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The Limits of Planning for Open Innovation Success ? Empirical Evidence from Life Science SMEs

AndreasAndreas Braun
BSP Business School Berlin Potsdam
Business Administration
andreas.braun@businessschool-berlin-potsdam.de

Christoph Ihl
RWTH Aachen University
Technology and Innovation Management Group
ihl@tim.rwth-aachen.de

Katharina Hoelzle
Universität Potsdam
Lehrstuhl für Innovationsmanagement und Entrepreneurship
katharina.hoelzle@ime.uni-potsdam.de

Abstract

Research on the open innovation paradigm has renewed the attention towards ways how firms can gain from the interaction with external knowledge sources. This study adopts the notion of inbound open innovation as external knowledge search and investigates the question to what extent formal innovation planning activities on project and strategic level can support firms in pursuing open innovation successfully. Drawing upon the distinction between potential and realized absorptive capacity, we differentiate the importance of formal innovation planning in the stages of (1) identifying and assimilating external knowledge sources, and (2) transforming and exploiting external knowledge into successful new products. Based on a sample of 132 German small and medium sized firms from life science industries, we find that project and strategic planning enhances firms? search effectiveness regarding the identification and assimilation of valuable external knowledge sources. However, regarding the transformation and exploitation of external knowledge into successful new products, project planning is only supportive for medium levels of openness. Strategic planning is even detrimental in the context of high levels of openness to external knowledge. Combining these opposing effects in a non-linear moderated mediation analysis of conditional direct and indirect planning effects, we conclude that formal innovation planning on project and strategic level is only beneficial for firms that aim at supporting low to medium

rather than high levels of openness to external knowledge.

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The Limits of Planning for Open Innovation Success – Empirical Evidence from Life Science SMEs

ABSTRACT

Research on the open innovation paradigm has renewed the attention towards ways how firms can gain from the interaction with external knowledge sources. This study adopts the notion of inbound open innovation as external knowledge search and investigates the question to what extent formal innovation planning activities on project and strategic level can support firms in pursuing open innovation successfully. Drawing upon the distinction between potential and realized absorptive capacity, we differentiate the importance of formal innovation planning in the stages of (1) identifying and assimilating external knowledge sources, and (2) transforming and exploiting external knowledge into successful new products. Based on a sample of 132 German small and medium sized firms from life science industries, we find that project and strategic planning enhances firms' search effectiveness regarding the identification and assimilation of valuable external knowledge sources. However, regarding the transformation and exploitation of external knowledge into successful new products, project planning is only supportive for medium levels of openness. Strategic planning is even detrimental in the context of high levels of openness to external knowledge. Combining these opposing effects in a non-linear moderated mediation analysis of conditional direct and indirect planning effects, we conclude that formal innovation planning on project and strategic level is only beneficial for firms that aim at supporting low to medium rather than high levels of openness to external knowledge.

Keywords:

open innovation, innovation planning, SMEs, life science industry

Introduction

The ability to explore and exploit external knowledge plays an important role in improving corporate innovativeness, and in consequence growth and profitability (Cohen and Levinthal, 1990; Jansen et al., 2005; Lane et al., 2001; Tsai, 2001). Recent research in the context of open innovation has renewed the attention paid towards strategies and practices that promote firms' successful interaction with external knowledge sources (Chesbrough, 2003, 2006; Dahlander and Gann, 2010). However, this line of research has also pointed out the limits of open innovation for firms that overstretch their manageable degrees of openness (Chen et al., 2011; Laursen and Salter, 2006).

Firms often struggle in their attempts to successfully interact with external partners in the innovation process (e.g. Knudsen and Mortensen, 2011; Lee et al., 2009). Difficulties arise in light of additional processing and coordination efforts that need to be managed in order to benefit from external knowledge sources. This is especially true for small and medium-sized enterprises (SME) with inherent capacity constraints (Parida et al., 2012; Van de Vrande et al., 2009). It has to be concluded that internal context factors and management practices that influence the adoption and success of open innovation are still not fully understood (Huizingh, 2011).

Literature on new product development (NPD) identifies essentially two internal determinants for innovation performance (Henard and Szymanski, 2001; Montoya-Weiss and Calantone, 1994; Evanschitzky et al., 2012), i.e. (1) an NPD strategy with formalized innovation objectives that all projects have to contribute to, and (2) an NPD process with ex-ante formalized goals, steps and gates that each project has to go through (cf. Cooper and Kleinschmidt, 1995). Both NPD strategy and process can be considered results of innovation planning activities on strategic and project level, respectively (Salomo et al., 2007; Song et al., 2011).

The empirical findings to date often yield positive effects of strategic and project planning of innovation success in general (Cooper and Kleinschmidt, 1986; Brown and Eisenhardt, 1995; Song and Parry, 1997; Salomo et al., 2007). However, there are also negative effects associated with innovation planning in the empirical literature due to overly formalized procedures that inhibit organizations' flexibility, creativity and improvisational capacity (e.g. Weick, 1979; Damanpour, 1991; Moorman and Miner, 1998; Song et al., 2011). These negative effects may outweigh the positive effects of innovation planning especially in open firms that heavily rely on external knowledge, which needs to be processed in unforeseen ways.

However, innovation planning in the context of firms' openness to external knowledge sources has not been thoroughly investigated yet, although it would be very useful from the perspective of organizational information processing theory (cf. Galbraith, 1974; Daft and Lengel, 1986). Openness to external knowledge determines the amount of information to be processed or the demand for information processing. This has to be aligned with an organization's information processing capacity which is largely influenced by the intensity of innovation planning. As one recent exception, the study by Leiponen and Helfat (2010) investigates the joint effect of external knowledge sources and the number of innovation objectives (as a planning result) on innovation success. Their results remain inconclusive, however, maybe because of their assumption of linear effects.

The present study wants to fill this gap by answering the following research questions: *(to what extent) do innovation planning activities on strategic and project level support or impede firms' innovation success derived from openness to external knowledge* *sources?* Three building blocks should contribute to a theoretically and empirically differentiated answer of our research question:

(1) We apply organizational information processing theory (cf. Galbraith, 1974; Daft and Lengel, 1986), such that openness to external knowledge is considered to determine information processing demand and innovation planning in turn determines information processing capacity. Following contingency theory (Venkatraman, 1989), the fit between information processing demand and capacity is modeled by an interaction effect between openness and planning. This allows for the analysis of partial planning effects for various levels of openness to external knowledge. (2) Drawing upon the distinction between potential and realized absorptive capacity by Zahra and George (2002), we differentiate the effects of planning activities for (a) identifying and assimilating external knowledge sources, and (b) transforming and exploiting external knowledge into new products. (3) In order to obtain a comprehensive picture of various innovation planning activities, we differentiate our analysis in terms of strategic planning (Song et al., 2011), project planning (Salomo et al., 2007) and innovation objectives (Leiponen and Helfat, 2010).

