An empirical investigation on the relationship between OPEN INNOVATION and innovation performance

Matthias Inauen

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Matthias Inauen

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Abbreviations

CDAX	Composite German Stock Index
CIS	Community Innovation Survey
ICB	Industry Classification Benchmark
ICT	Information and Communication Technologies
IP	Intellectual Property
IUS	Innovation Union Scoreboard
KOF	Swiss Economic Institute, ETH Zurich
MIT	Massachusetts Institute of Technology
NIH	Not Invented Here
OECD	Organization for Economic Co-operation and Development
RSS	Really Simple Syndication
R&D	Research and Development
SPI	Swiss Performance Index
WBI	Vienna Stock Index
ZEW	Centre for European Economic Research, Mannheim

CHAPTER 1

Introduction

Globalization and the increased connectivity of economic actors have led to increased competition in business markets. Innovation is a major driver enabling and sustaining of a competitive advantage and promoting increases in productivity in a contested environment. Especially in times of limited resources and economic downturns, innovations are essential for the survival of companies and industries as a whole. Notably, innovations are more than just the first occurrence of an idea; they include its successful introduction into markets. Therefore, innovations are defined as the implementation of new or significantly improved products (goods or services) or processes (OECD/Eurostat, 2005).

"Today no one needs to be convinced that innovation is important – intense competition, along with fast changing markets and technologies, has made sure of that. How to innovate is the key question" (Drucker, 1988, p. 149). The traditional perspective has followed Schumpeter (1934, 1939) and has emphasized the required abilities of the lone entrepreneur. Open innovation presents a more interactive way for companies to innovate and was first proposed by Henry Chesbrough (2003a, 2003b). He claims that internal research and development (R&D) is no longer the invaluable strategic asset that it used to be. Firms should make use of knowledge inflows and outflows to accelerate internal innovation and find new commercialization opportunities for internally developed knowledge (Chesbrough, 2006a). Hence, the open innovation model fosters the openness of R&D projects toward external stakeholders. Openness encompasses being open to new influences from outside the firm and bringing ideas and knowledge from the inside to the outside environment. Especially in early phases of R&D projects, openness is considered essential for successful innovations. The explanation lies in a fundamental characteristic of innovation: new innovations can consist of new combinations of existing ideas, capabilities, skills and resources. A greater variety of these factors leads to a greater scope and complexity of new combinations (Fagerberg, 2006). This fundamental logic has also been used to explain why, in ancient times, the inhabitants of the large Eurasian landmass have become more innovative and technologically sophisticated than more isolated populations, such as Native Americans and Australian Aborigines (Diamond, 1998; Fagerberg, 2006).

In the early and mid-20th century, diversification and integration were common strategies for R&D departments in large firms to acquire new knowledge and technologies (Chandler, 1977, 1990). Vertical integration counted as a barrier-raising investment that generates competitive advantages over existing and new rivals (Caves & Porter, 1977; Porter, 1980). Since the early 1960s, the innovation literature has emphasized interaction and described innovation as an information-creation process that arises out of interaction (Allen & Cohen, 1969; von Hippel, 1986; Trott & Hartmann, 2009). In practice, partnerships, strategic alliances and joint ventures have been rising rapidly since the 1970s as the costs for R&D and the risks involved continued to increase. Examples are the development of mobile communication technologies or treatments of AIDS and cancer, which are dominated by global competition between groups of firms (Hamel et al., 1989; Trott & Hartmann, 2009). Besides partnering with competitors, the companies have also become customer focused. Customer relationship management and customer involvement have their roots in marketing and quality management. Today, the inclusion of customers is important because they are better informed and have clear beliefs about product options and improvements (Reinartz et al., 2004; Dell'Era, 2010). The concept of lead user innovation, which embraces the co-creation and co-development of products with lead users, has become established in R&D practice (von Hippel, 1986, 2009). Further studies point to the importance of innovation partnerships with universities (Perkmann & Walsh, 2007; Buganza & Vaerganti, 2009). Supplier integration was first stressed in the literature on supply chain management, which notes that the willingness of the suppliers to cooperate can strongly depend on the suppliers’ dependence on the company (Kamath & Liker, 1990; Walton et al., 2006).

Open innovation takes a more general perspective by assuming that the innovation potential increases due to cooperation with multiple stakeholders from the external environment. Notably, a research gap exists regarding the impact of open innovation activities on the innovation performance of firms. Nearly all existing studies on open innovation do not emphasize performance implications and are based on single case studies in high-tech industries (West et al., 2006; Lichtenthaler, 2008; De Backer et al., 2008). Very few empirical large-scale analyses on the impact of open innovation on innovation performance exist. Laursen and Salter (2006) investigate the role of openness among English manufacturing firms and find that an intensive external search depth for innovation opportunities is associated with radical innovation. Lichtenthaler (2008) shows increased open innovation activity in medium- and large-sized firms in German language countries. However, his study does not analyze performance implications and is limited to technology-oriented sectors and manufacturing industries. Van de Vrande et al. (2009) analyze innovative small- and medium-sized enterprises in the Netherlands and find that open innovation is as relevant for service firms as it is for manufacturing firms. They identify organizational and cultural issues as the main barriers to the successful adoption of open innovation. The Swiss Economic Institute (KOF) Innovation Survey, the Mannheim Innovation Panel of Germany and the Community Innovation Survey of the European Union have not yet focused in detail on the effect of open innovation on innovation performance. Although the European Community Innovation Survey evaluates the existence and importance of innovation collaborations, no performance implications of different open innovation activities are reported (CIS/Eurostat, 2008).

The literature review manifests a lack of empirical evidence of performance implications of open innovation. To close the research gap, this thesis investigates whether firms that emphasize open innovation can positively influence their innovation performance and which open innovation activities contribute the most to innovation performance. Multiple types of performance measures are considered, namely, process and product innovations, incremental and radical innovations as well as the percentage share of sales made up of newly developed products and services. The study broadens the prevalent perspective by analyzing open innovation in manufacturing and service sectors except the banking and insurance sector. R&D managers of stock-listed enterprises in Germany, Switzerland and Austria are subjects of the empirical study. Data were collected through an anonymous online survey available via the associated Internet domain name http://www.open-innovations.ch (see Appendix for more information). Contact details of the firms' managers were collected via the companies' web pages and via telephone. A total of 783 companies were contacted in the survey period from April to June 2009. From these companies, 141 R&D managers provided complete valid responses, representing a response rate of 18 percent.

The terminology used in the questionnaire was based on the commonly agreed definitions provided by the Oslo Manual (OECD/Eurostat, 2005), which is relevant for both the manufacturing and the service sector. As three core processes of open innovation in R&D management exist (Gassmann & Enkel, 2005; Chesbrough & Crowther, 2006), the questionnaire was structured accordingly. Whereas companies monitor the environment and acquire knowledge in the *outside-in process*, the commercialization of in-house knowledge is the main purpose of the *inside-out process*. The *coupled process* combines outside-in and inside-out processes and focuses on network usage. In addition, we evaluated characteristics of the companies' innovation strategy and innovation culture. The thesis provides new empirical evidence that allows statements about the impact of open innovation activities on firms' innovation performance.

The second chapter focuses on the outside-in core process of open innovation and analyzes the impact of its openness on innovation performance. To represent determinants for openness, we measure the existence and intensity of outside-in open innovation activities during the five-year reference period from 2004 to 2008. The open innovation activities refer to knowledge acquisition from different stakeholders relevant for R&D. The stakeholder selection is similar to existing studies (e.g., CIS/Eurostat, 2008; Arvanitis et al., 2010) to facilitate the comparability of the results. The results reveal interesting differences between intra-industry and cross-industry cooperation. Whereas the first form of knowledge acquisition has a positive influence, the latter has a negative effect on innovation performance.

The third chapter analyzes the impact of an open inside-out core process on firms' innovation performance. Inside-out open innovation involves the exploitation of existing internal knowledge and technologies. The empirical results show that companies pursuing closed innovation are more likely to create incremental innovations. Companies that emphasize inside-out open innovation exhibit a higher radical (breakthrough) innovation performance.

The fourth chapter deals with firms' internal and external innovation perspective. The internal perspective focuses on firms' corporate culture and its internal openness to access the collective intelligence of the entire workforce. In particular, we examine the impact of cross-functional teams in R&D projects on innovation performance. The external perspective deals with the impact of coupled innovation activities resulting from Web 2.0 and social networking technologies. The results reveal that cross-functional teamwork in R&D projects has been increasingly implemented as a part of firms' internal network strategy. Remarkably, we found no significant effect of intensive cross-functional employee cooperation on firms' innovation performance. Regarding the coupled process, firms using Web 2.0 and social networking technologies to a greater extent show higher innovation performance. Additionally, the endurance of external networks and a fault-tolerant corporate innovation culture play a crucial role in achieving high innovation performance.

CHAPTER 2

The impact of outside-in open innovation on innovation performance

A version of this article is published in the
European Journal of Innovation Management[1]

2.1 Introduction

The phenomenon of business innovation began in early human settlements and has influenced civilizations and cultures ever since. The invention of new and innovative methods of production and supply has always been crucial to the survival of social groups in a competitive environment. A small number of innovations led to the agricultural and industrial revolutions, with their enormous and continuing impacts on human life (Bruland & Mowery, 2006). In the early and mid-twentieth century, key technologies were developed within large enterprises by industrial research departments and applied to the firm's own products. Vertical integration of companies was the most common form of acquiring new technologies and provided firms with competitive advantages over smaller and newer rivals (Chandler, 1977, 1990; March, 1991; West et al., 2006). Furthermore, economies of scale and scope have set large companies apart from their competitors. In this traditional setting, innovations are produced and commercialized only within the company's boundaries. This setting is what Chesbrough (2003a) de-

[1] Inauen, M. & Schenker-Wicki, A. (2011), "The impact of outside-in open innovation on innovation performance", European Journal of Innovation Management, Vol. 14 No. 4, pp. 496-520, © Emerald Group Publishing.

fines as a *closed innovation model*, in which successful innovations require control and firms have to be self-reliant because they cannot be certain of the quality, availability and capacity of other stakeholders. The companies have control over all internal R&D activities and no external knowledge or technology integration exists.

Nowadays, the closed innovation model is reaching its limits. Increasing mobility of knowledge and highly-skilled employees, rapid alternations in consumption and production functions and the shortening of product lifecycles are central factors of why industrial R&D is undergoing a paradigm shift toward practicing *open innovation* (Chesbrough, 2003a, 2003b; Afuah, 2003; West et al., 2006). In addition, the recent increases in the tradability of technology and intellectual property support this shift from a closed toward an open innovation model. The upsurge in technology markets has mobilized technology and intellectual property (Arora et al., 2001). Because useful knowledge is no longer concentrated in a few large organizations, it becomes necessary to open the R&D models of organizations. The potential for obtaining knowledge and technology from outside a firm's boundaries has significantly increased. Open innovation stresses the importance of capturing this external knowledge or technology and converting it into innovative products and services (Chesbrough, 2003a). Although open innovation was initially adopted in practice, it soon became a paradigm of considerable interest for scholars studying management and innovation processes (Christensen et al., 2005; Gassmann, 2006; Vanhaverbeke, 2006; West & Gallagher, 2006). In an open innovation model, R&D management needs to enhance technology in- and out-sourcing. Chesbrough (2006a) states that firms can and should use internal and external knowledge as well as internal and external commercialization paths, as the companies intend to advance their technologies. In this regard, open innovation models allow fostering collaboration with customers, suppliers and other innovation sources to everyone's benefit.

The open innovation paradigm not only depicts the sum of collaborative innovation instruments, but describes a holistic innovation management strategy that consciously explores and exploits a wide range of sources for innovation opportunities through multiple channels (West & Gallagher, 2006). The Philips Group Corporation, for instance, is the largest electronic company in Europe, and collaboration is the most important aspect of its open innovation management. In recent years, Philips' research and development center in Eindhoven has been transformed into an open innovation and business campus where 80 start-ups, academic institutes, consultants and investors work and live together with nearly 8,000 employees. The campus offers a highly sophisticated infrastructure, active engineering support and a lot of other opportunities for Philips' researchers to interact and cooperate. Whereas the R&D investments and revenues of the company have stayed almost constant during the last ten years, the number of patent rights has more than doubled (Viskari et al., 2007; Philips, 2009).

Notably, a research gap exists in the practical use of open innovation (West et al., 2006; Gassmann, 2006). Across all industries, the organizations start to recognize the limitations of their internal R&D department or activities. They realize that in order to thrive, they need to find new ways of accessing knowledge and technology in an increasingly complex and uncertain environment. Many firms are therefore in the process of changing their innovation system from a closed to an open innovation model (Chesbrough, 2003a; Chesbrough et al., 2006; Herzog, 2008). Although open innovation models have substantial benefits for R&D intense companies in high-tech sectors, little is known about their influence on innovation performance in traditional industries, such as manufacturing and service industries (Chesbrough & Crowther, 2006; Laursen & Salter, 2006; Muscio, 2007; van de Vrande et al., 2009). To address this research gap, our study not only includes R&D intense companies in high-tech sectors, but also less R&D intense firms in medium- and low-tech sectors.

Additionally, most previous studies are based on case studies to analyze the adoption of open innovation. West et al. (2006) emphasize that empirical studies are an appropriate way to examine the implementation of open innovation in practice. Likewise, De Backer et al. (2008) state that the current discussion on open innovation could highly benefit of further empirical evidence on this topic. This paper evaluates the adoption and use of open innovation in enterprises in German-speaking countries. It aims to explore the effect of an open R&D model on the firms' innovation performance. Using a structured questionnaire survey, the open innovation activities of stock-listed companies in Germany, Switzerland and Austria are examined.

The paper proceeds as follows: Section 2 presents the underlying theoretical framework of the study, including the definition of R&D openness as well as the hypotheses. Section 3 addresses the research methodology and the measures for innovation performance. Section 4 presents the empirical results, and section 5 summarizes the findings and discusses future research opportunities.

2.2 Literature review and development of the hypotheses

2.2.1 Resources and competences

Since open innovation fundamentally depends on the integration of resources and capabilities from a variety of internal and external sources, understanding the resource-based perspective is crucial. The theory of the resource-based view conceives enterprises as bundles of resources that differ across firms and industries and persist over time. Unique resources and their interactions lead to a sustainable competitive advantage. We thus define innovations as new combinations of existing or new resources and competences (Penrose, 1959; Wernerfelt, 1984; Herzog, 2008).

The term *competence*, which is used as a synonym for *capability*, refers to an ability to accomplish something using a set of tangible (e.g., equipment, machinery or a mailing list) and intangible (e.g., manufacturing know-how or an understanding of customer needs) resources. These resources are the basis of competences, which in turn enable a firm to use those resources to establish competitive advantages (Grant, 1991; Daneels, 2002). However, technological change can destroy competences. Previous studies have revealed that successful innovation requires both technological competences to create new products and marketing competences to commercialize these products (Dutta et al., 1999; Daneels, 2002, 2004). As a result, the underlying resources in an innovation process can be classified as technology- or market-related. Whereas technology-related resources are common in science-driven industries, market-related resources are prevalent in marketing-driven industries (Bröring, 2005; Bröring et al., 2006; Herzog, 2008).

Besides resources and competences, companies and their R&D departments additionally need to be able to explore and exploit external sources of technological knowledge. Cohen and Levinthal (1990) define *absorptive capacity* as a firm's ability to recognize the value of new information, assimilate it and apply it to commercial products, processes and services. They argue that internal R&D investments not only provide improvements in technologies and innovations, but also provide a capacity to absorb the relevant knowledge emerging in the external environment. However, Christensen (2006) argues that the question for firms still remains whether absorptive capacity needs to be internally developed or to what extent obtaining it via hiring new employees, cooperating with external stakeholders or contracting for consulting services.

