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Collaborative innovation with suppliers - a conceptual model for characterising supplier contributions to NPD

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Abstract: It is widely acknowledged that suppliers contribute positively to innovation in new product development. However, it remains rather unclear what suppliers actually contribute to innovation. Based on a literature review focusing on 80 articles, and a focus group meeting with strategic purchasing managers, a conceptual framework is developed categorizing different supplier inputs to innovation. This model is formulated by characterizing supplier inputs on a component level and architectural level, related to knowledge extension and knowledge reconfiguration respectively. Further, supplier inputs can be incremental or radical in nature, resulting in either a dependence on the supplier's process knowledge or the supplier's technology knowledge. These situations imply different conditions for knowledge integration.

Keywords: *collaborative innovation; supplier collaboration; supplier input; conceptual model; new product development; literature review; incremental innovation; radical innovation; component; system*

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1. Introduction

Innovation is not a company internal matter but is increasingly generated in collaboration with external firms. Suppliers may provide a valuable contribution to new product development (NPD) as they provide access to external knowledge that complements the firm's internal knowledge base. This external knowledge is important as innovation is considered the result of a recombination of elements from different knowledge bases (Henderson and Clark, 1990; Kogut and Zander, 1992), which usually do not reside within a single firm. Research in the field of supplier collaboration in NPD is quite extensive. Existing studies provide valuable insight into antecedents, motives, success factors etc. for supplier collaboration in NPD (for an overview see Johnsen, 2009). However, the actual contributions of suppliers to innovation are underexposed. This paper focuses specifically on *what knowledge* suppliers contribute to innovation. Several studies have found that supplier collaboration is positively related to innovation on the customer firm level (e.g. Un et al., 2010). However, many studies do not explicitly describe when and if suppliers actually are the brains behind the innovation, if they contribute with new technologies, if they are used as sparing partners, or if suppliers contribute in another way to innovation.

The purpose of this paper is to provide an overview of existing research, analyse what existing studies reveal about the contributions of suppliers to innovation, and develop a model categorizing supplier inputs to innovation and the conditions for knowledge integration.

This paper is organized as follows; first the theoretical perspective, continued by an explanation of the method and research approach. Then the literature overview provides an overview of the contributions made in the field of supplier collaboration in NPD, followed by the results from a focus group meeting. It is discussed to what extent the literature provides sufficient answers to what suppliers actually contribute to innovation and a framework for analyzing different contributions is formulated.

2. Knowledge integration and innovation

The theoretical starting point of this paper is related to the knowledge based theory of the firm. We adhere to Grant's (1996) knowledge-based view, where the critical input and the primary source of value is knowledge. In innovation, this knowledge is used in the recombination of components and/or linkages in the product architecture (Henderson and Clark, 1990). This article is focused on NPD which implicates specialization and application of many types of knowledge. As it is not likely that all necessary knowledge resides in one single firm (Grant and Baden-Fuller, 2004), innovation can only be achieved by inter-

organizational collaboration. The integration of the different inter-organizational knowledge bases then becomes the essence of organizational capability and competitive advantage.

According to the OECD (1997) the definition of an innovation is “the implementation of a new or significantly improved product or process”. Innovation can be considered to be either incremental or radical. An incremental innovation is a minor change that amplifies existent knowledge. A radical innovation on the other hand, requires completely new knowledge that fundamentally changes the activities and behaviors in an organization or society. This type of innovation is certainly discontinuous, since it creates a new market by allowing customers to solve a problem in a radically new way. It might even be disruptive, since a new market emerges while the old market is disrupted (Christensen and Bower, 1995). Although, the concepts of discontinuous and disruptive innovation have emerged strongly, these concepts focus on the external, *market*, side of innovation. We focus on the internal, *resource*, side of innovation and we mainly refer to radical and incremental innovation.

