Stage specific external collaboration for New Product Development. Does firm size matter for partner selection and performance?

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**Abstract**

This study makes a step in a new direction and measures the impact of external collaboration with various partners at five stages of the new product development process on the share of innovative sales. The data are drawn from the Mannheim Innovation Panel (MIP) and comprise of 317 large firms and 1475 small and medium enterprises (SMEs). The Resource-Based View of the firm (RBV) is used to hypothesize at which stages of the new product development process large firms and their smaller counterparts benefit from a collaboration with external partners. It sticks out that a collaboration with customers is valuable at almost every stage and a collaboration with suppliers especially at the middle stages. However, with regard to links at the value chain there are only slight differences observable between the two types of firms. Surprisingly the collaboration with universities has a positive impact at almost all stages for SMEs. For large firms this positive impact is observable mainly at the middle stages. The paper closes with careful recommendations for decision-makers in firm practice and innovation policy.
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Key words: stage specific open innovation, open innovation, SME, NPD
1. Introduction

Due to growing complexity of technology and shorter product life cycles, openness for external knowledge is nowadays a central part of the innovation activities of firms (Chesbrough, 2003; Cohen & Levinthal, 1990; Love, Roper, & Bryson, 2011). Collaboration with partners promises access to highly specialized knowledge and combinations of different external partners are common (Ahuja, 2000; Laursen & Salter, 2006). Accordingly, a wide variety exists when it comes to consortia configurations, approaches to cooperation management and impact on innovation output measures (e.g. Laursen & Salter, 2006, 2014; Mazzola, Bruccoleri, & Perrone, 2012). With regard to the latter literature has also stressed idiosyncrasies and the need to take contingency factors into account (e.g. Koufteros, Vonderembse, & Jayaram, 2005; Tsai, 2009).

Evidence on the performance effects of open innovation is still inconclusive (for an overview: Vanhaverbeke, Du, Leten, & Aalders, 2014). A possible explanation is the, often implicit, assumption that sourced knowledge turns into innovative output “automatically” (Bogers et al., 2017). Furthermore, prior investigations often focused on Research and Development (R&D), despite convincing demonstration that innovative activities consist of more than that (Marsili & Salter, 2006). Therefore, it seems reasonable to further differentiate tasks or stages in innovation processes and study possible performance effects of external cooperation separately (Love et al., 2011).

A second under-investigated area of research is open innovation in Small and Medium-sized Enterprises (SMEs) (Hossain & Kauranen, 2016). In many countries SMEs account for a large share of employment and many are innovators in their line of business (Bianchi, Campodall’Orto, Frattini, & Vercesi, 2010). Moreover, with respect to innovation performance, openness seems to be of greater importance for SMEs compared to their larger counterparts due to differences in available resources and capabilities (Spithoven, Vanhaverbeke, & Roijakkers, 2013; Vahter, Love, & Roper, 2014; Vossen, 1998).

This paper combines a task specific concept of external knowledge sourcing in firms’ New Product Development (NPD) processes with an investigation into differences in innovative output with regard to firm size. We employ arguments from the Resource-Based View of the firm (RBV) to hypothesize on how the use of external knowledge differs within five tasks (idea generation, R&D, design, testing, market launch) of the NPD for SMEs and large firms.
This study makes three contributions to the literature on open innovation and new product development. First, differentiating five tasks in the NPD it goes beyond most existing literature using generalized terms like knowledge sourcing, knowledge transformation and knowledge commercialization (Ganotakis & Love, 2012; Love et al., 2011). Second, we access the combined impact of the most prevalent external knowledge sources in a task-specific model for SMEs. Although task specific research on external collaboration in SMEs exists, evidence is mostly limited to the influence of partners at the value chain (Theyel, 2013) and universities (Buganza, Colombo, & Landoni, 2014). Third, while the majority of previous work often focused on single industries (Gruner & Homburg, 2000; Love et al., 2011), we use data from the wave 2008 of the Mannheim Innovation Panel (MIP) containing 1,475 SMEs and 317 large firms in a wide variety of industries.

The remainder of the paper is structured as follows: Section two contains a short literature review on open innovation in general and task/stage specific open innovation in particular. In section three we outline theoretical considerations and derive hypotheses on variation in innovative output because of collaboration differences with regard to external partners of SMEs and large firms. Section four introduces the sample, the method and relevant variables. In section five we present regression results. The paper finishes with the discussion in section six concluding our investigation with implications for different research fields and management practice.