The term *cognitive distance* is used to describe the difference in knowledge and competency structures between companies. Each company shares an individual perception, interpretation and evaluation system consisting of certain perceptions and values that sufficiently align their competences (Weick, 1979). Differences in this organizational focus, which is influenced by organizational culture, induce cognitive distances between firms. Nooteboom (1992) describes an inverted-U shaped relationship between cognitive distance and innovation performance. Initially, as cognitive distance increases, it has a positive impact on learning by interaction due to bridging and linking diverse knowledge. After reaching a certain level, cognitive distance can diminish mutual understanding and hinder organizational learning by interaction (Gultai, 1995; Wuyts et al., 2005; Nooteboom et al., 2007).

2.2.2 The potential role of intellectual property

A firm's use of intellectual property (IP) rights, such as patents, seems to conflict with the pursuit of open innovation. However, IP protection can be an enabler of open innovation activities because negotiating IP contracts increases the interactions of companies with suppliers, competitors or other stakeholders (Chesbrough, 2003a; Alexy et al., 2009). As IP is based on information and is therefore easily replicable, it possesses the traits of a public good. Thus, intellectual property rights protect the outcomes of R&D investments and represent important incentives for innovation. By granting temporary monopolies through IP rights, underinvestment in innovation is avoided.

Operating with the closed innovation model, companies have historically accumulated IP to protect rents from investments and to avoid costly litigation. In the open innovation model, IP represents a new class of assets that can deliver additional revenues and encourage entry into new businesses and new business models (Chesbrough, 2006c; West, 2006). Since cooperation is becoming more interdisciplinary, industry borders are shifting and IP rights are traded across industries. For instance, IBM became one of the world's largest holders of biotechnology patents (Gassmann, 2006).

As companies pursue open innovation to develop products and services in collaboration, however, IP security policy must become part of their R&D strategy. To mention a few examples in practice, Boeing and IBM have dedicated departments responsible for reselling IP, thus their IP libraries provide valuable assets and are a considerable source of revenues in their innovation process (Burkett & Finley, 2007; Enkel & Gassmann, 2009).

2.2.3 Innovation performance

Using Schumpeter's (1934, 1939) classification system, innovation performance measures can be grouped into five different categories: new products, new methods of production, new sources of supply, exploitation of new markets and new ways to organize business. However, most of the literature has focused on the first two areas of innovation, product and process innovations (Avlonitis et al., 1994; Cohen & Klepper, 1996; Fagerberg, 2006). Similarly, Schmookler (1966) argues that understanding the distinction between the related terms product technology (product innovation) and production technology (process innovation) is crucial for understanding innovations. Product innovations represent the invention and commercialization of entirely new products or services, whereas process innovations describe changing the production process of products and services through the adoption of new technology and innovations (Roberts, 1988, 2007; OECD/Eurostat, 2005). This study focuses on product and process innovations as the measures of innovation performance. Since the share of sales of newly developed products and services is also considered to be an accurate indicator of innovation performance (Smith, 1992, 2006), this third measure is also taken into account.

Another classification of innovations, which is not considered in the following analysis, is the distinction between two extreme types of innovation – incremental and radical innovations. Incremental innovations build on existing competences in companies and are related to minor technological changes. By contrast, radical innovations accompany fundamental technological changes and can therefore be competence destroying (Tushman & Anderson, 1986; Green et al., 1995).

2.2.4 The openness of R&D

An organizational change that arises with the current development toward open innovation is the capability to collaborate with multiple stakeholders from the outside environment. In the past, collaborations between two parties in the same industry were the most popular form of collaboration (Rosenberg, 1994). Additionally, the main contract partners were large high-tech firms because the R&D intensity in traditional industries was low. As is outlined below, these activities have become much more differentiated in the era of open innovation.

In the past, market research has focused primarily on forecasting customer acceptance of innovation and predicting the resulting changes in a company's marketing mix, the so-called 4Ps[2] (Borden, 1964). Nowadays, increasingly participative approaches are emphasizing customer involvement and co-creation in the

[2] Product (variation, differentiation, innovation, elimination), price (cost recovery and penetration pricing, price skimming), place (distribution channels, in/direct sales, e-commerce), and promotion (individual and mass communication, brand management, corporate identity).

development processes (Maklan et al., 2008). *Customer relationship management* has become of significant importance because customers are paying increased attention to product options, design and even aesthetic, symbolic or emotional meanings of products (Reinartz et al., 2004; Dell'Era, 2010). The concept of *lead user innovation* is based on the research of von Hippel (1986), who found that many commercially important products are initially conceptualized and prototyped by lead users rather than manufacturers. The difficult process of generating product and service breakthroughs can be significantly supported by them. For instance, 3M innovation projects that have been supported by lead users have delivered sales eight times higher than those of contemporaneous traditional projects (von Hippel, 2007, 2009; von Hippel & de Jong, 2010; 3M, 2010). Besides monetary rewards for the contributors, firms also have to consider intangible factors, such as community cooperation and entertainment availability (Antikainen et al., 2010).

Moreover, suppliers provide an essential external source of knowledge and technology transfer. The literature on *supply chain management* emphasizes the importance of long-term relationships between firms and their suppliers to optimize supply chain activities and key business processes (Lambert & Cooper, 2000; Kim, 2000; Walton et al., 2006). The willingness of suppliers to cooperate in innovation activities can strongly depend on the supplier's dependence on the company. According to Kamath and Liker (1990), dependent suppliers seem to be more willing to cooperate and invest in innovations to retain their customer, the company.

Cooperation with competitors is another common way to acquire knowledge, the Daimler-Toyota alliance being the latest example among multinational enterprises. The scope of competitive collaboration is broad and includes strategic alliances, joint ventures, outsourcing agreements, product licensing and cooperative research (Hamel et al., 1989; Hamel, 1991). Since economic theory distinguishes between less intense (Cournot, 1838) and more intense (Bertrand, 1883) competition, the number of participants in a market has considerable influence on the firms' investment and cooperation strategies. Whereas investing in a specific technology can increase the path dependency of the company, industry cooperation can decrease the uncertainty of market and technology development (Garud & Karnoe, 2000). The current literature on innovation distinguishes between intra-industry and cross-industry cooperation and highlights the imitation and retranslation of existing solutions from other industries (Herstatt & Kalogerakis, 2005; Gassmann & Zeschky, 2008). However, theory has just begun to recognize the value of knowledge, technologies and partners with a high cognitive distance. Cross-industry innovation enables creative imitation and retranslation of existing solutions from different industries in order to meet the current market needs. Examples of this practice include BMW’s iDrive system, which was transferred from the game industry, and Nike’s shock absorbers, which were adapted from Formula One racing technology (Enkel & Gassmann, 2010). In this study, we consider both intra- and cross-industry cooperation.

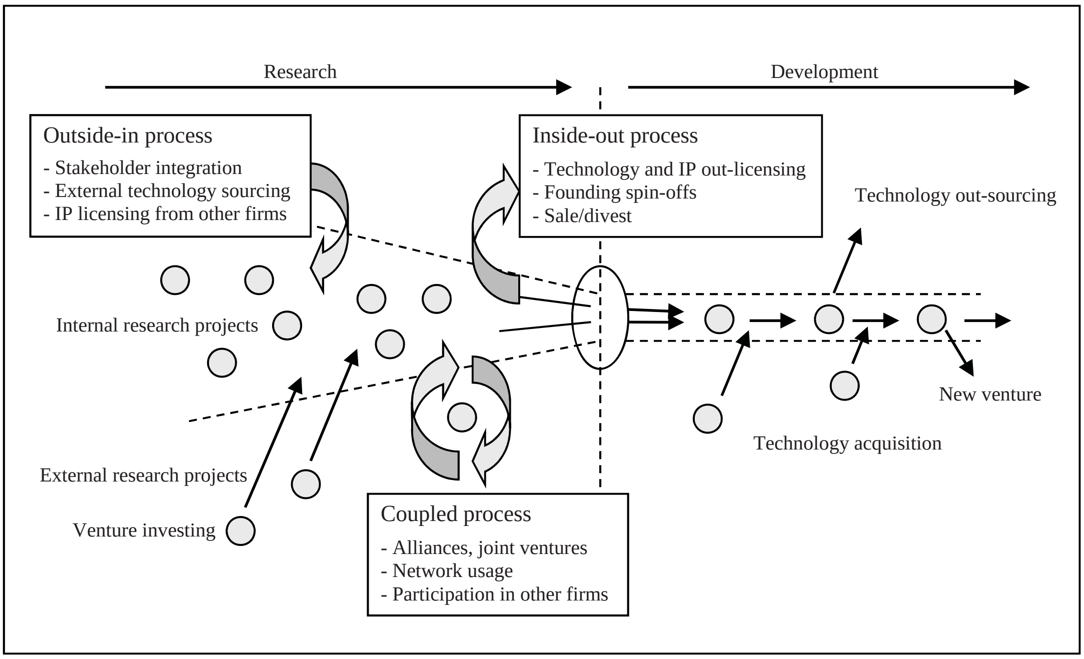
In addition, firms can engage private consulting organizations or cooperate with public research institutions to account for the creation and commercialization of new products, services and processes. Tether and Tajar (2008) find that service firms are more likely to engage private consultants than manufacturing firms, whilst their links to public research institutions are weaker. In recent years, the industry-university linkage has attracted interest among scholars and evidence suggests that such collaboration is widely practiced (e.g., Santoro & Chakrabarti, 2002; Hanel & St-Pierre, 2006; Gulbranson & Audretsch, 2008; Buganza & Verganti, 2009). Belderbos et al. (2004) analyze the innovation behaviors of Dutch firms and conclude that university cooperation is crucial for the sales of products that are novel to the market and for improving the growth performance of firms. Lööf and Broström (2008) find that collaborations between universities and firms have a positive effect on the ratio of innovative product sales and increase the probability that firms will apply for a patent.

To adopt the open innovation model, companies have to reorganize to allow collaboration with an increasing number of stakeholders during the innovation process. In the following section, we identify the core processes of open innovation.

2.2.5 Core processes of open innovation

Gassmann and Enkel (2005) define the three core processes of open innovation in R&D management (see Figure 1). The first core process, the so-called *outside-in process*, includes all activities for external technology sourcing. During this inbound open innovation process, companies monitor the environment to source knowledge and technologies from stakeholders, such as users or suppliers and to license IP from other firms. The second core process, the so-called *inside-out process*, refers to outward technology transfers. In such an outbound open innovation process companies initialize technology and IP out-licensing, make sales, divest and found spin-offs. The commercialization of in-house technology is the main purpose of this process. The third process, called a *coupled process*, combines outside-in and inside-out processes by working together with complementary partners or by participating in other companies. This mixed open innovation process results in alliances and joint ventures, whereat the focus lies on network usage (Gassmann & Enkel, 2005; Chesbrough & Crowther, 2006).

Figure 1: Core processes of open innovation in R&D



Note: Following Chesbrough, 2003a; Gassmann & Enkel, 2005.

The decision to either innovate internally or acquire technology from external sources is comparable to a classical make or buy decision. However, the increasing complexity of this decision and the growing need for interdisciplinary R&D forces management decisions to move beyond the make or buy dichotomy (Swan & Allred, 2003; Bröring & Herzog, 2008; Herzog, 2008). Along with user and supplier integration, licensing is one of the most frequently used methods for sourcing external technology. Licensing is defined as the exploitation of other firms' intellectual property within a certain time frame (Tidd & Bessant, 2009). From the inside-out perspective, the IP seller can also benefit from subsequent improvements in the technology introduced by the IP buyer. In addition to licensing or selling technologies, it is also possible to divest a part of the company. Spin offs, a specific form of divestment primarily utilized for technological reasons, are adequate if (1) the technology or research development does not match with the strategic core business of the company or if (2) the technology or developments require a different cost structure (Christensen & Overdorf, 2000; Lichtenthaler, 2005; Herzog, 2008).

In the coupled process, alliances can take the form of minority investments, corporate venture capital investments and joint ventures. Whereas minority investments and corporate venture capital investments generally allow the firm to access the full portfolio of technologies, joint ventures only expose those technologies and technological capabilities brought to the venture by the partnering firm (Folta, 1998; Dushnitsky & Lenox, 2005). In the case of networks, two basic venture types are possible. In centralized networks, partners are tied to a lead firm, such as suppliers in the Japanese automobile industry. On the other side, decentralized networks are more appropriate in a modular innovation setting, in which several equal partners contribute. Such decentralized networks are typical for open source software development, in which online communication plays a critical role in supporting knowledge sharing (Vujovic & Ulhoi, 2008). No single network member has total control and standards are determined though market processes or negotiation (Langlois & Robertson, 1991). Ensuring the compatibility of components, therefore, often requires more effort than in a centralized network (Farrell & Saloner, 1985).

2.2.6 Hypotheses

Many scholars have identified innovation as the main driver of prosperity, growth and profitability of companies (e.g., Drucker, 1988; Christensen, 1997; Thomke, 2001). Therefore, current research no longer defends the importance of innovation, but focuses instead on innovation methods and managing innovation processes (Elmquist et al., 2009). For the purpose of this study, we define *open innovation* to be a model for innovation that is based on cooperation with different stakeholders during the R&D process. In this sense, increased cooperation requires a firm's absorptive capacity to recognize the value of external knowledge and make use of it. This study elaborates on the research question of whether the openness of an R&D process has a positive impact on a firm's innovation performance. Thereby, the focus is on the openness toward multiple stakeholders involved. Of particular interest is the relationship between the first core process of open innovation, the 'outside-in process' and measures of 'innovation performance'. In existing research, innovation measurement has been addressed in different ways by different authors (Becheikh et al., 2006; Nieto & Santamaria, 2007). As mentioned earlier, we consider the following three different indicators for measuring the dependent output variable 'innovation performance': product innovations, process innovations and the percentage share of sales of newly developed products. The first two measures, product and process innovations, are considered direct innovation output effects. The third measure, the percentage share of sales of new products, represents an indirect innovation output effect. Hence the following research hypotheses are defined:

H_1: The more open a firm's outside-in process in R&D management, the higher the number of the firm's *product innovations*.

H_2: The more open a firm's outside-in process in R&D management, the higher the number of the firm's *process innovations*.

H_3: The more open a firm's outside-in process in R&D management, the higher the *percentage share of sales of new products*.

2.3 Research methodology

2.3.1 Sample and data collection

To test these hypotheses, we have chosen R&D managers as subjects of our study. Since existing empirically datasets such as the KOF Innovation Survey and the Mannheim Innovation Panel of the ZEW are not congruent with the specific focus of this study and since, “surveys are one way to dramatically expand the empirical evidence on open innovation” (West et al., 2006, p. 302), primary data were collected through an online survey with authorized login information. The survey targeted enterprises in German-speaking countries, including German companies listed on the CDAX Performance Index[3], Swiss companies listed on the Swiss Performance Index SPI[4] and Austrian companies listed on the Austrian stock index WBI[5]. The indices are comparable, as they represent composite indices including both general and prime standard. In March 2009, a pretest was conducted, in which we identified banks and insurance companies to be unable to fully provide all necessary innovation measures. Although possible adjustments were considered, they were ultimately excluded from the sample. For the following study, a total of 783 stock-listed enterprises were contacted, 498 in Germany, 203 in Switzerland and 82 in Austria. To enhance the response rate, each R&D Manager was contacted by email in the first step and by telephone two weeks later in the follow-up. During the survey period from April to June 2009, a total of 141 managers from R&D departments provided complete responses, representing a response rate of 18 percent. Most of the respondents hold positions such as head of the R&D department, chief technology officer, chief executive officer and R&D manager.

[3] cf. CDAX Composite German Stock Index, Frankfurt Stock Exchange.

[4] cf. SPI Swiss Performance Index, SIX Swiss Exchange.

[5] cf. WBI Vienna Stock Index, Vienna Stock Exchange WBAG.

2.3.2 Measures

Our study explores the relationship between the openness of the firms' outside-in innovation acquisition channel and their innovation performance. Openness is a characteristic of open innovation management and refers to the strategic orientation of the firm. As determinants for openness, we measure information on the intensity of open innovation activities during the five year reference period 2004 to 2008. The terminology used in our study is based on the commonly agreed definitions provided by the Oslo Manual (OECD/Eurostat, 2005) and includes questions relevant for both manufacturing and service sectors.

