Integrating supply chain partners into the front end of the innovation process: Empirical evidence from the German automotive industry

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Abstract

In today's global competitive environment, firms are being challenged by developing new products not only quickly but also economically, whilst simultaneously ensuring greater novelty and market fit. The notion that product innovation should emerge primarily from within a firm is becoming obsolete and integrating external actors into the new product development process has evolved to an essential part of managerial strategy to meet the mentioned challenges. However, there is still limited empirical knowledge about the value of integrating diverse external partners for a focal firm's innovation capability and about how to integrate these partners successfully. This holds particularly true for the front end of the innovation process, which has been recognized as critical to the innovation success, because decisions made during the early stages of new product development can make the difference between success and failure. Because integrating external partners also comes with challenges and requires resources, an effective management of the front end of new product development is virtually indispensable. The four research papers included in this thesis have two overarching objectives: (1) Creating empirical evidence about the benefits that a firm can obtain from the front-end involvement of certain partners in terms of innovative outcome; (2) Providing a better understanding of the successful design of integrating external partners into the front end of innovation. Specifically, this thesis focuses on customers and suppliers as crucial external partners along the supply chain of a focal firm, that is, from a downstream and upstream perspective. The included research papers use various empirical settings within the German automotive industry. Hence, this thesis considers an industry that would hardly be better suited as it has been undergoing a major upheaval for several years and increasingly relies on external partners to maintain competitiveness. This thesis thereby contributes important empirical findings to a highly relevant research area and its results provide valuable implications for managers who are developing strategies to access and exploit innovation ideas from external partners.

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Chapter 1

Introduction

1. Theoretical background and motivation

1.1 Open innovation and the search for external knowledge

In today's global competitive environment, firms are being challenged by developing product innovations not only quickly but also economically, whilst simultaneously ensuring greater novelty and customer benefit. The notion that innovation should emerge primarily from within a firm is becoming obsolete. Scholars and practitioners are increasingly suggesting that seeking help from external actors for innovation should be an essential part of managerial strategy, and advocate an open approach to new product development (NPD) to meet the challenges above-mentioned (Gesing et al., 2015; Laursen and Salter, 2014).

The underlying concept of open innovation—a term introduced by Chesbrough (2003)—advises firms to reach beyond their own boundaries to collaborate with external partners, such as customers or suppliers. In defining openness, Chesbrough (2003, p. XXIV) states that "open innovation is a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as firms look to advance their technology". By integrating a diverse set of external partners into NPD, focal firms are assumed to increase the likelihood of gaining access to valuable new knowledge and complementary assets, thereby boosting their innovation capability and ensuring their competitiveness (e.g., Criscuolo et al., 2018; Gesing et al., 2015; Menguc et al, 2014). This view is in line with the core tenets of management theories, such as the knowledge-based view (KBV) (Grant, 1996). According to the KBV, a firm's performance and competitiveness particularly depends on the ability to pursue the strategies that involve the integration, transfer, and creation of knowledge-based resources, which are usually difficult to imitate or substitute (Grant, 1996). Hence, knowledge is considered a key resource to manage in the firm, because it is the basis of a firm's existence and of its market superiority (Kogut and Zander, 1992). While knowledge-generating processes through internal sources still provide the basis, particularly "[t]he ability to exploit external knowledge is […] a critical component of innovative capabilities" (Cohen and Levinthal, 1990, p. 128).

Besides benefits, opening the innovation process also comes with challenges that need to be mastered to be successful. King and Lakhani (2013, p. 48) emphasize that "[t]he key to success is careful consideration of what to open, how to open it and how to manage the new problems created by that openness". Implementing open innovation brings challenges for focal firms, such as organizational and cultural issues or how to find appropriate collaboration partners (Enkel et al. 2009; van de Vrande et al. 2009), while at the same time ensuring internal engagement and accounting for the variety within the innovation partner network (Enkel et al. 2009; 2011). The preference for partners in an open innovation context is crucial and has several direct and indirect cost implications. Besides the search costs (Grimpke and Sofka, 2016; Laursen and Salter, 2006) and coordination costs (Criscuolo et al., 2018), Mina et al. (2014, p. 855) argue there are "opportunity costs of any choice of partners relative to available alternatives", for example, regarding innovation outcome quality. Lopez-Vega et al. (2016, p. 126) emphasize that it is important for the respective focal firm to understand "where the appropriate knowledge is "stored" […] to effectively search for it". So far, however, little is known about the effectiveness of different external knowledge sources, which are often considered homogenous (Criscuolo et al., 2018). Besides research gaps on *where* to search and from whom to draw on external knowledge, there is also limited knowledge of *how* to search, for instance, regarding the specific design of open innovation tools and instruments. Grimpe and Sofka (2016, p. 2036) highlight the still fragmented "current theoretical understanding of how firms should organize their search for external knowledge".

1.2 The front end of the product innovation process

The front end of innovation, or what is commonly labeled the "fuzzy front end", presents one of the greatest opportunities and challenges for the overall innovation process success (Koen et al., 2001). The term "fuzzy front end" (FFE) was popularized by Smith and Reinertsen (1991), and has been described as the "territory leading up to [the] organizational-level absorption of the innovation process" (Reid and de Brentani, 2004, p. 171). The FFE starts when an opportunity is first considered valuably of further ideation and assessment, and ends when a firm chooses to invest in the idea, commit resources to its development, and launch the project (Khurana and Rosenthal, 1998; Kim and Wilemon, 2002). In the FFE, a firm conducts early predevelopment activities ranging from idea generation to idea evaluation and the development of first product concepts (Kim and Wilemon, 2002; Murphy and Kumar, 1997). Once a firm decides that an idea is ready for development, the more structured and execution-oriented development phase begins with the final product as the eventual result (Kim and Wilemon, 2002).

Contrary to the well-structured development phase, the FFE is non-routine and characterized by high levels of dynamism and uncertainty. The idea generation and idea selection stages typically involve ill-defined processes and ad-hoc decisions (Kim and Wilemon, 2002; Montoya-Weiss and O'Driscoll, 2000). Focal firms are usually confronted with a broad and thin focus, a low degree of formalization, and unstructured management methods (Kim and Wilemon, 2002). Particularly, the FFE phase has been recognized as critical to the success of innovation projects because decisions made during the FFE can make the difference between NPD success and failure (e.g., Kock et al., 2015; van den Ende et al., 2015; Verworn et al., 2008). Hence, an effective management of the FFE, including the identification and selection of the most promising ideas is crucial and spending resources up-front in the innovation process is likely to pay off in the long-run (Schoenherr and Wagner, 2016). As Hauser, Tellis, and

Griffin (2006, p. 702) note, “there is no doubt that the ‘fuzzy front end’ of a PD process has a big effect on a product’s ultimate success”.

On a conceptual basis, existing research so far has investigated different sub-processes of the FFE (Griffiths-Hemans and Grover, 2006), established a set of proportions that can influence the quality of information flows to reduce the fuzziness in the FFE (de Brentani and Reid, 2012), or developed a model on the benefits and shortcomings of using intuition in the FFE decision process (Eling et al., 2014). On an empirical basis, there is a plenty of studies investigating the effects of certain FFE activities on the overall NPD performance (e.g., Kock et al., 2015; Markham, 2013). However, these studies largely consider the *intra-firm* perspective. In contrast, research on *inter-firm* involvement in the FFE can be still described in the starting blocks (Florén and Frishammar, 2012; Schoenherr and Wagner, 2016; Wowak et al., 2016). Calls for research point to, for instance, the need for an improved understanding of how to search for external ideas or the underlying mechanisms between FFE activities in an open innovation context and a firm’s innovation capability (e.g., Eling and Herstatt, 2017; Wagner, 2012).

1.3 The importance of supply chain partners as external knowledge sources

Open innovation partners may include customers (or users), suppliers, competitors, universities, and others. The focus of this thesis is on customers and suppliers as crucial external partners along the supply chain (or value chain) of a focal firm. Hence, this thesis considers the integration of external supply chain partners from both an upstream perspective (i.e., collaborating with suppliers) and a downstream perspective (i.e., collaborating with customers), as illustrated in Figure 1 (cf. Lau et al., 2010; Menguc et al., 2014; Wynstra et al., 2010).

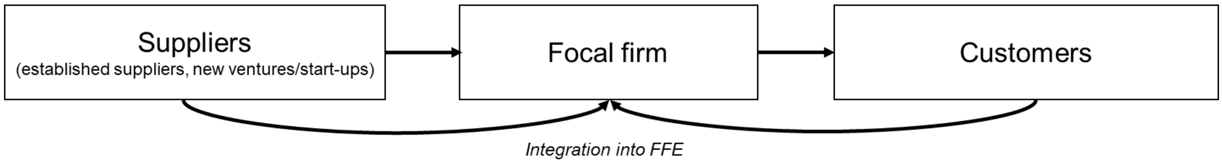

Fig.1: Simplified supply chain indicating the scope of this thesis

Integrating customers into NPD enables the focal firm to capture theirs needs and facilitates the creation of effective user-oriented designs (Menguc et al., 2014). It provides the focal firm with distinctive knowledge-based resources that can lead to a competitive advantage (Menguc et al., 2014) and enhance product performance (Lau et al., 2010). Ulrich and Eppinger (2008, p. 54) emphasize that firms "must interact with customers and experience the use environment of the product. Without this direct experience […] innovative solutions to customer needs may never be discovered." Von Hippel (2005) suggests that customers should share their knowledge about new product design, functions, and prototype assessment, that is, in the early stages of NPD. Knowing from early on what the customer wants can help avoid wasting time and making costly changes later in the NPD process (Un et al., 2010). Various instruments and methods, such as idea competitions, focus groups, or web-based toolkits (Creusen et al., 2013; Markham and Lee, 2013; von Hippel and Katz, 2002), can support the exploitation of customers' knowledge.

Research on user innovation distinguishes between "traditional" users and so-called "lead users" (e.g., Magnusson, 2009; Schweisfurth, 2017). The lead user status is a continuous and domain-specific characteristic (Morrison et al., 2004) with two core components (von Hippel, 1986). First, lead users are ahead of trends in the respective market, and thus experience needs before traditional users; second, lead users gain greater benefit from generating solutions to their problems and needs. Research on lead users has identified them as individuals possessing greater experience in the underlying field and more knowledge about product characteristics (Schreier and Prügl, 2008; Schweisfurth, 2017). Integrating lead users in a focal firm's innovation process usually follows a four-step methodology. After (1) lead user indicators are specified and (2) the required lead users systematically identified, (3) they are invited to internal workshops to generate product concepts, which are then (4) tested in the target market (Urban and von Hippel, 1988).

While open innovation has been considered for a long time from the customer integration perspective (West et al., 2014), the integration of suppliers as external sources of ideas has been increasingly taken into account (Antons et al., 2016). In recent years, supplier involvement in focal firms' innovation processes has changed from a minor activity to a strategic one, with a steady increase of suppliers' development responsibility that resulted in a transition of the supply base from the pure delivery of products to offering inimitable knowledge from the very early beginning of NPD (Schoenherr and Wagner, 2016). Collaborating with suppliers allows focal firms to access knowledge that is "part of a specialized set of skills" (Un et al. 2010, p. 678). By pooling the suppliers' knowledge and the internal expertise about which requirements need to be fulfilled and how to use suppliers' inputs in the final products, focal firms can draw on valuable technological and market knowledge while at the same time increasing the capacity for identifying and selecting the most promising solutions (Bodas Freitas and Fontana, 2018). Studies in different industries confirm that collaborating with suppliers positively affects a focal firm's product quality (Hoegl and Wagner, 2005), product variety (Al-Zu'bi and Tsinopoulos, 2012), or innovation performance (Bodas Freitas and Fontana, 2018; Menguc et al., 2014). Over recent years, focal firms have also started to extend their partner network by moving beyond the established supply base and increasingly rely on new venture suppliers (Zaremba et al., 2016; 2017), commonly labeled "start-ups". The innovative potential of new ventures is assumed to stand out "as a highly attractive feature" (Zaremba et al., 2016, p. 153) given their entrepreneurial capabilities, such as strong work ethics, high motivation, alertness, creativity, and willingness to take risks (Ouimet and Zarutskie, 2014; Ward, 2004; Weiblen and

Chesbrough, 2015; Zhao and Seibert, 2006). However, there is a lack of research on the use of start-ups as an extension of the established supply base, particularly when it comes to the early stages of a firm's innovation process (Kickul et al., 2011). Generally, existing research mainly focuses on supplier involvement in the well-formalized development phase, but less attention has been paid to the involvement in the crucial FFE (Schoenherr and Wagner, 2016; Wagner, 2012), which has been described as creating "a gap in scholarly understanding" (Wowak et al., 2016, p. 67).

1.4 Open innovation in the automotive industry

Quite different from any other industry sector, the automotive industry, which provides the empirical setting of this thesis, has been undergoing a major upheaval for several years. The automotive industry is the largest industry sector in Germany. In 2017, the automotive sector listed turnover of about €423 billion, which constitutes about 20% of the total German industry revenue. Germany is Europe's number one automotive market, accounting for about 30% of all passenger cars manufactured, and one of five cars worldwide are produced by German automotive manufacturers (GTAI, 2019). Despite these impressive numbers, the established models of the automotive industry are increasingly dissolving not only in Germany but also across the world. For instance, the conventional drivetrain technology is increasingly being replaced by alternative drivetrain technologies, the notion of driving the car yourself is being replaced by concepts of assisted and autonomous driving, and customers increasingly require digitization in the car (Bormann et al., 2018). This trend towards a new form of mobility requires firms to innovate in various technological fields, which, in turn, opens doors for new competitors and puts pressure on established automotive firms (Oliver Wyman and VDA, 2018).

To address this innovation pressure and to remain competitive, open innovation and the use of external knowledge sources for NPD has become increasingly important in the automotive industry over recent years (Cano-Kollmann et al., 2018; Ili et al., 2010; Schuster and Brem, 2015). Di Minin et al. (2010) demonstrate in their study about the Italian car manufacturer Fiat how adopting an open innovation strategy maintains a firm's innovation capability. Open innovation thus provides substantial benefits, which Lazzarotti et al. (2013, p. 53) describe based on case study findings with automotive firms, such as Robert Bosch, as "the enlargement of company's competence base, the stimulation of creativity and capability of generating new ideas, the reduction and sharing of risks related to innovation activities and costs of innovation process".

The importance of customers and suppliers (established suppliers and start-ups as potentially new suppliers) as open innovation partners within a firm's value chain holds particularly true for automotive firms. For instance, Volvo Cars regularly involves customers' needs in the front end of NPD through environmental scanning (Börjesson et al., 2006). Similarly, car manufacturers use web-based instruments, such as Audi does it with toolkits (Füller and Matzler, 2007) or BMW with ideation contests to co-create products and components with customers (Bartl et al., 2010). With regard to suppliers, the relevance is particularly high because recent decades witnessed a steady increase of product development outsourcing and a shift of both development tasks and knowledge from focal firms to suppliers (Cabigiosu et al., 2013; Chae et al., 2019). Today, automotive original equipment manufacturers (OEM) are heavily dependent on their suppliers, spending about 60% to 70% of their revenues on suppliers' goods. With an average of about 13,000 individual parts in a car, OEMs are dependent on their suppliers for a constant stream of innovative ideas (Yeniyurt et al., 2014). In addition, start-ups have become increasingly more important for automotive firms with helping them to find highly innovative solutions (e.g., Gassmann et al., 2010; Weiblen and Chesbrough, 2015; Zaremba et al., 2017).

While open innovation and the use of instruments in the automotive industry was often considered from the customer's point of view (Ili et al., 2010), firms have started to adopt open innovation practices with suppliers and start-ups, such as idea competitions (e.g., Lazzarotti et al., 2013; Schiele, 2010, Weiblen and Chesbrough, 2015), making the long-standing rigid collaboration form more open. However, research in this area is largely restricted to case study designs; quantitative studies using large sample sizes are lacking.

2. Research questions and thesis organization

As illustrated in the previous sections, open innovation and the integration of external sources of knowledge and ideas, such as customers and suppliers, are still rather nascent fields characterized by a lack of relevant empirical knowledge. This holds particularly true regarding a comprehensive view on the value of integrating customers and suppliers as crucial supply chain partners for a focal firm's innovation capability and on how to integrate these partners successfully, specifically when it comes to the integration into the front end of the innovation process. Given the importance and lack of empirical research in the automotive sector, this thesis uses the German automotive industry as the empirical setting. Following the notion that research should also produce results that are relevant and useful for practice, the overall goal of this thesis is to create knowledge that supports firms in the successful integration of external supply chain partners in the early stages of NPD. Accordingly, the overarching research questions of this thesis are:

> *RQ1: Which benefits in terms of innovative outcome can a focal obtain from the involvement of certain supply chain partners in the FFE?*
>
> *RQ2: How can a focal firm design the involvement of supply chain partners in the FFE successfully?*

Figure 2 depicts the general structure of the thesis, which includes four full research papers that has been published or are under review in reputable, international journals. While each paper investigates specific research questions, each of them contributes to various degrees to one or both of the aforementioned overarching research questions.

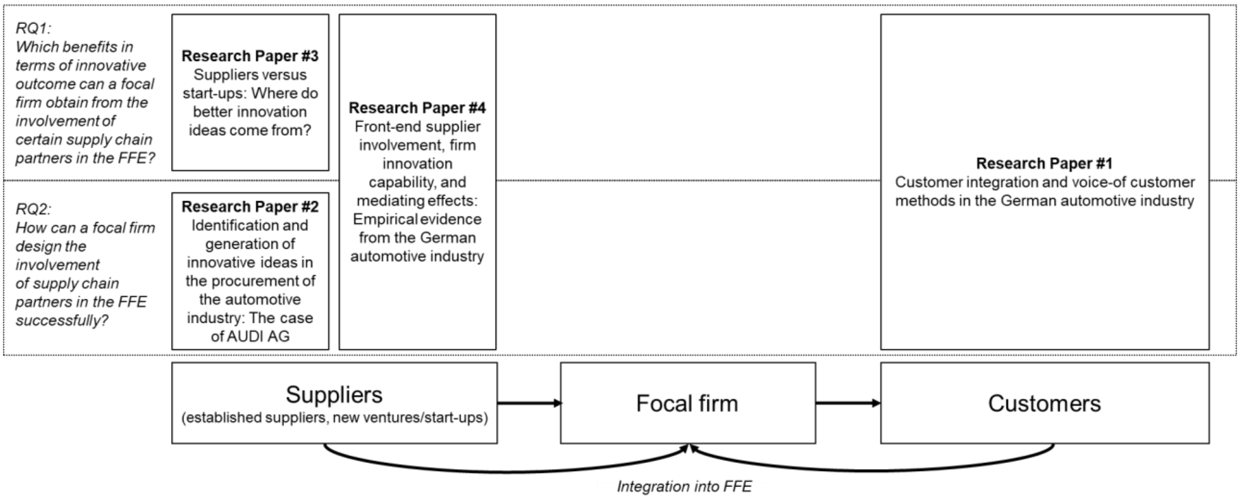

Fig. 2: Overview of research papers included in the thesis

As illustrated in Figure 2, research paper #1, entitled "Customer integration and voice-of customer methods in the German automotive industry", addresses both research questions by considering the customer as the external partner to be integrated into the focal firm's FFE. Based on 108 filled online questionnaires, the paper provides a general overview of the main innovation drivers and sources of innovative ideas in the German automotive industry and explores the specific value of innovative ideas coming from customers in terms of idea quality and quantity. Furthermore, the paper investigates the utilization of different voice-of-customer methods. A special focus is on the lead user method, which involves users who are ahead of the market, making them attractive sources for innovative ideas. Hence, research paper #1 does not only provide evidence about the value of customers' ideas compared to other external sources and among different players in the automotive value chain. It also provides interesting insights into which open innovation instruments can and should be used for generating innovative ideas.

Specifically, the results show that easy to use methods, such as idea workshops are frequently used; however, particularly if more-complex methods such as toolkits are frequently used, the quality of customers' innovative ideas is rated significantly higher. Regarding the lead user method, it can be noted that although the awareness is rather low, but if the usage frequency is high, negative aspects of the method become less important.

Given the even more limited knowledge on the integration of upstream partners into the focal firm's FFE, the remaining three research papers focus on suppliers (established suppliers and new venture suppliers/start-ups) as external partners. Research paper #2 "Identification and generation of innovative ideas in the procurement of the automotive industry: The case of AUDI AG" particularly contributes to the questions of how focal firms can design the involvement into the idea generation stage of NPD. Based on an in-depth case study of a large German automotive manufacturer and 18 expert interviews, the article explores nine open innovation instruments that help to structure the search for ideas in the FFE from both established suppliers and start-ups. In this context, research paper #2 particularly examines the role of procurement, how purchasers assess the relevance of suppliers and start-ups as external idea sources, and which challenges are related to extending the established supply base by collaborating with new ventures (e.g., integrating their technology quickly into the vehicle). Whereas extensive research exists on the importance of R&D or marketing interfaces, the paper addresses procurements' key role for a firm's innovation capability that has become increasingly important over recent years.

Research paper #3 "Suppliers versus start-ups: Where do better innovation ideas come from?" further takes up the trend that many firms have moved beyond their existing supply base and have increasingly used start-ups as an additional source of ideas. Yet there is no empirical evidence regarding whether start-ups' ideas actually outperform those of established suppliers.

Research paper #3 addresses this question by presenting a real-world comparison of 314 supplier and start-up ideas—ideas that were identified, evaluated, and followed up over the course of an open innovation initiative conducted by a large German automotive manufacturer. The results show that start-ups' ideas are characterized by a higher degree of novelty and—to some extent—higher end customer benefit when compared with ideas generated by established suppliers. However, suppliers' ideas provide a better fit with existing technologies and create more valuable business opportunities while meeting technical and economic criteria, thus being more likely to be selected for implementation. Hence, the paper provides valuable insights regarding the outcome of supplier and start-up involvement in the front end of the innovation process in terms of key quality dimensions.

Finally, while research papers #2 and #3 rely on data from a single case, research paper #4, entitled "Front-end supplier involvement, firm innovation capability, and mediating effects: Empirical evidence from the German automotive industry", uses survey data of 206 German automotive firms. The article examines the effects of involving suppliers in the FFE phase on the focal firm's radical innovation capability and incremental innovation capability and explores the underlying mechanisms through which supplier involvement in the FFE contributes to a focal firm's innovation capability. The results show that integrating suppliers into the FFE enhances the focal firm's radical and incremental innovation capability. While supplier ideas search practices mediate the relationship between supplier involvement in the FFE and a firm's incremental innovation capability, this is the case for supply base variety, non-monetary incentives, and early purchasing involvement with respect to a firm's radical innovation capability. Hence, research paper #4 contributes comprehensively to both overarching research questions. By doing so, it extends the hitherto limited knowledge on supplier involvement in the FFE from a theoretical point of view that, in turn, will help managers to decide whether they should work intensely with suppliers from early on and how the FFE should best be organized depending on the innovation objective.

Table 1 provides a summary of all research papers, which are included in the following chapters 2-5. Chapter 6 provides the conclusion of this thesis.

Table 1: Summary of research papers included in the thesis

	Title	Authors	Content of the research paper	Methodology	Sample size
Research Paper #1 [Chapter 2]	Customer integration and voice-of customer methods in the German automotive industry	Rese, A., Sänn, A., Homfeldt, F.	• Provides an overview of the main innovation drivers and sources of innovative ideas in the German automotive industry • Analyzes the specific value of innovative ideas coming from customers in terms of idea quality and quantity • Investigates the utilization of voice-of-customer methods for idea generation in the FFE with a specific focus on the lead user method	Survey	108
Research Paper #2 [Chapter 3]	Identification and generation of innovative ideas in the procurement of the automotive industry: The case of AUDI AG	Homfeldt, F., Rese, A., Brenner, H., Baier, D., Schäfer, T. F.	• Examines procurement's specific role in the early stages of NPD in the automotive industry • Investigates the relevance of suppliers and start-ups as external idea sources and which challenges are related to the extension of the established supply base • Explores a variety of open innovation instruments that help to structure the search for ideas in the FFE	Case study (interviews, secondary data, workshop)	1 case with 18 interviews
Research Paper #3 [Chapter 4]	Suppliers versus start-ups: Where do better innovation ideas come from?	Homfeldt, F., Rese, A., Simon, F.	• Compares innovation ideas generated by established suppliers and start-ups in an open innovation initiative in the FFE of an automotive manufacturer in terms of key quality dimensions (novelty, customer benefit, and implementation)	Natural setting of an open innovation initiative (idea database, secondary data, observation)	314
Research Paper #4 [Chapter 5]	Front-end supplier involvement, firm innovation capability, and mediating effects: Empirical evidence from the German automotive industry	Homfeldt, F., Rese, A.	• Examines the effects of involving suppliers in the FFE phase on the focal firm's radical innovation capability and incremental innovation capability • Explores the underlying mechanisms through which supplier involvement in the FFE contributes to a focal firm's innovation capability	Survey	206

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Chapter 2

Customer integration and voice-of customer methods in the German automotive industry

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Abstract:

Open innovation and the integration of external sources have become increasingly important for the automotive industry. Users and customers possessing needs and problems are major sources for innovative ideas. The idea generation can be supported by the use of specific methods and instruments. This study investigates internal and external sources of innovative ideas and the use of voice-of-customer (VoC) methods in the German automotive industry. A special focus is on the lead user method which involves users who are ahead of the market making them attractive sources for innovative ideas. The findings show that easy to use VoC methods are mostly used to gather customers' needs and wants. Nevertheless, more complex methods such as the lead user method proved advantageous with regard to the quality and quantity of innovative ideas. Because negative aspects became less important with increasing usage frequency, their usage should be encouraged.

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1. Introduction

The need for innovation is virtually unchallenged. This holds particularly true for the automotive industry and the current context of a crisis-coloured global environment. After the 2008–2009 global economic crisis, mature markets in the USA and Europe experienced a massive plunge in vehicle sales resulting in overcapacities and financial problems. Production more and more takes place in emerging economies such as China, Brazil or India with a strong demand for vehicles (Cruz and Rolim, 2010; Jullien and Pardi, 2013; van Biesebroeck and Sturgeon, 2010). In addition, national manufacturers of emerging countries are increasingly pursuing an internationalisation strategy with their products (Balcet et al., 2012). To remain competitive in 2011 German Automotive Original Equipment Manufacturers (OEM) invested €34.8 billion – €5 billion more than in 2010 – on R&D representing 9.4% of turnover (ZEW, 2013). Ili et al. (2010, p.246) describe the automotive industry as being “trapped by cost and innovative pressure”.

Nevertheless, innovations often fail to be financially profitable. Pauwels et al. (2004) mention styling changes (‘facelifts’) within the car model’s life cycle which do not cover costs. The high failure rates point to the need of companies to constantly improve innovation activities and innovation management. Customers’ needs and wants have been consistently identified as a critical success factor in the new product development (NPD) process (e.g., Callahan and Lasry, 2004; Cooper and Kleinschmidt, 1987; Ottum and Moore, 1997). Change in customer preferences, for example, with regard to environmental or social issues has to be taken into account (Loureiro et al., 2012; Nadin et al., 2009). Therefore, the integration of the customer in the product development process has been the focus of innovation management literature for some time (Gruner and Homburg, 2000; Jaworski and Kohli, 1993). The opening of the innovation process (Chesbrough, 2003; von Hippel, 2005) can have several benefits which Lazzarotti et al. (2013, p.53) describe for the automotive industry as “the enlargement of company’s competence base, the stimulation of creativity and capability of generating new ideas, the reduction and sharing of risks related to innovation activities and costs of innovation process".

The exploitation of customers' knowledge can be supported by various methods and instruments. In the following, research methods that investigate customers' needs and wants are called, in accordance with Cooper and Dreher (2010), 'voice-of-customer' (VoC) methods. Studying NPD best practices in Product Development and Management Association (PDMA) member firms Barczak et al. (2009) found that with regard to market research methods VoC came in third place and the lead user method in fifth place.

In the follow-up study (Markham and Lee, 2013), the ranking of the two methods even improved (VoC: first place, lead user method: fourth place). The lead user method focuses on customers being ahead of trends, e.g., in the automotive market (Urban and von Hippel, 1988). Several empirical studies confirmed that the lead user method can support idea generation and consequently company success (e.g., Lilien et al., 2002; Urban and von Hippel, 1988). Nevertheless, in analysing seven case studies of European and North American companies in the automotive and machinery sector, Lichtenthaler (2004) found that lead user analyses were only used sometimes. Recently, Kamp and Bevis (2012) emphasised the importance of opening the innovation process in the automotive industry due to the increasing car complexity and disruptive incidents such as the economic crisis.

This article focuses on VoC methods and especially the lead user method as methods for generating innovative ideas with external partners in the automotive industry. The issue of open innovation in the automotive industry is still at an early stage and mainly investigated with the help of case studies (Ili et al., 2010; Karlsson and Sköld, 2013; Lazzarotti et al., 2013; Lichtenthaler, 2004). Correspondingly, there is a lack of research in this area in terms of the relevance of VoC methods in general and of the lead user method in particular using a large scale sample. The main goal of the article is to investigate the following three research questions:

- What are the main sources of innovative ideas in the automotive industry?
- How frequently are VoC methods used in the automotive industry?
- How frequently is the lead user method used and how are pros and cons assessed?

To investigate the research questions a literature review and expert interviews were used to select relevant VoC methods in the German automotive industry. An online survey was conducted to evaluate the utilisation of VoC methods, especially the lead user method, and their effect on the generation of innovative ideas taking users/customers into account.

2. Review and selection of VoC methods

Different methods, tools and techniques have been developed and employed in the NPD process. Empirical studies often consider and investigate methods with regard to their benefits in the NPD process that could be used for different tasks in different phases (Creusen et al., 2013). One of these tasks is customer integration (see e.g., the literature review of Graner and Mißler-Behr, 2012). Research has established and confirmed the potential benefits of customer integration with respect to the company's knowledge base, and finally to NPD success [see e.g., Creusen et al. (2013) or Hemetsberger and Godula (2007) for more information regarding the literature]. Cooper and Dreher (2010) found that idea management was the most important driver of the sales of new products. Correspondingly, several authors propose the need for a 'systematic' approach to assess customers' needs and wants [Cooper and Dreher, (2010), p.39; Kärkkäinen et al., (2001), p.162]. Nevertheless, the knowledge of (VoC) methods and their application in the context of NPD is described as being 'limited' [Creusen et al., (2013), p.82].

VoC methods were chosen for this study based on a literature review that investigated empirical studies focussing on these methods (Table 1) as well as studies taking methods for the whole NPD process into account (Table 2). In addition, web-based methods, e.g., toolkits and netnography (Hemetsberger and Godula, 2007; Piller and Walcher, 2006), which have been used to integrate customers in the automotive industry (Füller and Matzler, 2007) were included in the analysis. Afterwards, the various methods identified were discussed with seven R&D managers from the German automotive industry [for a similar procedure, refer to Yeh et al. (2010)]. Members, managers and directors of innovation management along the automotive value chain – from a large German automotive manufacturer, three automotive suppliers, one automotive service provider, and one automotive consulting company –, and in addition a university professor and former head of a working group in the German Association of the Automotive Industry were asked to rate the different methods with regard to their importance to the automotive industry.

The literature revealed a paucity of empirical studies on VoC methods in NPD (see Table 1). Overall, the studies largely differed with regard to the selected methods. The determination of their usage frequency was always in the focus. In addition, Cooper and Dreher (2010) included perceived effectiveness of the respective methods, and Creusen et al. (2013) the type of gathered information and main usage reasons. With regard to usage frequency the results are inconsistent. For example, focus groups are twice ranked in second place and once rated in seventh place and in ninth place. Concept and product tests (e.g., alpha, beta, gamma testing, in-house use tests) were excluded from the analysis because of their use in the later stages of the NPD process. According to Engelbrektsson and Soederman (2004, p.147), “most customer contact appears to be in the early stages of the product development (i.e., in pre-studies and in concept generation)”.

Table 1: Empirical studies investigating VoC methods in NPD

Study	VoC methods		Sample
Barczak et al. (2009)	*Beta testing (1)* Customer site visits (2) Voice of the customer (3) *Alpha testing (4)* Lead users (5)	*Concept tests (6)* Focus groups (7) *Gamma testing (8)* Ethnography (9)	416 firms (predominantly PDMA practitioners) 59.1% B-to-B
Cooper and Dreher (2010)	Customer visit teams (1) Focus groups (2) Lead user analysis (3) Customer advisory board (4) Customer brainstorming (5)	Customer helps design product (5) Ethnography (7) Community of enthusiasts (8)	160 U.S. firms 67.8% B-to-B
Creusen et al. (2013)	Interview (1,1) Focus group (2,2) Complaint analysis (e.g. former customer service) (3,-) Segmentation (e.g. use of demographic data) (4,-) Images or mood boards (5,-) Questionnaire survey (6,3) Brainstorming (-,4) Internet communities (7,-) Creating typical consumers (e.g. personas, story writing) (8,-) Lead user analysis (9,6) Projective techniques (e.g. free association) (10,-)	Observational research (e.g. ethnography) (11,5) Co-design (-,7) Conjoint analysis (-,8) Homework tasks (e.g. cultural probes, workbooks) (12,-) Grouping tasks (e.g. repertory grid) (13,-) User design (e.g. internet idea competition, product configurator) (14,9) Laddering (means end chains) (15,-) Scenario techniques (-,10)	88 Dutch firms 100% B-to-C
Markham and Lee (2013)	Voice of customer (1) Customer site visit (2) *Beta testing (3)* Lead users (4) *Test markets (5)* *Alpha testing (6)* *Concept tests (7)* Ethnography (8) Focus groups (9)	*Gamma testing (10)* Concept engineering (11) Online focus groups/ surveys (12) Tradeoff analysis (13) *Pre-test markets (14)* Creativity sessions (15) Fusing methods (16) Online communities (17)	453 firms (predominantly PDMA practitioners) 56.4% B-to-B

Notes: PDMA: Product Development Management Association (North America).
In brackets: ranking of usage frequency; if two values are given the first describes the ranking in the early fuzzy front end, and the second the ranking in the late fuzzy front end.
In italics: methods excluded from further analysis.

Other empirical studies investigating the use of various methods over the whole NPD process also included VoC methods (see Table 2). Conjoint analysis was most frequently mentioned followed by focus groups and idea generation methods.