Henderson and Clark (1990) argue that the traditional way of looking at innovation as radical or incremental, is misleading. In fact they think it has disastrous effects on industry incumbents. They examine the field of innovation and propose a model based on innovations affecting only core components and innovations overturning the internal linkages between the core components. Only the combination of these two is coined by them as a radical innovation. This can be compared to a more traditional definition of radical innovation as fundamental changes in new products that represent revolutionary changes in technology (Song and Di Benedetto, 2008; Song and Thieme, 2009). Then again, incremental innovation according to Henderson and Clark (1990) only reinforces existing components while other definitions define incremental innovation as minor changes to existing products/components using current technologies (Song and Di Benedetto, 2008; Song and Thieme, 2009). Other types of innovation in Henderson and Clark’s (1990) model are modular innovation and architectural innovation. Modular innovation overturns the core concepts, but leaves the linkages between the components (i.e., the architecture) unchanged. Architectural innovation, does not change the core components, but changes the linkages between them.

Here a distinction can be made between two types of renewals: the *extending* of existing capabilities with additional knowledge and *reconfiguration* of existing knowledge into new types of capabilities. The former depends heavily on the characteristics of knowledge communicability. The latter is a more complex process by which the firm creates a comparative advantage. Architectural innovation may exemplify this process. This type of innovation destroys the usefulness of the firm’s knowledge about the linkages between the components, but it preserves its knowledge about the products’ components. Consequently, architectural innovation relies on the reconfiguration of existing knowledge. This complex process requires an ability to integrate knowledge across different disciplinary and organizational boundaries. In contrast, in modular innovation renewal by extending the existing capabilities is central. Henderson and Clark (1990) point to the importance of this analysis when looking at established organizations’ difficulty in adapting to architectural innovation. Much of what the firm knows needs to be applied to new products, but some of what it knows might just be a handicap, something that has been confirmed by Levinthal and March (1993).

3. Method and research approach

This paper is mainly based on an extensive literature review. However, to validate our findings with some empirical data, we also used a focus group. This focus group was chosen as it was assumed to have a broad knowledge that was highly representative for the area (Bryman, 2008). Therefore, the focus group meeting consisted of strategic purchasing

managers representing 20 Swedish companies. These strategic purchasing managers were asked questions concerning knowledge and capabilities of their suppliers, taking into consideration what the suppliers add to the NPD collaborations. Thus, these were questions directly related to the literature review.

The literature review aimed at identifying studies on supplier collaboration and innovation. An overwhelming amount of articles was found and it was decided to delimitate our search to the Web of Science. The Web of Science provides a comprehensive coverage of the main peer reviewed and relevant journals with a typically high impact.

During our initial searches several keywords were determined and systematically used in our further searches (see appendix). Our searches resulted in 272 examples. After an initial screening of the results, the selection was narrowed to 175 articles. In order to determine the relevance of the articles, all abstracts of these 175 articles were read. For further selection we identified articles with a focus on vertical relationships in the supply chain (as opposed to horizontal relationships, thereby excluding articles only focus on competitors, research institutes etc.). Furthermore, articles were selected that treat the concept of innovation in some way or another. For this purpose, a word count on the presence of the word 'innovation' in the articles was performed, assuming that articles with high counts represent a stronger focus on innovation. All in all, the selection resulted in 80 articles that form the basis of this literature review. Our focus on innovation resulted in the exclusion of some important contributions identified as central to the study of supplier involvement in product development (Johnsen, 2009), including well-cited articles as (Cusumano and Takeishi, 1991), (Ragatz et al., 1997), and (Kamath and Liker, 1994). However, as these articles do not mention innovation specifically, it could be argued that these articles are less central to the investigation of supplier contributions to innovation.

The 80 articles that form the basis for the literature review are published in 33 different journals (see appendix). A few of these journals, as Journal of Product Innovation Management, R&D Management, Research Policy, Industrial Marketing Management, IEEE Transactions on Engineering Management, Technovation represent half of the articles. The earliest article part of the review was published in 1994 and no less than 9 articles were published in 2010, indicating that the research topic is still relevant.

4. Analysing and characterizing the contributions

The 80 articles contribute to existing knowledge on supplier collaboration in NPD in different areas. Thus the articles were characterized according to their main contributions. Below, the antecedents, importance of internal integration, managerial practices, effects of supplier collaboration on innovation, and contributions from suppliers are described.

