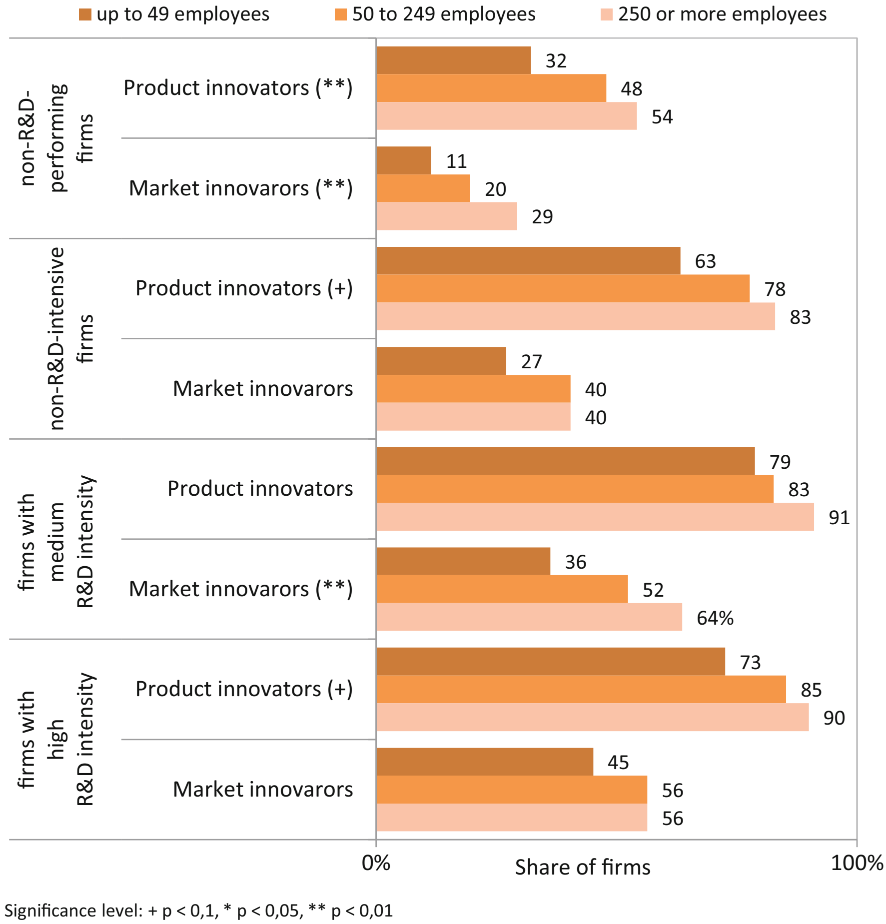

Fig. 7.5 Share of product and market innovators (Source: *German Manufacturing Survey 2012*)

investment in R&D. Within the group of non-R&D-intensive firms, the share of product innovators ranges between 63 % and 83 % depending on firm size, and the share of market innovators ranges between 27 % and 40 %. These shares are considerable given that these firms spend less than 2.5 % of their sales on R&D. Compared to firms with medium or high levels of R&D intensity, non-R&D-intensive firms still have less product and market innovation activity, but the difference is smaller than might be expected, particularly when their firm size is taken into account. If medium-sized and large firms of different R&D intensities are compared with respect to their product and market innovation activities, only small differences are found between non-R&D-intensive and R&D-intensive firms. Thus,

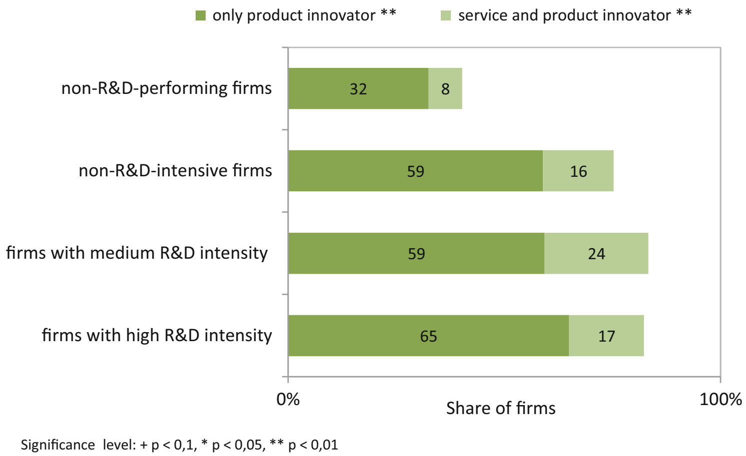

Fig. 7.6 Share of product and service innovators (Source: *German Manufacturing Survey 2012*)

part of the generally lower product and market innovation in non-R&D-performing and non-R&D-intensive firms can be attributed to their generally smaller firm size.

These results are quite remarkable, particularly with regard to the share of market innovators. The results indicate a relevant share of non-R&D-performing and particularly non-R&D-intensive firms are able to introduce products that are new to the market with no or little investment in R&D. These firms' success in this regard can be explained by their successful use and implementation of other modes of innovation and knowledge sourcing (see also Chaps. 8 and 9 in this book).

Taking a closer look at the share of product and service innovators among firms with different levels of R&D intensity, we find that 40 % of firms without any investment in R&D and as much as 75 % of non-R&D-intensive firms are product and/or service innovators according to the most recent empirical results. While a significantly greater number of firms are product innovators only rather than both product and service innovators, remarkably, no significant difference in innovation intensity is found between non-R&D-intensive firms and firms with medium or high levels of R&D intensity (Fig. 7.6). More than three-quarters of all the surveyed German non-R&D-intensive and R&D-intensive firms engaged in either product innovations or service and product innovations simultaneously in 2012. These results indicate that even very low investments in R&D—as is the case for non-R&D-intensive firms—enables firms to actively engage in product and service innovations. Only firms that completely lack R&D expenditures have substantially less product and service innovation activity. Nevertheless, a considerable share of these firms still manage to develop product and service innovations without investing in R&D. These firms' capacity in this regard might be due to their use of different modes of internal knowledge creation or their effective use of external knowledge sources for innovation (see also Chap. 8 in this book).

7.4 Innovation Output and Economic Performance of Non-R&D-Performing and Non-R&D-Intensive Firms from a Multivariate Perspective

To further validate the descriptive results, we perform an additional linear regression analysis on each of the different product and process innovation performance indicators while controlling for a number of possible intervening factors. The regression models aim to identify whether performance differences among firms with different levels of R&D intensity are indeed due to their R&D intensity or whether such differences arise from other structural differences. Thus, in addition to the level of R&D expenditures, a number of structural factors, such as the level of product complexity, the batch size, the type of product development (no product development, product development according to customers' specifications, standard program with alternatives, or standard program only), the firm size (logarithm of the number of employees), the qualification level of employees (share of university graduates among employees), the vertical range of manufacturing, the industrial sector and the export share are controlled for in the regression models. By controlling for these different structural factors, which may influence and even determine the innovation performance of different firms independently of their R&D intensity, we can detect the intervening effects resulting from firms' structural differences.[3]

The selection of this econometric strategy was based on the level of measurement of the dependent variables (Wooldridge 2002). Thus, for metric measures, a linear regression model was applied. To meet the model's assumptions of linearity, the constructs needed to be transformed. For the share of sales of new products, the square root transformation seemed to be most appropriate according to Tukey–Anscombe plots and model-fit parameters. Regarding labour productivity, total factor productivity, scrap rate, and manufacturing lead time, the assumptions of the model were met by using a logarithmic transformation to transform the dependent construct. For binary indicators indicating a firm's status as a product innovator or a service innovator, a classical logit regression model was applied.

The regression results partially confirm the previously discussed descriptive results, but in some cases, they contradict them. The widely assumed positive relationship between the level of R&D intensity and product development activity is again clearly confirmed both by analysing the product innovation activity of firms through the logistic regression model (see Fig. 7.7) and by more closely examining at the share of sales from new products (see Fig. 7.8).

The multivariate analysis shows that a higher level of R&D intensity alone has a significant, positive influence on both a firm's propensity to develop new products and a firm's share of sales resulting from product innovations when several important structural factors are controlled for. Further, two independent factors influence

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[3] The chosen reference groups in each regression model are manufacturers of machinery and equipment (sector), products with medium complexity (product complexity), a medium batch size (batch size), a basic production program with alternatives (type of product development), and firms with a medium level of R&D intensity (share of R&D expenditures).

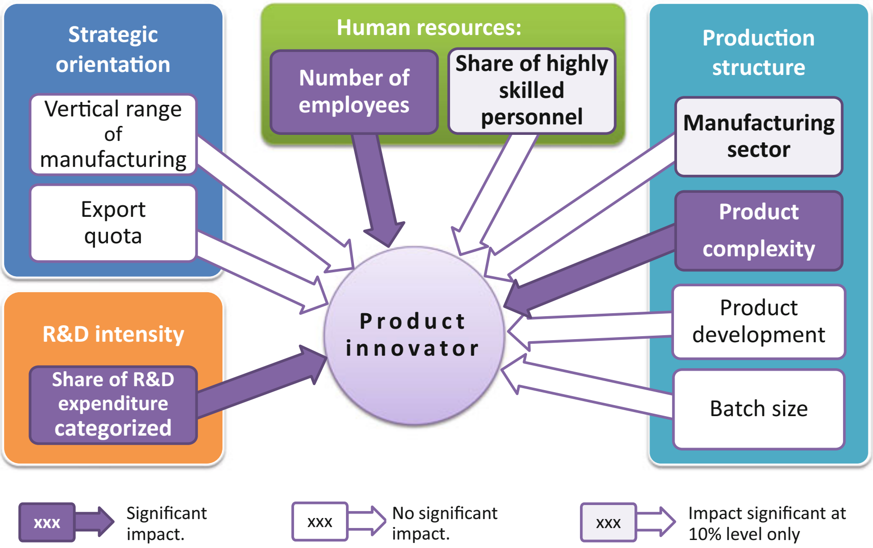

Fig. 7.7 Results of the logistic regression model with the dependent variable "product innovator" (N = 945, model significance p = 0.000, estimated model fit: Cox & Snell $R^2 = .217$) (Data: *German Manufacturing Survey 2012*)

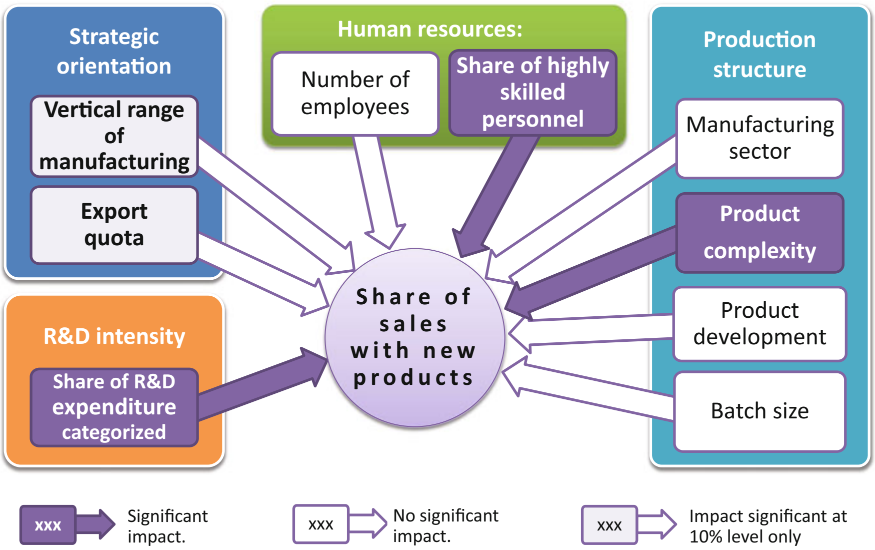

Fig. 7.8 Results of the linear regression model with the dependent variable "share of sales from new products". (N = 862, model significance p = 0.004, estimated model fit: Cox & Snell $R^2 = .052$) (Data: *German Manufacturing Survey 2012*)

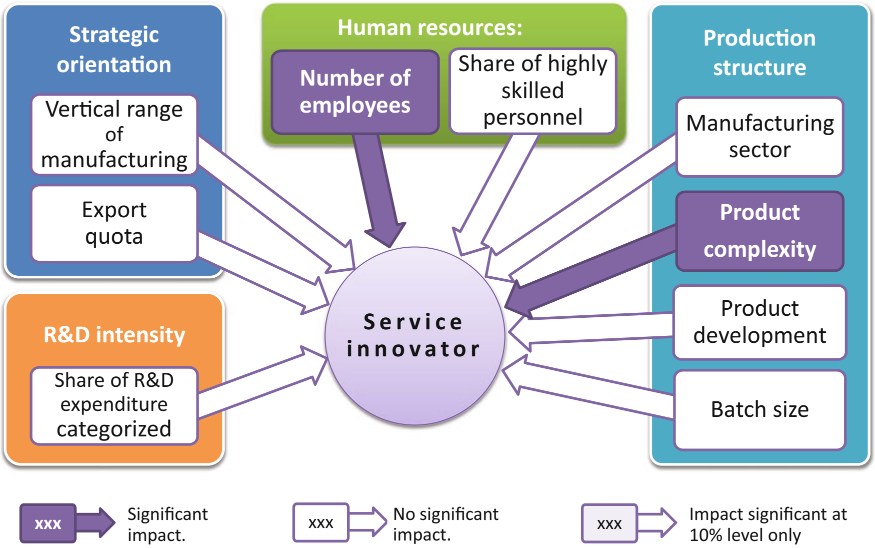

Fig. 7.9 Results of the logistic regression model with the dependent variable "service innovator" (Source: *German Manufacturing Survey 2012*)

firms' product innovation performance: a larger firm size and a higher product complexity both have a positive influence on firms' product development ability independent of firms' level of R&D intensity. Furthermore, a higher share of sales from product innovations seems to depend on a higher level of product complexity and a higher share of university graduates in a firm's employees. The impact of firms' sectoral affiliation, export intensity, and vertical range of manufacturing on firms' product innovation performance is not clear from the analysis, as these factors are only statistically significant at the 10 % level.

Three different structural dimensions seem to influence firms' product innovation performance, according to our analyses. A firm's level of R&D intensity therefore is not the only factor that determines its product innovation activity. Thus, less R&D-intensive firms that produce products with high complexity, that are larger in size, and/or that have a high share of skilled personnel might nevertheless be successful product innovators despite their low level of R&D intensity, as the descriptive analyses have already indicated.

Regarding the service innovation performance of firms with different levels of R&D intensity, the multivariate analysis once again confirms the results of the previous descriptive analysis. No statistically significant differences are found among firms with different levels of R&D intensity with respect to their success in introducing service innovations to the market (see Fig. 7.9).[4] While higher

[4] Because of data constraints, only firms' status as a service innovator could be analysed on a multivariate level. No statistically robust regression model could be calculated with the "share of sales from service innovations" as the dependent variable.

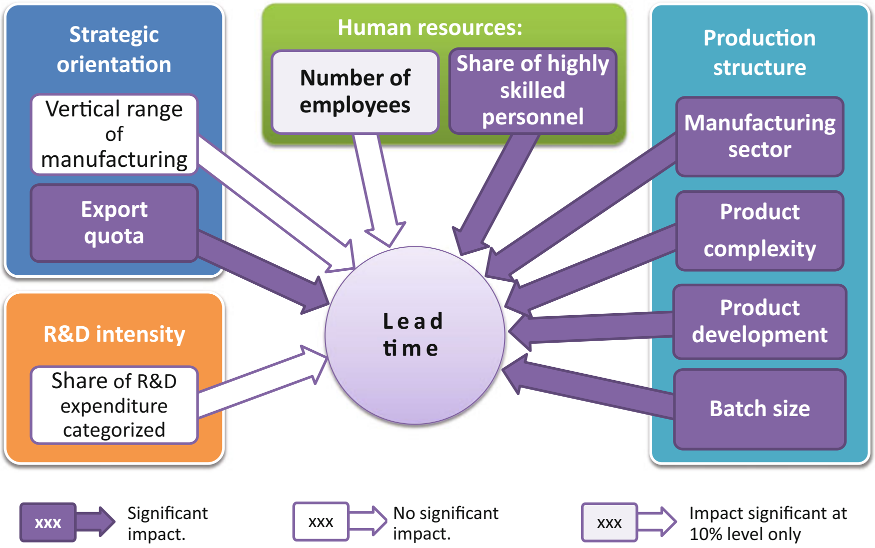

Fig. 7.10 Results of the linear regression model with the dependent variable "lead time". (N = 881, model significance p = 0.000, corrected $R^2 = .244$) (Data: *German Manufacturing Survey 2012*)

product complexity and a larger firm size have a significant, positive effect on firms' service innovation activity, no other structural factors have a direct influence on firms' service innovation activity. Firms' service innovation activity thus seems to be determined by factors that are independent of R&D intensity.

Moving from the product and service innovation performance indicators towards process innovation performance indicators, we use linear regression models to analyse the factors that influence lead time, scrap rate, and productivity (labour and total factor productivity).

Contrary to the results of the descriptive analysis, the results of the linear regression model for lead time reveals that the speed of a firm's manufacturing processes is not systematically determined by the firm's R&D intensity but rather is determined by a large number of different strategic and structural variables (see Fig. 7.10). In addition to export intensity, the share of skilled personnel in a firm and all the considered determinants of a firm's production structure have a statistically significant influence on the length of the firm's production process. These results indicate that less R&D-intensive firms' shorter lead times result from their production structure, e.g., lower product complexity and lower export orientation or larger batch sizes. Thus, non-R&D-performing and non-R&D-intensive firms that manufacture complex products in smaller batch sizes or through single-unit production are expected to have no systematic advantage in terms of production lead times over more R&D-intensive firms. Manufacturing speed is therefore unrelated to a firm's R&D intensity and is determined by other structural factors.

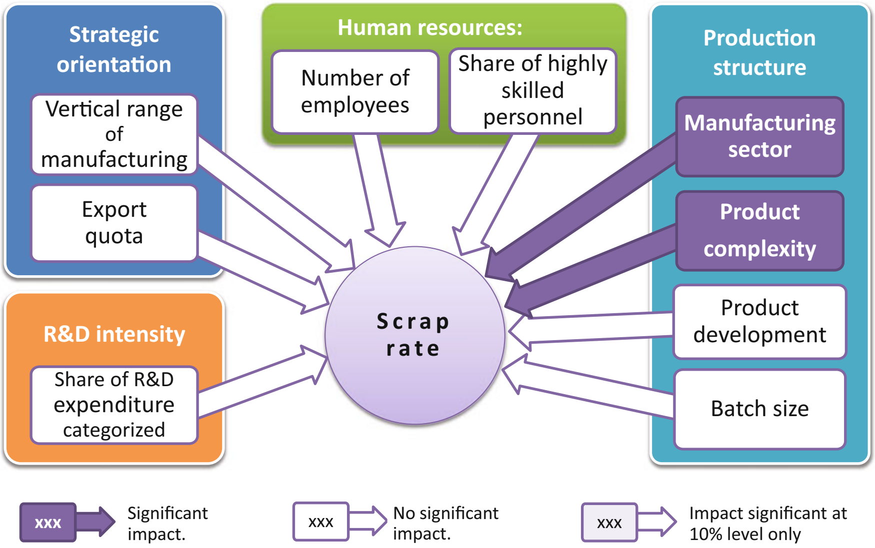

Fig. 7.11 Results of the linear regression model with the dependent variable "scrap rate". (N = 853, model significance p = 0.000, corrected R^2 = .046) (Data: *German Manufacturing Survey 2012*)

The results of the linear regression model addressing the chosen quality-related process performance indicator are quite similar to those of the model addressing manufacturing speed. Regarding the level of a firm's process quality, measured by the average scrap rate, no significant influence is found for firms' R&D intensity (see Fig. 7.11). The level of quality mainly depends on a firm's production structure, particularly its level of product complexity and sectoral affiliation.[5] Firms that produce simple products and firms from the food industry generally achieve higher levels of quality, as measured by lower scrap rates, regardless of their R&D intensity. According to the analysis, the quality of manufacturing processes thus seems to be mainly influenced by the type of product that firms produce. Given the same structural factors, firms with different levels of R&D intensity do not differ with respect to the quality of their manufacturing processes.

As a final overall indicator of process innovation performance, two different productivity measures are analysed more closely. While the descriptive analysis shows that firm performance significantly differs among firms with different levels of R&D intensity, with lower productivity levels for non-R&D-performing and non-R&D-intensive firms compared to R&D-intensive firms, the linear regression

[5] Because of the low statistical variance of the dependent variable and the dense accumulation of close-to-zero values, the overall quality of the model is low (a corrected R^2 of 0.046), but the results are still significant. Even considering the lack of other influencing factors, we can make initial conclusions about the impact of R&D intensity based on the model results.

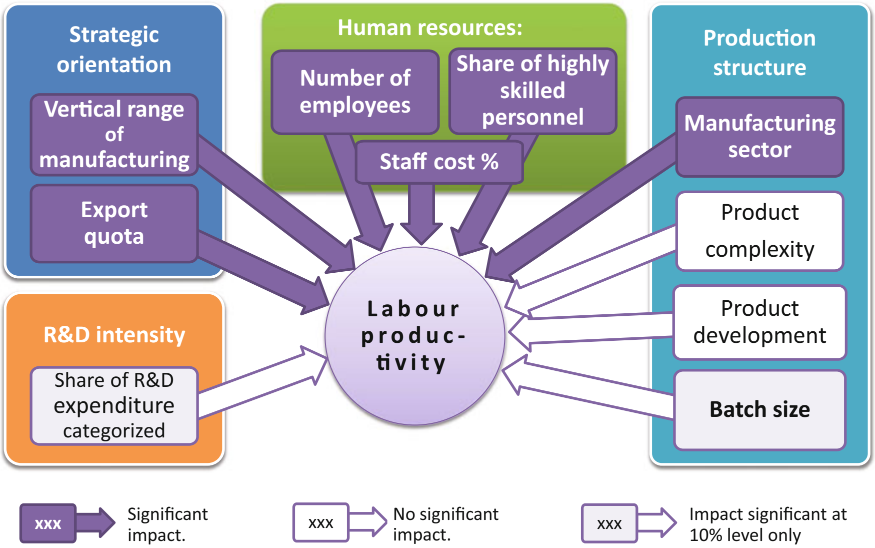

Fig. 7.12 Results of the linear regression model with the dependent variable "labour productivity". (N = 929, model significance p = 0.000, corrected R^2 = .391) (Data: *German Manufacturing Survey 2012*)

model reveals that R&D intensity has no statistically significant effect on labour productivity when various structural variables are kept constant. As Fig. 7.12 shows, labour productivity is significantly positively affected by firms' strategic orientation (with higher levels of internationalisation and a high vertical range of manufacturing increasing labour productivity), size (with larger firms being more efficient), level of qualified staff (with a higher level of qualified staff increasing labour productivity), and sectoral affiliation (with firms from the chemical industry being particularly efficient). The analysis reveals a possible impact of the level of a firm's R&D intensity but only on a 10 % significance level. Despite the assumption of overall higher labour intensity in non-R&D-performing and non-R&D-intensive firms compared to R&D-intensive firms, including staff costs as an additional relevant control variable in this particular regression model[6] strongly diminished the differences among firms with different levels of R&D intensity. As an explanation for the weak relationship between R&D intensity and labour productivity, R&D-intensive firms might lose some of their labour productivity advantage acquired through higher degrees of automatisation because of higher overall wage costs.

[6] In addition to the other structural indicators, the staff costs measured in terms of the share in total turnover are included in the model. Staff costs constitute a major explanatory factor in the sense that lower staff cost lead to higher labour productivity.

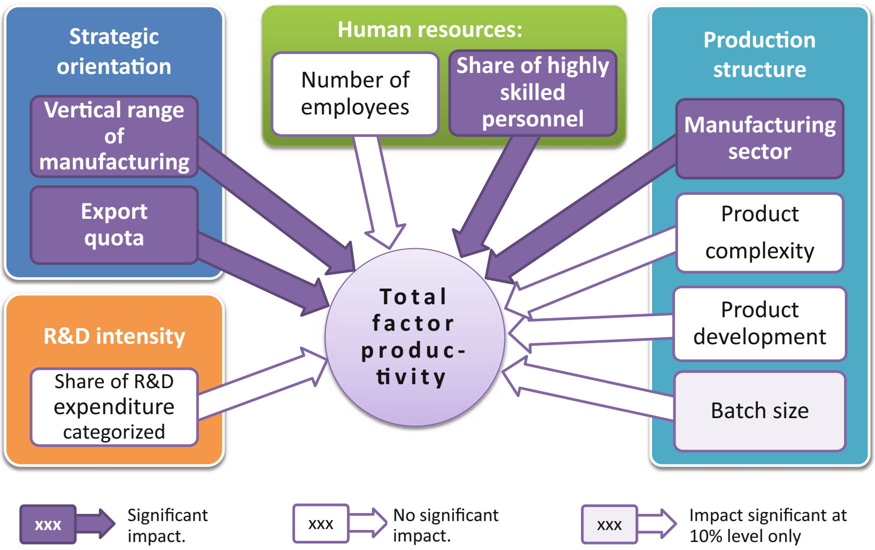

Fig. 7.13 Results of the linear regression model with the dependent variable "total factor productivity". (N = 839, model significance p = 0.000, corrected R^2 = .150) (Data: *German Manufacturing Survey 2012*)

To further examine the productivity of firms with different levels of R&D intensity from an additional perspective, we estimate another linear regression model with total factor productivity as the dependent variable. Total factor productivity takes into account the expenses for personnel and plant depreciation with respect to the value added (sales minus input). The resulting value indicates by how much higher the value added is than the mere sum of the human and capital costs that are invested. When we examine the overall productivity of firms with all the input factors, the differences among firms with different levels of R&D intensity disappear.

The previous descriptive results showing a clear advantage of R&D-intensive firms thus need to be revised in light of the results of this multivariate analysis. A firm's level of R&D intensity seems to have no separate influence on its total factor productivity (see Fig. 7.13). Rather, a firm's total factor productivity is explained by its sectoral affiliation, its level of highly skilled staff, and particularly its strategic orientation. Firms with a strong international orientation and a high vertical range of manufacturing have a significantly higher productivity performance (in terms of both labour and total factor productivity) than other firms. These structural factors have considerable explanatory power, whereas a firm's level of R&D intensity alone does not seem to have an impact on its productivity.

This chapter has analysed the innovation ability and innovation performance of firms with different levels of R&D intensity. An analysis of the latest available firm-level data from Germany revealed that a gap exists among firms with different levels of R&D intensity, especially between non-R&D-performing firms and other firms, with regard to the use of innovative process technologies and organisational methods. For non-R&D-performing firms, this gap partially arises because of their generally smaller firm size. Additionally, less R&D-intensive firms lag behind their more R&D-intensive counterparts with regard to the share of employees working in product development-related functions, such as R&D and construction and design. The results of the descriptive analysis of various innovation performance (output) indicators showed that non-R&D-performing, non-R&D-intensive firms, and R&D-intensive firms significantly differ with regard to their product innovation performance, as well as their labour productivity, as an aggregated measure of process efficiency. Although a considerable number of non-R&D-performing and especially non-R&D-intensive firms are product or even market innovators, their new products contribute less on average to their overall sales than those of more R&D-intensive firms. However, despite existing performance differences between the firms in product innovation, the descriptive analysis revealed no significant differences regarding the share of sales from service innovations, process quality, or manufacturing speed (as measures of process innovations).

An additional multivariate analysis on the selected product and process innovation performance indicators confirmed the weaker product innovation performance of non-R&D-performing and non-R&D-intensive firms relative to R&D-intensive firms; however, no relevant performance differences regarding service innovation activity, process quality, speed performance, and productivity were found among firms with different levels of R&D intensity. These results indicate that non-R&D-performing and non-R&D-intensive firms on average lag behind their R&D-intensive counterparts with respect to their product innovation performance but do not seem to have any systematic disadvantage relative to R&D-intensive firms with respect to their service innovation and process innovation performance, which may be expected to arise from their lack or low levels of R&D intensity.

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Chapter 8
Non-R&D-Intensive Firms' Innovation Sourcing

Oliver Som, Eva Kirner, and Angela Jäger

Abstract In times of increasing technological complexity and innovation dynamics, firms are no longer willing or able to have all the necessary knowledge and competences available within their enterprises. It is becoming increasingly more important for firms to explore and exploit external sources of knowledge and innovation impulses if they follow an open innovation approach. Based on novel empirical firm-level data, this chapter examines the types of external sources of knowledge and innovation impulses on which firms with different levels of R&D intensity rely and the types of external partners with which they interact in innovation collaborations. The findings show that both non-R&D-performing and non-R&D-intensive firms succeed in tapping into external sources of innovation knowledge but that they are more oriented towards practical and implicit stocks of knowledge coming from partners along their value chains or markets compared with R&D-intensive firms. As a result, both types of firms have large unused potential with regard to their collaboration activities, especially those with external R&D organisations.

8.1 Introduction

In the current hypercompetitive business environment, innovation is arguably the most effective and promising way for firms to ensure long-term business success. Innovation as a "core business process" (Tidd and Bessant 2009) is thus receiving increasing attention and is accordingly gaining increasing relevance for firms in all sectors and of all sizes. However, although many types of innovation exist (OECD 2005), R&D is still widely considered to be the main driver of innovation. Nevertheless, with too strong an emphasis on R&D, a firm might ignore the great variety

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of other available forms of innovation. Within this context, the capacity for innovation of one particular group of firms, namely, manufacturing firms with little or no R&D activities, is likely to be systematically underestimated (Arundel et al. 2008). Given that by definition, these firms do not possess any or possess few R&D resources, the lack of R&D resources can be easily considered a structural weakness regarding these firms' capacity for innovation. However, previous research has shown that non-R&D-intensive firms are not less innovative or competitive per se compared to their R&D-intensive counterparts (Santamaría et al. 2009, Barge-Gil et al. 2008; Kirner et al. 2009a). They simply do not often pursue a first-mover strategy, and they tend to focus to a greater extent on customer- and market-driven innovations (Kirner et al. 2009b; Som et al. 2010; Som 2012).

In light of the growing connectedness and exchange between different actors of the innovation system (Lundvall 1992; Edquist 1997; Nelson 1991), the permeability of firm boundaries, and the increasing openness of innovation processes (Chesbrough 2003), accessing external sources of knowledge has become a key element of innovation. Thus, both R&D-intensive and non-R&D-intensive firms face the increasing necessity to successfully assess and—if required—to adopt and implement external knowledge. This chapter highlights the different innovation-sourcing activities of non-R&D-intensive firms.

First, empirical evidence on firms' access to various sources of knowledge is presented. This dimension of knowledge is also related to firms' external innovation resources. However, in contrast to the approach to innovation through cooperation, this perspective does not concern the inter-firm combination of resources based on the relational view of the firm. Instead, the focus is on which sources of innovation knowledge are exploited by the firm, and thus, this perspective is strongly rooted in the knowledge-based view of the firm. Relevant information on a firm's innovation activity can be located inside or outside the firm. Thus, several aspects have to be considered to analyse the importance of knowledge sources for innovation as an innovation resource for firms.

Specifically, these resources reveal something about the nature of knowledge that is relevant for a firm's innovation activity. For instance, if the firm's own R&D department or external R&D organisations are its most important knowledge sources, one could argue that expert or science-based knowledge may play a decisive role in the innovativeness of the firm. However, firms without formal R&D may emphasise practical or experience-based forms of knowledge to a greater extent (Heidenreich 2009; von Tunzelmann and Acha 2005; Hirsch-Kreinsen 2004, 2008a, b; Sundbo 1996). Hence, it would be interesting to determine whether such knowledge within non-R&D-performing firms generated by modes of "learning by doing, learning by using, learning by interacting, learning by producing and learning by searching" (Lundvall and Johnson 1994) is linked to specific sources (e.g., other employees within the firm, customers, and/or suppliers). This potential link is addressed in the first part of this chapter.

Afterwards, the second part of this chapter analyses the concrete innovation collaboration activities of non-R&D-intensive firms based on recent firm-level data.

As the relational view of the firm (Dyer and Singh 1998; Gulati et al. 2000) argues, innovation resources do not necessarily have to be located within the firm. Instead, inter-firm collaborations and alliances represent another possibility for firms to either access valuable innovation resources outside the firm or to create such valuable innovation resources by combining the complementary innovation resources of the firm with those of an external partner. As these valuable resources outside the firm can also encompass valuable knowledge for innovation, the variables of innovation cooperation and the sources of innovation knowledge are similar to some extent.

However, innovation cooperation requires active cooperation with external partners. Such active cooperation not only encompasses the reciprocal flow of knowledge but also requires social networking abilities and collaboration competences (Lorenzoni and Lipparini 1999; Duschek 1998; Simonin 1997), and it is characterised by a much greater degree of mutual trust and interdependency among the cooperating partners. Innovation cooperation can take place with either other firms (e.g., customers, suppliers, competitors, and/or service providers) or external R&D organisations (e.g., universities, R&D laboratories, and/or non-profit R&D organisations). Therefore, innovation cooperation with external R&D organisations should not be confused with external R&D, as the quality of the reciprocal interaction in collaborations (the exchange of knowledge) by definition goes far beyond mere R&D subcontracting (the exchange of money for knowledge).

