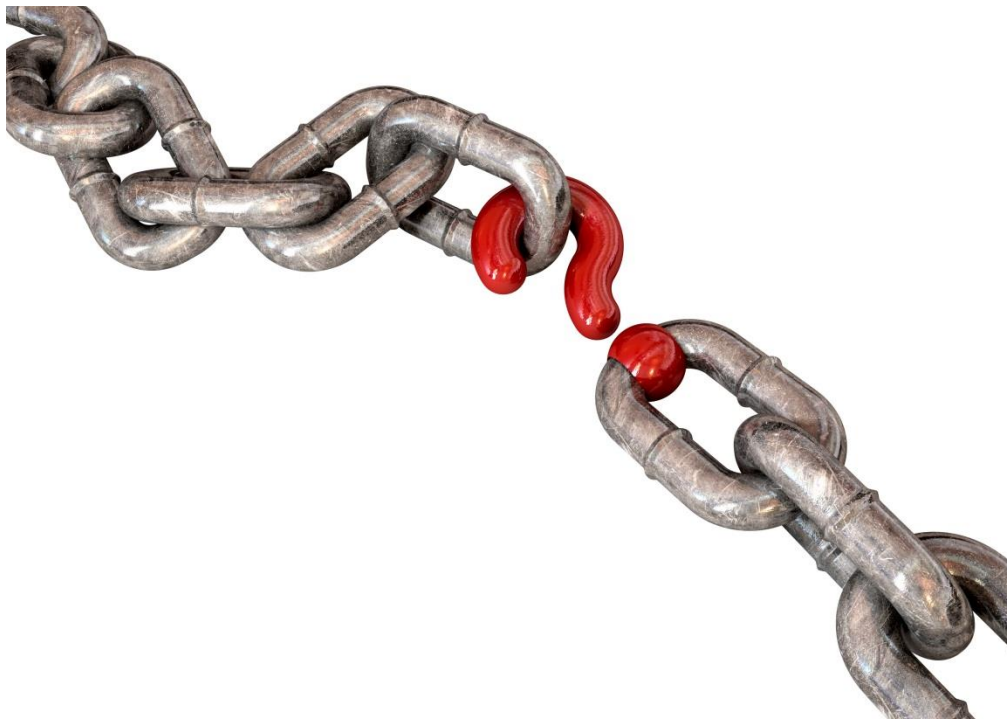


SUPPLIER INTEGRATION IN NEW PRODUCT DEVELOPMENTS

Antecedents for supplier integration in modular product designs



SUPPLIER INTEGRATION FOR NEW PRODUCT DEVELOPMENTS
ANTECEDENTS FOR SUPPLIER INTEGRATION IN MODULAR PRODUCT DESIGNS

DISSERTATION

To obtain the degree of doctor at the University of Twente,
on the authority of the rector magnificus,
Prof. dr. H. Brinksma,
on account of the decision of the graduation committee,
to be publicly defended on November 4th, 2016 at 12.45pm

by

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List of Abbreviations

AVE.....	Average variance extracted
ASA.....	American Statistical Association
CR.....	Composite reliability
CFA.....	Confirmatory factor analysis
Cronb. α	Cronbach's alpha
H.....	Hypothesis
HP.....	Hewlett-Packard
NPD.....	New product development
OEM.....	Original equipment manufacturer
OM.....	Operations management
OLS.....	Ordinary least squares
SEM.....	Structural equation modeling
SPSS	Statistical package for the social sciences

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Justus Erich Eggers

1. Chapter - Dissertation background and research structure

1.1. General Introduction

Increasing customer demands in globally connected markets require higher product complexities with shorter product life cycles from original equipment manufacturers (OEM). In consequence, OEMs can barely develop new products solely with internal resources (Corso, Martini, Paolucci, & Pellegrini, 2001; Eisenhardt & Schoonhoven, 1996; Grant & Baden-Fuller, 2004). To overcome bottlenecks of resource and to create competitive advantages, OEMs, therefore, integrate suppliers in new product developments (NPD) (Bonaccorsi & Lipparini, 1994; Droege, Jayaram, & Vickery, 2000; Jaakkola & Hakanen, 2013).