Key independent variables in our study evaluate whether or not and how often the firms cooperate in the outside-in process of R&D management with the following stakeholders:

(1) Customers
(2) Suppliers
(3) Competitors
(4) Cross-sector companies
(5) Consulting firms, and
(6) Universities and colleges

The similarity of this stakeholder selection to existing studies and innovation panels is intended to facilitate the comparability of our study. Stakeholder cooperation intensity is measured on the basis of a five-point Likert scale (never, rarely, sometimes, often, very often). Common innovation activities are defined as activities that are oriented toward co-development or implementation of new knowledge and innovations. Innovation cooperation involves active participation in innovation projects with the respective stakeholder. R&D management considers these innovation projects as important and the knowledge is shared verbally, in writing and through information and communication technologies (OECD, 2002; OECD/Eurostat, 2005).

In our study, three different dependent variables represent the innovation performance on an aggregated level: the amount of product innovations, the amount of process innovations and the percentage share of sales made up of newly developed products or services. In line with previous studies (Jung & Dönnges, 2007; Rammer & Bethmann, 2009; Arvanitis et al., 2010) and the results of our pretest, the number of product and process innovations is measured with an 11-point level scale (none, 1, 2, 3, 4, 5-10, 11-20, 21-30. 31-40, 41-50, more than 50). The percentage of sales of newly developed products is provided in a metric scale ranging from 0 to 1. According to the Oslo Manual, new products and services are defined as either market novelties or new to the firm but existent on the market. These are goods and services that differ significantly in their characteristics or intended uses from previous products. Product innovations are defined as the invention and commercialization of new or significantly improved products or services. They do not include products with only minor variations (e.g., customer specification and design adjustments). Process innovations represent significant improvements in the production process that occur through the adoption of new technologies and innovations (Roberts, 1988, 2007; OECD/Eurostat, 2005).

Considerable evidence suggests that innovation performance depends on firm size (Lichtenberg & Siegel, 1991; Cohen & Klepper, 1996; Kafouros et al., 2008). Furthermore, industry characteristics may significantly influence a firm's innovation performance. To avoid biased estimates resulting from this fact, dummies for firm size and for sector affiliation have been included. Whereas firm size is measured in number of full-time employees (small: less than 50, medium: 51-500, large: more than 500), sectors were defined according to the Industry Classification Benchmark[6] and grouped regarding their reliance on technology (low-tech, medium-tech, high-tech). Due to the fact that the innovation performance can strongly depend on a firm's R&D investments, this control variable is also taken into account. R&D investments include R&D costs and are measured as percentage of the firms' total sales, leading to a control variable range from 0 to 1.

In case the relevant information is not available to the R&D managers, they can optionally select 'unknown'. On the one hand, this option increases the quality of the valid answers, but on the other hand, it decreases the available number of answers available for analysis (N).

[6] The detailed ICB sector classification is provided on the website http://www.icbenchmark.com.

2.4 Empirical results

Table 1 contains the descriptive statistics and correlations of all research variables used in this study. Mean and standard deviation are presented in the first column, with the correlation coefficients and its corresponding significance levels between two variables in the remaining columns. All variables, except the 'share of sales of new products' and 'R&D investments (in Euro)', are measured in or transformed into nominal scale. Due to this measurement, the more robust Spearman rank correlation coefficients are used to identify the strength of correlation and whether the correlation is positive or negative.

Table 1: Descriptive statistics of outside-in open innovation

	Mean (St.dev.)	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1. Product innovations	5.300 (2.755)	1											
2. Process innovations	4.340 (2.600)	.521 ***	1										
3. Share of sales of new prod.	0.270 (0.258)	.330 ***	.151	1									
4. Customers	2.990 (1.000)	.214 **	.162 *	.285 **	1								
5. Suppliers	2.220 (1.178)	.148 *	.279 ***	.002	.149 *	1							
6. Competitors	1.09 (1.043)	.043	.283 ***	-.141	.196 **	.135	1						
7. Cross-industry firms	1.210 (0.939)	.218 **	.104	-.027	.178 **	.197 **	.354 ***	1					
8. Consulting firms	1.390 (1.082)	.065	.108	-.011	.006	.138	.276 ***	.354 ***	1				
9. Universities	2.095 (1.145)	.277 ***	.294 ***	.088	.009	.309 ***	.079	.337 ***	.319 **	1			
10. R&D investment	0.085 (0.144)	.075	-.137	.505 ***	.018	-.008	-.007	-.034	-.032	-.023	1		
11. Size	2.620 (0.651)	.245 ***	.375 ***	-.148 *	.096	.124	.147 *	.206 **	.281 ***	.269 ***	-.377 ***	1	
12. Sector	1.720 (0.794)	.230 ***	.156 *	.219 **	-.001	.107	-.043	.123	.061	.155 *	.199 **	.036	1

Significance levels: * = p<0.1, ** = p< 0.05, *** = p<0.01.

In the following, the results of the ordered Probit[7] and OLS estimations, with respect to the different stakeholders from the outside-in process, are depicted.

[7] For detailed information on the premises of the ordered Probit model, see Wooldridge (2002).

Whereas an ordered Probit regression is appropriate for both dependent ordinal scaled variables product and process innovations, a linear regression is adequate for the dependent metric variable percentage share of sales of new products. The estimated coefficients in an ordered Probit model only allow for statements about the significance and the corresponding sign of an effect but not about its extent.

First, Probit (1) in Table 2 shows the results of the first ordered Probit regression on the dependent variable ‘product innovations’. The coefficient for openness toward ‘customers’ (p=0.056[8]) is positive and statistically significant as well as the coefficient for openness toward ’universities’ (p=0.030). Thus, the openness of the outside-in process toward these stakeholders has a positive impact on product innovations. Furthermore, both the dummy for the ‘medium-tech’ (p=0.027) and ‘high-tech’ (p=0.064) sector have a positive influence on this dimension of the innovation performance. As expected, this indicates that compared to companies in the low-tech sector, companies in the medium- and high-tech sector display a higher product innovation performance.

Second, Probit (2) in Table 2 reports the results of the ordered Probit regression on the dependent variable ‘process innovations’. The coefficients for openness toward ‘suppliers’ (p=0.013), ‘competitors’ (p=0.006) and ‘universities’ (p=0.015) are significantly positive. Openness toward cross-sector companies has a significant negative effect (p=0.053). The dummy for the ‘high-tech sector’ (p=0.029) also has a positive and significant influence on the process innovation performance. This result implies that compared to the low-tech sector, companies in the high-tech sector perform better with regard to process innovations.

[8] All estimations in this research paper were performed using STATA 10.1. The p-values indicate the significance levels.

Table 2: Analytical statistics of outside-in open innovation

	Probit (1)	**Probit (2)**	**Lin Reg (3)**
Dependent variable	**Product innovations**	**Process innovations**	**Share of sales of new products**
Customers	**0.196*** (0.103)	0.151 (0.120)	**0.050**** (0.024)
Suppliers	0.049 (0.098)	**0.251**** (0.102)	-0.010 (0.020)
Competitors	-0.035 (0.111)	**0.320***** (0.120)	-0.004 (0.026)
Cross-industry firms	0.033 (0.112)	**-0.247*** (0.128)	-0.030 (0.025)
Consulting firms	-0.055 (0.099)	-0.089 (0.113)	-0.014 (0.024)
Universities	**0.109**** (0.050)	**0.118**** (0.048)	**0.022*** (0.012)
R&D investment	-1.001 (0.915)	-1.211 (0.929)	**1.482***** (0.306)
Dummy medium size	-0.289 (0.373)	-0.182 (0.392)	0.023 (0.093)
Dummy large size	-0.094 (0.391)	0.655 (0.411)	-0.039 (0.080)
Dummy medium-tech sector	**0.511**** (0.231)	0.134 (0.250)	**0.147***** (0.046)
Dummy high-tech sector	**0.524*** (0.283)	**0.531**** (0.244)	0.080 (0.059)
Number of observations	117	108	111
Pseudo R^2	0.047	0.101	
R^2			0.215

Significance levels: * = p<0.1, ** = p< 0.05, *** = p<0.01. Robust standard errors in parentheses.

Third, Lin Reg (3) in Table 2 presents the results of the linear regression (OLS) on the dependent variable ‘share of sales of new products’. Consistent with the first regression, openness toward customers has a significantly positive influence on the share of sales of new products (p=0.041). Again, openness toward universities also increases the share of sales of newly developed products (p=0.064). As expected, there is a positive and highly significant effect from ‘R&D investments’ (p=0.000), which means that the level of financial investment does strongly influence the share of sales made up of new products. Moreover, companies in the ‘medium-tech sector’ (p=0.002) have a significantly higher share of sales of newly developed products compared to companies in the low-tech sector.

2.5 Discussion

Recent studies confirm that open innovation models have become an integrated part of companies' innovation strategies (De Backer et al., 2008; Enkel & Gassmann, 2009). The Community Innovation Survey (CIS/Eurostat, 2008) shows that large companies are more likely to collaborate in the outside-in process than small and medium size companies. This is consistent with the findings of our study that reveal statistically significant correlations between company size and cooperation intensity with regard to competitors, cross-industry firms, consulting firms and universities. As the CIS studies evaluate the existence and stated importance of collaborations (De Backer et al., 2008), our study extends this focus and analyzes the intensity of stakeholder cooperation in the outside-in process. Compared to existing empirical evidence, mainly case studies, another specific contribution of the study is the cross-sectional data basis, which not only includes R&D intense companies in high-tech sectors, but also less R&D intense firms in medium- and low-tech sectors.

Our findings clearly emphasize the importance of university cooperation across sectors. Openness toward universities in R&D processes has a positive impact not only on product innovations and the resulting sales, as has been previously reported in the literature (e.g., Belderbos et al., 2004; Lööf & Broström, 2008), but also on process innovations. Thus, the openness in the firms' outside-in process toward public research institutions goes along with significant improvements in the production process. This result is of particular importance because, compared to the average OECD cooperation in innovation panels, Germany and Switzerland show intensive cooperation activities with universities and colleges (Rammer & Bethmann, 2009; Arvanitis et al., 2010).

Interestingly, our findings indicate that competitive intra-industry cooperation has a positive influence on process innovation, but cross-industry cooperation has a negative influence. Regarding open innovation theory, the first relationship is consistent, the latter, however, is quite surprising because cross-industry innovation is emphasized (Gassmann & Zeschky, 2008; Enkel & Gassmann, 2010). This phenomenon may be explained by the insufficient absorptive capacity of firms to absorb knowledge and technologies emerging in other industries. Cognitive distances between the firms' cross-industry partners offer another explanation because these differences represent gaps in the fundamental perception, interpretation and evaluation systems inculcated by their organizational cultures. Thus, cognitive distances can increase in cross-industry cooperation and preclude sufficient mutual understanding of innovation opportunities.

Our study adds new empirical evidence on the relationship between openness in a firm's outside-in process in R&D management and the firms' innovation performance. However, the aspect of international cooperation and the partners' location is not analyzed in our research study.

2.6 Conclusion

Using a cross-sectional data set of 141 stock-listed firms from German-speaking countries, this article provides empirical evidence on the relationship between the openness of the outside-in process in R&D management and the companies' innovativeness and innovation performance. According to the literature, product and process innovations as well as the proportional share of sales of new products have been considered as indicators for innovation performance. The openness of the R&D management toward customers, suppliers, competitors, cross-sector companies, consulting firms and universities was measured on a five-point Likert scale.

Regarding the direct innovation output effect, firms with a higher openness toward customers and universities are more likely to increase product innovations. On the other hand, as the indirect output effect, customer and university cooperation increases the percentage share of sales of products developed within the last five years. Furthermore, the more open the outside-in process toward suppliers, competitors and universities the more process innovations result. However, openness toward cross-sector companies decreases the process innovation performance.

The result that the openness of the outside-in process toward customers is crucial for product innovations and sales of new products is consistent with the results of von Hippel (2007, 2009) who emphasizes the role of customers and lead users in product development. Practices that are visible in open source software development were important for discovering that customers and users often freely reveal product improvements and innovations. Additionally, openness toward universities in R&D processes has a positive impact on all the examined measures of innovation performance. For process innovations, as evident from supply chain management theory, openness toward suppliers has a positive influence. Interestingly, our findings indicate that competitive intra-industry cooperation has a positive influence on process innovation, but cross-industry cooperation exerts a negative influence. Insufficient absorptive capacity and cognitive distances between the firms' cross-industry partners constitute explanations why mutual learning processes are not successfully established.

Our findings show that openness toward external sources can result in a higher level of innovation performance. For companies in all sectors, an overemphasis on internal sources can lead to competitive disadvantages and an increased probability of missing opportunities. Customer and user centered innovation is already a general phenomenon that reveals an enormous pool of knowledge and ideas about products and services. To increase product innovations and successful new products, cooperation in product development processes should already start in an early phase. Similarly, early supplier integration is a powerful management strategy for continuous improvements of process engineering. In this regard, companies in high-tech sectors such as the chemical or biotechnology sectors are clearly more affected. Notably, openness toward competitors not only increases the process innovation performance, but may also decreases path dependency resulting from investing in a specific technology. However, research relationships and collaboration with partners or institutions can also have path dependent characteristics.

University cooperation can be considered instrumental for enhancing product and process innovations as well as for increasing the share of sales of newly developed products. Therefore, the firms' innovativeness can strongly depend on cooperation with universities. By contrast, the engagement of consulting firms does not have any significant effect on the evaluated innovation performance measures. Thus, R&D management better choose to consult with public rather than private research institutions. Overall, cooperation with universities can lead to (1) continuous information about new knowledge and developments, (2) more speed and flexibility in innovation, (3) a valuable network with high level contacts both nationally and internationally and (4) reduced R&D costs due to publicly funded support of research projects (Holt, 1990; Harryson et al., 2008).

In a recent study of 25 cross-industry cases, Enkel and Gassmann (2010) could not find a direct relationship between cross-industry innovation and innovation performance. According to our findings, the impact of cross-industry innovation on the process innovation performance is negative. R&D managers should therefore carefully consider the degree of cognitive distance present in cross-industry cooperation and be aware of the possible disadvantages resulting from existing diversity. In product development processes, cross-industry openness is less critical because no significant impact on product innovation performance exists.

However, these results should be carefully interpreted, since the present study has some limitations. First, the cross-sectional data used has intrinsic limitations and, therefore, future research should be based on a longitudinal design that emphasizes time-lagged system dynamic. Second, the data are based on the perceptions and experiences of the respondents, which may vary across industries, companies, functions and work experience. For this reason, more quantitative measurement techniques should be considered. Third, intellectual property licensing, patenting and acquisitions as other forms of technology sourcing were not considered as part of the outside-in R&D process. Thus, future investigations may extend the focus and scope of this study. Fourth, additional moderating effects, such as industry specification, incremental versus radical innovations or the degree of novelty should be explored in future studies. Finally, this paper calls upon future research about how cross-industry cooperation can enhance innovation performance and the corresponding role of absorptive capacity and cognitive distance.

CHAPTER 3

The impact of inside-out open innovation on innovation performance

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3.1 Introduction

The ongoing globalization of economic activities and markets accelerates innovation processes. Drivers of innovation such as the global availability of knowledge, technology fusion and shorter innovation cycles have become important for companies. To develop and maintain their competitiveness and ensure economic success, firms must steadily improve their innovation performance, strive for more innovation and seek new opportunities for commercialization. One way to approach these aims is to introduce open innovation into R&D management. Open innovation moves beyond traditional business models and helps to open up firm boundaries. The focus shifts from the innovation itself to the search for novel knowledge (exploration) and to the means of applying knowledge (exploitation) (Gobbo & Olsson, 2010).