Based on a sample of 132 German SMEs from life science industries, we find that project and strategic planning enhances firms' search effectiveness regarding the identification and assimilation of valuable external knowledge sources. However, regarding the transformation and exploitation of external knowledge into successful new products, project planning is only supportive for medium levels of openness. Strategic planning is even detrimental in the context of high levels of openness to external knowledge. Combining these opposing effects in a non-linear moderated mediation analysis of conditional direct and indirect planning effects, we conclude that formal innovation planning on project and strategic level is only beneficial for firms that aim at supporting low to medium rather than high levels of openness to external knowledge.

The paper is structured as follows: In the next section, we present our theoretical framework that characterizes open innovation as external knowledge search, differentiates between the identifying and exploiting external knowledge sources, and derives the pros and cons of planning for open innovation success in terms of competing hypotheses. The third section presents the sample, measures and econometric analyses. The fourth section discusses the results, before the last section concludes with implications and limitations.

Theoretical Framework

Open Innovation as External Knowledge Search

Chesbrough (2003) and subsequent studies differentiate between in- and outbound activities of open innovation. Inbound innovation covers all activities geared towards incorporating external sources into the own innovation process, whereas outbound innovation relates to the way in which internal sources are revealed or commercialized vis-à-vis external actors (cf. for an overview Dahlander and Gann, 2010). With regard to inbound activities, Laursen and Salter (2006) documented the benefits and pitfalls of relying on external sources and identified that inbound activities are related to innovative performance in a curvilinear manner, based on a survey of UK manufacturing firms (cf. also Fey and Birkinshaw, 2005; Laursen and Salter 2006). For outbound activities Lichtenthaler and Ernst (2009) reported from a European cross-sector survey that the way in which organizations pursue open innovation (measured in terms of strategy process and content) impacts the performance of outbound innovation activities (in their case out-licensing).

The exploitation and utilization of external knowledge and ideas in internal innovation processes can be regarded as the core of the open innovation paradigm (Laursen and Salter, 2006). Activities with regard to connecting and exploiting external knowledge sources can be defined as a firm's knowledge search strategies (Sofka and Grimpe, 2010). In other words, open innovation activities find their expression in the specification of search strategies.

Knowledge search is conceptualized as an activity by which organizations solve problems and attempt to recombine knowledge for the objective of generating new products (Katila and Ahuja, 2002). By engaging in knowledge search, firms expand and renew their knowledge (base), which puts them in a position to be more innovative and successful (Levinthal and March, 1981; Rosenkopf and Nerkar; 2001). Knowledge search is one of the central aspects for the comprehension of innovation success (Nelson and Winter, 1982).

Knowledge search processes require a lot of resources in terms of time, skills, and financial resources (Cohen and Levinthal, 1990; Levinthal and March, 1993). Therefore, search activities may be constrained by the alternatives considered, as organizations and management may suffer from cognitive limitations (Ocasio, 1997; Gavetti and Levinthal, 2000). Accordingly, search processes of an organization are often very localized, which means that the organization's members search along trajectories, within known fields, and with regard to knowledge they already are familiar with (Stuart and Podolny, 1996). In order to stay competitive and constantly renew their knowledge base, however, organizations need to overcome these local search tendencies (Leonard-Barton, 1992; Rosenkopf and Nerkar, 2001; Stuart and Podolny, 1996).

Research has shown that it is beneficial for firms to differentiate their search efforts and to engage in more distant as opposed to local search (Laursen, 2012). This differentiation may relate to the distance of targeted technological fields (Katila and Ahuja, 2002), but also to organizational boundaries (Rosenkopf and Nerkar, 2001). External knowledge search beyond organizational boundaries, as opposed to internal search within a R&D department, has been shown to enhance innovation performance strongly (Laursen and

Salter, 2006; Leiponen and Helfat, 2010; Rothaermel and Alexandre, 2009). Hence, research on external and internal knowledge search provides a theoretical and empirical foundation of open innovation.

However, external knowledge search does not come free of limitations either. Earlier research has found that external knowledge search and sourcing has an inverted U-shaped effect on innovation performance (Faems et al., 2010; Katila and Ahuja, 2002; Laursen and Salter, 2006; Rothaermel and Deeds, 2006; Rothaermel and Alexandre, 2009; Deeds and Hill, 1996; Duysters and Lokshin, 2011). Search activities and the relations to the respective external sources need to be managed, and the acquired knowledge needs to be processed by the organization in order to exert innovation impact. The constraints firms face with regard to their processing capacities mainly derive from the restraints of attentive resources and the limitations of operational absorption capacities.

Identifying versus Exploiting External Knowledge

In their seminal work, Cohen and Levinthal (1990: 128) define absorptive capacity as the firm's "ability to recognize the value of new external knowledge, assimilate it and apply it to commercial ends". The influence of absorptive capacity on various measurements is well documented, including business performance (e.g. Koch and Strotmann, 2008; Lane et al., 2001; Vega-Jurado et al., 2009), innovation performance (e.g. Escribano et al., 2009; Grimpe and Sofka, 2009; Knott and Drive, 2008; Matusik and Heeley, 2005) and organizational learning (e.g. Bierly et al., 2009; Volberda et al., 2010).

Absorptive capacity has an obvious connection to open innovation and its performance effects (e.g. Laursen and Salter, 2006; West and Gallagher, 2006; Vanhaverbeke et al., 2008; Rothaermel and Alexandre, 2009; Spithoven et al., 2010). However, the concept of absorptive capacity bears considerable conceptual and empirical vagueness (Volberda et al., 2010). To approach a theoretical and empirical operationalization, we first distinguish between potential and realized absorptive capacity according to Zahra and George (2002), which basically refers to (a) identifying and assimilating external knowledge sources, and (b) transforming and exploiting external knowledge into new products.

This distinction between potential and absorptive capacity has also been deployed in other empirical studies, e.g. as separately measured variables with different antecedents (cf. Jansen et al., 2005). We follow the approach suggested by Fosfuri and Tribó (2008) who equate potential absorptive capacity with firms' identification of external knowledge sources and investigate realized absorptive capacity in terms of the moderating effect of integration practices.

Figure 1 summarizes the resulting research framework to address the unresolved issues of how innovation planning activities (1) directly influence openness, expressed by the number of identified and assimilated external knowledge sources, and (2) moderate the effect of openness on innovation success, representing the transformation and exploitation of external knowledge in terms of successful innovation projects.