8.2 Sources of Knowledge

The Shift from the R&D Paradigm to a Systemic Innovation Approach R&D represents one of the most crucial resources for firms to generate the necessary new knowledge to successfully develop new products, implement them in the market, and create technical processes and thus to gain a competitive advantage and achieve economic success. Following the arguments of the classical R&D-centred approach, firms that do not undertake R&D cannot themselves generate the necessary knowledge for innovation. They cannot generate profit from knowledge spillovers similarly to R&D performing firms because they have less access to the economy's stock of knowledge and thus face higher barriers to the development of new products or production methods. However, at least for the German manufacturing industry, this assumption has been partially contradicted by the short analysis of the macroeconomic performance of firms in non-R&D-intensive sectors presented in Chap. 3.

As a consequence, the notion of "innovation" began to attract increasingly more attention in the late twentieth century, as the definition of industrial R&D increasingly turned out to be too restrictive. This dissatisfaction with R&D indicators led to the development of a new set of "science, technology, and innovation" (STI) indicators within the framework of the OSLO Manual (1992).[1] The OSLO Manual extended the then-prevailing R&D focus of the Frascati Manual to the broader term of "innovation" and proposed harmonised guidelines for collecting and interpreting firms' innovation measures (Freeman and Soete 2009). Thus, it is widely recognised that R&D does not capture all aspects of innovation, which often occur through other channels.

In theory, today, the decline of the R&D focus is driven, on the one hand, by a shift in the analytical focus towards innovation-related activities that go beyond the scope of formal R&D and, on the other hand, by a shift in the understanding of the nature of the innovation process itself, as evident in works such as David (1996), Foray (1998), Lundvall and Johnson (1994), and Edquist and Texier (1998). The main developments are as follows:

- The understanding of firms' internal innovation resources, expressed in terms such as "routines", "capabilities", or "competences" (Nelson and Winter 1982; Winter 1987; Teece and Pisano 1994; Prahalad and Hamel 1990) has expanded, and "knowledge" is generally referred to as the most important predictor of innovation (e.g., Grant 1996a; Spender and Grant 1996).
- Engineering, design, production, and distribution activities (Kline and Rosenberg 1986; Freeman and Soete 1997; Koschatzky et al. 2001) as well as investment in capital equipment related to innovation are increasingly appreciated as additional determinants of successful innovation (e.g., Evangelista et al. 1998; Evangelista 1999).
- A firm's ability to systematically exploit the effects produced by new combinations and uses of components and practices in the existing stock of knowledge is acknowledged to be another crucial enabler of successful innovation (David and Foray 1995; Kline and Rosenberg 1986). This type of innovation frequently labelled "architectural innovation" (Henderson and Clark 1990). As Kline and Rosenberg (1986) argue, when firms are faced with the need to innovate, they first look to their existing stock of knowledge, and if the answer cannot be found there, they then consider whether it makes sense to spend resources on R&D.
- Firms are increasingly recognised to be embedded in social systems of innovation (e.g., Lundvall 1992; Nelson 1993). This recognition highlights the systemic nature of innovation processes, emphasising that firms normally innovate not in isolation but in collaboration and interdependence with other organisations (e.g., suppliers, customers, competitors), non-profit entities (e.g., universities, schools, and government ministries), institutions (e.g., laws, rules, and norms), and other social entities (e.g., local residents and consumers). Moreover, firms may intentionally and actively use their surrounding external sources in terms of collaboration (e.g., Dyer and Singh 1998; Nooteboom 1999), user-driven innovation (e.g., Lundvall 1985; von Hippel 2004), or "open innovation" (e.g., Chesbrough 2003).

[1] Until recently, the OSLO Manual has been published in three revisions (1992, 1997, and 2005), each taking into account the progress made in understanding the innovation process and its economic impact.

Because of these developments, the innovation process is understood to be complex and variable. There is no one best way to innovate. Instead, against the background of modern, knowledge-based economies, the use of R&D as a proxy or surrogate measure of a wider range of innovation is no longer adequate (Arundel et al. 2008; Raymond and St-Pierre 2010), and the theoretical focus needs to shift "from R&D to learning processes", as all knowledge produced within a firm cannot be attributed to formal research activities (Foray 2006). Rather, any activity involving the production or use of a good (or service) can lead to learning and hence knowledge production. A complex of different ideas and solutions are therefore equally important for effective innovation. Hence, formal R&D remains only *one* among many inputs and sources of innovation within firms (Smith 2005; Freeman 1994b; Nelson 2000; Schmiedeberg 2008).

The Knowledge-Based View of the Firm The concept of knowledge as a strategic resource for firms gained interest in the literature because industrialised economies experienced a shift in importance from tangible resources towards intellectual, intangible assets (Nooteboom 2009). This shift is commonly described by the term "knowledge-based economy" (Foray 2006) and is reflected in an ever-increasing proliferation of the production, processing, and transfer of knowledge and information. This evolution spread across the entire economic system, highlighted the importance of knowledge as a key driver of economic growth, and thus substantially contributed to the development of a knowledge-based theory of the firm (Hansen et al. 1999; Czarnitzki and Wastyn 2009).

The "knowledge-based view of the firm" (Spender and Grant 1996; Grant 2002) encompasses recent approaches within strategic management research that focus on a firm's specific knowledge bases and its ability to evolve its stock of knowledge through learning processes as the major, persistent source of the firm's competitive advantage in the context of dynamic market environments (Eisenhardt and Santos 2002; Spender and Grant 1996; Decarolis and Deeds 1999; Welge and Al-Laham 2008).

The knowledge-based view of the firm comprises a broad range of ideas and strands of research, including the resource-based theory (Barney 1986; Wernerfelt 1984; Rumelt 1984), and particularly draws on the competence- and capability-based analysis (Prahalad and Hamel 1990; Grant 1991; Amit and Shoemaker 1993), epistemological contributions (Polanyi 1958, 1966; von Hayek 1945), and organisational learning contributions (Levitt and March 1988; Huber 1991; Argyris and Schön 1978) of the resource-based theory. Key contributions to the knowledge-based view of the firm include Demsetz's (1988, 1991) analysis of the knowledge-based boundaries of firms, Brown and Duguid's (1991) examination of knowledge-based organisations, Kogut and Zander's (1992) view of the firm as a knowledge-processing institution, and Nonaka's (1994) analysis of knowledge creation within the firm, among others. With regard to theory construction, Grant (1996a, b), Liebeskind (1996), Szulanski (1996), and Spender (1996a, b) represent first attempts to reconcile and integrate some of these contributions and thus provide significant evidence on the importance of knowledge as a process and the necessity of coordinating knowledge to achieve a strategic competitive advantage. The knowledge-based view of the firm emerged in the context of the rapid upcoming and enormous competitive success of Japanese corporations such as Honda, Canon, Matsushita, NEC, and Sharp in the 1990s and their ability to respond quickly to customers, create new markets, rapidly develop new products, and dominate emergent technologies. As the secret to their competitive success was considered to be their unique approach to managing the creation and coordination of new and especially tacit knowledge (Nonaka 1991), this view paved the way for the development of the knowledge-based view of the firm.

What is common to all knowledge-based contributions is that firms are conceptualised as heterogeneous, knowledge-bearing entities that cannot be interpreted by examining their contractual constitution only (Kogut and Zander 1992). Proponents of the knowledge-based view underline the functional dimension of firms as organisational entities that are repositories of distinct productive (technological and organisational) knowledge and that can learn and grow on the basis of this knowledge (Foss 1996).

Empirical evidence indicates that firms persistently differ in their relative competitive performance. According to the knowledge-based view, firms persistently differ in their performance because they differ in their information and know-how, knowledge stocks, and knowledge flows. Thus, the persistence of the differences in firm performance lies in the difficulty of both transferring and imitating knowledge in terms of information and know-how (Kogut and Zander 1992). For this reason, the knowledge-based view has to progress beyond the mere classification of knowledge into information and know-how by determining *why* knowledge is not easily transmitted and replicated between firms and by identifying which characteristics of knowledge influence the degree to which it is transferable and replicable.

To develop a knowledge-based view of the firm, Kogut and Zander (1992), Grant (1996), and Nonaka (1994) identify several characteristics explaining why knowledge may not be easily transferable and replicable between firms:

– The type of knowledge (implicit and explicit knowledge)
– The carriers of knowledge (individuals and organisations)
– The content of knowledge (specificity and social complexity)

Because of data availability, the empirical findings presented in this chapter solely focus on the carriers or sources of knowledge.[2] This dimension of knowledge is located at the level of social interaction and concerns the differentiation between *individuals* and *organisation* as knowledge carriers. Considered as an entity, both levels form a firm's total knowledge stock. Individuals are the primary carrier of explicit and—most important—tacit knowledge. As shown above, individuals are the sole entities within an organisation that can create tacit knowledge (Nonaka 1994). However, the knowledge-based view postulates that only collective organisational knowledge serves as a source of competitive advantage. If individual

[2] For a brief overview on the knowledge-based view of the firm, its different dimensions and concepts, and suggestions for further reading, see Som 2012, pp. 191 ff.

knowledge remains implicit and if it is not transferred and integrated among the members of the organisation or aggregated into some type of organisational knowledge, it remains relatively valueless. Therefore, individual knowledge is primarily considered the necessary precondition on which organisational, firm-specific, and tacit knowledge can emerge and develop (van den Hooff et al. 2004; Haas and Hansen 2005). Firms do not attain a persistent competitive advantage until they manage to develop, exploit, and evolve a common stock of shared, "sticky" (von Hippel 1994) knowledge.[3] Hence, firms possess a common stock of "organisational" knowledge that is shared by all their organisational members (Pautzke 1989).

In contrast to the approach to innovation through cooperation, the knowledge-based perspective does not concern the inter-firm combination of resources based on the relational view of the firm. Instead, the focus is on which sources of innovation knowledge are exploited by the firm. Because relevant information on a firm's innovation activity can be located inside or outside the firm, several aspects have to be considered to analyse the importance of knowledge sources for innovation as an innovation resource for firms.

First, these resources reveal something about the nature of knowledge that is relevant for a firm's innovation activity. For instance, if the firm's own R&D department or external R&D organisations are its most important knowledge sources, one could argue that expert or science-based knowledge may play a decisive role in the innovativeness of the firm. However, firms without formal R&D may emphasise practical or experience-based forms of knowledge to a greater extent (Heidenreich 2009; von Tunzelmann and Acha 2005; Hirsch-Kreinsen 2008a, b). Hence, it would be interesting to determine whether such knowledge within non-R&D-performing firms generated by modes of "learning by doing, learning by using, learning by interacting, learning by producing and learning by searching" (Lundvall and Johnson 1994) is linked to specific sources (e.g., other employees within the firm, customers, suppliers).

Second, these resources provide information about the absorptive capacity (Cohen and Levinthal 1989, 1990) of a firm (see Chap. 9 in this book). As this concept is originally linked to a firm's R&D intensity, non-R&D-performing firms might be assumed to lack absorptive capacity and thus to rely on internal sources of knowledge to a greater extent than other firms. However, as these firms do not perform R&D activities, they lack one of the most important firm-internal sources

[3] For example, Haas and Hansen (2005) view organisational knowledge as "[. . .] a property of the overall firm, rather than of individual members or task units". Likewise, Dyer and Hatch (2006) stress the social dimension of organisational knowledge, as they argue that individual explicit or tacit knowledge does not become relevant for a firm's competitive performance until it is "[. . .] embedded in the firm's routines, human skills, and relationships". In contrast, Berman et al. (2002) suggest that the organisational knowledge that is required to perform a complex task is diffused among the individuals in a firm. Each individual possesses only a part of the entire organisation's knowledge.

of innovation knowledge and may thus be particularly dependent on external sources of information, which require a high level of absorptive capacity.

To measure firms' knowledge sources, we use a set of questions indicating firms' most relevant information sources for triggering innovation activities provided by the *German Manufacturing Survey* 2012 (Jäger and Maloca 2013), which is regularly conducted by the Fraunhofer ISI. We can therefore distinguish between firm-internal sources (e.g., own R&D, management, and employees in production) and firm-external knowledge sources (e.g., other firms such as customers, suppliers, and R&D organisations as well as conferences, trade fairs, and other professional events). Similar to the indicator of innovation collaboration, this variable also allows to determining the frequency of different knowledge sources to be stratified across the four fields of innovation (new products, new technical processes, new organisational or management concepts, and new product-related services).

Empirical Results This section reporting the empirical findings begins with a general overview of the relevance of internal and/or external sources of innovation knowledge and impulses for different fields of innovation (Fig. 8.1). First, different fields of innovation clearly differ in terms of the degree to which they rely on internal and external sources of innovation impulses. For instance, product innovations in the majority of firms benefit most from a combination of internal and external sources of innovation impulses across firms of all levels of R&D intensity. Nevertheless, firms with no or low R&D intensity more frequently state that they gain relevant impulses for new products from outside or inside their organisations only. In contrast, with regard to developing new firm-internal organisational processes such as new ways of organising work and production, more than two-thirds of the firms report that they receive impulses from inside their companies. This result seems to be reasonable, as external partners usually do not have the necessary insight into a firm's "way of doing things". With regard to technical process innovations (e.g., the implementation of new production processes) and product-related service innovations (e.g., installation, monitoring, and business models), a more balanced picture between internal and external sources is revealed. Approximately 30 % to 40 % of the firms state that they only rely on internal sources of impulses in these fields of innovation, while approximately between 50 % and 60 % receive impulses from both internal and external sources. Therefore, the higher share of firms reporting only external sources for service innovations can be explained by the fact that service users (i.e., customers) might also be carriers of valuable innovation impulses for service providers. Obviously, the potential for open innovation in terms of gaining external sources of innovation impulses greatly varies between different types of innovation.

As the above figure shows, no specific pattern of internal or external sources of innovation impulses is revealed for either non-R&D-intensive or non-R&D-performing firms. The results for these firms are generally aligned with those for firm of other levels of R&D intensity. Hence, there is no indication that these firms seek to (over-)compensate for their low level of in-house R&D by increasing their use of primarily external sources relative to firms with higher R&D intensity.

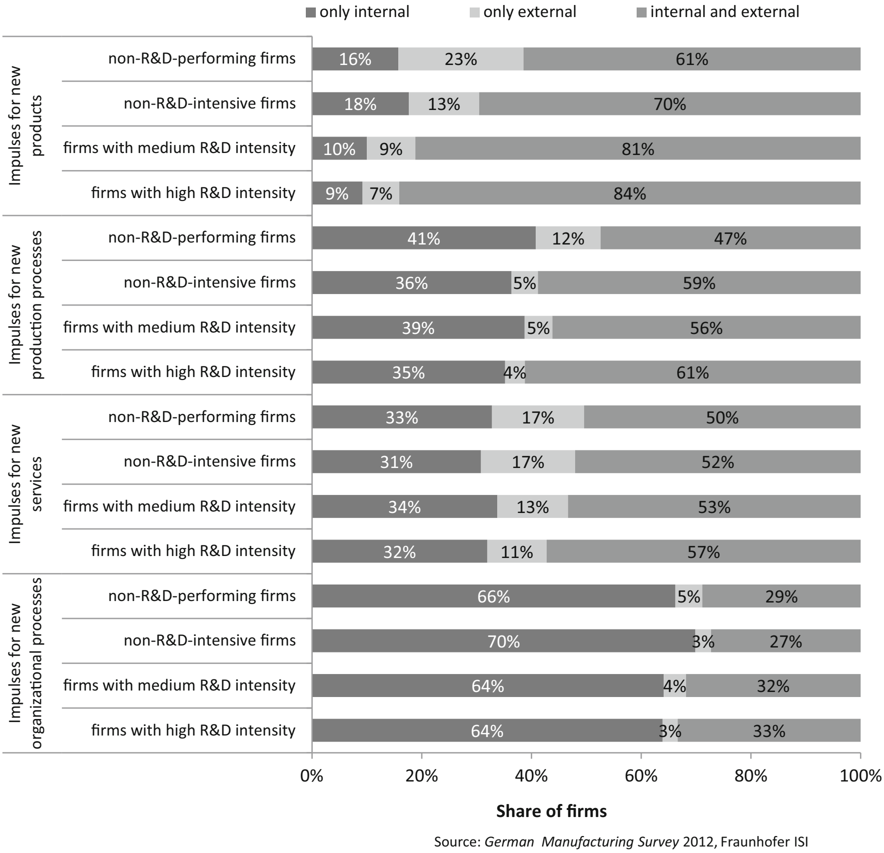

Fig. 8.1 Internal and external sources of innovation impulses

Nevertheless, the findings above reveal some peculiarities about non-R&D-intensive firms. For instance, with regard to product and technical process innovation, these firms more frequently rely on either internal or external sources of innovation impulses only.

To shed more light on this concept, the next figure (Fig. 8.2) shows the types of internal and external sources of innovation impulses that the surveyed firms stated at least once (i.e., regardless of the field of innovation).

The greatest differences between firms with no/low R&D intensity and the other firms relate to the sources of innovation impulses from "in-house R&D/engineering", "customer service", "suppliers", and "external research organisations". With regard to in-house R&D and engineering, the relevance of this source interestingly only slightly increases with a higher level of R&D intensity. Instead, the most determinate factor seems to be whether in-house R&D is performed at all. Nevertheless, interestingly, more than 40 % of non-R&D-performing firms name

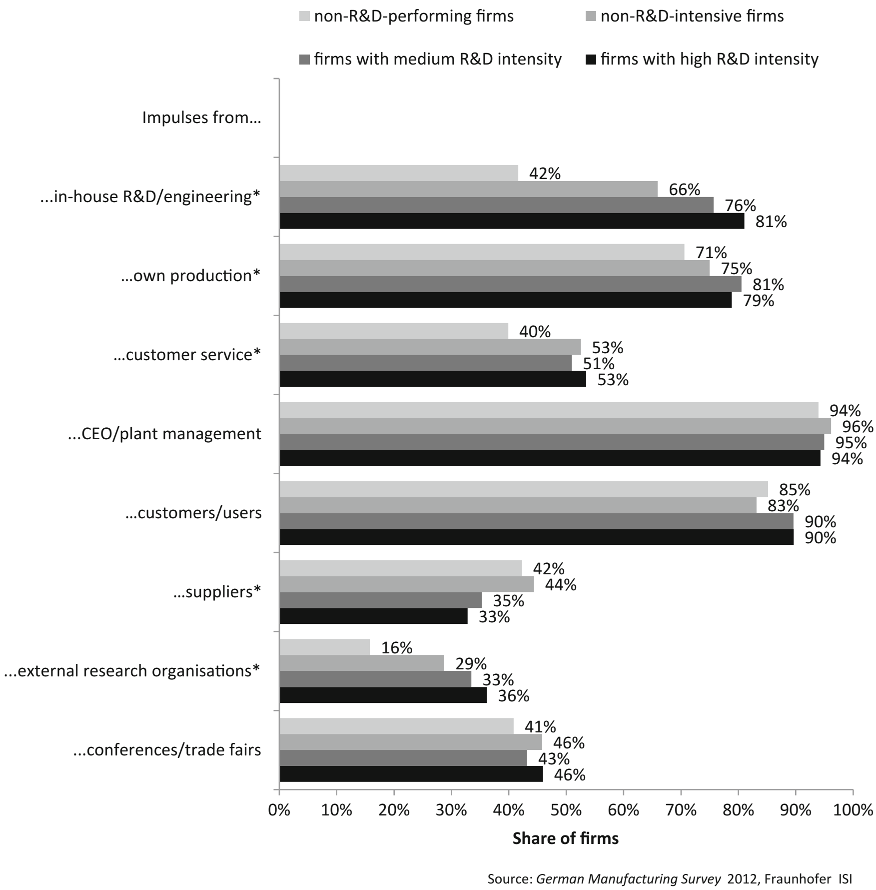

Fig. 8.2 Different sources of innovation impulses in general

engineering (which could not reasonably be R&D) as an important source of innovation impulses, which indicates that innovation impulses are not necessarily restricted to R&D. Moreover, in-house R&D is not the only relevant source of innovation impulses in general. Hence, impulses from production, the CEO/plant management, and customers and users are of equal or even greater importance for firms. The high values for CEO/plant management reveal that innovation in many firms still seems to be a top-down process that is actively driven by a few individuals in management instead of being rooted broadly in the entire enterprise.

Similarly, innovation impulses from external R&D organisations almost play no role for non-R&D-performing firms. This result underlines the previous findings that these firms do not compensate for their lack of internal R&D by extensively using external R&D knowledge. In contrast, impulses from internal and external R&D sources seem to complement rather than substitute for each other. This finding is in line with the concept of absorptive capacity (see Chap. 9 in this book), which states that in-house R&D is a necessary precondition for firms to be able to successfully exploit external stocks of innovation knowledge. Hence, it would be interesting to analyse in future research how these 16 % of non-R&D-performing firms nevertheless manage to absorb external R&D sources of innovation impulses. Nevertheless, a firm's orientation towards R&D organisations as external sources of innovation impulses mainly depends on whether the firm performs in-house R&D at all instead of whether the firm has a particular level of R&D intensity.

Innovation impulses from suppliers obviously play a more important role for both non-R&D-performing firms and non-R&D-intensive firms than for R&D-intensive firms. Given the finding that non-R&D-intensive firms often position themselves as process specialists in their value chain, suppliers can be assumed to provide them with impulses for new technical processes, for instance, by changing the requirements for new materials, parts, or equipment and thus by triggering the implementation of new manufacturing techniques. In contrast, firms with higher levels of R&D intensity often develop their own products and technical processes simultaneously within the same R&D project. Accordingly, impulses from suppliers may be less relevant for R&D-intensive firms.

Because R&D-performing firms are more active in product development, they more frequently offer product-related services to their customers. These services are also often developed and offered in parallel to new product. Consequently, innovation impulses from their customer service play a more important role for these firms, whereas there are no differences between firms of other levels of R&D intensity.

These preliminary findings and interpretations indicate that the importance of different sources of innovation impulses is likely to be distinctively linked to certain types of innovation. Hence, the following section elaborates on this relation by linking the relevance of individual sources of impulses to specific types of innovation.

Product Innovation The detailed findings presented for the field of product innovation in Fig. 8.3 below confirm our previous assumptions: relative to R&D-intensive firms, both non-R&D-performing and non-R&D-intensive firms more frequently receive impulses for new products from internal sources as well as external suppliers. The differences are statistically significant. In addition, in-house engineering (non-R&D-performing firms), in-house R&D (non-R&D-intensive firms), plant management, and customers and users are the most important sources of innovation impulses for both R&D-intensive and non-intensive/non-performing firms. This finding supports previous findings that product development in non-R&D-intensive/performing firms more strongly relies on stocks of practical and experience-based knowledge that is located in production than on formal, scientific knowledge. Surprisingly, our analysis does not support findings from previous studies that non-R&D-intensive firms are more strongly embedded in their local and regional niche markets and that they thus have closer interactions with their customers and users (e.g., Rammer et al. 2011).

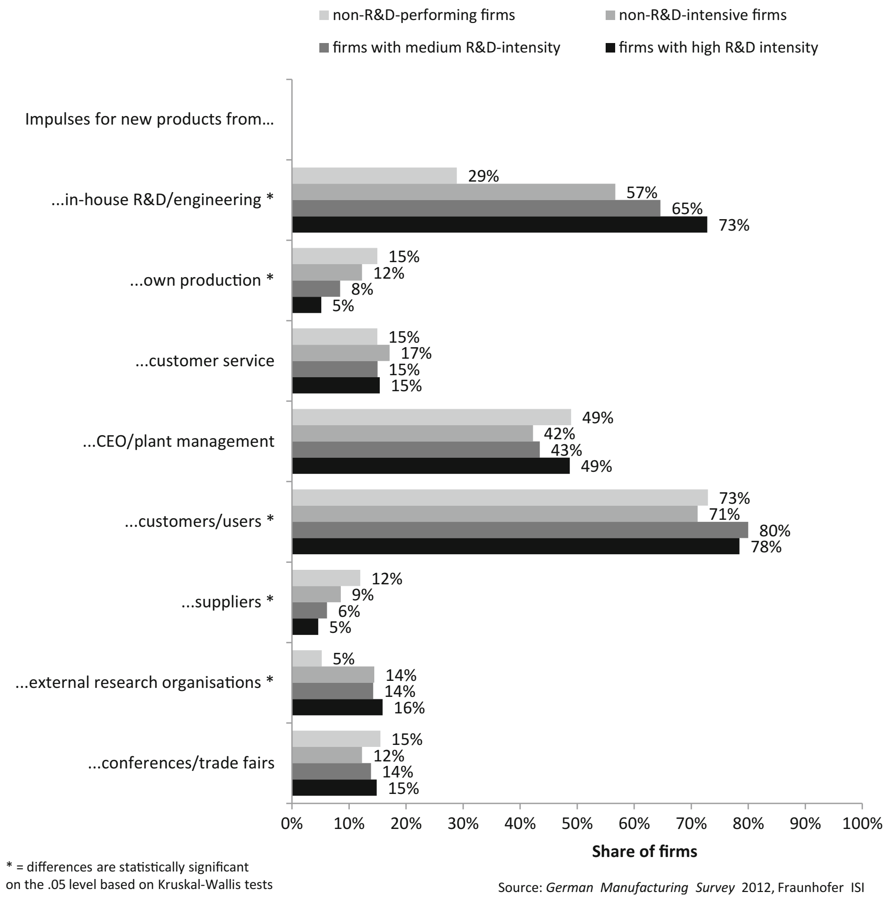

Fig. 8.3 Sources of impulses for product innovation

In contrast, firms with no or low R&D intensity consider innovation impulses from customers and users to be significantly less important than (very) R&D-intensive firms do. One reason for this result could be that R&D-intensive firms frequently develop products of high complexity, such as automation systems or high-performance machine tools, in a single batch in close interaction with their users and customers.

When we examine the success of different internally or externally oriented search strategies for innovation impulses in terms of product innovation implemented in the market, we find that a strategy balancing between internal and external sources of innovation impulses is the most successful. Firms that rely on internal and external sources to a greater extent have a statistically significant higher probability of implementing a new product in the market than firms that rely on internal or external sources of impulses only. Interestingly, a higher share of firms with only internal sources of innovation impulses are product innovators relative to their counterparts with only external sources. Both of these findings are persistent regardless of firms' innovation intensity.

These findings to some extent qualify the implicit assumption within the open innovation approach of "the more open, the better". In the case of market innovations that are offered for the first time in the market by a firm and that thus have a much higher degree of novelty, this trend becomes even more prominent. In this case, R&D-intensive firms that rely on internal sources of innovation impulses only (most likely those from their R&D department) are more frequently successful market innovators (up to 60 %) than R&D-intensive firms that rely on external sources only (approximately 30 %) or internal and external sources (between 30 % to 50 %). Obviously, opening up the innovation process in the development of market novelties could increase the risk that a firm loses relevant knowledge or increase its time to market. However, for non-R&D-intensive and non-R&D-performing firms, a different dynamic arises with regard to market innovation. For these firms, the share of market innovators (approximately 7 % to 10 % higher) is higher among those that combine internal and external sources than among those that rely on either internal or external sources of innovation impulses only.

Service Innovation Firms rarely rely on impulses from in-house R&D or engineering for product-related service innovations relative to physical product innovations, even though R&D-intensive firms more often name such sources as relevant (10–12 %) (Fig. 8.4). This result might be due to the simultaneous development of new products and their accompanying services, as new products can be engineered according to the requirements of the later service offer (e.g., by integrating sensors for online monitoring).

Generally, the most relevant sources of impulses for service innovation are customer service, management, and customers and users. This result holds for firms of all levels of R&D intensity, except for customer service, for which the differences are not statistically significant here.

With regard to non-R&D-performing firms, however, two findings are noteworthy. First, own production is significantly more relevant for non-R&D-performing firms than for the other firms as a source of service innovation impulses. This result may be observed because substantial engineering knowledge is located in production even if a firm does not have a dedicated department for engineering (Som 2012). Second, only 34 % of non-R&D-performing firms state that customer service is a relevant source of service innovation impulses. One the one hand, this result could indicate that customer service does not play an important role for these firms' rather simple, less complex products, such as metal or plastic parts that are manufactured in large batch sizes (e.g., screws and bolts), as these products do not provide many options for product-related service offerings. On the other hand, this result could also arise from an underestimation of the importance of informing service development based on feedback from customer impulses back into, the importance of institutionalised processes to secure this feedback.

With regard to the successful implementation of new services in the market, a balanced strategy of using internal and external sources of impulses for service

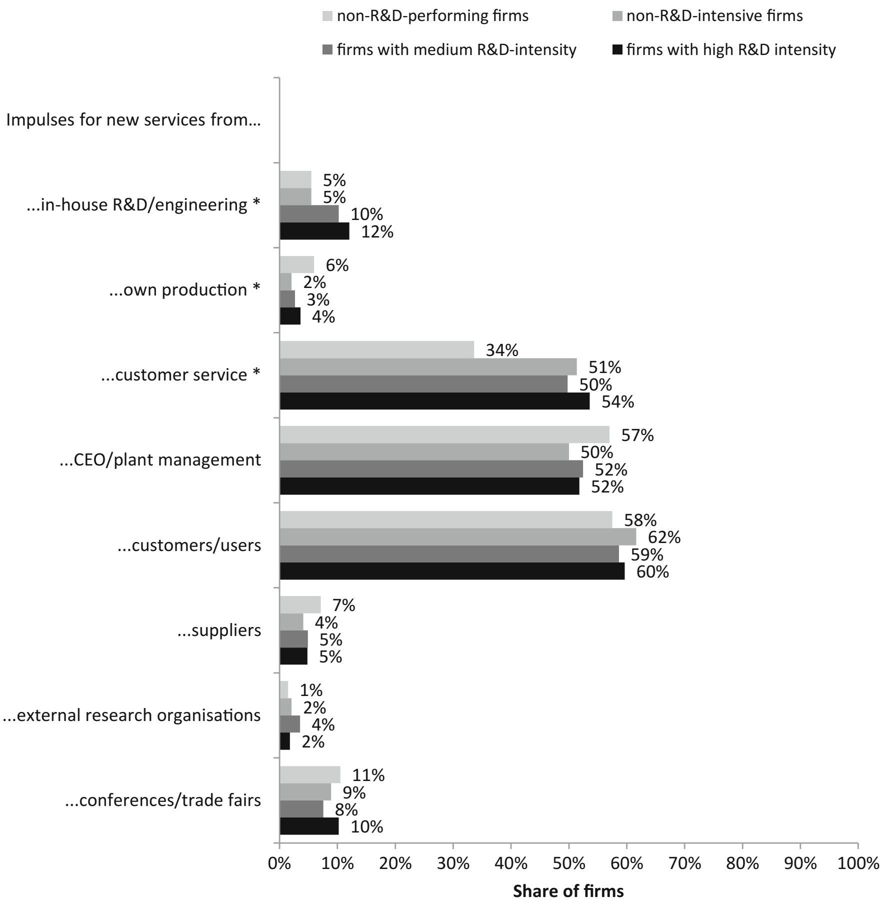

Fig. 8.4 Sources of impulses for service innovation

innovation is more beneficial than using external sources only. Obviously, recognising the potential for new service offerings requires intimate knowledge about a product and its architecture. Moreover, firms' capacity to recognise service benefits on the demand side still seems to be less developed than their capacity to recognise requirements to develop new functionalities for or increase the performance of physical products. For very R&D-intensive firms, firms that use only internal sources, only external sources, or both types of sources do not differ in their propensity to develop a new service. This result might be observed because these firms already include their customers in the development of their tailor-made and highly customised products and services.

Technical Process Innovation The analysis of the sources of innovation impulses in the field of technical process innovation provides a broad picture (Fig. 8.5) revealing that firms rely on multiple internal and external knowledge sources for

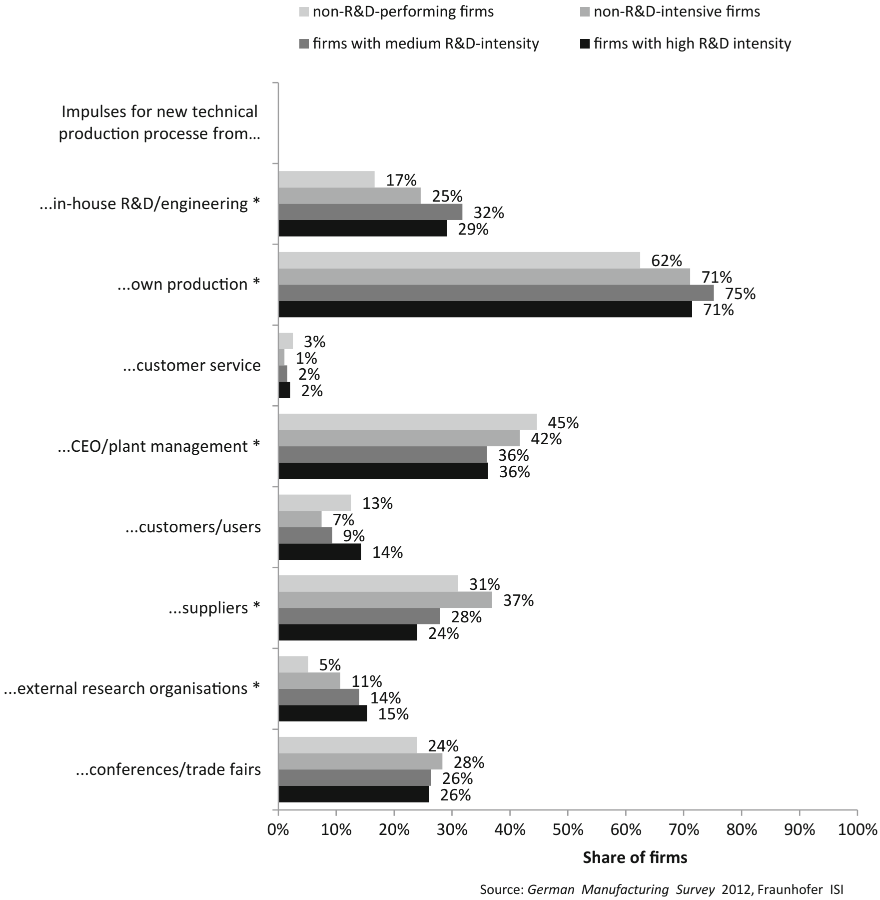

Fig. 8.5 Sources of impulses for technical process innovation

technical process innovation. As expected, own production is regarded as most relevant source impulses by most of the firms, followed by management, suppliers and in-house R&D/engineering, and conferences/trade fairs.