During the last decade, open innovation research has garnered increasing attention among both researchers and practitioners. This is demonstrated by the rapidly growing body of literature on the subject. Chesbrough (2003a, 2003b), who has

[9] Inauen, M. & Schenker-Wicki, A. (2012), "Fostering radical innovations with open innovation", European Journal of Innovation Management, Vol. 15 No. 2, pp. 212-231, © Emerald Group Publishing.

significantly contributed to the emergence of this new field, defines open innovation as "a paradigm that assumes that firms can and should use external as well as internal ideas, and internal and external paths to markets" (Chesbrough, 2006b, p.1). He distinguishes between *outside-in* and *inside-out* open innovation. Whereas the focus of outside-in open innovation is on the search for and adoption of ideas and technologies from outside the firm's boundaries, inside-out open innovation deals with the many ways in which innovations can be commercialized and markets can be entered. Rather than relying entirely on internal paths to market, companies can seek external support and find organizations with business models that are better suited to a given technology (Chesbrough & Crowther, 2006; Elmquist et al., 2009).

Although inside-out open innovation is an efficient strategy for increasing competitiveness, few studies have been conducted that increased our understanding of this kind of innovation (Lichtenthaler, 2008, 2009). West (2003) analyzes Apple, IBM and Sun, scrutinizing the level of intensity of outward technology transfers by each firm and concluding that all three firms were able to maintain control of their technologies even if they entered open-source competition. Henkel (2006) finds that 268 embedded Linux software developers protect half of the internally developed software code on average; they reveal the other half to profit from opportunities for open development and improvement. Working with multiple industries, Lichtenthaler and Ernst (2007) state that external technology commercialization is not fully leveraged at medium- and large-sized European firms but holds great potential that could be utilized if such campaigns were successfully implemented. The same authors (2009) analyzed 155 medium- and large-sized firms from Germany, Austria and Switzerland, and found that companies are increasingly licensing their knowledge. Bianchi et al. (2011) investigated inside-out open innovation in the bio-pharmaceutical industry and identified activities undertaken during clinical tests and post-approval processes that are intended to secure better and more rapid market access.

Researchers seeking to determine the performance implications of open innovation strategies (as compared with closed ones) will find that only rudimentary measurement systems with very few key performance indicators exist for this purpose. This makes it difficult to evaluate and compare the impact of different strategies on innovation performance (Enkel et al., 2009). To date, inside-out open innovation strategies have not been analyzed in depth. To close this gap, we have conducted a survey of the performance impact of various R&D strategies at stock-listed firms in Germany, Switzerland and Austria, and analyzed the influence of inside-out open innovation in detail. Our results show that inside-out open innovation strategies have a significant impact on innovation performance and are more likely to create radical innovations that could be of critical importance to R&D managers.

This paper is structured as follows: Section 2 presents the theoretical framework and hypotheses studied. Section 3 includes the data and model specifications, and details the survey conducted with stock-listed enterprises in the relevant countries. Section 4 presents and discusses the empirical results. Section 5 concludes the paper and recommends future research directions.

3.2 Theory and hypotheses

3.2.1 Open innovation strategy and innovation performance

In his early work, Schumpeter (1934, 1939) identifies innovation as a critical dimension of economic change and a stronghold for firms in an increasingly competitive environment. He defines the following five types of innovation: new products, new production processes, new sources of supply, the exploitation of new markets and new ways of organizing business.

To increase the comparability of this study with existing studies in the innovation literature, we distinguish product[10] and process innovations[11] according to Schumpeter (Schmookler, 1966; Avlonitis et al., 1994; Cohen & Klepper, 1996; Fagerberg, 2006). Whereas product innovations are defined as the invention and commercialization of entirely new products or services, process innovations represent significant improvements in the production process that occur through the adop-

[10] Related terms are ‘new products’ and ‘product technology’.

[11] Related terms are ‘new methods of production’ and ‘production technology’.

tion of new technologies and innovations (Roberts, 1988, 2007; OECD/Eurostat, 2005). Both product and process innovations can be ‘radical’ or ‘incremental’. Incremental innovations build on existing firm competences and are related to minor improvements to existing products or services (e.g., new car product lines or functional foods). In contrast, radical innovations, also referred to as breakthrough innovations, involve fundamental technological changes and result in revolutionary products and services (e.g., the steam engine, the telegraph or the Internet) (Green et al., 1995; Linton, 2009). The terms radical and incremental indicate different degrees of novelty (Un, 2010). In this regard, the general term ‘innovativeness’ is used to characterize the degree of novelty of products or services and the degree to which the organizational culture promotes and supports innovation (Garcia & Calantone, 2002; Jiménez-Jimémez & Sanz-Valle, 2011).

Since the 1980s, innovation models have highlighted the interactive character of the innovation process, suggesting that innovative companies rely heavily on innovation systems (e.g., Lundvall, 1992; Edquist, 1997) and on regular interaction with customers and lead users (e.g., von Hippel, 1988; de Jong & von Hippel, 2009), suppliers (e.g., Lambert & Cooper, 2000; Walton et al., 2006), universities (e.g., Lööf & Broström, 2008; Buganza & Verganti, 2009) and competitors (e.g., Gassmann & Zeschky, 2008; Enkel & Gassmann, 2010). The higher the degree of environmental and technological uncertainty for the innovators – for instance, in sectors with complex products such as aircraft – the higher the importance of R&D cooperation strategies in shaping the evolution of technology (Tushman & Rosenkopf, 1992; Laursen & Salter, 2006; Eisingerich et al., 2010).

Open innovation models mainly focus on interactive processes through which knowledge and technologies can easily flow through firm boundaries in both directions. Open innovation models are based on the fundamental assumption that invention and innovation do not necessarily have to take place at the same location as that in which they are being transformed into new products and then commercialized. In addition to technological acceleration and the global availability of knowledge and employees, there are important reasons for pursuing this type of open innovation strategy. First, open innovation enables companies to reduce fixed costs for R&D and allows them to establish new sources of research funding

(Chesbrough, 2006c). Second, the risks resulting from R&D projects, technologies or products can be shared with partners or competitors (Herzog, 2008). Therefore, the emergence of risk-sharing collaborations – which are common in the pharmaceutical and biotechnological industry – can be seen as a function of high-risk R&D projects and the significant costs involved (Reepmeyer, 2006). Co-creation and know-how transfer agreements with partners, competitors or research institutions represent other forms of open innovation collaboration.[12]

However, barriers remain to the proper functioning of know-how and technology markets. In open innovation strategy, knowledge about the fundamental economic problems associated with know-how and technology transfer is of critical importance. In his early work, Arrow (1962) described the problems of uncertainty, indivisibility and appropriability that hinder technology markets. Due to uncertainty, technological risk is unknown for both buyer and seller. Because ideas are indivisible, information can only be transferred once. It is impossible to share or sell just part of an innovative idea. The appropriability problem is a dilemma that firms face in the inside-out process. They may fail to generate a profit from an innovation that they reveal, or they may even fail to retain the value that they have created with that innovation. Moreover, the value of an idea or a technology is not known until it has been revealed at least partly (Arrow, 1962). As a result, licenses or patents do not prevent potential buyers from using information without paying for it. In this regard, strong intellectual property rights are necessary to reduce the intensity of the appropriability problem in the markets for know-how and technology (Kim & Vonortas, 2006).

In addition to these imperfections in technology markets, companies may have other reasons not to pursue an open innovation strategy. They may be reluctant to change their strategy because a more open business model can weaken a firm's competitive position and strengthen competitors by selling and transferring relevant knowledge (Rivette & Kline, 2000; Lichtenthaler, 2009). According to Kline (2003), this concern is rooted in the underlying fear of selling the company's

[12] The 10-year partnership between Novartis and the Massachusetts Institute of Technology, known as the Novartis – MIT Center for Continuous Manufacturing (MIT, 2007), presents a real-world example of know-how transfer from the university to the corporate world.

crown jewels. However, although pursuing an open innovation strategy can potentially have these negative effects, several studies prove that firms embedded in benefit-rich networks are likely to enjoy greater innovation input, innovation performance and learning effects (Powell et al., 1996; Walter et al., 1997; Becker & Dietz, 2004; de Luca & Atuahene-Gima, 2007). Furthermore, the innovation literature highlights the importance of cross-sector cooperation and the imitation and retranslation of existing solutions from other industries to fostering innovation performance (Herstatt & Kalogerakis, 2005; Gassmann & Zeschky, 2008). An open innovation strategy can build on cooperation with suppliers from neighboring markets and distant industries. Thus, the impact of an open innovation strategy on innovation performance can increase when the search for new technologies spans both organizational and technological boundaries (Li & Vanhaverbeke, 2009).

In addition, both direct and indirect ties can have positive impacts on innovation input and performance. Ahuja (2000) concludes that the optimal structure of interfirm networks depends on the objectives of the network members, although the aims of partners in R&D collaborations can be heterogeneous, as Belderbos et al. (2004) demonstrate. According to their study, supplier cooperation focuses primarily on incremental innovations intended to improve productivity performance. Competitor cooperation is instrumental in enhancing incremental innovation and increasing sales for innovative products. Additionally, customers and universities are important knowledge sources for firms pursuing radical innovations that facilitate growth in innovative sales. Tödtling et al. (2009) find that companies cooperating more often with universities and research organizations introduce advanced innovations, whereas firms relying more on knowledge links with business services have introduced less advanced innovations.

These studies indicate the relevance of open innovation strategies to increases in innovation performance. However, internal R&D remains a necessary complement to openness toward outside knowledge, and individual companies must evaluate whether outside ideas and technologies can substitute for internal R&D (Dahlander & Gann, 2010). Regarding the output of successful R&D management, process and product innovations, incremental and radical innovations and resulting sales from newly developed products can be considered as key innovation performance measures (OECD/Eurostat, 2005; Smith, 1992, 2006).

To advance innovation performance, an increasing number of organizations have transitioned from traditional R&D business models to more open ones. As part of this ongoing trend, companies are pursuing various open innovation strategies.

3.2.2 Definition of inside-out open innovation

Outside-in open innovation stresses the importance of external sources of innovation in fostering internal R&D activities. In this regard, customers, suppliers, competitors, cross-sector companies and universities are potential sources of ideas and technologies (Chesbrough, 2003a, 2003b). Chesbrough's model of open innovation suggests that "a company that is too focused internally (…) is prone to miss a number of opportunities because many will fall outside the organization's current businesses or will need to be combined with external technologies to unlock their potential" (Chesbrough, 2006d, p. 130). This proposition holds not just for the development of new technologies but also for the commercialization of existing internal ideas and technologies.

Unlike outside-in open innovation, inside-out open innovation refers to the commercialization of ideas, technologies and innovations via external distribution channels. "The inside-out process refers to earning profits by bringing ideas to market, selling intellectual property, and multiplying technology by transferring ideas to the outside environment" (Enkel et al., 2009, p. 312). The focus on this form of the externalization of knowledge and innovation allows ideas to be brought to market more rapidly than can occur through internal development. The locus of exploitation shifts outside the company's boundaries and profits are generated by transferring ideas and technologies to other companies. The firm participates in additional segments, which creates new opportunities and more revenue from innovation (Gassmann & Enkel, 2004; Enkel et al., 2009). Motorola, for example, estimates that the external use of its mobile-phone technologies could increase annual revenues by 10 billion USD (Lichtenthaler, 2010). Especially during times of continued economic contraction, companies may consider capturing additional value from their technologies using an inside-out open innovation strategy for R&D management.

3.2.3 Inside-out open innovation strategies

One of the most important facets of inside-out open innovation is licensing. Significant financial revenues can result when a firm licenses its own technology to other firms. Licensing agreements are a common form of inter-firm alliance, especially for firms looking to exploit an extensive technology patent portfolio. IBM, for example, received 370 million USD in licensing-based fees and an additional 228 million USD from the sale and transfer of intellectual property in 2009 (IBM, 2010). An analysis of US-traded companies shows that small firms in industries with 'simpler' technologies tend to sell more technology through licensing to their industrial partners than do large firms in industries with more 'complex' technologies, which engage in relatively more licensing across different sectors. Licensing across industries aims to decrease intellectual property risk and can occur when the licensor has a greater prior history of licensing (Kim & Vonortas, 2006). Globally, licensing during the period 1985-1997 involved an average of 1,150 transactions with a total value of over 25 billion USD per year (Arora et al., 2001).

In addition to the financial benefits involved, several strategic benefits can accrue from pursuing an inside-out open innovation strategy. Reputation is one reason for focusing on the inside-out process; firms may choose this strategy when they have strong development and commercialization departments but do not have a branded product in the target market. Firms can benefit indirectly from a partnership through an enhanced brand or through the strategic position of their partner. Setting industry standards presents another strategic benefit that can be of particular importance to the firms' long-term success (Lichtenthaler, 2008).

Firms can also divide existing know-how and technologies by selling or divesting (e.g., founding spin-offs). Hence, in addition to making the 'make or buy' decision, firms' must make 'keep or sell' decisions as well (Dittrich & Duysters, 2007). Accordingly, Fosfuri (2006) states that it is beneficial for companies to formulate an open innovation strategy that guides their individual 'keep or sell' decisions. Furthermore, Lichtenthaler (2009) points out that a firm's inside-out open innovation strategy is also affected by whatever technology transfer restrictions are introduced via national and international law (e.g., foreign investment law for companies investing abroad).

Both inside-out and outside-in open innovation make the boundary between the firm and its environment more porous, turning what was once a solid boundary into a 'semi-permeable membrane' (Chesbrough, 2003a; Herzog, 2008). Increased openness of firms calls for more frequent and improved communication with stakeholders. In this regard, open-source innovation shortens distances and time lags to and from potential contributors as described in the following section.

3.2.4 The impact of open-source innovation on R&D management

In the software industry, the open source trend can be considered the first important step toward open innovation. The opening-up of the innovation process then continued in high-tech and pioneer industries, including electronics, telecommunications, pharmaceuticals and biotechnology (Chesbrough, 2003a, 2003b). Even comparatively closed organizations such as Microsoft had initiated outside-in innovation processes by cooperating with decentralized research labs on university campuses (Gassmann et al., 2010). The trend toward open innovation is supported by information and communication technologies in essential ways (Hauge et al., 2010). These technologies allow different sectors and low-tech industries, including consumer goods, food, architecture and logistics, to begin opening their boundaries up systematically toward users, suppliers, universities and other stakeholders. Indeed, most innovation activities are based on online communication, which allows for collaboration both internally and across firm boundaries. Because the Internet offers real-time communication, it can be described as an e-R&D networking tool for internal and external collaboration. The Internet can foster internal learning networks by establishing and enhancing the quantity and quality of communications (Vujovic & Ulhoi, 2008; Kessler & Alpar, 2009).

However, the trend toward open-source innovation, with its focus on network usage, is not limited to the software industry. In the product and service sectors, an increasing number of R&D projects display a variety of characteristics that are usually associated with open-source software projects (Müller-Seitz & Reger, 2010). One major characteristic of open-source software development, i.e., its reliance on information and communication technologies, also holds for nearly all extant open innovation projects. Additionally, the term 'open source' denotes a wide range of behaviors allowed as part of the collaboration process; low levels of restrictions exist, and most rules are informal in nature (Müller-Seitz & Reger, 2010).

Furthermore, open-source projects are different from traditional projects because they are viewed as creating communities of practice characterized by a set of shared norms (Kogut & Metiu, 2001; Müller-Seitz & Reger, 2010). A study by Bughin et al. (2008) notes that brand affinity is the most important factor determining whether participants are willing to co-create with companies. Forty percent of would-be contributors refuse to co-create with companies out of a lack of trust. One-third of contributors who co-create with brands do so for financial reward: fame, fun and altruism are other, non-financial motives.

3.2.5 Development of hypotheses

The open innovation literature distinguishes between distinct types of R&D management strategies (Table 3). Firms that use a closed innovation strategy adhere to the philosophy that successful innovation requires control and that companies should develop, manufacture, market, distribute and service their products and services themselves (Chesbrough, 2003a; Mayle, 2006). In the following sections, this R&D strategy is referred to as in-house exploitation. As part of inside-out open innovation, firms can license their knowledge or intellectual property, share know-how in open-source projects or participate in other companies (Chesbrough, 2006b; Chesbrough et al., 2006).