------------------ Insert Figure 1 about here --------------------

The Ambiguous Effects of Innovation Planning

Previous research views planning activities as a double-edged sword with ambiguous effects on the number as well as the success of NPD projects (c.f. Song et al., 2011). One stream of research suggests that formalized planning activities has positive impact on various innovation measurements, such as the product development time (Griffin, 1997), the failure rate (Montoya-Weiss and Calantone, 1994) and the performance of the firm with regards to innovativeness (Olson et al., 1995) and output (Song and Parry, 1997). In this context, Miller and Cardinal, (1994) show that formal plans facilitate the operationalization of the innovation strategy and Brown and Eisenhardt (1995) find that planning activities advance the development and implementation of a clear strategic vision.

In contrast, another stream of research highlights a more improvisational approach of NPD projects (Eisenhardt and Tabrizi, 1995). Slotegraaf and Dickson (2004) show that formal designed planning activities institute routines that may prevent individuals from being innovative and organizations to adapt to changes in the market or technologies. In this context, valuable ideas laying beyond the strategic focus may be underestimate or rejected (Miller and Cardinal, 1994). Moorman and Miller (1998) suggest that a too high degree of formalization is contradictory to the inherent entrepreneurial nature of NPD projects.

Taking into account the contradictory views of the advantageousness of formalized versus improvised planning activities on both the absorption of knowledge and the innovation success, the paper applies a competing hypothesis approach comparing two plausible alternative hypotheses (Armstrong et al., 2001). This approach is suitable in cases where contradictory opinions impede an explicit hypotheses generation. Thereby, it enhances the objectivity and validity of the research approach (Armstrong et al., 2001).

To describe the firms' planning activities in the innovation process as precisely as possible, we distinguish two different levels for the development of our hypotheses: (1) Strategic planning refers to consistency of the innovation objectives. This type of activities consists of clear, long-term goals that are implemented in and controlled by the organization (Acur et al., 2012; Brown and Eisenhardt, 1995). (2) Project planning refers to the consistency of the innovation activities. Characteristic for this type of activities is the development of a structured innovation process with timelines, milestones, resource allocation and control mechanism (Salomo et al., 2007; Schultz et al., 2013).

Both project and strategic planning influence the capability and hence the process to explore and acquire knowledge outside the firm (Cooper and Kleinschmidt, 1990; Lambe et al., 2009). With respect to knowledge exploration and exploitation, formalization defines manageable areas of activities and codifies best practice approaches such as how to identify, apply, integrate and transfer external knowledge (Cordón-Pozo et al., 2006; Lin and Germain, 2003; Pertusa-Ortega et al., 2010). However, a strong emphasize on rules may lead to a loss of flexibility which in turns increases the danger to miss important innovation stimuli provided by external knowledge sources (Jansen et al., 2005; Jansen et al., 2006; Weick, 1979).

A high degree of formalization in project planning lowers the error rates and increases process efficiency (Hage, 1965; Ruekert et al., 1985). These findings are also applicable to the knowledge search. Thereby, formalization codifies best practices for with whom, how and when to interact with external knowledge sources (Lin and Germain, 2003; Pertusa-Ortega et al., 2010). Yet, a lower degree of formalization prevents firms from developing unchanging patterns of action and process inflexibility which in turn would lead to the inability to respond to changing markets (Slotegraaf and Dickson, 2004; Weick, 1979). To make allowance for the circumstance of opposing views, we state the two competing hypotheses:

H1a: Project planning positively effects the identification of external knowledge sources.

H1b: Project planning negatively effects the identification of external knowledge sources.

These findings confirm other research stating that a higher degree in openness and strategic flexibility increases the likelihood to identify unexpected, albeit valuable innovation opportunities (Katila and Ahuja, 2002; March, 1991; Nelson and Winter, 1982; Utterback, 1994). Contrasting these arguments, Okhuysen and Eisenhardt, (2002) argue that a lack of formalization compromises the search efforts due to a certain arbitrariness, which in turn results in inefficiency and un-organization.

More formalized strategic planning activities support the focusing on specific search areas, including technologies and markets, and the evaluation of potential valuable sources (Almirall and Casadesus-Masanell, 2010; Leiponen and Helfat, 2010). Yet, more flexible planning activities on the strategic level increase the firm's scope of knowledge search (Jansen et al., 2005; Weick, 1979) and hence the probability to of finding unexpected, albeit valuable innovation opportunities (Nelson and Winter, 1982; Utterback, 1994). Towards the end, we state the following two hypotheses:

H2a: Strategic planning positively effects the identification of external knowledge sources.

H2b: Strategic planning negatively effects the identification of external knowledge sources.

Formalized project planning that structure the occasionally long-lasting and complex innovation process in terms of certain phases with milestones, time-lines and responsibilities are found to increase the NPD success (Cooper and Kleinschmidt, 1990; Shenhar et al., 2002). Such structures and reduce ambiguity by allowing the employees and managers involved to monitor the knowledge transformation and exploitation activities within the product development process (Salomo et al., 2007; Tatikonda and Montoya-Weiss, 2001). At the same time, knowledge transformation and exploitation represents a creative process that may be limited or prevented by formalized project planning (Amabile, 1988; Sætre and Brun, 2012).

H3a: Project planning positively effects the exploitation of external knowledge sources.

H3b: Project planning negatively effects the exploitation of external knowledge sources.

Formalized strategic planning reduces the project teams' ambiguity in the expected outcome of knowledge exploitation and therefore reduces conflicts within the project group as well as between NPD and other organizational functions (Moenaert et al., 1994; Song and Thieme, 2006). Instability in the project objectives, for instance with regards to product specification, may lead to frustration within the project teams and a longer development cycle (Thomke and Fujimoto, 2000). In contrast, the strong insistence on previously defined strategic goals may impede the firms' ability to fully exploit the external knowledge due to cognitive constraints (Smith and Tushman, 2005). Therefore, we state the two hypotheses:

H4a: Strategic planning positively effects the exploitation of external knowledge sources.

H4b: Strategic planning negatively effects the exploitation of external knowledge sources.

Methodology

Sample and Measures

To test the effects of innovation planning on firms' open innovation success, we conducted a survey between January and March 2012 targeting small and medium sized firms in German life sciences industries, specifically pharmaceuticals, biotechnology and medical technology. The sampling frame consisted of 650 firms that signed up with one of the five major German industry associations. We identified name and email addresses of the respective CEOs and invited them via email to fill out a questionnaire. To increase the response rate, we sent out reminder mails after three weeks and additionally tried to call them after six weeks. After all, we received 139 usable responses. After elimination of observations with missing data in key variables, we were left with 132 firm observations, yielding response rate of 20.3%.

During the development of the questionnaire we conducted interviews with mangers in six SMEs, in order to ensure the comprehensibility of the questions as well as feasible length and complexity. The key independent variable by which we seek to measure innovation success is based on the question “How many innovation projects did your company successfully complete during the last five years (considering the strategic objectives relevant for innovation projects in your company that you selected from the previous question)?” Respondents answered this question by stating a whole number. The reference to the question measuring the breadth of firms’ innovation objectives will be explained in further detail below.