Table 2: VoC methods in empirical studies investigating method usage over the whole NPD process

VoC method	Reference
Conjoint analysis	González and Palacios (2002); Palacios and González (2002); Yeh et al. (2010); Nijssen and Frambach (2000); Nijssen and Lishout (1995); Chai and Yan (2006); Engelbrektsson and Soederman (2004); Mahajan and Wind (1992); Thia et al. (2005); van Kleef et al. (2005); Büyüközkan et al. (2004)
Focus groups	Nijssen and Frambach (2000); Nijssen and Lishout (1995); Chai and Yan (2006); Engelbrektsson and Soederman (2004); Mahajan and Wind (1992); Thia et al. (2005); van Kleef et al. (2005)
Idea generation methods (e.g. brainstorming, morphological analysis, synectics)	Yeh et al. (2010); Nijssen and Frambach (2000); Nijssen and Lishout (1995); Hidalgo and Albors (2008); Chai and Yan (2006); Mahajan and Wind (1992)
Delphi method	Nijssen and Frambach (2000); Nijssen and Lishout (1995); Mahajan and Wind (1992)
Clinic	Engelbrektsson and Soederman (2004); Mahajan and Wind (1992)
Lead user analysis	van Kleef et al. (2005)
Observation studies	Engelbrektsson and Soederman (2004)
Customer interviews (questionnaires, in person, telephone)	Engelbrektsson and Soederman (2004)
Laddering	van Kleef et al. (2005)

Note: Methods are sorted in descending order by the number of cited references.

The findings of empirical studies available up to 2012 were synchronised and together with web-based methods, e.g., toolkits and netnography, discussed with the automotive experts. In total, ten methods were selected to be investigated in the study. There follows a short description of these methods.

Questionnaire surveys are used to gather quantitative, statistically evaluative data of customers' opinion, needs and wants (Creusen et al., 2013). *Expert interviews (Delphi method)* can be described as a systematic, in-depth survey process which serves to assess future events or technical developments. *Conjoint analysis* is a specific multivariate method to determine the importance of product attributes and attribute levels using attribute-level-combinations as concepts to be evaluated by respondents (Green and Srinivasan, 1978). In *idea workshops* different creativity techniques (e.g. brainstorming) are used by a moderator so that the participants, e.g. customers, can generate as many ideas as possible which are evaluated at the end of the workshop (Creusen et al., 2013). *Idea competitions* also support the collection of potential innovative ideas. A company calls for ideas to a specific problem or issue within a competition that offers incentives for participation. After a predefined timeline the ideas are evaluated by a jury (Ebner et al., 2009). *Lead user analysis* focuses on innovative customers or users being “in advance of the market” (Urban and von Hippel, 1988, p.570) and are expected to “modify products or use them in unforeseen ways to meet their needs” (Eisenberg, 2011). After lead user indicators are specified and the required lead users systematically identified, they are then invited to company workshops to obtain data with regard to product attributes or concepts (Urban and von Hippel, 1988). In *focus groups* – contrary to lead user workshops – typical customers participate and discuss a specific issue, e.g. product attributes or concepts, supported by a moderator (Fern, 1982). Netnography and toolkits are two online-based methods. *Netnography* is a qualitative method identifying relevant existing online communities and examining contributions by users with regard to needs or attitudes (e.g. Kozinets, 2002). *Toolkits* are internet-based development environments supporting the conceptualization of new products. Customers can transfer their needs and wants in their own designs for new products or product modifications (Thomke and von Hippel 2002; von Hippel, 2001; von Hippel and Katz, 2002). In *car clinics* the detailed opinion and preferences of customers with regard to a new model car in a showroom environment are collected (Urban and Roberts, 1990).

3. Empirical research

3.1 Sample and data collection

Data collection started with seven expert interviews in July and August 2012. Besides the VoC method selection in general another focus was on the lead user method in the automotive industry in terms of knowledge and practical application, limitations and shortcomings as well as problems and obstacles and an outlook on future use. The results of the expert interviews were used to develop an internet-based questionnaire. Because research has shown that respondents might be familiar with a method, but not with the method name (Creusen et al., 2013; Nijssen and Lieshout, 1995), the method names were tagged with labels including a short description of the corresponding method.

3.2 The questionnaire

The questionnaire consisted of three parts. Part 1 concentrated on the knowledge and use of the lead user method. A brief description ensured that each respondent had the same understanding of the lead user method. Respondents were asked if they knew the lead user method. Only if this was the case would they assess the following questions starting with the frequency of usage of this method in their company on a five-point scale ranging from 1 = ‘not at all’ to 5 = ‘in each project’. In addition, the respondents indicated whether they had already had personal experience with the method themselves. After that, based on the literature, respondents were asked to assess the benefits of lead users as well as problems of the lead user method (costs, time exposure, and niche orientation). The items were rated on a 5-point scale ranging from 1 = ‘strongly disagree’ to 5 = ‘strongly agree’.

In part 2, all respondents selected the main driver of innovation and indicated for which reasons the user/customer is integrated in the product development process. Both the number and quality of innovative ideas generated by different stakeholder groups inside and outside the company was rated on a five-point scale ranging from 1 = ‘very low’ to 5 = ‘very high’. Subsequently, we asked all respondents to indicate for another nine selected VoC methods their level of knowledge or usage of the method in their company on a five-point scale ranging from 1 = ‘not at all’ to 5 = ‘in each project’. Part 3 collected data on company characteristics such as automotive category (e.g., manufacturer, supplier, engineering service provider) or size (small, medium-sized or large company). With regard to the respondents, information on their area of activity was gathered.

3.3 Data collection procedure

The data was collected in September and October 2012. The following steps were taken to enable the highest possible return: Several associations were requested to support the distribution of the internet-based questionnaire, e.g., the German Association of the Automotive Industry, the Bavarian Innovation and Cooperation Initiative for the Automotive Suppliers Industry (BAIKA), associations of German automotive suppliers (GVA, ARUA), the German Automobile Club (ADAC), DEKRA and TÜV as well as chambers of commerce. In addition, several German universities and students' associations (VWI) were asked to assist in the distribution of the internet-based questionnaire. The survey link was also placed in different online forums.

In total 109 survey participants completed the questionnaire. One participant belonging to another industry sector had to be excluded. Thus, 108 questionnaires were included in the analysis. The majority of the respondents were from automotive suppliers (56.5%), followed by engineering service providers (17.6%), automotive manufacturers including commercial vehicles (13.9%) and other service providers, for example, automotive or innovation management consulting firms (12.0%). Over half of the corresponding firms were medium-sized enterprises (54.6%), followed by large enterprises (25.9%) and small enterprises (19.4%). While automotive manufacturers were often classified as large enterprises (73.3%), this is only the case for about a quarter of the automotive suppliers (26.2%) and 7.7% of the other service providers. Automotive suppliers (57.4%), engineering service providers (52.6%) and other service providers (76.9%) were more frequently described as medium enterprises. Due to the non-availability of reliable data, a response rate could not be established. Nevertheless, Schade et al. (2012) found a similar company size distribution in their investigation of automotive suppliers. Thus, the study represented the players in the German automotive industry well with large OEMs, but also small and medium-sized suppliers. Corresponding to the topic of the survey most respondents operated in the following areas: R&D (39.8%), product/project management

(15.7%), marketing and sales (15.7%), innovation management (10.2%) and (general) management (6.5%).

4. Research results

4.1 Customer integration

As innovation drivers of automotive companies, changing customer demands, but also pressure from competitors or regulations, e.g., with regard to emission standards, were mentioned (Kamp and Bevis, 2012). Correspondingly, the majority of the respondents rated users/customers and their preferences as the primary driver of innovative activities (57.4%), followed by competitive pressures (23.1%), regulation (12.0%) and internal cost optimisation (7.4%). With regard to the automotive value chain, user/customer preferences played a significantly larger role for automotive suppliers, engineering service providers and other service providers ($p = 0.06$). In contrast, competitive pressures were the main innovation driver for automotive manufacturers followed by the user/customer and to some extent also internal cost optimisations. Regulation requires innovation especially from engineering service providers (see Table 3).

Table 3: Innovation drivers with regard to the automotive value chain (in %)

	User/customer	Competitors	Regulation	Internal cost optimization
Automotive manufacturers	33.3	46.7	0.0	20.0
Automotive suppliers	62.3	21.3	9.8	6.6
Engineering service providers	57.9	15.8	26.3	0.0
Other service providers/consulting	61.5	15.4	15.4	7.7

Customer integration occurred in all phases of the innovation process. Most frequently, customers are involved at an early phase to assess their needs (65.7%), trends (28.7%) and to generate innovative ideas (43.5%). Nevertheless, customers also played a role in later phases, e.g., screening and choosing concepts (45.4%) or testing concepts and prototypes (45.4%). When launching the product on the market customer integration was of minor importance (18.5%). Even if there were no significant differences with regard to the different automotive categories from which the respondents came, it can be noted that it was predominantly automotive suppliers who responded to the survey. From their perspective, the user/customer is usually the automotive manufacturer(s). Only very few respondents did not integrate customers in the innovation process (5.6%).

With regard to the generation of innovative ideas, users/customers as a source were ranked after designers and engineers in terms of quality and quantity (see Table 4). Automotive suppliers rated the quality of innovative ideas from users/customers significantly higher (see Table A1 in the Appendix), indicating that automotive manufacturers were integrated in the early phases of their innovation process. Interestingly, sources outside the company's borders, e.g., suppliers and especially industry outsiders, were considered to be of minor importance. Both categories are the only ones that are significantly correlated with $p < 0.01$ regarding the number ($r_s = 0.411$) and quality of innovative ideas ($r_s = 0.330$). In particular, automotive suppliers and engineering service providers rated outside sources low (see Table A1 in the Appendix), while automotive manufacturers and other service providers seem to be more satisfied. Overall, the results confirm that open innovation is still in the starting blocks in the automotive industry.

Table 4: Importance of sources of innovative ideas

	Number of innovative ideas[a]	Quality of innovative ideas[a]
Designers/engineers	3.94 (0.878)	4.06 (0.863)
Users/customers	3.03 (1.164)	2.93 (1.020)
Management	2.75 (1.254)	3.09 (1.124)
Employees of other company areas	2.43 (1.112)	2.64 (1.018)
Suppliers	2.13 (0.948)	2.69 (1.080)
Industry outsiders	1.75 (0.996)	2.05 (1.088)

Note: [a] Mean value (standard deviation) on a scale of 1 = ‘very low’ to 5 = ‘very high’.

4.2 Method use in general

On average about six of the methods were known (mean value: 6.44) and five methods (mean value: 4.68) were at least rarely used (value 2 or more on a usage frequency scale of 1 = ‘not at all’ to 5 = ‘in each project’). With regard to the awareness of the selected methods for idea generation and assessment of customers’ needs and wants, some methods were rather unknown to the participants. These were in particular more complex methods such as conjoint analysis, the lead user method and netnography. The lead user method was ranked in second to last place. In comparison ‘classic’ and easy to use methods such as idea workshops, questionnaire surveys as well as idea competitions and expert interviews were well known and rather well used (see Table 5). Nevertheless, if the participants were aware of a method, it was rather well employed by about 50% and more of these respondents. This is especially true for the lead user method which displayed the second highest usage rate. One exception is netnography. The analysis of online communities with regard to the consumers is rather unknown and infrequently used. Nevertheless, the usage frequency in innovation projects is rather high for those participants employing the method. Creusen et al. (2013) found a similarly high usage rate by Dutch B-to-C companies for methods such as (expert) interviews, focus groups and questionnaire surveys in the early phases of the innovation process.

Table 5: Awareness and use of selected methods (in %)

	Known by	Used by (if known) [a]	Used in every project	Frequency of use [b]	Ranking of usage level
Idea workshops	97.2	92.4	19.0	2.64	1
Questionnaire survey	90.7	71.4	4.1	1.87	7
Idea competitions	88.9	59.4	4.2	1.82	8
Expert interview	72.2	73.1	1.3	1.65	9
Focus groups	58.3	68.3	6.3	1.93	4
Toolkits	46.3	74.0	6.0	1.89	6
Car clinic	38.9	47.6	7.1	2.20	3
Conjoint analysis	35.2	55.3	2.6	1.82	8
Lead user method	28.7	80.6	3.2	1.92	5
Netnography	16.7	27.8	5.6	2.60	2

Notes: [a] At least value 2 on a usage frequency scale of 1 = ’not at all’ to 5 = ‘in each project’.
[b] Mean value.

The use of the methods is correlated (see Table A2 in the Appendix). In particular, if companies make use of car clinics and toolkits most other methods are significantly correlated. With regard to the lead user method, this is significantly the case for the following methods: focus groups (r_s = 0.386, p = 0.042), car clinic (r_s = 0.557, p = 0.011) and conjoint analysis (r_s = 0.454, p = 0.023).

With regard to the number and quality of innovative ideas of users/customers the findings show that especially if toolkits are frequently used the quality of users/customers’ innovative ideas is rated significantly higher (see Table 6). Toolkits also have a weak significant effect on the number of innovative ideas, as do idea competitions.

Table 6: Number and quality of innovative ideas from users/customers with regard to the frequency of method use

	Number of innovative ideas from users/customers [a]			Quality of innovative ideas from users/customers [a]		
	Non/rare use of method	Use of method (>=3)	F-value	Non/rare use of method	Use of method (>=3)	F-value
Idea workshops (n = 84[b])	2.83 (1.20)	3.08 (1.15)	0.86	2.63 (1.10)	3.01 (1.00)	2.73
Questionnaire survey (n = 38[b])	2.91 (1.26)	3.24 (0.94	1.19	2.80 (1.07)	3.16 (0.89)	3.09^{+}
Expert interview (n = 28[b])	2.96 (1.25)	3.21 (0.88)	0.97	2.88 (1.04)	3.07 (0.98)	0.77
Idea competitions (n = 31[b])	2.90 (1.21)	3.35 (0.98)	3.52^{+}	2.83 (1.04)	3.16 (0.93)	2.32
Focus groups (n = 25[b])	2.96 (1.17)	3.24 (1.13)	1.08	2.92 (1.08)	2.96 (0.79)	0.04
Toolkits (n = 23[b])	2.92 (1.20)	3.43 (0.95)	3.66^{+}	2.76 (1.01)	3.52 (0.85)	10.88**
Car clinic (n = 14[b])	2.98 (1.18)	3.36 (1.00)	1.29	2.91 (1.04)	3.00 (0.88)	0.08
Conjoint analysis (n = 7[b])	3.00 (1.20)	3.43 (0.98)	0.89	2.94 (1.03)	2.71 (0.95)	0.32
Lead user method (n = 17[b])	2.96 (1.16)	3.41 (1.12)	2.22	2.90 (1.08)	3.06 (0.66)	0.34
Netnography (n = 5[b])	3.02 (1.17)	3.20 (1.10)	1.11	2.93 (1.02)	2.80 (1.10)	0.08

Notes: [a] Mean value (standard deviation) on a scale of 1 = ‘very low’ to 5 = ‘very high’.
[b] In brackets: number of respondents with use of method >=3 (1 = ‘not at all’, ..., 5 = ‘in each project’).
$^{+}$ Significant with $p < 0.1$; ** significant with $p < 0.01$.

4.3 Utilisation and assessment of the lead user method

The lead user method is especially known and used by automotive manufacturers (40.0%) and (other) service providers who are active in automotive or innovation management consulting (53.8%). In contrast, the method is rather unknown by automotive suppliers (14.8%) and engineering service providers (15.8%). If (other) service providers – which in this case should have the necessary knowledge – were excluded, we found a weak correlation between company size and usage frequency ($r_s = 0.371$, $p = 0.074$, $n = 24$). The findings of Creusen et al. (2013, p.93) who argue that “(m)aybe small companies find the method too time intensive or do not possess the necessary knowledge about this relatively new method” were confirmed.

About two thirds (61.3%) of the participants who knew the lead user method had personal prior experience with this method. Nevertheless, prior experience did not have an effect on the usage frequency of the lead user method. Even if the usage frequency of these participants was higher (mean value: 2.74 on a scale of 1 = ‘not at all’ to 5 = ‘in every project’), there were no significant differences in comparison to those participants who did not have prior experience with the lead user method (mean value: 2.25). The lead user method was rather just as likely to be used to develop new technologies (10.5%), new car concepts (8.3%), line extensions (6.5%), improvement of internal processes (6.5%) and vehicle installations (6.5%).

The innovation drivers of the automotive companies did not have a significant effect on the awareness and use of the lead user method, e.g., it could not be established that the lead user method was better known or used more often if the user/customer is the driver of innovation. For example, the usage frequency of the lead user method was similarly high for companies with users/customers and their preferences as the primary driver of innovative activities (mean value: 2.50 on a scale of 1 = ‘not at all’ to 5 = ‘in every project’), as well as competitive pressures (mean value: 2.50), regulation (mean value: 2.75) and internal cost optimisation (mean value: 3.00).

If the lead user method was frequently used the number and quality of innovative ideas from sources outside the company (e.g., suppliers and industry outsiders) was rated significantly higher than if the method was not or rarely used (see Table 7). Nevertheless, the users/customers seem to play no significant role. These findings indicate that suppliers and industry outsiders, but not users/customers, are important for automotive companies as external partners when generating innovative ideas.

Table 7: Number and quality of innovative ideas from different sources with regard to the frequency of lead user method use

	Number of innovative ideas [a]			Quality of innovative ideas [a]		
	Non/rare use of method	Use of method (>=3)	F-value	Non/rare use of method	Use of method (>=3)	F-value
Designers/engineers	3.89 (0.85)	4.18 (1.02)	1.53	4.01 (0.88)	4.29 (0.77)	1.55
Management	2.74 (1.28)	2.82 (1.13)	0.07	3.07 (1.10)	3.24 (1.25)	0.32
Users/customers	2.96 (1.16)	3.41 (1.12)	2.22	2.90 (1.08)	3.06 (0.66)	0.34
Suppliers	1.98 (0.92)	2.94 (0.66)	16.99**	2.57 (1.07)	3.35 (0.93)	7.98**
Industry outsiders	1.57 (0.88)	2.71 (1.05)	22.25**	1.87 (0.98)	3.00 (1.17)	17.94**
Employees of other company areas	2.46 (1.11)	2.24 (1.15)	0.59	2.60 (1.03)	2.82 (0.95)	0.66

Notes: Non/rare use, n = 91 vs. use, n = 17.
[a] Mean value (standard deviation) on a scale of 1 = ‘very low’ to 5 = ‘very high’.
** Significant with $p < 0.01$.

The respondents were very well aware of the positive characteristics of lead users being ahead of trend, displaying strong needs, having experience and expertise with regard to their needs and providing innovative ideas (see Table 8). On the other hand, the lead user method was also connected with high costs and time exposure, a niche orientation and questioning of innovative ideas by developers/engineers as well as a lack of confidence in the method, because of the technology-driven innovations in the automotive industry. Nevertheless, these negative aspects were seen as less problematic with increasing usage frequency of the method (see Table 8). This is particularly true for the assessment of high costs, time exposure and lack of confidence in the method. In contrast, there was no significant (positive) relationship between the awareness of lead user benefits and usage frequency.

Table 8: Assessment of lead users and the lead user method

Benefits of lead users	Mean value [a]	Correlation with usage frequency [b]
Lead users are more interested that their needs are met than ordinary users.	4.13	-0.114
Lead users show requirements for the product earlier than ordinary users.	4.03	-0.021
Lead users have the expertise to develop solutions to problems.	3.58	0.289
Lead users deliver ideas that are so far unknown.	3.58	-0.061
Problems of the lead user method		
The implementation of the lead user method is too time-consuming.	3.26	-0.469*
The implementation of the lead user method is too costly.	3.03	-0.433*
The ideas of the lead users do not meet the needs of the majority of our customers.	2.90	-0.203
There is insufficient confidence to involve lead users in the innovation process.	2.81	-0.536**
The ideas of the lead users are rejected by the developers/engineers.	2.77	-0.259

Notes: [a] Scale: 1 = 'strongly disagree', ..., 5 = 'strongly agree'.
[b] Scale: 1 = 'not at all', ..., 5 = 'in each project'.
* Significant with p < 0.05; ** significant with p < 0.01

5. Conclusion and outlook

The topic of customer integration and the use of VoC methods to integrate different perspectives of external actors in and opening up the NPD process becomes increasingly important in the automotive industry (Gassmann et al., 2010; Ili et al., 2010). One VoC method which can also be assigned to the concept of open innovation is the lead user method (e.g., Urban and von Hippel, 1988). Against this background, the present study aimed to investigate the relevance of VoC methods in general and the lead user method in particular in the German automotive industry.

With regard to the sources of innovative ideas in the automotive industry, the study revealed the following results:

- The main sources of innovative ideas in the automotive industry are internal sources, in particular designers and engineers.
- Automotive suppliers also receive high quality innovative ideas from their users/customers, usually automotive manufacturers.
- Vice versa, within the automotive value chain automotive manufacturers rate the number of innovative ideas from their suppliers significantly highest.
- In contrast, the rating of automotive manufacturers with regard to the idea quality of (end) customers is significantly lowest.
- Industry outsiders are considered to be of minor importance, in particular by automotive suppliers and engineering service providers.

The findings show that the issue of open innovation is still in the starting blocks in the automotive industry especially with regard to automotive suppliers and engineering service providers. From a vertical perspective, automotive manufacturers and suppliers benefit from each other in terms of innovative ideas. The findings confirm the results of Al-Zu'bi and Tsinopoulos (2012), which state that the collaboration with suppliers (and lead users) is important for product variety. That seems not to be the case for the next links in the automotive value chain, e.g., engineering service providers. Thus, as a managerial implication these links should receive more attention. With regard to open innovation, Karlsson and Sköld (2013) emphasise that this kind of vertical innovation can in fact be a closed one. From a horizontal perspective, more attention should be paid to industry outsiders by automotive suppliers and engineering service providers. While innovative ideas from industry outsiders are already in the focus of automotive manufacturers and other service providers, in particular automotive manufacturers rate the quality of innovative ideas from (end) users rather low. Therefore, the integration of (end) customers in the product development process could still be improved (Ansart et al., 2006).

With regard to the usage frequency of VoC methods in the automotive industry, the following outcomes can be noted:

- A variety of VoC methods are used (about 5) to gather customers' needs and wants.
- Classic' and easy to use methods such as questionnaire surveys, idea workshops or focus groups are rather frequently used.
- In contrast, more complex methods such as netnography, the lead user method or toolkits are less frequently deployed.

In comparison to the literature (e.g., Creusen et al., 2013), more complex methods are used to a lesser extent in the automotive industry pointing to some use potential. However, only toolkits prove to be beneficial with regard to both the number and quality of innovative ideas from users/customers. Our results confirm the Audi case study of Füller and Matzler (2007, p.385) that online-tools such as toolkits "indeed allow customers to experience innovative products via the Internet and enable them to come up with new ideas".

Finally, we looked more closely at the lead user method:

- The awareness of the lead user method is rather low, but if the method is known, it is well employed.
- More medium-sized and big automotive companies make use of the method perhaps due to the time-consuming search for lead users.
- Nevertheless, if the usage frequency of the lead user method is high, negative aspects of the method – costs, time exposure and lack of confidence in the method – become less important.
- For the automotive industry, the lead user method proves to be especially appropriate for integrating suppliers and industry outsiders, but not (end) users/customers with regard to the generation of innovative ideas.

Although the negative aspects of the lead user method are perceived to a lesser degree with increasing usage frequency, the findings indicate some usage restrictions in the automotive industry. Corresponding with Creusen et al. (2013) the method seems to be more appropriate for larger firms. In addition, the findings confirm the results of the case studies of Daecke (2009, p.120) on the German automotive industry, which came to the conclusion that there are too few (end) lead users and systematic search methods for their identification have not proven to work so far. Instead of idea generation, the integration of (lead) users is used as a marketing argument to be closer to the customer and to increase customer loyalty towards the company.

Future research should take the contribution of VoC method usage for product success into account. Even though German automotive companies were the focus the results should also be of interest to other automotive companies in the globalised market.

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Appendix

Table A1: Number and quality of sources of innovative ideas with regard to different automotive categories

	Designers/engineers		Management		Users/customers		Suppliers		Industry outsiders		Employees of other company areas	
	No.	Qu.	No.	Qu.	No.	Qu.	No.	Qu.	No.	Qu.	No.	Qu.
Automotive manufacturers	3.80	4.13	2.67	2.93	3.07	2.27	2.67	3.13	2.27	2.60	2.73	2.67
Automotive suppliers	3.95	4.05	2.41	2.98	3.00	3.15	1.97	2.61	1.44	1.80	2.39	2.57
Engineering service providers	4.26	4.21	3.53	3.63	2.89	2.79	2.11	2.79	1.84	2.05	2.37	2.84
Other service providers/con-sulting	3.54	3.77	3.31	3.00	3.31	2.85	2.31	2.46	2.46	2.54	2.31	2.62
F-value	1.942	0.717	5.395**	1.820	0.344	3.400*	2.454^{+}	1.217	6.378**	3.409*	0.458	0.335

Notes: No. = number of innovative ideas, Qu. = quality of innovative ideas, mean values on a scale of 1 = 'very low' to 5 = 'very high'.
$^{+}$ Significant with $p < 0.1$; * significant with $p < 0.05$; ** significant with $p < 0.01$.

Table A2: Inter-correlations between the usage frequencies of the investigated methods

	Methods	1	2	3	4	5	6	7	8	9
1	Idea workshops									
2	Questionnaire survey	0.17								
3	Idea competitions	0.37**	0.37**							
4	Expert interview	0.34**	0.34**	0.32**						
5	Focus groups	0.39*	0.17	0.12	0.43**					
6	Toolkits	0.33**	0.36**	0.29*	0.35*	0.48**				
7	Car clinic	0.27	0.36**	0.32*	0.38*	0.71**	0.44*			
8	Conjoint analysis	0.27	0.34*	0.21	0.54**	0.47**	0.56**	0.72**		
9	Lead user method	0.30	0.12	0.17	0.16	0.39*	-0.03	0.56*	0.45*	
10	Netnography	0.42	0.28	0.21	0.24	0.24	0.63**	0.74*	0.75**	0.11

Notes: * Significant with $p < 0.05$; ** significant with $p < 0.01$.

Chapter 3

Identification and generation of innovative ideas in the procurement of the automotive industry: The case of AUDI AG

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Abstract:

Open innovation and the use of suppliers and start-ups as external idea sources have become increasingly important in the automotive industry. Since the purchasing function in a company has correspondingly become more strategic, scholars have taken the role of procurement in innovation more intensely into account. This study examines procurement's role in the innovation process of the automotive industry and investigates which and how open innovation instruments are used in order to benefit from the innovation capability of suppliers and start-ups. The empirical evidence is based on an in-depth case study of the automotive manufacturer AUDI AG. Several arguments are elaborated which justify a key role for procurement in the innovation process (e.g., interface role, economic activities). Furthermore, we identified nine pull and push instruments enabling procurement to contribute to Audi's innovation performance. Since the instruments are designed to meet different internal requirements (e.g., in relation to a vehicle project or not), interesting insights for scholars and practitioners are provided.

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1. Introduction

In today's global competitive environment, companies are challenged with the task of developing new products not only quickly but also economically, whilst simultaneously ensuring greater novelty and market fit. To meet these challenges, scholars and practitioners advocate an open approach to new product development (NPD) (Gesing et al., 2015). A central part of this so-called "open innovation model" (Chesbrough, 2003) is how companies search for innovative ideas outside their boundaries and use ideas from external partners in their early innovation process (Laursen and Salter, 2006), known as the fuzzy front-end (FFE) (Kim and Wilemon, 2002). Due to cost and innovation pressure, open innovation and the use of external partners for idea generation have become increasingly important in the automotive industry (Ili et al., 2010; Ciravegna and Maielli, 2011). Kamp and Bevis (2012) highlight the need for external knowledge given the increasing complexity of vehicles. Open innovation can thus provide substantial benefits, which Lazzarotti et al. (2013, p. 53) describe for the automotive industry as "the enlargement of company's competence base, the stimulation of creativity and capability of generating new ideas [and] the reduction and sharing of [. . .] costs of innovation".

Open innovation partners may include users, suppliers, universities and others. Of all the partners, suppliers seem to be the most important external source of ideas (Laursen and Salter, 2006; Un et al., 2010). Studies in different industries confirm that partnering with suppliers positively affects product variety (Al-Zu'bi and Tsinopoulos, 2012), product innovativeness (Lau et al., 2010) or innovation performance (Wagner, 2010; Menguc et al., 2014). Focussing on the automotive industry, the literature emphasises this crucial role. During recent decades, automotive original equipment manufacturers (OEM) have increased the outsourcing of car development, resulting in a shift of both development activities and knowledge from OEMs to suppliers (Takeishi, 2002). For example, Rese et al. (2015) found that OEMs rated the number of innovative ideas from their suppliers significantly highest in comparison to other sources. It is important to note that, beside established automotive suppliers, non-automotive suppliers from other industries are also important in order to stimulate cross-industry innovations (Brunswicker and Hutschek, 2010). The same is true for start-ups as future suppliers since they possess ideas that help OEMs to find breakthrough solutions in knowledge fields distant from their own business (Gassmann et al., 2010). Thus, large companies, e.g., from the automotive industry, have increasingly cooperated with start-ups over recent years (Weiblen and Chesbrough, 2015).

Consequently, scholars have begun to extensively investigate the role of procurement in innovation (e.g., Schiele, 2010; Luzzini et al., 2015) as it is the common interface between the company and its supply base (Araujo et al., 1999). Furthermore, the function of procurement in a company has become more strategic. Today, the focus is not only on acquiring parts at the best price, quality and time in a globalised market but also on strategic topics such as innovation (Luzzini et al., 2012). Luzzini et al. (2015, p. 110) even describe procurement as "a critical cornerstone for adapting innovation from suppliers and stewarding it through the product lifecycle". In order to fully benefit from the innovation capability of the supply base, authors point out the importance of open innovation instruments that procurement should use (e.g., Schiele, 2010). However, whereas the use of such instruments in particular involving users has intensely been explored (Graner and Mißler-Behr, 2012; Creusen et al., 2013; Rese et al., 2015), literature on the involvement of suppliers or start-ups under procurement's responsibility is rare. Existing work either describes the application of single instruments like supplier competitions (Langner and Seidel, 2009) in the FFE or gives only a brief overview of a very few instruments used by procurement in several companies, e.g., from the automotive industry (Schiele, 2010). What so far has been missing is a detailed investigation of an entire company showing which and how open innovation instruments are used by procurement to identify and generate ideas from suppliers and start-ups in the FFE. Our study closes this research gap and enriches the literature on the importance of procurement as well as suppliers (automotive/non-automotive) and start-ups regarding open innovation in the automotive industry. Thus, our research questions are:

- What is the role of procurement in the innovation process of the automotive industry?
- How do employees working within procurement assess the relevance of suppliers and start-ups as external idea sources in the automotive industry?
- Which open innovation instruments are used by procurement and how are they designed in order to benefit from the innovation capability of the supply base and meet internal requirements?

This paper is organised as follows. After a literature review on the role of procurement in innovation and open innovation instruments, we explain our research methodology and then present the results answering the above research questions. Finally, we discuss our findings and conclude with theoretical and managerial implications as well as suggestions for further research.

2. Literature review

2.1 Role of procurement in the innovation process

From an innovation point of view, the role of procurement has been largely ignored by the literature for a long time (Schiele, 2010). However, with an increasing number of studies investigating the supplier as an external idea or innovation source and its effects on company's innovation performance or related measures especially over the last 10 years (e.g., Knudsen, 2007; Lau et al., 2010; Wagner, 2010; Menguc et al., 2014; Luzzini et al., 2015), scholars have correspondingly taken the role of procurement in innovation more intensely into account (see Spina et al., 2013 for a literature review and a rise of publications in particular from 2008/2009). Companies increasingly recognise procurement's strategic role, which often manages more than 50% of company's expenditures (Luzzini et al., 2015). Nowadays, competitive priorities go beyond acquiring parts or reducing cost and include more and more strategic topics such as contributing to the company's innovation capability (Luzzini et al., 2012). Scholars and practitioners are thus increasingly giving attention to innovation-oriented supply chains where procurement plays a key role in the innovation process as compared to cost-oriented supply chains (Tracy and Neuhaus, 2013). Empirical studies show that a high involvement of procurement in the innovation process has a positive impact on the innovation performance (Nijssen et al., 2002; Hartmann et al., 2012).

Several arguments can be advanced to justify a key role for procurement in the innovation process. One argument is the interface role of procurement between the company and its supply base. As procurement is concerned with the acquisition of parts, it is thus in a key position to identify innovative ideas in the supply base, advertise these ideas internally and finally help to integrate them into new products (Preuss, 2007; Hartmann et al., 2012). Another argument is the selection of the right partners in order to successfully cooperate not only at the idea stage but also along the rest of the innovation process. Selecting unsuitable partners can have several negative effects leading to project obstruction (Primo and Amundson, 2002). In particular, purchasers have a total view of the product life-cycle which differs, e.g., from a mostly R&D-oriented view of engineers focussing on the core activities that take place in the early stages. In this context, the best partner for the development stage may not automatically be the best for the rest of the life-cycle. Choosing the right partners and thus avoiding negative effects is in procurement's area of responsibility (Schiele, 2010). Procurement is also responsible for the management of supplier relationships. A good buyer–supplier relationship leads in turn to more innovations (Clauß, 2012), more knowledge transfer between partners and positive project outcomes such as increased product quality or reduced time to market (Sjoerdsma and van Weele, 2015). Last but not least and beside all innovation-related benefits, one of procurement's tasks is still to ensure the company's commercial viability. Involving purchasers in the innovation process from the beginning can thus help to achieve cost benefits for innovations (Schiele, 2010). This is in particular important for the automotive industry, which Ili et al. (2010, p. 216) describe as “trapped by cost [. . .] pressure”.

2.2 Open innovation instruments

Several open innovation instruments which are suitable for identifying or generating ideas from suppliers or start-ups exist in the literature (see Table 1). According to the terminology of Wagner and Bode (2014), we divide the instruments into those where the buying firm is the active party and sets parameters (e.g., tasks, fields of technology), called “pull instruments”, and instruments where the external partner usually takes the initiative to present its ideas to the buying firm, called “push instruments”.

2.2.1 “Pull” instruments

One instrument, which addresses all relevant partner types, are *scouting activities*. Scouting activities help to identify pioneering technologies in their early stages (Rohrbeck, 2010) and new innovative partners such as start-ups (Weiblen and Chesbrough, 2015). OEMs such as BMW or Daimler use technology scouts in varied technological areas like Silicon Valley who screen the respective market, evaluate the technologies and transfer the information into their own business (Lazzarotti et al., 2013). One instrument usually focussing on established suppliers are *supplier days*. Supplier days are multi-day events organised by the buying firm (Groher, 2003). They can serve as pure information events at which the buying firm talks to key suppliers, presenting itself and the company’s strategy (Wagner and Johnson, 2004) or they can be used to discuss innovation trends as, e.g., General Motors does this through its three-day TechWorld conference (Wagner, 2009).