Several differences among the firms can be observed with respect to their R&D intensity. First, non-R&D-intensive/performing firms more frequently rely on impulses from suppliers and management for technical process innovation. These firms may rely on management in this regard because many non-R&D-intensive/performing firms are small-sized, family-managed firms with a CEO who often has a strong technical or engineering background and expertise. Second, as a competitive strategy, these firms often position themselves in the market as a "technical process specialist" (Som 2012). This strategy is strongly based on the ability to outperform competitors with outstanding process performance in terms of speed, quality, and complexity as well as the ability to handle new materials and functional surfaces.

To implement such a strategy, these process specialists are highly dependent on the quality and reliability of their manufacturing equipment suppliers and providers, which is often reflected in their close collaboration with these suppliers and providers (Som 2012; Hirsch-Kreinsen 2007).

Interestingly, non-R&D-performing firms could also be expected to consider their own production to be a more relevant source of impulses for technical process innovation, because they theoretically are not inferior to other firms in technical process innovation. Nevertheless, only 62 % of non-R&D-performing firms consider their own production to be a relevant source of impulses, whereas more than 71 % of firms the other groups consider their own production to be a relevant source of impulses. This result does not seem logical. However, one possible explanation could be that non-R&D-performing firms have higher shares of low and unskilled employees in production (Som 2012) than R&D-performing firms. Although these employees can be important sources of impulses for technical process innovation, many firms are neither currently aware of the value of these employees as sources of technical process innovation impulses nor able to exploit this source of impulses (Galiläer and Wende 2008a, b).

For R&D-performing firms, both in-house R&D and external R&D organisations are somewhat relevant sources of impulses, even if they are not the most important sources. However, the importance of R&D knowledge will likely increase in the future, as increasingly more firms start to couple the development of new products and processes to address the increased technological complexity of product development and to maintain the time to market for new products within a profitable range.

Finally, a strategy that balances both internal and external sources of innovation impulses is also most promising for the implementation of new technical processes. However, the share of technical process innovators within the past three years only slightly differs (by approximately 3 % points) between firms that use an internal-external sourcing strategy and firms that use a solely internal sourcing strategy. Thus, external sources of innovation impulses play a less important role for technical process innovation than for product innovation.

Organisational Innovation The findings regarding sources of organisational innovation impulses show that organisational innovation impulses (e.g., new concepts of work organisation and human resource management) mostly originate from inside firms, particularly from (top) management (Fig. 8.6). This result holds for firms of all levels of R&D intensity and corroborates findings from previous studies (e.g., Som et al. 2012). Moreover, changes in organisations often rely on informal and practical knowledge that cannot be simply transferred from one firm to another (Som and Diekmann 2014). Hence, even if external sources are recognised as important sources of organisational innovation impulses, which is more often the case for R&D-intensive firms, they have to be adapted to the context and specific needs of the organisation. Surprisingly, most firms lack the ability to adapt and implement organisational solutions on their own (Som and Diekmann 2014).

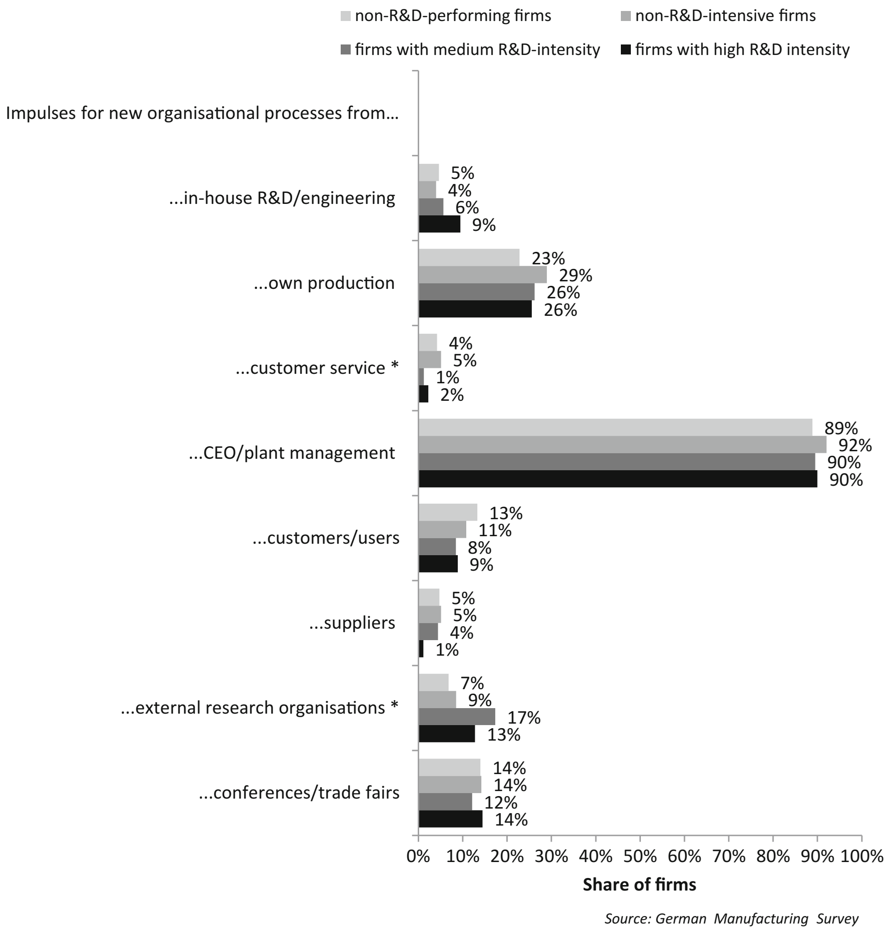

Fig. 8.6 Sources of impulses for organisational innovation

The second significant difference between non-R&D-intensive/performing firms and (very) R&D-intensive firms relates to the importance of customer service as an internal source of impulses. This difference is reflected in the relevance of customers/users as external sources of impulses, although the difference is not statistically significant for this source of impulses. Hence, it can be argued that customer service as the interface to customers operates as a communication channel by which customer impulses are fed into organisations. The greater relevance of customer impulses for non-R&D-intensive/performing firms might arise because they are suppliers for larger original equipment manufacturers (OEM), which have distinct requirements for the design of organisational processes on the supplier side. For instance, in the automotive industry, OEMs define strict criteria for the way in which product development processes are organised (e.g., stage gates and/or milestones) and thereby trigger changes in their suppliers' organisational processes.

Given these findings, it is not surprising that the probability of successfully developing and implementing a new organisational process does not differ between firms that primarily rely on internal sources and firms that rely on both internal and external sources. The strategy of solely relying on external sources seems to be less beneficial for organisational innovation.

Summary The empirical findings regarding the relevance of internal and external sources of innovation impulses presented in this section can be summarised as follows: First, regardless of firms' level of R&D intensity, internal and external sources of innovation impulses and knowledge shape different types of innovation in different ways. Firms more strongly rely on impulses from in-house R&D, external R&D, customers and users for product and service innovations, and mostly rely on internal sources for organisational innovation. In contrast, technical process innovation instead can be triggered by a multitude of different internal and external sources of impulses. Moreover, as the correlation analysis with the share of successful innovators in each field shows, firms require both internal and external sources for successful innovation. Further, sourcing strategies that focus on external sources only are less beneficial for firms. In this sense, the implicit line of argumentation within the open innovation approach (Chesbrough 2003) has to be qualified to some extent. A higher degree of openness towards external sources of impulses does not foster innovation by itself, and external sources of impulses are not able to substitute for a lack of internal sources of innovation impulses and professional innovation management processes. Instead, external sources of impulses can perfectly complement ideas and impulses from inside the company. Hence, firms must also possess well-functioning, systematic processes and a certain level of internal connectivity to ensure that their external sources of impulses can be successfully transformed into new products, services, and processes.

Therefore, non-R&D-performing/intensive firms are not able to (over)compensate for their low R&D intensity by increasing their use of external sources of innovation impulses and knowledge relative to other firms. As a result, the importance that non-R&D-performing/intensive firms assign to different internal and external sources is generally identical to that of R&D-intensive firms. Nevertheless, some structural differences arise between firms that are rooted in their level of R&D intensity: First, most obviously, impulses from in-house R&D and from external R&D organisations play a much less important role for non-R&D-performing/intensive firms than for R&D-intensive firms. Nevertheless, a certain share of non-R&D-performing firms seem to be able to successfully receive relevant impulses from external R&D partners. This finding raises the question of how these firms manage to receive these impulses. Second, suppliers and own production play a more important role as sources of impulses for non-R&D-intensive/performing firms than for R&D-intensive firms; the importance of these sources might be due to non-R&D-intensive/performing firms' specific knowledge culture (driven by implicit, practical knowledge) and their positioning in the market (process specialists). Further, the determining factor for the relevance of different sources of innovation impulses for a firm seems to be not whether the firm has a particular level of R&D intensity but whether the firm performs R&D at all. Thus, starting in-house R&D activities even on an occasional level might change the scope of the sources of impulses that can be used to trigger innovation projects.

Nevertheless, non-R&D-performing/intensive firms have a similar capacity to R&D-intensive firms to profit from external sources of innovation knowledge and impulses. Hence, the classical explanation of firms' absorptive capacity based on their level of R&D intensity appears to require conceptual and methodological improvement, as it cannot explain the empirical phenomenon of why firms with low or no R&D intensity are able to successfully exploit external sources of innovation knowledge and impulses. This point is addressed in more detail in Chap. 9 of this book.

8.3 Patterns of Innovation Collaboration

Many firms respond to the challenges of increased market competition by intensifying their collaboration activities with competent external partners. They aim to enhance their own existing core competences with additional external know-how and to compensate for their lack of own resources. Collaboration can open up additional channels for know-how exchange for mutual benefit and can enable firms, especially SMEs, to pool otherwise scarce or lacking resources. Furthermore, collaboration helps firms to share risks between partners. Risk sharing can be especially important for innovation projects, which are often associated with a considerable level of risk (Wiendahl et al. 2005; Tidd and Bessant 2013; Schuh et al. 2005; Prahalad and Hamel 1990).

With regard to the effect of collaboration activities on firms' innovation performance, our earlier analyses have shown that non-R&D-intensive firms strongly profit from R&D collaborations with both research institutions and other firms (Kirner et al. 2010). Collaborating non-R&D-intensive firms have a statistically significant superior innovation performance compared to those that do not collaborate. These results have been additionally verified by a matched-pairs analysis, confirming the positive effects of R&D collaboration activities on the product and market innovation performance of otherwise similar non-R&D-intensive firms (Kirner et al. 2010). Furthermore, a recent study of different strategic alliances shows that sharing resources, costs, and risks is particularly important for non-R&D-intensive firms (Li et al. 2013).

Given the potentially large advantage of external collaboration activities for non-R&D-intensive firms' innovation performance, considerable room for improvement with regard to their R&D collaboration intensity remains, as new empirical results show. According to the results of an analysis of the most recently available firm-level data from the German Manufacturing Survey 2012 (Jäger and Maloca 2013), a gap clearly exists among non-R&D performing firms, non-R&D-intensive firms, and R&D-intensive firms in terms R&D collaboration activity (see Fig. 8.7).

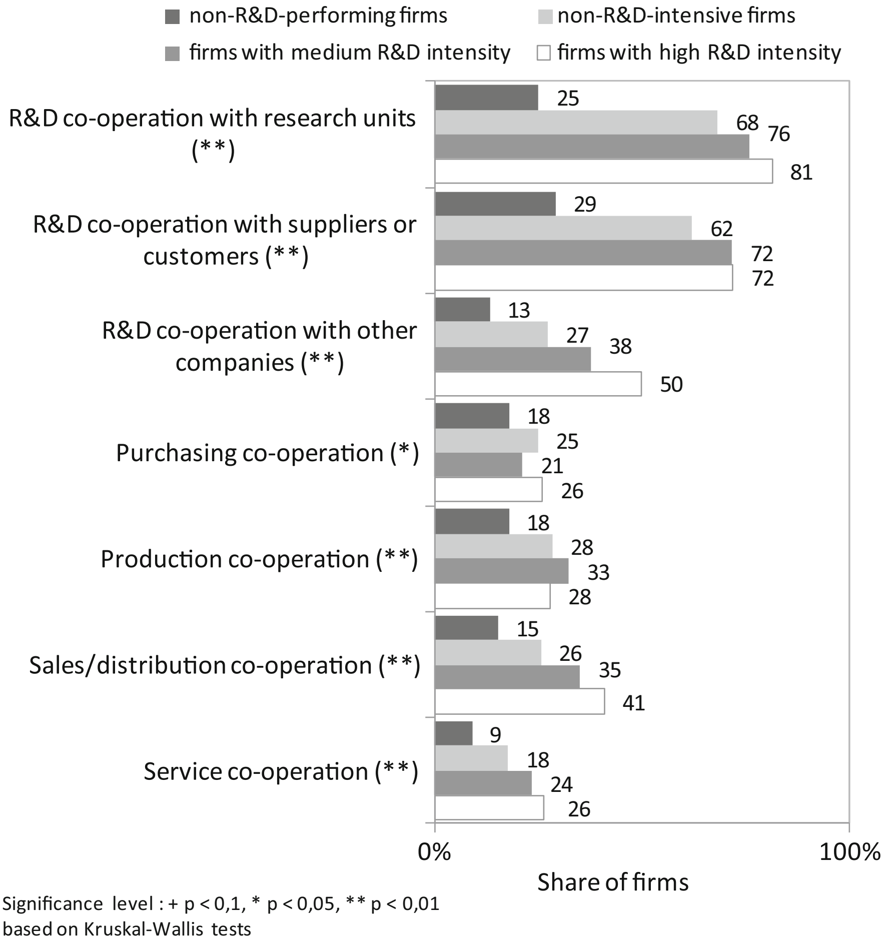

Fig. 8.7 Collaboration activities of firms without R&D activities, as well as low-, medium-, and high-tech firms (Source: *German Manufacturing Survey 2012*, Fraunhofer ISI)

R&D collaborations with research units and R&D collaborations along the value chain (with customers and suppliers) seem to depend on at least some investment in R&D by firms. Firms without any R&D expenditures significantly lag behind all other firms, even non-R&D-intensive (so-called low-tech) firms, in terms R&D collaboration activity. The frequency of R&D collaborations generally increases with the intensity of a firm's R&D expenditures. While the collaboration intensity of low-, medium-, and high-tech firms clearly differs to some extent, the difference in collaboration intensity is much larger between firms without any R&D expenditures and other firms. Among firms without any R&D expenditures, R&D collaborations with research units and with firms inside the value chain (customers and suppliers) are comparably rare. Only approximately one-quarter of firms without

R&D expenditures actively engage in such collaborations. R&D collaborations with firms outside the value chain are even less common among this group of firms (13 %). However, the R&D collaboration intensity doubles for non-R&D-intensive (low-tech) firms. Thus, once firms have at least some R&D expenditures, even if the amount is small, they seem to engage considerably more frequently in R&D collaborations with external partners than firms without any R&D investments. A firm's R&D collaboration activity might thus also be related to its absorptive capacity (see also Chap. 9). Firms that already have some level of R&D activity might be better able to absorb R&D-related external knowledge from collaboration partners than firms without any internal competences in R&D.

In the case of R&D collaborations with firms outside the value chain, we find a somewhat continuous increase in collaboration intensity as a firm's own R&D expenditures. The results accordingly show that a firm's R&D collaboration intensity strongly depends on its own R&D expenditures. Despite the large potential advantages of R&D collaborations, especially for non-R&D-intensive firms, the empirical results reveal that the share of collaborators is considerably lower among this group of firms relative to other firms. Non-R&D-intensive firms do not seem to compensate for their lack of R&D resources through intensified external R&D collaboration activity. This low external R&D collaboration activity among non-R&D-intensive firms may arise for several reasons, ranging from a lack of time or willingness to the lack of suitable forms of R&D collaborations that would be easily applicable to the frame conditions of non-R&D-intensive firms. The same weaker collaboration pattern of non-R&D-intensive firms is observed for service collaborations as well as sales and distribution collaborations, whereas non-R&D-intensive firms' collaboration intensity in the areas of production and purchasing is roughly comparable to that of more R&D-intensive firms.

The differences between the collaboration intensity of firms with different levels of R&D intensity are largely due to firm size. As Figs. 8.8 and 8.9 show, the overall lower collaboration intensity of non-R&D-performing and non-R&D-intensive firms might be partially linked to their predominantly smaller firm size (see also Chap. 6). Confirming previous results (Kirner et al. 2010), we find that larger firms tend to more frequently collaborate in the area of innovation than smaller firms, regardless of their level of R&D intensity.

Within the analysis of data from the *German Manufacturing Survey* 2012, the differences in R&D collaboration activities between small and large non-R&D-performing firms are quite striking. Among the group of firms without R&D expenditures, large firms collaborate more than three times as often with research units and twice as often with other firms relative to their small counterparts (see Fig. 8.8).

Focusing on non-R&D-intensive firms, we still find size-related differences with respect to their innovation collaboration activities, but these differences considerably smaller for non-R&D-intensive firms than for non-R&D-performing firms. We find significant differences between small and large non-R&D-intensive firms in terms of their R&D collaborations with research units: while approximately half of all surveyed small non-R&D-intensive firms engage in R&D collaborations with

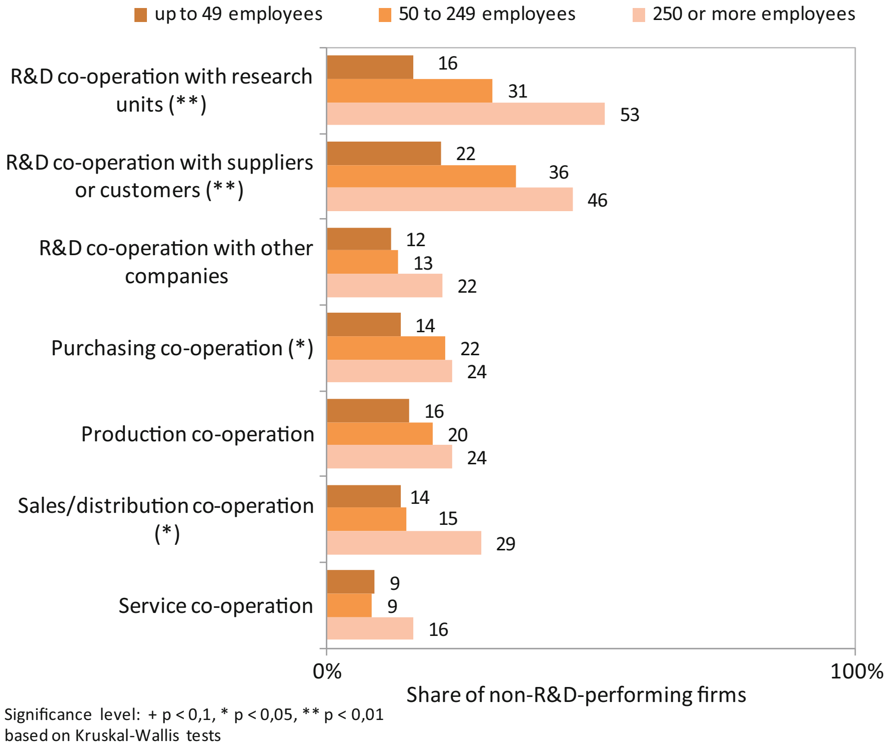

Fig. 8.8 Collaboration activities of non-R&D-performing firms by firm size (Source: *German Manufacturing Survey 2012*, Fraunhofer ISI)

external research units, this share rises to 77 % in large firms with more than 250 employees. However, firm size seems to affect non-R&D-intensive firms' collaboration intensity only in the case of R&D collaborations with research units. Regarding all other forms of collaboration, firm size does not play such an important role for less R&D-intensive firms (see Fig. 8.9).

The above results indicate that both non-R&D-performing and non-R&D-intensive firms engage in R&D collaborations (particularly with external research organisations) considerably more frequently once they reach a certain size. Although their collaboration intensity is still lower than that of their more R&D-intensive counterparts, more than half of non-R&D-performing and about three-quarters of non-R&D-intensive large firms actively engage in collaborations with external R&D facilities. These collaborations allow them to access and benefit from the R&D competences held by specialised R&D units.

Focusing on the relationship between the R&D collaboration activity of firms with different levels of R&D intensity and their level of product complexity (Fig. 8.10), we find that the R&D collaboration intensity of both non-R&D-performing firms and R&D-intensive (high-tech) firms is closely related to the complexity of their manufactured products. In the case of non-R&D-performing

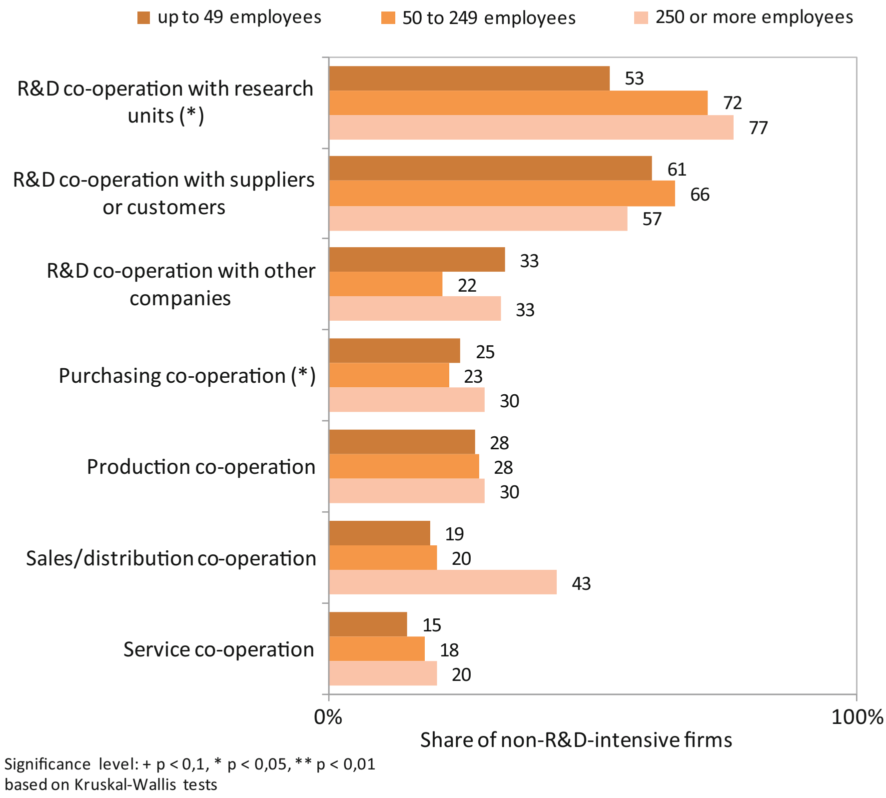

Fig. 8.9 Collaboration activities of non-R&D-intensive firms by firm size (Source: *German Manufacturing Survey 2012*, Fraunhofer ISI)

firms, firms that manufacture complex products collaborate twice as often with research units or other firms along the value chain relative to firms that produce simple products. While the overall R&D collaboration intensity of non-R&D-performing firms that produce complex products is still below the average R&D collaboration intensity of non-R&D-intensive (low-tech) and R&D-intensive firms, R&D collaboration intensity is nevertheless significantly related to product complexity. Firms that produce complex products more frequently take advantage of the benefits arising from R&D collaborations than firms that produce simple products. This result is logical because complex products generally require a higher level of sophistication; thus firms producing complex products might benefit from incorporating R&D-based know-how to a greater extent than firms producing simple products. Interestingly, this relationship is also holds for R&D-intensive firms. R&D-intensive (high-tech) firms that produce simple products also engage in R&D collaborations much less frequently than firms that manufacture complex products.

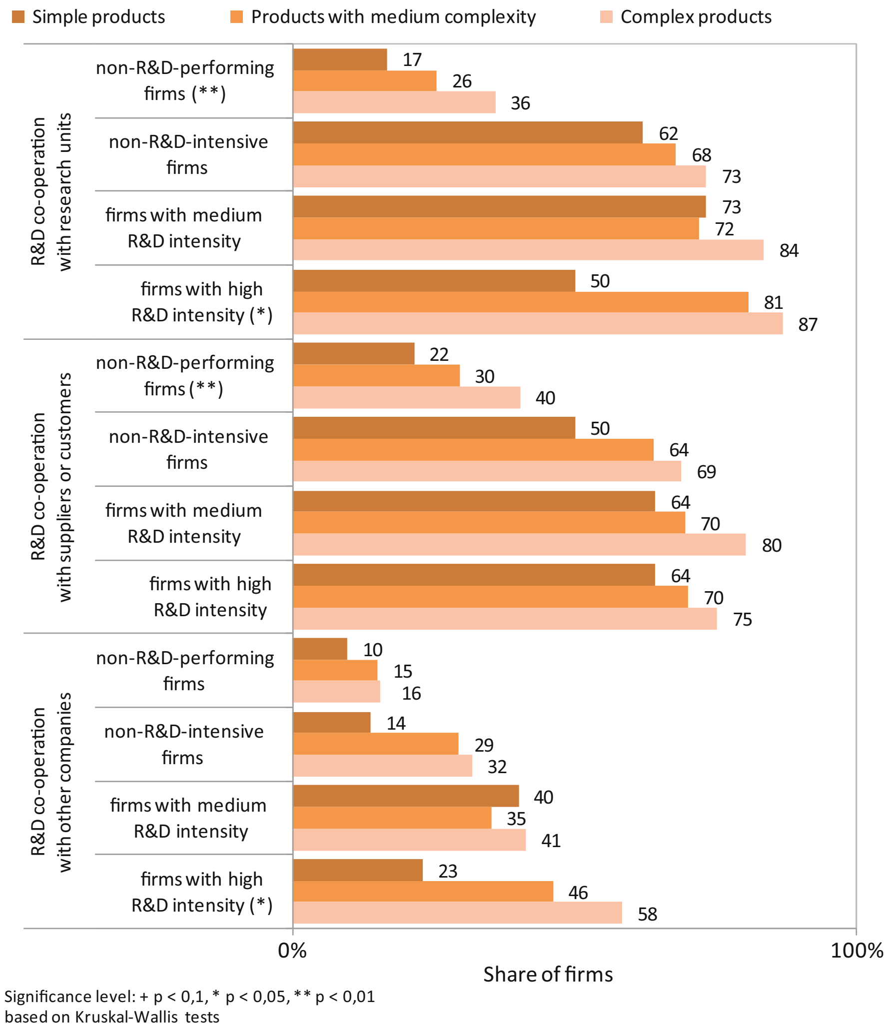

Fig. 8.10 Collaboration activities of firms with different levels of R&D intensity by product complexity (Source: *German Manufacturing Survey 2012*, Fraunhofer ISI)

With regard to the regional distribution of R&D collaborations, the empirical results reveal that the R&D collaborations of non-R&D-performing and non-R&D-intensive firms tend to be regionally and nationally focused. Only a very small share of R&D collaborations, if any, seems to involve international partners for these firms, and these collaborations are mainly involve partners along the supply chain (see Figs. 8.11, 8.12, and 8.13). Regarding all three selected forms of R&D collaborations, collaborations with national collaboration partners (across Germany) are the most common; regional collaborations also play an important role, especially for non-R&D-performing firms.

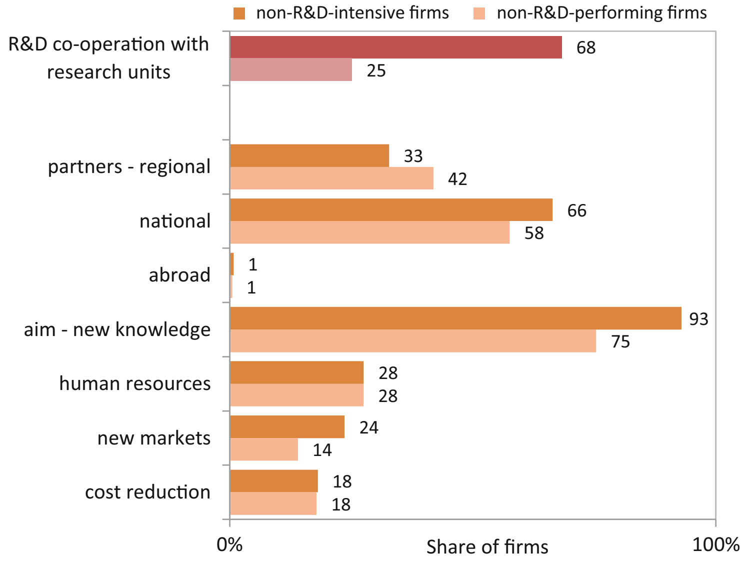

Fig. 8.11 R&D collaboration activities with research units of non-R&D-performing and non-R&D-intensive firms by regional focus and collaboration aim (Source: *German Manufacturing Survey 2012*, Fraunhofer ISI)

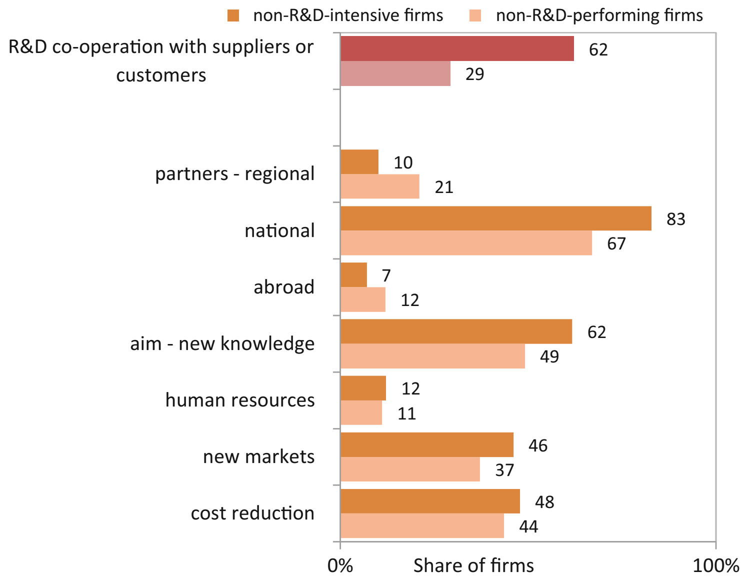

Fig. 8.12 R&D collaboration activities with suppliers or customers among non-R&D-performing and non-R&D-intensive firms by regional focus and collaboration aim (Source: *German Manufacturing Survey 2012*, Fraunhofer ISI)

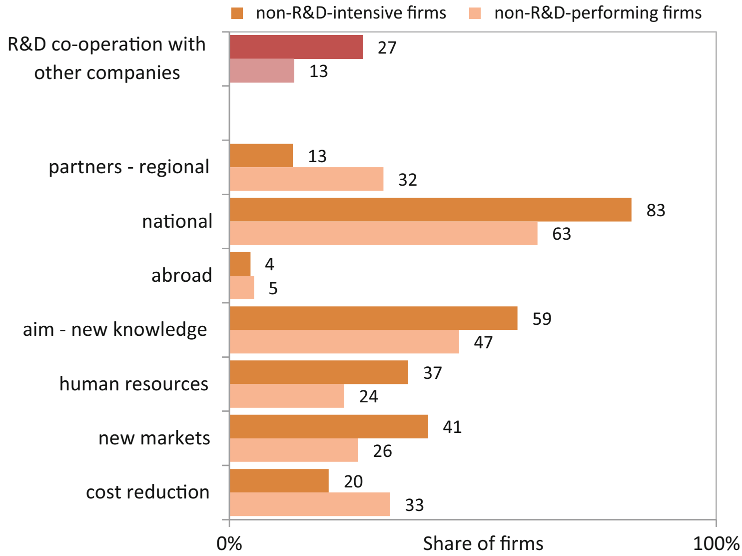

Fig. 8.13 R&D collaboration activities with firms outside the value chain among non-R&D-performing and non-R&D-intensive firms by regional focus and collaboration aim (Source: *German Manufacturing Survey 2012*, Fraunhofer ISI)

While R&D collaborations with research units serve the main purpose of allowing firms to acquire new knowledge, non-R&D-performing and non-R&D-intensive firms pursue R&D collaborations with other firms inside and outside the value chain to reduce costs and to access new markets. In the case of R&D collaborations with firms outside the value chain, the access to human resources also plays an important role. These results confirm that firms pursue R&D collaborations with other firms for the purpose of—apart from acquiring new knowledge—reducing costs by sharing investments, accessing qualified staff that might not be available the firm, and gaining better access to new markets through joint efforts. Overall, R&D collaborations seem to offer various benefits to non-R&D-performing and non-R&D-intensive firms once they actually engage in collaboration activities. Nevertheless, it remains a challenge to overcome existing obstacles to collaboration and to increase the overall collaboration activity of these firms. Further analysis is needed to identify the specific collaboration frame conditions that are relevant to these firms and the particular obstacles related to them.