The second (intermediate) dependent variable by which we seek to capture firms’ openness to external knowledge sources is based on the question “How important were the following external knowledge sources for your innovation activities during the last five years?”. Respondents could rate the importance of the following 10 knowledge sources on five point Likert scales ranging from „not at all important“ to „very important“: (1) Customers, (2) suppliers, (3) competitors, (4) consultants / service providers, (5) universities/ research institutes, (6) conferences, (7) trade fairs, (8) scientific publications, (9) databases, (10) internet platforms / communities. The internal consistency of this scale was sufficient (Cronbach’s alpha=0.768). In line with Laursen and Salter (2006), we created binary variables for each knowledge source that equal one if the respective knowledge source was considered to be important (=4) or very important (=5), and zero otherwise.

The key independent variables deal with facets of innovation planning. The first one referring to project planning was measured by the following six survey items that respondents rated on five point Likert scales ranging from “totally agree” “totally disagree” (cf. Salomo et al., 2007; Schultz et al., 2013): “(1) Detailed time and budget plans are prepared for every innovation project. (2) All innovation projects have to pass a standardized process with formal stage gates. (3) There are predefined stage gates and milestones for every innovation project. (4) A detailed project plan is prepared before the start of every innovation project. (5) Project plans are continuously evaluated during the execution of innovation projects. (6) At the end of every innovation project, there is a detailed comparison between the project plan and actual results.” The internal consistency of this scale was sufficient (Cronbach’s alpha=0.873). The items were averaged and standardized to create a factor score for further analysis.

The second planning variable referring to strategic planning was measured by the following three survey items that respondents rated on five point Likert scales ranging from “totally agree” “totally disagree” (cf. Cooper and Kleinschmidt, 1995; Cooper et al., 2004a, 2004b, 2004c): “(1) My company has developed a detailed innovation strategy. (2) My company has an innovation strategy that is followed by every new product development team. (3) Innovation projects of my company have to support an overall innovation strategy.” The internal consistency of this scale was sufficient (Cronbach’s alpha=0.858). The items were averaged and standardized to create a factor score for further analysis.

The third planning variable referring to innovation objectives was is based on the question “Which innovation objectives are relevant in your company to determine the success of new product development projects during the last five years? Please, check those that apply.” Respondents could select among the following objectives: (1) Reduced costs, (2) time-to-market, (3) meeting customer demand, (4) improved product quality, (5) expanded product assortment, (6) financial success, (7) positive image among new customers, (8) satisfaction of existing customers. Similar to Leiponen and Helfat (2010), we created an index by summing up the number of selected innovation objectives and standardized it for further analysis.

The following control variables were included in the analysis: (I) Vertical integration was based on the question “Which stages of value creation functions does your company provide? Please, check those that apply.” Respondents could select among the following functions: (1) Research, (2) development, (3) approval, (4) production, (5) marketing / sales. By summing up the selected functions an index was created that ranges from 0 to 5. (II) The number of innovation projects undertaken by the asampled firms was measured by the question “How many new product development projects was your company involved in during the last five years?” Respondents answered this question by stating a whole number. (III) Firm size was controlled for by asking for the number of employees working in the firm on average during the last five years. (IV) Firm age was measured in years since foundation. (V) Finally, we controlled for the three industries by two dummies for biotechnology and medical technology, respectively, with pharmaceuticals being the reference. Table 1 shows the descriptive statistics of all variables used in the study.

----------------- Insert Table 1 about here --------------------

Econometric Analysis

We treat the dependent variables, the number of successful innovation projects and the number of important external knowledge sources, as count variables. We model these dependent variables by the means of Poisson regressions, as tests for overdispersion in all specifications do not reject the null hypothesis of equidispersion, with chi squared test statistics below the critical value of 3.84 for one degree of freedom (Cameron and Trivedi, 1990). Thus, the probability to observe a specific count C_i, conditional on explanatory variables $\boldsymbol{X_i}$, is given by:

$$P(C_i|\boldsymbol{X_i}) = \frac{\exp(-\lambda_i){\lambda_i}^{C_i}}{C_i!}$$

The expected mean number of important external knowledge sources $\lambda_{OPEN,i}$ is specified by the following vector of explanatory variables and a corresponding coefficient vector:

$$\lambda_{OPEN,i} = \exp(\beta_{O,0} + \beta'_{O,1} * \ PLAN_i + \boldsymbol{\beta'_{O,2}} * \boldsymbol{CONTR_i})$$

The expected mean number of successful innovation projects $\lambda_{SUCCESS,i}$ is specified by the following vector of explanatory variables and a corresponding coefficient vector:

$$\lambda_{SUCCESS,i} = \exp(\beta_{S,0} + \beta'_{S,1} * OPEN_i + \beta'_{S,2} * OPEN_i^2 + \beta'_{S,3} * PLAN_i + \beta'_{S,4} * OPEN_i * PLAN_i + \beta'_{S,5} * OPEN_i^2 * PLAN_i + \boldsymbol{\beta'_{S,5}} * \boldsymbol{CONTR_i})$$

In order to determine the indirect effects of innovation planning that is mediated by openness, we need to obtain (1) the partial effects of the planning variables on the number of important external knowledge sources, and (2) the partial effect of the number of important external knowledge sources on the number of successful innovation projects. The former is obtained by taking the partial derivative of the expected mean function $\lambda_{Open,i}$ with respect to the planning variable. According to the chain rule, it follows:

$$\frac{\delta\lambda_{OPEN,i}}{\delta PLAN_i} = \beta'_{O,1} * \exp(\beta_{O,0} + \beta'_{O,1} * \ PLAN_i + \boldsymbol{\beta'_{O,2}} * \boldsymbol{CONTR_i})$$

The latter is obtained by taking the partial derivative of the expected mean function $\lambda_{Success,i}$ with respect to the number of important external knowledge sources. It follows:

$$\frac{\delta\lambda_{SUCCESS,i}}{\delta OPEN_i} = \left(\beta'_{S,1} + 2 * \beta'_{S,2} * OPEN_i + \beta'_{S,4} * PLAN_i + 2 * \beta'_{S,5} * OPEN_i * PLAN_i\right)$$
$$* \exp(\beta_{S,0} + \beta'_{S,1} * OPEN_i + \beta'_{S,2} * OPEN_i^2 + \beta'_{S,3} * PLAN_i$$
$$+ \beta'_{S,4} * OPEN_i * PLAN_i + \beta'_{S,5} * OPEN_i^2 * PLAN_i + \boldsymbol{\beta'_{S,5}} * \boldsymbol{CONTR_i})$$