Table 2: Open innovation instruments for idea identification or generation in the literature

Instrument	Initiative	Description	Target group	Examples from the automotive industry	References (e.g.)
Scouting activities	Pull	Search for new partners or technologies (e.g., use of trend-scouts, incubators, technology centres)	Suppliers, Start-ups	BMW, Daimler, Robert Bosch, Siemens	Lazzarotti et al. (2013); Weiblen and Chesbrough (2015)
Supplier days	Pull	Multi-day events with expert talks and discussions on innovation trends	Suppliers	General Motors	Wagner and Johnson (2004); Wagner (2009)
Supplier workshops	Pull	Selected suppliers generate ideas based on technology fields or tasks	Suppliers	BMW, Magna Steyr	Schiele (2010); Palmer et al. (2015)
Supplier competitions (idea or concept competitions)	Pull	Several suppliers compete and work out ideas or specific approaches for existing problems based on defined requirements	Suppliers	BMW	Langner and Seidel (2009); Bartl et al. (2010)
Start-up pitch	Pull	Buying firms invite start-ups to pitch their ideas in front of company members	Start-ups	—	Chesbrough and Brunswicker (2014); Weiblen and Chesbrough (2015)
Crowdsourcing	Pull	Outsourcing of innovation problem solving via an open call to external partners to submit ideas	Suppliers, Start-ups	BMW	Bartl et al. (2010); Chesbrough and Brunswicker (2014)
Supplier conversations	Push (Pull)	Suppliers can use regular conversations to present new ideas or innovations to the buying firm	Suppliers	Daily business at automotive companies	Groher (2003)
Technology shows	Push	Innovation fairs at buying firms where suppliers present their innovation portfolio	Suppliers	BMW	Groher (2003)
Web-based idea platform	Push	Innovative ideas can be submitted by external partners via an online form	Suppliers, Start-ups	BMW, Robert Bosch	Groher (2003); Rink and Wagner (2009); Lazzarotti et al. (2013)

A more specific instrument are *supplier workshops* where specific tasks are defined by the buying firm in advance and will then be elaborated by selected suppliers (Schiele, 2010; Palmer et al., 2015). Magna Steyr, for instance, conducts “joint thinking workshops”, while BMW organises so-called “innovation meetings”. One supplier and a selection of cross-functional personnel from BMW attend each innovation meeting. Beside generating and discussing ideas, the supplier is also encouraged to reveal his innovation roadmap and the status of his development projects (Schiele, 2010). Furthermore, *supplier competitions* can be carried out. They are most helpful in order to simultaneously compare ideas from several suppliers. While idea competitions serve to generate ideas for certain topics (Ebner et al., 2009), concept competitions support the generation of specific approaches or solutions for existing problems based on defined requirements given by the buying firm (Langner and Seidel, 2009). *Start-up pitches* follow a similar approach as supplier competitions but rely on start-ups. Here, the buying firm proactively invites start-ups to submit ideas via open competitive calls. Selected start-ups then have the opportunity to pitch their ideas in front of a jury. Cooperation and venture support are offered as incentives to winning teams (Chesbrough and Brunswicker, 2014; Weiblen and Chesbrough, 2015). Another mostly web-based instrument is *crowdsourcing*. It can basically be described as the outsourcing of innovation problem solving via an open call to external partners to submit ideas (Chesbrough and Brunswicker, 2014). It is often carried out in the form of idea competitions using an online platform. BMW, for instance, used its platform “Co-Creation Lab” and launched the idea contest “Tomorrow’s Urban Mobility Services” asking for ideas for innovative mobility services in future cities (Bartl et al., 2010).

2.2.2 "Push" instruments

Buyers and suppliers are in regular contact with each other. The buying firm typically uses supplier conversations for negotiations about prices, concluding contracts or technical clarifications. The supplier can also use such conversations to inform the buying firm about innovation topics, thus pushing its ideas to the buying firm (Groher, 2003). Of course, the buying firm can ask for new ideas as well and should do this at any time. Another push instrument is a technology show, which can be described as an internal innovation fair. In practice, key automotive suppliers often take the initiative and ask the buying firm to use the opportunity to present its innovation portfolio to company members. Here, the buying firm usually does not set any parameters, i.e., the supplier decides what innovations will be shown. At BMW, 10–12 suppliers each year get the chance to present their portfolio at BMW's Research and Innovation Centre (Groher, 2003). In order to reach all relevant partner types, a web-based idea platform can be used as BMW does with its "Virtual Innovation Agency" (Lazzarotti et al., 2013) or Bosch with its purchasing innovation portal (Rink and Wagner, 2009). An idea platform ensures to receive ideas from both suppliers and start-ups without playing an active role. The buying firm just needs to provide the infrastructure. After a relevance check on the submitted ideas, suitable ones are transmitted to the specialist departments (Groher, 2003). The passive idea platform can also be supplemented by a proactive crowdsourcing approach. Furthermore, open calls for start-up pitches can be published.

3. Research methodology

The empirical evidence of this article is based on a single case study. Case study research is recommended if knowledge in a research field is limited, specifically in relation to the investigation of instruments where "how" and "why" questions are being asked (Yin, 2009). Such an approach expects to gather rich descriptions and explanations (Eisenhardt, 1989). This is in particular true for the single case study as it is powerful in exploring and describing a phenomenon in its local context (Eisenhardt and Graebner, 2007).

Audi as a German OEM was chosen for our study. Audi has achieved a leading position in technological innovations, including (amongst others) close collaborations with established suppliers but also new external partners such as start-ups. In 2014, Audi started to introduce an innovation process in its procurement aiming to intensify the collaboration with its partners from a very early stage, called the “screening phase”. One essential part is the use of open innovation instruments to identify or generate ideas from suppliers (automotive/non-automotive) and start-ups, called “screening instruments”.

3.1 Data collection

Data for our research was collected in three phases, which allowed data triangulation (Gibbert et al., 2008; Yin, 2009). First, interviews were conducted, thereafter a document study was performed and additionally a workshop was conducted (for a similar procedure, see e.g., Aune and Gressetvold, 2011; Melander and Lakemond, 2015). The main data consists of 18 interviews with experts from the procurement business unit. As suggested by Eisenhardt and Graebner (2007), experts from different departments and hierarchical levels were included. All individuals were identified as being knowledgeable informants by our contact person at Audi. We interviewed purchasers from the strategy department, different commodity groups (electronics, exterior, interior, metal and powertrain) and from procurement for new product launches. Regarding the hierarchical level, we involved managers and team leaders, who usually have a complete overview of the activities within their department, as well as buyers, who could report from their own operational experiences (see Table 2 for more details). Collecting data from these different types diminishes common source bias and enhances the validity of our research (Wagner and Hoegl, 2006).

All interviews were semi-structured, thus providing an overall structure for data collection and improving the reliability (Yin, 2009). An interview guideline was used as an important research instrument since the components reflected our research questions. First, the experts described procurement's role in the innovation process. Second, we asked for the relevance of suppliers (automotive/non-automotive) and start-ups as external idea sources. The third part concentrated on screening instruments used by procurement including the design of the instruments, the chronological classification of each instrument within the innovation process, target group, participating internal functions, usage frequency, reasons for repeated usage as well as benefits and problems. Finally, we asked about the potential for improvements in the existing instrument portfolio. The interview guideline can be found in the appendix. However, deviations from the specific questions were permitted and follow-up questions were asked to pursue interesting and relevant new facets as they emerged. All interviews were conducted face-to face and lasted between 30 min and 1.5 h.

Table 2: Interview partners

Procurement division	Position	Duration
Strategy	Innovation management	1 hour
Electrics/electronics	Head of procurement infotainment, display, operation	45 minutes
Electrics/electronics	Assistant to the head of procurement electrics/electronics	1 hour
Electrics/electronics	Buyer, innovations procurement electrics/electronics	1 hour
Electrics/electronics	Buyer roof opening systems	45 minutes
Exterior	Head of procurement sealing systems/coatings/glass/convertible tops	1.5 hours
Exterior	Team leader bumpers/painted attachments	1 hour
Exterior	Buyer glazing, innovations procurement exterior	1 hour
Interior	Head of procurement seats/safety systems	30 minutes
Interior	Team leader cockpit	30 minutes
Metal	Assistant to the head of procurement metal	30 minutes
Powertrain	Assistant to the head of procurement powertrain	45 minutes
Powertrain	Team leader procurement E-traction	45 minutes
General procurement	Head of procurement IT, process management	1 hour
General procurement	Team leader procurement IT	1 hour
New product launches	Head of project procurement platform MLB	1 hour
New product launches	Coordination wide electrification	30 minutes
New product launches	Coordination Audi battery electric vehicle	30 minutes

In addition to the interviews, several documents provided by Audi and the interviewees were studied. The documents contained a general description of the innovation process in procurement, process descriptions of the investigated instruments as well as exemplary briefing documents which were handed out to suppliers when applying screening instruments. The process descriptions of the instruments served as a valuable addition to the interviews as they can be seen as method handbooks. Furthermore, the briefing documents helped us to better understand how the individual instruments differ with regard to, e.g., the degree of specification and as a consequence how different suppliers and start-ups are approached.

At the time when 9 of the 18 interviews were completed, and subsequent to the analysis of the documents provided by that time, we also used a workshop as an opportunity to present initial results. The workshop was a part of a workshop series at Audi aiming to further develop the innovation process in procurement. Each of the workshops involved around 10 professionals from purchasing, R&D and marketing. Our workshop was designed to be interactive: two researchers presented initial case study results with a focus on open innovation instruments used in procurement and discussed the findings with the workshop participants. The use of open innovation tools was recognised as highly important by participants in order to systematically exploit the idea potential of suppliers and start-ups in the FFE. It was also highlighted that each instrument is used for specific reasons due to its design and thus causes specific benefits and problems. Hence, the workshop served as an important forum for gathering additional aspects, verifying tentative findings and increasing the validity of our study.

3.2 Data analysis

As suggested by Miles and Huberman (1994), data analysis was a continual process and partly conducted during the data collection. For data analysis, we applied a three step approach of data reduction, data display and conclusion drawing (Miles and Huberman, 1994). Data reduction started with the decision of research questions, case selection and data collection methods. Within the decided setting, all collected data was read several times to increase familiarity with the topic. If clarification was necessary, we sent emails to interviewees or conducted phone calls. Next, data reduction was fostered by writing interview summaries and discarding irrelevant data (Miles and Huberman, 1994). In order to enhance validity, each summary was resubmitted to the respective interviewee for comments and corrections (Yin, 2009). For further analysis, data was transferred into a spreadsheet which was structured as a conceptually-ordered display. As a result, interview statements could be “clustered” according to the specific theme that they were exploring (Miles and Huberman, 1994). With regard to open innovation instruments used in procurement, interview data was complemented by the findings of the document study. Wherever possible, tables and charts were used to facilitate data display and conclusion drawing (Miles and Huberman, 1994). Finally, reliability was strengthened by a case study database containing the collected data (Yin, 2009).

4. Research results

4.1 Role of procurement in the innovation process of the automotive industry

When conducting the case study, it was clearly seen that the purchasers at Audi take a role that goes far beyond the mere buying of parts or materials. This holds in particular true for their involvement in the innovation process. Although there was a strong consensus between the interviewees that all innovation work can only be conducted in tandem together with the engineering departments and the role of engineering can still be seen as dominant in the technology minded automotive industry, we recognised purchasing’s aspiration to take a key role in the innovation process as one expert from procurement electrics/electronics stated:

> *"In the context of innovation management, the aim is to not get dictated anymore by the engineers [in the manner of]: 'There we have an innovation. With this partner we have been working together for let's say four years. [. . .] And now you have to take (nominate) him (the partner).' Instead, we want to be proactive and have a determining influence on which innovations come into the company and with which partners we work."*

Summarising the interviews, the key role of procurement in innovation can be addressed by three directions. Firstly, by identifying innovative ideas in the supply market and fostering these ideas internally; secondly, by economic activities; and lastly, by managing the supply base.

Regarding the first direction, a vast majority of the experts highlighted the interface role of procurement, which is in particular important in the automotive industry since it is characterised by a high degree of value added managed by suppliers. Due to this interface role, procurement is best positioned to screen the supply base for external ideas. On the other hand, the supplier approaches the respective buyer with an idea when there is a good relationship. One buyer from procurement electrics/electronics emphasised:

> *"While in the past the core tasks of procurement were ensuring the security of supply and price optimisation, the issue of supplier relationship will become more important in the future as procurement forms the direct contact between suppliers and OEMs. Hence, original tasks of technical development (idea generation) increasingly shift to procurement (idea finding). The challenge will be to quantify procurement's performance that was measurable in the original model."*

One expert from procurement exterior added that there is of course intensive contact between the technical development and suppliers, but in particular in the case of component-independent ideas, the supplier usually does not have an engineering contact. In this context, the same respondent underlined the total overview that procurement has: *"Engineers are often focussed on* *the component, purchasers see the big picture."* Together with procurement's task of managing new vehicle projects at Audi, innovative ideas can thus be promoted for several vehicles.

Regarding the second, economical direction, experts highlighted the opportunity to influence the costs of an innovation already at the early stage as, e.g., the informant from procurement strategy did: *"An essential contribution of procurement is to make innovations more affordable [since] innovations often fail because of costs."* As a result of the commercial framework, one buyer from procurement exterior furthermore added that *"[. . .] procurement enables the step from an invention to an innovation"*.

The last direction, managing the supply base, refers to the fact that procurement analyses, assesses and finally nominates suppliers. Different expert statements show that procurement ensures the company's flexibility, which is done by shaping the portfolio of partners. This can mean changing partners or building up new ones in order to prevent monopoly situations. One expert from the powertrain division elaborated on this issue:

> *"In addition to making innovations more affordable, attention should also be paid to making them 'interchangeable' [and] ensuring the possibility of standardisation or backward compatibility. Otherwise, monopoly situations may arise and no competition is possible."*

Here, the international focus of procurement when screening the market was highlighted by several interviewees, which is important for the identification of new innovative partners such as start-ups.

Nevertheless, there are some obstacles facing purchasers. Although strategic topics such as innovation are anchored in procurement, several experts criticised the fact that the incentive system is not designed for innovation work as the performance of buyers is often measured only by the savings achieved. Here, a conflict of objectives can arise as an expert from general procurement stated: *"[I see] difficulty in getting purchasing involved if the innovation creates no* *savings or even causes higher costs."* Furthermore, experts mentioned the "filter function" of engineers and that the acceptance for ideas identified by procurement could be still improved, thus addressing the Not-Invented-Here syndrome (Katz and Allen, 1982).

4.2 Relevance of suppliers and start-ups as external idea sources in the automotive industry

The relevance of automotive suppliers as external idea sources was assessed as very high by all interviewees. Several experts emphasised that the innovation leadership of an OEM significantly depends on the innovation capability of its suppliers. In particular, the know-how on the component level lies nowadays with suppliers. The OEM often just takes the responsibility for the integration into the overall system. According to the statement of a department manager, *"over 60% of the value added is already managed by the suppliers. With increasing electrification, digitalisation and connectivity, this percentage will rise in future"*.

Although the focus of cooperation at Audi is on established automotive suppliers, there are also fields of application for non-automotive suppliers. For example, two experts from procurement exterior named glass suppliers from the building industry who participated in a concept competition on a glazing topic. As another example, suppliers with a core business in forklift or lifting platform technology who should work out solution proposals for a hydraulic system in a car component were mentioned. Despite the opportunity to generate cross-industry innovations, the respondents underlined the challenges that are associated with such alliances. A crucial point is that the requirements between the respective analogue market and the automotive industry are almost always very different. In particular, achieving the quality standards in the automotive industry is quite challenging for non-automotive suppliers.

The relevance of start-ups differs between the business divisions. While the experts from procurement exterior, metal and powertrain indicated that startups are currently less important in their divisions compared to suppliers, purchasers from the fields of electronics and general procurement highlighted their importance:

> *"In classical automotive fields, the first-tier supplier will always be the driver of innovation. In the field of electronics, where technologies from the consumer sector increasingly find their way into the car and this is even more expected from the consumer in future, start-ups are the innovation driver."*

> *"The automotive industry is still very much characterised by classical mechanical engineering. Start-ups are more suitable for connectivity topics."*

> *"IT is a predestined field of application for start-ups due to short product life cycles and a volatile environment."*

Although start-ups are of minor relevance in some areas, the majority of the experts agreed that they are an essential part of the supply base regarding innovations. In this context, the expert from procurement strategy commented on seeing start-ups not as suppliers of whole assemblies but their ideas *"as a part of a system innovation"*. One respondent from procurement exterior added that startups foster *"out of the box thinking"*, i.e., how to adopt technology in order to generate truly innovative solutions. Nevertheless, the collaboration with start-ups has not achieved an adequate level of intensity in the automotive sector yet. Three major challenges were mentioned.

Identify innovative start-ups: While suppliers basically have branch offices close to the OEM, innovative start-ups are often based elsewhere worldwide. This makes the identification in general more extensive. The interviewee dealing with innovations in the electrics/electronics division commented on this challenge:

> *"The problem is to find them (start-ups) because start-ups do not proactively approach us (operational purchasing). [. . .] I think that's because they (start-ups) believe they do not have the required capital to collaborate with Audi and become*

> *'automotive-capable'. Most start-ups have ideas or concepts but cannot integrate them into a car like a big system supplier. [. . .] But that is not what they have to do — we are just looking for their ideas."*

In order to still exploit the idea potential, OEMs need to proactively approach start-ups appropriately. The next challenge is then to separate from a vast number of start-ups the suitable ones from the unsuitable.

Bind the start-up to the OEM: While an OEM is always interested in achieving a first-to-market position and getting exclusive rights for a certain period to use the technology, start-ups are interested in offering their technology to several companies in order to grow rapidly. This requires the OEM — and in particular procurement — to create a contractual framework that aligns the interests of both parties.

Integrate the technology quickly into the car: Another issue mentioned is the complex processes in an OEM and the high quality standards, which make it difficult to get a start-up in a position to deliver quickly. Automotive OEMs basically follow a sequential product emergence process (PEP) with clearly defined milestones and different responsibilities at different project phases, thus requiring time for decisions. On the contrary, start-ups usually employ a flexible development process with a flat hierarchy, thus expecting quick decisions. This contrast can lead to confusion and disappointment among start-ups. Here, procurement can serve as a communication interface. Keeping in mind that start-ups might not be able to produce the required volume, procurement can furthermore serve as an industrialisation partner alongside established suppliers.

4.2 Screening instruments at AUDI AG

The third part of our research concentrated on open innovation instruments used by procurement at Audi — called "screening instruments" — focussing on the design of the instruments, target group, participating internal functions, effort, usage frequency, reasons for repeated usage as well as benefits and problems. The division between pull and push instruments is maintained and the results are illustrated in Table 3. In total, we identified nine screening instruments, which are deemed to be equivalent and are discussed in chronological order within the FFE of procurement's innovation process (see Fig. 1). The instruments are briefly described and selected aspects are explained.

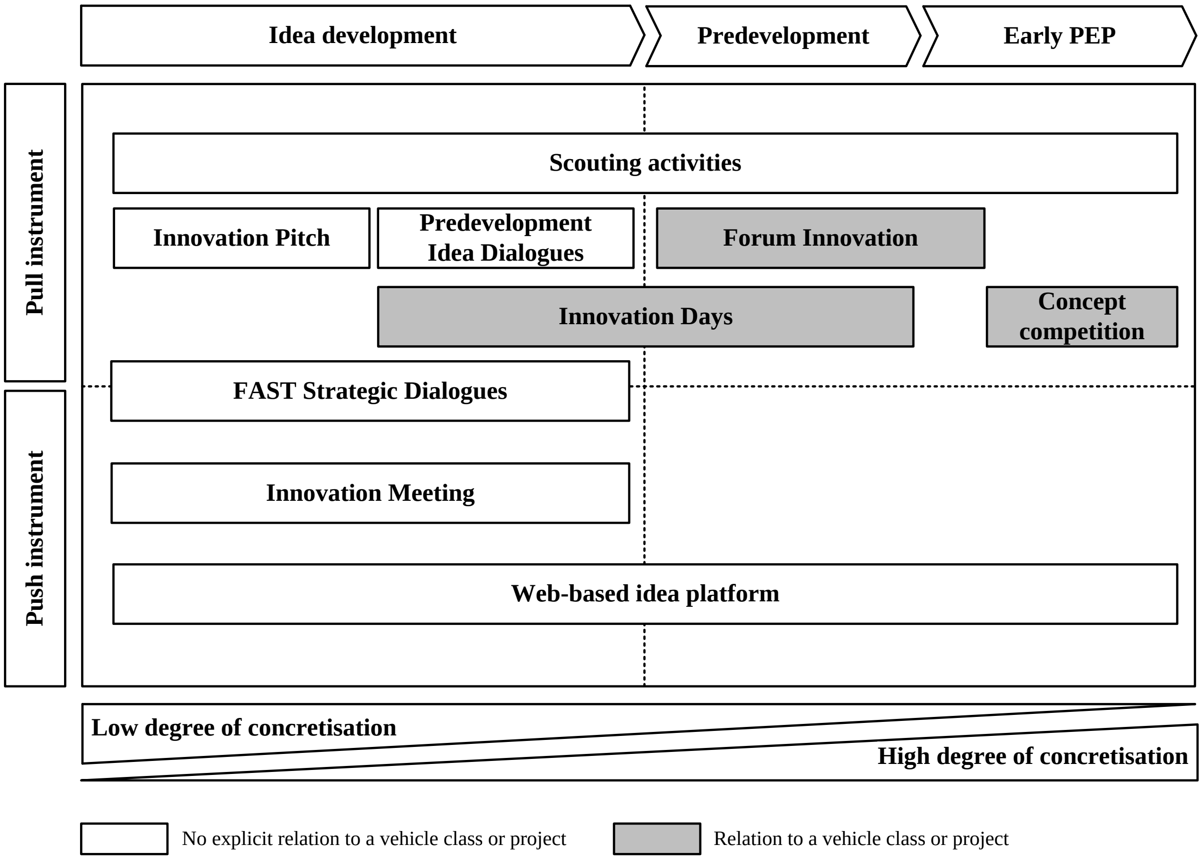

Fig. 1: Chronological classification of the screening instruments at AUDI AG within the FFE of procurement's innovation process

Table 3: Screening instruments at AUDI AG

	Pull instruments						Push instruments		
	Scouting Activities	Innovation Pitch	Predevelopment Idea Dialogues	Innovation Days	Forum Innovation	Concept Competition	FAST Strategic Dialogues	Innovation Meeting	Web-based Idea Platform
Description and design	Needs-based search for new partners or technologies (scouting trips, fair visits, regional sourcing offices)	Short presentation of start-up ideas and technologies based on pre-defined (non-automotive) search fields	Discussions on supplier ideas aiming to close identified "white spots" in predevelopment portfolio	Multi-day discussions with experts and top management on vehicle-related innovations based on pre-defined search fields	Competition for the best (concept) ideas based on one specific task	Competition for the best concepts based on a specification book	Confidential discussions on innovation roadmaps and technological search fields with top-management	Presentation of innovative ideas by one supplier (no prior definition of search fields or tasks)	Web-based solution for idea submissions
Target group	- Automotive & non-automotive suppliers - Start-ups	- Start-ups	- Automotive & non-automotive suppliers	- Automotive & non-automotive suppliers	- Automotive & non-automotive suppliers	- Automotive suppliers	- FAST suppliers	- Automotive suppliers	- Automotive & non-automotive suppliers - Start-ups
Participating internal functions	- Procurement - Technical Development - Sales and Marketing as required	- Procurement - Technical Development - Sales and Marketing as required	- Procurement - Technical Development - Sales and Marketing	- Procurement - Technical Development - Sales and Marketing	- Procurement - Technical Development - Sales and Marketing	- Procurement - Technical Development - Quality, Sales and Marketing as required	- Procurement - Technical Development as required	- Procurement - Technical Development - Sales and Marketing	For idea evaluation: - Procurement - Technical Development - Sales and Marketing
Effort (time, resources)	- Low to high	- Medium	- Medium	- High	- Medium to high	- Medium to high	- Medium	- Medium	- Low to medium

Table 3: Screening instruments at AUDI AG (continued)

	Pull instruments						Push instruments		
	Scouting Activities	Innovation Pitch	Predevelopment Idea Dialogues	Innovation Days	Forum Innovation	Concept Competition	FAST Strategic Dialogues	Innovation Meeting	Web-based Idea Platform
Usage frequency	- Continuously	- Demand-driven	- Planned annually	- Depending on new vehicle classes or platforms	- Several each year	- Several each year	- Planned annually with each FAST supplier	- Several each year	- Continuously
Reasons for repeated usage	- Staying up-to-date - Need for new partners or technologies - New trends	- Internal impulses (need for non-automotive technologies) - Implementation often together with scouting trips	- "White spots" in predevelopment portfolio if identified	- New vehicle class or platform	- Need from a vehicle project - Missing development partners for the task - Monopoly situation of a supplier	*see Forum Innovation* - Concept sourcing	- No specific trigger	- No specific trigger	- No specific trigger
Benefits	- Identification of trends, new technologies and partners - Personal relationship and trust is built up	- Transparency on start-up technologies - Separation of suitable start-ups from unsuitable	- Needs-based closing of "white spots" in predevelopment portfolio	- Great variety of ideas due to roughly described search fields - Early vehicle-related idea generation - Top management participation increases supplier motivation	- Creation of market transparency - Comparability of different concept ideas - Possibility of building up new suppliers	*see Forum Innovation* - Detailed concept as a result - Optimization potentials (cost and quality) due to defined targets in specification book	- Synchronization of innovation roadmaps - Identification of ideas with various levels of maturity - Information exchange with top-management	- Concentration on one supplier increases its motivation - Supplier is not restricted due to predefined search fields or tasks	- Addressing all external partners - Permanent availability

Table 3: Screening instruments at AUDI AG (continued)

	Pull instruments						Push instruments		
	Scouting Activities	Innovation Pitch	Predevelopment Idea Dialogues	Innovation Days	Forum Innovation	Concept Competition	FAST Strategic Dialogues	Innovation Meeting	Web-based Idea Platform
Problems	- Time-consuming follow-up process with new partners (e.g., auditing process)	- Pitches alone not sufficient for an overall evaluation (extensive follow-up meetings necessary)		- High effort (time, personnel and financial resources)	- High effort (time)	- High effort (time) - Smaller leeway for innovative solutions due to specification book		- More intensive comparison with internal needs necessary	- Risk of unsuitable ideas

4.2.1 "Pull" instruments

As a continuously used instrument in procurement experts listed *"Scouting Activities"*, e.g., visits to suppliers, fair visits (depending on the division, e.g., consumer electronic show or plastics fairs) and scouting trips. Furthermore, so-called regional sourcing offices, which screen international markets for new technologies and partners, were mentioned. Although all relevant partner types are addressed, experts referred to the recent focus on the scouting of start-ups and their technologies worldwide. Scouting trips are in particular implemented in order to stay up-to-date and to identify new partners or technologies. Audi has had initial experience with these. In particular, the identification of new partners such as startups was mentioned as a major benefit for increasing the innovation capability. On the other hand, the time-consuming follow-up process with new partners (e.g., the auditing process) was highlighted. According to an interviewee from procurement electrics/electronics, visits to suppliers are *"most effective because based on the communication and relationship which is built up to the supplier truly new ideas are exchanged"*.

When doing such start-up scouting trips, *"Innovation Pitches"* are often carried out at the same time. Here, pre-selected start-ups pitch their ideas in front of Audi personnel. The pitch format itself serves to get transparency on start-up technologies in a short time period and helps to get an initial overview on the suitability of the vast majority of start-ups. A weakness is that the innovation pitch alone was assessed as not sufficient for an overall evaluation. The usage frequency was seen by several experts as needing improvement.

An instrument focussing on the idea generation stage with suppliers is *"Predevelopment Idea Dialogues"*. Audi procurement strategy introduced this instrument in order to strengthen the influence on the predevelopment portfolio from technical development. Here, personnel from procurement, technical development as well as sales and marketing discuss ideas from suppliers with the suppliers. This instrument is used if so-called "white spots" in the predevelopment portfolio are identified; these can arise from the comparison of existing predevelopment activities with future customer requirements, thus reflecting possible needs for action and a major benefit for future development activities.

A step further into the innovation process is the instrument of *"Innovation Days"* since it was mentioned by experts as an instrument relating to a new vehicle class or platform. This instrument has been described as multi-day discussions on vehicle-related innovation topics based on several search fields which are defined across procurement, technical development as well as sales and marketing and then submitted to selected automotive and non-automotive suppliers. Whenever a new vehicle class or platform arises, the implementation of this instrument is checked. One expert indicated that the strength lies in the definition of roughly described search fields which lead to a great variety of vehicle-related ideas at a very early stage. Focussing on a vehicle class rather than a specific vehicle project was highlighted as necessary in order to facilitate innovation work in the FFE and enhance the innovation outcome, as an expert from procurement electrics/electronics commented:

> *"I see the change from consideration of purely vehicle-specific innovations to an innovation roadmap for each vehicle class (A, B, C, D class) as crucial. Hence, innovations would not disappear due to [e.g.,] a late target-vehicle, but could be brought to a decision for the next possible vehicle (e.g., sedan, coupe, SUV)."*

As another benefit, top management participation was mentioned as it increases the supplier's motivation to present highly innovative ideas. Since the whole planning process of the Innovation Days is scheduled for several months, the high effort in particular regarding the cross-divisional definition and agreement of search fields was highlighted.

More specific and thus used later in the innovation process is the *"Forum Innovation"* (FIN), which was characterised by the experts as a competition between several suppliers. Unlike the Innovation Days, no roughly described search fields are defined, but rather there is one specific task relating to a vehicle project or platform. When procurement, technical development as well as sales and marketing have defined the task, it is described by a briefing document, which is given to selected suppliers and serves as the basis for the idea generation. According to the department manager from procurement electrics/electronics, it is crucial to find the right balance between *"setting technical requirements but also allowing leeway for innovations"*. The FIN basically includes one or two interim presentations and is accompanied by a technical and economic evaluation process. The expert from procurement metal, who took part in a FIN, underlined the importance of interim presentations since they *"help to steer the suppliers in the desired direction and clarify open questions"*. The experts made clear that the instrument is used for three major reasons. Firstly, due to a need of a vehicle project or platform; secondly, if a development partner for a certain topic is missing or existing partners do not provide satisfying technical solutions; or thirdly, if a monopoly situation with a supplier exists for the respective issue. Due to the competition format with several suppliers, experts mentioned the creation of market transparency on one specific topic and the simultaneous comparability of several concept ideas as two benefits. The interviewee from procurement metal furthermore highlighted that *"in the competition it becomes clear which supplier is motivated to respond to wishes and requirements"*.

The instrument *"Concept Competition"* is based on the same principle as the FIN, but as the interviewees explained in detail, the difference lies in the degree of concretisation. Instead of a briefing document, which includes only the most important requirements, a more detailed specification book with target values is given to selected suppliers. Here, established automotive suppliers are usually involved. This is due to the experts emphasising the challenges when working with non-suppliers and the difficulty of fulfilling specific automotive requirements for partners from analogue markets. This instrument is basically used for the same reason as the FIN but usually later in the innovation process when a vehicle project has started and specific requirements are settled. The experts indicated that this helps to generate a detailed concept and provides optimisation potential due to defined targets on the one hand, but restricts the leeway for innovative solutions on the other hand. Unlike the previous instruments, the concept competition format was even mentioned as a part of the general sourcing process according to a respondent from procurement electrics/electronics:

> *"We basically have two big sourcing processes. There is 'global sourcing' and 'forward sourcing'. [. . .] In the case of innovations at a very early phase [and] when no specific parts but only concepts can be requested in the market, there is 'concept sourcing'. Such a concept sourcing contains concept competitions or conceptual discussions."*

4.2.2 "Push" instruments

As noted earlier, supplier conversations can be used as a push (and pull) instrument. Audi procurement uses not only regular conversions but goes a step further with *"FAST Strategic Dialogues"* where innovation roadmaps and technological search fields are discussed with top management from procurement and so-called "FAST suppliers". "FAST" stands for "Future Automotive Supply Tracks" and is a joint initiative in the Volkswagen Group. In a selection process called FAST qualifying, suppliers are assessed according to defined criteria. The best suppliers gain access to the FAST initiative. One informant from procurement exterior highlighted that, due to the fact that roadmaps cover a time period from now up to several years ahead, ideas with various levels of maturity can be identified.

The instrument *“Innovation Meeting”* has emerged from the “technology show” instrument (Groher, 2003), which is carried out at Audi under the name “Tech Day” with technical development as the instance responsible. According to the department manager from procurement interior, who took part in an implementation of the Tech Day, a weakness is that marketable products are presented rather than ideas at an early stage: *“[Tech Days are] often very technology-focussed and less future-oriented.”* Nevertheless, the principle of the instrument, i.e., concentrating on one supplier presenting its ideas without being restricted due to predefined search fields or tasks, has been considered to be useful. For this reason, Audi procurement adapted and implemented this principle with the “Innovation Meeting” instrument — not in the form of internal innovation fairs, but as discussions on innovative ideas with suppliers and colleagues from technical development as well as sales and marketing in the FFE. Although the missing restriction on pre-defined search fields or tasks was evaluated as beneficial for surprising ideas, a more intensive comparison with internal needs is necessary.

Considering web-based instruments, we could identify the Volkswagen Group *idea platform* (http://www.volkswagen-fast.de/en/contact-form). Prior to submission, external partners can choose to which group brand the idea should be submitted. The ideas are submitted to the innovation manager in procurement and then evaluated together with technical development as well as sales and marketing. A major benefit is that all external partners are addressed permanently. As a negative aspect, experts indicated the higher risk of unsuitable ideas.

5. Discussion

This study examines (1) the role of procurement in the innovation process of the automotive industry, (2) the relevance of suppliers and start-ups as external idea sources and finally (3) which and how open innovation instruments are used by procurement in order to benefit from their innovation capability.

Regarding the role of procurement, several arguments are advanced justifying its key role in the automotive innovation process. This key role can be addressed by three directions: firstly, by identifying ideas in the supply market and fostering these ideas internally, secondly, by economic activities, and lastly, by identifying new partners, thus ensuring the company's flexibility. These findings are in line with other studies emphasising the screening function of procurement and its ability to support the integration of new ideas into new products (Preuss, 2007; Hartmann et al., 2012). In order to incorporate ideas into the company and ensure commercial viability at the same time, literature confirms procurement's ability to achieve cost benefits (Schiele, 2010). Therefore, procurement helps to develop what Cavinato (1999, p. 77) calls "creative packages [. . .] for competitive advantage". Although some studies report that procurement's impact on strategic topics such as innovation is limited (e.g., Tassabehji and Moorhouse, 2008; Melander and Lakemond, 2015), our findings strengthen and justify the need of involving procurement in NPD processes.