4.1 Antecedents

Many studies focus on the antecedents of supplier collaboration for successful NPD. Here the focus is under what circumstances supplier collaboration actually takes place and succeeds. Supplier capability, technological uncertainty, modularization, geographical proximity, and trust and collaborative ties are frequently discussed (e.g. Schiele, 2006; Johnsen et al., 2009; Mikkola, 2003; Li and Vanhaverbeke, 2009; Walter, 2003).

Specialized and technically competent suppliers may provide the prerequisites for successful innovation (Schiele, 2006; Oh and Ree, 2010). Especially when suppliers have a strategic emphasis on product innovation, the outcomes of supplier collaboration are more positively related to product innovation (Wynstra, von Corswant and Wetzels, 2010). Innovative suppliers, with their strategic orientation on innovation, can build up a foundation

for knowledge transfer and the assimilation of knowledge resources (Jean, Sinkovics and Kim, 2010). This independent supplier NPD influences the technological depth of the supplier's offerings positively and the possibility of the supplier to contribute to innovation (Laamanen, 2005, Tangpong, Michalisin and Melcher, 2008). The importance of the suppliers' independent innovation capabilities can be put in contrast to the positive effect of supplier specific investments to fit well with the requirements of a particular firm in developing a radical innovation product (Song and Di Benedetto, 2008). The latter case concerns knowledge extension rather than knowledge reconfiguration (Appleyard, 2003). Both may be important though.

The situation of technological uncertainty is investigated by Johnsen et al. (2006), who argue that supplier relationships are less relevant, or only of explorative character under these circumstances. Technological uncertainty makes it difficult to know what suppliers to select, and in order to maintain design flexibility, the customer may opt for last-minute supplier selection or buying off-the-shelf components (Eisenhardt and Tabrizi, 1995). Here, the supplier capabilities may be important. When suppliers possess high levels of expertise or knowledge, customers may try to exploit this by initiating a close collaboration (Ragatz, Handfield and Petersen, 2002). Hence, the level of technological uncertainty also influences supplier collaboration practices (Primo and Amundson, 2002).

Modularization capabilities refer to the supplier's capability to integrate various parts into one, make parts for common uses, and to assemble modules and/or sub-systems (Oh and Rhee, 2010). The thought is to create an interface between the supplier and the customer, where specialist knowledge can be kept inside a module (i.e. the supplier) and be easily connected to the customer (Griffith et al., 2009; Mikkola, 2003). Organizing supplier collaborations around these modules may enhance organizational flexibility and innovation performance (Lin, 2004; Ro et al., 2007; Hoetker, 2006). However, although modular product architectures allow for more supplier autonomy in NPD, inter-firm knowledge integration is still necessary (Becker and Zirpoli, 2003; Hoetker et al., 2007; Mikkola, 2003; Howard and Squire, 2007; Koufteros et al., 2007).

Another antecedent of supplier collaboration for innovation concerns the geographical proximity between the buyer and the supplier. Schiele (2006) proposes that suppliers successfully collaborating with their customers are likely to be located in close proximity to each other. This is confirmed in a study by Li and Vanhaverbeke (2009) who focus specifically on pioneering innovations and suggest that it is important not only to search for suppliers from different industries to get access to various complementary external knowledge sources but also to find suppliers from the same or nearby countries for the sake of communication and coordination.

Supplier embeddedness provides prerequisites for building trust, a mutual understanding and commitment from the supplier (Isaksen and Kalsas, 2009). A high degree of trust facilitates supplier collaboration and inter-organizational creativity (Walter, 2003; Wang, Bradford, Xu and Weitz, 2008) and allows firms to capitalize on its collaborative ties by accessing the suppliers' knowledge bases (Koufteros et al., 2007). These ties build through cooperative and long-term relationships with suppliers and where possible assist suppliers in their development (McDermott and Corredoira, 2010). Although such efforts need to be accompanied with a supply base rationalization strategy, a too narrow supply base may have negative consequences for the contributions of suppliers to innovation (Choi and Krause, 2006). The use of contracts can be considered as complementary to trust (Carson, 2007; Blomqvist et al., 2005).