2. Open innovation and stage specific external collaboration

Openness for external knowledge is central to the innovation strategy of modern firms (Chesbrough, 2003), because of the ability to supplement missing internal resources (Eisenhardt & Schoonhoven, 1996). The combination of internal and external sources leads to new knowledge which in turn frequently results in innovation (Antonelli & Fassio, 2015; Laursen & Salter, 2014). Prior evidence suggests a difference in the impact of openness on innovative output with regard to specific partners and diversified portfolios thereof (Baba, Shichijo, & Sedita, 2009; Faems, De Visser, Andries, & Van Looy, 2010; Yli-Renko & Janakiraman, 2008). Furthermore, contingency factors for successful external sourcing like collaboration breadth, degree of technological uncertainty and the availability of firm internal resources have been identified (Berchicci, 2013; Laursen & Foss, 2003; Laursen & Salter, 2006; Melander & Lakemond, 2015). A more recent research strand deals with various forms of open innovation in SMEs (for an overview see: Hossain...
Some authors argue that due to their lack of internal resources, SMEs benefit relatively stronger from open innovation activities compared to their large counterparts (Spithoven et al., 2013; Vahter, Love, & Roper, 2014).

Task- and/or stage-specific considerations in open innovation are relatively rare. As a rationale for studying these and dividing external sourcing of knowledge further, Frishammar & Ylinenpää (2007) and Vanhaverbeke et al. (2014) cite differences in challenges, goals, incentives, restrictions and a different level of uncertainty within the specific task. Existing investigation on the issue mostly divide the innovation process into three parts: idea generation, knowledge transformation and knowledge commercialization (e.g., Roper et al., 2008). Roper and colleagues investigate how the use of a certain external knowledge source conditions the use of another and how the external knowledge sources as a whole influence the intensity of product innovation and the decision to engage in process innovation. In a final step, the authors examine the influence of product and process innovation on labor productivity, sales growth and employment growth. However, the impact of collaboration at later stages in the innovation process is not addressed. The same applies to Ganotakis & Love (2012). In a sample of U.K. service firms Love et al. (2011) point out that specific external partners have a different impact on innovation output at different stages of the innovation process. Other literature investigates collaboration at a limited number of stages (Knudsen, 2007), but concentrates on single industries or specific partners (Gruner & Homburg, 2000; Handfield, Ragatz, Petersen, & Monczka, 1999; Theyel, 2013; Zahay, Griffin, & Fredericks, 2011). To date there are only two studies that are dedicated explicitly to stage specific external collaboration in SMEs (Buganza et al., 2014; Theyel, 2013).

3. Theory and Hypotheses

The Resource Based View of the firm (RBV) focusses on performance differences within an industry and puts the resources of the firm in the center of consideration (Barney, 1991; Peteraf, 1993; Wernerfelt, 1984). It presumes that competing firms differ in their resources and that they are not perfectly mobile between organizations with the consequence that differences between firms are relatively persistent (Barney, 1991). Internal, as well as external knowledge is seen as a strategically important resource and can contribute to different forms of innovation (Foss, 1996; Grant, 1996). Especially if the internal knowledge base is insufficient or can be expanded only with high costs and high risk, firms rely on external knowledge (Eisenhardt & Schoonhoven, 1999).
The combination of internal and external knowledge is valuable because it is hard to imitate for competitors (Kogut & Zander, 1992). To integrate external knowledge, a firm needs absorptive capacity which is defined as the ability of a firm to assess, transform and commercialize external knowledge (Cohen & Levinthal, 1990). Absorptive capacity depends heavily on prior experience, formal R&D and the available in-house human capital (Fabrizio, 2009; Schmidt, 2010). This is relevant especially for SMEs, who have a limited resource base as is evident in smaller management teams, fewer financial resources and an under-developed R&D function (Narula, 2004; Parida, Westerberg, & Frishammar, 2012). Furthermore, SMEs have limited bargaining and market power and are therefore forced to employ collaboration strategies that differ from large firms (Hossain & Kauranen, 2016). On the other hand, SMEs face a number of advantages, like higher flexibility and speed in decision making and a closer proximity to customer concerns (Dahl & Moreau, 2002; Vossen, 1998).

**Customer collaboration**

The main reason to involve customers into new product development is that they operate in another logic than the focal firm. Customers possess unique knowledge on their own specific needs whilst the focal firm tries to commercialize products for a broad market (Lettl, Herstatt, & Gemuenden, 2006; Mahr, Lievens, & Blazevic, 2014). If it succeeds to capture the customer needs collaboration with customers can have a positive effect on innovation output (Belderbos, Carree, & Lokshin, 2004; Lau, Yam, & Tang, 2010; Spithoven et al., 2013).

- **H1a**: Collaboration with customers has a positive impact on the innovation performance of the focal firm (basic effect)