Summary Confirming earlier findings, the analysis of the innovation collaboration activities of non-R&D-performing and non-R&D-intensive firms reveals that considerable unused potential for collaboration remains for these firms, particularly among non-R&D-performing firms. Despite the substantial potential advantages that R&D collaborations can offer in terms of knowledge sourcing, risk sharing, and cost reduction, only few non-R&D-performing firms take advantage of R&D

collaborations to enhance their innovation activities. The low R&D collaboration intensity of these firms is partially due to their smaller average firm size and lower average product complexity, as small firms and firms that manufacture products with low complexity generally tend to collaborate less frequently in the area of R&D. Another reason for the low R&D collaboration intensity of these firms may relate to the high asymmetry between non-R&D-performing/intensive firms and R&D-intensive collaboration partners in terms of innovation management, knowledge culture, language, and inter-organisational interfaces (Som and Zanker 2011). When collaborating with R&D-intensive partners or research organisations, non-R&D-performing/intensive firms often face the challenge of adapting their own processes and less institutionalised level of innovation management to the requirements and needs of their partners. Additionally, smaller firms with no or low R&D intensity in particular often fail to assess the strategic risks and benefits of innovation collaborations. However, if non-R&D-performing/intensive firms manage to address these challenges, they can highly benefit from collaborating with R&D-intensive external partners and even external R&D organisations. Thus, future management and organisational research should explore the main barriers to collaboration and identify measures to overcome them. Initial attempts to develop new management solutions for these firms have been already been made and could serve as a starting point for further investigations.

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Chapter 9
The Absorptive Capacity of Non-R&D-Intensive Firms

Oliver Som, Eva Kirner, and Angela Jäger

Abstract This chapter analyses and compares different dimensions of non-R&D-intensive and very R&D-intensive manufacturing firms' absorptive capacity (AC). The empirical analysis is based on firm level data obtained by a telephone survey in early 2010 among more than 200 non-R&D-intensive firms and 88 firms with a high R&D-intensity in the German manufacturing industry. The results show that there is surprisingly little difference in the level of AC between R&D-intensive and non-R&D-intensive firms – if the firm specific relevance of such external impulses is being taken into consideration. This is a surprising finding in so far, as it indicates that R&D intensity might not be a limiting factor for firm's ability to recognize and implement scientific knowledge per se. Thereby, the findings presented in this chapter underline the necessity to further improve and supplement the measurement concept of firms' AC beyond their mere R&D intensity by taking into account the strategic importance of different types of external knowledge.

9.1 Introduction

The ability of firms to successfully assess and – if required – adopt and implement external knowledge has been described by Cohen and Levinthal (1989, 1990), who coined the concept of "absorptive capacity" (AC). However, because these researchers linked the AC of firms to the R&D intensity of firms based on the assumption that a large number of highly qualified R&D personnel increases the AC for new technological knowledge from external R&D organisations, it can be assumed that non-R&D-intensive firms show a significantly lower AC, are

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therefore isolated from such scientific knowledge and ultimately suffer from competitive disadvantages compared with R&D-intensive firms.

This assumption may be questioned for two reasons. First, the type of relevant external knowledge may differ greatly according to the particular form of innovation at hand. For instance, non-technological fields of innovation, such as product-related service innovation or organisational innovation, as sources of competitive advantage are not entirely rooted in R&D or science-based knowledge. Instead, these types of innovation may be more strongly stimulated by practical or customer-based knowledge. Hence, it could be argued that non-R&D-intensive firms show higher levels of AC regarding these types of knowledge. Second, the absence of R&D need not be equated with a lack of technological competence or a low level of knowledge intensity in firms (Som 2012; Hirsch-Kreinsen 2007). Non-R&D-intensive firms may be able to develop their AC along channels other than R&D if they consider science-based knowledge to be relevant to their competitive success, for instance, by further developing existing technological solutions or by transferring them to new contexts of application (Bender 2008).

For these reasons, this chapter aims to explore the AC of non-R&D-intensive firms. To develop and implement their innovations, non-R&D-intensive firms also require the general ability to access and assimilate relevant external knowledge. Given that such firms have little or no internal R&D competences, the question arises as to whether these firms are still able to access and absorb science-based knowledge or whether they instead focus more strongly on the recognition and assimilation of primarily customer-related forms of external knowledge. This research question can be subdivided into the following questions:

- Are non-R&D-intensive firms characterised by a lower AC for science-based knowledge than R&D-intensive firms are?
- Do non-R&D-intensive firms show a higher AC with regard to market- or customer-based knowledge than R&D-intensive firms do?
- To what degree is the AC of firms influenced by the strategic importance of the corresponding external knowledge?

In addition to these points, this chapter also contributes to the further development of a measurement concept of firms' AC by distinguishing various forms of AC and by presenting and testing an empirical approach to capture these two dimensions.

9.2 The Absorptive Capacity of Firms

The seminal conceptualisation of firms' AC has been developed by Cohen and Levinthal (1989, 1990), who described the AC of firms as the ability to recognise and assimilate the value of new external information and apply it to fulfilling commercial goals. The AC of a firm can be distinguished by two interdependent dimensions (Zahra and George 2002; Cassiman and Veugelers 2006; Arbussa and Coenders 2007):

- The ability to search and acquire new external information on technological trends
- The ability to adapt internal processes and resource configurations in a way that fully exploits their competitive potential

The basic assumption is that those firms that manage external knowledge flows more efficiently stimulate innovative outcomes and thus obtain superior competitive advantage (Escribano et al. 2009). Given that external sources of knowledge are becoming increasingly important for innovation, the capacity of firms to absorb relevant external knowledge is also gaining relevance (Camsión and Forés 2010).

Although the original concept of AC allows for a multidimensional understanding of the concept, many studies have linked AC predominantly to the R&D activities of firms (Veugelers 1997; Oltra and Flor 2003; Leahy and Neary 2007; Thérin 2007; Zahra and Hayton 2008). Internal R&D competences are believed to serve as an enabler of a firm's ability to recognise external trends and developments in technology, to evaluate them correctly, and to identify adequate solutions for implementing such external technological developments successfully into its own enterprise. Hence, AC is argued to be a cumulative result of internal R&D activities, which suggests that internal R&D capacity and external knowledge sourcing practices are complements (Ebersberger and Herstad 2010; Schmiedeberg 2008) rather than substitutes (Chesbrough 2003) for one another. This line of argumentation implies that firms with little or no internal R&D activities have a lower AC and are thus not as well equipped to benefit from external knowledge sourcing as firms with internal R&D capacities are.

However, this understanding of AC that is largely determined by the internal R&D activities of a firm has been increasingly criticised in recent works. According to authors such as Murovec and Prodan (2009), Spithoven et al. (2010) and Escribano et al. (2009), against the backdrop of the systemic nature of innovation processes in which firms are embedded in the social systems of multiple actors and forms of knowledge (Lundvall 1992; Foray 2006; Nooteboom 2009), the AC of an enterprise should not be constrained to merely the recognition and implementation of R&D- or science-based knowledge. Thus, it is also important for firms to have the ability to recognise, evaluate and benefit from external developments, trends and information regarding their market environment and their customers (Murovec and Prodan 2009; Escribano et al. 2009). Against this background, AC should be understood and measured as a multidimensional construct that encompasses both science-based capacities as well as customer- or market-based competencies and resources that can be absorbed from external partners, such as strategic alliances, collaboration or networks with different stakeholders (Schmidt 2005; Spithoven et al. 2010; Murovec and Prodan 2009). Following this line of argumentation advocating a more holistic understanding of the AC of firms, this paper explores these four distinct aspects of AC along two main dimensions:

- Science vs. customers
- Perception vs. implementation

According to Zahra and George (2002), AC can be differentiated according to an "AC_potential" and an "AC_realisation". "AC_potential" involves searching for and acquiring relevant knowledge and competences, whereas "AC_realisation" indicates that these competences and knowledge stocks can be successfully assimilated and exploited by a firm. Our distinction between recognition and implementation is consistent with Zahra and George's differentiation, except that we do not consider the acquisition of competences to be part of the recognition phase in relation to AC. We argue that the decision of whether a certain competence will be acquired by a firm is already part of the implementation phase. According to our understanding, recognition only includes becoming aware of relevant new science- and customer-based opportunities, trends and developments that may or may not be subsequently adopted and implemented by the firm, depending on its ability and/or strategic decision.

Both the successful recognition of relevant new trends and developments as well as the implementation of new competences can be conceptualised as processes of organisational learning (Nonaka 1994; Cohen and Levinthal 1990; Jiménez-Jiménez and Sanz-Valle 2011). In terms or organisational learning, the two dimensions of recognition and implementation closely correspond to the two different types of learning: explorative and exploitative learning (March 1991; Bishop et al. 2011). Explorative learning occurs when a firm is able to identify, recognise and access new sources of information that is potentially relevant to its business. Exploitative learning occurs when this new information is actually applied and implemented by a firm. Both types of learning, similar to both types of corresponding AC, are equally relevant for innovation and competitive success. However, it might not always be necessary for a firm to implement every newly explored opportunity. The decision of whether to implement/exploit a certain newly recognised trend will depend on a firm's overall business strategy. Not every new opportunity is equally promising for every firm. Although it is important not to ignore relevant new developments and trends, it is equally important to distinguish which new developments hold the potential to realistically lead to successful innovation outcomes, depending on a firm's own strategic priorities, existing capabilities/resources and market choices.

Furthermore, referring to a broad understanding of innovation, it also seems necessary to distinguish between science-based and customer-related knowledge in relation to the AC and learning of firms. Although R&D intensity is an established means of operationalising AC when new product development is of primary interest (Stock et al. 2001), R&D falls short of capturing learning capabilities that relate to other forms of innovation, such as market, process or organisational innovations for which R&D is less important. This distinction appears to be particularly relevant for capturing the AC of those firms whose strategy focuses primarily on customer-specific (often incremental) product innovations, process innovations or organisational innovations (Schumpeter 1934), and such a focus is frequently found in non-R&D-intensive firms (Kirner et al. 2009; Som et al. 2010; Rammer et al. 2011).

To analyse the AC of non-R&D-intensive firms, we therefore propose the use of a comprehensive, broader understanding of the AC of manufacturing firms that distinguishes not only between different phases of AC (recognition vs. implementation) but also between the science-based and demand-side forms of the external knowledge that is being accessed, respectively assimilated and transferred into practical solutions. This conceptualisation leads to four different forms of AC (Table 9.1):

Firms can be positioned differently among these four dimensions depending on their ability to recognise and implement new technological and market developments and depending on their strategic choice to pursue a certain innovation path that requires different types of external knowledge. In the empirical analysis, we distinguish between these four dimensions and compare the AC of two different groups of firms: firms with high and low levels of R&D intensity.

As previous research results have shown, non-R&D-intensive firms tend to pursue a great variety of different innovation paths. No single dominant innovation strategy can be identified (Som 2012). The observed heterogeneity of innovation paths among non-R&D-intensive firms suggests that different firms make different strategic choices related to their innovation activities. This heterogeneity also could affect the respective relevance of different external information and knowledge sources. Some firms may consider customer feedback to be a central source of external knowledge, whereas other firms may establish close collaborative relationships with research institutions to gain access to the latest technological developments – even if the firms are not intensively engaged in internal R&D themselves. We assume that individual innovation paths and priorities affect the level of AC in firms because firms are largely expected to channel their efforts into accessing and assimilating the types of external knowledge that they consider important. Therefore, we propose the following hypotheses:

Table 9.1 Different dimensions and examples of the AC of firms (Own illustration)

	Perception/recognition of external knowledge, information and trends	Implementation and exploitation of external knowledge
Externally available knowledge of technological solutions from R&D organisations	"laser welding"	Installation of a new laser welding device on the arm of an existing industrial robot in the production line
Externally available knowledge of current developments and trends in market demand and customer preferences	"Increased flexibility requirements"	Segmentation of the internal production system into product- or customer-related lines

- The AC of firms can refer to different types of external knowledge, such as science-based or customer-based knowledge.
- The level of AC depends on the specific strategic relevance of certain types of external knowledge for a firm.
- The level of AC is correlated with the principal orientation of a firm's technology management.

9.3 Database

To empirically capture the concept of AC and to test its interaction with firm performance and technological orientation, we analyse firm-level data from a research project on non-R&D-intensive firms in the German manufacturing industry. These data were obtained by a computer-aided telephone survey (CATI) in early 2010 with more than 200 non-R&D-intensive firms and 88 firms with high R&D intensity in the German manufacturing industry. The survey was designed to specifically address the characteristic innovation strategies of non-R&D-intensive firms and to enable comparisons with R&D-intensive firms on certain specific questions.[1]

However, following the empirical findings of previous studies by Kirner et al. (2009a), Som et al. (2010) and Som (2012), the industry classification based on R&D intensity only partially reflects the actual R&D intensity of firms, as non-R&D-intensive firms and R&D-intensive firms are represented in all industrial sectors. Thus, low-, medium- or high-tech sectors do not represent homogeneous agglomerations of firm-level R&D intensity.

To avoid generalisations regarding the R&D intensity of firms by examining only industry aggregate levels, firms were screened based on their R&D expenditures by applying the OECD-based sector classification of R&D intensity by Legler and Frietsch (2007). The aim was to cover two populations:

- Non-R&D-intensive firms: firms with less than 2.5 % of expenditures on R&D
- Highly R&D-intensive firms: firms with more than 7 % of expenditures on R&D.

By contrasting both groups and omitting the group of firms with mean R&D intensity, these comparisons can easily identify differences based on R&D intensity at the firm level.

The intended ratio between the two groups was 2.5. However, because there is no information available to identify these populations in external (address) data, it was not possible to draw the two samples directly. Therefore, in the first step, two samples of manufacturing firms with more than 20 employees were randomly drawn: one sample covering high-tech industries (N = 2,050) and another sample

[1] The complete standardised questionnaire for the telephone survey is available from the authors upon request.

covering medium- and low-tech industries (N = 1,047). The sample size relied on estimations based on the German European Manufacturing Survey 2009 (Kirner et al. 2009). In the second step, firms were screened according their R&D intensity at the beginning of the interviews. Thereby, firms with more than 3 % (for reasons of feasibility) or less than 7 % of expenditures on R&D were excluded. The return rate is difficult to assess considering the sample structure; nevertheless, the overall willingness to participate in the interviews was nearly 20 % in both samples with no significant differences. The number of interviews rejected because of the screening criteria differed considerably between the samples; this number was much higher in the low-tech sample than in the medium- and high-tech sample (Som et al. 2010). Additionally, the share of R&D-intensive firms was slightly overestimated; thus, at the end of the survey, interviews with non-R&D-intensive firms also had to be omitted.

In total, 220 interviews with non-R&D-intensive firms and 88 interviews with R&D-intensive firms were conducted. Both groups cover the entire range of manufacturing industries as well as the entire range of firm sizes (see Table 9.2).

Both aspects of AC were captured – for scientific knowledge and customer-based knowledge – on a self-assessment scale ranging from "succeed very often" or "succeed often" to "do not succeed often" or "almost never succeed". Additionally, the respondents were asked to assess the extent to which the respective types of

Table 9.2 Description of the CATI sample (Source: Telephone survey, own calculations)

	Non-R&D-intensive firms		Very R&D-intensive firms	
Sectoral affiliation	N	%	N	%
Food and textile industry	20	9 %	3	3 %
Manufacture of chemicals, rubber and plastic products	22	10 %	9	10 %
Metal industry	27	12 %	2	2 %
Machinery and equipment	55	25 %	27	31 %
Manufacture of electrical equipment (except NACE 33)	33	15 %	21	24 %
Manufacture of medical, precision and optical instruments etc.	21	10 %	16	18 %
Manufacture of transport equipment	13	6 %	3	3 %
Others (furniture, jewellery, music instr., sports equipment etc.)	29	13 %	7	8 %
Total	220	100 %	88	100 %
Firm size classes				
20–49 employees	105	48 %	43	49 %
50–249 employees	94	43 %	35	40 %
more than 249 employees	21	9 %	10	11 %
Total	220	100 %	88	100 %
Sample group				
sample (A): low tech sectors	90	41 %	17	19 %
sample (B): medium or high tech sectors	130	59 %	71	81 %
Total	220	100 %	88	100 %

knowledge (both science and customer-based knowledge) are of strategic importance for their firms' competitive success using a scale ranging from "very important" to "unimportant".

As shown in the table above, the group of non-R&D-intensive firms is equally composed of low-, medium- and high-tech sectors. Thus, non-R&D-intensive firms can be analysed considering their full variety of sector affiliation and heterogeneous innovation strategies (Som 2012). By contrast, the subsample of highly R&D-intensive firms primarily encompasses firms from high-tech industries. Correspondingly, the sector affiliation of both firm samples differs substantially. Whereas the sample of non-R&D-intensive firms is almost equally distributed across all manufacturing industries, the group of highly R&D-intensive firms predominantly represents typical high-tech industries: machinery and equipment; electrical equipment; and medical, precision and optical instruments. Regarding their firm size, both samples of R&D- and non-R&D-intensive firms show a similar structure with the largest share of small firms (20–49 employees) and medium-sized firms (50–249 employees). Larger firms with more than 249 employees account for only 9 % of the non-R&D-intensive firms and 11 % of the highly R&D-intensive firms. Because of the similar size distribution between the two firm groups, the effects of firm size are unlikely to differ.

Nevertheless, when interpreting the results, we must consider the limitations of the data. Primarily because of the disproportional size of the two initial samples, neither group provides a representative picture of its respective population. Thus, the data cannot be used for the analysis of sector differences. However, this problem does not appear to be a concern, as it is not the intention of this paper to examine sector differences in AC. Rather, this study aims to reveal whether non-R&D-intensive firms are able to develop AC and to determine the degree to which this AC differs from that of R&D-intensive firms. In addition, it must be noted that the ratio of both samples is not representative of the ratio of both firm groups in manufacturing. However, as the data cover the entire range of firm sizes and sectors, this data set provides a solid basis on which to analyse the differences between R&D-intensive and non-R&D-intensive manufacturing firms.

9.4 Operationalisation of the Dimensions of AC

Following the theoretical discussion, the measurement of the AC of firms is differentiates between a "science-based" dimension of R&D knowledge and information stemming from external R&D organisations ("AC_science") and a dimension of customer-based knowledge of demands and trends on the market side ("AC_customers"). Additionally, this measurement also differentiates between the ability to recognise relevant knowledge and information and the ability to implement this knowledge successfully into concrete solutions and concepts to increase firms' competitive advantage (Table 9.3).

Both aspects of AC (i.e., the perception of changes and new information as well as their successful implementation in the context of a specific firm) were captured

Table 9.3 Operationalisation of the dimensions of AC (Source: Telephone survey, own illustration)

	Perception	Implementation
AC_science	*"To what extent does your company succeed in recognising important scientific knowledge, findings and information from external R&D organisations?"*	*"To what extent does your company succeed in capturing such important scientific knowledge, findings and information and manage to implement them in new internal solutions?"*
AC_customer	*"To what extent does your company succeed in recognising important knowledge, trends and impulses from its customers?"*	*"To what extent does your company succeed in capturing such important knowledge, trends and impulses from its customers and manage to implement them in new internal solutions?"*

for both scientific knowledge and customer-based knowledge on a self-assessment scale ranging from "succeed very often" or "succeed often" to "do not succeed often" or "almost never succeed".

9.5 Empirical Findings

First, the theoretical assumptions regarding the various dimensions of AC reflected in the empirical data must be validated. We conducted a principal component analysis to test whether the two types of science- and customer-based AC considered in this paper represent distinct dimensions. Figure 9.1 reveals that the four variables used to measure the AC of firms indeed constitute two different dimensions.

Based on the four variables, it is possible to distinguish between the firms' AC for customer-based knowledge and firms' AC for science-based knowledge. Both dimensions account for 76.9 % of the total variance in all four variables. Additional non-parametric correlation analyses also validate this finding for each subsample of non-R&D and R&D-intensive firms. For all groups, highly significant correlations can be observed only between those two variables (perception variable and implementation variable) that jointly constitute a common dimension of AC, whereas only low intercorrelations between the science and customer dimensions can be observed. Hence, the variables used to measure the different dimensions of firms' AC are valid indicators for capturing the two dimensions of AC. Furthermore, this result justifies combining the two variables (perception and implementation) into an index for each of the two AC dimensions (science-based and customer-based) (see the following paragraph). Moreover, the findings emphasise that the two dimensions of firms' AC are not identical, as they describe different dimensions of firms' ability to recognise and transform externally available knowledge into internal solutions. The finding that both the AC_science and AC_customers of firms are not completely independent from one another appears reasonable, as they might be

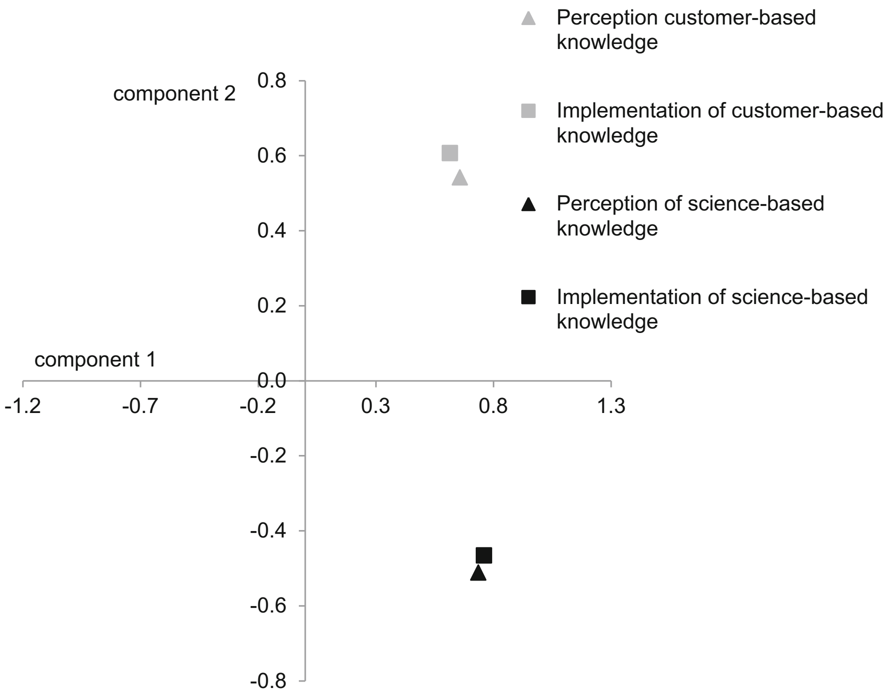

Fig. 9.1 Principal component analysis of AC dimensions (Source: Telephone survey, own calculations)

jointly affected by a firm's general ability to handle and manage its internal and external stocks of knowledge.

9.6 Developing Multiplicative Indices of Firms' AC for Science- and Customer-Based Knowledge

As discussed above, the AC of a firm is understood as the combination of the ability to recognise important external stocks of knowledge and information and the ability to capture this knowledge and transform it into concrete practical solutions within the firm to increase its competitiveness. Based on the findings from the principal component analysis, the two dimensions of AC were captured as a multiplicative index, yielding a range of 16 points, with 1 indicating the lowest AC and 16 indicating the highest AC in each respective dimension.

As the descriptive statistics show (Table 9.4), the mean AC_science value is 12.0 with a standard deviation of 3.1; 90 % of the firms have an AC level between 7 and 16. The average AC_customer value is much higher at 14.4 with a standard deviation of 1.6. For this dimension of customer-based knowledge, the constructed index differentiates less, as the AC of 90 % of the firms lies between 13 and 16. However, even if the construct does not discriminate at a high level of AC, it does allow for the description of this bidimensional concept.

Regarding the two different groups of firms, the results indicate that the non-R&D-intensive firms' mean AC for science-based knowledge is only slightly lower (11.7) than that of the highly R&D-intensive firms (12.7), which initially supports the assumption that non-R&D-intensive firms are less capable of absorbing externally available science-based stocks of knowledge than R&D-intensive firms. This finding is also supported by the distribution of the AC_science index for both firm groups (Fig. 9.2).

The shares of non-R&D-intensive firms in the lower and middle values of the AC_science index are higher, whereas the group of highly R&D-intensive firms has higher shares in the top categories of the AC index. Nevertheless, nearly 20 % of the non-R&D-intensive firms fall into the two highest categories of AC for science-based knowledge; thus, these firms are successful in both their perception and implementation of such knowledge. Finally, the variance in AC_science values is much greater for the non-R&D-intensive firms (10.7) than for the highly R&D-intensive firms (6.4). This result may indicate that the AC_science for non-R&D-intensive firms reveals a high level of interfirm heterogeneity based on the different innovation strategies that can be observed among them (Som 2012; Hirsch-Kreinsen 2007). This aspect will be addressed further in the next section when discussing the strategic importance of the knowledge dimension.

A deeper examination of the data reveals that highly R&D-intensive firms often succeed in the implementation and exploitation of science-based information within their enterprises. More than 80 % of the highly R&D-intensive firms state that they succeed very well or well in the implementation of such knowledge, which is significantly higher than that observed for the group of non-R&D-intensive firms (69 %). By contrast, the difference in the share of firms stating that they are able to monitor and recognise science-based external knowledge very well or well is slightly lower and accounts for approximately 9 % in favour of highly R&D-intensive firms. The finding that implementation and exploitation appear to cause greater problems for non-R&D-intensive firms may have arisen because non-R&D-intensive firms frequently do not have an internal R&D department and therefore lack an institutionalised innovation process to systematically promote the internal realisation of innovation projects (Som and Zanker 2011).

The results regarding the customer or market dimension of firms' AC reveal a much more homogeneous picture, which is also reflected in the low variance in the AC_customer index (approximately 2.1 for the highly R&D-intensive firms and 2.7 for the non-R&D-intensive firms). Compared with AC_science, the AC_customer values for the R&D and non-R&D-intensive firms are consistently higher (14.6 and 14.3, respectively). It is clearly easier for both groups of firms to handle "familiar" stocks of knowledge within the common knowledge culture along the economic value chain because firms are able to speak the same language as their customers.

Furthermore, there are no clear differences in AC_customer values between the R&D- and non-R&D-intensive firms in the distribution across the index categories.

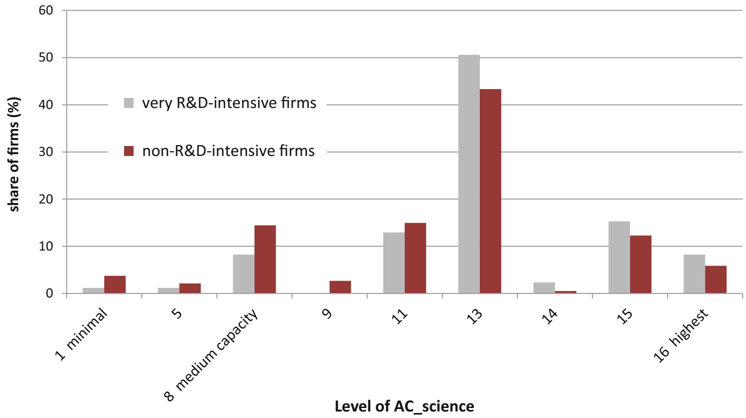

Fig. 9.2 AC index of science-based knowledge (Source: Telephone survey, own calculations)

A closer examination of the index data confirms this finding. The differences between the two firm groups regarding their perception and implementation abilities are marginal and less than 1 %. Hence, the few differences between highly R&D-intensive firms and non-R&D-intensive firms in the values for AC_customer should not be over-interpreted. Rather, it must be considered that the operationalisation of the customer dimension of AC used in our telephone survey is not sufficient to differentiate between the two firm groups. We will consider whether this suspicion still holds when accounting for the strategic importance of customer-based knowledge.

9.7 The AC of Firms in the Context of the Importance of External Science-Based and Customer-Based Knowledge

Continuing the previously presented argument that the heterogeneous innovation strategies of firms constitute different abilities to explore and exploit different types externally available knowledge (Srholec and Verspagen 2008; Som 2012), the development of AC makes sense only if a firm considers the respective knowledge to be of strategic importance to its innovativeness and competitive success. Otherwise, the accumulation of the corresponding type of AC does not appear to be reasonable from an economic perspective because the availability of personnel and organisational interfaces is highly cost intensive. Therefore, the firms in the telephone survey were asked about the importance of science-based and customer-based knowledge as a source of competitive advantage.

Table 9.4 below shows that the importance of both types of external knowledge differs significantly between the two samples of firms with different R&D intensity

Table 9.4 The strategic importance of external science-based and customer-based knowledge (Source: Telephone survey, own calculations)

		Non-R&D-intensive firms*		Very R&D-intensive firms		Total	
		N	%	N	%	N	%
Strategic importance of science-based external knowledge, findings and information	Very important	27	12.6	16	18.2	43	14.2
	Partially important	99	46.0	54	61.4	153	50.5
	Rather unimportant	67	31.2	17	19.3	84	27.7
	Unimportant	22	10.2	1	1.1	23	7.6
Total		215	100.0	88	100.0	303	100.0
Strategic importance of customer-based knowledge, trends and impulses	Very important	147	67.7	71	80.7	218	71.5
	Partially important	54	24.9	14	15.9	68	22.3
	Rather unimportant	16	7.4	3	3.4	19	6.2
	Unimportant	0	0.0	0	0.0	0	0.0
Total		217	100.0	88	100.0	305	100.0

* $p < 0.05$

levels. The findings have also been controlled for firm size and sector affiliation, but neither factor plays a significant role in the explanation of the differences. Most surprising and contradictory to our previous expectation, customer-based knowledge appears to be less important to non-R&D-intensive firms than to highly R&D-intensive firms, perhaps because R&D-intensive goods and products of greater complexity are often manufactured in close coordination with customers and users.

However, against the backdrop of appropriate measurement, it must again be noted that the customer dimension of AC as operationalised seems to not differentiate very well between the groups of firms. In both groups, at least two thirds of all firms in the subsample indicate that customer-based knowledge, trends and impulses are highly important to their competitive success; more than 90 % indicated that this type of knowledge is at least somewhat important partially important. Thus, the distribution is right-tailed, and its variance may be insufficient. Asking about the importance of external customer-based knowledge in this manner appears to generate the obvious result that almost every firm that is seriously interested in selling its products would agree that knowledge of their customers and clients is important.

The dimension of the importance of science-based knowledge and information also reveals interesting findings. The assumption that this type of external knowledge may be of lesser importance for non-R&D-intensive firms is reflected in the significantly lower shares of non-R&D-intensive firms that attribute medium or high levels of importance to this type of external knowledge compared to the shares of R&D-intensive firms. In turn, the share of non-R&D-intensive firms that reported science-based knowledge and information to be rather unimportant or unimportant is considerably higher than that of highly R&D-intensive firms. Nevertheless, nearly 60 % of the non-R&D-intensive firms perceive science-based knowledge and information as important or very important to their competiveness, which is remarkable when interpreted in absolute terms. Thus, firms with low R&D intensity should not necessarily be associated with an absence of (or lower relevance of) science-based stocks of knowledge and information per se.

It should be noted that three firms were set as missings and were excluded from subsequent analyses because they reported that neither science- nor customer-based knowledge are important to their competitiveness. Hence, it must be assumed either that these firms do not need to develop the corresponding types of AC or that their AC score may not be based on reliable estimations. Consequently, the assessments of AC are not analysed for firms that rated the respective type of knowledge as having no relevance at all, given that AC is meaningful only when the knowledge plays an important role in the competitiveness of a firm.

Finally, integrating aspects of the importance of the respective knowledge dimension and its corresponding level of AC results in the following findings (Tables 9.5 and 9.6).

For the science-based dimension, the results indicate that the importance of external science-based knowledge and information is the main determinant for the level of AC_science for non-R&D-intensive and highly R&D-intensive firms. Therefore, the importance that is ascribed to externally available science-based knowledge significantly influences the corresponding AC of firms, regardless of their firm size or sectoral affiliation, as non-parametric tests show. Moreover, as shown in the table, the ascribed importance offsets the previous differences in AC_science between non-R&D-intensive and highly R&D-intensive firms. Regardless of their R&D intensity, those firms that state that external science-based knowledge is highly or partially important show the same level of AC. Thus, if it is necessary to ensure their competitive success, non-R&D-intensive firms are able to develop the same AC for science-based knowledge as highly R&D-intensive firms can. With respect to those firms stating that science-based knowledge is only of partial importance for their competitiveness, the development of AC_science in non-R&D-intensive firms represents a strategic decision because their AC_science strongly decreases as soon as science-based knowledge is ascribed less importance. By contrast, highly R&D-intensive firms appear to have some type of a "basic" AC for science-based knowledge, which requires less effort to maintain. Highly R&D-intensive firms that regard external science-based knowledge as relatively unimportant still show a considerably high level of AC compared with firms that strongly value such knowledge.