Considering the relevance of suppliers and start-ups as idea sources, we found that automotive suppliers are — not surprisingly — of great importance. By comparison, non-automotive suppliers or start-ups currently play a subordinate role but are essential for a balanced innovation portfolio. In particular, start-ups are becoming increasingly more important for the automotive industry as a source of radical innovations especially in the fields of electronics since technologies from the consumer sector increasingly find their way into vehicles. Nevertheless, the cooperation with start-ups can be still described as a challenging approach in particular regarding the identification of innovative ones, binding them to the OEM and finally integrating their technologies quickly into the car. Our results confirm the case study findings of Gassmann et al. (2010) who illustrate how BMW and a start-up cooperated to develop a breakthrough innovation but had to overcome operational and strategic challenges, e.g., creating a mutually satisfying contractual framework, complex OEM structures and processes. In particular, procurement can help to overcome these challenges and reach out to improve the innovation potential of start-ups within the open innovation paradigm. Herzog and Leker (2010), for instance, present open innovation as a holistic approach to innovation management and as “systematically encouraging and exploring a wide range of internal and external sources for innovation opportunities, consciously integrating that exploration with firm capabilities and resources, and broadly exploiting those opportunities through multiple channels” (West and Gallagher, 2006, p. 320). This statement covers several aspects on how the purchasing organisation through its functions can serve as a booster to start-up innovations. In detail, procurement provides a platform especially for new external partners and their ideas, promotes these ideas internally and can serve as an industrialisation partner, i.e., helps to build up alliances between start-ups and established suppliers in order to enhance start-ups’ innovation performance (Neyens et al., 2010).

Finally, we identified nine pull and push instruments enabling purchasers from the automotive manufacturer Audi to identify or generate innovative ideas from suppliers and start-ups. Interestingly, the majority of the instruments is already used before PEP. That means the philosophy of procurement’s innovation activities at Audi is to identify innovative ideas even before a vehicle project has started and the decision on the initial vehicle is made during the pre-development phase. This emphasises the importance of the FFE. The instruments used at Audi cover a wide range of instruments mentioned in the literature but are designed to meet specific internal requirements. For example, “Innovation Days” can be described as supplier days at which ideas are discussed with selected suppliers (Wagner and Johnson, 2004) but on the basis of pre-defined search fields that help to generate a variety of new ideas at an early stage for a specific vehicle class or platform. When having more specific tasks instead of search fields, Audi uses via the FIN and “Concept Competition” different forms of competitions to proactively approach suppliers. Here, the differentiation in the literature between idea competition

(Ebner et al., 2009) and the more specific concept competition (Langner and Seidel, 2009) is reflected. On the contrary, different push instruments allow external partners to approach Audi without being restricted due to pre-defined search fields or tasks, e.g., “Innovation Meeting”. As such, Audi can be characterised as a company that has successfully operationalised the open innovation paradigm by implementing various open innovation instruments.

5.1 Contributions to the literature

Overall, this article adds new dimensions to the discourse on open innovation (Chesbrough, 2003) and the use of suppliers and start-ups. A central part of open innovation concerns the broad search for external technologies and companies that may be important to a company and its innovation process (Laursen and Salter, 2006). Because our article investigates the role of procurement in the innovation process and how ideas of suppliers and start-ups are identified, it can be seen as exploring one field of open innovation in greater depth. In doing so, our research expands the extant literature in several ways.

First, whereas extensive and far-reaching research exists on the importance of R&D interfaces (Griffin and Hauser, 1996), research on how the purchasing organization can facilitate NPD activities (Preuss, 2007; Schiele, 2010) and positively influence the innovation performance (Hartmann et al., 2012; Luzzini et al., 2015) is just in the starting blocks. Extending this emerging research stream, our research underscores the importance of procurement in the innovation process. We show that purchasers can even play a key role in the strongly technology-minded automotive industry by collaborating with both established suppliers and nonestablished new venture suppliers (Zaremba et al., 2016).

Second, existing literature on supplier integration has predominantly explored the use of suppliers as idea sources in general, and not the application of particular open innovation tools. In contrast, the use of user-focussed tools (e.g., lead user method, toolkits) is well-investigated (e.g., von Hippel, 1986; von Hippel and Katz, 2002; Franke and Piller, 2004; Sänn et al., 2013). On this point, this study makes a valuable and unique contribution to the literature because we present what we believe is the first empirical exposition of the variety of ways on how open innovation tools are used to identify or generate supplier and start-up ideas.

Finally, we contribute to theory by examining the involvement of suppliers in the FFE, a largely neglected area. Although the FFE has been recognised as a crucial phase that has a high impact on the success of innovation projects (Langerak et al., 2004; Verworn et al., 2008), only less attention has been paid to the involvement of suppliers in this NPD phase (Wagner, 2012; Menguc et al., 2014; Schoenherr and Wagner, 2016). Hence, research has still not come to terms on how to structure the FFE that is characterised by low levels of formalisation and ill-defined processes (Murphy and Kumar, 1997; Kim and Wilemon, 2002). With our research we reveal tools and methods that buying firms can apply to "defuzzy" the FFE and thus provide guidance on how the involvement of suppliers can be managed.

5.2 Practical implications

Overall, our article contributes to the management practice by helping companies to improve the NPD activities in their early innovation process by means of proposing a collaborative procurement perspective and the use of open innovation instruments. Buying firms should consider our results when developing their purchasing and supplier strategies. Since the timing of integration is crucial for innovation outcomes, managers should invest time and resources in the identification of suppliers and start-ups to be integrated in the FFE of the innovation process, e.g., by utilising open innovation tools. Although our data do not specifically include a performance measure, research shows that using methods in NPD positively affects new product success (Graner and Mißler-Behr, 2014; Tidd and Thuriaux-Alemán, 2016). Therefore and since such instruments are becoming increasingly more important in practice (Rohrbeck et al., 2009;

Chesbrough and Brunswicker, 2014), managers should foster their adoption and can use our results for implementation. We do not necessarily recommend to wholly centralise innovation work and tool adoption within procurement, but given the benefits relating to its involvement, purchasing should at least be part of it. The challenge for purchasing managers will be to bring both innovation work and the achievement of traditional goals such as savings into alignment since we found a possibility for conflicts of objectives to arise. Regarding collaborations with start-ups, firms must train their purchasing managers to adequately manage non-suppliers (Gassmann et al., 2010). From an overall perspective, managers must take current structures and processes into account and ensure a more flexible and quicker approach to cooperate with start-ups.

5.3 Limitations and future research suggestions

As is the case with any single case study, our findings have limited generalisability, so that issues emerge which provide great opportunities for future research. For example, we identified several challenges which are related to the collaboration with start-ups, e.g., identifying innovative start-ups and binding start-ups to the OEM. Picking up the mentioned challenges, research should investigate which criteria can be used in order to separate innovative start-ups from non-innovative. Furthermore, it would be interesting to find out more about the expectations of start-ups concerning cooperation, or in other words, which incentives need to be offered by the OEM in order to reach a preferred customer status. With regard to these two aspects, existing research mainly focusses on established suppliers (e.g., Schiele, 2012; Pulles et al., 2014) but not on start-ups. With regard to open innovation instruments, we showed which and how such instruments are used for idea generation with suppliers and start-ups but without empirical evidence on the effects of the usage as well as determining success factors. Future studies should focus on quantitative research in this area by answering, e.g., which tools affect which performance measures in general and at which stage of the NPD process (see e.g., Durmusoglu and Barczak, 2011 for the effects of IT tools). Future work should furthermore investigate tool adoption in other industries and from the perspective of suppliers.

6. Conclusion

This study examines the role of procurement in the innovation process of an automotive OEM and shows which and how open innovation instruments are used by procurement in order to benefit from the innovation capability of suppliers and start-ups. Although its role in innovation has become increasingly more important (Schiele, 2010; Luzzini et al., 2015), the concept of procurement as an instance responsible in the innovation process is not really present in the literature. Based on a single case study at Audi procurement, we show that procurement's function goes beyond just acquiring parts or reducing costs. Several arguments are elaborated that justify a key role for procurement in the innovation process (e.g., interface role, economic activities). In order to contribute to Audi's innovation performance, nine pull and push instruments are used ranging from, e.g., pitches with start-ups to different forms of supplier competitions. Since knowledge about how the integration of suppliers in the (early) innovation process (Aune and Gressetvold, 2011; Brem and Tidd, 2012; Wagner, 2012) and open innovation practices (Sjödin and Eriksson, 2010) should be organised and managed is rare, our study provides interesting insights for scholars and practitioners.

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Appendix

Questions asked in the interviews (translated from German)

0. Introduction and general information on research objectives

1. Role of procurement in the innovation process of the automotive industry

- Could you please describe the role of procurement in the innovation process?
- What benefits are related to the involvement of procurement in the innovation process?
- Are there challenges or obstacles that you face when doing innovation work?

2. Suppliers and start-ups as external idea sources in the automotive industry

- Could you please describe the relevance of suppliers (automotive/non-automotive) as external idea sources?
- Could you please describe the relevance of start-ups as external idea sources?
- In your opinion, when should suppliers and start-ups be integrated into the innovation process?

3. Use of open innovation instruments to identify or generate ideas from suppliers and start-ups

- Which open innovation instruments are used in order to identify or generate ideas from suppliers and start-ups?

The following questions were asked for each of the named instruments:

- Could you please describe how the instrument is designed? Which process underlies this instrument?
- What are the fields of application for this instrument?
- How is the instrument embedded chronologically in the innovation process?
- Which external parties (suppliers/start-ups/both) and internal functions (procurement/technical development/…) are involved when conducting this instrument?
- How frequently is this instrument used or planned to be used?
- What are the reasons for using this instrument?
- What are the benefits and problems of this instrument?

4. Need for improvements or additional instruments

- Which potential for improvements do you see regarding the existing instruments?
- Are there any instruments missing? How should possibly new instruments be designed?

Chapter 4

Suppliers versus start-ups: Where do better innovation ideas come from?

Co-authored by Alexandra Rese and Franz Simon

Abstract:
In the innovation process of firms, suppliers increasingly play a key role as external sources of ideas. Although the beneficial impact of supplier integration has been acknowledged, there is also evidence that not all such innovation efforts are successful, particularly regarding the identification of truly innovative solutions. Therefore, in recent years, large firms have begun to move beyond their existing supply base, drawing on innovation ideas from start-ups, that is, with young firms with whom they have no pre-existing bonds. Yet there is no empirical evidence regarding whether start-ups' ideas actually outperform those of established suppliers. We address this question by presenting a unique, real-world comparison of 314 supplier and start-up ideas – ideas that were identified, evaluated, and followed up over the course of an open innovation initiative conducted by a large automotive manufacturer. We find that start-ups' ideas are characterized by a higher degree of novelty and to some extent higher benefit for end customers but, on the downside, are less likely to be implemented than suppliers' ideas. However, the implemented start-up ideas are still more novel. Overall, our study adds new dimensions to the discourse on open innovation and provides valuable insights regarding the outcome of supplier and start-up involvement in the front end of the innovation process.

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1. Introduction

In today's dynamic marketplace, increasing customer needs for new products require firms to constantly innovate to sustain their competitive advantage. Because ideas are precursors to innovations (George, 2007), firms rely on a continuous stream of ideas into the front end of their new product development (NPD) process where ideation takes place (Björk and Magnusson, 2009; Kim and Wilemon, 2002). Today, there is a broad consensus that besides internal research and development (R&D) experts a key driver of a firm's innovation success is external knowledge sourcing, that is, the search for and use of new ideas from partners outside the firm (Chesbrough, 2003; Laursen and Salter, 2006).

The importance of knowledge that is difficult to imitate or substitute as a resource for firms has been highlighted by several management theories, such as the resource-based view (RBV) (Barney, 1991) and the knowledge-based view (KBV) (Foss, 1996; Grant, 1996). Among these theories, the common idea is the interconnectedness of organizations and their need for resources to achieve a competitive advantage (Kogut and Zander, 1993). Criscuolo et al. (2018, p. 115-116) refer to the "relatively well-understood" search process for new ideas, but also to research gaps such as the concentration on "either a single source of knowledge for innovation or […] external linkages to be a homogenous source." Although the effectiveness of integrative search strategies that rely on different internal and external knowledge sources has been studied, this does not hold true for a "purely external search strategy" or "go-all-outside" strategy (Criscuolo et al., 2018, p. 118), which compares the knowledge held by different external partners. Grimpe and Sofka (2016, p. 2036) point out the still fragmented "current theoretical understanding of how firms should organize their search for external knowledge."

Considering potential external partners, such as established suppliers, competitors, customers, or universities, suppliers relied on for parts or subassemblies seem to have the largest impact on product innovation (Un et al., 2010). Extensive research has shown that collaborating with suppliers positively affects the firm's innovative output (e.g. Bodas Freitas and Fontana, 2017; Lau et al., 2010; Wagner, 2012; Yeniyurt et al., 2014). However, there is also empirical evidence that not all innovation efforts with suppliers are successful, particularly regarding the identification of truly innovative solutions (Gassmann et al., 2010; Koufteros et al., 2005; Song and Thieme, 2009).

Not surprisingly, firms have begun to move beyond their established supply base looking for new partners and increasingly rely on new, young ventures (i.e. eight years old or younger) without pre-existing business relations to the buying firm, commonly labeled "start-ups" (Hom-feldt et al., 2017; Monteiro and Birkinshaw, 2017; Weiblen and Chesbrough, 2015; Zaremba et al., 2017). Compared with established suppliers, start-ups have a simple organizational structure, allowing them to be "more experimental, flexible, and even improvisational" (Eisenhardt and Tabrizi, 1995, p. 87), thereby being able to quickly respond to disruptive technological changes (Christensen and Bower, 1996). Start-ups' employee workforce is younger, with up-to-date skills, technical knowledge, and higher risk tolerance (Dorner et al., 2017; Ouimet and Zarutskie, 2014). Overall, the innovative potential of start-ups "stands out as a highly attractive feature" (Zaremba et al., 2016, p. 153). Vice versa, entering into partnerships with reputable firms is crucial for a start-up's survival because these established firms provide access to the necessary resources and help start-ups gain visibility and legitimacy, as well as the required market access for their ideas (Stuart et al., 1999).

Accordingly, academia has called for research on the use of start-ups, particularly when it comes to the early stages of a firm's innovation process (Kickul et al., 2011). While scholars have started to investigate how firms search for start-ups (Monteiro and Birkinshaw, 2017) and integrate them into their supply base (Zaremba et al., 2017), an examination of start-ups' actual innovative capabilities compared with those of established suppliers has been lacking. Specifically, the existing literature does not take the open innovation search scenario into account: a firm has specific innovation needs and will address these needs to start-ups and suppliers with the aim of identifying and implementing promising ideas. We aim to fill this gap by addressing the following research question: *How do established suppliers and start-ups perform compared with each other in generating promising innovation ideas?* Our attempt is novel because it offers the first real-world empirical comparison of suppliers' ideas and start-ups' ideas selected and evaluated within an open innovation initiative. This scenario allows us to study the crucial trade-off between the search for novel solutions by engaging new external partners and the ability to integrate and implement their ideas. Hence, our study is also of high practical relevance because in the long run the results can guide a firm's decision on whether or not to collaborate with start-ups, a process that typically involves more effort (e.g. search effort beyond the established supply base, on-boarding of start-ups into corporate structures and culture, setting up new contractual agreements) and uncertainty (e.g. in terms of proving the idea's feasibility, missing production routines, the absence of manufacturing infrastructure, and technical compatibility with existing standards, challenging scalability) compared with relationships with suppliers (Carvalho and Yordanova, 2018; Criscuolo et al., 2018; Konsti-Laakso et al., 2012; Nooteboom et al., 2007).

To answer the presented research question, we compare 314 supplier and start-up ideas in terms of key quality dimensions. All ideas were identified and evaluated over the course of an open innovation initiative conducted within the large automotive manufacturer AUDI AG. Suppliers, that is, firms from the manufacturer's existing supply base, and young start-up firms without prior business relations to Audi presented their ideas based on relevant innovation search fields. Each idea was evaluated in terms of its novelty and its benefit for end customers, followed by a decision on each idea regarding its implementation.

Our study adds new dimensions to search strategies in open innovation and external knowledge sourcing in particular against the background of KBV (Carayannopoulos and Auster, 2010; Fabrizio, 2009; Grimpe and Sofka, 2016; Lopez-Vega et al., 2016). We contribute to the growing stream of research on the use of start-ups as external sources of ideas (Monteiro and Birkinshaw, 2017; Weiblen and Chesbrough, 2015) and pursue the question of whether start-ups really constitute (more) promising innovation partners (than existing suppliers) from the perspective of a buying firm. At the same time, we shed more light on the involvement and outcome of suppliers in the front end of the NPD process, an area that has been left largely unexplored (Schoenherr and Wagner, 2016; Wowak et al., 2016). While the existing literature concentrates solely on comparing the quality of ideas generated by different user types (e.g. Lilien et al., 2002; Poetz and Schreier, 2012; Schweisfurth, 2017), our study is the first to consider suppliers and start-ups as increasingly important open innovation partners.

2. Theoretical background and hypotheses

2.1 Suppliers and start-ups as external sources of ideas for innovation

The preference for partners in an open innovation context is crucial and has several direct and indirect cost implications. Besides the search costs (Grimpke and Sofka, 2016; Laursen and Salter, 2006) and coordination costs (Criscuolo et al., 2018), Mina et al. (2014, p. 855) argue there are “opportunity costs of any choice of partners relative to available alternatives”, for example, regarding innovation outcome quality, such as novelty and benefit for end customers. Lopez-Vega et al. (2016, p. 126) emphasize that it is important for a firm to understand “where the appropriate knowledge is “stored” […] to effectively search for it”. So far, little is known about the effectiveness of different external sources, which are often considered homogenous (Criscuolo et al., 2018). When forming partnerships in searching for knowledge, research has shown that leading technology firms are more likely to “search for knowledge which does not yet exist" (Grimpe and Sofka, 2016, p. 2040). To shed more light on the potentially available knowledge in partner firms, we want to evaluate the effectiveness of ideas from more distant knowledge sources against established partners in terms of key quality dimensions.

Among external sources of knowledge, the crucial role of suppliers in NPD has generally been acknowledged (Brusoni et al., 2001; Cabigiosu et al., 2013). Several studies have highlighted the role of suppliers as external sources of innovation (Mina et al., 2014; Un et al. 2010), also against an automotive background (Rese et al., 2015). In line with the KBV, Un et al. (2010, p. 678) argue that suppliers possess additional complementary knowledge compared with the focal firm in terms of having a "specialized set of skills". Consistent with these arguments, empirical studies have shown supplier involvement in NPD to be positively related to a firm's innovative output, for example, in terms of product innovativeness (Lau et al., 2010), product variety (Al-Zu'bi and Tsinopoulos, 2012) or innovation performance (Bodas Freitas and Fontana, 2017). While most research has examined the impact of suppliers in NPD as a whole, Wagner (2012) is the first to explicitly consider supplier involvement in the front end of the NPD process where ideas are typically identified. The results indicate a positive relationship with NPD project performance, thus stressing the need to involve suppliers from a very early stage.

Despite a number of positive examples, not all studies agree with the findings of positive innovation returns on supplier involvement in NPD (e.g. Koufteros et al., 2005). In accordance with the KBV, suppliers are classified alongside customers as partners in particular supporting the specification of market requirements for innovations (Mina et al. 2014). Having previously interacted and developed innovations with the focal firm, suppliers tend to better understand and react to their particular needs (Grimpe and Sofka, 2016). However, several scholars have argued that established supplier partnerships have limited innovation potential. In particular regarding the identification of truly novel solutions, the literature suggests that new competencies and ideas from beyond the existing supply base are needed (Gassmann et al., 2010; Phillips et al., 2006; Primo and Amundson, 2002).

Start-ups, also referred to as “new ventures”, might provide such competencies and ideas. From a theoretical perspective, start-ups are characterized by the liability of newness (Singh et al., 1986). This leads to start-ups differing from established (supplier) firms in several aspects. Start-ups possess fewer resources, have lower manufacturing capabilities, have a lower degree of formalization, and lack legitimacy in the marketplace (Aldrich and Ruef, 2006; Terjesen et al., 2011; Zaremba et al., 2016). Instead, entrepreneurs and their employee workforce are endowed with entrepreneurial capabilities, such as strong work ethics, high motivation, alertness, creativity, and willingness to take risks (Ouimet and Zarutskie, 2014; Ward, 2004; Weiblen and Chesbrough, 2015; Zhao and Seibert, 2006). The ability to innovate is a crucial variable for start-up performance and is essential for gaining external visibility, as well as for accessing market shares to sustain survival (Schoonhoven et al., 1990). Because reputable buying firms can provide valuable inputs that compensate for these liabilities, start-ups have a clear incentive to enter into partnerships with these firms (Zaremba et al., 2017).

2.2 Hypotheses

The literature suggests various dimensions for assessing the quality of an idea; however, there are no uniformly applied dimensions, and the final choice depends on the context (Magnusson, 2009). What is undisputed, though, is that a key distinguishing feature of a promising idea is novelty, that is, the extent to which the idea is original and thus different from the solutions available in the market (Amabile et al., 1996; Franke et al., 2014). It is widely argued that entrepreneurship embodies a process prone to creating “newness” (Ireland and Webb, 2007).

The innovative behavior of start-ups is driven by limited resources originating from their liability of newness (Singh et al., 1986). While resource constraints restrict the ability of start-ups to experiment with multiple ideas and technologies (van Burg et al., 2012), they in turn spur creativity when focusing on a particular idea. The underlying mechanism of “bounded creativity” predicts that individuals will produce solutions that are more original when restrictions apply (Moreau and Dahl, 2005). Facing resource constraints, entrepreneurs are required to break away from conventional methods of ideation and to be more imaginative when deploying their limited resources, thus creating novel solutions (Baker and Nelson, 2005). Start-ups can use their resources creatively because they do not follow dedicated routines, which often represent a barrier to innovation. Instead of having already established structures as in established supplier firms, start-up processes are nascent and yield novel outcomes (Baker et al., 2003; Katila and Shane, 2005).

Research on creative performance shows that because of their past experiences, individuals and organizations are constrained when generating ideas; that is, they stick to schemes and strategies that have been successful in the past, thus preventing them from coming up with truly novel solutions (Audia and Goncalo, 2007). According to March (1991), the experience of success induces a shift from exploring new ideas to exploiting existing solutions because the exploitation of existing knowledge that has proven to be successful guarantees more certain results. Considering their lack of a product history, start-ups do not have this experience and do not stick to old technological paradigms (Anderson and Tushman, 1990). This is also true because the employee workforce of start-ups is younger and more diverse, having a more recent education and current technical knowledge (Dorner et al., 2017; Ouimet and Zarutskie, 2014). They can provide different knowledge as well as alternative perspectives and heuristics that may yield novel solutions to problems (Marengo et al., 2000). Regarding technology, start-ups can be straightforward in attacking established markets (Christensen and Bower, 1996). Start-ups tend to lead “highly ambiguous nascent markets and high-velocity “bubble” markets” (Davis et al., 2009, p. 415). Their structure enables faster product development in fast-paced and technologically disruptive markets, providing them with an advantage over established firms (Christensen and Bower, 1996; Davis et al., 2009).

In contrast, established suppliers usually draw on long-lasting business relationships and the breadth of new knowledge that a buying firm can gain for innovation may be rather limited (Un et al., 2010). For instance, Gassmann et al. (2010) illustrate in their case study with BMW how the automotive manufacturer screened its established supply base for innovative ideas for a new control concept solution. The authors find that “[d]espite its suppliers’ vast technological know-how and competence in technology integration, they could only come up with proposals that continued the contemporary trend toward ‘electronifying’ cars’ mechanical functions” (Gassmann et al., 2010, p. 645). Song and Thieme (2009) further reveal that market intelligence gathering activities with major suppliers in predesign tasks are positively related to success in incremental innovation projects but negatively to radical innovation projects. Overall, although the literature acknowledges the potential of suppliers to generate novel solutions from the perspective of the buying firm, we expect that start-ups perform better in terms of offering novel ideas. Hence, based on the overall discussion, we hypothesize the following:

> Hypothesis 1. Ideas proposed by start-ups that were selected within an open innovation initiative are characterized by a higher degree of novelty than the selected ideas proposed by suppliers.

Researchers studying innovation highlight that the novelty of an idea is only one of the two conceptual elements of a successful innovation. Accordingly, an idea must also be useful, that is, it has to meet a certain need and create benefits for a potentially large number of end customers (Amabile et al., 1996; Franke et al., 2014; Moreau and Dahl, 2005). To survive, start-ups need not only generate novel but also useful ideas that will appeal to some identifiable market (Ward, 2004). By founding a firm, start-ups align their entrepreneurial activities and resources with such a particular identified market opportunity (Alvarez and Barney, 2004). Discovering a promising opportunity at an early stage when potential end customers develop an interest in new solutions is an inherent capability of start-ups (Ireland et al., 2003). Thus, idea generation within start-ups can be described as not only resourceful but also “necessity driven” (van Burg et al., 2012). In so doing, start-ups apply methods such as design thinking or the “lean start-up” principle to support early interactions with end customers. Through the iterative testing of their ideas on the market, start-ups receive continuous feedback, allowing them to develop solutions that provide benefits to potential end customers (Blank, 2013). Because of their position at the edge of developments in a specific domain, start-ups perceive real-world needs and problems at an early stage and can generate solutions to these needs. In turn, established firms commonly focus on improving their existing solutions, which often result in a failure to satisfy consumer needs (Christensen and Bower, 1996; Ireland et al., 2003). Therefore, we propose the following:

> Hypothesis 2. Ideas proposed by start-ups that were selected within an open initiative are characterized by a higher degree of end customer benefit than the selected ideas proposed by suppliers.

Besides the distinguishing attributes of novelty and end customer benefit, creativity alone is not enough. The ultimate proof of an idea’s quality can be seen in its implementation by a firm (thus serving as a holistic quality measure), which is important to consider in the industrial context where many ideas fail to be implemented, for example, because they are not technically and/or economically feasible (Poetz and Schreier, 2012) or possess less organizational fit (Lilien et al., 2002). Levitt (1963, p. 79) already stated that “[i]deas are useless unless used”.

In recent years, firms have made substantial efforts to establish initiatives and mechanisms that are aimed at identifying start-ups’ ideas and transferring them into the firms’ NPD

(Weiblen and Chesbrough, 2015). However, recent research on how buying firms can leverage the innovative potential of new ventures shows that creating business relationships and conducting projects with start-ups is anything but a sure-fire success (Zaremba et al., 2017). Originating from the liability of newness, start-ups are less familiar with interacting with firms and have fewer management skills (Singh et al., 1986). This is accompanied with lower manufacturing capabilities and a lack of productive routines to transform the ideas and technologies into reliable products (Terjesen et al., 2011). Hence, there is a considerable amount of uncertainty for the buying firm in terms of strategic intent, capabilities, and product quality when deciding whether to enter into a development partnership with a start-up (Zaremba et al., 2017). These uncertainties are increased by the start-ups' unfamiliarity with the buyer's knowledge base and knowledge production capabilities. Grigoriou and Rothaermel (2017) emphasize the strain on the limited attentional capabilities of the buying firm fostering the "not-invented-here" syndrome (Katz and Allen, 1982). In contrast, established suppliers can usually draw on a long-lasting business relationship with the respective buying firm, which includes the establishment of industry-specific expertise (Gassmann et al., 2010). Given their expertise, fulfilling quality requirements and providing evidence for the technical feasibility of their ideas is usually not an issue (Primo and Amundson, 2002; Ragatz et al., 1997). Furthermore, established suppliers can benefit from accumulated experience (i.e. learning curve effects) and economies of scale (Zaremba et al., 2016), thus making their ideas and technologies more feasible from an economic standpoint. Ideas generated by suppliers can be described as "close in contextual knowledge distance to the [buying] firm" (Un and Asakawa, 2015, p. 143). Therefore, the ideas fit in better with existing technologies and hence might be easier to transfer into NPD by meeting technical and economic requirements (Gassmann et al., 2010; Un et al., 2010), whereas implementing start-up ideas is likely to be associated with higher effort and more resources. Salter et al. (2015, p. 489) mention "integration costs resulting from the cognitive challenge of bringing together knowledge from diverse settings and approval costs related to obtaining internal agreement to engagement with different external partners”. A firm must consider these aspects when it is faced with the decision on which ideas are going to be implemented. Based on these arguments, we predict the following:

Hypothesis 3. Ideas proposed by start-ups that were selected within an open innovation initiative are less likely to be implemented than selected ideas proposed by suppliers.

3. Methodology

3.1 Research setting

More than almost any other sector, the automotive industry is known for its dependence on suppliers as sources of innovation (Cabigiosu et al., 2013; Yeniyurt et al., 2014). In addition, start-ups have become increasingly more important for automotive firms with helping them find innovative solutions beyond their existing supply base (Homfeldt et al., 2017; Weiblen and Chesbrough, 2015). The automotive manufacturer AUDI AG cooperated in our study and was identified as having satisfactory conditions, as follows:

First, the firm has the aim of being at the leading edge of automotive innovation and offering customers appealing products; these aspects are of high strategic importance and part of the brand strategy.

Second, a key part of the firm’s innovation activities concerns the use of suppliers and start-ups. Moreover, suppliers and start-ups are strategic partners, as the firm highlights: “We aim to be our suppliers’ preferred customer so they come to us first with their innovative ideas […] [and] [w]e share knowledge on technical concepts with our partners right from the prede-velopment phase” (Audi, Annual Report, 2015, p. 72). In addition to suppliers, the need for start-ups has been recognized and pursued extensively over recent years. Start-ups are seen as important complementary innovators who offer fresh ideas often from non-automotive fields;

here, Audi offers the opportunity of joint development projects, thus acting as an enabler for their technologies, which might substitute established solutions once proven suitable.

Finally, supplier and start-up ideas are brought into new products in a systematic manner. Vehicle projects are developed based on a stage-gate model with a robust idea-to-launch process (Cooper, 2008), which includes the implementation of open innovation initiatives following a well-established identification and evaluation process. These initiatives are guided by the innovation management departments of the R&D and purchasing divisions and are jointly executed with subject-specific company experts. Figure 1 provides an overview of different open innovation search instruments, which can be classified by a push or pull approach and by the degree of concretization. Accordingly, in idea competitions, such as the initiative being studied, Audi proactively approaches suppliers and start-ups very early on in the innovation process, giving rather rough descriptions of innovation search fields as the basis for idea generation.

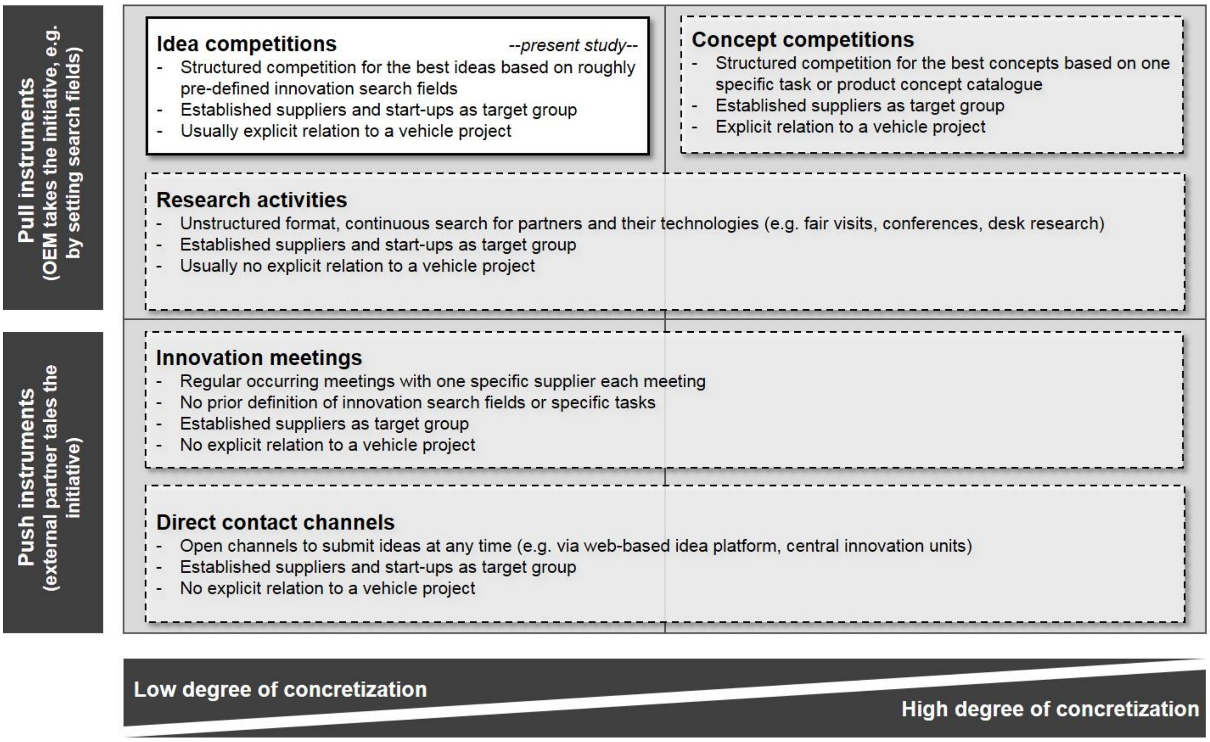

Fig. 1: Overview of open innovation search instruments

While Audi collaborated and enabled access to its innovation management, we were not able to use a controlled experimental design. Rather, the firm agreed to serve as an environment for our study where two of the researchers were given the opportunity to accompany the execution of an open innovation initiative. The general procedure of the initiative is shown in Figure 2. We also conducted interviews with key individuals to create an in-depth understanding of how external ideas are handled. In addition, we were given access to company records and to the company's idea database, which provided extensive documentation of all supplier and start-up ideas with rich information available to test our hypotheses. This naturalistic setting, which is similar to existing studies exploring the quality of innovation ideas (e.g. Björk and Magnusson, 2009; Lilien et al., 2002), allowed us to draw on unique data and investigate our research question under real-world conditions.