Table 3: Strategies of R&D management in the inside-out process

R&D management	
Closed innovation	**Inside-out open innovation**
• in-house exploitation and distribution	• licensing • open-source innovation • participation in other companies • sale or divestment

The general goal of open-source innovation is to share a certain amount of know-how to receive knowledge in exchange from potential contributors. Knowledge communication usually occurs via information and communication technologies – for instance, through online computing on web forums – supported by Web 2.0 applications (Müller-Seitz & Reger, 2010). We assume that companies with open-source projects share information without requiring anything from customers (business-to-customer) or business partners (business-to-business). The more formal form of open innovation collaboration involves participation in other companies, including different forms of alliances and joint ventures. Finally, innovation divestment strategies involve selling or divesting know-how and technologies.

Our study aims to analyze whether firms' use of inside-out open innovation enhances their innovation performance. Whereas the amount of product and process innovation is considered a direct effect of innovation output, the percentage of sales made up of new products is an indirect effect. Accordingly, the following hypotheses are proposed:

H$_1$: The more open a firm's inside-out open innovation processes, the higher the amount of *process innovations*.

H$_2$: The more open a firm's inside-out open innovation processes, the higher the amount of *product innovations*.

H$_3$: The more open a firm's inside-out open innovation processes, the higher the *percentage share of sales of newly developed products*.

Because markets and demand become saturated, successful firms depend not only on continuous incremental innovations, but also on radical breakthroughs in innovation. In analyzing the existence of radical innovations, we consider the degree of novelty of products and services as our forth important innovation performance measure. We therefore suggest the following hypothesis:

H_4: The more open a firm's inside-out open innovation processes, the higher the probability that the firm generates *radical product and process innovations*.

3.3 Data and model specification

3.3.1 Data

To test our hypotheses, we collected primary data through an online survey and defined R&D managers as the subjects of our study. The terminology used in our study is based on commonly agreed definitions provided by the Oslo Manual (OECD/Eurostat, 2005) and includes questions relevant for both manufacturing and service sector. The survey targeted enterprises in German-speaking countries, including German companies listed on the CDAX Performance Index, Swiss companies listed on the Swiss Performance Index SPI and Austrian companies listed on the Austrian stock index WBI. The indices are comparable, as they are composite indices including both general and prime standard. In March 2009, a pretest was conducted in which banks and insurance companies reported being unable to fully provide all necessary innovation measures. Although all possible adjustments were performed, all banks and insurance companies were ultimately excluded from the sample. In the study that followed, 783 stock-listed enterprises were contacted: 498 in Germany, 203 in Switzerland and 82 in Austria. Our first step was to contact each R&D manager by email and provide him or her with an outline of the purposes of the study and authorized login information for the online survey. The participants also had the option of filling out a printed questionnaire and returning the answers via mail or fax. In the telephone follow-ups that were conducted two weeks later, we contacted all individuals who had not responded to enhance the response rate. During the survey period from April to June of 2009, a total of 141 managers from R&D departments provided complete responses, yielding a response rate of 18 percent.

3.3.2 Model specification

The aim of our analysis is to assess the effect of inside-out open innovation on different innovation performance measures. The reference period for the innovation performance measures evaluated is from 2004 to 2008. Because whether incremental or radical innovations occurred in the reference period can be represented using a binary variable, binary logistic regression is used for the analysis. An ordered Probit model is used to determine the extent of process and product innovation at the companies, and linear regression (OLS) is used to determine the ratio of new product sales to total sales. Different types of regression analyses are necessary because the measures for innovation performance use different scales.

We use five different dependent variables to measure the firms' innovation performance, to obtain a fuller picture of the innovation success of the firms. The first two variables indicate the number of product and process innovations. In line with previous studies (Jung & Dönnges, 2007; Rammer & Bethmann, 2009; Arvanitis et al., 2010) and the results of our pretest, these two variables are measured with an 11-point level scale (none, 1, 2, 3, 4, 5-10, 11-20, 21-30. 31-40, 41-50, more than 50). As the third dependent variable, we use the percentage of sales of newly developed products and services, which is measured in a metric scale (ranging from 0 to 1). In accordance with the OSLO-Manual guidelines, new products and services are defined as either market novelties or new to the firm but in existence on the market. These are goods and services that differ significantly in their characteristics or intended uses from previous products (OECD/Eurostat, 2005). The final two dependent variables indicate whether the company introduced any incremental or radical innovations during the reference period and are binary variables (0 or 1).

The key independent variables in our study are the various inside-out open innovation strategies of the firms. The figures for licensing include only out-licensing intended to help firms gain additional commercialization revenues and do not include any form of in-licensing. Open-source innovation and participation in other firms are considered further explanatory variables because they indicate the use of inside-out open innovation strategies. Finally, the intensity of divestment and the use of closed innovation strategies, referred to as in-house exploitation, are also evaluated. Our survey asked R&D managers to identify the intensity of each activity using a five-point Likert scale (never, rarely, sometimes, often, very often). For this reason, these explanatory variables are measured using an ordinal scale. If the relevant information was not available to the R&D managers, they had the option of selecting ‘unknown’. On the one hand, offering this additional option decreased the number of answers available for analysis (N), but on the other, it increased the quality of the answers given.

Firm size represents an important control variable because considerable evidence suggests a positive influence on the firms’ innovation performance (Lichtenberg & Siegel, 1991; Cohen & Klepper, 1996; Kafouros et al., 2008). Furthermore, industry characteristics may have a significant influence. Hence, to avoid biased estimates, dummy variables for firm size and for sector affiliation have been included. Whereas firm size is measured in number of full-time employees (small: less than 50, medium: 51-500, large: more than 500), sectors were defined according to the Industry Classification Benchmark[13] and grouped regarding their reliance on technology (low-tech, medium-tech, high-tech). Due to the fact that the innovation performance can strongly depend on a firm’s R&D investments, this control variable is also taken into account. R&D investments include R&D costs and are measured as percentage of the firms’ total sales, leading to a control variable range from 0 to 1.

[13] The detailed ICB sector classification is provided on the website http://www.icbenchmark.com.

3.4 Empirical results

The descriptive statistics and the correlations between the variables used in this analysis are depicted in Table 4. The first column presents the means and standard deviations of the variables, and the remaining columns display the correlation coefficients and their respective significance levels. The variables ‘R&D investments (in Euros)’ and ‘share of sales of new products’ are measured using a metrical scale; all remaining variables are measured or presented using ordinal scales. Hence, the more robust Spearman rank correlation coefficients are reported for the ordinal variables so that we can identify the strength of each correlation and whether the correlation is positive or negative.

Table 4: Descriptive statistics of inside-out open innovation

		Mean (St.dev.)	1	2	3	4	5	6	7	8	9	10	11	12	13
1.	**Incremental innovations**	0.840 (0.371)	1												
2.	**Radical innovations**	0.35 (0.478)	-.162 *	1											
3.	**Process innovations**	4.340 (2.600)	.151 *	.032	1										
4.	**Product innovations**	5.300 (2.755)	.343 ***	.085	.521 ***	1									
5.	**Sales of new products**	0.270 (0.258)	.071	.104	.151	.330 ***	1								
6.	**Divesting**	1.05 (1.224)	-.012	.001	.023	.009	-.080	1							
7.	**Licensing**	1.640 (1.416)	-.045	.044	.031	.141	-.034	.352 ***	1						
8.	**Open-source innovation**	0.830 (1.036)	-.096	.096	.076	.020	.072	.392 ***	.421 ***	1					
9.	**Participation**	0.830 (0.938)	-.133	.088	.223 **	.095	-.003	.379 ***	.338 ***	.423 ***	1				
10.	**In-house exploitation**	3.310 (1.264)	.274 ***	.130	.104	.318 ***	.320 ***	.071	.199 **	.094 **	.004	1			
11.	**R&D investment**	0.085 (0.144)	-.017	.048	-.137	.075	.505 ***	.013	-.006	.105	-.026	.214 **	1		
12.	**Size**	2.620 (0.651)	.186 **	-.047	.375 ***	.245 ***	-.148 *	.095	.168 *	.184 **	.242 ***	-.003 ***	0.597 ***	1	
13.	**Sector**	1.720 (0.794)	.019	-.051	.156	.230 ***	.219 **	-.015	.139	.106	.085	.120	.225 ***	.036	1

Significance levels: * = p<0.1, ** = p< 0.05, *** = p<0.01.

The results of the regression analysis are depicted in Table 5. First, the column labeled Probit (1) shows the results of the ordered Probit regression on the dependent variable ‘process innovations’. The estimated coefficients in an ordered

Probit model only allow for statements regarding the significance and corresponding sign of an effect – they do not indicate its extent. The coefficient of the intensity of ‘participation’ (p=0.005[14]) is positive and statistically significant, indicating that this factor has a positive effect on process innovation. In addition, the independent variable ‘divesting’ (p=0.076) has a negative and moderately significant effect, which can be explained by a predominantly product-oriented strategy of these companies. The focus of these companies lies on new product and service bundles to divest knowledge and technology as a whole. Moreover, companies in the ‘high-tech sectors’ (p=0.053) displays a higher process innovation performance compared to companies in low-tech sectors.

The data in the column labeled Probit (2) depict the strongly positive effect of ‘in-house exploitation’ (p=0.000) on the dependent variable ‘product innovations’. Firms that develop and distribute products or services internally possess a significantly higher amount of product innovations. Compared to companies in low-tech sectors, companies in the ‘high-tech sector’ (p=0.018) have a significantly higher product innovation performance. Evidently, the closed innovation strategy and the sector affiliation are the dominant factors influencing innovation performance measured as the amount of product innovations.

[14] All estimations in this research paper were performed using STATA 10.1. The p-values indicate the significance levels.

Table 5: Analytical statistics of inside-out open innovation

	Probit (1)	**Probit (2)**	**Lin Reg (3)**	**Log (4)**	**Log (5)**
Dependent variable	**Process innovations**	**Product innovations**	**Share of sales of new products**	**Incremental innovations**	**Radical innovations**
Divesting	**-0.170***	-0.191	-0.022	-0.011	-0.045
	(0.095)	(0.126)	(0.017)	(0.024)	(0.042)
Licensing	-0.113	0.131	-0.009	-0.010	-0.002
	(0.083)	(0.082)	(0.017)	(0.027)	(0.038)
Open-source	0.065	-0.007	0.038	-0.058	**0.096****
	(0.116)	(0.104)	(0.024)	(0.044)	(0.043)
Participation	**0.303*****	0.028	0.005	-0.041	0.010
	(0.108)	(0.144)	(0.024)	(0.039)	(0.056)
In-house exploitation	0.166	**0.354*****	0.010	**0.090*****	0.024
	(0.105)	(0.085)	(0.015)	(0.342)	(0.042)
R&D investment	-0.568	-0.690	**1.670*****	0.053	-0.223
	(0.683)	(0.893)	(0.254)	(0.189)	(0.325)
Dummy medium size	-0.168	-0.412	-0.021	0.094	0.060
	(0.490)	(0.392)	(0.082)	(0.130)	(0.197)
Dummy large size	0.792	0.300	-0.040	**0.227***	-0.041
	(0.515)	(0.393)	(0.069)	(0.118)	(0.176)
Dummy mid-tech	-0.098	0.393	**0.157*****	-0.078	-0.005
sector	(0.260)	(0.242)	(0.049)	(0.072)	(0.115)
Dummy high-tech	**0.534***	**0.610****	0.029	0.038	0.000
sector	(0.276)	(0.257)	(0.054)	(0.070)	(0.120)
Number of observ.	103	112	106	113	113
Pseudo R^2	0.072	0.087			
R^2			0.402	0.195	0.054

Significance levels: * = p<0.1, ** = p< 0.05, *** = p<0.01. Robust standard errors in parentheses.

The column labeled Lin Reg (3) presents the estimations from the linear regression (OLS) for the dependent variable ‘share of sales of new products’. The positive coefficient for ‘open-source innovation’ is only nearly significant. Instead, ‘R&D investment’ (p=0.000) and ‘mid-tech sector affiliation’ (p=0.002) have a positive and highly significant impact on the share of sales of newly developed products or services.

The existence of incremental and radical innovations in the firm is a binary variable. Therefore, we conduct the binary logistic regression Log (4), the results of which are presented in the fourth column. The coefficient of ‘in-house exploitation’ (p=0.009) is significantly positive. This implies that companies that focus on closed innovation more often report possessing incremental innovations. In addition, ‘large-sized companies’ (p=0.057) exhibit more incremental innovations than small-sized companies.

Finally, the column labeled Log (5) presents the binary logistic regression on the dependent variable ‘existence of radical innovations’. It is evident that the strategy of ‘open-source innovation’ (p=0.029) is the only strategy that has a significantly positive effect on radical innovation. This result is robust and does not change when size and sector dummies are introduced. Thus, the more the company displays the pursuit of open-source innovation, the higher is its probability of possessing radical (breakthrough) innovations.

3.5 Discussion and conclusion

In the twentieth century, the global availability of knowledge has challenged the primacy of closed innovation. The open innovation model suggests that companies should be aware of external ideas, technologies and opportunities for commercialization. The literature on open innovation distinguishes between two core R&D processes. Whereas the outside-in process focuses on the adoption of ideas and technologies from different potential contributors outside of the firm, the inside-out process involves outward-oriented technology transfer intended to improve innovation performance and increase profits. In particular, inside-out open innovation aims to bring ideas, technologies and innovations to markets by participating in segments outside the firms’ boundaries.

Analyzing a cross-sectional data set of 141 stock-listed enterprises from Germany, Austria and Switzerland, we provide empirical evidence of the relationship between the openness of the inside-out process within the R&D management context and the innovation performance of the firms in question. We have analyzed different R&D management strategies and thereby focused on how companies commercialize and distribute their products and services. In our analysis, we distinguished between closed and open innovation strategies. Whereas closed innovation is related to in-house exploitation and distribution, inside-out open innovation includes licensing, open-source innovation, participation in other companies and divestment.

First, we evaluated the influence of distinct R&D strategies on the product and process innovation performance. Our results reveal that an intensive participation strategy will yield better process innovation performance. Therefore, external participation, which includes alliances and joint ventures with partners and competitors, can foster new or extensively improved production methods and techniques. No significant effects emerge if the company strategy is more focused on the licensing and divesting. Therefore, it appears difficult for companies to exploit existing know-how through licensing and remain innovative in terms of its production processes.

With regard to product innovation, another important measure of innovation performance, our analysis reveals that none of the open innovation strategies examined has a significantly positive influence. The explanatory variables for high product innovation performance are the focus on in-house exploitation and the high-tech industry affiliation. This result indicates that companies that employ closed innovation are more likely to exhibit better product innovation performance. Closed innovation appears to create continuous product improvement. In addition, companies in the high-tech sector display more product innovations than do companies in the low-tech sector. Increased product complexity, a dearth of license holders and greater technological uncertainty are reasons why companies in this sector strengthen their product innovation performance.

The share of sales of newly developed products is a further innovation performance measure used in this study. Again, sector affiliation is an explanatory variable, and companies positioned in the mid-tech sector show significantly better innovation performance than do companies in the low-tech sector. Open-source innovation has only a nearly significant positive effect on the percentage of sales made up of new products. This is due to the fact that the control variables R&D investments and mid-tech sector affiliation have highly significant influences in the model.

We have also evaluated the influence of distinct R&D strategies on the degree of innovativeness of products and services. Our findings indicate that closed innovation companies, which focus on in-house distribution channels, show a significant higher probability of producing incremental innovations. This effect can be explained as a function of this type of closed strategy, which involves the continuous improvement of internal products and services.

Companies that emphasize open-source innovation are more likely to develop radical innovations. Hence, open-source innovation involves an orientation toward increasing diversity which allows firms to enhance the radicalness of their products and services. In our study, we did not define open-source projects as limited to the software industry. Rather, we characterized them as displaying similar characteristics, such as a low level of restrictions on the collaboration process, reliance on information and communication technologies and the existence of community-oriented project teams. The general purpose of open-source innovation is to share a certain amount of knowledge, most often supported by interactive web applications, and thereby to attain knowledge in exchange from potential contributors. For companies, this strategy represents an informal method of knowledge-sharing that does not create an obligation for either the initiator or the contributor. R&D management should emphasize radical innovations because they are based on entirely new benefits for customers and therefore make new market segments accessible.