Table 9.6 provides an overview of the customer dimension of AC based on the importance of customer-based stocks of knowledge. The results are similar to the results for the AC_science index. The firms' AC for customer-based knowledge is

Table 9.5 AC_science of firms depending on the strategic importance of external science-based knowledge (Source: Telephone interviews, own calculations)

		Non-R&D-intensive firms				Very-R&D-intensive firms				Total			
		Mean	Std. Dev.	Median	N	Mean	Std. Dev.	Median	N	Mean	Std. Dev.	Median	N
Strategic importance of external science-based knowledge, findings and information***	Very important	12.9	1.5	13	33	13.2	2.9	13	31	13.1	2.3	13.0	64
	Partially important	12.2	3.0	13	85	12.4	2.4	13	37	12.2	2.8	13.0	122
	Rather unimportant	10.3	3.8	11	64	12.5	2.0	13	17	10.7	3.6	11.0	81
	Unimportant	13.0	3.1	13	5					13.0	3.1	13.0	5
Total		11.7	3.3	13	187	12.7	2.5	13	85	12.0	3.1	13.0	272
Strategic importance of external science-based knowledge, findings and information (dummy)***													
	Rather important	12.9	1.52	13	33	13.2	2.9	13	31	13.1	2.3	13.0	64
	Rather unimportant	11.4	3.49	13	154	12.4	2.2	13	54	11.7	3.2	13.0	208
Total		11.7	3.28	13	187	12.7	2.5	13	85	12.0	3.1	13.0	272

*** $p < 0.001$/controlling for firm size and sector affiliation (NACE 2-digit)

Table 9.6 AC_customer of firms depending on the importance of externally available customer-based knowledge (Source: Telephone interviews, own calculations)

		Non-R&D-intensive firms				Very-R&D-intensive firms				Total			
		Mean	Std. Dev.	Median	N	Mean	Std. Dev.	Median	N	Mean	Std. Dev.	Median	N
Strategic importance of external customer-based knowledge, trends and impulses	Very important	14.5	1.5	15	137	14.6	1.3	15	61	14.6	1.4	15.0	198
	Partially important	14.1	1.5	13	50	14.4	1.9	15	21	14.2	1.6	15.0	71
	Rather unimportant	13.3	2.9	13	18	15.0	1.2	15	5	13.7	2.7	13.0	23
	Unimportant	14.5	1.7	14.5	4	13.0	.	13	1	14.2	1.6	13.0	5
Total		14.3	1.6	15	209	14.6	1.4	15	88	14.4	1.6	15.0	297
Strategic importance of external customer-based knowledge, trends and impulses (dummy)													
	Rather important	14.5	1.5	15	137	14.6	1.3	15	61	14.6	1.4	15.0	198
	Rather unimportant	13.9	1.9	13	72	14.5	1.7	15	27	14.1	1.9	15.0	99
Total		14.3	1.6	15	209	14.6	1.4	15	88	14.4	1.6	15.0	297

Controlling for firm size and sector affiliation (NACE 2-digit) significantly determined by the strategic importance given to customer knowledge with respect to a firm's own competitive success, regardless of its level of R&D intensity. For the group of non-R&D-intensive firms, these findings again hold when we control for firm size and sectoral affiliation in non-parametric testing. However, because of the lack of differentiation in the customer dimension, the AC_customer differences for the group of highly R&D-intensive firms are not statistically significant. Furthermore, in contrast to their science-based AC, non-R&D-intensive firms maintain their level of AC_customer even when such firms view customer-based knowledge as less important.

Summarising the results for AC_customer, we note that the operationalisation turned out to be unsatisfying because of the lack of differences observed. Future empirical studies on firms' AC for customer-based knowledge should consider this point and aim to develop a measurement of the concept of customer-based AC that accounts for its importance to individual firms, which would be a more appropriate measurement method. For this reason, the customer dimension of AC should be excluded from the following analyses. Nevertheless, despite the lack of differences observed in measuring the customer dimensions of AC, the findings presented above underline the necessity to consider the strategic importance of such knowledge when assessing the customer-side AC of firms.

Conclusion and Outlook

The results reveal surprisingly little difference between non-R&D-intensive firms and highly R&D-intensive firms in their ability to absorb external sources of knowledge – including science-based or customer-based knowledge – if the firm-specific relevance of such external impulses is considered. Given that some firms (whether R&D- or non-R&D-intensive firms) do not compete on the basis of a first-mover strategy, significant differences can be observed between firms with regard to their perceptions of the importance of the early adoption of new technological trends. A relevant share of R&D-intensive firms does not perceive that it is highly necessary to monitor and implement current technological developments. By contrast, a considerable number of non-R&D-intensive firms do consider the recognition and implementation of the latest scientific knowledge from R&D organisations to be relevant to their business, and such firms therefore engage in practices that allow for the successful monitoring and implementation of these trends. The results indicate that a firm's level of R&D intensity does not critically influence its science-based AC. Both highly R&D-intensive and non-R&D-intensive firms are equally able to recognise and successfully implement new technological trends if such trends are relevant and complement their competitive strategy.

(continued)

This finding underlines the necessity of a broader understanding of firms' AC and rejects the argument that the AC for science-based knowledge is solely determined by the R&D intensity of firms. Instead, the results revealed that the importance ascribed to a particular external knowledge source appears to be crucial to the AC of firms. Moreover, there is a close interrelationship between a firm's principal orientation of technology management (its own technological development vs. the purchase of ready-to-use solutions) and its level of AC. Firms that have in-house technological development competences tend to show higher levels of AC regardless of their levels of R&D intensity.

However, non-R&D-intensive firms' specialisation in the absorption of customer-based knowledge in contrast to the science orientation of R&D-intensive firms that is described in previous research could not be confirmed with the available data in this study. In fact, both groups of firms showed high levels of customer-related AC.

Moreover, the analysis revealed some important points for further research. First, the operationalisation of the importance of customer-related knowledge was unsatisfying because of lack of differentiating power, as a vast majority of firms indicated that this knowledge dimension is highly important. A more differentiated measurement likely may have confirmed the stronger customer orientation of non-R&D-intensive firms compared with R&D-intensive ones. Thus, there is a need for future research to refine the measurement of customer-related dimensions of AC by developing more detailed measurement concepts. Secondly, because of the limited number of cases, the database does not allow for complex causal modelling. Hence, the findings presented are explorative in character and must therefore be confirmed by larger empirical studies.

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Chapter 10
Managing Innovation in Non-R&D-Intensive Firms

Katharina Mattes, Christoph Zanker, and Oliver Som

Abstract *Innovations with little R&D, or without it, do not necessarily represent isolated cases; they just are different!* Companies can compete innovatively on a global scale without incurring (high) R&D costs. Because the innovation processes of non-R&D-intensive companies are less formalised and more heavily customer driven, current solutions for innovation strategies based on R&D activities are not suitable. Thus, this chapter presents two case studies that focus on increasing innovativeness and competitive advantage by utilising two approaches: the organisation of internal innovation processes and the assessment of innovation cooperation. The aim of the selected case studies is to illustrate both approaches to processing the problems and issues identified in these companies as well as the individually generated solutions and organisational measures. Each case study is introduced more generally from a conceptual perspective and concludes with a reflection summarising the significant findings compiled during the course of the joint work phases. In particular, the conceptual perspective can provide guidance for the application of these approaches in different industrial contexts and can thus be adopted by other companies in the same form and sequence.

10.1 Strategic Management and Innovation

In the field of strategic management theory, the ability of firms to gain competitive advantages and achieve economic success can be investigated using two distinctive firm-level approaches: the market-based perspective (cf. Chap. 6) and the resource-based perspective. In this chapter, interfirm heterogeneity and innovation behaviour in non-R&D-intensive firms are explained using the resource-based theory of the firm (e.g., Wernerfelt 1984) as well as modifications of the knowledge-based (e.g., Grant 1996) and relational-based views (e.g., Dyer and Singh 1998) of the firm. Because the competitive advantage and innovativeness of non-R&D-intensive

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firms cannot be explained solely by internal R&D activities, an integrated framework of these three approaches seems suitable for examining other potential innovation (re)sources beyond mere R&D.

The resource-based theory includes all approaches and theories that explain the persistent differences in firm performance and sustainable competitive advantage based on heterogeneous, firm-specific sets or bundles of strategically relevant resources and their combination as well as the competences and capabilities that exist within each firm (Welge and Al-Laham 2008; Wernerfelt 1984). Resources are input into productive processes and can be tangible – such as special factory facilities or machines adapted to production processes – or intangible, such as special patents, a firm's reputation, capabilities (e.g., the creativity of employees) or skills (e.g., knowledge of certain technologies) (Nooteboom 1992). Because material resources originate from a company's environment, competitive advantage primarily relates to intangible, company-specific resources (e.g., knowledge and capabilities). When equipped with a unique and superior set of resources and/or when using such resources more effectively or efficiently, a firm can be more successful than its competitors (Peteraf 1993). Thus, companies that are equipped with identical resources can exhibit substantial heterogeneity in their performances, as only the intelligent and targeted combination of different resources and their continued further development can lead to sustainable competitive advantages. The linkage, coordination and exploitation of these resources are achieved by the ability and competences of individual companies, which leads to differences with respect to economic performance (Grant 1991).

According to the knowledge-based view, the explicit and tacit knowledge of a firm is its most important strategic resource – together with its ability to create knowledge through organisational learning – to generate competitive advantage and explain firm heterogeneity (Welge and Al-Laham 2008; Prahalad and Hamel 1990). In particular, tacit knowledge is the most valuable resource for gaining competitive advantage and thus contradicts the necessity for R&D to create innovations, as R&D by definition focuses on "grounding solutions to inter-subjectively replicable methods" (Som 2012).

The relational-based view supersedes the intrafirm perspective and accounts for external resources outside of a firm. Consequently, firms do not inevitably possess these resources; they can access them through interfirm collaboration, strategic alliances or networks with external partners. "By either combining already existing complementary resources or generating new valuable resources" (Som 2012), firms can obtain a sustainable competitive advantage. The ability to cooperate to acquire missing, valuable and intangible resources is a favourable strategy for firms. Thus, this approach explains how competitive advantage is achieved through collaboration with external partners that provide new ideas and information that may lead to innovation (Dyer and Singh 1998). Moreover, networks and firm alliances may also facilitate the exchange of system solutions or the coverage of international markets (Oelsnitz and Graf 2006). To collaborate successfully, firms must be characterised by suitable organisational interfaces and employee skills (Kirner 2005).

In conclusion, the three streams within the resource-based theory explicitly consider the different resource endowments and the heterogeneity of firms that lead to different innovation behaviours and generate competitive advantage. In particular, "they complement each other by each emphasizing a particular aspect" and allow for identifying possible innovation resources of non-R&D-intensive firms beyond formal R&D (Som 2012).

10.2 The Specific Challenges of Innovating with Little or no R&D

Innovations with little R&D, or without it, do not necessarily represent isolated cases; they just are different! Neither a mere truism nor a slogan, this statement reflects many aspects of innovative thinking that affect not only individual companies but also associations and policymaking. The significance of this statement extends from its macroeconomic relevance to non-R&D-intensive companies to the constitution of discrete sub-aspects within a company or between companies.

In principle, companies can compete innovatively on a global scale without incurring (high) R&D costs. Low levels of R&D investment do not necessarily result in poor firm performance. Across all sectors of the German manufacturing industry, many companies compete innovatively and successfully despite little or no investment in R&D (cf. Chap. 7). The research findings offer an authoritative basis from which to conclude that *innovation without R&D* does not necessarily represent a compromise or a less than ideal situation as a result of the lack of financial, organisational and personnel-related resources for companies undertaking R&D. On the contrary, *innovation without R&D* can be considered a valuable part of a rational innovation and competitive strategy adopted by companies despite limited success in highlighting the novelty of a product or market. The innovation strategies of non-R&D-intensive companies are multifaceted and wide-ranging, extending from the production of simple, standardised goods developed through small, highly layered, incremental innovations to productive, highly flexible and market-oriented solutions; additionally, such strategies may even include process specialisation for use in high-tech processes.

The importance of non-R&D-intensive companies within industrial value chains whose end products may be high-tech products must not be underestimated. Non-R&D-intensive companies play an important role in value chains as partners for R&D-intensive companies. The interaction between R&D-intensive and non-R&D-intensive companies in terms of a combination of complementary competences generates strong potential, which can be beneficial to both parties but particularly beneficial to non-R&D-intensive companies. Moreover, in the context of innovation cooperation, non-R&D-intensive companies advise their R&D-intensive partners, for instance, in the beginning of a new project to develop an optimal solution with respect to technical and economic criteria.

Non-R&D-intensive companies are often small or medium-sized. Such companies seldom possess sufficient resources to produce innovations of their own accord. By cooperating in innovation projects, non-R&D-intensive companies can gain access to external knowledge sources through partners. Such knowledge can be assimilated directly into innovations. An important finding also suggests that non-R&D-intensive companies follow a different trajectory in how they choose partners. Rather than working with external research institutions, such companies work closely with customers and suppliers, partly in areas that directly relate to their core competences. In addition, in certain fields of innovation, there is a greater propensity for non-R&D-intensive companies to enter into cooperative partnerships with third-party service providers or even with competitors than there is for companies with higher research intensity. By entering into such R&D partnerships, non-R&D-intensive companies can successfully develop new products more frequently than companies that do not participate in such partnerships.

Additionally, because of their practical knowledge and experience regarding the usage of challenging technologies, non-R&D-intensive companies serve as valuable initiators and problem solvers in innovation projects.

In general, cooperation between non-R&D-intensive and R&D-intensive companies promises great benefits to both partners. Nevertheless, non-R&D-intensive companies in particular do not completely absorb the opportunities and potential that innovation cooperation with external partners can offer and therefore do not optimally exploit this potential. In particular, collaborating with high-tech partners is associated with numerous hurdles. In this context, non-R&D-intensive companies are confronted with the following characteristic challenges and barriers that must be overcome in the process of generating successful cooperation, particularly with a high-tech partner:

- Organising a structured and systematic internal innovation process without an established R&D department
- Absorbing external technological and innovative impulses and adapting to new technologies/innovations
- Configuring organisational and personnel aspects of intercompany interfaces
- Strategically assessing the risks and opportunities of innovation partnerships

To overcome these challenges and barriers, different methods and instruments were developed to incorporate the specific needs of non-R&D-intensive companies. With these methods and instruments, strategies can be generated to solve company-specific problems that arise during the course of innovation cooperation. The newly developed methods and instruments were tested in different companies, albeit in different application contexts. This article describes two company case studies based on two approaches: the organisation of internal innovation processes and the assessment of innovation cooperation.

The aim of the case studies is to illustrate each approach to processing the problems and issues identified in companies as well as the individually generated solutions and organisational measures. Each case study is introduced using a more general conceptual perspective and concludes with a reflection summarising the significant findings compiled during the course of the joint work phases. In particular, the conceptual perspective can provide guidance for application of the two approaches in different industrial contexts and can therefore be adopted by other companies in the same form and sequence.

10.3 Managing Internal Organisational Structures and Processes – the Process Innovation Manager

Innovation processes in non-R&D-intensive companies are configured differently than they are in R&D-intensive companies. For instance, R&D-intensive companies tend to emphasise high levels of professionalisation and institutionalisation in their innovation processes. At a minimum, this tendency involves the existence of a specialised R&D department with highly skilled R&D personnel. Parallel structures in non-R&D-intensive companies that typify innovation processes evolve over time and are highly company-specific; however, they characteristically display a lower degree of professionalisation and formalisation. The underlying condition is that the competences necessary for innovation processes are not primarily anchored in or channelled through an R&D department that is specifically responsible for these processes and that provides clear interfaces to the inside and outside world. Instead, such competences are dispersed across different divisions, ranging from construction to production and from quality management and purchases to sales and marketing. Thus, it must be assumed that the salience of innovation processes in non-R&D-intensive companies lies in how the role and function of process innovation managers (PIMs) are defined. In non-R&D-intensive companies, this position generally functions without the support of a distinct R&D department as the central driver of innovation.

Innovation projects in non-R&D-intensive companies are often strongly customer driven. Individual milestones and process phases are explicitly determined according to the demands and exigencies of customers. In the case of internal innovation projects that are not driven by specific customer demands, non-R&D-intensive companies often have few process structures or possess only those that have evolved over time. In addition to the scarce systematisation of innovation processes, the innovation activities and competences of non-R&D-intensive companies are often concentrated in the hands of a select few individuals. As a result, many of these self-initiated innovation projects cannot be fully integrated into the daily operational routine and thus are not systematically promoted. For that reason, innovation processes either experience considerable delays or are completely abandoned. In both cases, such a company fails to take advantage of important opportunities that would allow it to create its own customer-independent technology or product portfolios as its unique selling proposition and thus fails to enhance its competitive advantage.

In view of these considerations, developing the field of the *process innovation manager* as a problem-solving approach was considered highly relevant by the case study companies. This approach primarily focuses on organising, managing, and executing the internal innovation processes of non-R&D-intensive companies towards the twin goals of optimisation and professionalisation. Thus, there are many similarities and overlaps between the roles of the PIM and the *standard* innovation manager. However, process innovations assume greater significance than product innovations in the technical and organisational operations of non-R&D-intensive companies, which results in the preservation and strengthening of their competitiveness. For this reason, process innovations are often central to the innovation activities of non-R&D-intensive companies. In addition, the structure of innovation processes at non-R&D-intensive companies is distinct as a result of the absence of an in-house R&D department. Thus, the central challenges of this approach are identifying special requirements regarding the personal skills and abilities of the PIM as well as his/her organisational integration in non-R&D-intensive companies.

In the following, the conceptual perspective to managing internal innovation processes and its application in the context of a case study are presented. The case study concludes with a reflection summarising the significant findings.

Recommended references (the role of the boundary spanner – focus on external interfaces): Johnson and Chang (2000), Leifer and Delbecq (1978), Tushman and Scanlan (1981), Aldrich and Herker (1977), Neumann and Holzmüller (2007), Kirner (2005), Kinkel et al. (2004), Armbruster et al. (2005), Eggers and Engelbrecht (2005), Siegesmund (2007).

10.3.1 The Conceptual Perspective

To address the existing problems of the case study companies in terms of their innovation processes, a process-oriented approach was chosen to specifically identify the job specification for the PIM role within companies. The innovation success that the case study companies actually garnered was not central to this approach; instead, the focus was on the internal flows and processes of internal innovation projects as well as their concomitant internal (intracompany functions) and external interfaces (e.g., customers, competitors, research institutions, suppliers). In contrast to the existing approaches often used to establish *best-practice* processes as their point of departure on the basis of which internal processes are positioned and which white fields are identified, this approach adopted a course of action that accounts for the highly company-specific character of these processes. The reason for this decision is that the existing process models predominantly rely on the findings of R&D-intensive companies, and their applicability to non-R&D-intensive companies thus had to be challenged. Models of innovation processes that are particularly suited to the needs of non-R&D-intensive companies remain underdeveloped.

The following section outlines the basic steps executed within the case studies to process the relevant challenges and problems. These steps can be adopted by other companies in the same form and sequence.

Step 1: Preparing for and visualising the internal innovation process

A starting point for defining the role of the PIM is the prototypical innovation process used within a company, which maps the relevant divisions within the company, the external partners involved, the tasks to be fulfilled and the decisions to be made over the period beginning with the brainstorming phase and ending with the serial production phase. In addition, this process also indicates the channels of communication between the different key players, their decisions and the feedback loops.

It is important that the innovation process is described by the participating employees of the company and is not predetermined by third parties, as the innovation processes in every company differ in terms of their design, development and specifications. Moreover, this procedure ensures that the participating employees reflect on the entire innovation processes adopted by their company. A similar analysis should also extend to relevant company divisions, participating external partners, corresponding interfaces, existing tasks and feedback loops and should consider what could potentially be regarded as crucial process steps.

A *bottom-up* approach eases the process of preparing and showcasing the company-specific innovation process, whereby specific examples of the company's more recent innovation projects can be incorporated as the point of departure for documentation. Based on this *portrait* of the internal innovation process, the core processes and standard sequential operations are abstracted for use in the conceptualisation of the majority of innovation projects (Fig. 10.1).

To visualise the innovation process, the participants are provided with a *container* with discrete process modules that describe detailed elements within the main categories, such as *company departments*, *the idea phase*, *the definition phase*, *the implementation phase*, and *the evaluation phase*, and that cover the entire innovation process in the manufacturing companies. All process modules can be assigned as often as necessary if, for instance, several internal or external company divisions must execute the same process step. In the same vein, not all process modules must be used if corresponding equivalents cannot be found within the company structure. The discrete process modules are then plotted along the time axis according to the sequence of operations followed by the company. The discrete process modules can be modified by each company accordingly.

Moreover, by using arrows, all communication channels, controls and feedback loops between the process modules can be included in the representation to ensure that a customised portrait of the company's specific innovation process beyond the norm of standard solutions can be obtained, with all its interactions, loops and parallelisms.

To create a customised visual display integrating the specificities of the innovation processes adopted by the company, it is advisable to include all the different company divisions participating in innovation projects, with their specific

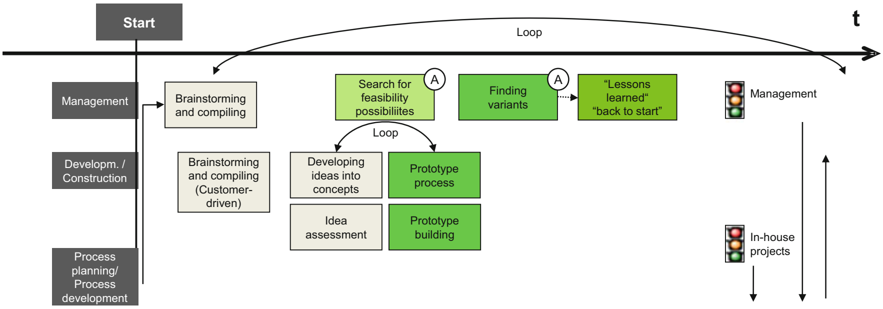

Fig. 10.1 Example of the visualisation approach to depicting the internal innovation process (Segment)

perspectives, and management should have a comprehensive overview of all company processes. The participation of external innovation partners would further broaden the scope of the innovation process.

Step 2: Identifying the crucial phases and major problems in the innovation process and defining an approach

By visualising the internal innovation process, the crucial process elements, phases and communication loops can be identified. Additionally, one can strategically analyse whether the existing problems could be better addressed using an organisational or personnel-centred approach. The innovation process model allows for experimentation with both approaches using cards to design and assess different internal processes and company interfaces.

Step 3: Establishing the duties and responsibilities of the potential PIM in the innovation process

Once the approach is selected, its practical application involves assigning a specification profile to each of the crucial process phases. Together with the company representatives, specific challenges are identified, and the relevant internal and external interfaces are defined. For this purpose, the identified process phases are isolated and displayed along the horizontal axis. This specification profile serves as the main reference point for a content-specific restructuring of the organisational processes as well as for the internal and external interfaces – for instance, detailing the type of information that should be compiled at what time and for what tasks.

Step 4: Determining a competence profile for a change in personnel

In cases in which a personnel-centred solution is developed, the tasks and requirements specified above are used as a point of departure for creating a detailed competence profile for a prospective employee who would be expected to assume the PIM role.

A more thorough classification is undertaken to generate a profile of the technical and social competences. Technical competences are differentiated in terms of the required knowledge through such categories as *basic*, *user*, or *expert*. The important social competences are differentiated on the basis of *must*, *should*, and *can* criteria.

This competence profile not only helped identify the conditions that a prospective employee potentially needed to meet but was also used to determine whether one/some of the existing employees could represent the best possible choice for the role of the PIM and in what areas they would potentially need to seek further qualifications or certification.

Step 5: Embedding the PIM in the organisational structure

In the last step, the company must examine whether and to what extent organisational adjustments must be made to support a prospective PIM and how the expectations for this person could be met. Based on the company's innovation process model as well as the model for integrating the new position within the innovation process, the essential structure underlying the channels of information, budget and staff responsibility, decision-making and managerial functions, and/or the roles of internal committees are clarified.

10.3.2 Deciding Between "Oddballs" and "Go-Getters" for a Sustainable and Professional Internal Innovation Process

Company A responded to the world economic crisis of 2008/2009 by bolstering its involvement in innovation projects to a significant degree to improve and strengthen its future competitiveness. However, the increased number of innovation projects has also presented a new set of challenges, such as quality concerns. Company A has introduced new material and technologies, envisioned new markets and entered into cooperative partnerships. This activity has resulted in a significant, unprecedented spike in the number of innovation projects that could scarcely be managed beyond the daily operations performed by an initially small group of people. Thus, the aim was to include a broader spectrum of employees in the innovation projects and to position them accordingly within the organisation. The following aims of the management board were at the forefront:

- Reducing the workload of employees currently responsible for innovation projects

- Encouraging employees at the second and third organisational levels to be more involved in innovation management responsibilities – with the medium-term objective that employees would learn to implement innovation projects independently
- Developing a concrete employee job specification that would serve as the basis for new appointments, (further) qualifications and performance evaluations
- Creating organisational framework conditions for optimal integration of employees

10.3.2.1 Approach

A multilayered approach was adopted to reach these goals. To obtain a detailed overview of the innovation processes implemented at company A, the first step in the workshop was to identify the specifications of the innovation projects and to create a visual display of the process with assistance from the managers of the innovation process to ensure that it could be applied to diverse innovation projects.

During the process, it became clear that two different types of innovation projects were primarily being conducted at company A: the customer project was motivated by external factors, and the in-house research project was based on internally generated ideas. *Customer-driven innovation projects* arise through customer inquiries or cooperation with external partners and manifest in relatively low levels of innovation. The first priority of such projects is to *manage* the innovation. Because company A is a supplier for the automobile industry, there is an established and even stipulated sequential arrangement for the process that is accompanied by well-defined criteria and critical milestones – all of which are common in this sector. Customers have high expectations regarding the degree of formalisation and professionalisation. The results are measured by how well the quality specified by their customers is implemented. The risks underlying customer-driven innovation projects are rather negligible; however, there is a substantial possibility of losing the customer in the event that a project fails. The technological setup depends primarily on the customer order. However, there is a certain degree of ambivalence surrounding customer-specific technological arrangements: on the one hand, new technologies could emerge and thereby generate unique selling propositions; on the other hand, new customers could be alienated.

At company A, *in-house research projects* are primarily the responsibility of the managing director as a result of the sheer number of new ideas; he has an intuition for innovations and is the active initiator and architect of these ideas. The impetus for new ideas arises, for instance, from visiting trade fairs and entering into alliances with research institutions. The degree of novelty or innovation here is significantly higher than that found in customer-driven innovation projects because in-house research projects must create value for customers in the future. In-house research projects are still at great risk with respect to their implementation and the resulting market positioning.

Both innovation projects were first visualised as models to identify and clarify which key players are involved in the innovation process, which tasks had to be executed and which interfaces were available. Thus, it was possible to project the weak points or the challenges involved in an innovation process. It was also possible to establish, for instance, that customer-driven innovation projects had been well organised and were already successful based on the external stipulations imposed by automobile manufacturers. Challenges deriving from in-house research projects, however, were greater for company A because of the prospect of having to systematically pursue, advance and implement innovative ideas and initiatives. Although many new ideas for innovation projects were generated, these ideas often failed because there was no structured approach to implementing and pursuing these ideas outside of the company's daily operations. Valuable innovation potential was wasted as a result. The effects were most harmful when other competitors were able to launch the same idea in the market more quickly only because company A did not have the internal capacities for such implementation. Management was aware of this operational failure of execution and the opportunity costs that were consequently incurred and was therefore willing to appoint a PIM who would launch new innovation projects in a targeted manner and ensure and oversee the continuation of the innovation process for in-house research projects or possibly even assume responsibility for project management. For this reason, the PIM should not be involved in daily operations.

A catalogue of specifications for the prospective PIM for the in-house research process was prepared by the management team. The actual scope of the functions and responsibilities was determined, specific challenges were investigated, and internal and external interfaces were identified and specified. Every individual step in the process was checked to determine the appropriateness of either a creative approach – to introduce new ideas – or a managerial approach – to manage and realise these ideas. At company A, the scope of such activities and the specific challenges for the PIM can be categorised as follows.

Strategy and Timing

The PIM must determine whether the ideas are compatible with the company strategy, conduct market analyses to determine the most appropriate time for a market launch to garner technical and economic benefits in the development of innovations, test the innovations with customers and in trade publications, and foresee and predict future trends.

Knowledge transfer and networks

The PIM must essentially adopt a mindset that is application oriented, apply knowledge to actual issues and problems, select and channel information, and communicate specifications and stipulations to the participating company divisions. The PIM is responsible for providing and collecting feedback and for performing long-term knowledge management to ensure the continued improvement of processes.

Idea management and assessment

The PIM must manage the existing impetus for innovation and new ideas and apply them to new problems. His or her creativity must be applied more to general problem-solving strategies than to the development of specific technical solutions. Furthermore, the PIM must assess the systems and alternatives that emerge from the innovation process, execute simulations and assume responsibility for controlling the evolution of the projects.

Integration of actors

The PIM is responsible for assembling all key players of networks and interactions between the specialist, sales and manufacturing divisions within the company as well as the networks of all technology-relevant external players, such as universities, patent lawyers, suppliers and customers.

The tasks allocated to the PIM demonstrate the necessity of *tying up loose ends*. Ideas and potential approaches, knowledge and key players must all be brought together at the appropriate time. An analysis of the innovation process also demonstrated that deciding between managerial and creative aspects posed a challenge because some process steps contained shades of both managerial and creative activities that had to be conducted by the PIM. Thus, the role of the PIM is complex and characterised by a vast range of duties and responsibilities. The PIM must develop innovative ideas and approaches and then drive the innovation process forward as the designated *oddball*. Simultaneously, he or she must also choreograph and control the innovation process by being responsible for the steadfast pursuit of ideas developed by mobilising the relevant players and the knowledge necessary to implement them. At the other end of the spectrum of this responsibility is the *doer*, who manages the innovation projects.

The tasks discussed were documented in detail in a catalogue for the PIM that specified the necessary expertise and social competences as well as the qualifications for each process step. Thus, other companies must adjust to their own specific conditions.

10.3.2.2 Conclusions and Review of the Case Study

In retrospect, company A has achieved its goals and has successfully expanded its circle of employees who handle and assist with innovation projects and processes. The findings of the case study show that the specification profile developed according to the innovation process model can be applied constructively. The modelling of the innovation process and the approach to the integration of a PIM were so successful that – based on the catalogue of specifications – two PIMs were appointed simultaneously to assist with and oversee the innovation projects because of the broad scope of the envisaged operations. Both new employees are responsible for overseeing only innovation projects within the company and are intentionally not involved in the company's daily operations to circumvent recent problems, such as insufficient time for innovation projects or a lack of focus because of the urgency of daily operations.

To date, the experience of employing both project managers has been exceedingly positive. The evolving structure of innovation management has been used and has constantly undergone further development through CIP measures. Both innovation managers are in a circular relationship with one another. One assumes the function of the product innovation manager, and the other assumes the function of the PIM. Through on-going professional trainings, these two new employees have an opportunity to grow into their roles.

Innovation projects are launched now at a slower pace because certain processes must be conducted to implement a systematic approach. However, innovation project results are being obtained within increasingly shorter and more competitive time ranges. To prevent the possibility of reverting to old habits (e.g., absorbing both innovation managers into daily operations), accountability must largely remain with the supervisor of the two PIMS, who is required to exercise discipline and tenacity. Other foreseeable challenges concern the strategic integration of innovation projects into the immediate context of the company and other standardisation measures related to the process flows of innovation projects.

10.3.3 Summary of Reflections from the Case Study

Orientation to case study projects

Experience has shown that company-specific innovation processes are best developed with entry points based on two to three innovation projects that currently exist, that were completed in the recent past or that were prematurely terminated. This *bottom-up approach* ensures that the processes within the company cannot be analysed only on the basis of a formally established *ideal process*. In particular, these specific projects fulfil the purpose of documenting the *actual process* based on real examples of the process, which thereby also draws attention to potential problems or weak points.

Once a visual model is created for these specific projects, the overall project and the central and/or standardised core processes can be conceptualised to avoid the confusion caused by single-case project specifications. In addition, this approach ensures that solutions and creative measures based on these process models can be applied to the large majority of innovation projects.

No recourse to existing general best practice models of innovation processes

Many of the current problem-solving strategies in the management literature addressing the aforementioned problems cannot be applied without changes to non-R&D-intensive companies. These approaches and concepts have largely been developed on the basis of R&D-intensive companies; for instance, they prescribe conventional R&D processes that are irrelevant to non-R&D-intensive companies. On the contrary, the innovation processes and key players are anchored broadly within the company and typically contain many parallelisms or feedback loops, as they have evolved with the company, albeit with minimum systematisation.

As a result, it must be assumed that even the area of operations and the demands placed on the PIM role in the context of non-R&D-intensive companies must be represented differently or may even need to be structured differently than in R&D-intensive companies. Thus, most existing approaches do not adequately consider the specific structure of non-R&D-intensive companies. On the contrary, the necessary actions derived from these models can even be counterproductive for such companies because the targeted results may not suit the specific situation and special character of these companies. As a result, non-R&D-intensive companies cannot accommodate the standard processes in the same way that R&D-intensive companies can. Instead, solutions must be designed to suit the specific strengths and weaknesses of non-R&D-intensive companies.