Earlier studies have shown that the number of collaborations between buyers and suppliers grew continuously (Duysters, Kok, & Vaandrager, 1999), so that supplier expertise account for around 70% of an OEM end-product (Enkel, Gassmann, & Chesbrough, 2009). Through their increasing role, suppliers represent one of the most important external sources of knowledge, innovation and development capacities for OEMs (Laursen & Salter, 2006; Un, Cuervo-Cazurra, & Asakawa, 2010). Research implies that supplier integration contributes not only to a large share of the end-product, but also fosters the performance of buying OEMs. For example, the innovation ability of suppliers was identified as a key factor for technical leadership and innovation performance of buying firms (Azadegan & Dooley, 2010; Rosell & Lakemond, 2012; Tödtling, Lehner, & Kaufmann, 2009; Von Hippel, 1988; Wagner, 2009). In addition to innovation, the integration of suppliers in product development is reasoned to enrich OEM's product development performance in terms of productivity, speed and product quality (Clark, 1989; Primo & Amundson, 2002; Ragatz, Handfield, & Petersen, 2002). Researchers also witnessed a positive influence of supplier integration on the commercial success of final OEM products (Faems, Van Looy, & Debackere, 2005).

To provide larger product variety and more customized products in order to satisfy diversified customer demands, companies share components and other assets across products and product families through platform architectures (Halman, Hofer, & Van Vuuren, 2003). This approach helps companies to balance product variety and product standardization (Krishnan & Gupta, 2001; Meyer & Lehnerd, 1997; Skoeld & Karlsson, 2007) and enables many advantages such as increased flexibility, reduced development cost, and improved ability to upgrade products. By looking at supplier integration in relation to platform architectures, an increasing number of scholars have shown that modular product structures can have an influence on the allocation of development activities to suppliers (Baldwin & Clark, 2003; Baldwin & Von Hippel, 2011; Campagnolo & Camuffo, 2009; Henderson & Clark, 1990; Howard & Squire, 2007; Muffatto & Roveda, 2002; Nepal, Monplaisir, & Famuyiwa, 2012; Sako & Murray, 1999). In detail, the decoupled structure of product modularity allows modifications of one part of the end-product with limited influence on other parts of the end-product. Thus, outsourced modules are not interfering with other modules of the product, so that the development of large parts of the end-product can be allocated to suppliers (Baldwin & Clark, 2003; Baldwin & Von Hippel, 2011; Campagnolo & Camuffo, 2009; Henderson & Clark, 1990; Howard & Squire, 2007; Muffatto & Roveda, 2002; Nepal et al., 2012; Sako & Murray, 1999). Thereby, companies use supplier knowledge for supplementary development activities allowing buying firms to assimilate internal

resources to their core competences (Langlois & Robertson, 1992; Sako & Murray, 1999). The automotive and aircraft industry can be seen as examples, where modularization of products has given buying firms the lead in product development, while a large share of the actual development work is delegated to suppliers (Frigant & Talbot, 2005; Gadde & Jellbo, 2002).

Modular design concepts are now widely applied in multiple industries like the field of manufacturing (Colombo & Harrison, 2008; Stephan, Pfaffmann, & Sanchez, 2008), electronics (Sanderson & Uzumeri, 1997), automotive (Zirpoli & Becker, 2011), heavy duty truck (Vahlne, Ivarsson, & Johanson, 2011), agriculture equipment (Gavioli, 2005), computer hardware and in many service industries (Baldwin & Clark, 1997; Friedman, Kermarrec, & Raynal, 2008; Miozzo & Grimshaw, 2005; Sanchez & Mahoney, 1996). Simultaneously, supplier involvement is expected to increase also in industries other than automotive and high tech (which have thus far been the focus of inquiries regarding supplier involvement) (Wagner & Hoegl, 2006).

Despite the increasing relevance of supplier integration for module developments, research connecting product modularity with supply chain management represents a relatively new research stream (Salvador, Forza, & Rungtusanatham, 2002a) and the area of supplier integration in NPD has received limited attention in the past (Gassmann, Enkel, & Chesbrough, 2010).