We obtain the indirect effect of innovation planning that is mediated by the number of external knowledge sources as a product of these two partial effects. The direct effect of innovation planning on the number of successful innovation projects is obtained as the partial derivative of the expected mean function $\lambda_{Success,i}$ with respect to the planning variables:

$$\frac{\delta\lambda_{SUCCESS,i}}{\delta PLAN_i} = \left(\beta'_{S,3} + \beta'_{S,4} * OPEN_i + \beta'_{S,5} * OPEN_i^2\right) * \exp(\beta_{S,0} + \beta'_{S,1} * OPEN_i$$
$$+ \beta'_{S,2} * OPEN_i^2 + \beta'_{S,3} * PLAN_i + \beta'_{S,4} * OPEN_i * PLAN_i$$
$$+ \beta'_{S,5} * OPEN_i^2 * PLAN_i + \boldsymbol{\beta'_{S,5}} * \boldsymbol{CONTR_i})$$

Hence, the total of effect innovation planning is obtained by the sum of the indirect and direct partial effects:

$$Total\_Effect(PLAN_i) = \frac{\delta\lambda_{OPEN,i}}{\delta PLAN_i} * \frac{\delta\lambda_{SUCCESS,i}}{\delta OPEN_i} + \frac{\delta\lambda_{SUCCESS,i}}{\delta PLAN_i}$$

Basically, our approach is an analysis of moderated mediation and conditional indirect and direct effects (cf. Hayes, 2013; especially his model framework 74). Two aspects make our setting special: (1) the constituent path from the mediator (number of important external knowledge sources) to the dependent variable (number of successful innovation projects) involves a quadratic relationship (cf. Hayes and Preacher, 2010), and (2) both regression equations are non-linear Poisson models. As shown, we take care of these issues by deriving the partial effects involved in an appropriate way that considers the interaction and quadratic terms involved (cf. Ai and Norton, 2003). Furthermore, we support the interpretation of the estimation results by plotting each of the effects as a function of the number of important external knowledge sources together with significance levels obtained by the Delta method (cf. Greene, 2000, 2010).

Results and Discussion

Table 2 shows the Poisson estimation results explaining the number of important external knowledge sources that firms considered important. The key independent variables are the three planning variables. If entered separately in the regressions (models 2-4), each of them has a positive significant impact. Project planning shows the strongest and innovation objectives the weakest impact. If entered simultaneously (model 5), only the project planning variable keeps its significance. We can conclude that all three facets of innovation planning are somewhat helpful to identify important external knowledge sources, but eventually project planning seems to mediate higher level planning effects when it comes to identifying important external knowledge sources. We also tested for non-linear effects of the planning variables, but these were insignificant.

------------------ Insert Table 2 about here --------------------

Table 3 shows the Poisson estimation results explaining the number of successful innovation projects. Model 6 only includes the planning variables and shows that only project planning directly impacts innovation success. Model 7 introduces the proposed inverted u-shape relationship of openness as the number of important external knowledge sources, which turns out to be significant. Model 8 introduces the moderating effect of project planning on the success impact of the number of important external knowledge sources. The significant moderation effect of both the linear and the quadratic term suggests a reinforcement of the inverted u-shape.

------------------ Insert Table 3 about here --------------------

To investigate this moderating effect in more detail, we plot the predicted number of successful innovation projects as a function of the number of external knowledge sources for high and low values of project planning (plus and minus one standard deviation). These predictions from model 8 in figure 2 show that innovation success is higher for high levels of project planning within the range of one to eight important external knowledge sources. Based on the standard errors computed by the Delta method we use the approach suggested by Long (2009) to compare these predictions. We can conclude that the difference is statistically significant within the range of two to seven knowledge sources, while the superiority of low levels of project planning for very low and high levels of external knowledge sources is not significant.

------------------ Insert Figure 2 about here --------------------

Model 9 introduces the moderating effect of strategic planning on the success impact of the number of important external knowledge sources. The significant moderation effect of the quadratic term suggests a reinforcement of negative effects for very high levels of external knowledge sources. The plotted predictions from model 9 in figure 2 support this suggestion. From approximately eight or more external knowledge sources, low levels of strategic planning are superior to high levels. Otherwise, the differences are insignificant.

Model 10 introduces the moderating effect of the number of innovation objectives, both on project and strategic levels. The high and significant moderating effect of both the linear and the quadratic term suggests an even stronger reinforcement of the inverted u-shape. The plotted predictions from model 10 in figure 2 again support this suggestion. For a medium number of external knowledge sources (i.e. around four to five), many innovation objectives lead to significantly more successful innovation projects compared to few innovation objectives. On the other hand, only few innovation objectives are superior for either very few (two or less) or very many external knowledge sources (eight or more). The following two findings stand out in our analysis of how innovation planning can support the exploitation of external knowledge sources: we find (1) a detrimental effect of strategic planning, but (2) a complementary effect of project planning as well as "flexible" plans with many innovation objectives at least when it comes to supporting a medium number of external knowledge sources.

A final step deals with a combined analysis of indirect and direct effects of innovation planning conditional on the number of external knowledge sources (cf. Hayes, 2013). This analysis can help to strike the balance between the positive effects of innovation planning on identifying external knowledge sources on the one hand and the limited effects on exploiting these external knowledge sources on the other hand. An increase in innovation planning may help to identify external knowledge sources to an extent that cannot be exploited anymore, as implied by the inverted u-shape relationship. Additionally, an increase in innovation planning may be useless or even detrimental for exploitation, as shown above.

Figure 3 shows the results of this analysis for each planning variable. The indirect effect lines correspond to the performance effect that arises from identifying additional external knowledge sources by increasing the innovation planning variables by one unit. The direct effect lines correspond to the performance effect that arises from exploiting additional external knowledge sources by increasing the innovation planning variables by one unit. The total effect lines result from the sum of both indirect and direct effects. The lines are dashed in those ranges where the effect is insignificant.

------------------ Insert Figure 3 about here --------------------

The results indicate that additional effort invested in project planning pays off in terms of identifying additional external knowledge only within the range of up to five sources. An increase in project planning to identify additional knowledge sources beyond six is even detrimental. In terms of exploiting external knowledge, additional effort invested in project planning pays off within the range of two to seven sources. Taken together, an increase in project planning pays off only when supporting openness levels of one to six external knowledge sources and is costly beyond eight knowledge sources.

Strategic planning helps to identify external knowledge only within the range of up to five sources and is harmful beyond seven sources. It does not support exploitation at all, but is even harmful when more than eight sources are to be exploited. Taken together, an increase in strategic planning pays off only when supporting openness levels of two to five external knowledge sources and is harmful costly beyond seven knowledge sources. The effect of innovation objectives on the external knowledge identification is rather limited. The exploitation of external knowledge can be supported within a range of four to six sources, but is harmful below three and above seven sources.