The medal of collaboration with customers has two sides. On the one hand, customers possess specialized knowledge about the functionality of products and often modify them to improve their usability (Lettl et al., 2006; Lüthje, Herstatt, & Von Hippel, 2005). The knowledge from customers can in principle be captured easily due to the fact that customers use the products that are well known to the focal firm. On the other hand, customers have difficulties expressing their needs, fail to think long-term-orientated and their needs are often idiosyncratic (Enkel, Kausch, & Gassmann, 2005; Sánchez-González, González-Álvarez, & Nieto, 2009). A careful assessment of customer needs is necessary to assure representativeness for all relevant customers (Bonner & Walker, 2004;
von Hippel, 1988). Thus an early integration of customers seems to be useful irrespective of the focal firm’s size. To ease the valuation and increase the relevance, firms increasingly engage in active collaboration instead of assessing customer knowledge through instruments of market research at the beginning of the innovation process (Kazadi, Lievens, & Mahr, 2016; Mahr et al., 2014). A participation of customers in the new product development process facilitates product innovation through better information flows, reduced coordination requirements and enhanced trust (Fang, Palmatier, & Evans, 2008). With their specialization in niche markets, SMEs are particularly suited to handle differentiated customer needs, but the positive impact of an active participation has been shown for all firm sizes (Christensen et al., 2005; Mahr et al., 2014; Morris, Koçak, & Özer, 2007). Furthermore, the design stage has an important function for firms. Through design, the first prototype is translated into a marketable product (Marsili & Salter, 2006). A participation of the customer into design activities can enhance the acceptance of the new product (Melton & Hartline, 2010). For those reasons a collaboration at the middle stages of the new product development process is expected to be positive for both types of firms. Several authors emphasize that SMEs lack market power because of their limited access to distribution infrastructure and networks (Lee, Park, Yoon, & Park, 2010; Man, Lau, & Chan, 2002). Therefore SMEs have to take a proactive approach to overcome this limitations and a cooperation with customers at late stages should be beneficial for SME.

• **H1b:** For SMEs a collaboration with customers at all stages has a positive effect on the innovative performance of the focal firm.

• **H1c:** For large firms a collaboration with customers at the early and middle stages has a positive effect on the innovative performance of the focal firm.

Supplier collaboration

Suppliers can influence the success of new product development in manifold ways. Through increasing modularization of new products and further specialization of firms the influence of suppliers on new product development success is getting larger (Jayaram, 2008). Basic mechanisms for the positive contribution of supplier involvement in new product development are the increase of market adaptability (Song & Parry, 1997), the reduction of lead times (Clark, 1989; Hartley, Meredith, McCutcheon, & Kamath, 1997) and access to specialized knowledge (Lawson,
Petersen, Cousins, & Handfield, 2009). The collaboration with suppliers leads to a greater propensity of product innovation (Fossas-Olalla, Minguela-Rata, López-Sánchez, & Fernández-Menéndez, 2015; Hagedoorn, 2002) as well as to an increased share of innovative sales (Lau, Tang, & Yam, 2010).

- **H2a: Collaboration with suppliers has a positive impact on the innovation performance of the focal firm (basic effect)**

Several scholars emphasize that an integration of suppliers at early stages of the new product development process reduces the risk of wrong decisions, leads to better cooperation in the subsequent process and finally enhances the financial performance in organizations (Petersen, Handfield, & Ragatz, 2005; Ragatz, Handfield, & Petersen, 2002). Furthermore, it becomes possible through an early integration to assess the capabilities of suppliers (Bonaccorsi & Lipparini, 1994). The careful selection of suppliers can minimize the need for further coordination in the development process (Koufteros, Cheng, & Lai, 2007). Previous studies on the timing of supplier integration did not differentiate between large firms and SMEs. Small firms face at least two factors that limit the value of collaboration at early stages. On the one hand-side, small firms have concentrated portfolios which goes hand-in-hand with high specialization in very specific domains of knowledge (Bianchi et al., 2010). Together with their limited base of human and financial resources, it becomes difficult to assess capabilities and motivations of their suppliers (Vossen, 1998). Additionally, it can be argued that the low demand volumes of SMEs decrease the will of the supplier to negotiate specific solutions at early stages of the new product development process (Koufteros et al., 2007; Tether, 2002). Because of the large and direct impact of suppliers on the costs and the success of new product development, several studies have shown that a collaboration with suppliers at the middle stages is useful (Ragatz, Handfield, & Scannell, 1997). The transfer of tacit supplier knowledge can be enhanced through various mechanisms like inter-organizational teams, use of information technology, delegation of responsibility and much more (Handfield et al., 1999; Jayaram, 2008). A high extend of supplier integration is necessary if the supplier has a high responsibility for design issues or if the delivered parts have a high strategic relevance (Parker, Zsidisin, & Ragatz, 2008; Petersen et al., 2005). Furthermore, an intense and continued collaboration builds up trust and increases the will of the supplier to share technological knowledge (Yeniyurt, Henke, & Yalcinkaya, 2014). It is supposed that large firms as well as SMEs
benefit from the enhanced knowledge flows as a consequence of supplier collaboration at middle stages. However, supplier integration in late stages of new product development seems to be not beneficial, because in this case it would be only a small step for the suppliers to integrate forward and reap the benefits by themselves.