In sum, the relevance of supplier integration for module developments is potentially growing, which raises aspects that were not addressed by research yet, but which will be analyzed within this dissertation.

1.2. Focus of this research and research questions

This dissertation addresses the topic supplier integration in NPD with special emphasis on module developments. In view of that, supplier integration in product family development is the general setting of this research. The focus is not on how suppliers can contribute to the development of a modular product architecture that functions as a platform within a product family. In contrast, this project looks at supplier characteristics which enable suppliers to contribute to module developments of the OEM.

In general, we follow the definition from Van Echtelt, Wynstra, Van Weele, and Duysters (2008) and perceive supplier integration as *“resources (capabilities, human resources, information, knowledge and ideas) that suppliers provide, the tasks they carry out and the responsibilities they assume regarding the development of a part, process or service for the benefit of a current and/or future buyer’s product development projects.”*

The theoretical background of this dissertation builds the relational view, which claims that vital resources are often located at external stakeholders - “embedded in interfirm resources and routines” (Dyer & Singh, 1998, p. 650). In view of that, firms who are able and willing to combine internal and external resources may realize a competitive advantage (Dyer & Singh, 1998). Previous research has demonstrated that suppliers represent a fruitful group of external stakeholders with valuable resources (for example Primo & Amundson, 2002; Ragatz et al., 2002), which makes successful supplier integration increasingly important for buying firms.

The vertical integration of suppliers that modular product structures encourage leads to the establishment of networks of producers. Networks among firms can show a centralized and

decentralized structure (Langlois & Robertson, 1992). Within a centralized network, suppliers are tied to a "lead" firm as it is for example often seen in the automobile industry. Nevertheless, buying firms need to identify and select the most capable suppliers from the supplier market. Accordingly, this dissertation focuses on centralized networks and looks at supplier characteristics that enable suppliers to play a leading role in module development activities within a product architecture that is defined by the lead firm. Supplier characteristics are highly relevant for module developments, since supplier contributions depend on the type of component that needs to be developed (Von Hippel, 1988). Considering the high complexity of module (Novak & Eppinger, 2001; Salvador, Forza, & Rungtusanatham, 2002b), suppliers integrated in module developments potential need special characteristics (Oh & Rhee, 2010) to cope with the complexity of module (Handfield, Ragatz, Peterson, & Monczka, 1999; Wasti & Liker, 1997). For example, Doran (2003) has addressed the nature of buyer-supplier relationships in a modular context and proposed a reclassification of the term "first-tier" supplier as the emerging modular environment changes the role of suppliers.

Despite the key role of supplier characteristics, previous scholars have focused on analyzing customer integration in the NPD process (for example Carbonell, Rodríguez-Escudero, & Pujari, 2009; Fuchs & Schreier, 2011), but the area of supplier integration in NPD has not received as much attention (Gassmann et al., 2010). The significant failure rate of interfirm collaborations (Duysters et al., 1999; Sadowski & Duysters, 2008) and the increasing recognition of selecting the right partner for product development activities (Emden, Calantone, & Droge, 2006) exemplifies the need to select the right supplier. Many reports, accordingly, underline the relevance to select competent suppliers to avoid complications such as project disruptions (Flynn, Flynn, Amundson, & Schroeder, 2000; Hartley, Zirger, & Kamath, 1997; Primo & Amundson, 2002; Zsidisin & Smith, 2005).

This dissertation has the objective to enhance the current understanding of supplier integration for modular product developments by analyzing characteristics of module suppliers. The emphasis lies on supplier characteristics for module development, so that implications from modular product structures like reuse of modules or application of product families are not in scope of this dissertation. As a result, technical, relational and product characteristics of suppliers are identified which foster successful collaborations between suppliers and buyers within a modular product structure. Findings of this dissertation advance the limited understanding of supplier integration in NPD (Gassmann et al., 2010) and help practitioners to make better sourcing decision within modular product designs.

The central aim of this study can be summarized with the following primary research question:

What supplier characteristics facilitate supplier integration in new product developments with modular product architectures?