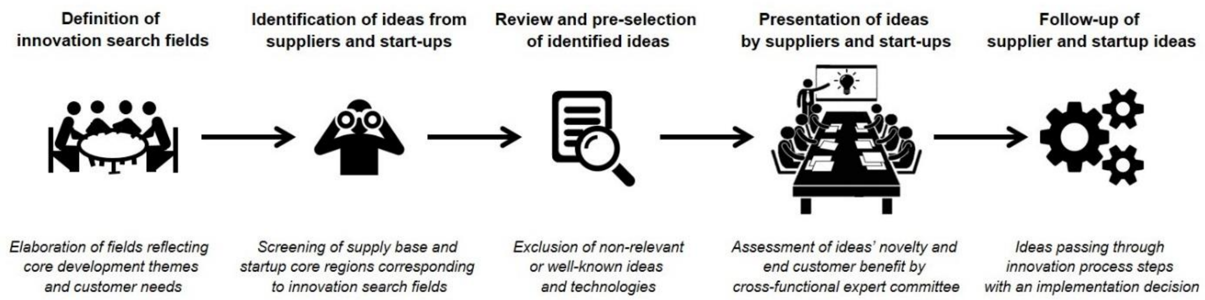

Fig. 2: Procedure of the open innovation initiative under study

3.2 Data

The data for our study refers to an open innovation initiative started in 2015 and guided by the firm's two innovation management departments. To enhance the innovation portfolio for forthcoming vehicle generation, the existing supply base and several start-up core regions areas were screened for innovative ideas based on relevant innovation search fields. Workshops with experts from R&D, purchasing, and marketing led to the definition of several search fields that reflected core development themes and end customer needs. Accordingly, ideas were sought in the fields of "alternative drivetrains and e-mobility", "artificial intelligence and digitalization", "new materials and sustainability", "sensor and safety technologies", as well as "visualization and interaction technologies".

Suppliers from the existing supply base and non-established start-ups from four representative start-up regions (e.g. Israel) were invited to submit and present their ideas (i.e. technological solution proposals). Suppliers were contacted by the automotive manufacturer. All relevant suppliers with development activities fitting the respective search fields were contacted and informed about the initiative. The supplier sample comprised 122 firms worldwide with a wide range of commodity groups given the diversity of search fields. Because these firms were not statistically different ($p > 0.10$) from other 100 randomly selected development suppliers in terms of firm size (log transformation of number of employees), firm age, relationship length with Audi, geographical location (Germany vs. rest of the world), and transaction volume (log transformation of turnover in the respective year), our sample is generally representative for the supplier population. Start-ups were approached with the help of external scouting partners, such as venture scouting firms. For each of the four start-up regions, an external scouting partner with profound expertise and the required network in the respective market was used to identify and contact relevant start-ups according to the defined search fields (cf. Monteiro and Birkinshaw, 2017).

To facilitate idea submission, search field descriptions were provided, along with a template with which the ideas could be briefly described. All submitted ideas were then reviewed for their relevance, and the firms of the relevant ideas were invited to personally present their solutions in detail. Given that promising ideas are pursued in the form of development projects and potential purchasing contracts, the initiative offered the opportunity to enhance or establish business relations with the automotive manufacturer—incentives communicated to both parties. The process also included the conclusion of non-disclosure agreements if desired to protect the knowledge of the idea providers.

The overall identification process yielded 993 ideas. The 515 supplier ideas were provided by 86 firms, which corresponds to a participation rate of 70.5%. All suppliers that were selected to present their ideas accepted the invitation. The 478 new venture ideas were spread over 472 firms. Because external scouting partners administered the identification, we cannot determine an accurate "first-contact" rate, but interviewed scouts responsible for two start-up regions stated that far more than three-quarters of the contacted firms participated in the call. However, of the 149 new venture firms invited to present their ideas, 127 were willing to share technological details. This represents a rate of 85.2%. Overall, we can expect that bias due to "non-response" is not a concern given such high participation rates (Armstrong and Overton, 1977).

Several workshops with experts from the R&D, purchasing, and marketing divisions were used to review the submitted information. To ensure idea comparability and avoid bias in the later assessment, ideas that (1) did not fit the respective search fields or (2) were already well-known were excluded from the further process. We emphasize that this decision was made based on the firm's idea, not on firm-specific variables, such as a supplier's transaction volume with Audi or whether a start-up had prior experience with other companies, because such information was not made available to the selectors. Overall, 197 supplier ideas and 129 new venture ideas passed the evaluation process.[1] Because there is no strict threshold at Audi, we reviewed all new ventures regarding their company age and excluded 12 ideas from our analyses provided by firms not meeting the age criterion of a maximum of eight years, a commonly used threshold (McDougall et al., 1994; Zahra, 1996). Hence, the dataset to test our hypotheses consists of 314 ideas (197 ideas from 61 suppliers and 117 ideas from 115 start-ups).

Despite the need to pre-select ideas, we acknowledge the problem of having a nonrandom sampling that may bias our results. It could be argued that the pre-selection process might

[1] As a result of the pre-selection, 350 ideas (199 ideas from 61 suppliers and 151 from 149 new ventures) were selected as being relevant and of potential interest. The firms who provided all of the relevant ideas were invited to personally present their solutions in detail. For 24 ideas, however, the respective firms did not follow the invitation, leading to 326 ideas (197 ideas from 61 suppliers and 129 ideas from 127 new ventures) that passed the evaluation process.

mainly screen out ideas submitted by start-ups because the bar set by Audi to accept their ideas may be higher than for those submitted by established suppliers, which could then explain the better quality results of the start-ups' ideas. However, the rejection rate during the pre-selection is higher for suppliers than start-ups, which contradicts this assumption. Furthermore, it could be argued that only start-ups with the best ideas participate in the initiative, whereas suppliers might submit any idea they have because these firms have usually been in a long-term relationship with Audi, so they might even benefit from positive rather than negative selection bias. Arguing that a lower bar has been set for suppliers' ideas in this pre-selection stage, this should then result in much more heterogeneous idea quality. In contrast to this assumption, the variance of the scores granted to supplier ideas is lower in the case of novelty ($\sigma^2_{\text{suppliers, n=197}} = 0.32$, $\sigma^2_{\text{start-ups, n=129}} = 0.71$) as well as end customer benefit ($\sigma^2_{\text{suppliers, n=197}} = 0.64$, $\sigma^2_{\text{start-ups, n=129}} = 0.78$) but is only slightly higher regarding implementation ($\sigma^2_{\text{suppliers, n=197}} = 0.11$, $\sigma^2_{\text{start-ups, n=129}} = 0.05$).[2] To further address potential sample selection bias, we employed the widely used Heckman's (1979) two-stage procedure (see Table A1). Accordingly, we employed a probit model in the first stage to predict the likelihood that an idea was selected in the workshops for further consideration using all 993 ideas and calculated the inverse Mills ratio (IMR) based on these results. Ideas considered further were coded as 1, otherwise as 0. To effectively control for selection bias, this probit model should include at least one additional instrumental variable not appearing in the second-stage regression model (commonly referred to as the exclusion restriction) that explains selection but that cannot explain the ultimate dependent variable in the second stage.[3] We used the timing of the workshop within a selection week as the exclusion

[2] The higher variance scores for novelty and end customer benefit granted to start-up ideas also show that the evaluators did not consistently assign high-quality values to ideas from start-ups just because these ideas arrived from firms with which the experts were supposedly less familiar.

[3] We note that the variables concerning the evaluators as well as timing of the presentation and evaluation refer in the first-stage model to the workshop sessions and in the second-stage model to the personal presentations of supplier and start-up ideas. This is in line with, for example, Rudy and Black (2018), who utilize variables in the first-stage probit model that are similar, but not necessarily identical, to the variables used in the second-stage analysis. However, our first-stage and second-stage variables were qualitatively the same and not statistically different from each other.

restriction, specifically whether the pre-selection of the ideas was done at the beginning (i.e. on Monday or on Tuesday, coded as 1) or at the end of a selection week (i.e. on Wednesday or on Thursday, coded as 0), which emerged as a significant predictor (b = -0.200, p = 0.050).[4] In the second stage, we inserted the IMR obtained in the first stage as an additional control variable into our main models to account for potential selection bias. We only report the Heckman procedure for novelty and end customer benefit as dependent variables, but not for implementation. Because the rejected ideas were neither evaluated in terms of novelty and end customer benefit nor followed-up on within a certain time, we consequently lack sufficient first-stage information on these variables, which are part of our model investigating implementation as dependent variable. However, in the case of novelty and end customer benefit (and their interaction), the IMR did not significantly affect the idea quality dimensions. Moreover, the results are robust and largely consistent with those presented in our original models testing the hypotheses (see Table 3). Overall, we are confident that sample selection bias does not pose a significant threat to the validity of our results.[5]

3.3 Measurement

3.3.1 Dependent variables: novelty, end customer benefit, and implementation

To allow adequate idea evaluation, suppliers and start-ups presented their ideas to cross-functional groups of company experts. To enable personal presentations of all ideas while keeping the workload at an acceptable level and preventing negative effects such as “evaluation fatigue”, the presentations were spread over five multiday events comprising more than 150 working

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[4] Certo et al. (2016) recommend using the correlation between the IMR and the independent variable as well as the pseudo R^2 associated with the first-stage probit model as indicators for exclusion restriction strength but without providing clear threshold values. Although our exclusion restriction has a rather medium effect ($r_{\text{IMR, start-up idea}}$ = 0.57; pseudo R^2 = 0.095) according to the simulation conditions of Certo et al. (2016), it was the best variable we could identify. However, because the recommendations made by Certo et al. (2016) are largely fulfilled (i.e. significant independent variable in the first stage, significant exclusion restriction, insignificant IMR, large sample size), we are confident that our conclusions regarding sample selection bias are meaningful.

[5] We thank one of the anonymous reviewers for the excellent comments and guidance on the sample selection issue.

hours of presentations. For organizational reasons, however, there were four events where only start-up ideas were presented (one event each for the ideas from each of the four start-up regions) and one event where all the supplier ideas were presented. The presentation procedure was identical throughout the events. To ensure consistent framework conditions, presentation guidelines were provided, and the time for each idea presentation was limited to around 20 minutes followed by a 10-minute question-and-answer session. The experts were also equipped with the descriptions of the ideas. To provide a better understanding of their ideas and technologies, the suppliers and start-ups were asked to show prototypes or proof-of-concept, if applicable. Whereas this approach might be subject to presenter bias, it is likewise questionable whether a paper-based assessment would be appropriate: as one innovation expert emphasized, the true value of complex technological ideas cannot be assessed only based on a description. In particular, presentation formats, also referred to as “pitches”, are suitable for ensuring a better understanding of the underlying idea and are hence widely used in innovation practice (e.g. Weiblen and Chesbrough, 2015).

Directly after the presentation, each respective idea was evaluated according to the criteria: *novelty* (degree of innovation, i.e. the extent to which the idea/technology is new and different from existing solutions on a scale from “1 – very low” to “5 – very high”) and *end customer benefit* (automotive customer impact, i.e. the extent to which the idea/technology creates value for end customers on a scale from “1 – very low” to “5 – very high”). These criteria and the process by which the ideas were evaluated are well-established within the company.

Given the diversity of the innovation search fields and ideas to be evaluated as well as the different extent to which the ideas affected vehicle components, the evaluation committee varied in terms of the composition and number of experts, but there were at least three experts and, in a very few cases, up to 18 professionals with both a technical background (R&D professionals) and a business background (purchasers or marketers). In this way, it was ensured that the ideas were evaluated by those professionals who were familiar with the idea domain (i.e. innovation search field) (Amabile, 1982; Amabile et al., 1996). Overall, the evaluation procedure was designed to be interactive: the experts assessed the ideas individually, but they also could discuss their potentially different opinions and judgments, and based on the joint discussion, they could also adapt and refine their assessments (Franke et al., 2014; Poetz and Schreier, 2012). For each idea and for each of the two dimensions, the evaluations were aggregated into an average committee rating that we used for further analysis (Füller et al., 2017). We were able to assess interrater reliability based on 2,928 individual ratings among both dimensions by using intraclass correlation (ICC) (Shrout and Fleiss, 1979). Because the ideas were evaluated by varying experts and because the number of experts ranged from three to 18, we calculated ICC(1) coefficients, with each representing one amount of experts.[6] The average ICC for novelty was 0.68 (median = 0.71, with ICCs ranging from 0.21 to 0.91) and for end customer benefit 0.69 (median = 0.69, with ICCs ranging from 0.35 to 0.91). Given that the ideas covered a wide range of innovation fields and that the ideas were assessed by many different experts from different divisions, these statistics are satisfactory for a setting such as ours (cf. Amabile et al., 1996; see also Woehr et al., 2015 pointing out that ICC(1) coefficients are generally characterized by lower values and, in contrast to ICC(2) statistics, hardly reach commonly used reliability cut-offs).

Each idea then passed to the next steps of the firm’s front end of the innovation process. After the presentation, those departments in whose field of activity the respective idea fell pursued each idea separately. The follow-up and subsequent implementation decision focused on the internal fit as well as the technical and economic aspects of each respective idea. Here, the

[6] We calculated ICC(1) coefficients instead of ICC(2) coefficients because of the varying composition of the rating committee. Calculating the ICC usually requires a consistent number of evaluators. Because in our setting the number of evaluators varied from three to 18, we calculated ICC coefficients for each configuration to determine reliability, that is, ICC coefficients for ideas evaluated by three experts, four experts, and so forth.

firm was generally interested in the whole spectrum of ideas, ranging from incremental improvements to radically new solutions. Firm-specific factors (e.g. funding amount) did not play an active role in the decision process. Central to the decision process was whether an idea matched the internal development roadmap and could fulfill technical as well as economic target parameters. The follow-up included internal discussions and bilateral discussions with the respective suppliers and start-ups, including an exchange of samples, initial testing, and creation of a business case. Technical and economic requirements were shared openly with both partner types during the follow-up (e.g. in the form of specification sheets). In particular, with ideas from start-ups, the experts took time and held an intensive exchange, which is indicated by the higher follow-up duration (3.5 months for start-ups' ideas versus 2.5 months for suppliers' ideas, $p < 0.01$). Once enough information had been gathered, a decision on whether, and if so, how the respective idea will be implemented was made (i.e. joint development project, consideration for sourcing). Senior managers in the organizational hierarchy were involved in decision making. We scanned all available follow-up protocols stored in the company's idea database. The sample extracts in Table 1 show that the implementation decision was based on profound expert assessments with a clear focus on the ideas' internal fit as well as technical and economic aspects.

Table 1: Examples of follow-up actions and decisions

Idea domain, search field	Follow-up protocol extracts
New materials and sustainability	"Material is not seen as applicable for automotive applications as by nature it should be degraded biologically but automotive parts need to hold long time. No further activities suggested."
Artificial intelligence and digitalization	"Get demo software to test on site. Ask the electronics department about what is an acceptable false positive rate. […] Interesting is the robustness against photo-fakes and the learning of facial changes."
Sensor and safety technology	"Discussion within sensor department. Expert analyzes sample and gives feedback. According to expert, no really technology advantage and costs for offered technology not attractive."
Alternative drivetrains and e-mobility	"Company sends test results. […] Prototypes are requested. Construction of window patterns in preparation."

Overall, our variable implementation serves as a holistic quality measure, making a statement about the quality of an idea in terms of fitting in with the organization and strategic planning, being technically feasible, and creating business opportunities for the manufacturer (cf. Salter et al., 2015). The decision regarding each idea was documented in the idea database. It is worth emphasizing that unlike most studies that simply rely on subjective rater assessments of idea feasibility (e.g. Magnusson, 2009; Poetz and Schreier, 2012; Schweisfurth, 2017), we consider whether the ideas were actually selected for implementation by an innovating firm (cf. Schemmann et al., 2016). Consequently, the *implementation* variable is dichotomous: if an idea was selected for implementation, it was coded as 1; otherwise, the idea was coded as 0.[7]

3.3.2 Independent variable: supplier or start-up idea

The independent variable of this study is the external source of each respective idea, that is, whether the idea originated from a supplier (i.e. a firm from the existing supply base) or from a start-up (i.e. a young firm without a pre-existing business relationship with the automotive manufacturer). Empirically, it is difficult to determine the maximum age of start-ups because different cut-off values exist. However, even though different age ranges have been used, there is an established consensus that firms eight years old or younger are considered to be start-ups (e.g. McDougall et al., 1994; Song et al., 2008; Zahra, 1996). We follow this classification and define start-ups as firms with a maximum age of eight years at the time of idea presentation and, in further contrast to suppliers, have no pre-existing business relationship with the respective buying firm. Accordingly, our independent variable is dichotomous, with a value of 1 for all ideas provided by start-ups and a value of 0 for all ideas coming from suppliers.

[7] Although we were unable to check whether the ideas were finally implemented in the product portfolio (because the vehicle development process typically takes several years from the ideation phase, thus exceeding the time period of our study), their implementation is expressly envisaged because human and financial resources are allocated to the project once the implementation decision is made (see Salter et al., 2015 for a similar measure).

3.3.3 Control variables

Given the naturalistic setting, we included several variables in our analyses to control for possible confounding effects because of individual or situational factors. Because ideas from different domains are included in this study, we controlled for any effects that the *innovation search fields* might have by including dummy variables in our analysis. This effectively controls for all constant and unmeasured differences across the domains and that might explain the differences in the variables and relationships investigated, such as origin or type of the idea, as well as the background of the experts evaluating and pursuing the idea. We also controlled for the *level of maturity* because more mature ideas might give a better impression of being original, having benefit for end customers, or might be easier for the firm to implement. Based on the information provided by the suppliers and start-ups, we included a dummy variable for the level of maturity, with a value of 1 for all ideas that have already reached the initial proof-of-concept/prototype stage at the time of presentation and a value of 0 otherwise. Furthermore, we considered controls for the events in which an idea's novelty and end customer benefit were assessed. Note that simply including dummy variables for the different events is inappropriate because the variables would be the equivalent of our independent variable (because the suppliers and start-ups presented their ideas separately from each other within the events), thus leading to multi-collinearity problems.[8] However, and perhaps more importantly, we took into account the *timing of presentation and evaluation* of an idea within each event because it might influence an idea's assessment, for example, because of possible learning effects. We included dummy variables for the different presentation timings (early, mid, and late), each accounting for one-third of the ideas in our dataset within each of the five events. Because an expert committee that varied in terms of composition and number evaluated the novelty and end customer benefit, we also controlled for these factors. In terms of *committee professional background*,

[8] A one-way ANOVA test displayed no significant differences among the start-up events with respect to our key dimensions of novelty and end customer benefit.

both experts with a technical (R&D experts) and a business background (purchasers or marketers) were part of the committee. Existing research (e.g. Schweisfurth, 2017) suggests using a balanced set of technical and non-technical experts for assessing ideas, for example, because an overbalance of technical experts possessing high domain knowledge might undervalue more novel ideas (Moreau et al., 2001). Hence, we considered whether an imbalance of evaluators with a technical background and a business background affects the evaluation result. We measured this with a dummy variable that equals 0 if the idea was evaluated by the same ratio of technical and economic experts and 1 if the ratio was imbalanced. Furthermore, we included the *number of evaluators*, which can be seen as a proxy for an idea's complexity, as a control variable. In the case of implementation as dependent variable, we did not control for the number of experts but for the *number of different departments* that were involved in the follow-up process and implementation decision. Here, we also included *novelty* and *end customer benefit* as control variables because it is likely that these criteria have an impact on the decision regarding whether an idea is going to be implemented. Finally, we used the *time until decision* (expressed in months after an idea's presentation) to control for any temporal effects in the decision process.

4. Results

4.1 Hypotheses tests

All analyses were conducted at the idea level (n = 314). We used regression analyses to investigate the effects of whether ideas originate from suppliers or start-ups on the idea quality dimensions (cf. Schweisfurth, 2017). Table 2 shows the descriptive statistics and correlations of our variables. No problematic levels of multi-collinearity could be found: the correlations were within acceptable ranges and the variance inflation factors for the variables were all below 3.00. We note that while we have more or less a one-to-one correspondence between the start-up ideas in our sample, we have multiple ideas submitted by the same supplier firm, which could introduce a correlation in the error terms. This can usually be addressed by clustering the standard errors by firm ID, but because each start-up only submitted one idea, this approach could not be implemented.

We used ordinary least squares (OLS) regression to test Hypotheses 1 and 2. The results appear in Table 3. Model 1 includes the relevant control variables: dummies for the innovation search fields, level of maturity, dummies for the timing of presentation and evaluation, committee's professional background, and number of rating experts. Model 2 introduces the independent variable to test for the hypothesized effects. In the case of both novelty and end customer benefit as dependent variables, Model 2 provides a good fit, as indicated by the significant F value and increasing R^2 after including our independent variable. Regarding novelty, the positive and significant estimated coefficient strongly supports Hypothesis 1, predicting that the ideas generated by start-ups are characterized by a higher degree of novelty than the ideas generated by suppliers ($b = 0.235$, $p = 0.006$).

Table 2: Descriptive statistics and correlations

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Novelty																	
2	End customer benefit	0.42***																
3	Implementation	0.15*	0.13*															
4	Start-up idea	0.16**	0.14*	-0.10^{+}														
5	Alternative drivetrains and e-mobility	0.00	-0.26***	-0.07	-0.16**													
6	Artificial intelligence and digitalization	-0.16**	0.12*	0.04	0.15**	-0.32***												
7	New materials and sustainability	0.07	-0.12*	0.05	-0.002	-0.28***	-0.28***											
8	Sensor and safety technologies	0.03	0.08	0.05	-0.01	-0.25***	-0.25***	-0.22***										
9	Visualization and interaction technologies	0.09	0.23***	-0.08	0.03	-0.25***	-0.24***	-0.21***	-0.19**									
10	Level of maturity	0.07	0.02	-0.01	0.14*	0.03	0.11^{+}	0.08	-0.16**	-0.09								
11	Timing of presentation and evaluation: early	0.01	0.12*	0.08	0.03	0.08	0.26***	-0.15**	-0.12*	-0.12*	0.07							
12	Timing of presentation and evaluation: mid	-0.08	-0.19**	-0.08	-0.02	0.02	-0.03	-0.06	0.16**	-0.08	-0.03	-0.50***						
13	Timing of presentation and evaluation: late	0.07	0.08	-0.01	-0.01	-0.10^{+}	-0.23***	0.21***	-0.04	0.20***	-0.04	-0.50***	-0.50***					
14	Committee professional background	0.01	-0.01	0.02	-0.11^{+}	0.01	-0.02	0.02	-0.02	-0.01	-0.04	0.01	0.01	-0.03				
15	Number of evaluators	-0.05	0.15**	-0.02	-0.20***	-0.16**	-0.16**	-0.17**	0.07	0.48***	-0.06	0.01	0.05	-0.06	-0.08			
16	Number of different departments	0.20***	0.19**	0.09	-0.10^{+}	0.02	-0.15*	-0.07	0.15**	0.07	-0.12*	-0.12*	0.18**	-0.06	0.01	0.14*		
17	Time to decision (in months)	0.27***	0.19**	0.07	0.21***	0.06	-0.10^{+}	0.06	-0.07	0.06	-0.05	-0.003	-0.03	0.04	-0.02	-0.02	0.12*	
	Mean	3.27	3.12	0.10	0.37	0.25	0.24	0.20	0.17	0.16	0.88	0.33	0.33	0.33	0.82	6.87	3.88	2.85
	Standard deviation	0.70	0.85	0.30	0.48	0.43	0.43	0.40	0.37	0.36	0.32	0.47	0.47	0.47	0.38	2.76	1.52	2.44

N = 314 ideas.

$^{+}$ $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Table 3: OLS regression results for novelty and end customer benefit as dependent variables

	Novelty						**End customer benefit**						**Two-way interaction**					
	Model 1			Model 2			Model 1			Model 2			Model 1			Model 2		
	b	S.E.		*b*	S.E.		*b*	S.E.		*b*	S.E.		*b*	S.E.		*b*	S.E.	
(Intercept)	3.571	(0.238)	***	3.363	(0.248)	***	3.397	(0.271)	***	3.238	(0.284)	***	12.790	(1.419)	***	11.432	(1.471)	***
Alternative drivetrains and e-mobility[a]	-0.283	(0.147)	+	-0.185	(0.150)		-0.768	(0.168)	***	-0.694	(0.172)	***	-3.758	(0.876)	***	-3.120	(0.891)	***
Artificial intelligence and digitalization[a]	-0.509	(0.153)	***	-0.468	(0.152)	**	-0.216	(0.174)		-0.185	(0.174)		-2.614	(0.909)	**	-2.347	(0.902)	**
New materials and sustainability[a]	-0.189	(0.149)		-0.124	(0.149)		-0.599	(0.170)	***	-0.550	(0.171)	**	-2.832	(0.888)	**	-2.406	(0.888)	**
Sensor and safety technologies[a]	-0.159	(0.148)		-0.113	(0.148)		-0.174	(0.169)		-0.139	(0.169)		-1.348	(0.884)		-1.050	(0.878)	
Level of maturity	0.186	(0.124)		0.140	(0.123)		0.113	(0.141)		0.078	(0.142)		0.925	(0.736)		0.621	(0.734)	
Timing of presentation and evaluation: early[b]	0.071	(0.104)		0.055	(0.104)		0.058	(0.119)		0.045	(0.119)		0.300	(0.622)		0.190	(0.615)	
Timing of presentation and evaluation: mid[b]	-0.064	(0.100)		-0.077	(0.100)		-0.316	(0.114)	**	-0.325	(0.114)	**	-1.129	(0.600)	+	-1.210	(0.591)	*
Committee profes-sional background	0.001	(0.102)		0.037	(0.102)		0.003	(0.117)		0.030	(0.117)		-0.098	(0.610)		0.134	(0.607)	
Number of evaluators	-0.032	(0.017)	+	-0.019	(0.017)		0.014	(0.019)		0.023	(0.020)		-0.071	(0.100)		0.012	(0.103)	
Start-up idea[c]				0.235	(0.086)	**				0.179	(0.098)	+				1.531	(0.509)	**
R^2		0.055			0.078			0.163			0.172			0.096			0.122	
F value		1.961	*		2.555	**		6.585	***		6.304	***		3.590	***		4.223	***

N = 314 ideas.
Unstandardized regression coefficients are presented.
[a] With innovation search field “visualization and interaction technologies” as reference category.
[b] With “timing of presentation and evaluation: late” as reference category.
[c] Coding of independent variable: 0 = idea originates from a supplier; 1 = idea originates from a start-up.
[+] $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

In terms of end customer benefit, the effect is less strong, as shown by the smaller and less-significant coefficient but still supports Hypothesis 2 to some extent ($p < 0.10$), which proposes that the ideas generated by start-ups are characterized by a higher degree of end customer benefit than the ideas generated by suppliers ($b = 0.179$, $p = 0.069$). The positive and significant coefficient with respect to the two-way interaction term of both dimensions provides additional support for our hypotheses ($b = 1.531$, $p = 0.003$). As noted, the Heckman estimation produces similar results (see Table A1).

We reran our models using quantile regression with the same set of variables (see Table 4). So far, we have assumed that any differences in the dependent variables of novelty and end customer benefit are equally important. However, in reality, a firm looking for ideas might be interested in a more nuanced picture as it pursues different innovation objectives, for example, developing radical innovations or just incremental improvements. For this purpose, we used quantile regression to model the relationship between the independent variable and the specific percentiles (5th, 10th, 25th, 50th, 75th, 90th, 95th) of both dependent variables. In terms of novelty, we find negative and significant effects for the 5th and 10th percentile ($b_{5\%} = -0.318$, $p < 0.001$; $b_{10\%} = -0.303$, $p = 0.014$), indicating that supplier ideas can be rather classified as incremental when compared with start-up ideas. Interestingly, the effect switches in favor of start-up ideas and the coefficient increases the closer we move to the upper tail of the distribution with the highest value being found for the 95th percentile ($b_{95\%} = 0.560$, $p < 0.001$). This is in line with managers who search for radical ideas. With respect to end customer benefit, we can detect a similar pattern in the data with the strongest effect for the 90th percentile ($b_{90\%} = 0.333$, $p = 0.0014$), even though the overall significance is not as high when compared with novelty.

Table 4: Quantile regression results for novelty and end customer benefit as dependent variables

	5%			10%			25%			50%			75%			90%			95%		
Novelty																					
	b	S.E.		*b*	S.E.		*b*	S.E.		*b*	S.E.		*b*	S.E.		*b*	S.E.		*b*	S.E.	
(Intercept)	2.151	(0.693)	**	2.684	(0.434)	***	3.048	(0.341)	***	3.377	(0.190)	***	3.560	(0.242)	***	4.115	(0.235)	***	4.347	(0.319)	***
Start-up idea[a]	-0.318	(0.091)	***	-0.303	(0.122)	*	0.042	(0.149)		0.457	(0.115)	***	0.438	(0.053)	***	0.500	(0.091)	***	0.560	(0.075)	***
Pseudo-R^2 (Koenker and Machado)	0.068			0.089			0.046			0.060			0.118			0.054			0.169		
End customer benefit																					
	b	S.E.		*b*	S.E.		*b*	S.E.		*b*	S.E.		*b*	S.E.		*b*	S.E.		*b*	S.E.	
(Intercept)	1.720	(0.434)	***	2.088	(0.389)	***	2.750	(0.326)	***	3.420	(0.263)	***	3.743	(0.334)	***	4.378	(0.493)	***	5.168	(0.466)	***
Start-up idea[a]	-0.108	(0.164)		-0.157	(0.116)		0.014	(0.124)		0.080	(0.133)		0.300	(0.141)	*	0.333	(0.103)	**	0.271	(0.130)	*
Pseudo-R^2 (Koenker and Machado)	0.173			0.171			0.194			0.126			0.076			0.063			0.095		
Two-way interaction																					
	b	S.E.		*b*	S.E.		*b*	S.E.		*b*	S.E.		*b*	S.E.		*b*	S.E.		*b*	S.E.	
(Intercept)	1.492	(2.342)		6.836	(1.977)	***	8.636	(1.743)	***	10.148	(1.465)	***	13.728	(2.058)	***	16.463	(2.321)	***	18.104	(4.097)	***
Start-up idea[a]	0.103	(0.471)		-0.265	(0.387)		0.556	(0.530)		1.473	(0.690)	*	2.514	(0.863)	**	3.820	(0.376)	***	3.816	(0.995)	***
Pseudo-R^2 (Koenker and Machado)	0.066			0.081			0.080			0.087			0.094			0.120			0.179		

N = 314 ideas.
All models include the same control variables as in the OLS regression (see Table 3).
[a] Coding of independent variable: 0 = idea originates from a supplier; 1 = idea originates from a start-up.
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

To test Hypothesis 3, we conducted binary logistic regression because the dependent variable under investigation is binary, asking whether an idea was selected for implementation or not. Table 5 reports the estimated parameters. Model 1 contains the relevant controls: dummies for the innovation search fields, level of maturity, number of different departments pursuing an idea, novelty, end customer benefit, and time to decision. The independent variable is included in Model 2 to examine the effect of the idea origin on implementation. Model 2 provides a better fit with the addition of our independent variable, as indicated by the declining log-likelihood value, the increasing significant chi-square value, and the increasing Nagelkerke's R^2. In line with existing research (e.g. Schemmann et al., 2016), the novelty of an idea is positively associated with its chance of being implemented (b = 0.890, odds ratio exp(b) = 2.435, p = 0.025).[9] Most importantly, the negative and significant coefficient of our external source dummy reveals an even stronger effect, supporting Hypothesis 3 that ideas generated by start-ups are less likely to be implemented than ideas generated by suppliers (b = -1.525, odds ratio exp(b) = 0.218, p = 0.006).

Our results reveal that even though start-ups' ideas perform better regarding novelty and end customer benefit, this creative performance alone is not enough; indeed, there are particular factors relating to the internal fit and economic performance as well as proof of the technical feasibility of the respective idea that tip the scales for implementation. The innovation idea "Holographic Display Technology" offered by a start-up and belonging to the search field visualization and interaction technologies is an example of this observation. The technology, which was initially developed for mobile devices, enables the projection of holographic imagery out of a screen, including an interaction functionality that does not require eye-wear or special gear. The idea was evaluated very high in terms of novelty and end customer benefit. Even though there were several use cases fitting the automotive context, this start-up idea

[9] We did not identify a curvilinear effect. The squared novelty term was negative but insignificant and its addition did not significantly improve our model statistics.

Table 5: Binary logistic regression results for implementation as dependent variable

	Implementation					
	Model 1			Model 2		
	b	S.E.		*b*	S.E.	
(Intercept)	-7.092	(1.587)	***	-7.912	(1.703)	***
Alternative drivetrains and e-mobility[a]	1.068	(0.914)		0.831	(0.926)	
Artificial intelligence and digitalization[a]	1.762	(0.858)	*	1.927	(0.871)	*
New materials and sustainability[a]	1.736	(0.877)	*	1.571	(0.889)	+
Sensor and safety technologies[a]	1.565	(0.854)	+	1.637	(0.861)	+
Level of maturity	-0.355	(0.625)		-0.117	(0.638)	
Number of departments	0.139	(0.125)		0.083	(0.125)	
Novelty	0.561	(0.341)	+	0.890	(0.398)	*
End customer benefit	0.394	(0.291)		0.387	(0.303)	
Time to decision (in months)	0.014	(0.071)		0.084	(0.075)	
Start-up idea[b]				-1.525	(0.556)	**
-2 log likelihood	185.532			176.510		
Pseudo-R^2 (Nagelkerke)	0.110			0.167		
Chi-square	16.857		+	25.879		**

N = 314 ideas.
[a] With innovation search field "visualization and interaction technologies" as reference category.
[b] Coding of independent variable: 0 = idea originates from a supplier; 1 = idea originates from a start-up.
$^+$ $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

differed from well-established solutions and could not satisfy the internal automotive quality standards at that time. Thus, the adoption of this idea would have required a considerable amount of resources with an uncertain outcome regarding its technical feasibility and economic added value. In contrast, the supplier idea "Innovative Lightweight Tire" belonging to the search field new materials and sustainability was selected for implementation, even though it was evaluated slightly worse in terms of its novelty and end customer benefit. Beneficially, this supplier idea fitted in with an existing component and improved it in a way that created enhanced business opportunities for the automotive manufacturer. Because of special material use and configuration, the weight and material consumption would be reduced while still meeting the defined technical performance and cost parameters. Still, even though the ideas coming from start-ups were less likely to be implemented than the ideas from suppliers, the implemented start-up ideas scored higher in terms of novelty ($mean_{start\text{-}ups} = 4.07$ versus $mean_{suppliers} = 3.43$, $t = 2.762$, $p = 0.010$). In the case of end customer benefit, however, the mean difference is not significant ($mean_{start\text{-}ups} = 3.71$ versus $mean_{suppliers} = 3.38$, $t = 1.285$, $p = 0.214$).

We performed several robustness checks. We replaced our independent dummy variable with the age of the firms and found support for our arguments, as indicated by the decreasing innovative outcome (novelty: $b = -0.122$, $p = 0.032$; end customer benefit: $b = -0.114$; $p = 0.077$; two-way interaction: $b = -0.889$, $p = 0.008$) and increasing implementation ($b = 0.558$, $p = 0.070$) as firm age increased. Furthermore, we re-tested our hypotheses with the complete dataset ($n = 326$) and obtained similar results (novelty: $b = 0.260$, $p = 0.002$; end customer benefit: $b = 0.200$, $p = 0.035$; two-way interaction: $b = 1.676$, $p = 0.0007$; implementation: $b = -1.605$, $p = 0.004$).