- **H2b**: *For SMEs a collaboration with suppliers at the middle stages has a positive effect on the innovative performance of the focal firm.*

- **H2c**: *For large firms a collaboration with customers at the early and middle stages has a positive effect on the innovative performance of the focal firm.*

**University collaboration**

Universities are an important knowledge source of firms for the collaborative generation and adoption of new technology (Arvanitis & Woerter, 2009). They offer knowledge from the front edge of technology. In principle universities can influence the innovation process of firms in two ways. On the one hand side adding new ideas derived from latest research results and on the other hand side by saving projects which are jeopardized to fail otherwise (Cohen, Nelson, & Walsh, 2002). Empirical evidence suggests, that applied as well as basic research can contribute to achieve innovation in firms and enhance the share of innovative sales (Arvanitis, Sydow, & Woerter, 2007; Grimpe & Kaiser, 2010; Un, Cuervo-Cazurra, & Asakawa, 2010).

- **H3a**: *Collaboration with universities has a positive effect on innovation performance of the focal firm (basic effect)*

University knowledge is grounded in basic research and follows a different logic than knowledge from linkages at the supply chain (Bercovitz & Feldman, 2005). Due to its high distance from the market university knowledge bears a high risk of failure in application (Link, Siegel, & Bozeman, 2007). Scholars have emphasized the necessity of employing high qualified staff for a successful identification, translation and absorption of university knowledge (Fabrizio, 2009; van den Bosch, Volberda, & de Boer, 1999). Furthermore the ability to acquire external knowledge is a by-product of internal R&D (Cassiman & Veugelers, 2002). With their limited human resources and lower structured R&D one would expect that SMEs have problems to assess the value of university knowledge. However, evidences show that universities are desirable cooperation partners for large firms as well as for SME (Cassiman & Veugelers, 2006; Mohnen & Hoareau, 2003). Even more scientists are inclined to initiate collaborations especially with small firms (Goel, Göktepe-Hultén,
One possible explanation might be that scientists are more interested in finding solutions for problems and not in conducting administration. Therefore they prefer collaboration with more flexible partners like SMEs (Christensen et al., 2005; Goel et al., 2017). Another explanation is that collaboration with universities is possible in manifold ways. In addition to contract research (Jensen & Thursby, 2001) firms can collaborate via licensing agreements (Mowery & Ziedonis, 2015), consulting (Jensen, Thursby, & Thursby, 2010) or even through informal contacts (Grimpe & Fier, 2010). Furthermore universities offer a broad range of supporting structures like science parks, subsidized laboratory space, access to networks and business assistance which can be used especially by small firms (Huggins, Johnston, & Steffenson, 2008; Löfsten & Lindelöf, 2005). The broad variety of transfer channels allows for SMEs to collaborate with universities at a relatively low risk and in a flexible way. Thereby they can substitute their scarce internal resources through university collaboration (Eom & Lee, 2010; Veugelers & Cassiman, 2005). This variety makes it possible that a collaboration between universities and SMEs can be fruitful at almost every time of the new product development process.

However, an alternative collaboration pattern is conceivable for small firms. Due to their limited absorptive capacity some scholars argue that SMEs may collaborate at later stages of the new product development process and delegate clearly defined problems to the university (Buganza et al., 2014; Santoro & Chakrabarti, 2002). So the impact of university-industry collaboration on the innovation performance of SMEs is examined with two alternative hypothesis. However, large firms use collaboration with universities to increase their stock of technological knowledge which makes collaboration at the R&D stage likely (Arvanitis & Woerter, 2009; Tether, 2002). Due to their higher absorptive capacity ideas from the university can be more easily assessed in large firms. A collaboration with universities at the late stages of the new product development process should have no effect at the innovative output. Usually universities are not specialized in commercializing new products.

- **H3b**: For SMEs a collaboration with universities at the early and middle stages has a positive effect on the innovation performance of the focal firm.

  or:

- **H3c**: For SMEs a collaboration with universities at the middle stages has a positive effect on the innovation performance of the focal firm.
• **H3d:** *For large firms a collaboration with universities at the early and middle stages has a positive effect on the innovation performance of the focal firm.*

**Competitor collaboration**

The potential benefits of collaborating with competitors are rather based in sharing the often enormous costs of risky innovation projects than in getting access to complementary knowledge (Miotti & Sachwald, 2003). An overlap of interests and capabilities eases the absorption of knowledge but bears also an enormous risk of unintended knowledge outflow and opportunism (Dussauge, Garrette, & Mitchell, 2000; Ritala & Hurmelinna-Laukkanen, 2009; Wu, 2014). Because of this ambiguity it is not surprising that studies which investigated the impact of collaboration with competitors reveal blurred results. Some scholars found a negative impact on innovation (Fitjar & Rodríguez-Pose, 2013; Nieto & Santamaría, 2007), whereas others found a positive impact innovation (for German IT firms: Bouncken & Fredrich, 2012; Bouncken & Kraus, 2013). Others found an inverted u-shaped relationship between cooperation with competitors and innovative performance (Kang & Kang, 2010; Wu, 2014) and again others found a positive effect on incremental innovation (Belderbos et al., 2004; Tsai, 2009).