Encouragement of a broad spectrum of employee involvement

A comprehensive phase-by-phase review of the internal innovation process is best conducted by including a wider circle of employees who are already involved in the company's innovation projects (e.g., in management, sales and quality management). Even when staffing costs and other related expenses initially appear to be quite high, broad-based participation allows for a more comprehensive and holistic perspective. In this case study, some underlying problems related to the innovation process emerged only because of the inclusion of different divisions and perspectives. Therefore, such integration of a broad spectrum of employees contributes to a significantly increased degree of acceptance and support for the solutions garnered.

Visualisation of *diffuse* innovation processes

Beyond the benefit of problem identification alone, a visual display of the internal innovation process enables representation and documentation of the processes that are deemed *diffuse* and are *perceived* differently by different employees. This step raises the company's awareness of the *crucial* steps and phases inherent to its own innovation processes. Moreover, this step also provides inspiration for undertaking a general inspection of the process flows within innovation projects, identifying internal and external innovation initiators and drivers, and easing the process of determining and allocating duties and responsibilities across the process phases, both for the entire organisation and for individual staff members.

During the problem-solving phase, the model can be used as a *playing field* to present and assess the prospective organisational structures of the internal innovation processes and those pertaining to external partners. This method ensures the continuous and future use of the visual model of the company's process for innovation management. Visualising the individual internal innovation processes was thus the point of departure for systematically developing and testing solutions that were better suited to the company.

Solutions are largely company specific

In practice, companies prefer multiple approaches. Regarding the personnel-oriented strategy of the company case study, which is attributable to the specific requirements of the company, two PIMs were employed to fulfil the different sets of responsibilities compiled for them: one was responsible for the execution and realisation of the innovation processes in technical manufacturing as a central aspect of the competitive strategy, and the other was directly responsible for product innovations as the *product innovation manager*. Both remain separate from the company's daily operations. As promoters of innovation, these managers are responsible for the decisive implementation and execution of *internal research projects* as well as for the mobilisation of the relevant internal and external partners and sources of knowledge and ideas. Since the implementation of these measures, the company has reported significant success and improvements. In particular, the losses incurred from the tension between different internal and external players in the innovation process and those resulting from delays have been significantly reduced. Additionally, the enhanced level of professionalisation in the implementation of innovation projects has significantly improved the company's image and reputation among external partners.

Moreover, it is remarkable that the functional role of the PIM can be created by adopting either an organisational or personnel-oriented approach. A personnel-oriented approach is not necessarily linked to specific individuals; instead, different facets of the same role can be allocated to several persons. In conclusion, this case study showed that it was possible to integrate the extremely company-specific solutions into existing structures and specifications.

Creation of internal and external interfaces without division

From the innovation management perspective, it is remarkable that the creative choices available within the company are not categorically differentiated between external and internal interfaces in the innovation process. Theoretically, the role of the *PIM* within the innovation process is focused on *internal interfaces*.[1] In reality, however, there is no explicit division. Because internal innovation processes are increasingly becoming open to the involvement of external partners, thereby enhancing their systemic character, internal and external elements can no longer be operatively separated from one another because of the increased interconnectedness between the company and its environment. Given this development, one can speak of a movement towards a *PIM 2.0*.

Multiple demands on employees at these external or internal interfaces in the innovation process

The increasing interconnectedness between internal and external interfaces in the innovation process has the effect of continually increasing the complexity of the scope of operations and the demands placed on the role of the *PIM*. Thus, the PIM becomes more of a *generalist* than a *specialist*. The PIM must filter, structure, evaluate and channel the flow of information to the internal and external interfaces, monitor and control the execution of the innovation process, coordinate relevant knowledge and key players at the appropriate time, recognise opportunities for innovation, inspire improvements in the company, and contribute to the development of new solutions.

For non-R&D-intensive companies in particular, this situation takes a toll on employees who must shoulder increasing demands in their roles. Because the innovation processes are marginally systematised, the common knowledge base in the company is not documented (e.g., as patents or as formalised process flows). Rather, company know-how gleaned from practice or experience is circulated as implicit knowledge within the company and to several key external players.

Process innovation models continue to prove their worth in determining the technical and social specifications and competence profile for the identified job specifications. The competences that are hereby meaningful in the crucial process phase(s) – modified to address the respective problem – can be determined in a targeted manner (e.g., through a directly formulated job description).

Clear definition and communication of the duties and responsibilities of the PIM and sustained integration of the PIM into the organisational structure

The experience gained from cooperative work and implementation phases with industry partners has clearly shown that companies must consider whether it may be preferable to spread the range of work responsibilities over several persons because the work is complex and heterogeneous at times. Combining organisational and

[1] By contrast, the role of a “boundary spanner” is focused on external interfaces.

personnel-related measures could also generate an alternative solution. The idea of an all-in-one problem-solving device that comprehensively fulfils all demands is utopian.

It is apparent that the complexity of the duties and responsibilities of employees in the internal and external interfaces of the innovation process has given rise to three basic risks:

1. **The risk of *operational incapacitation* that arises from unclear focus alternating between daily operations and innovation projects:** A clear definition of – and absolute transparency in – the duties and responsibilities within the company are indispensable because they inhibit conflicts and prevent the PIM from being overburdened by numerous complex demands. For instance, there must be clarity as to whether the PIM will be released from daily operations – and under what circumstances he or she may be asked to contribute.
2. **The risk of *cognitive incapacitation* as a result of conflicts of purpose or a lack of clarity as to whether the focus during the innovation process was on creative or management-related elements:** This risk includes the decision regarding the capacity in which the PIM should be involved, whether in the development of new innovations (as a *creative oddball*) or in the coordination and monitoring of the innovation process (as a *reliable doer*).
3. **The risk of *structural incapacitation* resulting from a lack of organisational basis in the company:** To successfully induct a PIM into the company, organisational framework conditions play a central role, in addition to the respective technical and social competences of individual employees.

In conclusion, the following selected experiences of the case study company illustrate which aspects should be considered when creating the appropriate organisational framework conditions:

- Clarifying budget responsibility and decision-making power
- Clarifying the position of the PIM in the hierarchy
- Defining how the PIM is integrated into information flows and work processes throughout the company
- Ensuring acceptance of the position within the company (on a micro level)
- Developing a functioning system of internal support
- Promoting, seriously considering and fulfilling the desire for higher qualifications/further education

10.4 Managing External Organisational Boundaries – Strategic Planning and Control of Innovation Cooperation

With the aim of securing tangible benefits by increasing their own innovation potential, companies seek cooperating partners in innovation projects because having cooperative partners allows them to build on specific forms of intermediate inputs, resources and competencies that they may not possess. With access to these external sources, non-R&D-intensive companies in particular gain opportunities to enhance their innovation capabilities and competitiveness over the long term. These companies' own (generally limited) resources and competences are seldom sufficient for survival in the global competitive context.

Innovation cooperation fundamentally differs from standard customer-supplier relations for the following reasons:

- **Intangible aspects of cooperation:** Exchange relations centre on intangible resources, such as specific technological know-how as well as know-how regarding technical and non-technical procedures, markets and customers. This knowledge can take the form of physical goods.
- **Novelty creates a heightened degree of uncertainty:** For the receiving partner, the object of exchange is characterised by a high degree of novelty. This novelty can also generate a heightened degree of uncertainty as to which benefits such an exchange can bring to one's own company, and the company must rely heavily on the knowledge and experiences of the cooperation partner.
- **Highly strategic significance for the recipient:** In particular, non-R&D-intensive companies often collaborate with third parties in the domain of their core competences. This cooperation is likely to have primary significance for the company and its competitiveness. The readiness of the company to cede its influence and independence must first be examined.

Thus, decision makers often face the challenge of evaluating on-going or imminent innovation cooperation in terms of its (expected) benefits and (potential) risks. Management must therefore determine whether certain innovation benefits are best derived from an external partner or whether the preferred option may not be to make the corresponding competences available within the company as a means of safeguarding its own competitiveness.

The present approaches, such as the instruments for appraising suppliers or the methods of managing core competences, do not provide reliable answers to these complex problems, as they evaluate either the cooperation partner or the capacities inherent in the company. For that reason, an approach was developed to integrate both perspectives, building on the principles underlying a SWOT (strengths, weaknesses, opportunities and threats) analysis. A SWOT analysis is an established instrument for analysing and planning strategic management. Each company must view its own strengths and weaknesses in the broader context of the business world (markets, customers, competitors, and suppliers). Changes transpiring outside of the company are juxtaposed with its internal strengths and weaknesses to facilitate an evaluation of the company's risk and opportunities or to determine the appropriate course of action that will allow the company to respond to foreseeable changes.

The SWOT approach can be applied to the present problem of evaluation because planning future innovation cooperation and appraisal of innovation cooperation rely on the combination of two perspectives. The expected benefit and significance of the innovation benefits are fostered by the company's cooperation and result in *risks and opportunities*. Moreover, these risks and opportunities may be fundamentally influenced by the *strengths and weaknesses* of the cooperation partner (i.e., the provider of the innovation benefit).

These perspectives reveal that the logic of evaluation must be changed: the strengths and weaknesses of the external partner are considered in relation to the risks and opportunities that the company derives from the innovation benefits secured from the external partner. The sequence of the individual steps within the appraisal process therefore plays an important role because decision makers within the company often evaluate partners and their respective strengths and weaknesses without much clarity about what important assessment criteria the company must adopt from its own perspective. The assessment criteria are determined largely on the basis of the subject matter of the exchange. Similarly, as with the choice of a partner in one's private life, the following statement applies: *Before we know who is suited to us, we must know what is appropriate for us.*

10.4.1 Conceptual Perspective: Analysis of the Risks and Opportunities Derived from the Innovation Capabilities of External Partners

A new methodology is indispensable for the strategic assessment of cooperation relations centred on innovations according to the outlined assessment guidelines. First, it must be clearly established how the innovation solutions secured from third parties contribute to the company's competitive strategy to be able to analyse the risks and opportunities derived thereof. To evaluate the significance of the resources procured from external sources for the company's competitiveness, it is important to remember what competitive strengths are at the disposal of the company and the particular reasons that actually contributed to the competitive strengths of the company. Although management must actually be cognisant of the company's own competitive strengths, determining the basis on which the company derives its competitive strength is no trivial task (cf. 10.1: *Strategic management and innovation*). To analyse the risks and opportunities of drawing on external innovation capabilities, five substeps are applied.

Step 1: What can we do better than our competitors?

First, it is important to reflect on the company's competitive advantages with respect to those of the competitors. Simply naming the competitive strategy by taking recourse to strategic principles such as *price leadership* is insufficient. Rather, the central pillars of the company's own product market strategy must be concretely defined. For example, this definition might be based on specific competitive factors, such as *price*, *quality*, *flexibility*, and *innovativeness*; thus, the competitive strategy *price leader in the qualitatively demanding product segment* *of 'upper middleclass'* could also be termed *fast followers in innovations* – if there is a similar capacity for flexibility in response to high quantities and variants.

Step 2: What generates competitive advantage?

The most important question in the second step is as follows: "*Which resource does our company most rely on, and from which resources or resource bundles (cooperating resources) do our competitive strengths derive?*" or "*What resources do we lack to be competitive?*" An initial approach to this complex issue involves taking inventory of the company's history. Thus, actions that were important in the past to improve company performance must be listed. Second, it is worth noting those individual domains that are associated with better performance compared with competitors. For example, an established quality management system that core competitors do not have in such an elaborate form is a significant contribution to securing quality leadership. Even tangible resources, such as highly automated production facilities, can represent an important piece of the large mosaic if, for instance, such resources concern the manufacturing of bulk goods at a greater cost advantage. The existing resource base is important to both the past and present success of the company. Moreover, the analysis clearly indicates which resources (resource bundles) are of greater significance for future competitiveness and must therefore be maintained and further developed. It is also important to identify blind spots.

A so-called resource map can be used to record and track resources. A *resource map* is two-dimensional. Different resource categories are divided into two domains: the resources that are already at the company's disposal and the resources procured from external partners. The other dimension covers the different sectors of a company according to the product development process, functional divisions or certain subsystems.

By examining and visualising firm-specific resources and, more importantly, by demonstrating the interrelations between individual resources in the form of resource bundles, management can achieve greater clarity about which resources are particularly important for the company. A resource map reveals the fact that individual resources are often connected to other resources, depending on what type of competitive advantage is sought.

Step 3: What significance (risks and opportunities) do externally procured innovation resources have for our present and future competitiveness?

The resource map vividly displays the degree of actual and potential importance of externally procured resources, which can reveal both opportunities and risks. Opportunities in the form of expected profits for the company can be easily determined and estimated. However, risk assessment is more difficult to undertake, primarily because of the generally narrow view of the concept of risk. Risk can be described as a function of the probability of the occurrence of a damaging event and the resulting damage. The staff members responsible for risk assessment primarily focus on the analysis of default risk or, in effect, the probability of the failure of a resource supplier to perform. Therefore, only one of the two central aspects is considered. In the consideration of risk, the main task is to first undertake an impact analysis – which must initially be viewed independently from the resource supplier. Preliminary assessments of the actual condition, particularly using the resource map, offer good points of departure to identify the consequences, such as present and future competitiveness in the event that the company no longer has access to external innovation resources. The impact spectrum can range from "*In the short and medium term, not much or nothing happens*" to "*Our innovation capability is massively affected*". In the process, the responsible persons must, however, mentally discard the classic ABC categorisation of cooperation partners, for instance, as applied to the suppliers of intermediate goods. Even the shortage of a resource that appears small and insignificant on the surface can greatly affect the innovation capability of a company. This logic of analysis attempts to assess the existing resources garnered from external sources in terms of their current significance. However, an ex-ante assessment of external resources is more important to the analysis of the future significance of these resources for the company and the identification of how the externally procured resources can be integrated into the multilayered network of internal resources. This assessment is especially important for innovation cooperation because the value of certain resources can undergo a fundamental change.

Second, the possibility of no longer having access to external resources (or no longer having them in the form required or originally planned) must be explored. This probability of failure is significantly dependent on the strengths and weaknesses of resource suppliers.

Step 4: Assessment of the strengths and weaknesses of the resource provider (cooperation partner).

An entire range of approaches is available for conducting a general assessment of cooperation partners, ranging from the classic financial rating criteria to supplier assessment tools or audits. However, these approaches constitute only the initial point of departure for the assessment of innovation cooperation partners. For example, a credit check is absolutely necessary. Equally important, it is worth establishing at the outset whether a cooperation partner works according to certain standards or has the requisite certifications.

However, a company must be able to pose certain fundamental questions precisely in sensitive and significant matters such as innovation capabilities because externally procured resources can be decisive for the sustainability of the company: What are our values, and are the values of the cooperation partner compatible with ours? Do the strengths of the cooperation partner support and bolster our strengths? Will their weaknesses be risky for our core competences? Their strengths, their core competences and particularly their bases can be gleaned from the resource map.

In this context, typical issues should be further addressed, such as the intersection of market activities and the resulting conditions of competition, the compatibility of different (innovation) cultures, the compatibility of strategic goals, the company's significance as a cooperation partner for the supplier, the reliability and opportunistic behaviour of the supplier, and the risk of know-how leakages.

Each company must necessarily develop a set of criteria to fit its own circumstances. The set or the weighting of individual criteria is not solely dependent on the procured resource. If, for instance, an innovation partner has deeper insights into the innovation processes within the framework of the cooperation or even has potential access to the company's know-how, then the trustworthiness of the cooperation partner is of greater significance. Thus, a standard set of criteria can be beneficial only to a limited extent, and a company-specific or even resource-specific system is needed.

Step 5: Combining the perspectives and drawing from prevailing standard strategies.

The final step combines the previous partial results, the assessment of externally procured resources and the respective suppliers. The overall result can be recorded in a matrix (cf. Fig. 10.2) that plots the significance of the corresponding resource in one dimension and the risk assessment of the corresponding suppliers in the other

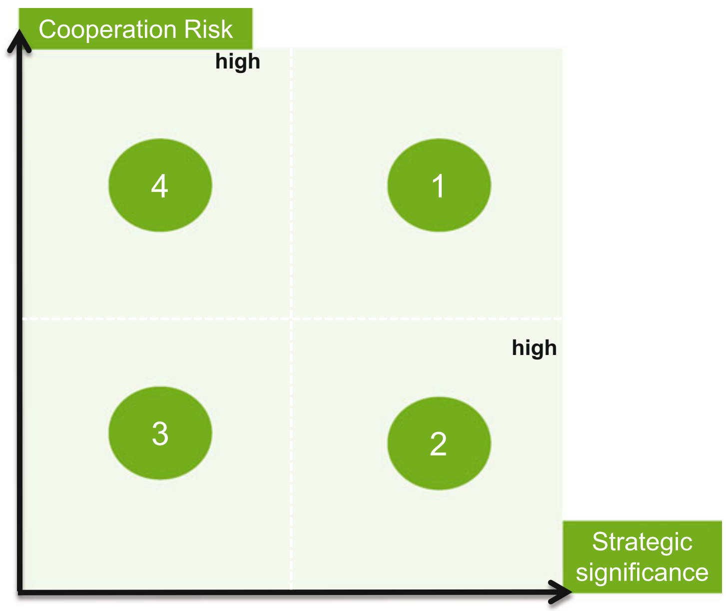

Fig. 10.2 Four-field matrix for determining the risk of cooperation and the strategic significance of resources

dimension. When possible, the current and future meaning of the resource must be considered.

Along the four fields of the matrix, generic strategies can be derived in relation to the externally procured resource or to the resource suppliers, which can be used by management as a tool for further brainstorming.

Course of action, field 1: A case wherein a resource is highly significant and the resource supplier is simultaneously considered to be fraught with risk must be viewed critically and requires action. Thus, the risk should be minimised by risk distribution (e.g., by distributing the risk over several cooperation partners) or by exercising a stronger influence on resource suppliers. Moreover, alternative resources should be accessed to substitute for existing resources successively. In certain cases, particularly when the strategic innovation resources are intrinsically important, it has been shown that developing corresponding resources or competences within the company represents a realistic alternative.

Course of action, field 2: Strategically important innovation resources that are procured from reliable partners first indicate that the cooperation relationship is to be secured and stabilised to optimally ensure that the relationship remains immune to possible disruptions. Furthermore, recommendations similar to field 1 also apply, albeit in a weaker form.

Course of action, field 3: This area concerns rather insignificant innovation resources that are procured by reliable cooperation partners. Thus, there is no urgent need to act.

Course of action, field 4: For strategically less important resources that stem from risky cooperation partners, either the cooperation or the cooperation partners must be subject to scrutiny. Searching for alternative cooperation partners that promise greater security or a greater influence on the partner would be an alternative course of action. If these alternatives do not meet the target, then insourcing innovation resources would be worth considering.

The courses of action described above offer the company's decision makers important methods for addressing certain cooperation relations. It is thus crucial to critically analyse each aspect of innovation cooperation individually.

The outlined approach to assessment is suitable in this form or in a marginally modified form for different contexts of application, such as the *ex-ante assessment of future innovation cooperation*, the *assessment of present innovation cooperation* and the *development of strategic cooperation partners*. Moreover, the approach allows even small and medium-sized companies to assess their innovation cooperation strategically and to plan accordingly.

The following case study relates to the ex-ante assessment of future innovation cooperation. Thus, it should be clarified in advance which aspects within the framework of a cooperation relationship could become crucial and which aspects must be consciously created to ensure that cooperation can be successful.

Recommended references: Risk management in cooperation: Das and Teng (1998), Lo Nigro and Abbate (2009), Kraege (1997), Link (2001); *Strategic Planning and assessment/competence management:* Welge and Al-Laham (2008), Mills et al. (2003), Zanker (2011).

10.4.2 Opportunities Through the Cooperative Insourcing of a Strategically Important Production Line

To survive as a manufacturer of electrical heating units in a high-tech country, especially without a proper facility in which to conduct R&D, company B works with several cooperation partners (customers, suppliers, research facilities and competitors) within Germany and abroad. Over time, this cooperation has resulted in a dense network of partner companies. The key players involved can thus assume the function of system suppliers with respect to customers to a certain extent. By combining their respective core competences, the cooperating companies can gain access to the entire range of business activities as a *full solution package*, beginning with the idea generation phase, technical development, and manufacturing and continuing through the corresponding sales partners. In this manner, company B achieves economies of scale, higher flexibility and, in particular, innovation advantages that are reflected in the high quality, reliability, and customer-specific modifications of the company's own products. Apart from preparing very small batch sizes, company B offers the benefit of shorter response times in delivery and service.

Over time, this network led to the formation of a dense network of cooperation and interaction between the partners as well as certain dependencies. For instance, company B purchased all its electric heating cartridges from a European cooperation partner to sell them in addition to the heating elements that it manufactured itself on the German market. However, company B began to experience difficulties with this European cooperation partner. Because the heating cartridges were increasingly in demand in the German market, the business unit grew and gained strategic importance. Meanwhile, the European cooperation partner experienced increasing difficulties in meeting the specifications stipulated by company B regarding short delivery times and flexibility, particularly regarding smaller quantities. As a result, there were increasing instances of supply bottlenecks and delays in the delivery of heating cartridges. Because they were marketed in Germany under the name and direction of company B, these supply problems and corresponding customer complaints negatively affected company B's image. Thus, company B worried that longer delivery periods would result in a loss of customers. These developments would culminate in eroding the significant competitive advantages that company B had amassed, which included shorter response times, high flexibility and supplier reliability.

Company B attributed the possible cause of the recurring problems of the European partner to the structure and organisation of its work processes. The partner was shaped by a strong Tayloristic work organisation, which essentially meant a hierarchical organisational structure with standardised communication procedures. As a result, the partner's decision-making powers were concentrated solely at the management level, which led to extended response times. By contrast, company B relies heavily on a flat hierarchy with decentralised decision-making powers as well as shorter communication and process flows. In addition, company B privileges the possibility of decoupling tasks from employees and trains its employees to accept different tasks and positions on an as-needed basis. The company's employees can thus be engaged flexibly, and projects can be processed on short notice.

The differences in organisational structure are dependent on the respective market environment of both companies. The European partner primarily manufactured simple standard heating elements on a large scale, whereas company B, with its more complex product offering, largely negotiates niche markets and responds to a different hierarchy of requirements with regard to flexibility and a short response time rather than mass markets with a stable demand structure. Because the heating cartridges delivered to company B were rather complex and manufactured on a small scale and thus did not constitute the core business of the European partner, it was not possible to expect the European partner to make comprehensive changes to its organisational model solely on account of this business unit.

Company B then considered manufacturing the same heating cartridges that were once procured externally and then from a corresponding evolving production line. Larger volumes of heating cartridges and other heating elements bound with higher profit margins could still continue to be purchased from the same European cooperation partner. In addition to solving these problems, company B adopted an approach that promised better possibilities for exploring unknown market potential for the business unit *Heating Cartridges* through extended market access. Above all, customer loss resulting from the long supply times needed to be prevented, as such a loss of customers would automatically have affected other product lines of company B.

These considerations constituted the foundation on which a joint workshop with company B was developed to facilitate the decision-making process if the heating cartridges procured from the European cooperation partners continued to be purchased or manufactured in parallel at company B. The final decision could not overlook the fact that company B had not yet mastered the process of manufacturing the added product, and in view of the necessary transfer of technology and process know-how, the company had to rely on the cooperation of the European partner. In addition, the feasibility of manufacturing heating cartridges in-house should not have prevented company B from continuing to purchase other heating elements from the European partner.

The decision to partially insource production in this context, particularly for the smaller batch sizes of heating elements, required consideration of whether the product or backward integration would be compatible with company B's competitive strategy. Second, company B had to clarify whether the product was such a highly strategic product that it had to be manufactured within the company. Moreover, important preconditions and framework conditions for the independent production of these heating cartridges had to be identified to result in success for company B, and the company had to analyse whether and how it could actively create and influence these preconditions and framework conditions. Finally, company B needed to determine how these changes could best be communicated to the European cooperation partner and to customers.

To analyse these requirements, the described five-step conceptual approach was applied. In this context, particularly the points of maximum profitability, business value, and other strategic points needed to be investigated, and the central aspects contributing to the success of the project as well as their configuration needed to be derived. It became possible to identify the potential effects of the failure of insourcing cooperation on the competitive advantages derived by company B and, correspondingly, to proactively reduce and control those potential risks. Additionally, company B was confronting immense financial risks based on the investments that would become necessary in terms of additional machines and facilities.

10.4.2.1 Approach

The strategic assessment of innovation cooperation at company B was planned as a multilayered process. To test the compatibility of the product and to emphasise the strategic relevance of the product based on the competitive advantage of company B, strategically relevant internal and external resources were listed. How company B derives its competitive edge can be described with five concepts:

1. Innovation leaders in the niche market
2. Production of premium quality products
3. Flexibility to ensure customer-driven adjustments and the ability to provide different batch sizes
4. Short response times regarding delivery and service
5. Customer proximity

These competitive advantages cannot be viewed in isolation; instead, they build upon or are derived from one another. In the second step, the innovation resources directly contributing to competitiveness were itemised and organised on the resource map.

The sheer number of crucial innovation resources was categorised using the larger fields of *technique/technology*, *organisation*, *employees*, and *management*. The corresponding internal and external and tangible and intangible innovation resources were then categorised accordingly. Figure 10.3 shows a selection from the resource map used for company B. The dark colour indicates the in-house resources, and the light colour indicates the external resources provided by partners

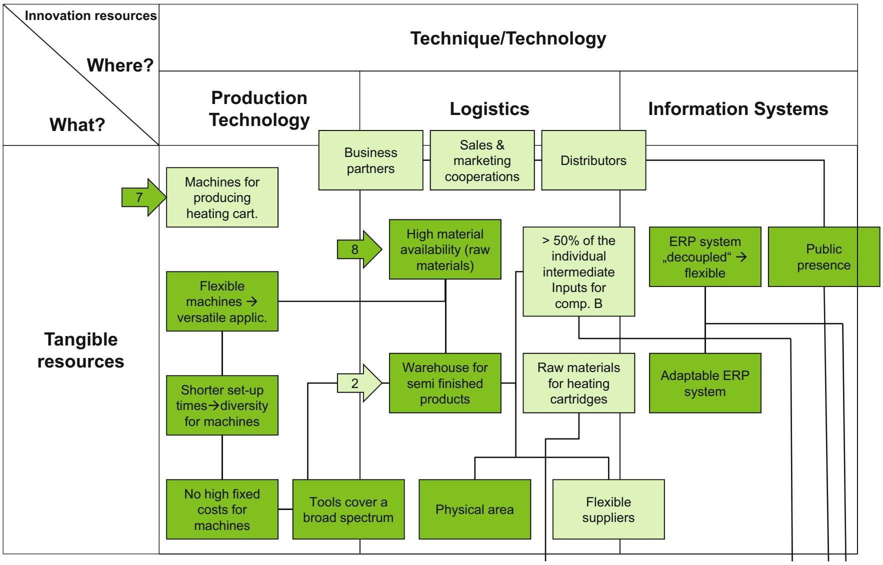

Fig. 10.3 A selection from the resource map of company B

and suppliers. Such resources are important for strategic reasons because, for instance, they may be used only for building specific types of production machines.

The colour-coordinated resource bundles on the resource map indicate how innovation resources are combined and ensure the competitiveness of company B. The following examples offer insight into the resource map of company B:

- A large production area is available in which the production line for heating cartridges can be developed (tangible resources/logistics).
- The cultivation of long-term partnerships with suppliers ideally offers a win-win situation (intangible resources/logistics).
- The quality management system can be used to undertake product control on an on-going basis (intangible resources/information systems).
- The decentralised organisational structure allows for achieving shorter delivery times (intangible resources/process organisation).
- Personnel development is regulated through a personnel development plan. Measures such as job rotation can thus be implemented. Each employee has a tandem partner who can assume the required tasks when necessary (intangible resources/personnel development).
- The high demand for products can be attributed to the hallmark of quality: *Made in Germany*. These high expectations can be met because of the production location and the high quality requirements (intangible resources (titles that are subject to claim, such as licences, patents and copyrights, and goodwill)/ leadership).

Thus, a broad variety of tangible and intangible resources of all categories contributes to the company's competitiveness. For example, the resources underlying the competitive advantage derived from flexibility include flexibly deployable machines, shorter set-up times, a high degree of material availability, short-term performance reserves among employees and flat hierarchies. The question of how the resources interact with one another is not addressed, but the resources clearly show the high standards to which company B subjects its production process to remain competitive.

Based on the resource map, the strengths and weaknesses of the cooperation partner were then identified and assessed to describe their relevance (with available options ranging from *especially important* to *not as important*). These strengths and weaknesses of the European cooperation partner were then unified by means of the resource map to map the effects on the resource bundles. The affected resources and resource bundles were marked for that purpose. The strengths and weaknesses of the cooperation partner thus simultaneously exercise both strengthening and weakening influences on the resources as well as the resource bundles of company B. For example, the high quality of the products, which constitutes one of the strengths of the cooperation partner, has resulted in a distinctly lower customer complaint rate at company B. By contrast, the Tayloristic work organisation of the partner and the extended communication chain have a negative effect on company B's ability to provide flexibility.

To obtain a holistic overview of the influence of all the strengths and weaknesses of the cooperation partner on company B's crucial resource bundle, concrete implications for company B's competitive advantage were depicted. For each competitive advantage accrued to company B, the risks and opportunities derived from the cooperation to date or from the possible future in-house production of heating cartridges were documented.

These competitive advantages notwithstanding, the study also included the potential effects on the financial situation and on the costs of losing or generally discontinuing the cooperation alliance. Significant courses of action and negotiation could be generated through this perspective, such that the participants were asked to assess the relevance of the individual risks and opportunities connected with each competitive advantage. The following points, among others, could be identified as the main courses of action.

- Ensuring the compatibility of the product quality of the European cooperation partner with the process quality of company B
- Ensuring the flexibility and delivery times for the old and planned new products
- Securing knowledge transfer
- Securing benefits for the European cooperation partner

For each of the main courses of action and negotiation fields, a checklist or a catalogue of measures was created to maximise opportunities and minimise risks for both partners. Thus, the cooperation partner could, for instance, optimise its internal processes by exclusively producing large batch sizes, which would require less set-up time. To ensure the safe transfer of know-how, an exchange of specialists was conceivable.

10.4.2.2 Conclusions of the Case Study

Currently, company B has chosen to strategically expand its cooperation with the European cooperation partner and has already spearheaded this change. By identifying the core action and negotiation fields, a catalogue of measures could be prepared as the basis for engaging in successful negotiations. In addition, a workshop at company B raised awareness of the changes that resulted from the insourcing measures. Thus, the relevance of the different parameters, possible problems and risks, and the extent of the potential problems were clarified and exemplified to allow all open questions to be addressed during the negotiations and to enable the removal of all constraints. Hence, the workshop at company B bore a strongly reflexive character.

10.4.3 Summary of Reflections on the Approach

A brand new procedure needed to be developed to respond to the specific manner in which innovation-centred cooperation relations were to be strategically assessed, and both the competences within the company as well as the strengths and weaknesses of the cooperation partner had to be developed. The basic idea resembles the SWOT logic, but numerous adjustments were necessary. Although the SWOT approach initially appears structured, the task of infusing individual fields with substantial content and creating a link between them is challenging.

The experiences gained from the case studies have shown that the assessment of current and future cooperation relations cannot be undertaken without generating the corresponding capacities and intellectual effort. Nevertheless, the results and the knowledge gained from this approach justify such efforts in that they exceed initial expectations.

In general, the new assessment approach can be easily and profitably adapted to various application contexts within the scope of field-testing. For instance, the case study involving company B illustrates how potential risks and opportunities deriving from a strategically important innovation partner can be measured in advance. Such an analysis resulted in action plans for realising an optimal cooperation arrangement with the company's partner.

The new planning and assessment approach has generated the following findings:

A logical and practical framework concept rather than standard operating procedures

The approach must not be viewed as a standard operating procedure for interactions with strategically important innovation partners. The approach delivers *only* the methodological framework for the instrument to generate corresponding plans based on a concrete and specific problem. These plans therefore fully depend on which content the participants plan on developing within the framework of the process. It was important in this context that the company executives were able to track the individual steps, the partial results and the overall result. The case study showed that the process does not present an unequivocal, optimal solution; instead, it generates different courses of action that are strategically well founded and correspondingly resilient and serves as a decision support instrument.

Customised approach

The preliminary hypothesis held true: standardised assessment tools reach their limits when challenged to respond to specific strategic questions. Such instruments are certainly helpful, for instance, for assessing a supplier, for managing innovation and technology, and for use within the narrowly defined application context. However, these instruments are extended to their limits within the broad scope of the assessment problems discussed herein because the competences available within the company need to be considered in conjunction with those of the cooperation partner, along with its strengths and weaknesses, to ensure that they are documented and processed purposefully.

The present planning and assessment approach must be regarded neither as a versatile prefabricated tool nor as a *stand-alone* instrument. As the practical examples have shown, the approach must be adjusted to the specific problem for a meaningful application. However, the approach is heavily based on numerous information sources, which may depend on other instruments.