Additionally, to check whether the evaluation of start-up and supplier ideas was done in a similar manner, a propensity score-matching procedure was run in R taking the timing of presentation and innovation search field (pre-treatment effects) into account (Caliendo and Kopeinig, 2008; Ho et al., 2007). With regard to end customer benefit, the OLS regression reveals significant effects for the related categorical variables, for example, negative effects for presentations in the middle of an event and for the two search fields "alternative drivetrains and e-mobility" and "new materials and sustainability" (see Table 3). The analyses show that the distribution of start-up ideas significantly differs from those of suppliers, for example, including fewer ideas in the search field "alternative drivetrains and e-mobility" and "less favorable" for end customer benefit (15.4% vs. 29.9%). Instead, start-ups provided more ideas in the search field "artificial intelligence and digitalization" (31.6 % vs. 18.8%). Possible effects regarding the technology area and end customer benefit could be that the areas themselves varied or that the experts were more or less open to the ideas. By comparing the start-ups' ideas that have a similar propensity score to those of suppliers' ideas across the search fields, we can attribute the differences in outcomes to the treatment condition (start-up or not start-up).

Because the experts might not have considered the search fields as equally important in their impact on end customer benefit, it might also be possible that the search fields, which are assumed as having potentially less-promising ideas, might have been scheduled at times colliding with biological rhythms and related human fatigue effects. For example, about 50% of the presentations in “sensor and safety technologies” were scheduled predominantly in the middle of an event. While start-ups and suppliers provided a comparable number of ideas in this technology area (16.2% vs. 16.8%), it is possible that the scheduling for start-ups’ presentations is different from suppliers’ presentations. For example, most suppliers’ presentations were scheduled in the middle of an event, but only a few start-up presentations were scheduled in the middle. By comparing only start-ups’ presentations to those of suppliers in this area with a similar propensity score, we can eliminate this alternative explanation.

For the different presentation timings and search fields, the R procedure “MatchIt” was run on the 314 ideas, yielding a subsample of 210 ideas with a similar propensity score compared with ideas presented in the middle of the event. Comparing the results of the OLS regression with the full sample, the time effect stays negatively significant, indicating a pre-treatment effect for the timing of presentation regarding end customer benefit.

In the next step, we checked whether start-up ideas and supplier ideas were treated in a similar way. Supplier ideas were presented at an exclusive event and were not integrated into the four start-up events. By comparing the timing of presentation of start-up ideas with supplier ideas with a subsample of 234 ideas, the positive effect of the start-up ideas on end customer benefit remains. Therefore, there were no scheduling effects that treated start-ups and suppliers differently. Interestingly, the start-up effect becomes insignificant when also including the search fields. Although the analysis with the overall sample of 314 ideas supports our assumption with regard to end customer benefit to some extent ($p < 0.10$), the effect needs to be interpreted with caution and start-ups might not necessarily perform better when taking the propensity score matching with the balanced subsample into account. With regard to novelty, the positive start-up effect remains significant in all the analyses.

4.2 Within-group analysis

So far, we have not considered the heterogeneity among suppliers and start-ups and what effects this heterogeneity might have on the idea quality dimensions. In addition to the current variables, we therefore included several firm-specific key variables in our regressions and explored firm heterogeneity within each of our two groups. Here, we aimed to capture as much information as possible by drawing on several internal and public data sources; however, to circumvent missing data issues, we employed the listwise deletion method.

In the case of start-ups, we considered firm age, firm size, whether the firm had prior experience with other established companies or customers, several funding-related variables, and the firm's competitive situation. We thereby covered key factors that might affect start-ups' performance or companies' intention to cooperate (Ko and McKelvie, 2018; Schoonhoven et al., 1990). All data refer to the time of the idea's presentation. Those start-ups selected for presentation were asked—but not forced—to provide the above information to obtain a basic understanding of those firms being eligible for cooperation. Because not all start-ups provided complete or consistent data (e.g. some reported whether they received funding or not, while others reported the funding amount), we drew on publicly available information, such as venture databases or firm websites, to maximize the number of observations. We particularly used the CrunchBase database to validate the self-reported information and supplement missing data (cf. Ko and McKelvie, 2018); CrunchBase is a premier source of information on technology-based start-ups and includes company profiles and investment histories (including the date of investment). For further validation purposes, we supplemented and confirmed the data with information from other databases, such as CB Insights, PitchBook, and Owler. *Firm age* was measured as the number of years elapsed since foundation (mean = 3.18 years, std. dev. = 1.84 years). Firm size was measured as the *number of employees* (mean = 30.14, std. dev. = 50.57). In cases where we could only draw on employee ranges (e.g. 1-10, 11-50), we took the midpoint of the reported range. We treated having *customer experience* as a binary variable and coded start-ups as 1 if they reported already having registered sales or prior collaboration projects with established organizations and 0 otherwise (mean = 0.56, std. dev. = 0.50). To capture funding-related information, we used three different measures. Each measure only considers external funding (e.g. venture capital equity, convertible notes) acquired up to the time of the idea's presentation and does not consider funding provided by the founders. First, we used a dummy for *funding received*. Start-ups that received funding were coded as 1, and non-funded start-ups were coded as 0 (mean = 0.63, std. dev. = 0.48). Second, we used the *funding amount*, operationalized as the log transformation of the U.S. dollar amount of funding ($\text{mean}_{\text{non-log}}$ = USD 10,674,840, $\text{std. dev.}_{\text{non-log}}$ = USD 29,663,906). Third, we included several dummy variables for different *funding stages* (Pre-funding, Seed stage, Series A, Series B, and Series C). Finally, the start-ups were asked to list their competitors, and we used this *number of competitors* to capture the competitive situation (mean = 2.57, std. dev. = 2.09). The regression results are shown in Table 6. We included the firm-specific variables step-by-step to stay at a maximum number of observations in each model. Because we lacked sufficient information on the number of competitors for start-ups whose ideas were (not) implemented, we do not report these results. Overall, the quality dimensions are largely unaffected by the firm-specific variables. Start-ups with prior customer experience tend to offer more novel and customer beneficial ideas that are, at the same time, less likely to be implemented, but the results are not significant ($p > 0.10$). In addition, no significant results can be found regarding the general funding receipt and funding amount ($p > 0.10$). However, significant results can be found with respect to the funding stage. Specifically, start-ups in the Series C stage are shown to be more likely to provide ideas with a higher degree of novelty ($b = 1.039$, $p = 0.022$) and end customer benefit ($b = 0.827$, $p = 0.075$). Even though funding is not an implementation criterion, we find some evidence that ideas from start-ups in the Series B stage are more likely to be implemented (*b* = 5.144, *p* = 0.055), probably because these start-ups have achieved a sufficient degree of professionalism and financial resources to prove the technical and economic feasibility of their ideas (Dorner et al., 2017).

In the case of suppliers, we likewise included firm-specific variables in terms of experience and firm size, along with factors relating to the extant buyer-supplier relationship that might influence the idea quality dimensions. All financial data refer to the fiscal year of initial contact. *Firm age* was measured as the number of years elapsed since foundation (mean = 75.01 years, std. dev. = 61.00 years). Firm size was operationalized as the log transformation of the U.S. dollar amount of *firm revenue* ($\text{mean}_{\text{non-log}}$ = USD 15,238 million, $\text{std. dev.}_{\text{non-log}}$ = USD 21,739 million). Data for both variables were taken from publicly available information, such as annual reports and company websites. With respect to the established buyer-supplier relationship, we considered whether the supplier was part of the group-wide *supplier award program* or not (coded as 1 if yes, 0 otherwise) (mean = 0.26, std. dev. = 0.44), the *relationship length* in years (mean = 9.70 years, std. dev. = 4.47 years), and the *purchasing volume*, operationalized as the log transformation of the U.S. dollar amount in the respective year ($\text{mean}_{\text{non-log}}$ = USD 384,070,841, $\text{std. dev.}_{\text{non-log}}$ = USD 867,963,799). These data were taken from Audi's internal supplier database. Table 7 reports the regression results. No significant effects are found between the firm-specific variables and the quality dimensions of novelty and end customer benefit. Regarding implementation, we find that ideas coming from "big players" (*b* = 0.570, *p* = 0.072) but also those firms with a less-dependent partnership in terms of relationship length (*b* = -0.150, *p* = 0.078) and purchasing volume (*b* = -0.198, *p* = 0.021) were selected for implementation.

Table 6: Within-group analysis for start-ups only

	Novelty					**End customer benefit**					**Implementation**			
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 1	Model 2	Model 3	Model 4	Model 5	Model 1	Model 2	Model 3	Model 4
(Intercept)	3.432***	3.498***	4.141***	3.655***	4.318**	3.614***	3.730***	4.045***	3.902***	5.045***	-11.096*	-12.306*	-14.140*	-21.950*
	(0.734)	(0.781)	(0.811)	(0.788)	(1.254)	(0.724)	(0.769)	(0.783)	(0.812)	(1.167)	(5.074)	(5.901)	(6.875)	(9.738)
Alternative drivetrains and e-mobility[a]	0.010	0.148	0.092	0.347	-0.097	-0.180	0.068	0.149	-0.025	-1.259^{+}	-1.71e01	-1.68e01	-1.65e01	-1.65e01
	(0.336)	(0.366)	(0.406)	(0.366)	(0.756)	(0.331)	(0.361)	(0.392)	(0.378)	(0.703)	(2.42e03)	(2.68e03)	(3.07e03)	(2.47e03)
Artificial intelligence and digitalization[a]	-0.558*	-0.432	-0.573^{+}	-0.340	-0.576	-0.274	-0.102	-0.134	-0.075	-0.199	1.987	2.347	2.687	4.426^{+}
	(0.272)	(0.295)	(0.312)	(0.290)	(0.536)	(0.268)	(0.290)	(0.302)	(0.300)	(0.499)	(1.544)	(1.786)	(2.013)	(2.397)
New materials and sustainability[a]	-0.142	-0.107	-0.216	0.176	-0.417	-0.657*	-0.528	-0.550^{+}	-0.383	-1.292**	-0.730	0.135	0.476	1.291
	(0.294)	(0.324)	(0.337)	(0.335)	(0.478)	(0.290)	(0.319)	(0.325)	(0.346)	(0.444)	(1.925)	(2.155)	(2.321)	(2.228)
Sensor and safety technologies[a]	0.003	0.093	0.074	0.088	-0.179	-0.143	0.013	-0.042	-0.091	0.035	-0.304	-0.154	-0.141	1.179
	(0.299)	(0.318)	(0.334)	(0.319)	(0.532)	(0.295)	(0.314)	(0.322)	(0.329)	(0.495)	(1.722)	(1.749)	(1.837)	(2.107)
Level of maturity	0.276	0.271	-0.245	-0.085	0.593	-0.118	-0.090	-0.463	-0.428	-0.552	-1.485	-1.719	-2.033	-0.935
	(0.427)	(0.438)	(0.482)	(0.466)	(0.620)	(0.422)	(0.431)	(0.466)	(0.480)	(0.577)	(1.879)	(1.903)	(2.016)	(2.442)
Timing of presentation and evaluation: early[b]	-0.009	-0.082	-0.139	0.038	0.141	-0.445*	-0.530*	-0.568*	-0.489^{+}	-0.043				
	(0.218)	(0.234)	(0.236)	(0.242)	(0.408)	(0.215)	(0.230)	(0.228)	(0.249)	(0.380)				
Timing of presentation and evaluation: mid[b]	-0.070	-0.090	-0.187	0.012	-0.361	-0.218	-0.306	-0.366	-0.201	-0.408				
	(0.211)	(0.229)	(0.233)	(0.230)	(0.432)	(0.209)	(0.226)	(0.225)	(0.237)	(0.402)				
Committee professional background	0.153	0.063	0.012	0.089	-0.133	0.171	0.043	0.144	0.045	-0.221				
	(0.260)	(0.283)	(0.285)	(0.292)	(0.545)	(0.257)	(0.278)	(0.276)	(0.301)	(0.507)				
Number of evaluators	-0.039	-0.058	-0.069	-0.059	-0.142	0.012	0.015	-0.015	0.025	-0.092				
	(0.063)	(0.067)	(0.067)	(0.065)	(0.098)	(0.062)	(0.066)	(0.065)	(0.067)	(0.091)				
Number of departments											0.625	0.744	0.921	1.387^{+}
											(0.458)	(0.513)	(0.563)	(0.808)
Novelty											1.553	1.674	1.856	3.114^{+}
											(0.981)	(1.030)	(1.130)	(1.715)
End customer benefit											-0.166	-0.162	-0.170	-0.520
											(0.839)	(0.877)	(0.895)	(1.136)
Time to decision (in months)											0.218	0.171	0.162	0.317
											(0.156)	(0.165)	(0.178)	(0.235)
Firm age	0.004	0.009	0.040	-0.009	0.065	-0.041	-0.046	-0.05e-02	-0.048	0.054	0.132	0.059	0.036	-0.016
	(0.051)	(0.058)	(0.060)	(0.061)	(0.105)	(0.050)	(0.057)	(0.058)	(0.063)	(0.098)	(0.290)	(0.298)	(0.306)	(0.419)
Number of employees	-0.001	-0.002	-0.003	-0.004^{+}	-0.019	0.003^{+}	0.003	-0.002	0.001	-0.013	0.012	0.010	0.005	-0.005
	(0.002)	(0.002)	(0.002)	(0.002)	(0.023)	(0.002)	(0.002)	(0.002)	(0.002)	(0.021)	(0.011)	(0.012)	(0.013)	(0.026)
Customer experience	0.241	0.145	0.291	0.256	0.196	0.170	0.025	0.137	0.128	0.265	-0.743	-0.668	-0.743	-2.375

	(0.183)	(0.200)	(0.207)	(0.205)	(0.321)	(0.181)	(0.197)	(0.200)	(0.212)	(0.299)	(1.118)	(1.140)	(1.173)	(1.589)
Funding receipt		0.232			-0.207		0.010			-0.273		0.814		
		(0.210)			(0.344)		(0.207)			(0.320)		(1.209)		
Funding amount			0.037					0.006					0.276	
			(0.033)					(0.031)					(0.221)	
Seed stage[c]				0.272					-0.123					0.551
				(0.236)					(0.244)					(1.688)
Series A[c]				-0.022					0.103					2.495
				(0.296)					(0.306)					(2.297)
Series B[c]				0.596^{+}					0.080					5.144^{+}
				(0.355)					(0.366)					(2.685)
Series C[c]				1.039*					0.827^{+}					3.137
				(0.444)					(0.458)					(3.595)
Competitors					-0.010					-0.057				
					(0.073)					(0.068)				
Observations	109	98	91	90	46	109	98	91	90	46	109	98	91	90
(Pseudo-)R^2	0.096	0.106	0.158	0.214	0.271	0.169	0.162	0.209	0.192	0.380	0.349	0.350	0.374	0.517
F value/Chi-square	0.851	0.763	1.108	1.242	0.823	1.622^{+}	1.247	1.560	1.082	1.359	15.334	14.855	15.513	22.085

Unstandardized regression coefficients are presented with standard errors in parentheses.

[a] With innovation search field “visualization and interaction technologies” as reference category.

[b] With “timing of presentation and evaluation: late” as reference category.

[c] With “pre-funding” as reference category.

$^{+}$ $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

This reflects the firm's general openness to collaborate with less-established partners in this initiative.

Table 7: Within-group analysis for suppliers only

	Novelty	End customer benefit	Implementation
(Intercept)	3.534*** (0.768)	2.825* (1.185)	-10.694** (3.789)
Alternative drivetrains and e-mobility[a]	-0.185 (0.237)	-0.869*** (0.229)	1.081 (0.923)
Artificial intelligence and digitalization[a]	-0.431 (0.269)	-0.172 (0.241)	-0.089 (0.937)
New materials and sustainability[a]	-0.039 (0.250)	-0.338 (0.209)	2.085* (0.898)
Sensor and safety technologies[a]	-0.186 (0.212)	-0.092 (0.219)	1.966* (0.923)
Level of maturity	0.079 (0.137)	0.111 (0.112)	0.672 (0.858)
Timing of presentation and evaluation: early[b]	0.151 (0.118)	0.455** (0.164)	
Timing of presentation and evaluation: mid[b]	-0.040 (0.102)	-0.273+ (0.140)	
Committee professional background	-0.059 (0.104)	-0.154 (0.136)	
Number of evaluators	0.001 (0.022)	0.033 (0.025)	
Number of departments			0.093 (0.143)
Novelty			0.673 (0.592)
End customer benefit			0.402 (0.447)
Time to decision (in months)			0.097 (0.170)
Firm age	0.001 (0.001)	0.0004 (0.0009)	-0.003 (0.009)
Firm revenue	-0.018 (0.069)	0.038 (0.123)	0.570+ (0.317)
Supplier award program	-0.077 (0.091)	-0.023 (0.177)	0.265 (0.555)
Relationship length	-0.014 (0.014)	-0.018 (0.017)	-0.150+ (0.085)
Purchasing volume	0.006 (0.018)	0.017 (0.019)	-0.198* (0.086)
Observations	190	190	190
(Pseudo-)R^2	0.077	0.353	0.260
F value/Chi-square	1.331	9.056***	26.671*

Unstandardized regression coefficients are presented with standard errors in parentheses. Standard errors were clustered by firm ID.

[a] With innovation search field "visualization and interaction technologies" as reference category.

[b] With "timing of presentation and evaluation: late" as reference category.

+ $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

5. Conclusion and implications

In recent years, many firms have moved beyond their existing supply base and have increasingly used start-ups as an additional source of ideas. Motivated by this phenomenon, the current study examined how the ideas generated by both suppliers and start-ups perform against each other in terms of key quality dimensions. The relevance of this question is high because the results can provide guidance for decision makers on whether to go a more uncertain route and invest in the identification of and collaboration with non-established start-up companies. Based on a unique, real-world empirical comparison of 314 supplier and start-up ideas, we find empirical evidence showing that ideas generated by start-ups are characterized by a higher degree of novelty and—to some extent—higher end customer benefit when compared with ideas generated by established suppliers. The findings from the quantile regression underline this, showing that supplier ideas can be classified as rather incremental, whereas start-up ideas particularly perform better when focusing on more novel ideas. This is in line with managers looking for radical ideas. On the downside, we find that start-ups' ideas are less likely to be implemented, implying that suppliers' ideas provide a better fit with existing technologies and create more valuable business opportunities while meeting technical and economic criteria. However, the ideas from start-ups that were selected for implementation are still more novel. Our study is the first to empirically show these results using a large-scale idea dataset, thereby providing valuable theoretical and managerial contributions.

5.1 Contributions to theory

Our study contributes to the growing literature on open innovation and external knowledge sourcing in several ways. First, we add to the stream of research within the KBV (Foss, 1996; Grant, 1996) focusing on partner selection within the collaborative mode (Carayannopoulos and Auster, 2010). Interfirm collaboration is closely related to search theory, namely relational search (Grimpe and Sofka, 2016). Innovative ideas obtained from suppliers and start-ups during an idea competition were compared in terms of novelty, end customer benefit, and implementation. Accordingly, we add to the research on purely external search (e.g. Criscuolo et al., 2018) by comparing two different external sources. When searching for novel ideas, start-ups should be engaged. When it comes to end customer benefit, start-ups also perform better to some extent, but the results are less clear here. In addition, the trade-off between the search for novel ideas and their implementation becomes apparent by favouring established suppliers. We provide evidence that these sources are not homogenous and that drawing on knowledge from cognitively distant domains, that is, from beyond the existing supply base, can facilitate the identification of promising solutions. Hence, our research contributes to the dimensions of search in open innovation in the context of the KBV by shedding some additional light on "where to search" for external knowledge (Lopez-Vega et al., 2016).

Second, we add to the emerging stream of research on the use of start-ups as external sources of ideas; we do this by showing how their ideas differ from those provided by established peers. Research has only recently started to investigate how start-ups and their ideas can be identified (Monteiro and Birkinshaw, 2017; Weiblen and Chesbrough, 2015), as well as how firms can leverage the potential of innovative start-ups and integrate them into their existing supply base (Zaremba et al., 2017). Our study adds the puzzle piece of how start-ups perform, thus responding to the call for research on start-ups' innovative capabilities in the early stages of a firm's innovation process (Kickul et al., 2011). Considering established suppliers as opponents, we show that start-ups indeed constitute promising open innovation partners that can deliver novel ideas that have an end customer benefit for innovation fields in which a firm aims to innovate.

Third, we contribute to theory by examining the involvement of suppliers in the front end of the NPD process. Although this phase, in which new product ideas are identified and generated, has been recognized as crucial to the success of innovation projects (van den Ende et al., 2015; Kim and Wilemon, 2002), less attention has been paid to the involvement of suppliers in this NPD stage. According to Wowak et al. (2016, p. 67), neglecting the role of suppliers in the early stages of NPD “has created a gap in scholarly understanding”. While there is extensive research that considers suppliers as co-development partners (Koufteros et al., 2005; Lau et al. 2010) providing input in various NPD stages (Al-Zu’bi and Tsinopoulos, 2012), studies on the involvement and subsequent outcome of suppliers in the front end of the NPD process have just started to appear (Homfeldt et al., 2017; Schoenherr and Wagner, 2016; Wagner, 2012). We add to this evolving research stream by examining supplier contributions in the early stages and provide a better understanding of the value of supplier ideas.

Fourth, taking the above accounts in tandem, we contribute to a more holistic view of the value of the diverse set of external sources of ideas. With regard to interfirm cooperation on idea generation, the literature has largely concentrated on comparing the quality of ideas generated by different user types (e.g. Magnusson, 2009; Poetz and Schreier, 2012; Schweisfurth, 2017) or compared internal basic search with collaborating with scientists (Cassiman and Veugelers, 2006; Fabrizio, 2009). Our study is the first to consider suppliers and start-ups as increasingly important external sources of ideas. We believe this is an important contribution to the field of open innovation, where past research has mainly focused on users as external partners (see also the recent literature reviews of Bogers et al., 2017 and Randhawa et al., 2016).

5.2 Implications for managerial practice

Our study has implications for managers who are developing strategies to access and exploit innovation ideas from external partners. The findings of the present study suggest that firms in need of ideas for new products should reach beyond their established supply base and integrate start-ups into the ideation phase, for example, by implementing open innovation search instruments. While such an approach can facilitate the identification of exceptionally novel ideas, the beneficial outcomes might occur at the expense of realization. Although we could not provide a detailed analysis of the reasons behind what makes the implementation so difficult, firms must be prepared for the fact that bringing start-up ideas into the final product is a challenging and resource-intensive undertaking. If firms want to gain a competitive advantage through start-up integration, they must be willing to invest resources into the implementation of start-up ideas and ensure that they have the required mechanisms and mindsets that enable the transfer and handling of knowledge from beyond the established supply base. To increase the chance of implementing start-up ideas, a useful approach can also be to encourage collaboration between a firm's suppliers and promising start-ups, thus combining the specific strengths of both parties and boosting new venture performance, as shown by Song and Di Benedetto (2008). This approach becomes even more relevant if a start-up's idea is not directly exploitable or adaptable by the buying firm. In that case, handing over the development responsibility (including the achievement of technical and economic target parameters) to a supplier would save opportunities for the buying firm to profit from start-up innovation.

Although our results justify the integration of start-ups into the ideation phase, it is not to say that start-ups can or should replace established suppliers. The firm's strategy must depend on its objectives. When the goal is radical innovation, start-ups unequivocally constitute a promising source. However, in many cases, incremental improvements to existing solutions, which are more likely to come from suppliers, are often not too costly and hence are considered to be quick wins. From an overall perspective, we therefore suggest that the ideal approach for a successful firm innovation portfolio is to use both partner types.

6. Limitations and future research

Despite its theoretical and managerial contributions, our study is not without limitations, which in turn provide potential avenues for future research. First, our sample comprises ideas identified, evaluated, and pursued over the course of an open innovation initiative conducted within a single automotive firm. Although we consider Audi and the setting to be quite representative for other large firms and initiatives (ideation was based on diverse innovation search fields in a complex industry), we are aware that the generalizability of our results is limited. More empirical research within different firms and industries is needed to validate our findings. In particular, studies within different (less mature) industrial contexts (e.g. the consumer goods sector) would deepen our understanding of whether the capability of start-ups and suppliers to provide promising ideas is influenced by the underlying product category or industry sector.

Second, a trade-off in our study is the naturalistic setting, which strengthens external validity at the cost of internal validity. Although we controlled for and found possible confounding factors, future work may use controlled experimental designs for further confirmation and elaboration of our results. For instance, whereas the evaluations in our study are—to a great extent—based on the impressions gained during the personal presentations of suppliers and start-ups, experimental studies usually rely on paper-based assessments where experts evaluate each idea blind to the source. However, we believe that in a setting like ours, where highly technology-driven ideas had to be assessed, evaluations only based on an idea description would not be appropriate. Also, the selection process of the ideas was performed solely by internal experts. Particularly, the first-stage ideas were evaluated "thumbs up or down" with the risk of overlooking potentially interesting ideas that only could emerge after a more in-depth look. Therefore, an analysis of data material using "big data methods" such as text mining might be promising and a possible additional step before finally selecting the ideas for presentation (Hoornaert et al., 2017). The same holds true for innovation search fields, with regression analyses indicating a lack of sufficient novel ideas in the field of artificial intelligence and digitalization or less customer-appealing ideas in the field of new materials. Overall, the idea selection process—in particular the evaluators' openness to external sources of ideas—should be investigated in more detail (Salter et al., 2015) to better understand idea selection and improve the idea selection process. In addition, it would be interesting to see what exactly motivates start-ups and suppliers to participate in the early stages of a firm's NPD process and to provide high-quality ideas (LaBahn and Krapfel, 2000). While in our setting suppliers and start-ups were equally motivated by the fact to advance business relations, future research might control for different motivational factors, whether it is incentives or rather relational aspects. Furthermore, future studies may also consider the internal idea creators at a company to provide a more comprehensive view of closed versus open innovation outcomes in ideation (Schweisfurth, 2017).

Third, although we provided a better understanding of the value of ideas generated by suppliers compared with ideas generated by start-ups in terms of key quality dimensions, our study is limited in figuring out the impact of involving both partners and using their ideas on the success of a firm's final output, that is, products introduced into the market. Future studies might use other research settings to investigate the comparative effect of start-up and supplier involvement on firms' performance measures (see, e.g., Al-Zu'bi and Tsinopoulos, 2012 who examine the relative impact of integrating suppliers and lead users in the NPD process on a firm's product variety). In addition, it would be interesting to investigate whether taking part in a competition is generally beneficial for the performance of external partners, for example, by looking at start-ups and suppliers that did not get an idea selected.

Fourth, our results indicate obstacles regarding the implementation of start-up ideas but do not provide a detailed analysis of the reasons and barriers in the specific context (e.g. technical, economic, relational, lack of know-how). This is particularly true for potential difficulties in the "understanding of the norms, habits, and routines" (Laursen and Salter, 2006, p. 135) of unknown start-ups compared with known suppliers, but also for problems related to the scalability or technological compatibility in terms of existing standards or the manufacturing infrastructure (Carvalho and Yordanova, 2018, Konsti-Laakso et al., 2012). Thus, qualitative longitudinal studies covering the process from idea generation to implementation should be used to better understand why an implementation fails or how an implementation works successfully, thus providing helpful guidance for practitioners.

Finally, our analysis remained at the firm level. How individuals search for innovations (Maggitti et al., 2013) within different open innovation search instruments would shed further light on "how to search". Faced with potential biases, idea evaluation processes must be carefully designed. A range of influences on different levels—such as evaluators' personality traits, educational backgrounds, their embeddedness into social and organizational structure, or the framing of the ideas—must be taken into account and must be further researched (Cattani et al., 2018; Lu et al., 2018; Zaggl et al., 2018; Zhou et al., 2018).

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Appendix

Table A1: Heckman two-stage estimation

	First stage (Probit)			Second stage (OLS)								
	Selection			Novelty			End customer benefit			Two-way interaction		
	b	S.E.		*b*	S.E.		*b*	S.E.		*b*	S.E.	
(Intercept)	0.174	(0.309)		3.263	(0.305)	***	3.256	(0.349)	***	11.061	(1.812)	***
Alternative drivetrains and e-mobility[a]	0.116	(0.144)		-0.186	(0.148)		-0.693	(0.169)	***	-3.132	(0.876)	***
Artificial intelligence and digitalization[a]	0.145	(0.144)		-0.465	(0.150)	**	-0.186	(0.171)		-2.335	(0.887)	**
New materials and sustainability[a]	-0.062	(0.142)		-0.140	(0.150)		-0.547	(0.172)	**	-2.469	(0.892)	**
Sensor and safety technologies[a]	0.001	(0.148)		-0.119	(0.146)		-0.138	(0.167)		-1.072	(0.886)	
Level of maturity	-0.087	(0.141)		0.131	(0.123)		0.080	(0.140)		0.590	(0.728)	
Timing of presentation and evaluation: early[b]	-0.021	(0.107)		0.063	(0.103)		0.044	(0.118)		0.221	(0.611)	
Timing of presentation and evaluation: mid[b]	0.096	(0.107)		-0.074	(0.098)		-0.326	(0.112)	**	-1.199	(0.582)	*
Committee professional background	0.156	(0.253)		0.041	(0.101)		0.029	(0.115)		0.152	(0.598)	
Number of evaluators	-0.074	(0.016)	***	-0.022	(0.018)		0.029	(0.020)		0.003	(0.105)	
Early pre-selection workshop	-0.200	(0.102)	*									
Start-up idea[c]	-0.248	(0.096)	**	0.210	(0.096)	*	0.183	(0.109)	+	1.440	(0.567)	*
Inverse Mills ratio				0.123	(0.227)		-0.022	(0.259)		0.458	(1.345)	
Observations	993			314			314			314		
(Pseudo-)R^2	0.095			0.079			0.172			0.123		
F value/Chi-square	69.339		***	2.344		**	5.713		***	3.838		***

Unstandardized regression coefficients are presented.
[a] With innovation search field “visualization and interaction technologies” as reference category.
[b] With “timing of presentation and evaluation: late” as reference category.
[c] Coding of independent variable: 0 = idea originates from a supplier; 1 = idea originates from a start-up.
$^{+}$ $p < 0.10$; * $p \leq 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Chapter 5

Front-end supplier involvement, firm innovation capability, and mediating effects: Empirical evidence from the German automotive industry

Co-authored by Alexandra Rese

Abstract:

In recent years, supplier involvement in focal firms' innovation processes has changed from a minor activity to a strategic one, with a steady increase of suppliers' development responsibility that resulted in a transition of the supply base from the pure delivery of products to offering inimitable knowledge from the very early beginning of new product development. Motivated by this phenomenon, this study examines suppliers' involvement in the fuzzy front end (FFE) phase of focal firms' new product development processes, in which new product ideas are generated and evaluated. While supplier involvement in the more formalized development phase has been well investigated, much less is known about the effects of involving suppliers in the FFE phase and about the underlying mechanisms through which supplier involvement in the FFE contributes to a focal firm's innovation capability. We address these issues and pro-vide some new evidence based on data from 206 automotive firms. Our results show that sup-plier involvement in the FFE has a positive impact on both a focal firm's radical innovation capability and incremental innovation capability, with, however, a stronger effect in terms of incremental innovation. In addition, we find significant effects regarding several mediator variables, such as supplier ideas search practices, supply base variety, non-monetary incentives, and early purchasing involvement. Interestingly, these effects differ between both types of innovation capability, thus providing valuable insights for scholars and practitioners.

This chapter is under review at a reputable, international journal in the area of innovation management.

1. Introduction

In today's global competitive environment, firms are being challenged by developing product innovations not only quickly but also economically, whilst simultaneously ensuring greater novelty and customer benefit. The notion that innovation should emerge primarily from within a firm is becoming obsolete as a growing number of firms obtain product ideas through external knowledge sources to meet the above-mentioned challenges (Chesbrough and Brunswicker, 2014; Gesing, Antons, Piening, Rese, and Salge, 2015). Quite different from any other industry sector, the automotive industry, which provides the empirical setting of the current study, has been undergoing a major upheaval for several years. The need for innovations in new technological fields such as e-mobility or autonomous driving puts pressure on firms and opens door for new competitors (Oliver Wyman and VDA, 2018). Because of this innovation pressure, the use of external knowledge sources for new product development (NPD) has become increasingly important in the automotive industry (Cabigiosu, Zirpoli, and Camuffo, 2013; Homfeldt, Rese, and Simon, 2019; Ili, Albers, and Miller, 2010).

Considering the potential set of external partners, such as suppliers, customers, competitors, or universities, suppliers that are relied on for parts or subassemblies seem to have the largest impact on a firm's product innovation capability (Un, Cuervo-Cazurra, and Asakawa, 2010). Studies in different industries have shown that collaborating with suppliers positively influences a focal firm's innovative output (e.g., Al-Zu'bi and Tsinopoulos, 2012, Bodas Freitas and Fontana, 2018; Lau, Tang, and Yam, 2010). Focusing on the automotive industry, the crucial role of suppliers is particularly relevant because recent decades have witnessed a steady increase of product development outsourcing and a shift of both development tasks and knowledge from focal firms to suppliers (Cabigiosu et al., 2013; Yeniyurt, Henke, and Yalcinkaya, 2014).

Focal firms can tap suppliers' knowledge and competencies at different stages of the NPD process (Wagner, 2012). In this regard, the literature generally partitions the NPD process into two main phases—the *fuzzy front end* (FFE) and the *development phase* (Kim and Wilemon, 2002). In the FFE, a firm conducts early predevelopment activities ranging from idea generation to idea evaluation and the development of first product concepts (Kim and Wilemon, 2002). Ill-defined processes, ad-hoc decisions, and high levels of dynamism characterize this phase (Montoya-Weiss and O'Driscoll, 2000; Murphy and Kumar, 1997). Once a firm decides that an idea is ready for development, the more structured and execution-oriented development phase begins with the final product as the eventual result (Kim and Wilemon, 2002). Particularly, the FFE phase has been recognized as critical to the success of innovation projects (e.g., Kock, Heising, and Gemünden, 2015) because the decisions made during the FFE set the path for new products and, hence, play a crucial role in the NPD success (Wagner, 2012). As Hauser, Tellis, and Griffin (2006, p. 702) note, "there is no doubt that the 'fuzzy front end' of a PD process has a big effect on a product's ultimate success". Therefore, it is not surprising that firms have started to increasingly put effort into the effective management of supplier involvement in the FFE. For instance, the world's largest car manufacturer, Volkswagen AG, initiated a specific supplier program, called "Future Automotive Supply Tracks", in 2015. The program aims to intensify the collaboration with strategic suppliers in the early stages of the innovation process, including early insights into Volkswagen's development roadmap, access to innovation events, and strategic dialogues with top decision makers on the suppliers' ideas (Volkswagen, 2019).