• **H4a:** *Collaboration with competitors has a no effect on innovation output of SME and positive effect of the innovation performance of large firms (basic effect)*

Cooperation with competitors can be beneficial if it is carried out very carefully (Wu, 2014). It seems to be plausible that firms can reap the benefits of cooperation with rivals optimally, if they cooperate at the R&D stage to share the enormous costs and the risk of failure. Such kind of cooperation is likely foremost in large technologically advanced companies (Gnyawali & Park, 2011; Miotti & Sachwald, 2003). Cooperation with competitors enables insights into technology, business models and practices of the partner. At the stage of idea generation should be detrimental because of the risk of underestimating the competitors capabilities to develop and implement ideas more quickly (Arrow, 1962). There are a few papers that investigate coopetition in SME. In their conceptual work Gnyawali & Park (2009) derive some propositions about factors from literature, which make the collaboration with competitors in SME more likely. They argue that collaboration with competitors in SMEs are triggered by especially by uncertainty in high-tech environments. The motivation to collaborate with competitors seems to be similar like in the large firms. Other
authors emphasize the need, to develop standards to enhance efficiency together with competitors (Casseres, 1997; Eikebrokk & Olsen, 2005; Levy, Loebbecke, & Powell, 2003). It is rather unclear at which stage a collaboration with competitors should make sense for SMEs. Due to the fact that the R&D function is structured modestly in SMEs a collaboration at the R&D stage is unlikely (Bougrain & Haudeville, 2002; van de Vrande, de Jong, Vanhaverbeke, & de Rochemont, 2009).

- **H4b**: Collaboration with competitors at all stages has no impact on the innovation performance of SMEs.
- **H4c**: Collaboration with competitors has a negative impact on the innovation performance if it occurs at the early stages and a positive impact on the innovation performance if it occurs at the middle stages in large firms.

4. Data and Method

This paper relies on the German version of the Community Innovation Survey (CIS). The Mannheim Innovation Panel (MIP) includes a plethora of indicators, which are not mandatory for CIS data but discussed in the current literature on innovation economics (Peters & Rammer, 2013). For the analysis the survey wave of the year 2008 is used. This wave includes a battery of special issue items to cover external collaboration at five different stages/tasks of the innovation process\(^1\). Potential partners are business customers, consumer customers, material suppliers, service firms, universities and competitors. A cooperation with each of those partners is possible at the tasks idea generation, R&D, design, testing and market launch (based on the stage-gate model: Cooper, 2009; Cooper, Edgett, & Kleinschmidt, 2002). The survey measures the collaboration behavior in the years 2005-2007 and the innovative output in 2007. After cleansing the data from nonresponse 1475 SMEs and 317 large firms from 22 industries remain for analysis\(^2\). In contrast to other CIS data the Mannheim Innovation Panel (MIP) is conducted annually and has a panel structure (Peters & Rammer, 2013). This allows to re-estimate the models with a one year time lag as a first robustness check.

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1 In the MIP-survey the collaboration along the “innovation process” is requested. However, the original stage gate model is dedicated explicitly to new product development. We use both terms as synonyms in this paper.

2 Chi-square tests point out that large firms respond to a significant lesser extent to the requested share of innovative sales. However, there seems to be no difference in collaboration patterns between responding and non-responding large firms. The same holds true for the collaboration patterns of SMEs.
4.1. **Dependent and independent variables**

As a dependent variable the share of innovative sales stemming from incrementally improved products respectively from products new to the firm (radical innovation) is used. Those measures capture the realized success of innovative products and have been used frequently in literature (e.g. Marsili & Salter, 2006; Tsai & Hsieh, 2009). Due to the fact that the dependent variable is double-censored a tobit model is employed (Greene, 2012). Tobit models require a normal distribution of the error term. For this reason the dependent variable was logarithmized \((\ln(1 + \text{share of innovative sales}))\)\(^3\) (Laursen & Salter, 2006). To avoid problems with heteroscedasticity all of the models are estimated with robust standard errors. Every model was estimated separately for large firms and SMEs after a sample split\(^4\).

To estimate the basic effect (hypothesis 1a, 2a, 3a and 4a) dummy variables where created for each of the above named partners (dummy business customer – dummy competitor in summary statistics). Those dummies measure if there is a collaboration with one specific type of partner or not but do not take into account the timing of collaboration. For the main question of this paper dummies for the cooperation at a specific stage of the innovation process are used. Thereby it becomes possible to pursue the effect for every type of partner named above at each of the five tasks of the innovation process.

4.2. **Control variables**

The control variables cover firm specific characteristics which have shown to influence the innovation output. Firm size is covered by the logarithmized number of full time employees (Grimpe & Kaiser, 2010). As a proxy for absorptive capacity the percentage of employees with an academic degree and the R&D intensity is used (Ganotakis & Love, 2012; Lokshin, Belderbos, & Carree, 2008). Export intensity is used as a control variable because firms can gather information from foreign markets and have a larger sales market for their new product (Love & Roper, 2015). Furthermore a dummy variable for east and west Germany and industry dummies are included\(^5\).

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\(^3\) The authors emphasize that a lognormal transformation of the dependent variable does not change the signs, the significance and the relative size of the parameters.