Guided by the central research questions, this study will likewise answer secondary research questions:

1. *What are antecedents for supplier integration in NPD?*
2. *Which supplier characteristics drive innovative supplier contributions in buyer-supplier collaborations?*
3. *Which supplier characteristics foster supplier integration in module developments?*
4. *How do different characteristics of suppliers interrelate with supplier integration approaches within a modular product design?*
5. *What kind of suppliers should be integrated for module development activities?*

1.3. Research approach and methodology

1.3.1 Research approach

In contrast to “pure” basic science which observes phenomena and explains them with theory development, applied science employs hypotheses and explanations that are provided by basic science and aims at applying them to practical problems (H. Ulrich, 1981). The research procedure pursued in this dissertation follows applied science and is routed on a research concept of applied science proposed by H. Ulrich (1981).

P. Ulrich and Hill (1976) divided the research process of management science in three perspectives namely exploration, reasoning, and application. In accordance to the basic steps, this dissertation investigates and describes challenges occurring in business reality, gives explanations by means of qualitative and quantitative analysis, and develops theoretical and practical contributions from the analysis.

Guided by the secondary research questions, five challenges were identified which will be addressed in individual chapters of this dissertation (chapters two to six). All challenges relate to the overall topic supplier integration in NPD and focus on required supplier characteristics. This common underlying topic ensures a strong scientific connection through all challenges. The sequence of this dissertation evolves from a general perspective on the topic supplier integration in NPD towards a detailed analysis of supplier characteristics for module development.

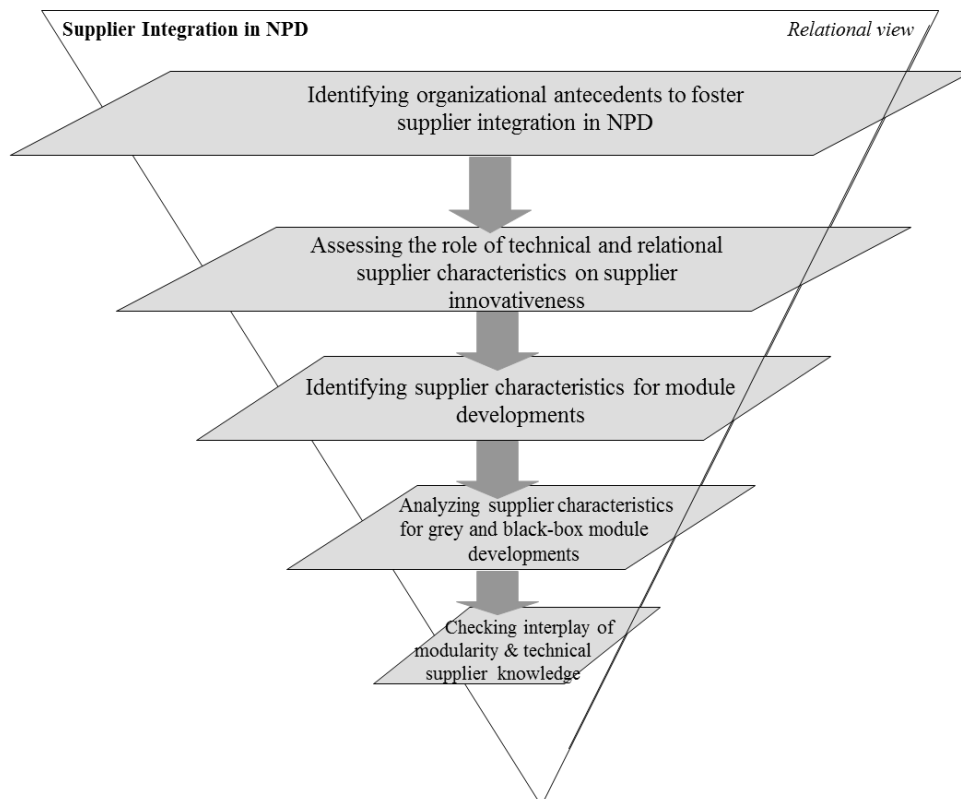
First, this dissertation addresses the identification of organizational antecedents for supplier integration in NPD. Thereby, this research examines the role of purchasing as integration agent for supplier integration, which is rarely addressed by previous literature (e.g. Ellegaard & Koch, 2012; Schiele, 2010; Van Echtelt et al., 2008). In detail, organizational factors are identified that foster purchasing inclusion in NPD. As result, this dissertation provides explanation on how to facilitate supplier integration within buying firms from a general point of view.