However, the existing research mainly focuses on supplier involvement in the well-formalized development phase (e.g., Koufteros, Vonderembse, and Jayaram, 2005; Lau et al., 2010), with less attention having been paid to the involvement of suppliers in the crucial FFE (Menguc, Auh, and Yannopoulos, 2014; Schoenherr and Wagner, 2016). This focus on backend activities (Yan and Dooley, 2014) has been described as creating “a gap in scholarly understanding” (Wowak, Craighead, Ketchen, and Hult, 2016, p. 67). Recent studies have thus far examined which factors lead to a higher supplier involvement in the FFE (Schoenherr and Wagner, 2016) or used qualitative designs to explore how supplier ideas can be searched for in the FFE (Homfeldt, Rese, Brenner, Baier, and Schäfer, 2017). However, substantial research on a large empirical basis investigating the effects supplier involvement in the FFE has on the innovation capability of the focal firm and which factors do mediate these effects is lacking (Wagner, 2012). In this context, Wowak et al. (2016, p. 78) call to “consider the type of innovation (radical versus incremental) when designing studies” on supplier involvement in the FFE. Likewise, Eling and Herstatt (2017) have called for more research on the underlying mechanisms between FFE activities and the generation of both radical and incremental innovation. The generation of both innovation types is necessary for ensuring a firm’s competitive advantage (Ritala and Hurmelinna-Laukkanen, 2013; Subramaniam and Youndt, 2005), yet the role of suppliers in generating these specific types has been less investigated. Accordingly, we developed and—based on survey data from 206 automotive firms—tested a model that answers the following two research questions: *(1) Which effect does supplier involvement in the FFE have on a firm’s radical and incremental innovation capability? (2) Which of the factors that a firm can influence may mediate this relationship?* Addressing these questions is important because doing so extends the limited knowledge on supplier involvement in the FFE from a theoretical point of view that, in turn, will help managers to decide whether they should work intensely with suppliers from early on and how the FFE should best be organized depending on the innovation objective.

The main contribution of our study is to the literature on early supplier integration (Menguc et al., 2014; Wagner 2012; Wowak et al, 2016). Our research framework builds primarily upon the knowledge-based view (KBV) of the firm. At its core, our framework concerns supplier involvement in the FFE as a key factor for a focal firm's capability to generate radical and incremental innovation. Furthermore, a set of mediating hypotheses is developed, with the aim being to investigate factors that govern the relationship between supplier involvement in the FFE phase and a focal firm's radical and incremental innovation capability. The considered mediators span a range of scholarly relevant factors—supplier ideas search practices, supply base variety, monetary and non-monetary supplier incentives, and early purchasing involvement—that will also suggest important recommendations for managerial practice.

2. Theory and hypotheses development

2.1 Influence of supplier involvement in the FFE

The KBV emphasizes the importance of knowledge in the creation of strategic opportunities that may represent new sources of revenue (Foss, Lyngsie, and Zahra, 2013). According to the KBV, a firm's performance and competitiveness particularly depends on the ability to pursue the strategies that involve the integration, transfer, and creation of knowledge-based resources, which are usually difficult to imitate or substitute (Grant, 1996). Hence, knowledge is considered a key resource to manage in the firm, because it is the basis of a firm's existence and of its market superiority (Kogut and Zander, 1992). However, scholars have scrutinized whether it is the absolute amount of resources or the deployment of such resources that result in firm performance differences (Menguc et al., 2014; Newbert, 2007). Capabilities, which are defined as "the ability to deploy resources effectively so that inputs can be transformed into desirable outcomes" (Menguc et al., 2014, p. 315), may explain why firms with a similar level of resources achieve different performance levels. A firm's ability to innovate new products is a crucial capability because this ability is closely tied to the overall performance of the firm (Lau et al., 2010; Menguc et al., 2014). When it comes to product innovation capability, the literature distinguishes between incremental innovation capability and radical innovation capability. Firms that possess incremental product innovation capability can develop products that refine existing products and reinforce the potential of prevailing product lines; thus, these products are seen by customers as ones that slightly enhance their benefit without significantly deviating from prior knowledge. In contrast, firms with a radical innovation capability can generate products that fundamentally change existing ones, which often make the prevailing products and technologies obsolete; these products significantly enhance customers' benefit and require them to learn new skills to perceive the new usage experience (Chandy and Tellis, 1998; Subramaniam and Youndt, 2005).

Focal firms can limit the scope of their product innovation process and knowledge-creation to internal parties or they can involve external partners. Nowadays, knowledge-generating processes regularly extend beyond firm boundaries and involve external sources (Salter, Ter Wal, Criscuolo, and Alexy, 2015). As Cohen and Levinthal (1990, p. 128) highlight, "[t]he ability to exploit external knowledge is thus a critical component of innovative capabilities." Suppliers are potentially promising external knowledge sources to be involved in a focal firm's NPD process. Accordingly, the current study conceptualize collaboration with suppliers as a space that allows a focal firm to acquire, create, and share knowledge-based resources throughout the FFE phase of the NPD process, which, in turn, can enhance the focal firm's product innovation capability (cf. Bodas Freitas and Fontana, 2018; Homfeldt et al., 2019; Un et al., 2010).

Partnerships with suppliers in NPD have become an important strategy for focal firms because they are recognizing that supplier involvement is crucial in the pursuit of competitiveness (Menguc et al., 2014). In accordance with the KBV, collaborating with suppliers allows focal firms to access knowledge that is "part of a specialized set of skills" (Un et al. 2010, p.

678). NPD outsourcing has increasingly changed from a minor activity to a strategic one, indicating that suppliers possess deeper knowledge about the components they develop and deliver. Focal firms also gain insights into the required functionalities derived from the market or can even self-determine them (Menguc et al., 2014). Furthermore, because suppliers commonly maintain business relations with several focal firms, suppliers also gather knowledge about the practices used in other firms, which they implicitly incorporate into the own development activities (Un and Asakawa, 2015). By pooling the suppliers' knowledge and the internal expertise about which requirements need to be fulfilled and how to use suppliers' inputs in the final products, focal firms can draw on valuable technological and market knowledge while at the same time increasing the capacity for identifying and selecting the most promising solutions (Bodas Freitas and Fontana, 2018).

Consistent with these arguments, empirical studies have shown supplier involvement in NPD to be advantageous for the focal firm. Most research, however, focuses on "classical" performance measures such as increased product quality, shorter development times, lower development costs (e.g., Hoegl and Wagner, 2005; Primo and Amundson, 2002; Wagner, 2012), and, consequently, better firm financial performance (e.g., Bodas Freitas and Fontana, 2018; Menguc et al., 2014; Petersen, Handfield, and Ragatz, 2005). Surprisingly, the effects of supplier involvement in terms of a focal firm's capability to generate innovative products has been less investigated, and the prevailing results are not consistent. For instance, Lau et al. (2010) find that product co-development with suppliers is positively associated with focal firms' product innovativeness, and Al-Zu'bi and Tsinopoulos (2012) reveal a positive impact of supplier collaboration on firms' product variety. In contrast, Koufteros, Vonderembse, and Jayaram (2005) find that assigning more product development responsibilities to suppliers has a negative effect on the firms' ability to offer new products and features. Likewise, Gassmann, Zeschky, Wolff, and Stahl (2010) illustrate in a case study of BMW that the automotive manufacturer failed to identify radically innovative solutions from its suppliers. The authors find that "[d]espite its suppliers' vast technological know-how and competence in technology integration, they could only come up with proposals that continued the contemporary trend toward 'electronifying' cars' mechanical functions" (Gassmann et al., 2010, p. 645). Accordingly, the current study aims to shed more light on the effects of supplier involvement on the innovation capability of the focal firm, here while theorizing that integrating suppliers in the FFE tips the scales for both radical innovation and incremental innovation, an issue that has been unexplored so far and that researchers have called to further investigate (Wowak et al., 2016).

We argue that, from a KBV perspective, the earlier suppliers are involved in the focal firm's NPD process the closer the contextual knowledge distance between both parties becomes (Un and Asakawa, 2015). If suppliers are involved right from the beginning of NPD, complementary capabilities can be combined early, and common goals could be better developed (Un et al., 2010), in turn facilitating the transfer and integration of knowledge (Un and Asakawa, 2015). Hence, if a focal firm foster supplier involvement in the FFE, it can exploit suppliers' knowledge early before concept decisions are made, increasing the likelihood of identifying a broad spectrum of both radical and incremental product ideas that are not available to the focal firm that can be further developed into final products (Homfeldt et al., 2019).

Research shows that early supplier involvement in NPD is associated with a closer buyer-supplier relationship (Parker, Zsidisin, and Ragatz, 2008). By working intensively together in the FFE, suppliers and the focal firm are more likely to establish close communication, produce more effective problem-solving strategies, and improve the management of their activities in response to market requirements (Al-Zu'bi and Tsinopoulos, 2012). Having incorporated these requirements early into the joint development work, suppliers can better react to particular market needs (Grimpe and Sofka, 2016). Accordingly, in a market environment where customers require a balanced portfolio of radical innovation and incremental innovation, suppliers will respond to market needs by providing knowledge and suitable product ideas that the focal firm can benefit from. Furthermore, intensive supplier collaboration during the early stages has been shown to to enhance suppliers' commitment to the focal firm (LaBahn and Krapfel, 2000; McIvor and Humphreys, 2004). This commitment increases suppliers' flexibility, thus leading to an openness to adaptation when circumstances change (Heide and Miner, 1992). Because in radical innovation projects—and even in incremental ones—a high level of uncertainty needs to be mastered in the FFE (Song and Thieme, 2009), suppliers' commitment and openness will help the focal firm increase its radical and incremental innovation capability.

Finally, when involved in the FFE, suppliers can provide their technical knowledge to evaluate the feasibility of new product ideas very early, that is, before large investments are made. This, in turn, may avoid cost-wasting and time-consuming product changes in the later development phase (Crawford and Di Benedetto, 2006). Consequently, the focal firm will have more resources available to pursue a wider range of NPD proposals, from which the particularly radical innovation projects require a large amount of financial and human investments (Song and Thieme, 2009). Therefore, based on the overall discussion, we hypothesize the following:

H1a: Supplier involvement in the FFE is positively related to a focal firm's radical product innovation capability.

H1b: Supplier involvement in the FFE is positively related to a focal firm's incremental product innovation capability.

2.2 Mediating effects

Supplier ideas search practices. The question of how firms organize their search for new knowledge and innovative ideas and turn these ideas into products is central within the KBV stream of research (Grimpe and Sofka, 2016; Lopez-Vega, Tell, and Vanhaverbeke, 2016). The overall objective of a firm search is to look for "tall peaks" or "optimal choices" in a search space (Knudsen and Srikanth, 2014, p. 410) to find new inventions or solutions to fix problems or create new products (Lopez-Vega et al., 2016). Knudsen and Srikanth (2014, p. 410) describe the search process as a balance between the "exploration of new domains and exploitation of known domains". Hence, the results of the search process can range between ideas for incremental innovations and new inventions that have yet to be developed and introduced onto the market (Hagedoorn and Cloodt, 2003).

In terms of the external knowledge search from suppliers, we suggest that having established search practices is necessary for the focal firm when it comes to developing effective and continuous collaboration linkages and knowledge flow (Martini, Neirotti, and Appio, 2017). Idea search practices and tools are of particular importance in the FFE and can take different forms, such as technology scouting or web-based approaches (Koen et al., 2001; Spieth and Joachim, 2017). For instance, the automotive manufacturer AUDI AG has implemented distinct mechanisms to structure the search for new product ideas in the FFE from its suppliers. The company uses search instruments ranging from "push instruments" (i.e., suppliers take the initiative), such as regular innovation meetings without explicit relation to a specific task or problem, to "pull instruments" (i.e., manufacturer takes the initiative), such as idea or concept competitions based on defined search fields covering specific innovation needs (Homfeldt et al., 2017). Hence, idea search practices provide a framework for scanning the environment and for the identification of responses to specific problems, and they enact to lead the processes of internal and external knowledge exchange required to develop different types of innovation. Accordingly, established search practices are complementary with formalized mechanisms through which firms can steer the continuous generation of ideas and innovation in their operating business (Anand, Glick, and Manz, 2002; Bodas Freitas and Fontana, 2018; Martini et al., 2017). Furthermore, from an internal firm behavior perspective, "external search practices support the sense-making efforts of relevant environmental trends when they become institutionalized in firm's processes and routines" (Martini et al., 2017, p. 203). Institutionalizing search practices for suppliers' ideas—particularly in the FFE—limits the intentionality in acting but determines how to search outside the firm and, therefore, guarantees a continuous knowledge transfer that fits the internal objectives (Martini et al., 2017), that is, radical or incremental innovation. Vice versa, having established mechanisms and searching for supplier ideas using distinct practices, such as concept competitions based on specific internal requirements, helps to synchronize the external input with internal needs. This "reflective reframing" is crucial in the context of high uncertainty, such as in the FFE, to align subsequent activities for successful product innovation capability (Bodas Freitas and Fontana, 2018; Grodal, Nelson, and Siino, 2015). Therefore, we hypothesize the following:

H2a: Supplier ideas search practices mediate the relationship between supplier involvement in the FFE and a focal firm's radical product innovation capability.

H2b: Supplier ideas search practices mediate the relationship between supplier involvement in the FFE and a focal firm's incremental product innovation capability.

Supply base variety. A firm's capability to innovate is closely linked to the firm's ability to think differently, looking at things from different perspectives and combining previously unrelated knowledge-based resources into something novel (Fleming, Mingo, and Chen, 2007). Thus, a major element of innovation capability is whether a firm can access heterogeneous and varied knowledge bases. Phelps (2010, p. 894) emphasizes the importance of variety as "the extent to which a system consists of uniquely different elements, the frequency distribution of these elements, and the degree of difference among the elements". Although focal firms often rely on the knowledge of a small number of known key suppliers that often operate in the same industry (Chen and Paulraj, 2004; Paulraj, Lado, and Chen, 2008), we argue that particularly in the FFE of NPD, that is, when ideas are generated and the foundation is made for products, accessing heterogeneous knowledge from a varied supply base is necessary for providing a fertile ground for innovation (Gao, Xie, and Zhou, 2015). Supply base variety (e.g., accessing suppliers from different industries) enables the focal firm to tap into and combine dissimilar knowledge elements (Gassmann et al., 2010), which has been described as being a fundamental cognitive process for producing novel insights (Rodan and Galunic, 2004). Using heterogeneous knowledge sources in the early stages of NPD also offers firms access to new problem-solving heuristics. Accordingly, this challenges firms' current cognitive structures and views on cause and effect relations, which is likely to facilitate the generation of varied novel solutions (Fleming, 2001; Phelps, 2010). Furthermore, by accessing a varied supply base in the FFE, the focal firm detects diverse expertise and perspectives in different fields and then applies, modifies, and experiments with solutions in diverse domains, consequently, enhancing its radical innovation capability and incremental innovation capability (Gao et al., 2015; Hargadon and Sutton, 1997). Hence, we propose the following hypotheses:

H3a: Supply base variety mediates the relationship between supplier involvement in the FFE and a focal firm's radical product innovation capability.

H3b: Supply base variety mediates the relationship between supplier involvement in the FFE and a focal firm's incremental product innovation capability.

Supplier incentives. Transferring knowledge and new product idea suggestions by suppliers is central in an open collaborative buyer-supplier relationship. However, particularly in the FFE, when there is a critical knowledge exchange request for protection to prevent leakage to competitors and, thus, a loss of competitiveness (Wagner, 2012), suppliers might be discouraged to provide substantially innovative ideas to the focal firm in the FFE to protect their knowledge and skills (Lau et al., 2010). Focal firms may choose to offer incentives to counteract this and motivate hesitant suppliers.

Here, an incentive is defined as a stimulus that motivates future behavior (Berstein and Nash, 2008). Although the use of incentives has been widely explored in the behavioral sciences (at the individual or group level), research in the field of supply chain management is rather limited, with existing studies largely focusing on how to incentivize downstream supply chain partners, but not upstream supply chain partners and their corresponding effects for the focal firm (Terpend and Krause, 2015).

In the context of buyer-supplier cooperation, incentives may range from monetary ones (e.g., focal firm's willingness to pay higher prices for very innovative product ideas) to non-monetary ones (e.g., allowing the supplier to benefit from industrial property rights, offering favorite access to procurement/development needs at an early stage by the focal firm) (Carlsson, Corvello, and Kutvonen, 2011; LaBahn and Krapfel, 2000). At the individual level, research has proposed and shown that non-monetary rewards are positively related to intrinsic motivation and, in turn, increase innovation performance (Markova and Ford, 2011). In contrast to the proposed relationship, monetary or extrinsic incentives also have a positive impact on the innovation performance in terms of patenting activities (Shapiro, Tang, Wang, and Zhang, 2017). Focal firms that offer incentives in the early stages of NPD are attractive customers for suppliers because they signal the willingness of the focal firm to share rewards generated through the cooperation with the supplier (LaBahn and Krapfel, 2000). In turn, this communicates fairness (Terpend and Krause, 2015), which has been shown to be an important driver in maintaining successful collaborations (Jap, 2001). For instance, joint buyer-supplier development activities are usually preceded by discussions regarding the contribution of technologies of the respective partners and what industrial property rights the supplier has to the resulting innovations (Helper, 1991; LaBahn and Krapfel, 2000). Accordingly, if the focal firm allows its suppliers to benefit from generated industrial property rights regarding the potential joint development of ideas delivered by suppliers, this should increase the suppliers' interest in participating in focal firms'

FFE activities and in delivering a wide range of innovative ideas (Henke and Zhang, 2010; LaBahn and Krapfel, 2000). Furthermore, a focal firm may offer preferred access to its procurement/development needs from very early on in NPD processes for innovative suppliers. Early disclosure of the development roadmap by the focal firm signals trust to the supplier. High trust reduces transaction costs and facilitates relation-specific investments (Dyer, 1997). The supplier will align its idea generation activities with the focal firm's needs and will bring knowledge into the joint collaboration (Homfeldt et al., 2019). Hence, based on this, we argue that supplier incentives offered by the focal firm reflect a key underlying mechanism through which supplier involvement in the FFE contributes to a focal firm's innovation capability. Therefore, we propose the following:

H4a: Non-monetary supplier incentives mediate the relationship between supplier involvement in the FFE and a focal firm's radical product innovation capability.

H4b: Monetary supplier incentives mediate the relationship between supplier involvement in the FFE and a focal firm's radical product innovation capability.

H4c: Non-monetary supplier incentives mediate the relationship between supplier involvement in the FFE and a focal firm's incremental product innovation capability.

H4d: Monetary supplier incentives mediate the relationship between supplier involvement in the FFE and a focal firm's incremental product innovation capability.

Early purchasing involvement. Scholars within the KBV argue that a firm's competitiveness depends on both external and internal assets. More specifically, research advocates that external integration, such as supplier involvement, requires specific internal capabilities (Koufteros et al., 2005; Luzzini, Amann, Caniato, Essig, and Ronchi, 2015). Whereas extensive research exists on the importance of R&D or marketing interfaces (e.g., Brettel, Heinemann, Engelen, and Neubauer, 2011), research on procurements' key role in a firm's innovation capability has become increasingly important only in recent years (e.g., Legenvre and Gualandris, 2018; Mikkelsen and Johnsen, 2019). Firms increasingly have recognized procurement's strategic role, which often manages more than 50% of companies' expenditures (Luzzini et al., 2015). Today, a purchasing department's competitive priorities go beyond acquiring parts or reducing costs and increasingly include strategic topics such as contributing to the focal firm's innovation performance (Luzzini, Caniato, Ronchi, and Spina, 2012). Thus, scholars and practitioners are giving more and more attention to innovation-oriented supply chains, where procurement plays a key role in the early phases of the innovation process when compared with cost-oriented supply chains (Homfeldt et al., 2017; Tracy and Neuhaus, 2013).

Rooted in the KBV, the importance of purchasing knowledge in terms of several dimensions has been highlighted (Schütz, Kässer, Blome, and Förstl, 2019). Regarding innovation capability, we argue that a high level of purchasing knowledge involved in the FFE, such as extensive expertise in the supply market, is an essential condition because purchasing has access to a variety of suppliers as a source of radical and incremental innovation ideas (Schiele, 2010). Because procurement is concerned with the acquisition of components and is the interface between the firm and its supply base, it holds the key role when it comes to identifying diverse ideas in the supply base very early on, advertising these ideas internally, and, finally helping to circulate them throughout the company (Hartmann, Kerkfeld, and Henke, 2012; Homfeldt et al., 2017). Luzzini et al. (2015, p. 110) even describe procurement as "a critical cornerstone for adapting innovation from suppliers and stewarding it through the product lifecycle". Furthermore, purchasing professionals have technical knowledge and generate a good technical understanding of the firms' products because these individuals usually serve as transmitters of internal innovation demands. While monitoring the supply base, purchasers can interpret any changes and consequences for their own product base (Carr and Smeltzer, 2000).

Integrating this knowledge in the uncertain and dynamic FFE is decisive for aligning a successful, balanced innovation portfolio (Mikkelsen and Johnsen, 2019). Finally, even though radical innovations are often more costly compared with incremental innovation and procurement is responsible for ensuring focal firms' commercial viability, we argue that procurement's economic knowledge in the early phase of NPD will particularly help make radical innovation more affordable (Homfeldt et al., 2017). From the arguments above, we postulate the following:

H5a: Early purchasing involvement mediates the relationship between supplier involvement in the FFE and a focal firm's radical product innovation capability.

H5b: Early purchasing involvement mediates the relationship between supplier involvement in the FFE and a focal firm's incremental product innovation capability.

Figure 1 depicts the framework and the hypothesized relationships.

Fig. 1: Conceptual framework

3. Methodology

3.1 Data and sample

To test our hypotheses on a comprehensive empirical basis, we conducted a self-administered Internet-based survey among German automotive companies. The data were collected between August and October 2019. The automotive industry was identified as being appropriate for our research objective for two reasons: First, more so than almost any other sector, the automotive industry is known for its dependence on suppliers as sources of innovation (Cabigiosu et al., 2013; Yeniyurt et al., 2014). Second, in particular, automotive companies are faced with the challenge of generating both incremental innovations for the survival of technologies and radical innovations arising from new market needs as, for instance, the field of drivetrain technologies (conventional vs. alternative) shows (Homfeldt et al., 2019).

Our sampling frame consisted of automotive firms listed in the “German Association of the Automotive Industry (VDA)”. The VDA is the most representative association of the automotive industry in Germany and consists of about 600 small to large companies that are involved in automotive production. Because our research concerns firms that generate product innovations, we excluded those companies that did not pursue their own product development (e.g., pure technical service providers), leading to a sample of 517 firms that were contacted.

Our study targeted key informants (Montabon, Daugherty, and Chen, 2018). In particular, we addressed senior managers who were likely to have an overarching, boundary-spanning view of their firms’ development process and supplier cooperation activities. The informants had job titles such as head of product (pre-)development, business line director, or head of corporate innovation management (Al-Zu’bi and Tsinopoulos, 2012; Lau et al., 2010). To check key informant quality, the respondents were asked a single-item confidence question about their level of knowledge considering all issues under investigation (1 = very limited knowledge, 7 = very substantial knowledge). The mean score of 5.7 provides confidence that the respondents were knowledgeable, also compared with the levels of knowledge indicated in similar studies in this field (e.g., Schoenherr and Wagner, 2016).

In exchange for their participation, the respondents were offered a summary of the survey results and a published, practitioner-oriented article on the topic (Sauermann and Roach, 2013). The initial mailing and two follow-ups at intervals of two to three weeks generated 223 firm responses, of which two contained missing data and hence were discarded. The resulting 221 usable responses represents an effective response rate of about 42%, which is above the average in this field of research and, therefore, can be considered very satisfactory (Lau et al., 2010; Wagner and Bode, 2014). The proactive offer of some respondents for an in-depth qualitative exchange on the topic further confirms the high interest and relevance of our research.

Because our study investigates how focal firms collaborate with suppliers throughout the FFE, the survey contained a question on whether the respective firm involved suppliers in the NPD process at all, regardless of the exact manner and timing. Overall, 206 firms indicated that they involve suppliers into NPD, which represents a rate of 93.2%. This confirms automotive firms' dependence on suppliers as external sources of knowledge. Accordingly, the dataset for testing our hypotheses consists of 206 firms. We checked whether our sample firms and firms not involving suppliers in NPD differed regarding firm characteristics (firm size expressed in logarithms, firm age expressed in logarithms, whether the firm is part of a group or not, whether the firm manufactured whole vehicles or not, environmental turbulence, and competitive intensity). We found significant differences only in terms of environmental turbulence ($p = 0.043$). The other five variables did not differ significantly between the sample firms and firms not included in the sample ($p > 0.05$). Based on these findings, we are confident that our sample is unlikely to be affected by selection bias.

Table 1 provides a detailed overview of the sample characteristics. The sample is characterized by a heterogeneous set of firms covering a broad range of firm sizes and manufacturer groups, without any evidence of systematic bias. The firms' number of employees ranged from 20 to 300,000 (mean = 23,597, std. dev. = 50,758). The distribution of manufacturer groups represented in the sample is as follows: manufacturers of whole vehicles (9.2%), manufacturers of system parts and modules (53.4%), manufacturers of composite components (21.9%), manufacturers of single components (13.1%), and manufacturers of materials (2.4%). Most of the respondents (79.1%) were part of the top or middle management of their respective firm. The average number of years the respondents had worked with the firm was 13.3 years (std. dev. =

9.3 years). These data further indicate a high level of key informant quality (Montabon et al., 2018).

Table 1: Sample firm characteristics

	Overall (*N* = 206)
Manufacturer groups	
Whole vehicles	19 (9.2%)
System parts and modules	110 (53.4%)
Composite components	45 (21.9%)
Single components	27 (13.1%)
Materials	5 (2.4%)
Firm sizes	
1-250	23 (11.2%)
251-1,000	43 (20.9%)
1,001-5,000	53 (25.7%)
5,001-10,000	28 (13.6%)
>10,000	59 (28.6%)
Group affiliation	
Part of a group	129 (62.6%)
Independent firm	77 (37.4%)
Firm age (average years)	79.6

To determine the presence of non-response bias, we applied two techniques. First, because late respondents are expected to be similar to non-respondents (Armstrong and Overton, 1977), we checked whether early (initial email) and late (after reminder emails) respondents differed with respect to all the variables included in our models. The results of the t-tests and chi-square tests showed no statistical significance between the two groups ($p > 0.05$). Second, we compared the responding firms with non-responding firms from the initial sample in terms of firm size (expressed in logarithms) and firm age (expressed in logarithms). Of the 296 non-responding firms, we were able to collect information on the firm size of 175 firms and on the firm age of 267 firms. Again, no statistically significant differences between these two groups were found ($p > 0.05$). Overall, the results indicate that non-response bias does not pose a significant threat to the validity of this study.

3.2 *Survey instrument and measures*

The survey and measures were developed in several stages, respecting standard techniques (Dillman, Smyth, and Christian, 2009; Sauermann and Roach, 2013). Accordingly, a preliminary questionnaire was drafted in the first step. Based on an extensive review of the innovation and supplier integration literature, we identified relevant constructs and previously operationalized scale items (see Table 2). However, to fit the original scales to the specific context (i.e., supplier involvement in the particular front-end stage of the focal firms' NPD process), it was necessary to adapt the wording or add certain items. For the survey instrument, we paid particular attention to the ease of use and a low level of burden on the respondents, as well as maintaining the respondent's interest until completion of the survey. To assess face and content validity, the drafted survey was discussed and pretested with 10 practitioners, covering expertise both with manufacturers of whole vehicles and with manufacturers of components/modules. They were asked to provide comments on the content, design, clarity, and scaling. Several minor changes were made as a result of this feedback. To avoid any inference problems arising from collecting data at levels inappropriate to the hypotheses under study (Markus and Robey, 1988), all variables were measured at the firm level. Unless otherwise stated, the items were presented using 5-point Likert scales (1 = strongly disagree/does not apply at all, 5 = strongly agree/does fully apply) and formulated as reflective indicators.

Dependent variables. Radical innovation capability and incremental product innovation capability were each measured with an item scale adapted from Subramaniam and Youndt (2005) and Menguc et al. (2014). Accordingly, radical product innovation capability assessed a firm's competency to generate innovations that fundamentally change existing products and that have a high benefit for customers. Similarly, incremental innovation capability assessed a firm's ability to generate innovations that refine existing products and slightly enhance customers' benefit. The respondents were asked to rate their firm's capability of generating the above innovation types relative to their principal competitors (1 = a lot worse than competition, 5 = a lot better than competition).

Independent variable. Supplier involvement in the FFE is defined as the degree to which suppliers are involved in the focal firm's NPD activities prior to the actual development phase, for example, idea generation, idea evaluation. Our scale is based on measurement items developed by Wagner (2012).

Mediator variables. To infer causality, the respondents were asked to explicitly refer their answers to the early phase of their firm's NPD process (i.e., idea phase/concept phase), that is, prior to the actual development phase.

Our variable supplier ideas search practices taps a focal firm's orientation to an actively organized search for innovative ideas from its supply base in the early stages of the NPD process. Three items were adapted from Spanjol, Qualls, and Rosa (2011). Two new items were added to enhance the explanatory power of the measure with respect to the use of specific methods and tools to identify suppliers' ideas (cf. Homfeldt et al., 2017; Schiele, 2010).

Based on the conceptual work of Choi and Krause (2006), we generated new items to capture the domain of a focal firm's supply base variety in the early stages of a focal firm's NPD because we could not identify an appropriate scale. Accordingly, our employed measurement items encompass the number of suppliers, the degree of differentiation of suppliers (e.g., involving cross-industry partners), and the level of inter-relationships among suppliers (i.e., fostering collaboration with non-direct suppliers, e.g., Tier 2, Tier 3).

For our newly developed supplier incentives scales, we adapted several items from LaBahn and Krapfel (2000) and Terpend and Krause (2015). The scales capture the extent to which a focal firm offers monetary incentives (e.g., paying higher prices for innovative ideas) and non-monetary incentives (e.g., offering preferred access to procurement needs at an early stage) for suppliers and their ideas.

The early purchasing involvement measurement is based on items developed by McGinnis and Vallopra (1999) and captures the importance of procurement in the early stages of a focal firm's NPD process.

Control variables. We included several control variables in our models to eliminate undesirable sources of variance in the hypothesis testing procedure. First, we controlled for firm size, measured as number of employees (expressed in logarithms), because larger firms have more resources to fund innovation and establish more powerful R&D centers (Hofman, Halman, and Song, 2017; Lau et al., 2010). Second, we controlled for the age of the firm as the number of years that have elapsed since foundation (expressed in logarithms) to mitigate the effects of the firms' establishment in its product categories over time, which may affect a firm's innovation capability (Al-Zu'bi and Tsinopoulos, 2012). Third, our models control for whether the firm belongs to a group or is an independent firm because this may influence a firm's innovation portfolio. For instance, firms that are part of a group were found to have a higher propensity for incremental innovation (Cassiman and Veugelers, 2006). We measured this using a dichotomous variable that equals 1 if the firm was part of a group and 0 otherwise (Bodas Freitas and Fontana, 2018). Fourth, because firms along different tier levels are included in the present study, we controlled for any constant and unmeasured differences across these manufacturer groups by including dummy variables in our analysis (manufacturer of whole vehicle, systems and modules, composite components, single components, or materials; cf. Wynstra, von Corswant, and Wetzels, 2010). Finally, because a firm's environment may influence how active a firm is in its product innovation capabilities, we included the firm's environmental turbulence (captured by market turbulence and technological turbulence) and competitive intensity in our models as controls (Menguc et al., 2014). For the measurement of each of the variables, we used a subset of items, as suggested by Jaworski and Kohli (1993).

3.3 Measurement validation

We made several efforts to check the uni-dimensionality, reliability, and validity of each multi-item measure employed. We first conducted exploratory factor analyses using principal component method to check how the items loaded on the hypothesized factors. As anticipated, most of the items loaded onto their underlying construct. We reviewed each construct and deleted items where necessary to ensure measurement quality. Factor loadings higher than 0.7 are considered appropriate, while loadings between 0.4 and 0.7 can be kept unless their deletion is required to bring reliability above the minimum threshold, or unless their deletion negatively affects content validity (Hair, Black, Babin, and Anderson, 2010; Stevens, 1992). Throughout this process, we also performed confirmatory factor analysis to check for additional necessary adjustments. Each remaining item loaded significantly on its hypothesized factor, which supports convergent validity and uni-dimensionality. As indicated in Table 2, the reliability analyses show Cronbach's α values of the established constructs reaching the threshold value of 0.7 recommended by Nunnally (1978), thus suggesting internal consistency. In addition, we computed composite reliability (CR) scores to assess construct reliability. All CR values exceed the suggested cut-off value of 0.6 (Bagozzi and Yi, 1988). The average variance extracted (AVE) values also provide satisfactory results by exceeding the benchmark of 0.5 (Fornell and Larcker, 1981), which further indicates good convergent validity. Furthermore, the squared correlation between each pair of constructs is less than the AVE estimates for each of the respective individual constructs (see Table 3), thus providing support for discriminant validity (Fornell and Larcker, 1981).

Based on a confirmatory factor analysis, the established nine-factor measurement model achieved a satisfactory fit with a chi-square of 691.095 (df = 459, $p < 0.01$) and 1.51 chi squares per degree of freedom (Bentler and Bonett, 1980). Confirmatory factor analysis was conducted using the software package *Lavaan* in *R* (Rosseel, 2012). For the sake of prudence, we applied maximum likelihood estimation with standard errors and a mean-adjusted chi-square test statistic robust to non-normality (Satorra and Bentler, 2001). The measurement model's fit indices confirmatory fit index (CFI) = 0.92, Tucker–Lewis index (TLI) = 0.90, standardized root mean square residual (SRMR) = 0.063, root mean square area of approximation (RMSEA) = 0.050 are all indicative of acceptable model fit (Hu and Bentler, 1999). In addition, the RMSEA confidence interval is 0.042-0.057, thus representing a good degree of precision (Byrne, 2001).

Overall, we conclude that the measurement model adequately fits the data. Having established the validity and reliability of the reflective scales, we used unweighted scale averages as latent variable scores for the hypotheses testing procedure.