\(^4\) According to the definition of the OECD Firms with more than 250 employees were considered as large firms, whereas firms with fewer than 250 employees are considered as SMEs (OECD, 2005).

\(^5\) Because of partially low case numbers issues of variance appeared in several industries. Therefore industries where clustered into low-tech, medium-low-tech, medium-high-tech and high-tech industries according to OECD standard.
5. Results

Results from descriptive analysis

The descriptive statistics (planned for online extension) reveal that compared to their smaller counterparts a substantially higher share of large firms collaborate with external partners. This observation holds true for a vast majority of stages and partners. However, no large differences can be observed between the two types within the control variables. The correlation matrix (planned for online extension) shows that multicollinearity is not an issue for the main part of the variables. Only the partner-specific collaboration variables between the different stages are correlated to a higher extend. This entails serious issues of multicollinearity in partner specific models. For that reason the data are analyzed with stage specific models which include the collaboration with each of the partners at one specific stage\(^6\).

Results from regression analysis

Table 2 contains the basic effects without a stage specific consideration of collaboration. The results offer support for hypothesis 1a. A collaboration with business and consumer customers pays off in terms of incremental as well as radical innovation. Hypothesis 2a is supported as well. Firms benefit from collaboration with material suppliers and service firms with regard to incremental and radical innovation. The collaboration with universities has a positive effect on the share of innovative sales offering full support for hypothesis 3a. However, hypothesis 4a has to be rejected. Despite the fact that the hypothesis 1a until to 4a where not established separately for SMEs and large firms it sticks out in the regressions that there are at least some differences between the two types of firms. Those differences are further explored in tables 3 and 4. Table 3 contains the stage specific models which measure the impact of external collaboration on the share of innovative sales stemming from incremental product innovation and table 4 analogous the share of innovative sales from radical product innovation.

The results offer support for hypothesis 1b. For SMEs a collaboration with customers pays off at all stages of the innovation process. A significant positive effect is observable for the collaboration with business customers and consumer customers in the models which measure the impact on the

\(^6\) Another reason for employing a stage specific approach is that this paper aims to explain at which stages of the NPD-process a collaboration is valuable in principle. If an intensified collaboration can raise the benefits is a different question which requires other methodological approaches (see section discussion).
share of sales from incremental innovation. In the models for radical innovation the impact of consumer customers is restricted to the stages idea generation and market launch. However, there is only partial support for hypothesis 1c. For the case of business customers large firms benefit with regard to incremental innovation all stages. Especially the positive effects at late stages are not covered by the theoretical argumentation. With respect to radical innovation the significant positive effect at the R&D stage is missing. For the collaboration with consumer customers hypothesis 1c does not fit. In large firms consumer customers have a positive effect at the stage of market launch (β=0.627**) for incremental innovation. For radical innovation a significant positive effect is observable at the testing stage (β=0.685*) and the stage of market launch (β=0.831**)

Hypothesis 2b is largely accepted. The collaboration with material suppliers at the R&D (incremental: β=1.367***; radical β=1.032***) and testing stage (incremental: β=0.913***; radical β=0.496*) has a strong positive effect on the innovation performance of SMEs. Additionally a positive effect for the stage of idea generation (β=0.475**) is observable in the model for incremental innovation. Furthermore the collaboration with service firms has a positive impact at all stages in the models for incremental and radical innovation. The estimations offer large support for hypothesis 2c. Large firms benefit from the collaboration with material supplier at the stage of idea generation (β=0.331**) and the R&D stage (β=0.620***) in terms of incremental innovation. For the share of innovative sales stemming from radical new products a positive effect is observable only at the R&D stage (β=0.482**). However, the benefits from a collaboration with service firms are comparable to the effect on the performance of the SMEs in the model for incremental innovation. Large firms benefit from a collaboration at the stage of idea generation (β=0.374**), the R&D stage (β=0.412**), the design stage (β=0563***) and the testing stage (β=0.403**). In terms of radical innovation a positive effect is observable at the design stage (β=0.492**) and the stage of market launch (β=0.456*).

Hypothesis 3b is fully accepted due to the results of the models for incremental as well as radical innovation. SMEs benefit from the collaboration with universities at all stages with the exception of the market launch stage. Thus hypothesis 3c has to be rejected. However, the results offer only partial support for hypothesis 3d. Large firms benefit from collaboration at the R&D stage (β=0.591***), the design stage (β=0.560**) and the testing stage (β=0.395**) in the models for
incremental innovation. In the models for radical innovation the positive impact is observable like hypothesized.

The results offer full support for hypothesis 4b. For SMEs a collaboration with competitors pays off at no stage of the innovation process. This holds true for incremental as well as for radical innovation. However, hypothesis 4c has to be rejected. For the share of sales from incremental innovation a negative effect of collaboration with competitors is found at the R&D stage ($\beta=-0.722^{**}$). For the share of sales from radical innovation no effect could be found.

With regard to the control variables a few differences can be observed between large and small firms. Both measures for absorptive capacity have a positive impact on innovation performance in almost all of the models although with different effect sizes. One large difference is that the total number of employees has a positive effect only within the SME subsample.