Second, after identifying general antecedents for supplier integration, this dissertation reflects on the increasing relevance of external sources of innovation (Chesbrough & Crowther, 2006; Gassmann, 2006) and focuses on antecedents to foster supplier innovation in buyer-supplier collaborations. Accordingly, technical and relational supplier characteristics are evaluated in regards to supplier innovativeness in buyer-supplier collaborations. Even though scholars agree

that a substantial part of innovation creation occurs between buyers and sellers in the supply chain, analysis of open innovation literature shows that the supplier perspective of innovation competences is less intensively researched (Gassmann et al., 2010; Roy, Sivakumar, & Wilkinson, 2004). Findings of this dissertation enhance the current understanding by highlighting that technical and relational supplier characteristics are enabling factors which foster innovative supplier contributions in buyer-supplier collaborations.

As the first and second part provide guidance on how innovative supplier integration can be empowered, the third part takes into consideration that product modularity has an influence on supplier integration (e.g. Campagnolo & Camuffo, 2009). Due to the fact that module suppliers need special characteristics (Oh & Rhee, 2010), but research which combines modularity and supply chain management is relatively new (Salvador et al., 2002a), this dissertation addresses supplier characteristics required for module developments. Initially, we analyzed three case companies to understand the characteristics required for a module supplier. These identified characteristics are then empirically tested in accordance to joint buyer-supplier developments (grey-box) and self-dedicated module developments by suppliers (black-box). Lastly, the interplay between modularity and buyer-supplier collaboration is tested in relation to technical knowledge residing at the supplier site. Applying the identification, empirical verification and detailed analysis of module supplier characteristics, this dissertation helps to portray the ideal supplier for buyer-supplier collaborations within modular product designs. Figure 1 illustrates the sequential research approach of this dissertation.

Figure 1 - Research approach



1.3.2. Research methodology

This dissertation applies a mixed set of research methodologies by combining four quantitative analyses (chapters two, three, five and six) and one qualitative analysis (chapter four). We have chosen to include a qualitative case analysis, which is applicable for purchasing related research (Stuart, McCutcheon, Handfield, McLachlin, & Samson, 2002), to explore supplier competences for successful module development within its real-life context (Yin, 2013). Thereby, we could investigate the cause and effect relationship by asking for how and why (Yin, 2013). In contrast, the quantitative pieces build on an existing body of knowledge by testing hypotheses upon a neutral research model (Bryman & Bell, 2015; Croom, 2009).

Data for this dissertation was gathered specifically for the research problem at hand by using procedures that suite the research problem best. In view of that, this research project relies on primary data. The primary nature makes the data well fit for the research interest and relevant as it is up to date (Hox & Boeije, 2005). By this means relevance of data increases, whereas the risk decreases that results are out of date (Bryman & Bell, 2015; Yin, 2013). Secondary data stands for data which is gathered and compiled by someone else. Kind and timing of data collection cannot be controlled which might result in a less accurate and obsolete data (Bryman & Bell, 2015). Due to the disadvantages of secondary data in means of potential missing relevance and lack of control, primary data collection was the most suitable choice for this study.

In addition to collecting primary data, chapter three includes the empirical analysis of dyadic data that compiles buyer and supplier responses. Even though, scholars claim that a dyadic perspective could enhance research of buyer-supplier relationships (Monczka, Callahan, & Nichols, 1995; O'Toole & Donaldson, 2002), buyer-supplier relations have been rarely tested from both the buyer and the supplier site (Terpend, Tyler, Krause, & Handfield, 2008). Therefore, chapter three presents a distinctive research approach including responses from both relationship partners.