Based on the combination of conditional indirect and direct planning effects of identifying and exploiting external knowledge sources, respectively, we can conclude that formal innovation planning on project and strategic level is only beneficial for firms that aim at supporting low to medium rather than high levels of openness to external knowledge.

Conclusions

To what extent do formal innovation planning activities on project and strategic level support or impede firms in pursuing OI successfully? In response to the current debate in OI and NDP literature this study develops a conceptual framework distinguishing between the knowledge exploration and exploitation process. Considering the opposing views with regards to formalization versus improvisation hypotheses were developed according to the competing hypotheses approach.

First, the model investigates the effects of formalized planning activities on the planning and strategic level on inbound openness, measured as the number of external knowledge sources integrated in the innovation process. The results indicate that both project and strategic planning enhance firm’s search effectiveness regarding the identification and assimilation of valuable external knowledge sources. In turn this aspect militates in favour of a more formalized planning approach in the exploration phase and supports earlier findings (Lin and Germain, 2003; Pertusa-Ortega et al., 2010). These findings suggest that formalized planning activities on process level, including timetables and responsibilities, and on the strategic level with respect to goal orientation, ease the integration efforts. Concerning the strategic objectives the results also indicate in line with previous research by Leiponen and

Helfat (2010) that having multiple goals is beneficial for the identification of external knowledge. With other word: Having multiple, or even conflicting strategic goals does not impede inbound openness as long as firms stick to the once defined strategy.

Second, the study contributes to the extant literature on NPD by investigating the relation of planning activities on innovation performance in the context of openness. The results thereby support and enrich previous findings of the inverted u-shape relation between inbound OI and innovation performance as initially proposed by Laursen and Salter (2006). In other words, firms that engage in OI activities are well advised to balance their approach towards openness carefully. In this context the present study contributes to literature by showing how planning activities moderate the u-shape relation. The results show that regarding the transformation and exploitation of external knowledge into successful new products, project planning is only supportive for medium levels of openness, whereas strategic planning is even detrimental for high levels of openness to external knowledge.

Third, combining these opposing effects in a non-linear moderated mediation analysis of conditional direct and indirect planning effects, the results indicate that formal innovation planning on project and strategic level is only beneficial for firms that aim at supporting medium rather than high levels of openness. Once again with these findings the paper sheds light on internal context factors that moderate the u-shape relationship.

Our study has several limitations. First, this study is limited to a specific sample with regards to size, industry and country specifics. We only chose SMEs in the German life sciences industry. This may exclude certain aspects in the generation and commercialization of products. Testing our model with large firms in other industries and/or in other countries would improve the generalization of our findings taking into account differences such as protection mechanisms and competitive pressure across industries. Second, we suggest a conceptual model that explains how planning activities on the process and strategic level influence inbound openness and moderate innovation success. Although the results are very robust, additional research should also include other internal or external context factors, such as innovation culture (Herzog and Leker, 2010) or industry turbulence (Lichtenthaler and Ernst, 2009). Third, we tested the direct and indirect impact of planning activities on inbound openness and innovation success, both measured in terms of numbers of external sources and of projects, respectively. Future research should test other dependent variables, including outbound openness, and number of failed versus successful NPD projects.

All in all, we are not only able to give some practical advice on how to manage open innovation, but also able to reconcile some of the conflicting results on the effectiveness of innovation planning in light of varying information processing demands implied by open innovation.

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Figures and Tables

Figure 1: Theoretical framework

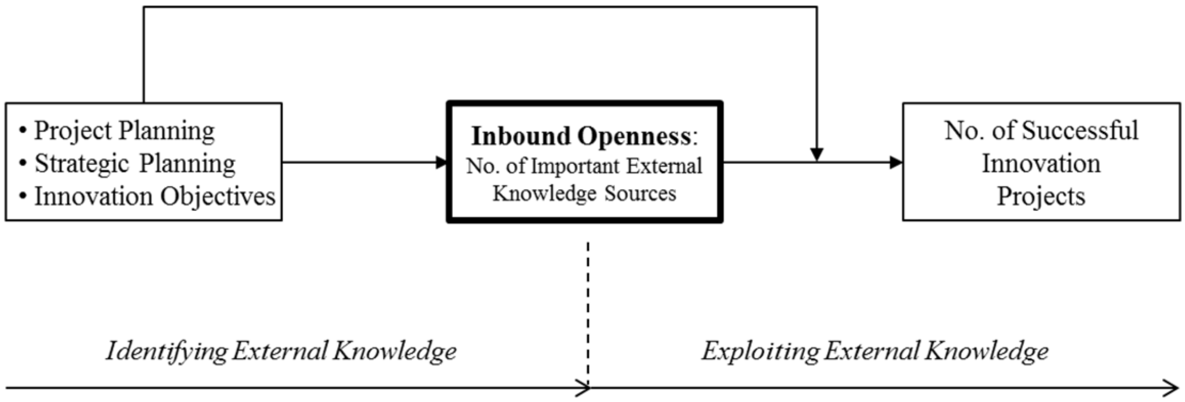

Figure 2: Predicted number of successful innovation projects as a function of external knowledge sources for high and low levels of planning