Robustness checks

Additional models where calculated to check the robustness of the results. An overview can be found in the online appendix. Firstly, the models where re-estimated with a time lag of one year between dependent and independent variables. Rationale for this kind of variation is that large firms and small firms might have different processing time to capture the value of external knowledge. Consequently a reaction at the market might be measurable only with some time lag. Secondly, the dependent variable was normalized by industry average of innovative sales to control for remaining inter industrial differences. The only change that can be observed here systematically is the decreasing effect size. Thirdly, the sample was restricted to producing firms because service firms might not stage their innovation process like producing firms or are faced by other mechanisms of appropriation. No systematic differences appear. The changed dependent variable and the restriction of the sample was combined with the different time lag. In sum it sticks out that some of the effects from the reported models cannot be called stable. The collaboration with consumer customers seems to be stable only in the stages idea generation and market launch in the subsample for SMEs. The significant positive effects of collaboration with material suppliers as well as with service firms in the stage of idea generation disappears in most of the other models. The same holds true for the positive effect at the idea generation stage for the collaboration with universities in large firms.
Additionally a sample split was made to investigate if there are differences between small (< 50 employees) and medium sized firms (50-250 employees) (Teirlinck & Spithoven, 2013). Only slight differences can be observed. Namely that the firms with less than 50 employees do not benefit from university collaboration at the stage of idea generation.

6. Discussion and Implications

Discussion

This research paper explores the impact of the timing of open innovation activities along different tasks of the new product development in large firms and SMEs. A noteworthy result is that large firms benefit at different stages from external knowledge compared to their small counterparts. Regardless to the size of firms, customers are an important partner in new product development, which is in line with previous research (Tether, 2002; Zeng, Xie, & Tam, 2010). Moreover, a collaboration with customers pays off at all stages for SMEs. A slight difference to large firms is that they do not benefit directly from a collaboration at the R&D stage. This can be explained by large firms conducting internal R&D continuously and are therefore not dependent on the collaboration at the R&D stage (Hossain & Kauranen, 2016). This is also in line with recent results that emphasize the better access to the market and a deepened understanding of customer needs as a main motives for SMEs to engage in open innovation (van de Vrande et al., 2009). Through the specialization into niche markets, SMEs focus on catering very specific customer needs (Christensen et al., 2005). One means to achieve this goal would be to collaborate at various stages with customers. However, the results are only partially congruent with other stage specific research. Knudsen (2007) found negative effects of customer collaboration at two stages; Theyel (2013) found a positive effect at least at the initial stage and Gruner and Homburg (2000) found a positive impact at early and late stages in a sample of German engineering firms.

For the impact of suppliers as collaboration partners no large differences can be observed between large firms and SMEs. At least two facets are remarkable. Firstly, the collaboration with suppliers at early stages seems not always effectuate the innovation performance positively. At a first glance this runs counter to previous results. Several authors have emphasized that an early integration of suppliers enables the firm to assess the capabilities of suppliers and improves the whole process of new product development (Handfield et al., 1999; Parker et al., 2008). However, most of the
papers which investigate supplier integration into new product development use measures of project efficiency instead of the share of innovative sales. However, for large firms the positive effect at early stages is at least observable in the models with a larger time lag. Due to the marginal differences between the two types of firms in terms of absorptive capacity measures the positive effect of an early stage collaboration in large firms is also explainable from a perspective of market power. Due to their lower demand volumes SMEs might not have the required market power to negotiate about individualized solutions with suppliers at a very beginning of the new product development process (Tether, 2002). Secondly, SMEs benefit in contrast to large firms at the stages R&D and testing. Although SMEs might have no scope in negotiating about individualized solutions with their suppliers but instead of that make adaptions to their own needs at later stages. Another explanation for the instable effects might be that an early stage collaboration with suppliers is a necessary but no sufficient condition to increase the share of sales. This issue will be discussed in the implications section.

The most surprising differences between large firms and SMEs are observed for the collaboration with universities. The positive effect at early stages is in line with the results of prior stage specific studies (Gruner & Homburg, 2000; Knudsen, 2007). The positive effects of collaboration in the middle stages fit better into existing research. Several authors have emphasized that firms supplement their lacking internal R&D capability through collaboration with universities (Eom & Lee, 2010; Veugelers & Cassiman, 2005). However, the results speak for widening the view on university-industry collaboration in SMEs. Firstly, a collaboration with universities seems not be restricted to radical innovation like discovered in previous studies (Kaufmann & Tödtling, 2001; Knudsen, 2007). Secondly, a positive impact of university collaboration is not limited to later stages of the innovation process like argued from Buganza et al. (2014). Especially the beneficial effect of university collaboration in early stages can be seen as surprising. Scholars have argued that SMEs might not have the capabilities to employ extensive search strategies (Laursen & Salter, 2014). Apparently the assessment of external knowledge as a first step in the process needs no highly specialized technological capabilities but well established knowledge about a potential use of the knowledge and trends in the area of the own business (Arbussa & Coenders, 2007). The strong impact of university collaboration might be characteristically for the German innovation system. In Germany a high share of graduates from natural and engineering disciplines can be observed which work not only in the large companies but also in SMEs. However, for large firms
a direct positive effect of collaboration with universities is restricted to the middle stages, namely R&D and testing. This might reflect their strong internal capabilities so that ideas from science might not have an additional impact.