Apart from chapter six, this dissertation applies the theoretical lense of relational view to look at buyer-supplier collaborations. In the past, scholars used the theoretical foundations of the resource-based view and its relationship specific approach, the relational view, to explain potential performance benefits in vertical alliances (I. J. Chen, Paulraj, & Lado, 2004; Mesquita, Anand, & Brush, 2008). The relational view was also previously used to enlighten performance improvement factors of relationship-specific capabilities and processes in different settings, including relational contracting, cross-licensing agreements, logistics processes and value co-creation (Morgan & Hunt, 1994; Rai, Keil, Hornyak, & Wüllenweber, 2012). The relational view of the firm is an extension of the resource-based view by considering firm-external factors as potential source of competitive advantages (Dyer & Singh, 1998). Recent studies promote the relational view as a useful theoretical lens to analyze supply chain collaborations and to examine the partners' individual and joint impacts on relational outcomes (D. Q. Chen, Preston, & Xia, 2013; Zhou, Zhang, Sheng, Xie, & Bao, 2014). In addition to relational view, chapter six introduces the mirroring hypothesis which discusses the relation between product design and inter-organizational relationships (Cabigiosu & Camuffo, 2012b; Sanchez & Mahoney, 1996).

This dissertation intends to provide a great level of applicability and practicality. We therefore combined the input of industrial and academic stakeholders (Hatchuel, 2001; Schiele & Krummacker, 2010; Starkey & Madan, 2001; Tranfield, Denyer, Marcos, & Burr, 2004; Vermeulen, 2007) during the development of our conceptual model at the beginning (Forza, 2002; Sekaran; Wacker, 1998). Accordingly, all survey instruments of this dissertation were established and pretested with experts from practice and from academia.

The following paragraph provides further details about the research methodology per chapter:

Chapter two discusses the relation of purchasing integration and supplier involvement based on collected data from 101 respondents representing firms across the German and Austrian industry structure. The responses origin from a survey that was conducted among members of German and Austrian purchasing associations as well as members from the mailing list of h&z, a consulting firm specialized in supply management. Regarding the analysis of data, we followed Hair, Ringle, and Sarstedt (2011) who stated that formative measures, a complex structural model, and a medium sample size favor structural equation modeling (SEM) based on partial least squares (PLS). Since all three aspects are apparent in the research model of chapter two, we used the SmartPLS software (Ringle, Wende, & Becker, 2015) to evaluate our measures and test the hypotheses.

Chapter three applies a dyadic research approach to examine supplier innovativeness in context of buyer-supplier collaborations by considering the role of sub-suppliers. The analysis combines responses from direct material suppliers and a focal agriculture equipment OEM headquartered in the United States. Similar to the automotive industry, suppliers of the agriculture industry have the tendency to supply goods to multiple OEM's (Dyer & Singh, 1998; Ellis, Henke, & Kull, 2012), which implies that the sample represent the broader supply base of the agriculture equipment industry. In total 196 suppliers participated with a diverse background of different products and countries of origin. To reflect the dyadic nature of buyer-supplier collaborations, 93 suppliers out of the total of 196 were evaluated by the dedicated buyer from the OEM. To estimate the interaction effects, we employ ordinary least squares regression (OLS) by estimating a multiple regression which examines many-to-one relationships and indicates how much each variable contributes to the relationship.

Chapter four discusses supplier characteristics for joint module developments between suppliers and customers through qualitative case studies. To overcome common weaknesses of case analysis in form of external validity (Cook, Campbell, & Day, 1979; Kidder & Fine, 1987) and the threat of paradox sampling (Kaplan, 1964), the research sample is based on two principles: theoretical sampling and criterion sampling. Following theoretical sampling, the sample is limited to companies producing tangible products with the focus on four wheel vehicles (Eisenhardt & Graebner, 2007). Second, the criterion sampling approach increases the probability to select information-rich cases that highlight the issues under study significantly (Patton, 1990). Thus, we considered multinational industry leaders from the automotive, rail vehicle and focal agriculture equipment industry. Within the 22 individual expert interviews, data was gathered in a moderate way of openness and structure (Lamnek, 2002). Detailed instruments included face-to-face and telephone interviews in combination with archival data from the internet. To ensure