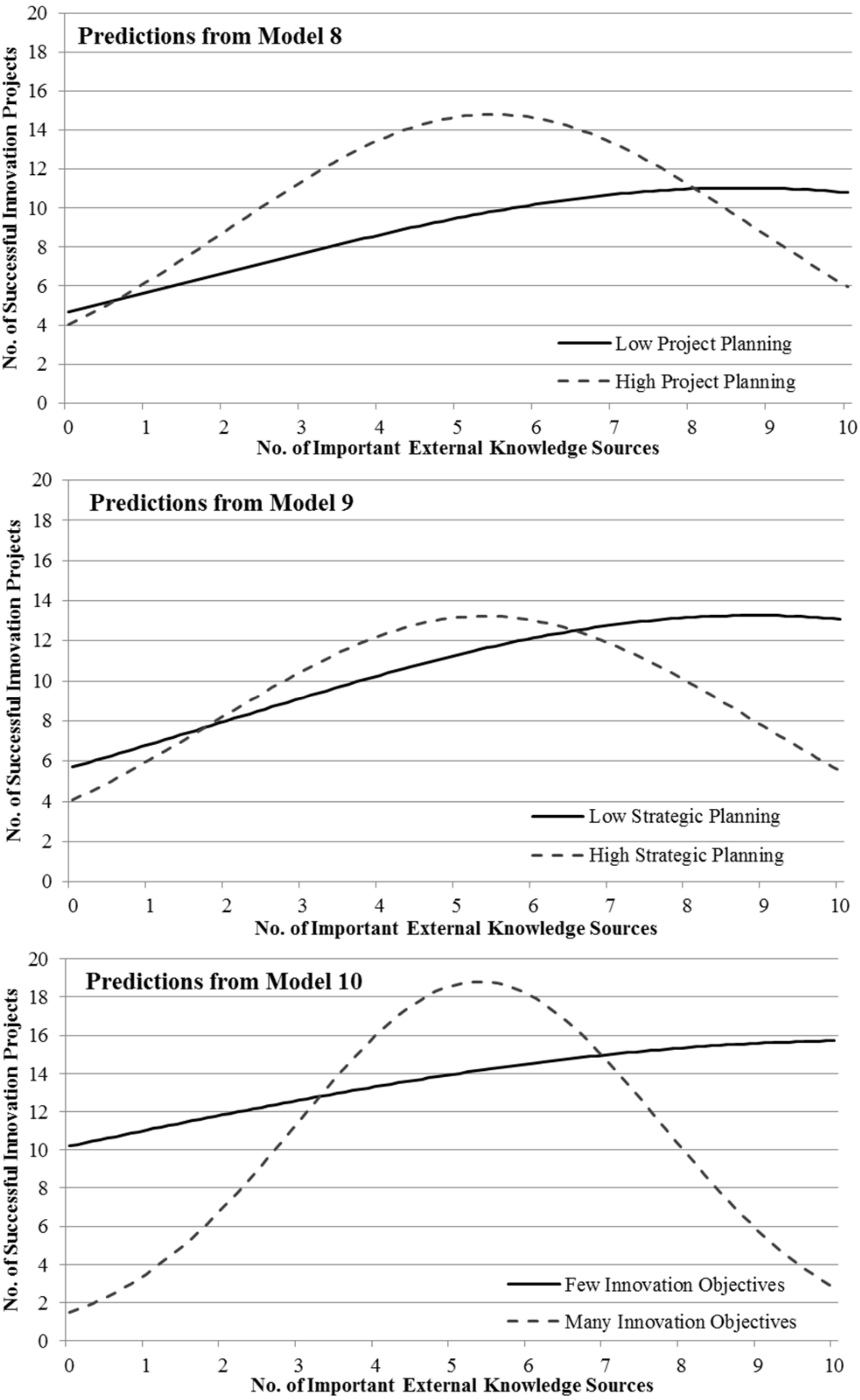

Figure 3: Indirect, direct and total effects of planning conditional on the number of external knowledge sources