Visualising and identifying the resources and core competences

A method of analysis was created using the resource map and the corresponding relevant processes. The obtained results proved insightful, especially upon further consideration. At first glance, the action scenarios were judged to be complex and laborious. Injecting relevant content into the resource map and exploring the corresponding resource bundles were possible within the framework of a workshop with the entire executive team that lasted three-quarters of a day. The participants were clearly inspired by how much they learned through a systematic reflection on their own company's competitive advantage and, above all, by gaining an awareness of the different pillars of competitive advantage. Management found clarity regarding not only the individual factors and underlying connections but also the white spots on the company's resource map. The intense discussions at the workshop also helped management to systematically compile the information known to individual executive managers to generate a comprehensive overview.

Highlighting the dependency relations

In the same vein, the resource map can be used to depict crucial dependency relations. The simple question of "*What happens when the company can no longer rely on the corresponding resource?*" has occasionally prompted eureka moments. It became obvious that small innovation partners can initially be highly significant to the innovation and competitiveness of a company or to the determination of what type of dependency relationship the company can have with seemingly *low-risk* partners. A positive side effect of the analysis process was that even the intracompany dependency relations became clear. If an individual employee is solely responsible for one resource or even an entire resource bundle that is crucial to the innovative capability of the company, then this factor cannot be overlooked.

Thus, the approach described above has proved indispensable to the strategic assessment of innovation cooperation. This assessment approach produces strategically founded and correspondingly resilient plans and action plans that support the decision-making process. The results must therefore be viewed as complementing the business instinct – the much-celebrated gut feeling – that is frequently responsible for the final decision on innovation-centred cooperation.

Conclusions

Innovations with little R&D, or without it, do not necessarily represent isolated cases; they just are different! This statement fully encapsulates the core findings of the integrated research project Low2High, of which the conceptual perspectives and case studies described in this chapter were a part. This research project, funded by the German Ministry of Education and Research, examined how non-R&D-intensive companies generate successful innovations beyond R&D activities. As a result, this project has shown that innovation processes of these types of companies are less formalised than those in R&D-intensive companies. Moreover, innovation processes of non-R&D-intensive companies are heavily customer driven, which may result in the gradual fading of ideas. Thus, existing solutions for innovation strategies based on R&D activities are not suitable, nor is the usage of standardised instruments and solutions instead of tailor-made and adjusted approaches (Erler and Wilhelmer 2010; Willke 2011).

In this chapter, two different approaches for non-R&D-intensive companies have been described to increase the innovativeness and competitive advantage that can be adopted by other companies with little effort and change. By developing and visualising the operational innovation process within a company, this study has built a foundation for identifying answers to the question of how internal innovation processes in non-R&D-intensive companies can be fundamentally improved. Thus, the innovation processes

(continued)

adopted by individual companies can be revealed, which is an important condition for identifying the crucial phases and problems pertinent to configuring suitable approaches. In particular, this approach accounts for both the organisational structure and individual employees. The recruitment of a PIM was among the many potential incremental improvements that were made within the company. This newly created role is essentially a catalyst that spurs the innovation process in non-R&D-intensive companies, even as it coordinates innovation activities both internally and externally with respect to partners. A process was established to plan and implement the function of a PIM that allows both the creation of a job specification for such a position and assistance in creating the necessary organisational framework for successfully integrating this function within the company.

Previous analyses have shown that innovation cooperation among non-R&D-intensive companies has high strategic relevance for such companies. Such companies may not always be aware of this relevance and may not even have adequate resources at their disposal to undertake such necessary analyses and planning. The approach that was introduced in relation to the strategic planning and control of innovation cooperation is useful for assessing innovation cooperation with external partners in terms of their risks and opportunities. The strengths and weaknesses of any (potential) innovation partner are assessed in relation to their specific strategic relevance for the company, and risks and opportunities are derived on that basis. These findings can in turn serve as the basis on which to determine specific courses of action – for instance, to determine whether certain competences should be developed internally even if they had previously been procured from the partner. The case study here presented instruments and the resulting derived solutions that can be used in diverse fields of application.

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Chapter 11
Policy Implications and Future Challenges

Gunter Lay and Oliver Som

Abstract The findings on the innovation capabilities and practices of non-R&D-performing and non-R&D-intensive companies have implications for German science and technology policy. The goal of this chapter is to outline those potential implications. The chapter begins with an assessment of the current role of non-R&D-intensive ("low-tech") industries in German innovation and technology policymaking. Based on the shortcomings identified in this book, this chapter outlines how the frequently overlooked innovation potential of non-R&D-intensive industries and firms could increasingly attract the attention of policy makers to support more comprehensive policies that promote and strengthen innovation in German industries

11.1 Introduction

The previous chapters clearly demonstrate that the absence of R&D does not prevent companies from engaging in knowledge generation and acquisition activities. In an attempt to generate reliable and comprehensive metrics for accurately assessing R&D performance across the board, our study analogously demonstrates that innovation and technological competence and consequently competitive success are realistic goals even for non-R&D-performing companies. Alternative strategies adopted by such companies to leverage in-house and external innovation resources and stocks of knowledge – technical or non-technical, product- or process-related – also facilitate sustainable competitiveness and growth. Such strategies largely allow these firms to excel in a market competition environment that, as a growing body of evidence suggests, is not solely driven by costs and product prices.

Our findings on the innovation capabilities and practices of non-R&D-performing companies have implications for German science and technology

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policy. This chapter outlines those implications. The chapter begins with an assessment of the current role of non-R&D-intensive ("low-tech") industries in German innovation and technology policymaking. Based on the shortcomings identified in this book, this chapter outlines how the frequently overlooked innovation potential of non-R&D-intensive industries and firms could increasingly attract the attention of policy makers to support more comprehensive policies that promote German innovation strength.

11.2 On the Current Status of the Low-Tech Sector in German Technology and Innovation Policies

In many industrial economies, the funding and promotion of science, technology, and innovation are conventionally viewed as strictly the domain of the state (OECD 2012). Germany is no exception, and its technology policies reflect an approach and a belief system that date back to the 1960s (Frietsch and Kroll 2010).

The German federal government's "High-Tech Strategy", which was initially formulated in 2005 and subsequently updated in 2010, outlines the goals and instruments of German technology policy (BMBF 2010). In the section titled "Ideas. Innovation. Growth", the High-Tech Strategy identifies five fields of action in which new solutions must be sought: climate/energy, health/nutrition, mobility, security, and communication. Core technologies in these demand areas are deemed drivers of innovation. Promoting these core technologies and improving the conditions for innovation – as established in the "High-Tech Strategy" – would ideally lead to growth and improvement in the identified demand areas. The High-Tech Strategy thus aims to orient Germany's research and innovation policies towards that central mission (BMBF 2010).

The core technology areas identified in the High-Tech Strategy as the drivers of innovation in need of targeted funding and promotion are bio- and nanotechnology, micro- and nanoeletronics, optics, microsystems, raw materials and production technology, service research, aeronautics technology, and information and communication technology (BMBF 2010). With such a strong technological focus, German research and innovation policies privilege those research and knowledge-based technologies that traditionally form the core of the measures charted in technology policies and that are (even if in varying degrees) globally regarded as core technologies for innovative products (Gehrke et al. 2013).

When comparing the list of core technologies for innovations identified in the "High-Tech Strategy" with the levels of differentiation within different technology fields, such as high-tech or medium high-tech and low-tech or other non-research-intensive areas (Legler and Frietsch 2007), it is possible to note commonalities between research and innovation policies in the extent to which they privilege core, cutting-edge technologies or knowledge-intensive sectors. The highest innovation potential is thus ascribed to the high-tech sector for its presumed ability to address

Table 11.1 Sectoral breakdown of German federal spending on commercial organisations and companies engaged in science, research and development from 1993 to 2011 (Source: BMBF data portal (http://www.datenportal.bmbf.de); own calculation)

Economic sectors	1993 to 2011 in million Euro	1993 to 2011 in %
Vehicle manufacturing (road vehicles and locomotives, ship building, air and spacecraft building)	10,198.7	24.81
Manufacturing data processing devices, electronic devices and optical instruments	9,154.4	22.27
Miscellaneous services provided by companies and professional services	8,517.0	20.72
Machine building	3,382.5	8.23
Manufacturing of chemical and pharmaceutical products	1,695.7	4.12
Manufacturing of electric devices	1,460.1	3.55
Metal production and processing, manufacturing of metal products	1,279.1	3.11
Energy supply (not including mining)	763.0	1.86
Manufacture of rubber and plastics, glass making industry, ceramics, manufacture of non-metallic mineral products	722.7	1.76
Textile, apparel and leather industry	486.4	1.18
Other economic sectors	3,451.0	8.39
Total	41,110.6	100

complex social challenges. The High-Tech Strategy thus advances a recommendation of the German Expert Committee for Research and Innovation (EFI), whose 2010 opinion paper raised objections that Germany's strong R&D focus for the privileged domains of cutting-edge technologies while simultaneously neglecting other segments of premium technology had negatively affected the dynamics of innovation in Germany (Rammer et al. 2011).

This equation of premium technology with innovation-intensive technologies is reflected in the 1993–2011 spending of the Federal Republic of Germany on commercial organisations and companies involved in the management of knowledge and R&D, here analysed on the basis of a sectoral breakdown of the recipients of federal funding (cf. Table 11.1**)**.

This table shows that more than half of the federal funding reserved for knowledge and R&D is devoted to R&D-intensive high-tech industries, such as aircraft and spacecraft manufacturing; data processing, electronic and optical device manufacturing; and knowledge-intensive service sectors, including miscellaneous services.[1] Medium-tech industries or – in the diction of the EFI Commission – the manufacturers of premium, cutting-edge technologies, such as road-vehicle

[1] It is hereby reasonably implied that the vehicle manufacturing industry, which is not available in a more detailed classification in the BMBF database, is a composite with equal shares of road vehicles, locomotives and ship builders on the one hand and air and spacecraft manufacturers on the other hand.

manufacturers, machine building industries, manufacturers of electrical equipment and manufacturers of chemical products, received more than a quarter of federal contributions. Non-R&D-intensive industries – such as manufacturers of metal products or plastics, textile, apparel and leather as well as manufacturers of non-metallic mineral products – constitute the remaining 15 % of federal funding.

The federal funds for science and R&D allocated to commercial associations and companies are thus largely concentrated in industries that employ only a small fraction of the German working population. Table 11.2 clearly shows that high-tech sectors constitute less than 5 % of the working population. Even the combination of high-tech and medium high-tech industries with knowledge-intensive service providers constitutes only 20 % of those employed. In effect, the sectors employing one-fifth of the work population receive nine-tenths of state funding with the express mandate to develop innovations that address social challenges.

With state funding disproportionately concentrated in specific sectors, it is clear that the promotion of German innovation is largely based on the idea that innovations occur in select sectors and primarily through R&D. Table 11.2 shows not only the share of employment of the different sectors but also the share of various sectors in the government's R&D spending. According to this table, the high-tech and medium-tech sectors together represent a 90 % share of private businesses' total

Table 11.2 Employment and federal R&D expenditure for 2011 according to a sectoral breakdown of the economy (Source: Statistisches Bundesamt 2013 and Stifterverband 2013 M; own calculation)

Economic sectors	Number employed in 2011 in %	Internal and external R&D spending in 2011 in %
Vehicle manufacturing (road vehicles and locomotives, ship building, air and spacecraft building)	3.4	45.6
Manufacturing data processing devices, electronic devices and optical instruments	1.2	12.0
Scientific, technical and insurance-related services	8.5	6.6
Machine building	4.0	8.6
Manufacture of chemical and pharmaceutical products	1.7	14.2
Manufacture of electric equipment	1.9	2.8
Metal production and processing, manufacture of metal products	4.2	2.2
Energy supply (without mining)	0.8	0.4
Manufacture of rubber and plastics, glass making industry, ceramics, manufacture of non-metallic mineral products	2.4	2.0
Textile, apparel and leather industry	0.6	0.2
Other economic sectors	71.2	5.2
Total	100	100

R&D expenditures. This value significantly corresponds to this economic sector's entire share of federal spending intended to stimulate innovations that address high-priority social challenges.

Because the German federal advisory service for "Research and Innovation" explicitly distinguishes between federal funding measures for research purposes and federal measures for promoting innovation among small and medium-sized enterprises (SMEs) (http://www.foerderinfo.bund.de/index.php), our analysis seeks to determine whether both action areas privileged high-tech or medium-tech sectors to the same extent. Federal research funding generally occurs through direct project sponsorship within the framework of technology-oriented sponsorship programmes (http://www.foerderinfo.bund.de/de/166.php). Information on more than 110,000 ongoing or completed projects that received funding from the Federal Ministries for Education and Research (BMBF), for Environment, Natural Conservation, Building and Nuclear Safety (BMUB), and for Economy and Energy (BMVI) can be found in the sponsorship catalogue (http://foerderportal.bund.de/foekat/jsp/StartAction.do). Approximately 9,000 of these projects that received funding totalling 3.3 billion euros were approved in the previous year (2013); thus, information on those projects is now fully accessible. Downloaded on March 12, 2014, this information forms the basis for the present analysis.

The evidence suggests that approximately 38 % of project funds approved in 2013 were accorded to projects that are under the jurisdiction of and are accountable to an administrative unit (federal administration, federal states, municipalities, and research institutions, as well as universities, colleges and schools under the jurisdiction of the federal government or one of the federal states). Approximately 35 % of the funds were diverted to projects for non-profit organisations (e.g., organisations funding science and research (MPG, DFG, FhG), Helmholtz Centres, Leibniz Institutes, registered associations, foundations). Commercial organisations and enterprises received approximately 27 % of the project sponsorship of research projects. In approximately 2,600 of the projects in this last group, the federal state invested approximately 880 million euros. The recipients of these grant benefits were classified by economic sector as specified by the Federal Statistical Bureau (Destatis 2008), following the internal portal www.firmenwissen.de of the Registered Society of the Credit Reform Union (Verband der Vereine Creditreform e.V.).

Table 11.3 demonstrates that in 2013, nearly four-fifths of the recipients of federal funding for projects were in the high-tech, medium-tech or knowledge-intensive service sectors.

Table 11.3 also shows that the firms who received the greatest share of project funds and subsidies within this group were providers of freelance professional and technical services (e.g., consultants, engineering offices), claiming 13.4 % of the funding; this group was followed by manufacturers of data processing (DP) devices and electronic and optical instruments with 13.1 % and enterprises undertaking scientific research and development at approximately 11 %.

In effect, approximately 23 % of project funds were allocated to groups outside of the high-tech or medium-tech branches and knowledge-intensive service companies. Individual entities within this group of companies with the greatest share of

Table 11.3 Sectoral breakdown of project funds allocated to commercial organisations and companies by BMBF, BMUB, BMWi, BMEL and BMVI in 2013 (Source: http://foerderportal.bund.de/foekat/jsp/StartAction.do and independent estimates)

		Grant amount in euros	Grants allocated in %
High-tech sectors	Manufacture of pharmaceutical products (Destatis 2008: 21)	11,993,955	1.36
	Manufacture of data processing devices, electronic devices and optical instruments (Destatis 2008: 26)	115,721,058	13.13
	Aircraft and spacecraft building (Destatis 2008: 30)	19,352,621	2.20
Medium-tech sectors	Manufacture of chemical products (Destatis 2008: 20)	24,541,827	2.79
	Manufacture of electric equipment (Destatis 2008: 27)	51,993,907	5.90
	Machine building (Destatis 2008: 28)	46,602,156	5,29
	Road vehicle manufacturers (Destatis 2008: 29)	84,319,616	9.57
Knowledge–intensive service sectors	Service providers for information technology and information (Destatis 2008: 62 through 63)	65,481,900	7.43
	Providers of freelance professional and technical services (Destatis 2008: 69 through 71)	117,982,902	13.39
	Scientific research and development (Destatis 2008: 72)	96,718,559	10.98
	Other knowledge-intensive service sectors (Destatis 2008: 58-61, 64-66, 73-75, 77-82, 84-88, 90-96)	44,979,977	5,10
Total for high-tech sectors, medium-tech and knowledge-intensive sectors		***679,688,478***	***77.15***
Total for sectors not considered high-tech, medium-tech or knowledge-intensive services		***201,350,402***	***22.85***
Total grants for projects launched by commercial organisations and companies in 2013		**881,038,880**	**100**

allocated funds were energy suppliers (Destatis 2008) at 4.2 %, companies from the traffic and logistics sector (Destatis 2008) with 3.2 %, and manufacturers of metal products and metal manufacturers (Destatis 2008) with 2.8 %.

These numbers emphasise that public grants for projects proposed by commercial enterprises and organisations scarcely reach the non-research-intensive sectors of the manufacturing industry, given the narrow focus on technologies privileged in the High-Tech Strategy of the German government. The persistence of this explicit refusal to pursue the goal of broad-based innovation sponsorship in equal consideration of all sectors is not surprising at all. Furthermore, it is equally necessary to investigate whether the initiatives of the federal government targeting medium-sized businesses ("Mittelstand") largely show a similar exclusion of non-R&D-intensive industries.

Measures for funding innovations in medium-sized companies include the Central Innovation Programme for Medium-Sized Companies (ZIM or das "Zentrale Innovationsprogramm Mittelstand"), the ERP Innovation Programme, R&D funding for non-profit external industrial research institutions in East Germany and the diverse funding initiatives of KMU-innovativ (BMBF 2012). The premise of these funding measures is that medium-sized companies are most in need of state subsidies and funding to launch innovative products, processes and services. In particular, the funding and subsidy programmes of the German federal government would offer SMEs the necessary assistance to specifically generate greater investment within the group in research, development and innovation processes; to reduce and absorb the risks involved when undertaking R&D projects; to affect the market with speedy and efficient implementation and incorporation of R&D findings; to expand the scope of cooperation between SMEs and R&D organisations; and to increase the participation of SMEs in R&D collaboration and innovative networks (BMBF 2012).

Although this funding philosophy was not originally restricted to a distinct set of technologies and branches, the initiatives of the KMU-innovativ, for instance, again target a limited group of select technologies. Even here, biotechnology, information and communication technology, nanotechnology, optics, production technology, resources and energy efficiency, and security-related research represented the technology fields whose innovation projects received support from KMU-innovativ. As a result, even an initiative that specifically caters to SMEs inevitably privileges knowledge-intensive, high-tech or medium-tech sectors. An evaluation of the funding initiative of KMU-innovativ from 2011 (ZEW et al. 2011) shows that on the whole, the distribution of the funding recipients reveals almost no correlation with the distribution of sectors among the group of SMEs (cf. Table 11.4).

Table 11.4 demonstrates that 88 % of the recipients in the initiative proposed by KMU-innovativ are from the high-tech and medium-tech sectors or are knowledge-intensive service companies. Companies from non-R&D-intensive sectors, or non-knowledge-based service sectors showed only up to 12 % participation in this measure, although these companies constitute more than half of this reference group. Such an innovation support initiative is more blatantly focused on high-tech and medium-tech sectors than the project funding analysed above.

In contrast to the KMU-innovativ, the Central Innovation Programme (Zentrales Innovationsprogramm Mittelstand, or ZIM) launched by the Federal Ministry for Economy and Energy and generally deemed secondary to the innovation funding initiative for medium-sized companies has expressly been conceived as being available to all technologies and sectors (BMWi 2014). The listed prerequisites (BMWi 2014) stipulate that the funded projects

Table 11.4 Sectoral distribution of the KMU-innovativ participants and the SME reference group (e.g., ZEW et al. 2011)

Sector group	Sectoral distribution of the KMU-innovativ participants in %	Sectoral distribution of the SME reference group in %
High-tech sectors	19	5
Medium-tech sectors	18	19
Knowledge-intensive service companies from the software and EDP sectors	26	11
Other knowledge-intensive service providers	25	15
Industries outside of the high-tech and medium-tech sectors	10	46
Other services	2	5
Total	100	100

- develop new products, processes or technical services that clearly outperform previous products, methods or technical services in terms of their functions, parameters, or features;
- aspire to influence the state of the art of international technology and indicate the applicant company's greater commitment to technological excellence and innovational competence;
- assume a significant but calculable technical risk;
- sustainably enhance the competitiveness of the applicant company; and
- must be unable to implement the project at all – or only with significant delay – without the funding.

Under such conditions, innovation can be viewed as being independent of a certain technological basis in welcoming proposals for innovation projects across sectors. Because there is explicit mention of the possibility that technical services can be recommended for funding, this funding measure is also available to companies from the service sectors.

The ZIM programme was initiated on July 1, 2008, and by April 28, 2014, the volume of grants issued had reached a total of 3,351.2 million euros (http://www.zim-bmwi.de/statistik). However, there is unfortunately no available information on the sectoral distribution of the companies that received financial assistance from ZIM. Thus, no conclusive determination can be made with respect to how widely distributed the ZIM allocations were across sectors. In particular, the question of whether high-tech, medium-tech and low-tech sectors were appropriately represented and reflected in their share in the overall economy or among the R&D-performing companies cannot be answered based on those data.

Information published by BMWi on statistics relating to the ZIM programme (http://www.zim-bmwi.de/statistik), however, offers some reference points related to this question. Based on that information, Table 11.5 shows the sectoral distribution of financial assistance approved under the ZIM programme according to the technology sectors to which the ZIM-funded projects were assigned. This table demonstrates that such projects also exhibit significant intersections with the core technologies defined in the High-Tech Strategy of the German federal government as well as with technologies that had been funded by KMU-innovativ:

- Core technologies defined in the High-Tech Strategy – such as bio- and nanotechnology, micro- and nanoelectronics, optics, microsystems, material and production technology, tertiary research, spacecraft technology, and information and communication technology – are all technology sectors in which ZIM is represented and to which 55 % of ZIM funding resources are allocated.
- Technology fields deemed worthy of financing under the initiatives of KMU-innovativ – such as biotechnology, information and communication technologies, nanotechnology, optics technology, production technology, resources and energy efficiency, and security and safety-related research – are the technology fields in which 49 % of ZIM funds are concentrated.
- Both technology lists constitute 62 % of ZIM funding resources.

Technology fields generally classified as low-tech sectors, such as textile technology, food engineering, wood technology, ceramics technology, and paper technology, are either minimally represented on the list of ZIM funded projects (e.g., textile research at 2.9 %) or subsumed under the category of other technologies, representing a 4 % total share (cf. Table 11.5).

Table 11.5 Approved funding under the Central Innovation Programme (ZIM) for medium-sized companies as of April 28, 2014 (Source: http://www.zim-bmwi.de/statistik; own calculation)

Technology field	Financial assistance in millions of euros	Financial assistance in %
Production technologies	747.6	22.3
Material technologies	377.3	11.3
Electrical engineering, measurement technology, sensor technology	375.1	11.2
Information and communication technologies	356.5	10.6
Health research, medical technology	230.0	6.9
Energy technologies	186.9	5.6
Biotechnologies	178.4	5.3
Building technologies	161.1	4.8
Environmental technologies	156.9	4.7
Vehicle and traffic technologies	129.9	3.9
Optics technologies	100.9	3.0
Textile research	96.2	2.9
Microsystems technology	54.4	1.6
Security technologies	39.4	1.2
Nanotechnologies	27.6	0.8
Miscellaneous technologies	133.1	4.0
Total	3.351.2	100.0

For that reason, it is possible that the ZIM programme, which privileges and pursues the same sectoral focus as in the federal funding programmes or the KMU-innovativ, is no different after all, as low-tech sectors appear to be under-represented even in ZIM projects. Combined, the knowledge-intensive sectors or high-tech and medium-tech sectors appear to be the predominant recipients of funding assistance for innovators in general.

The extent to which this information reflects the dire lack of applications received from low-tech sector companies at ZIM or is an artefact of the ZIM self-selection process cannot be fully assessed here. Information based on the evaluation of the ZIM programme from its inception through 2010 (cf. Kulicke et al. 2010) shows that by June 30, 2010, 13,899 applications had been received for ZIM financing, of which 8,795 had been approved for funding. Neither the applicants nor the approvals are categorised any further.

It remains an open question as to whether the previously discussed findings – concerning the tight, insular focus of German technology and innovation policies on high-tech, medium-tech and knowledge-intensive tertiary sectors – are adequate to support discussion of a "high-tech obsession" in the state's research and innovation policies (Hirsch-Kreinsen 2008). However, we must now discuss the implications of such innovation policies, as even the Expert Commissions on Research and Innovation (EFI) have come to the same conclusion, recommending a stronger integration of non-R&D-intensive and non-R&D-performing innovators (EFI 2011). Such implications will be outlined based on the studies conducted by Hirsch-Kreinsen (2005), Som et al. (2010), and Rammer et al. (2011).

11.3 Leverage Points for Integrating Low-Tech Industries More Strongly into Research and Innovation Policies

An innovation policy that predominantly aims to stimulate R&D activities tends to overlook the particular strengths of non-R&D-intensive firms that are innovative and imposes upon these firms an innovation strategy that does not fit their individual situations. It is thus a key task of innovation policy to adopt a broader understanding of innovation and to embrace the insight that innovative ability can no longer be equated with R&D activities alone. Such policies must support activities and measures that raise awareness for non-R&D-intensive firms and their specific needs and conditions according to their functionally differentiated systemic interrelationships within industrial value chains.

It is imperative to promote stronger integration of low-tech industries into research and innovation policies, as summarised in five areas in the form of propositions below:

Proposition 1 The theoretical basis of the research and innovation policy in Germany must reflect the current status of innovation research more strongly than before.

Science and innovation policy, as in any federal measure, must justify its interventions in the economy and show how economic development and the well-being of the state can be optimised through state interventions. Until now, this justification has been sought primarily based on endogenous growth theory models. Proponents of endogenous growth theory (Romer 1986, 1990) posit that technological progress through the endogenous, intentional R&D activities of firms is the source of economic growth. The relationship between technological progress and economic growth is thereby characterised as a linear, steady-state growth pattern that can be adjusted relatively easily by "turning the knobs of the R&D process" (Verspagen 2005). The continued popularity of this linear, R&D-based model of innovation in public debate and political discussion is largely based on its simplicity and rhetorical nature. "It is a thought figure that simplifies and affords administrators and agencies a sense of orientation when it comes to thinking about allocations of funding to R&D" (Godin 2006). Once technical progress and innovation began to define the science and economic policy agenda as the key determinants of economic growth, the existing statistics on R&D were used as a legitimate proxy to measure technological innovation because these data included the development of new products and technical processes. Over time, the R&D-based model became entrenched in political and public discourses with the help of economic research, statistics and methodological rules. Even today, the linear R&D-based model of innovation remains a "social fact" (Godin 2006).

For these reasons, the R&D-based model of innovation and economic growth is appealing to policymakers.[2] From a political science perspective, a policy measure can essentially derive its legitimacy from two perspectives. On one side is the dimension of input legitimation, which means that a policy is believed to be normatively "right" if it corresponds to the ideology, values and norms of the people. For this purpose, the linear model offers a readily understandable and reasonable causality. Almost no one would seriously question the line of argument that new technical solutions to the major challenges of modern, developed societies originate from basic and industrial R&D activities. On the other side is the dimension of output legitimation: a policy measure is legitimised once the intended positive effects occur as anticipated. Hence, output legitimation derives from the actual effects and outcome of a certain policy. In this case, the output legitimation of R&D is supported by numerous empirical findings from innovation and economic research, which suggest that positive outcomes of R&D are both predictable and ex-ante calculable.

Contrasting this approach with the complex and interwoven systemic picture generated by modern, systemic innovation approaches within the twenty-first

[2] Between 2004 and 2006, Anthony Arundel and his colleagues at UNU-MERIT interviewed 67 members of the policy community – 55 from 15 European countries and 12 from Canada, Japan, Australia and New Zealand – on their use of and need for innovation indicators. R&D indicators were the most widely used and were considered to be the most valuable. By contrast, only a minority of respondents referred to the use of indicators drawn from the CIS or similar innovation surveys in policy making or evaluation (Arundel 2007).

century innovation paradigm – with its difficulties in clearly separating cause-and-effect relationships – it is obvious why policy makers prefer the linear R&D-based model. This preference is understandable given that the positive relationship between R&D and innovation with respect to economic growth. Hence, R&D provides the perfect platform for policy makers seeking to justify their normative-political goals using statistical and empirical research data.

However, as some authors state, this preference for the simple linear R&D-based model of innovation has metamorphosed into a "high-tech obsession" (Hirsch-Kreinsen 2008) or perhaps an "obsession [with] competitiveness" (Godin 2004) in innovation policy in recent years. This development is reflected in the dominance of supply-side R&D support programmes in national and European innovation policies, including the following examples: the EU Lisbon Agenda, which sought to transform the European community into the most competitive, knowledge-based economy in the world[3]; the European Council's Barcelona initiative, which sought to counteract the EU's decline in competitiveness with a proposal to increase European R&D intensity to 3 % of GDP by 2010; and the so-called "High-Tech Strategy" of the German government to secure and enhance the international competiveness of German industry in the future. The generally obvious common feature of these innovation policies is that they systematically aim to stimulate the R&D activities of firms while overlooking the fact that R&D is not the sole source of innovation.

In innovation theory, the decline in R&D focus today is driven by a shift in analytical focus towards innovation-related activities that extend beyond the scope of formal R&D as well as by a changing understanding of the nature of the innovation process itself, as in the works of David (1996), Foray (1998), Lundvall and Johnson (1994) and Edquist and Texier (1998). In parallel with the increasing dissatisfaction with the R&D focus in current innovation theory, the understanding of innovation processes has shifted from a linear, sequential and thus predictable nature towards complex and self-referential cycle models (Kline and Rosenberg 1986; Rothwell 2003; Dodgson 2000; Tidd and Bessant 2009) that account for multiple recursive feedback loops and other sources of innovation knowledge. As Rosenberg (1994) claims, "everyone knows that the linear model of innovation is dead." Few scholars of innovation research continue to defend this theoretical understanding of innovation. In theory, innovation is frequently considered to result from cooperation in social *and* economic activities. Thereby, the innovation process links technical and economic considerations. This process normally includes many types of interactions, and innovations need not be radical; on the contrary, innovations involve incremental social and organisational changes as well as technological advances. Consequently, innovations are not merely the results of scientific work in a laboratory-like environment; rather, they are generated within networks of actors

[3] However, the underlying theoretical reasoning and the measurement strategy of the Lisbon Agenda are closely tied to R&D intensity (Hahn 2007; Hirsch-Kreinsen 2008).

from different backgrounds who are involved in the process of establishing new demands for innovativeness.[4]

As a result, the innovation process is understood as complex and variable. There is no single optimal way to innovate. Instead, against the background of modern knowledge-based economies, the use of R&D as a proxy for a wider range of innovation is no longer adequate (Kline and Rosenberg 1986; Freeman 1994b; Arundel et al. 2008; Raymond and St-Pierre 2010), and the theoretical focus needs to shift "from R&D to learning processes", as one cannot attribute all knowledge produced within a firm to formal research activities (Foray 2006). Instead, any activity involving the production or use of a good (or service) can generate learning and hence knowledge production; therefore, there is a complex set of different ideas and solutions that are equally important for effective innovation. Thus, formal R&D remains only *one* of many inputs and sources of innovation within firms (Smith 2005; Arundel 1997; Freeman 1994b; Nelson 2000; Schmiedeberg 2008).

We therefore deem it necessary to release research and innovation policy from the shackles of the endogenous growth theory model. We urge the creation of a comprehensive basis on which to draft a more inclusive research and innovation policy for the first time – a policy that would encompass all potential sites of innovation within the economy.

Proposition 2 The communication and administration of research and innovation policy must be freed from the narrow domain of R&D.

If we can shift the aforementioned theoretical underpinnings of research and innovation policy to successfully address and reflect the current state of innovation research, then in the second step, it is important to free the communication and administration of these policy fields from the confines of R&D. Two examples underscore the necessity of this approach.

Our first example draws on a development that has occurred in the Federal Reporting on Research and Innovation, albeit only formally. Submitted to the German parliament every 2 years until 2006, a document, titled the "Federal Report on Research" or BuFo (Bundesbericht Forschung) addressed structural questions concerning German research and its financing, provided information on funding resources for science and R&D within Germany as opposed to what was on offer internationally, and reformulated the research and technology policies of the federal states and of international collaborations in research and technology.

The report to the German Parliament has continued since 2008 under the title "Federal Report on Research and Innovation" (Bundesbericht Forschung und

[4] Grupp (2008) also campaigns for a functional rather than deterministic understanding of the relationship between R&D and innovation. In this view, R&D serves as a tool for solving problems that may occur in each stage of the innovation process (idea, theory, discovery/technical design/product design, innovation/imitation, improvement, diffusion, exploitation, and disposal) that cannot be solved by drawing on the existing stock of knowledge and experiences alone. "But innovation is possible without R&D if the knowledge stock available to the firm and in the published science is sufficient."

Innovation (BuFI)). However, the name change has not triggered a sustained change in reporting content. Although the term "innovation" was added to the title of each of the main chapters, the focus of the report is nearly exclusively on research: thus, the chapter "Structures of German Research and Innovation Systems" chapter solely concerns R&D – where it is performed, who finances it and who performs it. Innovations are reduced to R&D-based outcomes; in other words, innovations without R&D are not considered. Medium-sized enterprises are mentioned in what is now termed the Federal Research and Innovation Policy when their institutional infrastructure is described, but the focus does not stray far from the initiatives of the ZIM and KMU-innovativ, which, as shown above, primarily privilege R&D-intensive sectors. Even these subsidies and financing measures primarily support only R&D projects aiming to promote innovation (BMWi 2014; BMBF 2013); hence, innovation projects without the implied R&D dimension are not deemed worthy or capable of receiving support.