4.2 Internal knowledge for external collaboration

Effective NPD requires firms to combine and integrate internal and external knowledge (Grant, 1996). Consequently, in order to facilitate the integration of knowledge, supplier collaboration also requires internal adaptations. The concept of absorptive capacity refers to this issue of using existing internal knowledge for assimilating and utilizing external knowledge (Cohen and Levinthal, 1990). A firm with high levels of absorptive capacity, i.e. a high level of internal NPD activities and training programs for technological activities, is better able to create and exploit linkages with suppliers. Tsai (2009) finds that absorptive capacity positively moderates the impact of supplier collaboration on performance in completely new or significantly improved products.

This is confirmed by Takeishi (2001) who argues for the importance of internal knowledge for external collaboration. His results imply that supplier collaboration does not work effectively without extensive internal effort and an investment in (supplier) component-specific knowledge in order to be able to quickly evaluate and use new component technologies when available. In addition to overlapping knowledge, external collaboration also necessitates internal coordination. In essence, these authors acknowledge the importance of a knowledge overlap between buyers and suppliers for knowledge integration as well as an ability to coordinate (Beecham and Cordey-Hayes, 1998, Takeishi, 2001, Takeishi, 2002, Tsai, 2009, Ulrich and Ellison, 2005; Koufteros, 2005).

4.3 Managerial practices

In the late 1990s, Beecham and Cordey-Hayes (1998) showed that firms often underestimate the amount of management effort required to make supplier collaboration to work. This was confirmed in later studies, such as Andersen and Dreijer (2009). They note that, while supplier involvement in product development projects can contribute with valuable knowledge and expertise, such involvement also poses organizational and managerial challenges.

McIvor et al. (2006) argue that there has to be a re-examination of the total supply network. However, on a firm level, successful supplier collaboration is dependent on management's ability in coordinating design, execution, and evaluation of strategic long-term processes as well as operational short-term processes (Van Echtelt et al., 2007; Van Echtelt et al., 2008). Long-term collaboration benefits can only be captured if a company can build long-term relationships with key suppliers, with which it builds learning routines and ensures that the capability sets of both parties are aligned and remain useful for future joint projects. Consequently, activities related to prioritizing, mobilizing, coordinating, and timing are necessary (Wynstra et al., 2003). These activities are related to supplier selection and resource allocation, getting a commitment from suppliers, coordinating the development work, and making sure that information exchanges are taking place in a timely and correct manner. The latter activity is related to sharing technology information and sharing of decision making (Kim and Oh, 2005; Petersen et al., 2003, Bozdogan et al., 1998; McIvor and Humphreys, 2004). Sharing of technology information and decision making is facilitated by integrating the suppliers on the development team (Biehl, 2006). This approach is similar to an integrated approach to NPD project coordination (Lakemond et al., 2006b), which provides good conditions for knowledge integration.

Purchasing fulfills an important function in coordinating the efforts of the supplier by initiating regular innovation meetings with suppliers and developing technology roadmaps linking firm strategy, innovation strategy, sourcing strategies (Schiele, 2010), and supplier

development (Reed and Walsh, 2002). By performing these activities, purchasers act as important supplier relationship promoters (Walter, 2003).

Roy et al. (2004) argue that interactions between the buyer and the supplier are essential for successful product innovation. Especially knowledge-sharing routines, i.e. the systematic pattern of buyer–seller interactions permitting transfer of knowledge and information, are important in supplier collaboration (Wang et al. 2008). These refer to assigning budgets for information sharing, rules and procedures for information sharing activities, and reward or incentive systems to encourage creativity. These activities provide opportunities for establishing direct contact with the individuals possessing the necessary complementary knowledge (Sobrero and Roberts, 2002). Consequently, frequent interaction, team-working, communication, and collaboration with the supplier from an early stage are important for achieving innovation outcomes (Cousins and Lawson, 2007; Hartley et al., 1997; Verganti, 1997).

Successful management of supplier collaboration in NPD requires commitment from top management. This commitment results in a positive attitude to supplier collaboration and allowing a willingness to learn, instead of trying to instinctively protecting personal interests and creating an ambiguous situation of partly collaborative and partly competitive relations, which makes it difficult to integrate working relationships with suppliers (Aylen, 2010, Beecham and Cordey-Hayes, 1998).