Increasingly knowledgeable stakeholders are an important reason for R&D managers to begin open innovation projects that will improve the radicalness of their products and services. Open-source innovation, for instance in the form of crowdsourced development, is a strategy that a firm can use to explore ideas and knowledge related to products and processes from a large group of contributors. During open-source projects, R&D departments can consider financial incentives and other kinds of rewards to participating members.

Our findings can help R&D managers to better understand the impact of distinct open innovation strategies on companies’ innovation performance. However, the question of whether inside-out open innovation strategies support innovation performance needs to be further examined because the study presented here has some limitations. Our cross-sectional approach could be replaced with a longitudinal design that emphasizes the time-lagged element of firms' innovation systems. Moreover, our data are based on the perceptions and experiences of R&D managers, which may vary across industries, companies, functions and types of work experience. Future research might also extend the focus and concept of this study and explore additional closed and open innovation strategies. Finally, future research should be conducted to analyze how open-source innovation can best be operationalized to enhance the innovation performance of firms.

CHAPTER 4

Key drivers for enhancing innovation performance of innovation networks

4.1 Introduction

Innovation is considered a key driver of business success and economic growth. To remain competitive, firms need to consider new innovation strategies that go beyond traditional mindsets. The establishment of innovation networks represents an adequate strategy to increase innovation potential. In this study, an innovation network is defined as a series of R&D cooperation activities between a firm and its stakeholders or partners (Freeman, 1991; Harisson et al., 2001). The innovation network strategy refers to opening innovation management both internally and externally to profit from the extensive knowledge and creativity of employees, customers, suppliers and competitors. In the past decade, the importance of innovation networks and open innovation has increased due to globalization, increased labor divisions and the rise of new networking technologies (Dahlander & Gann, 2010).

This research paper distinguishes between firms' internal and external innovation network perspective and focuses on the impact of network activities on innovation performance. The internal perspective encompasses firms' corporate culture and its internal openness to access the collective intelligence of the entire workforce. Openness is a characteristic of innovation networks, and we define the existence of cooperation and the cooperation intensity as determinants of openness. Firms increasingly emphasize internal knowledge sharing, which also enables organizational learning across different units. Cross-functional teams lead to internal innovation networks and enable internal knowledge sharing and accumulation. A cross-functional team is defined as a social system or network of three or more employees from different functional units that is embedded in an organization and whose members collaborate on a common task (Hoegl & Gemuenden, 2001). Several studies find a positive relationship between cross-functional teams and innovation outputs (Cooper & Kleinschmidt, 1995; Gupta & Wilemon, 1996; Love & Roper, 2009). However, the existing empirical evidence is conflicting, as other studies also report a negative relationship between the use of cross-functional method and innovation (Ancona & Caldwell, 1992; Hoegl & Gemuenden, 2001; Mitchell & Nicholas, 2006). Therefore, sharp lines have been drawn between pessimists who worry about coordination problems resulting from diversity and optimists who emphasize the learning benefits of cross-functional team environments. An important drawback of increased diversity is that it can involve higher transaction costs in networks (Reagans & Zuckerman, 2001). The question that remains is whether the benefits of such innovation teams can outweigh the difficulties and additional costs that they provide.

The external perspective focuses on firms' external network management, which aims to access outside knowledge. The emphasis on innovation networks with the outside world has consequently led to an increasing utilization of web-based technologies to collaborate with a large number of contributors, such as customers or lead users. Currently, web-based technologies support businesses in product development, market research, competitive intelligence gathering and revenue generation (Murugesan, 2007). As value creation through web communities and distributed co-creation moves into the mainstream (McKinsey, 2011), this raises serious questions for R&D managers about the return of investment of these collaboration technologies.

In 2001, however, after the bursting of the dot-com bubble, many observers concluded that the financial valuation of the web and its technologies were overhyped. Nonetheless, many successful companies and technologies survived and entered the following, even more powerful era of *Web 2.0*. This term represents the transition from previously statically delivered content to participation-based Internet communities that allow the utilization of collective wisdom (Adebanjo & Michaelides, 2010). Amazon, eBay, Yahoo or Google are examples of companies that have successfully embraced the power of the web to harness collective intelligence (O'Reilly, 2005). According to McKinsey's (2010) global survey, 65 percent of the executives surveyed in 2010 report that their companies plan to increase investments in Web 2.0 technologies over the next three years.[15] Social networking tools are the most common technologies in use, followed by blogs (McKinsey, 2010). Further studies on Web 2.0 technologies emphasize resulting strategic advantages (McAfee, 2006) and the positive impact on knowledge management, as it places collective intelligence at its core (Shimazu & Koike, 2007; Kirchner et al., 2009).

The present study aims to analyze the impact of internal openness resulting from cross-functional employee collaboration as well as external openness resulting from web-based applications, which allow collaborating with a broad set of external contributors. Using data from 141 stock-listed enterprises from Germany, Switzerland and Austria, we investigate whether the openness of internal and external innovation networks enables increases in the innovation performance of firms.

The paper proceeds as follows: Section 2 discusses the theoretical development and hypotheses. Section 3 includes methodology, data and model specifications. Section 4 presents the empirical results of the study, and the final section discusses and summarizes the research results.

[15] In the year 2007, 47 percent of the executives stated that they were increasing their investments in Web 2.0. The percentage share of executives who were unsure whether to invest in Web 2.0 technologies, dropped from 28 percent in 2007 to 10 percent in 2010 (McKinsey, 2010).

4.2 Theoretical background and previous research

The first section deals with the theoretical background of the research study. We then analyze two distinct forms of innovation networks: internal and external innovation networks. Whereas internal networks are established by participating employees from cross-functional departments, external networks rely on the participation of external stakeholders such as customers and users. The final section presents our research hypotheses.

4.2.1 Theoretical background

We consider *network theory* to be important for understanding communication patterns and the resulting effects of innovation networks. Network theory is an extension of the classical value chain perspective, in which relationships between firms and stakeholders are described bilaterally as exchange relations. In innovation networks, firms collaborate with a lot of participators and jointly create values in so-called *value networks* (Vanhaverbeke et al., 2007). Network theory also builds on work by Porter (1985, 1990), who points out the importance of supplier integration to provide less expensive and more flexible access to resources and inputs. Therefore, the vertical integration of suppliers is regarded as a barrier-raising investment that generates competitive advantages over existing and new rivals (Caves & Porter, 1977; Porter, 1980). Similarly, the literature on diversification and integration emphasizes the advantages of acquiring and integrating knowledge and technologies (e.g., Chandler, 1977, 1990). The general idea of network theory is that it can be beneficial for organizations to engage with different types of partners and stakeholders to acquire ideas and resources rather than innovate in isolation. Innovation limited to an internally designated place can even send a negative signal to employees that only a small fraction of the organization is meant to be inventive (Chesbrough, 2003a; Dahlander & Gann, 2010). Network knowledge transfer provides opportunities for mutual learning and stimulates new knowledge creation between employees or stakeholders. If network knowledge is acquired successfully, *knowledge diversity* and *creativity* increase, which generates new innovation opportunities due to combinations and linkages with existing knowledge (Katz & Shapiro, 1985; Cohen & Levinthal, 1990; Rowley, 1997; Nieto & Santamaria, 2007). Though, the process of implementing internal and external networks entails a significant organizational change. For R&D managers, it is important to know that the so-called *not invented here* (NIH) syndrome can hinder successful implementation of external innovation networks due to the employees' attitude to deny ideas and knowledge from potential network partners (Katz & Allen, 1982; Lichtenthaler & Ernst, 2006; Herzog, 2008). In particular, employees with long organizational experience are likely to exhibit NIH syndrome, as it threatens comfortable or predictable work practices and behavioral patterns (Harada, 2003).

Furthermore, *the resource-based theory* of the firm and the *theory of absorptive capacity* are important perspectives to deepen our understanding of conceptualization and analysis. Whereas the first perspective has developed an understanding of how a firm's resources and capabilities are related to overall organizational performance (Penrose, 1959; Wernerfelt, 1984; Huff et al., 2006), the theory of absorptive capacity focuses on recognizing and utilizing external knowledge within a firm (Cohen & Levinthal, 1990). A firm's absorptive capacity strongly depends on the diversity of knowledge in the firm and enables learning and innovation through new combinations (Ostergaard et al., 2011). According to the resource-based theory, we define innovations as new combinations of existing or new resources and capabilities.[16] Thereby, resources can be tangible (e.g., equipment, staff) or intangible (e.g., manufacturing know-how, experiences of individual employees). Capabilities refer to the ability to deploy resources routinely, whereas *dynamic capability* is the firm's ability to integrate, learn and reconfigure resources (Wu, 2006; Lee & Slater, 2007). The latter is essentially strategic in nature and provides the firm a foundation on which to achieve a competitive advantage. Therefore, dynamic capabilities are of crucial importance in innovation networks as they shape the firm's path of development (Zahra & George, 2002).

[16] Capabilities have also been referred to as (core) competencies or core competencies (Grant, 1991; Tarafdar & Gordon, 2007).

Aside from these fundamental requirements for successful innovation network management, other network characteristics account for innovation network performance. Van der Valk et al. (2010) conclude that a lack of cohesion and centralism represent important weaknesses of innovation networks. They find a non-linear relationship between network cohesion and network performance, as limited cohesion does not enable the accumulation of social capital and high cohesion reduces the variety of knowledge. Networks with a higher degree of centrality often operate more efficiently, and their participants have a clearer sense of leadership roles. In addition, Bohlmann et al. (2010) detect heterogeneity as an important driver of innovation network performance. Opinion leaders play a vital role in innovation networks because members can only conduct interpersonal communications with a very small fraction of other members within the whole network. Similarly, von Hippel (1986, 2009) emphasizes the role of lead users in customer relationship networks. The so-called *sticky knowledge* of lead users about products and processes qualifies them as inventors and co-developers in innovation projects.

However, the increasing number of contributors in innovation projects also leads to the *tournament theory* (Lazear & Rosen, 1981; Fullerton & McAfee, 1999). Unlike in closed innovation settings, members in innovation networks with multiple participators have to fear that their effort might not be rewarded. This fact can lead to an underinvestment in effort, and thus to diminished innovation performance. Companies need to be conscious of this effect and should design the award structure correspondingly. Whereas a winner-takes-all award structure offers stronger incentives for contributors with high endowed expertise, a multiple-price award structure is more attractive for contributors with low endowed expertise (Terwiesch & Xu, 2008). The number of potential contributors in an innovation network should carefully be considered because an underinvestment in effort can occur due to the reduced probability of winning. The literature considers free entry to be suboptimal for R&D tournaments and suggests limiting the number of contributors (Taylor, 1995; Che & Gale, 2003; Kvasov, 2007). Terwiesch and Xu (2008) demonstrate the importance of increased diversity resulting from a larger group of contributors, which can outweigh the possible negative underinvestment effect. To further increase the contributors' effort in innovation networks, they suggest taking the skillful contributors from the first round and allowing them to contribute in a limited second-round contest. This implies no entry barriers in the beginning of innovation projects and an evaluation procedure to select the most promising contributions.

Based on this theoretical background, the following two sections discuss the two distinct forms of innovation networks: (1) internal innovation networks and (2) external innovation networks.

4.2.2 Managing internal innovation networks: Cross-functional cooperation

Internally, companies can enhance the participation of employees in R&D projects by establishing a culture of cross-functional cooperation. The literature on innovation management, lean production and Total Quality Management consider cross-functional teamwork to be a crucial success factor for innovation (Mohrman et al., 1995; Finegold & Wagner, 1998; Cooper, 2001). Also in practice, cross-functional cooperation has become an established strategy to enhance organizational performance (Rosenberg, 1982; Somech, 2006; Kim et al., 2010; Gemser & Leenders, 2011). This form of cooperation leads to an organizational environment and culture in which employees from different disciplines and functions work together toward goals of common interest.

In an experiment, Page (2007) demonstrates that a randomly composed group of average people with heterogeneous backgrounds achieves more innovative solutions than a homogenous academic group of highly skilled Harvard experts. Therefore, his *diversity trumps ability theorem* assumes that under certain plausible conditions, diversity is of greater importance than expertise. Not only does the innovation literature highlight the potential benefits of diversity, so does the literature on psychology and organizational behavior (e.g., Marwell & Schmitt, 1972; Lichtenstein, 1986; Cohen et al., 2010). In this literature, the key concept is diversity, which affects the quality of cooperation. Whereas diversity refers to a condition or status (such as function, experience or gender), cooperation activities in the innovation management literature refer to organizational processes aiming to improve information and knowledge flows. However, some of this literature also predicts a negative effect of increased team diversity on the team outcome. Referring to the social categorization perspective, negative cognitive, emotional and behavioral biases can result when employees perceive other group members to be different from themselves (Gemser & Leenders, 2011).

In the innovation management literature, several studies have examined the relationship between cross-functional internal cooperation and the effectiveness of individual projects (Hayes et al., 1988; Clark & Fujimoto, 1991; Campion et al., 1993; Love & Roper, 2009). However, existing empirical evidence regarding the impact of teamwork on the success of innovative projects is conflicting. Past studies report a significant positive impact when team members assess innovation performance but report no significant impact when team-external superior managers assess the innovation performance of an innovation team (Cooper & Kleinschmidt, 1995; Cohen et al., 1996; Hoegl & Gemuenden, 2001). In addition, existing studies suggest a predominantly positive relationship between cross-functional collaboration and personal trust (Moenaert et al., 1994) as well as the higher integration of employees in core development processes (Liker et al., 1999). In the high-tech sector, cross-functionality is already of great importance for firms pursuing an R&D-intensive strategy (Keller, 2001; Moses & Ahlström, 2008). Nonetheless, employees as one important group of potential innovators have so far been quite neglected in less R&D-intense companies (Reinhardt et al., 2010).

Research has paid very little attention gathering empirical evidence about the innovation performance of cross-functional teams in R&D projects across sectors. To close this research gap, this research paper empirically analyzes the impact of cross-functional teams on firms' innovation performance across sectors. Network theory suggests a positive influence of the integration of additional network members on knowledge diversity, creativity and thus on new innovation opportunities. Accordingly, our first hypothesis assumes a positive relationship between internal cross-functional team cooperation and innovation performance.

H$_1$: Cross-functional team cooperation in internal innovation networks is positively related to innovation performance.

4.2.3 Managing external innovation networks: The role of web-based technologies

Von Hippel (2005, 2009) introduced an extreme form of a cooperation model, which can be described as *democratizing innovation*. This new innovation model is a radical departure from past practices of centralized innovation management in which the innovative genii are sought in internal organizational units, project management designs and incentive systems (Huff et al., 2006). A general assumption is that the "users' ability to innovate is improving radically and rapidly as a result of the steadily improving quality of computer software and hardware, improved access to easy-to-use tools and components for innovation, and access to a steadily richer innovation commons" (von Hippel, 2005, p. 13). Furthermore, it is difficult for companies to allocate high-cost resources for innovation support to the right participants because the firms have limited information about the participants in advance (effort intensions, quality of contributions). The solution is to democratize the opportunity to create and innovate, which gives rise to crowdsourcing as the new form of customer integration (Howe, 2008). To interact with this increasing amount of contributors, developments in web and social networking technology are of critical importance for companies in all sectors (Enkel et al., 2009).