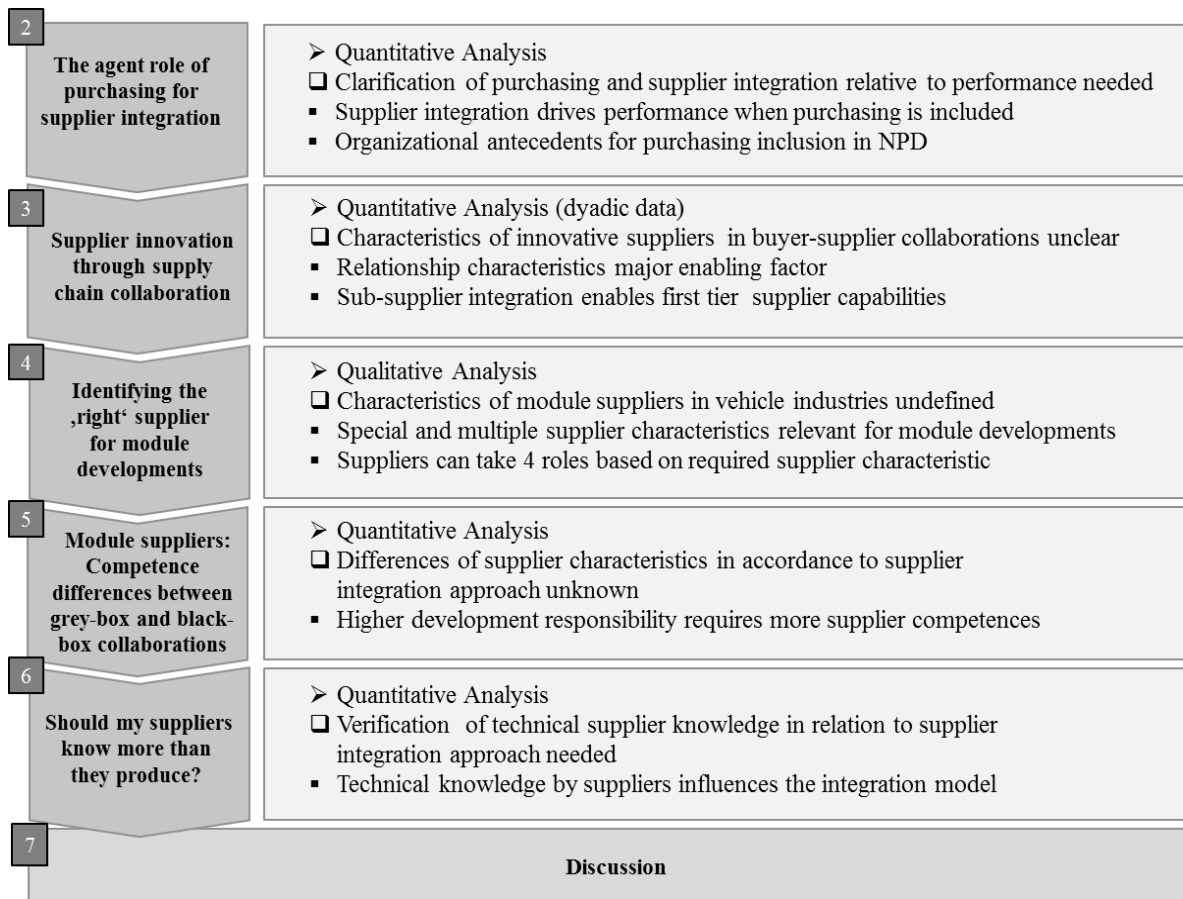
reliability and external validity of the observations, a second set of data was collected at a purchasing conference with participants from another automotive OEM and its suppliers.

Chapter five and six rely on data from 196 direct material suppliers of an American based focal agriculture equipment OEM. To avoid sample biases, suppliers were randomly selected based on the global commodity strategies from the OEM. Thereby, active suppliers with a realistic level of relevance were included. All direct material commodities of the OEM were involved, so that the sample represented a diversified group of suppliers with different industry, product and technology backgrounds. The analysis methodology and theoretical orientation differs between chapter five and chapter six. Chapter five uses partial least squares structural equation modeling (PLSSEM) to test the formulated hypothesis model (Fornell & Cha, 1994). Moreover, the research model is based on relational view (Dyer & Singh, 1998) and previous literature about modular product developments (Chai, Wang, Song, Halman, & Brombacher, 2012; Robertson & Ulrich, 1998). In contrast, chapter six applies a hierarchical regression analysis to measure interaction effects. Thus, blocks of variables were consecutively added to the research model by using OLS. The theoretical foundation of chapter six lies on the ongoing debate, if modularity in product designs fosters ‘loose’ inter-organizational collaborations (Cabigiosu & Camuffo, 2012b; Sanchez & Mahoney, 1996) or increases the need for ‘thick’ interfirm relationships (Hsuan, 1999; Jacobs, Shawnee, & Droge, 2007).