The managerial practices for supplier collaboration in NPD need to be interpreted carefully as different contextual situations may demand different ‘best practices’. This may concern company specific (e.g. low-volume, high-volume industries) but also the characteristics of a specific project. Therefore, it is important to develop procedures that adequately reflect the inherent needs of individual projects (Lakemond et al., 2006b; Maffin and Braiden, 2001; Tatikonda and Stock, 2003; Wagner and Hoegl, 2006).

4.4 Supplier collaboration and innovation

For a single firm it is almost impossible to manage the knowledge necessary for product innovation completely internally (Corso et al., 2001). Many firms have become specialized nodes within complex and dynamic knowledge creating networks. Suppliers are part of these networks and may actually contribute positively to innovation (e.g. Lau et al., 2010; Li and Vanhaverbeke, 2009; Su et al., 2009; Tsai, 2009; Un et al., 2010). However, it seems that the contributions of suppliers can be related to different aspects.

On the one hand, Belderbos et al. (2004) find that supplier collaboration only contributes to incremental innovation that improve a firm’s productivity. Here, suppliers enable improvements to product quality, adherence to product cost targets, development budgets and development schedules and may contribute to market intelligence (Hoegl and Wagner, 2005; Primo and Amundson, 2002; Song and Thieme, 2009). Su et al. (2009) do not find suppliers to contribute to innovation at all while Song et al (2006) find a negative effect of supplier collaboration on knowledge generation. Knowledge generation is however a narrower concept than knowledge creation which also includes dissemination, and application.

On the other hand, Un’s et al. (2010) findings indicate that suppliers are the most important source for product innovation. They argue that although suppliers have a relatively narrow knowledge base, buyers can easily access this knowledge base for product innovation. Other reasons for the positive effects of supplier collaboration on product innovation are related to the suppliers’ expertise and comprehensive knowledge regarding the parts and components. Supplier collaborations allow firms to incorporate this expertise and complementary knowledge of suppliers to improve its solutions (Bonaccorsi and Lipparini, 1994). Here, it may not always be the best strategy to improve product innovation by inviting current

suppliers. Product innovation may also demand that new collaborations are initiated with suppliers with the 'right' complementary knowledge (Appleyard, 2003; Lau et al., 2010).

Suppliers contribute with new technologies of material components and systems (Ritter and Gemunden, 2004). Benefits of supplier collaboration can also result from innovations in the system architecture that are enabled by suppliers (Bozdogan et al., 1998). Here, the concept of architectural innovation can be extended so that product features are matched with the associated specialized technical skills of partners in the development team.

Lee and Veloso (2008) categorize innovations as architectural or component innovations, studying technology-forcing regulations imposed by the government on the auto industry from 1970 to 1998, a period changing from high to low uncertainty. Their results confirm that suppliers dominate component innovation whereas assemblers lead on architectural innovation. More importantly, when facing uncertainty, firms adjust their knowledge boundary by increasing the knowledge overlap with their supply-chain collaborators. Thus, for assemblers, life-cycle effects may dominate over task uncertainty in determining their relative effort in component versus architectural innovation. The study supports the idea that architectural and component knowledge are critical elements in the alignment of cognitive frameworks between assemblers and suppliers. These elements are keys for information-exchange effectiveness and resolution of task uncertainties in inter-firm innovation.