In terms of collaboration with competitors the study brings only a little increase in existing knowledge. Despite the fact that the study uses a large scale cross-sectional sample no effects are observable for SMEs. This reflects the state of the art to a certain extend. Most of the research papers that investigate collaboration with competitors in SMEs stays at a conceptual level or is based on case studies (Eikebrokk & Olsen, 2005; Gnyawali & Park, 2009). Also for large firms the effects are not stable. One explanation could be that effects of collaboration with competitors can rather be explained by the will to share risks than to jointly develop new products (Miotti & Sachwald, 2003; Nieto & Santamaría, 2007).

The results of this paper help in their entirety to increase our understanding of open innovation in SMEs. Prior research has focused on determinants of openness in SMEs (Freel & Robson, 2016), patterns of search strategies (Brunswicker & Vanhaverbeke, 2015) or performance effects in comparison to large firms (Spithoven et al., 2013; Vahter et al., 2014). Through the use of distinct tasks of the new product development it becomes possible to get insights for which tasks SMEs collaborate. Finally, the results emphasize the necessity to have a broader view on open innovation practices of firms instead of investigating them purely R&D-centered.

**Limitations and implications for future research**

The MIP-data offer great advantages in terms of their generalizability and the differentiation of the innovation process into clearly definable tasks. Nevertheless large scale data sets have also some shortcomings which offer several opportunities for future research. Firstly, as explained in the data section it is not possible to estimate partner specific models due to issues of multicollinearity. So in this paper the question if a collaboration with one type of partner along several tasks of the innovation process rises the innovative output of the focal firm remains unexplored. It should be investigated with different methodological approaches to which extend a collaboration with one partner at several stages is advantageous.

Secondly, the stage specific items are not requested at a project level. On the one hand side firms can have very different projects with distinct requirements. On the other hand side firm level
capabilities have shown to be persistent (Hannan, Burton, & Baron, 1996). Nevertheless an analysis at the project level can help to reduce fuzziness and allows to assess additional contingency factors.

Thirdly, the mode of collaboration remains unexplored. Future research can have a look if it makes a difference if a firms engage in contractual or loose forms of collaboration. Moreover it would be interesting to examine what kind of knowledge is sourced. A firm can access readily developed solutions at markets for technology, use facilities of the partner or develop solutions collaboratively. This would be particularly interesting for the collaboration with universities. As explained above universities can offer a large variety of different knowledge, knowledge-related services and the relationships can be established in a variety of ways. Future research can also link the question of the timing with the question of the use of different transfer channels.

Fourthly, with regard to Lane and Lubatkin (1998) it would be desirable to have detailed information on the characteristics of the collaboration partners to explain potential success or failure. Such information can contain the number of partners from one type, the size of the partner, firm strategy or different forms of proximity like organizational structures, technological similarity and geographical distance (Boschma, 2005).

Due to the fact that the MIP-data cover only German firms a repeated study for other countries with a different innovation system and another qualification of the workforce would be desirable to assess the stability of the observed patterns.

Recommendations for the management of external partnerships can be made only very carefully because only the timing decision and no management practices else were investigated. Foremost, as a firm decision maker it seems to be reasonable to keep in mind the entire process of new product development. Openness for external knowledge is by no means restricted to idea generation or R&D. Furthermore especially the collaboration with customers should begin at very early stages and end at the stage of market launch to capture the customer needs. Especially SMEs should not hesitate in beginning a collaboration with universities and pick up a collaboration mode that fits the own needs. The same holds true for policy makers in authorities. They should be aware that the collaboration with universities has an impact on the innovation performance of large firms and in particular of SMEs. Here further investigation can help to deepen the understanding and choose the right policies.
References:


Appendix:

Table 1: relative frequencies of stage specific external collaboration (rounded to the full number); the first number represents the percentage of SMEs engaged in collaboration at the certain stage and the second number represents the percentage of large firms engaged in collaboration at the certain stage.

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Table 2: basic models; Tobit models with robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
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Table 3: stage specific models share of sales incremental innovation; Tobit models with robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
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<th>testing</th>
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<td>Pseudo R-Square</td>
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<td>0.115</td>
<td>0.0953</td>
<td>0.0945</td>
<td>0.110</td>
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<td>Log-Likelihood</td>
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<td>-407.6</td>
<td>-414.8</td>
<td>-410.1</td>
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<td>-1,366</td>
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<td>7.966</td>
<td>7.107</td>
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<td>42.02</td>
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Table 4: stage specific models share of sales radical innovation; Tobit models with robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

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