The development of web technology in the last 10 years has led to a new type of web services. Whereas previous Internet technologies (*Web 1.0* or *static web*) were characterized by the one-directional spreading of information from one central information sender to many different receivers, present Internet technologies (*Web 2.0* or *social web*) are characterized by communication processes from many senders to many receivers (Hüsig & Kohn, 2009, 2011). However, there still exists disagreement about the current definition of Web 2.0 and its future development (O'Reilly & Battelle, 2009). O'Reilly (2005) coined the term and describes it as the transformative force characterized by harnessing collective intelligence, openness and network effects. He states that “one of the key lessons of the Web 2.0 era is this: users add value” (O’Reilly, 2005, p. 3). Web 2.0 technologies, which rely on user collaboration, include web forums, wikis, blogs, RSS and social networking tools[17] (OECD, 2007). Accordingly, the present study regards social networking technology as a subset of Web 2.0 technologies. If companies attempt to collate information from multiple sources, their business model requires an ‘architecture of participation’. R&D departments with a closed innovation strategy and no external innovation networks can be regarded as isolated information silos. The introduction of Web 2.0 technologies is a strategy of creating and distributing information and web content, thus overcoming such isolated information silos (Adebanjo & Michaelides, 2010).

OECD (2010) presents 3-4 percent growth in the global industry of information and communication technology for 2010 and continued growth in 2011. The Forrester Research group forecasts that firms spending on Web 2.0 technologies will grow strongly and reach 4.6 billion USD per year by 2013 globally. By 2010, already 65 percent of analyzed companies in North America, Europe and Asia Pacific have adopted at least one Web 2.0 technology, but most companies are focusing on a subset of tools – wikis, discussion forums and blogs (Forrester Research, 2008, 2010). The importance of these technologies is further supported by the results of McKinsey’s (2010) global survey, which collects data from nearly 1,700 executives from around the world and across a range of industries and functional areas. According to this study, the adoption rates between 2007 and 2010 increased from 50 to 65 percent for internal uses and from 45 to 63 percent for customer uses. The only specific innovation performance measure evaluated in the study is that 28 percent of the executives report an increasing number of innovations resulting from using Web 2.0 technologies internally. A total of 24 percent report an increasing number of innovations resulting from using the technologies with customers (McKinsey, 2010). However, the study does not further analyze innovation performance implications resulting from the

[17] Wikis are web pages where users can add and change content. Blogs are web pages that contain personal entries and comments. RSS (Really Simple Syndication) enables websites to inform subscribers of new content. Social networking tools allow access to virtual communities that are structured to delineate and build on members’ relationships (Adebanjo & Michaelides, 2010)

adoption of Web 2.0 technologies. Other studies discuss limitations of actual social networks and state that network contents are often declared as boring and that members only collect information – most often about other network members – out of their own curiosity (Breslin & Decker, 2007; Kirchner et al., 2009). A recent empirical study of Corrocher (2011) finds that the compatibility of Web 2.0 technologies with users' needs and behaviors plays an important role in the intensity of usage.

However, only very few empirical evidence exists on the adoption and role of Web 2.0 technologies in firms' external innovation networks. To close this research gap, our second research hypothesis aims to empirically analyze the impact of Web 2.0 and social networking technologies on firms' innovation performance. As previously mentioned, network theory suggests a positive influence of the amount of contributors on knowledge diversity and creativity. Web technologies provide comfortable tools for data collection, can lead to improved decisions in innovation management, and thus enhance the effectiveness of firms' innovation systems (Hüsig & Kohn, 2009, 2011). Accordingly, our second hypothesis assumes a positive relationship between the use of Web 2.0 and social networking technology and firms' innovation performance.

H_2: The use of Web 2.0 and social networking technologies for managing external innovation networks is positively related to innovation performance.

4.3 Research methodology

4.3.1 Sample and data collection

To understand how internal and external innovation networks are managed and supported, we collected data by means of a web-based questionnaire. The framework of the questionnaire is based on the open innovation literature (Chesbrough, 2003a, 2006b, 2006c; Enkel et al., 2009) by analyzing the outside-in, inside-out and corporate culture dimensions of firms' R&D management. We have chosen R&D managers as subjects of the study and adopt stock-listed enterprises in German-speaking countries as the research sample. In particular, German companies listed on CDAX Performance Index[18], Swiss companies listed on the Swiss Performance Index SPI[19] and Austrian companies listed on the Austrian stock index WBI[20] were contacted. These indices are comparable, as they represent composite indices including both general and prime standard. A pretest with follow-up interviews was conducted in March 2009, in which banks and insurance companies were unable to provide the necessary data for the innovation measures. Although adjustments have been made, banks and insurance companies were ultimately excluded from the sample. At the end, 783 stock-listed enterprises were contacted: 498 in Germany, 203 in Switzerland and 82 in Austria. Our first step was to contact the R&D managers by email and provide them an outline with the purposes of the study and authorized login information for the online survey. Respondents who had not responded within two weeks were re-contacted to enhance the response rate. During the survey period from April to June of 2009, a total of 141 companies provided complete responses, yielding a valid response rate of 18 percent. Most of the respondents held positions such as head of the R&D department, chief technology officer, chief executive officer and R&D manager.

[18] cf. CDAX Composite German Stock Index, Frankfurt Stock Exchange.

[19] cf. SPI Swiss Performance Index, SIX Swiss Exchange.

[20] cf. WBI Vienna Stock Index, Vienna Stock Exchange WBAG.

4.3.2 Measures

The terminology used in our study is based on commonly agreed definitions provided by the Oslo Manual (OECD/Eurostat, 2005) and includes questions relevant for both the manufacturing and service sectors. Accordingly, we define new products and services as either market novelties or new to the firm but already existing on the market. These are goods and services that differ significantly in their characteristics or intended uses from previous products. Product innovations are defined as the invention and commercialization of entirely new products or services. They do not include products with only minor variations, such as customer specification and design adjustments (Roberts, 1988, 2007; OECD/Eurostat, 2005). Another classification of innovation considered in this paper is the distinction between two extreme types of innovation – incremental and radical innovation. Whereas incremental innovations build on existing competences in companies and are related to minor technological changes, radical innovations go along with fundamental technological changes and can also be described as breakthrough innovations. The literature suggests that an increased diversity and creativity of innovation networks enables the enhancement of radical innovation performance (Tushman & Anderson, 1986; Green et al., 1995; Linton, 2009). As the focus of our first hypothesis is on the cross-functional method in R&D management, we measure the existence of such teams in R&D projects.

To analyze the companies' innovation performance, three different measures were distinguished: the existence of radical innovations, the amount of product innovations and the percentage share of sales made up of newly developed products or services. The first is a binary variable that indicates whether the company introduced any radical innovations during the reference period. The second variable indicates the extent of product innovations and is measured similarly to previous studies (Jung & Dönnges, 2007; Rammer & Bethmann, 2009; Arvanitis et al., 2010) with an 11-point level scale (none, 1, 2, 3, 4, 5-10, 11-20, 21-30. 31-40, 41-50, more than 50). Using the percentage share of sales made up of newly developed products or services as the third metrical variable (ranging from 0 to 1), we obtain a fuller picture of the innovation success.

To test our hypotheses, the first key independent variable in our study is the existence of cross-functional employee teams. The second key independent variable is the use of Web 2.0 and social media technologies for managing external innovation networks. We consider the traditional form of non web-based networking as well as the endurance of innovation networks as control variables. We define network endurance in terms of an active cooperation period and five-year cooperation as the minimum for an enduring network. As the innovation literature highlights the importance of a fault-tolerant corporate culture (Ryan, 1996; Tushman & O'Reilly, 1997; Herzog, 2008), this control variable is also included in the analysis. Tolerance of mistakes is an essential element in the development of an innovative organizational culture. The way in which mistakes are handled will determine whether employees feel free to act creatively and innovatively (Martins & Terblanche, 2003).

Industry characteristics may also have a significant influence on innovation performance. To avoid biases resulting from this fact, dummies for firm size and sector affiliation have been included. Whereas firm size is measured in terms of the number of full-time employees (small: less than 50, medium: 51-500, large: more than 500), sectors were defined according to the Industry Classification Benchmark[21] and grouped regarding their reliance on technology (low-tech, medium-tech, high-tech). Due to the fact that innovation performance can strongly depend on a firm's R&D investments (Lichtenberg & Siegel, 1991; Cohen & Klepper, 1996; Kafouros et al., 2008), this control variable is also taken into account. R&D investments include R&D costs and are measured as a percentage of a firm's total sales, leading to a control variable range from 0 to 1. The reference period of the evaluated innovation measures is from 2004 to 2008.

[21] The detailed ICB sector classification is provided on the website http://www.icbenchmark.com.

4.4 Analysis and results

As a first step, we provide the descriptive statistics of the variables used in this study. The first column of Table 6 presents the means and standard deviations of the variables, and the remaining columns display the correlation coefficients and their respective significance levels. The more robust Spearman rank correlation coefficients are used to identify the strength of each correlation and whether the correlation is positive or negative.

Table 6: Descriptive statistics of innovation networks

		Mean (St.dev.)	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1.	**Product innovations**	5.300 (2.755)	1										
2.	**Sales of new products**	0.270 (0.258)	.330 ***	1									
3.	**Radical innovations**	0.350 (0.478)	.085	.104	1								
4.	**Web 2.0**	1.910 (1.302)	.160 *	.256 **	.025	1							
5.	**Networking**	2.820 (1.129)	-.012	.105	-.054	.553 ***	1						
6.	**Network endurance**	2.970 (0.892)	.039	.082	.103	.136	.212 **	1					
7.	**Fault tolerance**	2.990 (0.851)	.022	-.005	.073	.072	.098	.024	1				
8.	**Cross-funct. teams**	3.370 (0.785)	-.021	.038	.032	.075	.031	.125	.342 ***	1			
9.	**R&D investment**	0.085 (0.144)	.075	.505 ***	.048	.277 ***	.198 **	.036	-.068	.014	1		
10.	**Size**	2.620 (0.651)	.245 ***	-.148 *	-.047	-.128	-.020	-.029	-.032	.133	-.377 ***	1	
11.	**Sector**	1.720 (0.794)	.230 ***	.219 **	-.051	-.048	-.067	-.096	-.074	.072	.199 **	.036	1

Significance levels: * = p<0.1, ** = p< 0.05, *** = p<0.01.

In our study, 83 percent of the companies reported the use of cross-functional teams in R&D and 37 percent use Web 2.0 for external innovation network management on a regular basis. For an outlook, we asked the companies whether they aim to increase external innovation network activities in the next three years. A total of 70 percent stated to increase activities due to restricted internal capacities and the rising complexity of technologies and markets.

Table 7 presents the regression analysis results on the three innovation performance measures. Different types of regressions are used because the measures for innovation performance have different scales. To analyze the impact on the amount of product innovations, an ordered Probit regression is presented in the first column labeled Probit (1). The amount of product innovations is significantly and positively influenced by the companies' use of 'Web 2.0 and social networking technologies' (p=0.082) and their 'network endurance' (p=0.067) and 'fault tolerance' (p=0.043). Moreover, companies in the 'mid-tech' (p=0.003) and 'high-tech' (p=0.018) sector exhibit significantly higher product innovation performance.

Table 7: Analytical statistics of innovation networks

	Probit (1)	**Lin Reg (2)**	**Log (3)**
Dependent variable	**Product innovations**	**Share of sales of new products**	**Radical innovations**
Web 2.0	**0.184***	0.031	0.025
	(0.106)	(0.021)	(0.055)
Networking	-0.082	-0.010	-0.054
	(0.543)	(0.027)	(0.065)
Network endurance	**0.258***	-0.012	**0.132****
	(0.141)	(0.025)	(0.054)
Fault tolerance	**0.264****	0.050	-0.063
	(0.130)	(0.034)	(0.070)
Cross-functional teams	-0.054	0.034	0.031
	(0.147)	(0.029)	(0.067)
R&D investment	-0.822	**1.319*****	0.409
	(1.266)	(0.475)	(0.670)
Dummy medium size	-0.473	0.144	-0.075
	(0.480)	(0.113)	(0.246)
Dummy large size	-0.034	0.009	-0.118
	(0.460)	(0.089)	(0.232)
Dummy mid-tech sector	**0.830*****	**0.256*****	0.002
	(0.277)	(0.058)	(0.125)
Dummy high-tech sector	**0.747****	**0.141***	-0.077
	(0.316)	(0.076)	(0.141)
Number of observations	88	83	89
Pseudo R^2	0.059		
R^2		0.421	0.081

Significance levels: * = p<0.1, ** = p< 0.05, *** = p<0.01. Robust standard errors in parentheses.

The influence on our metrical innovation performance measure – the ratio of new product sales to total sales – is analyzed using a linear regression (OLS), presented in the second column labeled Lin Reg (2). Evidently, the control variable 'R&D investment' (p=0.007) has a positive and highly significant influence, whereas the use of Web 2.0 only has a nearly significant effect. Furthermore, affiliation with the 'mid-tech' (p=0.000) and 'high-tech' (p=0.067) sector has a positive and significant influence, which means that companies in these sectors display a higher share of sales of newly developed products compared to companies in the low-tech sector.

As our final measure – the existence of radical innovations in the reference period – is a binary variable, a binary logistic regression analysis is depicted in the third column labeled Log (3). As can be seen from Table 7, 'network endurance' exhibits the only significantly positive coefficient (p=0.017) in this regression, indicating the importance of long-term (longer than five years) innovation networks.

4.5 Discussion and conclusion

4.5.1 Discussion

Regarding the Innovation Union Scoreboard (IUS, 2011)[22] for the year 2010, Germany, Switzerland and Austria do not show any major differences in their national innovation systems. Switzerland is the overall innovation leader and displays relative strengths in open, excellent and attractive research systems, intellectual assets, innovators and outputs. Germany ranks fifth, and Austria ranks eighth, with both being above the average EU27 performance level. Innovation performance measures in the IUS ranking are categorized into eight dimensions: human resources, research systems, finance and support, firm investments, linkages and entrepreneurship, intellectual assets, innovators and economic effects (IUS, 2011). However, our research does not focus on the national perspective, but on the firm-level perspective. The present analysis covers two dimensions: the corporate culture side (internal innovation networks, human resources) and the technological side of innovation networks (external innovation networks, Web 2.0 and social networking technologies).

According to the innovation literature, an important determinant of a successful corporate innovation culture is the existence of cross-functional teams in innovation management (Cooper & Kleinschmidt, 1995; Gupta & Wilemon, 1996; Love & Roper, 2009). Because organizations are increasingly using cross-functional

[22] The formerly well-established European Innovation Scoreboard has been reworked and renamed the Innovation Union Scoreboard (IUS) in October 2010.

teams, and due to the fact that prior empirical evidence on the impact of cross-functional teams is conflicting, our first hypothesis aims to analyze the impact of these teams on firms' innovation performance. Interestingly, the regression results do not support our first hypothesis, as no significant effect on all three innovation performance measures is found. This finding casts doubt on the literature claiming that successful product development strongly depends on the existence of cross-functional teams (e.g., White & Schneider, 2004). Aside from emotional and behavioral biases, the cognitive distance between employees and team members can hinder performance. Empirical evidence indicates an inverted-U shaped relationship between cognitive distance and innovation performance (Nooteboom, 1992; Wuyts et al., 2005; Nooteboom et al., 2007). As cognitive distance increases in the beginning, it has a positive effect on learning by interaction due to bridging and connecting diverse knowledge. Reaching a certain level, however, cognitive distance can lead to less mutual understanding and prevent organizational learning by interaction. Nevertheless, we found a fault-tolerant innovation culture as an important driver in internal innovation networks for product innovation performance.

Regarding firms' external innovation networks, firms increasingly rely on collaboration with external stakeholders. Inauen and Schenker-Wicki (in press) examine the influence of particular stakeholder subgroups in innovation networks and find a positive impact of openness toward customers and universities as well as a negative impact of cross-industry collaboration. To establish and maintain innovation networks, the use of Web 2.0 and social networking technologies is rapidly growing. Nonetheless, to date, very few studies have examined the influence of Web 2.0 adoption in the R&D process on the companies' innovation performance. Our regression results support the second hypothesis that the use of Web 2.0 is positively related to innovation performance. In particular, these technologies have a significantly positive effect on product innovation performance. These results point to the important role of Web 2.0 and social networking technologies in open innovation management. Key driver for the existence of radical innovations is the endurance of external innovation networks, which means that only networks older than five years have a substantial positive effect.