4.5 Contributions from suppliers

But what do suppliers actually do? Are they just enablers, or are they actually taking responsibility for and are the brains behind these innovations? Sobrero and Roberts (2002) develop four different typologies, closely related to the degree of supplier responsibility. In the first case, all design work and related problem-solving is done by the customer. In this case, the supplier contribution is very limited. In the second case, suppliers are involved in the design of components, which might critically impact other parts of the project. In this case, the control over suppliers' design freedom is imposed indirectly by the up-front definition of the interface specification provided. In this type of relationship, suppliers are recognized as an important source of knowledge, but the characteristics of the component limit their freedom in problem solving activities. In a way, they are integrated into the manufacturer's problem solving logic and process. In the third case, suppliers work on components with low interdependency with the rest of the project. The manufacturer limits its own activities by selecting a low critical area of the project (e.g. a sub-system or module) and delegating it entirely to the supplier. The supplier domain of action was therefore widened, albeit limited to areas of their activities. In this type of relationship, the manufacturer tried to access a specific knowledge domain of the supplier, without limiting its potential outcome by a predetermined set of solutions. As the component criticality is low, it is not likely that the supplier contributes to a high degree of innovation. This situation considers refinement of an existing production process or product (Schiele, 2006). In the fourth case, suppliers are responsible for the whole problem solving activity for highly critical components. Despite the potentially high influence on the overall project, suppliers are given freedom to define the solution starting from the concept design. In fact, suppliers are the brains behind the innovation in the component or sub-system. Schiele (2006) refers in this context to the purchasing of innovation, where the buyer only commissions the development.

5. Results from the focus group

The focus group was asked to return a short questionnaire before the focus group meeting. The questions focused on the most usual contribution of suppliers to innovation, the

importance of the supplier's understanding for the technologies used, the importance of the supplier's understanding for the product's business case, working methods, and the role of purchasing. 6 questionnaires out of 20 were returned, mainly representing medium sized and large manufacturing companies in the Swedish context. The results are presented in Table 1.

Table 1: Results from the focus group (Scales: 1 = not important, 7 = very important)

	(1) Existent component /process	(2) New component	(3) Existent module/ system/ subsystem	(4) New module/ system/ subsystem
Most usual contribution	1	2	3	4
Percentage distribution	38 %	26 %	18 %	18 %
Importance of the supplier's understanding of:	5 (4,5 ±1,97)	5 (5,0±1,63)	6 (6,3±0,94)	7 (6,7±0,74)
- technology				
- commercial Prerequisites	4 (4,0±1,91)	5 (4,7±1,37)	6 (5,5±0,96)	6 (6,0±1,15)
- firm's working methods	4 (3,8±2,03)	5 (4,5±1,60)	5 (5,0±1,53)	6 (5,8±1,56)
Importance of purchasing's role	5 (4,8±1,67)	6 (5,7±0,94)	6 (5,8±1,34)	7 (6,7±0,47)

It was found that the contribution of suppliers was usually linked to improvement of components (38%). Development of new module/system/subsystem was least common (18%). There was a large variance in the responses. One explanation for this, except for the small sample, might be that strategic purchasing managers have different views, as they belong to different industries. Another explanation, which was mentioned as a possible explanation among the participants, was that they deal with different values and volumes.

However, the strategic purchasing managers from eleven firms that participated in the discussions, found the four categories relevant where different inputs from suppliers could be identified and analyzed. They also confirmed that different knowledge and capabilities are needed, depending on which category we are taking into consideration. The majority found knowledge and capabilities within the suppliers to be most important developing modules/systems/subsystems and less important on components. The same can be said about the importance of the role of purchasing. In the former situation the people involved must have a broad knowledge and capability, including technical, commercial, and organizational capability.

6. Discussion and conclusion

Existing literature on supplier collaboration in NPD provides many insights into important antecedents, including the importance of supplier capabilities technology uncertainty, modularization, geographical proximity, and supplier embeddedness. All these factors are necessary to consider when initiating supplier collaboration. In addition, the importance of internal knowledge and knowledge overlaps between the buyer and the supplier, and

consequently the internal integration necessary at the buyer firm is also an important aspect in achieving successful supplier collaborations. It should not be forgotten however that supplier collaboration also requires an extensive management effort, with interaction, frequent information flows, and teamwork as important prerequisites for innovation. Here, there is no one size fits all approach; management practices need to be adjusted to the specific contextual situation.