Table 2: Measurement scales

Scales	Principal component factor loadings
Radical innovation capability (α = 0.76; CR = 0.85; AVE = 0.58)	
Innovations that fundamentally change existing products.	0.80
Innovations that make existing products obsolete.	0.72
Innovations that significantly increase the benefits for our customers.	0.83
Innovations that require different ways of learning from customers.	0.69
Incremental innovation capability (α = 0.74; CR = 0.86; AVE = 0.67)	
Innovations that reinforce our existing product lines.	0.78
Innovations that reinforce our existing expertise in existing products.	—
Innovations that reinforce on how we currently compete.	0.84
Innovations that slightly increase the benefit for our customers.	0.82
Supplier involvement in the FFE (α = 0.74; CR = 0.84; AVE = 0.56)	
We involve suppliers in the generation of new product ideas.	0.79
Ideas of our suppliers are used in the specifications of new products.	0.79
We involve suppliers in the evaluation of new product ideas.	0.71
We involve suppliers in the development of concepts for new products.	0.71
Supplier ideas search practices (α = 0.87; CR = 0.90; AVE = 0.65)	
We search very actively for new product ideas from our suppliers.	0.78
We monitor our suppliers consistently for new product ideas.	0.77
We have established mechanisms for searching for new product ideas from our suppliers.	0.86
We use methods and tools to search for new product ideas from our suppliers (e.g. innovation workshops or competitions with suppliers).	0.84
We have instruments in place where suppliers can proactively provide their ideas (e.g. web-based innovation portal, regular innovation meetings).	0.79
Supply base variety (α = 0.70; CR = 0.83; AVE = 0.62)	
The number of suppliers we involve in the early stages of our NPD process is high.	—
We involve suppliers in the early stages of our NPD process that operate in other markets than we do (i.e., cross-industry partners, e.g., aerospace industry).	0.71
We involve non-established partners in the early stages of our NPD process (e.g., start-ups as potentially new suppliers).	0.89
We foster the collaboration with non-direct suppliers in the early stages of our NPD process (e.g., Tier 2, Tier 3 suppliers).	0.75
Supplier incentives (non-monetary) (α = 0.80; CR = 0.88; AVE = 0.64)	
We reward our most innovative suppliers (e.g., supplier awards).	0.75
For innovative suppliers, we offer favored access to our development/procurement needs at an early stage.	0.87
For innovative supplier ideas, we offer exclusive development/sourcing commitment at an early stage.	0.87
We allow our suppliers to benefit from generated industrial property rights when it comes to a joint development of suppliers' ideas.	0.70
Supplier incentives (monetary) (α = 0.91; CR = 0.96; AVE = 0.92)	
For innovative supplier ideas, we share investment costs when it comes to a joint development.	—
For innovative supplier ideas, we are willing to pay a higher price than prevailing market prices.	0.96
For innovative supplier ideas, we are flexible regarding price adjustments to the suppliers' supply agreements.	0.96
Early purchasing involvement (α = 0.91; CR = 0.94; AVE = 0.79)	
Purchasing plays a major role in the early stages of our NPD process.	0.85
Purchasing consistently provides input in the early stages of our NPD process.	0.91
Purchasing plays an important role in identifying suppliers who offer innovative ideas that are important to NPD.	0.89
Purchasing plays an important role in cross-functional teams in the early stages of our NPD process.	0.90

Table 2: Measurement scales (continued)

Scales	Principal component factor loadings
Environmental turbulence (α = 0.74; CR = 0.84; AVE = 0.57)	
Our customers' product preferences change quite a bit over time.	0.80
Our customers tend to look for new products all the time.	0.80
New customers tend to have product-related needs that are different from those of existing customers.	—
The technology in the product categories in which we operate is changing rapidly.	0.76
Technological changes provide big opportunities in the product categories in which we operate.	—
Technological developments in our product categories are rather minor.[R]	0.64
Competitive intensity	
Competition in the product categories in which we operate is very high.	—
Our competitors are relatively strong.	—

Scales in italics signifies an item dropped during the scale purification process.
R = reverse-scored item; α = Cronbach's alpha; CR = composite reliability; AVE = average variance extracted.

3.4 Common method bias

Because our employed data are of self-reported nature and based on the same survey instrument, we acknowledge the possibility of common method bias in our data. Following prior recommendations (Podsakoff, MacKenzie, Lee, and Podsakoff, 2003), we inserted various measures to counteract the potential problem of common method bias. We applied ex ante remedies that concern the design of the research, for example, the administration of the questionnaire or the survey design, as well as ex post remedies after the responses had been collected.

Regarding the design of our research, the survey provided only general information on the study's objectives, but no clues about the actual relationships under investigation. We ensured that the questions related to our dependent, independent, and mediator variables were in different sections of the survey, making it unlikely that the informants could predict the model specification and be part of their theory-in use (Chang, van Witteloostuijn, and Eden, 2010) when responding. Hence, biases arising from respondents' "guessing" relationships are unlikely. In addition, the respondents were asked to base their answers on the firm's general practice and we pointed out that there were no right or false answers and that the respondents should answer as honestly as possible. Furthermore, we offered anonymity and confidentiality for the respondents to reduce social desirability bias in the responses.

In addition to these ex ante remedies, we formally tested for the presence of common method bias in our data. First, we conducted Harman's single-factor approach (Podsakoff and Organ, 1986). We entered *all* rating-scale items into an unrotated exploratory factor analysis. The analysis yielded multiple factors with eigenvalues greater than 1.0 rather than a single factor. Further, the largest factor did not account for a majority of the variance (about 20%), suggesting that common method bias should not be a problem. To further rule this out, we applied the correlational marker technique (Lindell and Whitney, 2001). For this, we used the respondent's tenure as a correlational marker (cf. Krishnan, Martin, and Noorderhaven, 2006, see also Williams, Hartman, and Cavazotte, 2010 for the use of demographic marker variables) because it is theoretically unrelated to the dimensions under investigation. As a more conservative estimate, we used the second-smallest positive correlation (r = 0.019) between the marker variable and one of the other variables for determining common method–based adjusted correlations (Lindell and Whitney, 2001; Malhotra, Kim, and Patil, 2006). We compared the zero-order correlations among all dependent, independent, and mediator variables before and after partialing out the marker variable. Significant zero-order correlations remained significant (except for supplier incentives (monetary) and supplier ideas search practices, where the *p* value changed from 0.097 to 0.157) and did not change in height more than 0.02. In sum, both tests indicate that common method bias does not pose a significant threat to the validity of our results.

4. Results

We used hierarchical regression analysis to test our hypotheses. Table 3 shows the descriptive statistics and correlations of our variables. No problematic levels of multi-collinearity could be identified: the correlations were within acceptable ranges (|r| < 0.60) and the variance inflation factors (maximum = 1.87) for the variables in all the reported models were substantially below the commonly suggested threshold (Cohen, Cohen, West, and Aiken, 2003).

Table 3: Descriptive statistics, bivariate correlations, and average variances extracted

		1	2	3	4	5	6	7	8	9	10	11	12	13
1	Radical innovation capability	*0.58*	0.29	0.03	0.02	0.12	0.04	0.01	0.05	0.00	0.01	0.00	0.00	0.09
2	Incremental innovation capability	0.54***	*0.67*	0.03	0.05	0.05	0.03	0.00	0.04	0.00	0.01	0.00	0.00	0.08
3	Supplier involvement in the FFE	0.17*	0.18**	*0.56*	0.12	0.04	0.08	0.02	0.10	0.00	0.00	0.00	0.00	0.00
4	Supplier ideas search practices	0.15*	0.23**	0.35***	*0.65*	0.18	0.25	0.01	0.10	0.09	0.04	0.03	0.02	0.00
5	Supply base variety	0.34***	0.22**	0.19**	0.42***	*0.62*	0.07	0.07	0.01	0.05	0.00	0.00	0.02	0.02
6	Supplier incentives (non-monetary)	0.19**	0.18*	0.29***	0.50***	0.26***	*0.64*	0.14	0.05	0.14	0.01	0.04	0.03	0.00
7	Supplier incentives (monetary)	0.10	0.02	0.15*	0.12+	0.26***	0.38***	*0.92*	0.01	0.00	0.00	0.00	0.04	0.01
8	Early purchasing involvement	0.22**	0.19**	0.31***	0.32***	0.07	0.23**	0.11	*0.79*	0.01	0.00	0.00	0.00	0.00
9	Firm size[a]	0.01	-0.03	-0.03	0.30***	0.22**	0.38***	-0.002	-0.08	–	0.06	0.14	0.02	0.01
10	Firm age[a]	0.07	0.11	0.01	0.20**	0.03	0.09	-0.04	0.03	0.24**	–	0.01	0.00	0.00
11	Part of a group	0.02	-0.01	-0.002	0.16*	0.05	0.21**	-0.003	-0.03	0.37**	0.12+	–	0.00	0.00
12	Environmental turbulence	0.04	-0.04	0.04	0.14*	0.14*	0.17*	0.21**	0.05	0.15*	-0.02	0.05	*0.57*	0.01
13	Competitive intensity	-0.30***	-0.28***	0.01	-0.01	-0.15*	-0.002	-0.09	-0.01	0.12	0.06	0.01	0.12+	–
	Mean	3.46	3.66	3.27	2.74	2.38	2.50	2.72	3.24	3.56	1.81	0.63	3.34	4.03
	Standard deviation	0.59	0.58	0.66	0.78	0.72	0.89	0.88	0.92	0.92	0.31	0.49	0.79	0.79

N = 206.

Pearson correlation coefficients are below the diagonal, diagonal values in italics represent average variances extracted (where appropriate), and squared correlations are above the diagonal.

[a]Expressed in logarithms.

Significance levels: + $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Table 4 and Table 5 show the results of the regression analyses with radical innovation capability (see Table 4) and incremental innovation capability (see Table 5) as the dependent variables. For each dependent variable, Model 1 is the baseline model and contains only the control variables. Model 2 includes the main effect of supplier involvement in the FFE on radical innovation capability and incremental innovation capability. Models 3 to 7 include each of the hypothesized mediators separately to identify their respective mediating effect of the former relationship. Model 8 is the full model. In the case of both dependent variables, Models 2 to 8 provide a good fit, as indicated by the significant F value and increasing R^2 after including our independent variable and mediators.

To assess the hypothesized mediation effects, we followed the common four-step procedure suggested by Baron and Kenny (1986). First, we examined the relationship between supplier involvement in the FFE and our dependent variables. As illustrated in Model 2, supplier involvement in the FFE is positively and significantly related to a focal firm's radical innovation capability ($b = 0.15$, $p = 0.014$) and incremental innovation capability ($b = 0.17$, $p = 0.004$), with a stronger effect here in terms of incremental innovation. This confirms Hypothesis 1a and Hypothesis 1b.

In the second step, supplier involvement in the FFE needs to be significantly associated with the mediator variables. We ran additional regression analyses with our mediator variables as the dependent variables and supplier involvement in the FFE as the independent variable with all control variables included. The results show that supplier involvement in the FFE is significantly related to supplier ideas search practices ($b = 0.43$, $p < 0.001$), supply base variety ($b = 0.21$, $p = 0.005$), both incentive variables ($b_{non\text{-}monetary} = 0.40$, $p_{non\text{-}monetary} < 0.001$; $b_{monetary} = 0.20$, $p_{monetary} = 0.036$), and early purchasing involvement ($b = 0.44$, $p < 0.001$). Third, the mediator variable needs to be significantly related to the dependent variables. Fourth, the significant relationship between supplier involvement in the FFE and radical and incremental innovation capability needs to become insignificant (complete mediation) or need to be reduced (partial mediation) when a potential mediator is included in the regression model.

Regarding the potential mediator supplier ideas search practices included in Model 3, we found a partial mediation effect in terms of incremental innovation capability (b = 0.12, p = 0.039), but not radical innovation capability (b = 0.07, n.s.). Hence, Hypothesis 2a is not supported and Hypothesis 2b is supported.

Hypotheses 3a and 3b concern supply base variety as a potential mediator included in Model 4. Consistent with these hypotheses, supply base variety in the early stages partially mediates the relationship between supplier involvement in the FFE and both a firm's radical innovation capability (b = 0.25, $p < 0.001$) and incremental innovation capability (b = 0.12, p = 0.028). Thus, Hypothesis 3a and Hypothesis 3b are supported.

Furthermore, in favor of Hypothesis 4a and 4c, we find that non-monetary incentives partially mediate the relationship between supplier involvement in the FFE and both a firm's radical innovation capability (b = 0.11, p = 0.034) and incremental innovation capability (b = 0.09, p = 0.071) as indicated in Model 5. Interestingly, no mediation effects could be found in terms of monetary incentives (H4b, d) as it is shown in Model 6.

Finally and according to Model 7, it is shown that early purchasing involvement completely mediates the relationship between supplier involvement in the FFE and a focal firm's radical innovation capability (b = 0.13, p = 0.006) but not its incremental innovation capability (b = 0.06, n.s.). Hence, Hypothesis 5a is supported and Hypothesis 5b is not supported.

Table 4: Results of hierarchical regression analysis (DV = radical innovation capability)

	Controls	Main effect	Mediators					
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
(Intercept)	3.87***	3.37***	3.36***	3.00***	3.38***	3.32***	3.11***	2.80***
	(0.37)	(0.41)	(0.41)	(0.41)	(0.41)	(0.42)	(0.42)	(0.41)
Firm size[a]	0.01	0.02	0.01	-0.03	-0.02	0.02	0.03	-0.04
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
Firm age[a]	0.18	0.18	0.15	0.19	0.18	0.18	0.16	0.21
	(0.14)	(0.14)	(0.14)	(0.13)	(0.13)	(0.13)	(0.13)	(0.13)
Part of a group	-0.001	-0.002	-0.01	0.01	-0.02	-0.002	-0.004	0.004
	(0.09)	(0.09)	(0.09)	(0.08)	(0.09)	(0.09)	(0.09)	(0.08)
Whole vehicles[b]	-0.20	-0.21	-0.22	-0.24[+]	-0.24[+]	-0.20	-0.24[+]	-0.31*
	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.13)
Composite components[b]	-0.04	-0.01	-0.001	0.01	-0.003	-0.01	0.02	0.04
	(0.11)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
Single components[b]	-0.10	-0.07	-0.06	-0.10	-0.06	-0.07	-0.06	-0.09
	(0.13)	(0.13)	(0.13)	(0.12)	(0.13)	(0.13)	(0.12)	(0.12)
Materials[b]	0.04	-0.03	-0.03	-0.002	0.03	-0.04	0.11	0.11
	(0.27)	(0.27)	(0.27)	(0.25)	(0.26)	(0.27)	(0.27)	(0.26)
Environmental turbulence	0.06	0.05	0.05	0.02	0.04	0.04	0.05	0.02
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.06)	(0.05)	(0.05)
Competitive intensity	-0.23***	-0.23***	-0.23***	-0.19***	-0.22***	-0.23***	-0.22***	-0.18***
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
Supplier involvement in the FFE		0.15*	0.12[+]	0.10[+]	0.11[+]	0.15*	0.10	0.04
		(0.06)	(0.07)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
Supplier ideas search practices			0.07					-0.10
			(0.06)					(0.06)
Supply base variety				0.25***				0.28***
				(0.06)				(0.06)
Incentives (non-monetary)					0.11*			0.12*
					(0.05)			(0.06)
Incentives (monetary)						0.03		-0.06
						(0.05)		(0.05)
Early purchasing involvement							0.13**	0.13**
							(0.05)	(0.05)
R^2	0.11	0.14	0.15	0.22	0.16	0.14	0.17	0.27
F value	2.77**	3.18***	3.01**	4.85***	3.36***	2.91**	3.69***	4.68***

N = 206.
Unstandardized regression coefficients with standard errors in parentheses are reported.
[a]Expressed in logarithms.
[b]With manufacturer group “system parts and modules” as reference category.
Significance levels: + $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Table 5: Results of hierarchical regression analysis (DV = incremental innovation capability**)**

	Controls	Main effect	Mediators					
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
(Intercept)	4.20***	3.64***	3.63***	3.46***	3.65***	3.67***	3.51***	3.49***
	(0.35)	(0.40)	(0.39)	(0.40)	(0.39)	(0.40)	(0.40)	(0.42)
Firm size[a]	-0.02	-0.007	-0.03	-0.03	-0.04	-0.007	-0.001	-0.06
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
Firm age[a]	0.28*	0.27*	0.22+	0.28*	0.27*	0.27*	0.26*	0.25+
	(0.13)	(0.13)	(0.13)	(0.13)	(0.13)	(0.13)	(0.13)	(0.13)
Part of a group	-0.03	-0.03	-0.04	-0.02	-0.04	-0.03	-0.03	-0.04
	(0.09)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)
Whole vehicles[b]	0.26+	0.25+	0.23+	0.23+	0.22	0.25+	0.23+	0.18
	(0.14)	(0.14)	(0.13)	(0.13)	(0.14)	(0.14)	(0.14)	(0.14)
Composite components[b]	0.03	0.06	0.08	0.07	0.07	0.06	0.07	0.10
	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
Single components[b]	-0.10	-0.07	-0.05	-0.08	-0.06	-0.06	-0.06	-0.05
	(0.12)	(0.12)	(0.12)	(0.12)	(0.12)	(0.12)	(0.12)	(0.12)
Materials[b]	-0.44+	-0.52*	-0.40	-0.51*	-0.47+	-0.52*	-0.45+	-0.36
	(0.26)	(0.25)	(0.26)	(0.25)	(0.25)	(0.25)	(0.26)	(0.26)
Environmental turbulence	-0.01	-0.01	-0.02	-0.03	-0.03	-0.01	-0.02	-0.03
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
Competitive intensity	-0.23***	-0.24***	-0.22***	-0.21***	-0.23***	-0.24***	-0.23***	-0.21***
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
Supplier involvement in the FFE		0.17**	0.12+	0.14*	0.13*	0.17**	0.14*	0.08
		(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
Supplier ideas search practices			0.12*					0.034
			(0.06)					(0.06)
Supply base variety				0.12*				0.12*
				(0.06)				(0.06)
Incentives (non-monetary)					0.09+			0.09
					(0.05)			(0.05)
Incentives (monetary)						-0.01		-0.07
						(0.04)		(0.05)
Early purchasing involvement							0.06	0.05
							(0.04)	(0.05)
R^2	0.13	0.17	0.19	0.19	0.18	0.17	0.18	0.22
F value	3.36***	3.98***	4.07***	4.14***	3.96***	3.61***	3.83***	3.52***

$N = 206$.
Unstandardized regression coefficients with standard errors in parentheses are reported.
[a]Expressed in logarithms.
[b]With manufacturer group “system parts and modules” as reference category.
Significance levels: + $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

As an additional analysis, we conducted a series of Sobel tests. The Sobel test provides a method to determine whether the reduction in the effect of the independent variable, after including the mediator in the model, is a significant reduction (Sobel, 1982). For each significant mediator effect reported above, the test revealed a significant reduction of the relationship between our independent and dependent variables at least at $p < 0.10$. Furthermore, we re-ran the analyses by including the mediators simultaneously (see Model 8 in Table 4 und Table 5). The mediation effects from the analyses above were largely confirmed. However, we note that supplier ideas search practices and non-monetary incentives were not significant in the overall model for incremental innovation capability. While the significant mediation effect regarding non-monetary incentives was confirmed after conducting bootstrapping (based on 5.000 bootstrap samples), this was not the case for supplier ideas search practices. In addition, although we explicitly theorize mediator variables, we also ran moderation tests but found (with one exception in terms of monetary incentives and incremental innovation capability) no significant interaction effects. This further strengthens our assertions of governing effects.

5. Discussion and implications

In recent years, supplier involvement in focal firms' NPD processes has changed more and more from a minor activity to a strategic one, with a steady increase of suppliers' development responsibility that resulted in a transition of the supply base from the pure delivery of products to offering inimitable knowledge from the very early beginning of NPD (Schoenherr and Wagner, 2016). Motivated by this phenomenon, the current study examined suppliers' involvement in the focal firms' FFE phase, in which new product ideas are generated and evaluated. While supplier involvement in the subsequent and well-formalized development phase has been well investigated, much less is known about the effects of involving suppliers in the FFE phase and about the underlying mechanisms through which supplier involvement in the FFE contributes to a focal firm's innovation capability. Hence, the current study aimed to address these issues and provided some new evidence based on survey data of 206 automotive firms.

First, our results show that supplier involvement in the FFE has a positive impact on both a focal firm's radical innovation capability and incremental innovation capability but with a stronger effect in terms of incremental innovation. This result is in line with the literature arguing that supplier collaboration is generally beneficial for innovation, because it enables the firm to gather additional knowledge and explore a broader range of possible solutions to specific problems and application contexts (Bodas Freitas and Fontana, 2018). However, because there is also evidence that not all innovation efforts with suppliers are successful, particularly when it comes to the identification of truly innovative solutions (e.g., Gassmann et al., 2010; Koufteros et al., 2005; Song and Thieme, 2009), our study underscores the importance of involving suppliers' knowledge right from the beginning. It is also in line with our arguments derived from the KBV perspective that the earlier suppliers are involved in the focal firm's NPD process, the closer the contextual knowledge distance between both parties becomes, in turn facilitating the transfer and integration of knowledge (Un et al., 2010; Un and Asakawa, 2015).

Second, our tests of the mediating effects revealed several noteworthy insights. It was argued—but only partially supported—that supplier ideas search practices mediate the relationship between supplier involvement in the FFE and a focal firm's radical and incremental innovation capability. Our assumption is only supported in terms of incremental innovation capability. Although more research on this is needed for validation, our results are somewhat in line with the recent findings made by Bodas Freitas and Fontana (2018), who show that formalizing NPD does not necessarily improve innovation performance, particularly in the context of high uncertainty and in the absence of established industry knowledge, as this is the case when generating radical innovation. The authors argue that the "[s]tabilization of knowledge flows can limit the learning focus, reduce learning incentives […] and may lead to premature rejection of radically different solutions" (Bodas Freitas and Fontana, 2018, p. 573).

With regard to the mediating effect of supply base variety, our hypotheses were confirmed. Supply base variety in the early stages of NPD is an underlying mechanism through which supplier involvement in the FFE contributes to a focal firm's radical and incremental innovation capability. Although some scholars argue for decreasing innovation outcomes when the supply base variety is too high (Choi and Krause, 2006), we show in line with the KBV that in the FFE of NPD, that is, when the foundation is made for new products, accessing heterogeneous knowledge resources is necessary for providing a fertile ground for innovation (Gao et al, 2015; Gassmann et al., 2010; Homfeldt et al., 2019).

In terms of the use of incentives, we show that only non-monetary incentives have a mediating impact between supplier involvement in the FFE and a firm's innovation capability. Surprisingly, there is no mediation effect of monetary incentives. Hence, incentives merely focused on *economic* outcomes become less important. Rather, the result suggests that a successful cooperation between a focal firm and its suppliers requires—at least in the knowledge-critical early stages of NPD—the establishment of incentives that reflect a relationship based on *social* outcomes (e.g., getting insights into the focal firm's development/procurement needs, being allowed to benefit from industrial property rights, etc.). The use of social benefits in a buyer-supplier relationship has gained increasing attention over recent years (e.g., Terpend and Krause, 2015).

Our last result concerns the mediating effect of early purchasing involvement. Because incremental innovations are often not too costly and one of procurement's tasks is to ensure the firm's commercial viability, we expected that early purchasing involvement would unquestionably have a mediating impact. However, our findings show that early purchasing involvement mediates the relationship between supplier involvement in the FFE and a focal firm's radical innovation capability but not its incremental innovation capability. This confirms the transition of procurement from a mere buying department to having a key role in the innovation process, because purchasers offer valuable internal knowledge capabilities, such as technical and market knowledge (Homfeldt et al., 2017; Legenvre and Gualandris, 2018; Schütz et al., 2019).

5.1 Contributions to theory

In essence, our study contributes to the literature on early supplier integration, with the FFE focusing on the critical phase "between when an opportunity is first considered and when an idea is judged ready for development" (Kim and Wilemon, 2002, p. 269). Although the FFE phase has been recognized as crucial to the success of innovation projects (Hauser et al., 2006; Kock et al., 2015), only less attention has been paid to the involvement of suppliers in this NPD stage. While there is extensive research that considers suppliers as co-development partners (Koufteros et al., 2005; Lau et al., 2010) providing input in various NPD stages (Al-Zu'bi and Tsinopoulos, 2012), studies on the involvement of suppliers in the particular front end of the NPD process have just started to appear (Homfeldt et al., 2019; Schoenherr and Wagner, 2016; Wagner, 2012). Thus, we add to this evolving research stream by examining suppliers' contributions when involved in the early stages of NPD and provide a better understanding of governing factors through which supplier involvement in the FFE contributes to a focal firm's ability to generate innovations. By considering radical innovation and incremental innovation, we respond to recent research calls to consider the type of innovation when designing studies on front end supplier involvement (Wowak et al., 2016) and to provide more evidence on the underlying mechanisms between FFE activities and the generation of both innovation types (Eling and Herstatt, 2017). Due to considering the focal firms' actual innovativeness, we further extend the literature on performance outcomes related to supplier involvement, especially considering that extant research largely focuses on "classical" performance measures such as product quality, development speed, or financial performance (e.g., Bodas Freitas and Fontana, 2018; Hoegl and Wagner, 2005; Petersen et al. 2005; Primo and Amundson, 2002; Wagner, 2012).

From a broader perspective, our study also complements and extends the existing theory on interorganizational collaboration and open innovation (Chesbrough, 2003) by showing that using knowledge from suppliers from the very beginning of NPD is beneficial for the focal firm's innovation capability. While the existing research in this field has largely focused on customers as open innovation partners in the FFE (e.g., Hauser et al., 2006; Ozer, 2007; Rese, Sänn, and Homfeldt, 2015; Schweitzer, Palmié, and Gassmann, 2018), we add to the research by considering the role of suppliers as crucial open innovation partners in the FFE.

5.2 Implications for managerial practice

In a context in which a growing share of new products is developed in collaboration with suppliers, our results also have implications for NPD and supply chain managers. By integrating suppliers early, focal firms can acquire, create, and share unique knowledge-based resources throughout the FFE phase of the NPD process, which in turn enhances the focal firm's product innovation capability. Considering the positive effects in terms of both radical innovation and incremental innovation, firms are called to not only rely on the voice of their customer for idea generation and evaluation but should particularly invest in the integration of suppliers in the FFE phase of NPD.

As such, supplier involvement in the FFE is a strategic, worthwhile approach that, however, is not straightforward (Laursen and Andersen, 2016) because knowledge accumulated over time on supplier involvement in the well-formalized development phase cannot be readily transferred to the FFE because of its more unstructured and dynamic context (Schoenherr and Wagner, 2016). There are several internal and relational aspects that need to be considered, and the focal firm must provide an appropriate framework to enable successful involvement

(Schoenherr and Wagner, 2016; Wagner, 2012). What we found as significant effects between our mediator variables and the different types of innovation capability might provide helpful guidance here.

6. Limitations and future research

Despite its theoretical and managerial contributions, our study is not without limitations, which point to potential avenues for future research. First, our study relies solely on data collected from firms in the German automotive industry. Although we consider the German automotive industry as adequate for examining supplier involvement in firms' NPD process and as representative for other complex and technology-driven industry sectors, we are aware that the generalizability of our results is limited. Hence, we call for replication across other industries and countries to validate our findings.

Second, this study adopts a single respondent strategy that may potentially produce common method bias. Although the application of ex ante remedies and the statistical tests applied suggest that common method bias is not a cause for concern in our study, future work might use multiple data sources for further validation (i.e., using multiple informants or objective data for outcome variables).

A third limitation of this study is its cross-sectional design. Although we can show indications for our model and the dependencies, the causality is only implied because our data renders testing for causal effects over time impossible. Future studies could overcome this limitation by using longitudinal data collection.

Fourth, although we provided a better understanding of the underlying mechanisms through which supplier involvement in the FFE contributes to a focal firm's innovation capability, more research should be conducted on the micro-processes behind these mechanisms. Qualitative research methods could be used to gain a deeper understanding and derive practical advice of, for instance, how search instruments are established within firms or how the purchasing department is organized in terms of innovation scouting.

Fifth, because our analysis did not reveal statistical significance of all our mediators and the proportion of the variance explained by our models is below 30%, future studies should aim to identify additional mediators.

Sixth, our study did not capture information on the characteristics of buyer-supplier collaboration, for example, information on whether or not or for how long the focal firms had collaboration experience with suppliers. Existing research emphasizes that the extent of partner-specific experience particularly affects the collaborative performance (Bodas Freitas and Fontana, 2018; Zollo, Reuer, and Singh, 2002). Similarly, the mediator effects might differ between, for instance, long-term collaborations and first-time collaborations. Further in-depth research, for example, using project-level empirical data of buyer-supplier collaborations in the FFE could consider these characteristics and their impact.

Finally, considering the importance of supplier involvement in the FFE for radical innovation and incremental innovation, future research might assess the antecedents that determine the intensity of supplier involvement in the FFE (Schoenherr and Wagner, 2016).

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Chapter 6

Conclusion

Open innovation and the integration of external sources of ideas, such as customers and suppliers as crucial supply chain partners, into the front end of a firm's NPD process has evolved to an essential part of managerial strategy to maintain competitiveness, which holds particularly true for the automotive industry. However, existing research has thus far failed to investigate comprehensively the value of integrating customers and suppliers for a focal firm's innovation capability and how to integrate these partners successfully into the front end of NPD process, which has been recognized as crucial to the overall innovation success. Against this background, this thesis pursued the following overarching research objectives: (1) Creating empirical evidence about the benefits that a firm can obtain from the integration of customers and suppliers in terms of innovative outcome; (2) Providing a better understanding of how to integrate customers and suppliers successfully into the front end of innovation.

With regard to the value of integrating customers and suppliers into the front end of innovation and related benefits for the focal firm, the following outcomes can be noted:

- From a downstream perspective, the perceived quality of innovative ideas coming from customers largely depends on the position of the focal firm within the supply/value chain.
- From an upstream perspective, integrating suppliers into the focal firm's front end of innovation process positively influences its radical innovation capability and incremental innovation capability. Firms are also recommended to reach beyond their established supplier network and increasingly involve new venture suppliers, so-called "start-ups", because their ideas are characterized by a higher degree of novelty and—to some extent—higher end customer benefit when compared with ideas generated by established suppliers. However, suppliers' ideas provide a better fit with existing technologies and create more valuable business opportunities while meeting technical and economic criteria, thus being more likely to be selected for implementation.

With regard to the successful design of integrating customers and suppliers into the front end of the innovation process, the following central results can be noted, which in turn provide valuable implications for managerial practice:

- From a downstream perspective, focal firms should use open innovation methods to exploit ideas from customers in the early stages of NPD. Classic and easy to use methods, such as idea workshops or focus groups, are frequently used to integrate customers; however, particularly if more complex, web-based toolkits are frequently used, the quality of customers' innovative ideas is rated significantly higher. The awareness of the lead user method, which is used to integrate a specific group of users ahead of the market trend, is rather low and the method seems to be more appropriate for larger firms. However, because negative aspects became less important with increasing usage frequency, their usage should be encouraged.
- From an upstream perspective, focal firms are also recommended to structure their search for suppliers' innovative ideas. Based on case study findings, several open innovation instruments are suggested that focal firms can apply to "defuzzy" the front end of innovation and thus provide guidance on how the involvement can be managed. Particularly, having established supplier ideas search practices mediates the relationship between early supplier involvement and a firm's ability to generate incremental innovation, but, interestingly, not radical innovation. In contrast, the thesis findings reveal that having supplier incentives in place, involving purchasing professionals from the very early beginning of NPD, and drawing on a varied supply base constitute underlying mechanisms through which supplier involvement in the front end of innovation contribute to a focal firm's radical innovation capability. Besides the benefits of extending the supply base by, for instance, collaborating with start-ups, the findings

also highlight related challenges and shortcomings that need to be addressed by managers.

Overall, this thesis contributes important empirical findings to a highly relevant research area and its results provide valuable implications for innovation managers who are developing strategies to access and exploit innovation ideas from external partners. Lastly, I hope that this thesis will motivate scholars either to take up the various future research opportunities mentioned in the included research papers or to develop new ones. I am sure, there are many worth to pursue.

Appendix

Academic output of research papers and individual contributions

Appendix A: Academic output of research papers

This dissertation is cumulative in nature; this means that chapters two to five are based on individual papers. These papers have been published in or are under review at academic journals. The following list summarizes the included papers and their respective academic output.

Research Paper #1 (Chapter 2). Rese, A., Sänn, A., and Homfeldt, F. (2015). Customer integration and voice-of-customer methods in the German automotive industry.
This paper has been published in the International Journal of Automotive Technology and Management, Volume 15, Issue 1, pages 1–19.
(VHB JOURQUAL 3: Category C)

Research Paper #2 (Chapter 3). Homfeldt, F., Rese, A., Brenner, H., Baier, D, and Schäfer, T. F. (2017). Identification and generation of innovative ideas in the procurement of the automotive industry: The case of AUDI AG.
This paper has been published in the International Journal of Innovation Management, Volume 21, Issue 7, 1750053 (31 pages).
(VHB JOURQUAL 3: Category B)

Research Paper #3 (Chapter 4). Homfeldt, F., Rese, A., and Simon, F. (2019). Suppliers versus start-ups: Where do better innovation ideas come from?
This paper has been published in Research Policy, Volume 48, Issue 7, pages 1738–1757.
(VHB JOURQUAL 3: Category A)

Research Paper #4 (Chapter 5). Homfeldt, F. and Rese, A. (2020). Front-end supplier involvement, firm innovation capability, and mediating effects: Empirical evidence from the German automotive industry.
This paper is under review at the Journal of Product Innovation Management.
(VHB JOURQUAL 3: Category A)

Appendix B: Individual contributions to the included research papers

All included research papers were written in settings with multiple authors. In the following, I will detail the settings and my individual contribution to each of the four papers included in this thesis.

Research paper #1, which is presented in chapter 2, was authored by three researchers with Alexandra Rese serving as the corresponding author, being mainly responsible for writing the article and analyzing the data. Together with Alexander Sänn, I was substantially involved in developing the overall motivation and conceptualization of the study, including the development of the survey instrument and collection of the data. Furthermore, I contributed to the paper by conducting literature review and supporting during the revision process of the article.

Research paper #2, which is presented in chapter 3, was developed by five authors—two of them serving as innovation managers at AUDI AG during the creation of the paper, who contributed to the conceptualization of the study. As the corresponding author, I was responsible for conceptualizing the study, carrying out the literature review, developing the research design, conducting the interviews, analyzing the data, writing the article, and managing the revision process. Alexandra Rese and Daniel Baier contributed through constant conceptual and methodological advice and various revisions of the paper.

Research paper #3, which is presented in chapter 4, was written by three researchers. As the corresponding author, I was responsible for conceptualizing the study, carrying out the literature review, analyzing the data, writing the article, and managing the revision process. Furthermore, I accompanied the open innovation initiative underlying this study. Franz Simon supported throughout all these steps, particularly in the early stages of the paper. Alexandra Rese was substantially involved in each step of the study and contributed through constant conceptual and empirical advice and various revisions of the paper.

Research paper #4, which is presented in chapter 5, was written by two researchers. As the corresponding author, I was responsible for conceptualizing the study, carrying out the literature review, developing the survey instrument, collecting and analyzing the data, and writing the article. Alexandra Rese provided valuable feedback on the survey instrument and guidance on the development of the included version of the article.