4.5.2 Limitations and future research directions

Our results should be carefully interpreted, as the research we conducted has several limitations. Our cross-sectional approach does not emphasize time-lagged system elements and could be replaced with a longitudinal design. Moreover, our data are based on the perceptions and experiences of R&D managers, which may vary across industries, companies, functions and types of work experience. To gain a more detailed picture, the operationalization of future studies could be improved with a more narrowly defined subset of networking practices. This particularly applies to the use of Web 2.0 and social networking technologies, which could be separated into multiple variables. Future research about innovation networks should also include the role of intermediaries, such as providers of media and networking platforms. Another interesting aspect is the development dilemma that companies have to deal with (Murugesan, 2007). When do they have to decide for fast and easy development supported by the new web tools, and when should research and development be well designed and engineered?

4.5.3 Conclusion

In an increasingly global world, it is important to change the mindset of innovation management toward integration of knowledge from many sources. The model of open innovation highlights the benefits of innovation networks, as they allow harnessing the extensive knowledge and creativity of employees, customers and other stakeholders. More diversity supports learning and innovation processes and increases the possibilities for new knowledge combinations in innovation projects. Whereas internal innovation networks go beyond the R&D unit and encourage the collaboration of employees, external innovation networks reach the outside world and establish interactive processes through which knowledge can easily flow.

Analyzing a cross-sectional data set of 141 stock-listed companies from Germany, Switzerland and Austria, we provide empirical evidence about key drivers for successful internal and external innovation networks. Regarding firms' internal innovation networks, we focus on innovation performance effects resulting from cross-functional employee teams in R&D projects. Firms' external network perspective is examined with a focus on the impact of Web 2.0 and social networking technologies. As innovation performance measures, we distinguish between the existence of radical innovations, the amount of product innovations and the percentage share of sales of newly developed products.

Existing empirical studies on the influence of the interaction among a firm's different functional areas show ambiguous results. Our results indicate that already 83 percent of the companies have introduced cross-functional teams in R&D projects on a regular basis. Interestingly, we found no significant effect of an innovation culture that emphasizes cross-functional teamwork on the innovation performance. A positive relationship exists between a company's fault tolerance and product innovation performance. Fault tolerance is of particular importance when companies aim to build on existing products or services. When a firm is aiming toward an increased degree of innovativeness that allows the development of radical innovations, the results show the endurance of external networks as a key driver in this endeavor.

Although several studies show the trend that companies are increasingly investing in collaborative technologies for innovation management, little is known about their influence on innovation performance. The use of knowledge-gathering technologies in innovation networks encourages stakeholder contribution and harnesses their collective intelligence. Our results reveal that companies with higher levels of Web 2.0 and social networking technologies in external network management are more likely to have a higher product innovation performance. Therefore, the knowledge from participators in external innovation networks can be successfully transferred and has a substantial impact. To make the participation for stakeholders more attractive, R&D managers should consider an incentive system. Terwiesch and Xu (2008) suggest an award structure that depends on the distribution of the target contributor expertise. This implies that a winner-takes-all award structure is optimal to attract experts and a multi-prize award structure is better suited for low-expertise innovation projects.

To summarize, R&D managers can use Web 2.0 and social networking technologies to increase innovativeness and thus competitiveness. External networks lasting longer that five years can enhance the development of radical innovations and a fault-tolerant corporate innovation culture can encourage product innovations. Finally, the hypothesis that internal team diversity in R&D projects is trump could not be confirmed.

CHAPTER 5

Final remarks

In global competition, European countries can rely on limited own natural resources and are confronted with high labor costs. In addition, average labor productivity in the European Union is 30 percent lower than in the United States, and the developing countries are catching up fast (Eurostat, 2011). The current financial crisis further weakened the European countries' position. Under these circumstances, innovation is an imperative for firms to increase productivity and gain competitive advantages. The key question is how innovation can be fostered to achieve higher performance. Leveraging internal innovation capacities through bilateral cooperation between companies and institutions has a long tradition going back to the early and mid-20th century. Today, open innovation as a multilateral form of cooperation has become a growing trend across industries, as companies are increasingly searching for new innovation opportunities in their external environment.

The aim of this thesis was to analyze whether companies that emphasize open innovation can positively influence their innovation performance and which open innovation activities contribute the most. The study distinguished between the core processes of open innovation. R&D cooperation with different stakeholders was analyzed by regarding the outside-in process, and additional commercialization channels for internal knowledge were analyzed by examining the inside-out process. The study included firms' internal perspective, which encompasses internal teamwork and the corporate innovation culture. Web 2.0 and social networking technologies were also considered, as their use has steadily increased in recent years.

The results imply that openness of the outside-in process in R&D management is of crucial importance for achieving high direct and indirect innovation output effects. In particular, openness toward customers, suppliers, universities and intra-industry competitors has a significant positive impact on innovation performance. Regarding openness toward cross-sector companies, the analysis reveals a significant negative effect on innovation performance. This finding indicates cognitive distances in cross-industry cooperation, which preclude mutual learning processes in innovation projects. An implication for R&D management is to align the companies' cognitive maps and communication processes in cross-industry settings. As cognitive distance strongly depends on the range of knowledge and capabilities of the employees (Lazaric & Raybaut, 2007), a certain level of internal cognitive variety is necessary. The cognitive variety of employees can increase the compatibility of knowledge in cross-industry projects and fosters more flexible organizational capabilities.

Employees can also hinder the successful adoption of open innovation if they deny ideas and knowledge from the outside world (*not invented here syndrome*). Consequently, R&D management should evaluate whether such a negative attitude toward external knowledge, partners or institutions exists. Boundary-spanning activities (physical or virtual) and network-building initiatives can help to build a more tolerant organizational culture. After a firm has opened its boundaries, sufficient internal absorptive capacity is crucial for recognizing and transferring external knowledge. This absorptive capacity can be enhanced internally by training employees and exchanging or hiring them from the target fields. In particular, R&D managers should focus on feedback and feed-forward loops while training their employees. Feed-forward enables the simulation of possible future decisions and developments (Trott & Hartmann, 2009). Therefore, an R&D department can anticipate disruptions in the stability of its innovation system, such as unforeseen barriers and market developments.

The results of the third chapter reveal that different open innovation activities in the inside-out process have different effects on innovation performance. An intensive participation strategy is positively related to high process innovation performance. Hence, R&D management should favor participation in the form of alliances and joint ventures if they aim to foster new or extensively improved production methods and techniques. Furthermore, open-source innovation significantly supports the radicalness of products and services. Open-source projects allow informal knowledge sharing without obligations and make new market segments accessible by creating new benefits for customers. The focus on licensing and divesting shows no significant positive effect on innovation performance, which indicates difficulties for companies to exploit existing know-how and to remain innovative simultaneously. Regarding closed innovation, companies that favor in-house exploitation are more likely to exhibit a higher incremental product innovation performance. This clearly points to the relevance of developing and maintaining internal innovation capabilities. R&D management should therefore consider open innovation capabilities as a complement for firms' internal innovation and management capabilities.

The fourth chapter shows the impact of a firm's corporate culture on innovation performance. Firms increasingly use cross-functional teams in R&D to access the collective intelligence of the entire workspace. However, the results showed no significant effect of this kind of internal openness on innovation performance. According to our result, R&D management should establish a fault-tolerant innovation culture, as it is positively related to product innovation performance. The value of such a culture results from more innovative ideas and process transformations developed and presented by employees, which can be further stimulated by a rewarding system.

Regarding the impact of Web 2.0 and social networking technologies, the results show a positive relationship between the use of these new technologies for external innovation network management and product innovation performance. For R&D management, these collaboration technologies provide important tools and applications to transfer R&D relevant knowledge in innovation networks. Again, an award structure should be considered to avoid low levels of contributor efforts.

In addition, the results reveal the endurance of external innovation networks as a key driver for the existence of radical innovations. Innovation networks that are older than five years have a substantial positive influence on product innovation performance and on the existence of radical innovations.

To conclude, the most significant implication for managerial practice is that the adoption of the open innovation model can enrich internal innovation capabilities and enhance innovation performance. R&D management can profit from both the exploration of new external knowledge and the exchange of existing internal knowledge. Firms that apply web-based networking technologies can foster and accelerate interactive communication and knowledge sharing with external stakeholders. This leads to an environment in which the R&D management can actively design knowledge flows inward and outward to increase innovation performance.

6. Appendix: Questionnaire

Open innovation in German-language countries

Definitions[23]

Open innovation: Open innovation refers to the use of purposive inflows (outside-in) and outflows (inside-out) of knowledge to accelerate innovation performance.

Innovation cooperation: Innovation cooperation involves active participation of the respective stakeholder in innovation projects. R&D management considers these innovation projects as important and the knowledge is shared verbally, in writing and through information and communication technologies.

New products: Are either market novelties or new products or services to the firm but in existence on the market. They are goods and services that differ significantly in their characteristics or intended uses from previous products.

Product innovation: If the innovation involves **new** or **significantly** improved products or services.

Process innovation: If the innovation involves **new** or **significantly** improved methods, equipment and/or skills in the production process.

Radical innovation: Innovations that go along with fundamental technological changes and can also be described as breakthrough innovations.

Incremental innovation: Innovations that build on existing competences in companies and are related to minor technological changes.

Company information

Country: ....

Number of employees (in full-time equivalents): ....

Number of employees in research and development (R&D) in %: ....

Total sales (except VAT) 2008 in EURO: ....

R&D costs and R&D investments 2008 in % of total sales: ....

Year of the company's establishment: ....

Sector (ICB classification): ....

Distribution policy (multiple answers possible):
- ☐ Business-to-consumer
- ☐ Business-to-business

[23] To provide **clear definitions**, we added **mouse-over popup information** (onmouseover script) in the online version, which was visible through a different color of the respective text passage. The password protected online version was available at the internet domain name **http://www.open-innovations.ch**. We programmed the web page using HTML, PHP and JavaScript; and created an interlinked MySQL database.

1. How is R&D organized in your company?
   - O No R&D activities
   - O Organization via single projects
   - O Own R&D department
   - O Several own R&D departments
   - O One department for research and one for development

2a. How often does your firm conduct R&D activities?
   - O Never
   - O Rarely
   - O Sometimes
   - O Often
   - O Very often

2b. Number of active R&D projects? ....

2c. How many percent of all R&D projects within the last five years were aborted or not introduced to market? ....%

2d. Has your company ever transferred non-completed R&D projects to third parties? ☐ Yes ☐ No

3a. How many product and process innovations did your firm introduce within the last five years?

Number of product innovations: ....

Number of process innovations: ....

3b. Did your firm introduce incremental and/or radical innovations within the last five years?

☐ Incremental innovations ☐ Radical innovations

4a. Please indicate the percentage share of sales made up of newly developed products introduced during the last five years? ....%

4b. Please indicate the number of newly introduced products within the last five years? ....

5a. Does your company collect innovation performance measures? ☐ Yes ☐ No

5b. If yes, please state the three most important measures: ....

....

6. Which of the following instruments uses your company in innovation management?

☐ Lifecycle analysis ☐ Risk analysis ☐ Portfolio analysis ☐ Benchmarking

☐ Balanced Scorecard ☐ Innovation Scorecard ☐ Scenario- and trend analysis

Outside-in process

7. Please indicate the cooperation intensity with the following partners in R&D projects:

	never	rarely	sometimes	often	very often	unknown
Customers:	O	O	O	O	O	O
Suppliers:	O	O	O	O	O	O
Competitors:	O	O	O	O	O	O
Cross-industry firms:	O	O	O	O	O	O
Consulting firms:	O	O	O	O	O	O
Universities and colleges:	O	O	O	O	O	O

8. R&D projects directed to third parties in % of total R&D costs and investments: .... %

9. R&D projects in cooperation with third parties in % of total R&D costs and investments: .... %

10. Please indicate the intensity of the following activities to acquire technologies and knowledge in R&D projects?

	never	rarely	sometimes	often	very often	unknown
Buy licenses:	O	O	O	O	O	O
Buy patents:	O	O	O	O	O	O
Strategic alliances (incl. joint ventures):	O	O	O	O	O	O
Participation of other companies:	O	O	O	O	O	O
Takeovers:	O	O	O	O	O	O
Open sources solutions:	O	O	O	O	O	O

11. How often does your company make use of the following information sources in R&D projects?

	never	rarely	sometimes	often	very often	unknown
Internet:	O	O	O	O	O	O
Web 2.0:	O	O	O	O	O	O
Networking:	O	O	O	O	O	O
Expert conferences:	O	O	O	O	O	O
Specialist literature:	O	O	O	O	O	O

12a. How many technologies were brought to market in new products by your company within the last five years? ....

12b. How many percent of these technologies originate from external sources? .... %

12c. How many patents have you purchased within the last five years? ....

Inside-out process

13. Please indicate the intensity of the following activities to commercialize internally developed technologies and knowledge:

	never	rarely	sometimes	often	very often	unknown
Sale / Divest:	O	O	O	O	O	O
Licensing and patenting:	O	O	O	O	O	O
Open source cooperation:	O	O	O	O	O	O
Participation in other companies:	O	O	O	O	O	O
In-house exploitation:	O	O	O	O	O	O

14a. How many percent of all internal developed technologies are brought to market through external channels? .... %

14b. How high is the annual volume of sales of these externally commercialized products (in % of total sales)? .... %

14c. Number of submitted patents by your company within the last five years? ....

Coupled process

15. Please answer the following questions concerning cooperation relationships in the network with external R&D partners:

	no	very low	low	high	very high	unknown
a) How high is the organizational trust in the company's own technological competence?	O	O	O	O	O	O
b) How high is the organizational trust towards external R&D partners?	O	O	O	O	O	O
c) How high is your network endurance with external R&D partners (high indicates longer that five years)?	O	O	O	O	O	O
d) How high is the probability that your company increases network cooperation intensity within the next three years?	O	O	O	O	O	O

i) Please state reasons for increase / decrease: ....

....

Innovation strategy and innovation culture

16. Please indicate whether you agree or disagree with the following statements:	strongly disagree	disagree	agree	strongly agree	unknown
a) Your company possesses a clearly formulated innovation strategy.	O	O	O	O	O
b) Your company possesses the ability (competences) to generate innovations itself.	O	O	O	O	O
c) Your company possesses the ability (competences) to acquire innovations.	O	O	O	O	O
d) Your company identifies and assesses the organizational core competences.	O	O	O	O	O
e) Your company focuses on the organizational core competences.	O	O	O	O	O
f) The organizational resistance towards external technologies and knowledge is high.	O	O	O	O	O
g) The organization possesses a fault-tolerant culture.	O	O	O	O	O
h) Cross-functional teams are an organizational standard in R&D projects.	O	O	O	O	O
i) Please indicate the percentage of employees who attended further education in the past year: .... %					

Innovation performance

17. Please indicate whether you agree or disagree with the following statements:	strongly disagree	disagree	agree	strongly agree	unknown
a) Your own R&D department can successfully satisfy all (technological) demands.	O	O	O	O	O
b) Open innovation is of concern for your company.	O	O	O	O	O
c) Your company can successfully hire high-qualified personnel for R&D.	O	O	O	O	O
d) Compared to competitors (if existent), your company exhibits a higher innovation performance.	O	O	O	O	O
e) Your company is satisfied with the innovation performance.	O	O	O	O	O

18. Please indicate your function and contact details: ....

Thank you for your cooperation.

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8. Curriculum Vitae

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EDUCATION

01/2007 – 09/2011	**University of Zurich, Switzerland** PhD studies at the Department of Business Administration Chair of Performance Management
10/2001 – 08/2006	**University of Zurich, Switzerland** Master degree in Management and Economics Diploma thesis: Design and use of performance-management-systems in Switzerland
1995 – 2000	**Cantonal High School, Frauenfeld, Switzerland** Swiss Federal Maturity, Type C (Natural Sciences)

WORKING EXPERIENCE

01/2012 – today	**Biognosys AG, Zurich, Switzerland** Manager Business Development
01/2007 – 11/2011	**Department of Business Administration, University of Zurich, Switzerland** Research and Teaching Assistant at the Chair of Performance Management
2000 – 2001	**High Medical Technologies AG, Lengwil, Switzerland** Accountant