Returning to our initial question in this paper “Can we get innovation out of suppliers?”, the literature overview shows, with some exceptions, that suppliers contribute positively to innovation. However, the aggregate level of analysis in many of the studies makes it difficult to determine what suppliers actually contribute. The literature provides some indications of actual contributions of suppliers to innovation. Input from suppliers may concern process and production aspects related to cost reduction and quality improvement, but also to the provision of innovative knowledge about new technologies. The former can be considered to be incremental inputs, the latter more radical input. Of all these inputs of suppliers, innovative knowledge in terms of new technologies and know-how are the most valuable elements (Li and Vanhaverbeke, 2009). However, despite these indications of contributions, there seems to be no general framework for categorizing different contributions of suppliers to innovation.

What seems to be clear though is that suppliers dominate component innovation, whereas buyers lead on architectural innovation (Lee and Veloso, 2008, Li and Vanhaverbeke, 2009, Sobrero and Roberts, 2002). This was also confirmed in the focus group study, as it indicated a slight difference between the two.

The distinction between component and architectural innovations may be important in understanding different supplier inputs to innovation. Using the component level and architectural level as two distinct situations and distinguishing between incremental inputs and radical inputs, the inputs of suppliers to innovation can be categorized, as presented in Figure 1.

		Component level: Extending existing knowledge	Architectural level: Reconfiguring existing knowledge
INPUT BY THE SUPPLIER	Radical	Development of a completely new component (e.g. an advanced material that revolutionizes performance in breaking pads)	Development of a completely new system (e.g. a completely new breaking system for a vehicle using a new technology)
	Incremental	Improvement of a component (e.g. a lighter component within a disc-brake that gives better performance and stability)	Improvement of a system (e.g. new versions of a breaking system for vehicles with better performance)

Figure 1: Categorization of supplier inputs to innovation – a conceptual model

For component innovations, which concerns knowledge extension, suppliers can contribute with incremental innovations by initiating and enabling improvements to product quality, adherence to product cost targets, development budgets and development schedules (e.g. Belderbos et al., 2004). This considers improvement of components and processes, which imply a dependency of the supplier's process knowledge. However, the buyer dictates the knowledge extension (Sobrero and Roberts, 2002).

Suppliers can also contribute with radical innovations by taking responsibility for problem-solving activities for highly critical components (e.g. Schiele, 2006). In this case, suppliers are free to define the solution starting from the concept design and are the brains behind the innovation. Thus, the supplier dictates the extension of knowledge and the buyer becomes dependent on the supplier for technology knowledge (Sobrero and Roberts, 2002). This considers the development of completely new components.

Another type of renewal of knowledge involves reconfiguration of existing knowledge into new types of capabilities. In this complex process of knowledge renewal in architectural innovation, it is less likely that the supplier is the brain behind the innovation. Instead, the buyer organization usually takes the lead and suppliers can enable this type of innovation by assisting the design of a new product (Bozdogan et al., 1998) and take part in the buyer's problem-solving logic. In incremental innovation this assistance consists of refinement of existing processes and product designs of architectural concepts. This takes place when improving systems.

Radical input of suppliers on an architectural level is less likely, but when facing radical innovations, suppliers may increase the knowledge overlap by expanding their knowledge base more into architectural knowledge (Lee and Veloso, 2008). In this joint knowledge reconfiguration buyers are, although not completely, dependent on the technology and process knowledge of the supplier. This concerns the development of completely new systems.

The categorization of supplier inputs to innovation and conditions for knowledge integration is important as it can be expected that different inputs are subject to different knowledge integration practices. Since information needs are expected to be different for incremental inputs and radical inputs as well as component levels as architectural levels, supplier collaborations activities may differ (cf. Song and Thieme, 2009). This was also confirmed when we validated our conceptual model with help of focus groups. Therefore, the categorization of supplier inputs can provide the starting point for future research, in which we will investigate to what extent knowledge integration practices are contingent upon the type of supplier contribution.