Our second example is the "High-Tech Strategy" of the German federal government. Although its theoretical underpinnings may not exclusively highlight companies from R&D-intensive high-tech sectors, the label "high-tech" alone validates the suspicion that only a narrowly defined sector of the German industry is being addressed and acknowledged. Notwithstanding its conceptual focus on shortfalls and shortages – and not necessarily on subsidising and promoting high-tech sectors – the distribution of federal expenditures on innovation presented above shows that the high-tech strategy does in fact primarily fund the high-tech sectors. No new inroads have been made to change the heuristics of the sponsoring agencies that could materially affect their decision-making and assessment criteria; thus, an R&D or high-tech focus continues to dominate.

Meanwhile, a balanced view of both sectors that considers their complementarities and respective strengths generates greater potential for stimulating stronger innovation and competitive capabilities for the German economy as a whole. Opportunities for participation already exist, but they must be communicated more actively because, as already shown, the mere term "High-Tech Strategy" suggests a focus on research-intensive sectors. Even by expanding this High-Tech Strategy (HTS 2) to address the core demands arising from global challenges, such as climate/energy, health/nutrition, mobility, security, and communication (areas in which Germany should ideally assume a pioneering global leadership role by providing key solutions through innovations in key technologies), the potential for misunderstanding or misinterpretation has not been averted. This problem is even more serious because important innovation knowledge and existing solutions are likely to also be rooted in non-R&D-intensive industries including new materials (e.g., functional textiles and high-performance ceramics) or biotechnology (e.g., food and beverages). The only way to address this problem is to ensure more explicit communications listing the resources available to companies from non-intensive sectors.

In terms of economic policy, a stimulus developed with a stronger domestic orientation towards non-research-intensive industries can offer the benefit of creating higher domestic value added and of providing greater employment opportunities than would be possible by merely subsidising research-intensive sectors. The stimulation in domestic demand arising from greater labour intensity in these sectors could also improve the employment situation within Germany as a result of the strong domestic focus on facilitating improvement in company and locational infrastructures. In addition, it is also possible to indirectly generate significantly higher employment numbers from the intensive interdependency among upstream suppliers and outfitters that are often research intensive, which would again primarily occur within Germany on account of the strong domestic orientation.

Proposition 3 The portfolio of research and innovation policy-based measures must be expanded through additional instruments to include innovations that are not R&D based.

To base innovation policy measures on the strengths identified in non-research-intensive industries and enterprises, a broader view of innovation is necessary to promote innovation activities. Future growth potential does not rely solely on R&D-based product innovation but can also emerge through technical or organisational process innovations as well as through service innovations. When comparing research-intensive and non-research-intensive enterprises, the latter group does not appear to have foreseeable disadvantages in developing process, organisation and service innovations, for instance, with respect to relevant concerns such as size and products. From this perspective, another objective of innovation policy, private enterprises and their intermediaries must be to secure and expand the strength of non-research-intensive companies in the areas of technical and non-technical process and service innovations.

It may be critical to provide strong innovation incentives to non-research-intensive companies in addition to other forms of support already offered rather than to pursue the previous policy of stimulating only R&D-based activities. Technical and non-technical product and process innovations cannot occur within non-research-intensive companies – or research-intensive companies – without concurrently developing the internal competences and capabilities needed to market and support the "diffusion" of in-house innovations and to successfully integrate external developments and concepts ("absorptive capacity"). Thus, it is often necessary to have adequate innovation funds in addition to R&D funds (e.g., for marketing purposes) to undertake customer-specific reconfiguration, construction, (service) design or marketing budget or to invest in new assets or advanced training if adopting new technology.

The successful inclusion of such measures from German technology and innovation policy is evidenced in the attempt to secure more widespread dissemination of CAD/CAM and CIM systems in the funding practices of the 1980s. These indirect yet specific measures stimulated the in-house adoption of innovative process-technologies and reached a broad spectrum of clients.

Another option for technology and innovation policymakers to consider would be to institute more comprehensive innovation incentives that account for the dissemination and adoption of innovations for which non-research-intensive and research-intensive businesses and sectors must be better integrated to improve interactions and generate greater levels of reciprocity. Apart from the supply-oriented promotion of technologies, other concrete measures must be implemented, such as those aimed at accelerating dissemination processes on the demand side or the early integration of non-research-intensive business users in pre-competitive cooperative projects – or in other appropriate "arenas", such as early interaction with research-intensive actors. Large-scale measures beyond the existing initiatives of technology and innovation policy can aim to create innovation-friendly conditions based on suitable concepts relating to education policy, regulation, public acquisition and taxation.

In this context, even the popular demand for tax relief or subsidies for R&D expenses in Germany (e.g., BDI 2014; Dortans 2009; ZEW et al. 2009; Hülskamp and Koppel 2006; EFI 2014) must be challenged. In view of the arguments listed above and the corresponding empirical findings, the demands of relevant groups of non-research-intensive companies are not being addressed by the existing framework. As previous studies have already shown, the absence of in-house R&D operations typically does not imply a lack of financial capital (Rammer et al. 2011); rather, it represents an economically rational, viable strategy adopted by companies under certain marketing and competitive conditions.

For this reason, it may be important to privilege tax relief for innovation expenses in the broader sense to ensure that companies have greater potential and opportunity to adapt innovation activities to their competitive strategy of choice. Although the financial costs of this new measure would be higher than the costs of providing tax relief only for R&D activities and although redefining what ultimately constitutes innovation expenses would raise new questions, the positive outcomes of offering a comprehensive tax relief for innovation rather than tax support for R&D activities alone would be more expedient.

Proposition 4 A system of indicators for monitoring innovations must be developed further to enable the findings of innovation policy to be assessed more comprehensively and not merely on the basis of the share of R&D-performing companies.

In the context of the call for action discussed here, even indicators such as "R&D expenses" or "R&D intensity" must be critically questioned. Our analyses have clearly shown that R&D intensity cannot be veritably linked to the technological and customer-oriented absorption capability of companies; thus, it does not appear to be a suitable indicator in this context. In science and research, R&D intensity often continues to be used as an indicator of the absorptive capacity of a company. However, the explanatory power of R&D intensity indicators for the innovation capability of a company must be challenged if a more comprehensive view of innovation is instead used as the basis for analysis. As indicated above, the capacity to develop and adopt technical and non-technical products, processes and service innovations requires different types of competences outside of the classic R&D model. The architecture of innovation expenses would provide the basis for developing input indicators that are better suited to assessing innovative competence in a more holistic manner.

An even greater challenge, however, lies in the task of developing appropriate output indicators for the various non-technological fields of innovation that are analogous across branches and sectors. Even the EU is determined to set itself up to the same task of "developing a new indicator to register innovation" as stated in its Europe Strategy 2020.[5]

Proposition 5 Research and innovation policy must be more closely interwoven with the initiatives established in German financial and employment market policy.

Research and innovation policy should be increasingly recognised as a policy action field with large-scale implications. The High-Tech Strategy of the federal government explicitly underscores the broad range of applications, but in practice, the High-Tech Strategy has been implemented primarily according to the dictates of the BMBF. Within the scope of the High-Tech Strategy, the actions of the BMWi, which was transferred to the technology department of the BMFT, are of significantly lower value, especially in that ministry. Other ministries are significantly less involved.

Given these considerations, it is now appropriate to implement a broader understanding of innovation that also considers innovation practices beyond the scope of R&D, such that the activities of other ministries do not remain immune to this conceptual transformation. The findings depicted here appear to offer both opportunities and challenges in equal measure (e.g., for employment policy). However, non-research-intensive enterprises in the manufacturing industry – when compared with the low-paying sectors in many tertiary service areas – are one of the last segments of the economy to offer relatively attractive pay scales to less qualified workers. Furthermore, the task of preserving and perhaps specifically supporting the non-research-intensive industrial sectors in Germany must be deemed a relevant policy priority. However, the proportion of semi-skilled and unskilled workers among the employed is decreasing, as are the employment numbers. This development is likely to further exacerbate the current shortage of semi-skilled and unskilled labour in the market.

For this reason, it remains to be discussed what plans must be formulated for incentivising further training of semi- or unskilled workers based on the specific requirements of non-research-intensive industries and in conjunction with employment policies, interest groupings and parties to wage agreements. Furthermore, the implications for the system of educating highly qualified workers are well known. Even non-research-intensive companies perceive the need to act expediently, given the lack of qualified applicants with the necessary skill-sets. The skilled worker

[5] An initial attempt to shift European innovation policy from a solely R&D-based view to a broader understanding of innovation can be found in the recent EU 2020 strategy: "It is also clear that by looking at R&D and innovation together we would get a broader range of expenditure which would be more relevant for business operations and for productivity drivers. The Commission proposes to keep the 3 % target while developing an indicator which would reflect R&D and innovation intensity" (European Commission 2010).

shortage that is being thoroughly discussed today will not automatically end today or anytime in the near future, even for these sectors.

Finally, even financial and economic policies must be actively promoted. Thus far, non-research-intensive enterprises have been able to survive the economic downturn surprisingly well. To prevent such companies from losing this advantage, the stringency of loan provisions in the aftermath of the credit crisis must lead to more organised and creatively managed funding measures that support investment projects for modernising production processes and for pre-financing customer orders. Because many non-research-intensive businesses intend to increase their levels of investment in the coming years, policy makers should reconsider the policy of restricting loans and consider offering attractive alternatives to maintain the growth trends in these sectors.

Conclusion

In conclusion, heavy reliance on a linear R&D-focused model of innovation causes policy makers to neglect important industrial segments. As industrial knowledge bases are increasingly distributed across highly interwoven innovation systems with multiple actors, an innovation policy that focuses on R&D as the sole innovation resource results in disregarding alternative strategies practised by both R&D performers *and* non-R&D performers in successfully innovating, and such a policy thus overlooks the valuable potential to increase the competitiveness of the economy and strengthen economic growth in the long term. Hence, the paradigm of a twenty-first century innovation and technology policy should support *overall innovation ability* rather than merely the *R&D intensity* of firms and sectors. With regard to the necessary justification for such policy measures, it is the responsibility of innovation researchers to provide policy makers with more scientific insights into non-R&D based patterns of innovation as well as corresponding assessment tools and indicators that can be used to identify which innovation policies are needed and to control ex post whether the intended effects were achieved.

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Chapter 12
The Economic Relevance, Competitiveness, and Innovation Ability of Non-R&D-Performing and Non-R&D-Intensive Firms: Summary of the Empirical Evidence and Further Outlook

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Abstract This book has attempted to look inside the "black box" of non-R&D-intensive sectors and firms to investigate their economic relevance, competitiveness, and innovativeness. Given that non-R&D-intensive sectors and firms used to be neglected both as innovators and innovation drivers by the mainstream innovation literature, this anthology reflects the latest research from different collaborative projects at Fraunhofer ISI. Although the presented research focuses on the German manufacturing industry, the results are broadly relevant, as they reflect economic and structural patterns that are likely present—to varying degrees—in other industrialised countries. For instance, other industrialised countries within and beyond the EU even have higher shares of non-R&D-intensive firms and industries than Germany. Starting with an overview of the research from the past decade (Chap. 2), which has shown that non-R&D-intensive sectors and firms play an important role in national competitiveness and innovativeness in developed economies, eight chapters have provided details from different analytical angles on the six leading research questions stated in the editorial of the book.

What is the economic relevance of non-R&D-intensive firms and sectors in Germany? How strongly do they contribute to national economic, employment, and qualification development? Starting from a macroeconomic perspective, aggregate data have been used to determine the economic relevance of sectors with different levels of R&D intensity. Non-R&D-intensive sectors account for a relevant share of industrial value added (41 %), and they are thus an important

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economic factor in highly developed economies such as Germany. In terms of employment, these sectors account for 11 % of the total workforce, which is a high share considering the rapid overall shift of employment from industrial/ manufacturing sectors to service sectors. Despite the continuous shift of employment shares to service sectors, non-R&D-intensive industries still employ the majority of the industrial workforce in Germany. Additionally, the share of highly skilled staff has continuously increased in both non-R&D-intensive and R&D-intensive sectors. Further, the demand for high-level qualifications is intensifying in non-R&D-intensive sectors, indicating their expanding innovation potential.

Sectoral input-output calculations have revealed that an additional demand impulse in non-R&D-intensive sectors triggers a higher average increase in domestic production than the same additional demand impulse in R&D-intensive sectors would trigger. Because of the smaller import share of non-R&D-intensive sectors, their contribution to domestic value added is larger. Additional demand in non-R&D-intensive sectors also triggers a higher increase in direct and indirect employment compared to that in R&D-intensive sectors, as non-R&D-intensive sectors are generally more labour intensive than high-tech sectors. Moreover, these findings appear to be widely stable in recent decades. Hence, there is no empirical evidence of the hollowing-out of non-R&D-intensive industries that some authors expected. Instead, non-R&D-intensive industries continue to account for a large share of employment and value added in industrialised economies. Moreover, there are no detectable differences among firms with different levels of R&D intensity with respect to either their market stability over time or their potential for start-up and entrepreneurial activity.[1]

How innovative are non-R&D-intensive sectors of the economy and non-R&D-intensive technological fields with regard to patenting activity? Given the protection of new technological knowledge, German patents filed in non-R&D-intensive technological areas are above average internationally. Small and medium-sized enterprises (SMEs), which account for the majority of non-R&D-performing and non-R&D-intensive firms, issues the largest portion of German patents. A high level of patenting activity is also present in technological areas that are not high tech, indicating the likely future economic relevance of these technological solutions. Interestingly, non-R&D-intensive sectors are also quite active in high-level

[1] Contrary to the widespread assumption that non-R&D-intensive industries offer limited opportunities for entrepreneurial activity owing to their mature character, there are indications that the phenomenon is finally emerging in these traditional sectors. For further reading on the phenomenon of entrepreneurship in non-R&D-intensive industries, we recommend the book, "Knowledge-Intensive Entrepreneurship In Low-Tech Industries", which was recently published by Hirsch-Kreinsen and Schwinge (eds.) (2014). The authors identify the typical patterns, prerequisites, and impacts of knowledge-intensive entrepreneurship, as well as the distribution of entrepreneurial activities in low-tech sectors. The authors conclude with policy recommendations to promote such activities.

and leading edge technologies. Approximately one-third of the patenting activity in non-R&D-intensive industries targets high-level and leading edge technological areas. These results reveal that patents originating from non-R&D-intensive industries are more strongly directed toward downstream, directly marketable applications rather than basic scientific inventions and that the patents tend to target market applications that are already foreseeable. However, a considerable share of non-R&D-intensive firms successfully protects inventions that are considered to be sufficiently relevant to require formal knowledge protection through patenting.

In which markets are non-R&D-performing and non-R&D-intensive firms active? What are their most important competitive factors? Moving from the macroeconomic to microeconomic level of analysis, we used firm-level data to show that a relevant share of firms are non-R&D-performing and non-R&D-intensive firms in all industrial sectors, including the high-tech sectors. These firms are a vital part of the overall German industrial value chain, and they play a role in the entire industrial system. Given that they are predominantly found among SMEs, the firms are primary contributors to the strong SME backbone of the German economy, which is known as the "Mittelstand".

Given their low levels of R&D capacity, non-R&D-performing and non-R&D-intensive firms may be expected to be suppliers of other firms rather than manufacturers of finished goods (end-product manufacturers). However, the analysis of the latest firm-level data shows that these firms are not merely suppliers of other firms. No differences can be found among firms with different levels of R&D intensity with regard to their position in the value chain. Approximately equal shares of all firms are suppliers and manufacturers of finished goods, regardless of their R&D intensity. Thus, low levels of R&D investment do not automatically predispose firms to be in a downstream position in the industrial value chain. Firms are apparently able to compensate for their level of R&D intensity through other competences that are highly valued by customers. Nevertheless, on average, non-R&D-performing and non-R&D-intensive firms are more often manufacturers of simple products relative to their R&D-intensive counterparts.

The most important competitive factors of non-R&D-intensive firms include their product and process quality and their ability to satisfy customers' specific demands. Non-R&D-intensive firms mainly attribute their competitiveness to these two competitive factors, followed by their short delivery times and the breadth of product variants that they can offer to customers. Non-R&D-intensive firms' competitive advantage appears to be related to the quality and efficiency of their processes rather than the novelty of their products.

Their robust position in the industrial value chain is reflected in their expectations regarding future market developments. The majority of non-R&D-intensive firms plan to expand in existing markets or even to enter new markets, mainly through the envisioned development of new products. Despite structural factors related to their lack of R&D investment, these firms thus nevertheless have significant innovation potential. New products usually do not result from R&D activity; rather, they are developed based on input from close customer contacts.

Although non-R&D-performing and non-R&D-intensive firms tend to have a stronger focus on the domestic market than their R&D-intensive counterparts, a considerable share of these firms are also able to compete in international markets, which is evident in their average export shares. Smaller firms are generally less active in international markets than larger firms, particularly among non-R&D-performing and non-R&D-intensive firms. In contrast, large firms are similarly active in international markets, regardless of their R&D intensity. Low R&D investments do not prevent large firms from being active and successful in international markets.

How innovative are non-R&D-performing and non-R&D-intensive firms with regard to product, service, and technical and organisational process innovations? The latest firm-level data from Germany revealed a gap between non-R&D-performing firms and other firms with regard to their use of technical process innovations and organisational methods, which is partially due to their generally small firm size. On a descriptive level, innovation performance (output) indicators revealed significant performance differences between R&D-intensive firms and both non-R&D-performing and non-R&D-intensive firms with regard to the share of sales from product innovations and labour productivity, which indicates firms' level of overall process efficiency. Although a considerable share of non-R&D-performing and especially non-R&D-intensive firms are product or market innovators, their new products tend to contribute less to their overall sales than those of R&D-intensive firms. However, despite existing performance differences between the firms in terms of product innovation, the descriptive analysis revealed no significant differences with respect to the share of sales from service innovations, product quality, and manufacturing speed (as measures of process innovations).

Additional multivariate analyses on these selected product and process innovation performance indicators confirmed the weaker product innovation performance of non-R&D-performing and non-R&D-intensive firms relative to R&D-intensive firms. However, when we controlled for a number of relevant structural factors, we found no performance differences with respect to service innovation activity, process quality, speed performance, and productivity among firms with different levels of R&D intensity. This finding indicates that non-R&D-performing and non-R&D-intensive firms tend to lag behind their R&D-intensive counterparts with respect to product innovation performance but do not seem to have any systematic disadvantage relative to R&D intensive firms with respect to their service innovation and process innovation performance, which may be expected to arise from their lack or low levels of R&D intensity.

Which types of internal and external knowledge sources are most important for non-R&D-performing and non-R&D-intensive firms? Where do their relevant external sources of innovation impulses come from, and how do these assimilate innovation impulses? Regarding the relevant sources of knowledge for the innovation activities of non-R&D-performing and non-R&D-intensive firms, firm-level analyses showed that the relevance of knowledge sources is highly dependent on the type of innovation. For product and service innovations, a mix of internal and external knowledge sources is favoured by all firms, regardless of their level of R&D intensity. In contrast, impulses for technical process innovations, and especially organisational innovations, tend to originate from internal sources within firms. Thus, the analysis does not reveal that non-R&D-performing and non-R&D-intensive firms systematically compensate for a lack of internal R&D sources by relying to a greater extent on external sources of innovation impulses. Further, these firms do not appear to rely on external innovation sources more frequently than their R&D-intensive counterparts. However, examining the specific forms of internal and external knowledge sources, we found significant differences between non-R&D-performing/non-R&D intensive firms and R&D-intensive firms. While in-house R&D and/or engineering are among the primary sources of innovation impulses for all firms, these sources play a significantly less important role as internal sources of product innovation impulses in non-R&D-performing and non-R&D-intensive firms than in R&D-intensive firms. In non-R&D-performing and non-R&D-intensive firms, the production/manufacturing department frequently serves as a source for new product ideas. Similarly, regarding external knowledge sources, suppliers play a much more important role for non-R&D-performing and non-R&D-intensive firms than for R&D-intensive firms, and customers remain the most common external source of innovation impulses for all firms. These results indicate that when engaging in innovation activities, non-R&D-performing and non-R&D-intensive firms tend to rely on practical, experience-based knowledge rather than formalised knowledge. However, almost no systematic differences in sources of knowledge are present between non-R&D-performing/non-R&D intensive firms and R&D-intensive firms.

Another aspect that is closely related to firms' external knowledge sourcing is firms' collaboration with external partners. External collaborations provide an intense form of external knowledge sourcing, as they involve repeated interactions among firms' collaboration partners. Analysing the collaboration activity and collaboration patterns of firms with different levels of R&D intensity, we found no overall tendency of non-R&D firms to compensate for their low R&D intensity by collaborating with external partners. Although collaborations with external innovation partners can help non-R&D-performing and non-R&D intensive firms access knowledge and resources, these firms engage in innovation-related collaborations with external partners considerably less frequently than their R&D-intensive counterparts. However, this lower degree of collaboration is largely due to the generally smaller firm sizes of non-R&D-performing and non-R&D-intensive firms. Given that small firms of all levels of R&D intensity tend to be less active in external collaborations than larger firms, these results are not surprising.

The results nevertheless indicate that collaboration represents a large unused source of potential innovation benefits for non-R&D-intensive firms, as these firms tend to benefit from innovation collaborations to a greater extent than R&D-intensive firms. Thus, it is important for these firms to overcome existing collaboration barriers related to the accurate assessment of the risk associated with collaboration and the management of organisational boundaries, knowledge flows, and different innovation cultures among collaboration partners with different levels of R&D intensity and to subsequently develop specific management solutions in this regard. Furthermore, additional analyses may show how different types of non-R&D-performing and non-R&D-intensive firms pursue different innovation knowledge sources and collaboration strategies based on their organisational context and specific strategic/market orientation.

The importance of a firm-specific strategic orientation is reinforced by the results regarding non-R&D-intensive firms' absorptive capacity. Contrary to the assumption that non-R&D-performing and non-R&D-intensive firms systematically lack a high level of absorptive capacity because of their lack of internal R&D competences, new analyses of firm-level data showed surprisingly small differences among firms with different levels of R&D intensity with respect to their ability to absorb external sources of science-based or customer-based knowledge. Depending on the strategic value that firms place on specific types of external knowledge, firms' level of related absorptive capacity may differ. Thus, absorptive capacity appears to be influenced by a firm's specific strategic orientation rather than its level of R&D intensity. If firms highly value science-based external knowledge, they also appear to be able to access and absorb that knowledge, regardless of their level of R&D intensity.

The above insight supports the implications of the empirical results from Chaps. 6, 7, and 8 regarding the necessity to better differentiate among different types of non-R&D-performing and non-R&D-intensive firms. While average calculations are valuable for identifying general tendencies and common features of these firms, future research should better distinguish and understand different sub-types of non-R&D-performing and non-R&D-intensive firms. Different firms may adopt different innovation strategies according to their specific structural and market conditions. Lacking one resource, namely R&D, does not predispose firms to display homogenous behaviour. Therefore, average figures likely conceal a multitude of firm types with different needs and strengths.

What are the specific requirements for innovation management in non-R&D-performing and non-R&D-intensive firms? The need for further insight into different innovation strategies and behaviours is also supported by a firm's internal innovation management perspective, which in-depth case studies and action research on non-R&D-intensive SMEs have highlighted. Case studies are useful for mapping and visualising a firm's specific innovation processes and for clarifying a firm's individual competitive and innovation strategies, which are sometimes only known implicitly. Based on this bottom-up approach, critical process phases can be identified, and clear responsibilities can be assigned to facilitate the transition between different stages of the innovation process. One important aspect is to clearly define the role of a "process innovation manager" and a "boundary spanner" or to connect agents among different innovation process stages within and outside the firm. This role needs to be firmly anchored within the organisational structure by assigning well-defined responsibilities and corresponding competences. The better this process innovation management role is clarified and anchored within a firm, the more effective the individual in the role can contribute to the management of successful innovation activities in non-R&D-intensive firms. Given that the majority of available innovation management approaches within the literature are based on experiences derived from R&D-intensive firms, these methods cannot be easily applied to small non-R&D-intensive firms. Thus, specific innovation management tools and methods are needed to successfully address the specific needs and frame conditions of these firms.

Despite the multitude of empirical research on the innovativeness of non-R&D-intensive sectors and firms that is presented in this book, as well as additional recent findings, non-R&D-driven innovation activities are still largely neglected by public innovation policy (see Chap. 11). Little public funding is available to support innovation that does not involve R&D. In Germany, the majority of public innovation funding schemes target high- and medium-tech sectors and largely neglect non-R&D-intensive industries. Given the findings presented in this book, this focus appears to be problematic; technology and innovation policies that primarily focus on R&D run the risk of overlooking important potential to stimulate, increase, and maintain the innovativeness and international competitiveness of the German economy.

One reason for the focus on R&D-intensive industries is that indicators for R&D-oriented innovation inputs and outputs are well established, while relatively few indicators adequately reflect innovation paths outside R&D. Despite increasing efforts to identify and include non-R&D-based innovation indicators in established statistical innovation measurement systems (e.g., the Community Innovation Survey, CIS), all relevant innovation indicator systems still strongly emphasise R&D-based innovation indicators. Thus, policy makers are likely to design funding schemes on the basis of available reference systems that systematically favour R&D. As this overview of current funding programmes and participant structures has demonstrated, public innovation funding inadequately addresses and supports the innovation efforts of many firms that innovate outside the classical R&D-driven paradigm. The ideal solution would be to complement the existing innovation funding efforts with funding schemes that specifically target innovation efforts apart from R&D activity. Such funding schemes would allow non-R&D-performing and non-R&D-intensive firms to successfully access and participate in public innovation support, which has thus far been limited.

The research results in this book will contribute to a better understanding of the existing "innovation logics" in non-R&D-performing and non-R&D-intensive firms.

12.1 Innovation Research

Firms that do not invest in formal R&D activities pose a challenge to mainstream innovation theory, as they call into question the predominant belief that R&D intensity is the element that determines the innovativeness and competitiveness of manufacturing firms. Innovation should no longer be assumed to take place only within firms or within sealed-off R&D departments. Instead, firms closely and interdependently collaborate with other firms, organisations, institutions, and social entities as external innovation resources to innovate through collaborations and strategic alliances. Furthermore, firms' internal innovation resources may encompass not only R&D knowledge but also competences in engineering, design, production, and distribution activities, as well as the knowledge embodied in new technologies and capital investments.

R&D nevertheless still plays an important role for firm-level innovativeness. R&D represents a major source of explicit knowledge, and it relies heavily on the systematic and intentional deployment of scientific methods, which can be documented and intersubjectively transferred among individuals. Moreover, R&D is not subject to the same type of economic constraints as the regular production of goods and services. The ability to perform exploratory activities that would otherwise not be possible in everyday business life is a key factor that supports rapid knowledge advances in firms. The key is that R&D is only one of many resources generate a competitive advantage for firms.

One of the major challenges for future innovation research is to develop and improve appropriate measures and indicators to assess innovativeness apart from R&D. One recent and promising approach, which is used in the CIS, is to gradually replace the "R&D expenditures" indicator with the broader "innovation expenditures". Innovation expenditures include all expenditures that are devoted to innovation projects by a firm within a surveyed period, including expenditures for machinery and equipment acquisition, engineering, product design, marketing, licences, patenting, and job training for employees. However, as discussed in Chap. 4, in the case of latent, often non-technical innovation resources, such as "routines" or "capabilities", developing new innovation indicators remains difficult. The problem is that the constructs are difficult to measure, not only because of their diffuse nature, but also because their impact on a firm's innovativeness and competiveness is difficult to separate from other effects.

12.2 Innovation Management

Regarding manufacturing firms in general, the empirical results reported in this book have revealed several key aspects that bridge the cognitive gap between R&D- and non-R&D-based innovation. The results strongly support the view that non-R&D activities are crucial for understanding the innovation process of any firm. Against the backdrop of the overwhelming presence of R&D in empirical innovation research and the manifold evidence that formal R&D is the driving force in manufacturing firms, many firms adopted a narrow, R&D-focused view in their strategic innovation management. Consequently, because many firms and strategic decision makers intuitively think about reducing the number of employees to lower manufacturing costs, many firms consider formal R&D to be the best way to enhance their innovativeness. Conversely, the overemphasis that has been placed on R&D as the major source of innovation may have discouraged many firms from attempting to innovate, as they perceive R&D to be a costly and uncertain undertaking that demands specific and substantial investments.

However, the empirical results presented in this book have shown that activities other than R&D, some of which are closer to daily routines, may also serve as sources of innovation. One conclusion may be that firms should generally widen their search for innovation opportunities, for instance, by exploiting the existing knowledge bases of their employees or by accessing external knowledge and resources through cooperation and strategic alliances. As several of the identified innovation patterns show, innovativeness is not limited to the technical dimensions of a firm. Instead, non-technical processes and product innovation, such as the use of organisational concepts and management tools or the provision of product-related services, can also maintain and increase a firm's innovativeness and competitive advantage. Thus, managers who are primarily interested in fostering their firms' innovation performance should be aware that decisions related to R&D are not the only relevant decisions to be made, as many other actions and sources yield favourable results with respect to innovation. In short, the absence of R&D does not imply the absence of innovation or competitive success.

12.3 Innovation and Technology Policy

First, in terms of statistical data and economic research, the categorisation of industry into sectors of low, medium and high technology according to the level of R&D intensity can only provide a more or less valid categorisation of firms with different levels of R&D. However, these categorisations do not reflect the empirical reality, as there are no true "non-R&D-intensive" or "low-tech" sectors. Instead, we observe significant shares of non-R&D-intensive or non-R&D-performing firms within high or very high R&D-intensive sectors.[2] The contribution of non-R&D-performing firms to the international competitiveness of the German economy is both direct and indirect. In addition to their direct contribution in successfully exporting a relevant share of products abroad, non-R&D-performing firms also

[2] As stated by Professor Joseph Tidd from SPRU during the 2014 ISPIM Conference in Dublin, the distinction between high-tech and low-tech sectors should be considered to be obsolete in research on firms' innovation behaviour.

indirectly contribute to the international competitiveness and economic growth of the German economy by supplying R&D-intensive firms with high-quality intermediate or end products. Therefore, the strong international competitiveness of the German high-tech industry is partially due to non-R&D-performing firms. Moreover, by acquiring advanced manufacturing technology, non-R&D-performing firms are frequently consumers of high-tech products, such as automation systems, industrial robots, and other advanced techniques; thus, non-R&D-performing firms indirectly stimulate innovation activities in "high-tech" firms that produce these products.

Second, as mentioned above, the absence of R&D does not imply the absence of knowledge, innovation, or competitive success. Non-R&D-performing firms employ many strategies to exploit technical and non-technical, product- and process-related, and internal and external innovation and knowledge resources. These strategies allow non-R&D-performing firms to successfully compete and survive in a market that is not necessarily only driven by costs and product prices. Hence, innovation policies that only aim to stimulate R&D activities tend to overlook the particular strengths of individual firms, as firms may be forced to use innovation strategies that do not fit their organisational contexts. A key task of innovation policy makers is to adopt a broader understanding of innovation. Furthermore, a firm's innovative ability should no longer be equated with its R&D activities alone; rather, a firm's innovative ability should support activities and measures that increase awareness for the firm's specific needs and conditions according to its functionally differentiated, systemic interrelations within the industrial value chain. One possibility could be to supplement R&D-focused policy programmes with policy instruments that support innovation activities beyond formal R&D activities (e.g., support for technology diffusion between firms or between firms and R&D organisations, support for generating capabilities in engineering, marketing, and design, or support for the development of non-technical innovations, such as product-related services or organisational concepts and management tools).

Third, simply providing data on the number of firms that perform R&D is insufficient. The present results reveal that the group of firms that innovate without performing R&D should also be disaggregated, as policy makers should not expect non-R&D-intensive or non-R&D-performing firms to compose a homogeneous group. Against the background of their heterogeneous innovation strategies, a "one-size-fits-all" approach to stimulating innovation activities within these firms may be misguided. Instead, this type of detailed information could assist policy analysts in identifying weaknesses in the innovation ability of non-R&D-performing firms, which will lead to policies that encourage firms to enhance their innovativeness.

Finally, the empirical results presented in this book have shown that non-R&D-performing firms are characterised by high labour intensity and a high share of low and unskilled employees. On the one hand, against the background of employment policy, exploiting the higher labour intensity non-R&D-performing firms may lead to more positive effects than solely stimulating R&D-performing firms. On the other hand, by employing a significantly higher share of low and unskilled employees, non-R&D-performing firms are one of the last remaining segments of the German manufacturing industry that continues to provide attractive jobs for people with low qualifications.

To conclude, if policy makers rely solely on the linear, R&D-focused model of innovation and economic growth, they are likely to neglect an important group of firms. However, because industrial knowledge bases are increasingly distributed across highly interwoven innovation systems involving multiple actors, if policy makers solely focus on the innovation resource "R&D", they will disregard alternative strategies that can also lead to successful innovation. By neglecting these alternatives, policy makers run the risk of overlooking valuable potential to increase the economy's competitiveness and economic growth in the long run.