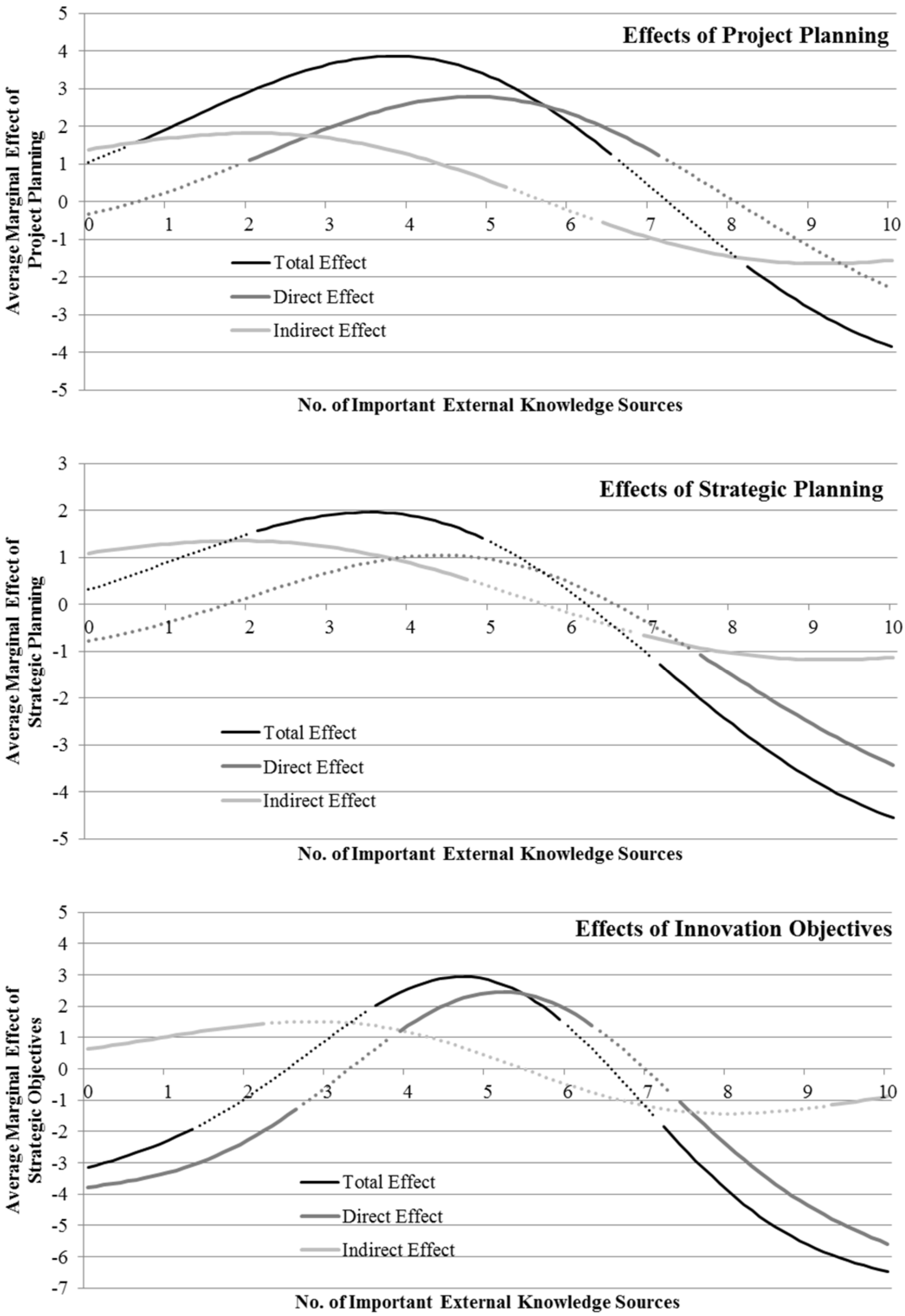

Table 1: Descriptive Statistics

Variable		Mean	Std.Dev.	Min	Max	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1)	No. of Successful Projects	9.01	19.74	0.00	200.00	0.16	0.13	0.11	0.07	0.16	0.97	0.26	0.08	-0.12	0.12	-0.01
(2)	No. of External Knowledge Sources	5.40	2.41	0.00	10.00		0.29	0.25	0.13	-0.03	0.12	-0.04	0.02	0.23	-0.19	-0.03
(3)	Project Planning	0.00	1.00	-2.60	1.49			0.51	0.24	0.26	0.14	0.10	0.06	0.03	-0.05	0.02
(4)	Strategic Planning	0.00	1.00	-2.22	1.55				0.22	0.13	0.08	-0.02	-0.26	0.26	-0.18	-0.06
(5)	Innovation Objectives	0.00	1.00	-2.01	2.47					0.24	0.08	0.07	-0.01	-0.06	0.01	0.06
(6)	Vertical Integration	3.52	1.33	0.00	5.00						0.16	0.28	0.19	-0.20	0.28	-0.12
(7)	No. of Innovation Projects	12.43	25.56	0.00	240.00							0.25	0.11	-0.13	0.08	0.04
(8)	No. of Employees	107.27	130.61	5.00	375.00								0.14	-0.31	0.22	0.08
(9)	Age [years]	13.23	5.84	2.00	20.00									-0.24	0.08	0.18
(10)	Biotech	0.28	0.45	0.00	1.00										-0.67	-0.29
(11)	Medical	0.54	0.50	0.00	1.00											-0.51
(12)	Pharma	0.18	0.39	0.00	1.00											

Table 2: Estimation results explaining the number of important external knowledge sources

Model	**1**			**2**			**3**			**4**			**5**		
Independent variables	Parameter		(S.E.)	Parameter		(S.E.)	Parameter		(S.E.)	Parameter		(S.E.)	Parameter		(S.E.)
Main Variables															
Project Planning				0.136	***	(0.042)							0.109	**	(0.048)
Strategic Planning							0.105	**	(0.042)				0.044		(0.049)
Innovation Objectives										0.062	*	(0.032)	0.037		(0.039)
Controls															
Vertical Integration	-0.002		(0.031)	-0.033		(0.032)	-0.020		(0.032)	-0.015		(0.032)	-0.042		(0.033)
No. of Innovation Projects	0.002	*	(0.001)	0.002		(0.001)	0.002		(0.001)	0.002		(0.001)	0.002		(0.001)
No. of Employees	0.000		(0.000)	0.000		(0.000)	0.000		(0.000)	0.000		(0.000)	0.000		(0.000)
Age [years]	0.005		(0.007)	0.004		(0.007)	0.009		(0.007)	0.006		(0.007)	0.007		(0.007)
Biotech	0.222	*	(0.118)	0.208	*	(0.118)	0.178		(0.119)	0.238	**	(0.118)	0.202	*	(0.119)
Medical	-0.042		(0.107)	-0.014		(0.107)	-0.020		(0.108)	-0.024		(0.108)	-0.002		(0.108)
Pharma	*(Ref.)*			*(Ref.)*			*(Ref.)*			*(Ref.)*			*(Ref.)*		
Constant	1.555	***	(0.159)	1.658	***	(0.159)	1.559	***	(0.158)	1.575	***	(0.159)	1.652	***	(0.161)
No of obs.	132			132			132			132			132		
Parameters (k)	7			8			8			8			10		
Log likelihood (2)	-304.12			-304.12			-304.12			-304.12			-304.12		
Log likelihood (k)	-298.59			-293.16			-295.51			-296.30			-292.20		
Chi-square	11.07 *			21.93 ***			17.23 **			15.64 **			23.84 ***		
McFadden R^2	0.018			0.036			0.028			0.026			0.039		

Two-tailed t -tests; * < 0.1, ** p < 0.05, *** p < 0.01

Table 3: Estimation results explaining the number of successful innovation projects

Model	**6**			**7**			**8**			**9**			**10**		
Independent variables	Parameter		(S.E.)	Parameter		(S.E.)	Parameter		(S.E.)	Parameter		(S.E.)	Parameter		(S.E.)
Main effects															
External Knowledge Sources				0.392	***	(0.069)	0.339	***	(0.076)	0.314	***	(0.080)	0.516	***	(0.076)
External Knowledge Sources ^2				-0.035	***	(0.006)	-0.028	***	(0.007)	-0.026	***	(0.007)	-0.046	***	(0.007)
Project Planning	0.112	***	(0.042)	0.141	***	(0.043)	-0.079		(0.190)	0.109	**	(0.046)	0.140	***	(0.044)
Strategic Planning	-0.009		(0.044)	-0.032		(0.044)	-0.035		(0.044)	-0.170		(0.199)	-0.019		(0.045)
Innovation Objectives	-0.023		(0.035)	-0.053		(0.035)	-0.055		(0.035)	-0.053		(0.036)	-0.965	***	(0.228)
Moderating effects (Mod)							*(Project Planning)*			*(Strategic Planning)*			*(Innovation Objectives)*		
Mod * External Knowledge Sources							0.141	*	(0.082)	0.125		(0.078)	0.434	***	(0.087)
Mod* External Knowledge Sources ^2							-0.016	**	(0.008)	-0.015	**	(0.007)	-0.042	***	(0.008)
Controls															
Vertical Integration	0.074	**	(0.030)	0.078	***	(0.030)	0.091	***	(0.031)	0.084	***	(0.030)	0.095	***	(0.030)
No. of Innovation Projects	0.015	***	(0.000)	0.017	***	(0.001)	0.018	***	(0.001)	0.018	***	(0.001)	0.019	***	(0.001)
No. of Employees	0.000		(0.000)	0.001	**	(0.000)	0.001	**	(0.000)	0.000		(0.000)	0.001	**	(0.000)
Age [years]	-0.031	***	(0.006)	-0.032	***	(0.007)	-0.032	***	(0.007)	-0.031	***	(0.007)	-0.026	***	(0.007)
Biotech	-0.285	***	(0.109)	-0.219	*	(0.114)	-0.251	**	(0.115)	-0.270	**	(0.118)	-0.113		(0.116)
Medical	0.015		(0.084)	0.059		(0.087)	0.043		(0.089)	0.029		(0.088)	0.180	**	(0.091)
Pharma	*(Ref.)*			*(Ref.)*			*(Ref.)*			*(Ref.)*			*(Ref.)*		
Constant	1.892	***	(0.134)	0.907	***	(0.223)	0.916	***	(0.228)	1.006	***	(0.247)	0.272		(0.254)
No of obs.	132			132			132			132			132		
Parameters (k)	10			12			14			14			14		
Log likelihood (2)	-1,228.79			-1,228.79			-1,228.79			-1,228.79			-1,228.79		
Log likelihood (k)	-494.39			-476.80			-473.87			-473.22			-457.25		
Chi-square	1,468.80	*		1,503.97	***		1,509.83	**		1,511.13	**		1,543.08	***	
McFadden R^2	0.598			0.612			0.614			0.615			0.628		

Two-tailed t -tests; * < 0.1, ** p < 0.05, *** p < 0.01