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APPENDIX

Keywords and results in searches

Search strings	Number of counts	Selected abstract reading
'open innovation' AND 'supplier'	8	4
'incremental innovation' AND 'supplier'	8	6
'radical innovation' AND 'supplier'	9	6
'innovation' AND 'supplier' AND 'collaboration'	43	31
'interfirm' AND 'supplier' AND 'collaboration'	14	10
'interorganizational' AND 'supplier' AND 'collaboration'	22	10
'product innovation' AND 'supplier'	168	108
TOTAL	272	175

The articles and journals part of the review

Articles	Journal	Number of articles
((Appleyard, 2003, Bonaccorsi and Lipparini, 1994, Droge et al., 2000, Lau et al., 2010, Lee and Veloso, 2008, Petersen et al., 2003, Sanchez and Perez, 2003, Song and Thieme, 2009, Tatikonda and Stock, 2003, Un, Cuervo-Cazurra and Asakawa, 2010, van Echtelt et al., 2008, Wynstra et al., 2010))	Journal of Product Innovation Management	12
(Aylen, 2010, Bidault et al., 1998, Bozdogan et al., 1998, Lakemond et al., 2006a, Mikkola, 2003, Schiele, 2010, Song et al., 2006, Veganti, 1997))	R&D Management	8
(Belderbos et al., 2004, Bidault, Despres and Butler, 1998, Chung and Kim, 2003, Laamanen, 2005, Sobrero and Roberts, 2002, Tsai, 2009)	Research Policy	6
(Corso et al., 2001, Fliess and Becker, 2006, Jaspers and van den Ende, 2006, Johnsen and Ford, 2007, Schiele, 2006, Wagner and Hoegl, 2006, Wynstra et al., 2003)	Industrial Marketing Management	7
(Hartley et al., 1997, Hua and Wemmerlov, 2006, Reed and Walsh, 2002, van Echtelt et al., 2007; Ro, 2008)	IEEE Transactions on Engineering Management	5
(Andersen and Drejer, 2009, Beecham and Cordey-Hayes, 1998, Blomqvist et al., 2005, Chen and Liu, 2005, Li and Vanhaverbeke, 2009)	Technovation	5
(Choi and Krause, 2006, Koufteros et al., 2007, Paulraj et al., 2008, Petersen et al., 2005, Primo and Amundson, 2002, Song and Di Benedetto, 2008)	Journal of Operations Management	4
(Johnsen et al., 2006, Ragatz et al., 2002, Ritter and Gemunden, 2004, Walter, 2003)	Journal of Business Research	4
(Hong et al., 2009, Howard and Squire, 2007, Johnston and Kristal, 2008, Spina et al., 2002)	International Journal of Operations and Production Management	3
(Koufteros et al., 2005, Koufteros et al., 2010, Tangpong et al., 2008)	Decision Sciences	3
(Langner and Seidel, 2009, McCutcheon et al., 1997, McIvor et al., 2006)	Journal of Engineering and Technology Management	2
(Hoetker, 2006, Kaufman et al., 2000)	Strategic Management Journal	2
(Eisenhardt and Tabrizi, 1995)	Administrative Science Quarterly	1
(Biehl et al., 2006)	Annals of Operations Research	1
(Su et al., 2009)	Asia Pacific Journal of Management	1
(Cousins and Lawson, 2007)	British Journal of Management	1
(Isaksen and Kalsaas, 2009)	European Planning Studies	1
(Corso, Martini, Paolucci and Pellegrini, 2001)	International Journal of Management Reviews	1
(Maffin and Braiden, 2001)	International Journal of Production Economics	1
(Lin, 2004)	International Journal of Production Research	1
(Wang et al., 2008)	International Journal of Research in Marketing	1
(McDermott and Corredoira, 2010)	Journal of International Business Studies	1
(Jean et al., 2010)	Journal of International Marketing	1
(Hoegl and Wagner, 2005)	Journal of Management	1
(Carson, 2007)	Journal of Marketing	1
(Roy, Sivakumar and Wilkinson, 2004)	Journal of the Academy of Marketing Science	1
(Griffith et al., 2009)	Journal of World Business	1
(Oh and Rhee, 2010)	Management Decision	1
(Hoetker et al., 2007)	Management Science	1
(McIvor and Humphreys, 2004)	Omega – International Journal of	1

	Management Science	
(Takeishi, 2002)	Organization Science	1
(Ulrich and Ellison, 2005)	Production and Operations Management	1
(Kim and Oh, 2005)	Supply Chain Management- An international Journal	1
(Velofo and Fixfon, 2001)	Technology Forecasting and Planning	1
		80