1.4. Research structure and findings

In total, this dissertation consists of five research papers, which are connected by a strong scientific relation as outlined by the research approach. Each paper takes a different angle on the topic supplier integration. This dissertation starts with a general perspective on supplier integration in chapter two, evolves towards supplier innovation in buyer-supplier collaborations in chapter three and takes a detailed look at supplier integration in modular product architectures in chapter four, five and six. The last chapter (chapter seven) presents a discussion section which summarizes results of the research chapters. The structure of this dissertation is illustrated by Figure 2.

Figure 2 - Structure of dissertation



The content of the individual chapters, each representing an individual research paper, can be summarized as follows:

Chapter two studies the relation between supplier integration in NPD and performance of the buying firm by considering the moderating effect of purchasing inclusion in NPD. Following the idea of purchasing's agent role, chapter two evaluates, if involved purchasing representatives enable the supporting stimulus of supplier integration on buying firms' performance. In addition,

organizational antecedents for purchasing inclusion are verified in order to provide an explanation on how to successfully integrate purchasing in NPD.

To the best of our knowledge, chapter two presents the first analysis providing empirical evidence that the positive influence of supplier integrations on buying firm performance is conditional to the inclusion of purchasing representatives in NPD. Moreover, chapter two goes beyond and offers an explanation on how to include purchasing representatives in NPD activities. Thus, this dissertation emphasizes four organizational antecedents that help practitioners to drive purchasing inclusion. In consequence, chapter two indicates the relevance of purchasings' integrator role for positive supplier integration and provides explanation of how to realize successful purchasing inclusion through organizational adaptations.

Chapter three looks at sub-supplier integration by first-tier suppliers and the resulting effects on supplier innovativeness in buyer-supplier collaborations. Based on theoretical perspective of relational view and the paradigm of collaborative advantage, two assets of relational rents are tested as mediating factors between sub-supplier integration and supplier innovativeness.

Chapter three adds the supply chain perspective to research about buyer-supplier relations and enhances the understanding of key characteristics of innovative suppliers. The empirical testing of dyadic data including buyer and supplier responses examines antecedents of supplier innovation in buyer-supplier collaborations. Prior research has mainly tested antecedents and dynamics of buyer-supplier relations either from the buyer or the supplier perspective, but rarely from both sites (Terpend et al., 2008). The test of dyadic data stands for a new way of analysis that could build a role model for future research of buyer-supplier relations. The model combined the paradigm of collaborative advantage and relational view by doing so sub-supplier integration was identified as a driving factor for supplier innovativeness. However, findings imply that engineering capabilities and preferred customer treatment are necessary for innovative supplier contributions for buying firms, since both act as mediator between sub-supplier integration and innovative benefits for the buying firm. For practitioners, the analysis provides guidance on how to identify most innovative suppliers for buyer-supplier collaborations.

Chapter four examines supplier characteristics for module developments by looking at four wheel vehicle companies. In detail, three case companies coming from the automotive, agriculture equipment and rail vehicle industry are studied to identify characteristics of suppliers that are integrated for module developments. Specially, grey-box and black-box supplier integrations for module developments are subject of analysis. After the identification of characteristics during expert interviews, four different roles of suppliers for module developments were derived and summarized in a conceptual model.

Key contributions of chapter four signify supplier characteristics most suitable for module developments. Throughout the case studies, chapter four takes a novel perspective on supplier characteristics relevant for module developments. The supplier characteristics are linked to integration approaches from theory, so that a unique framework of potential supplier roles for module developments could be developed. Moreover, based on the case findings a check list was formulated that help practitioners to make the best sourcing decision for their individual case. By identifying supplier characteristics and formulating potential roles of suppliers within module

developments, chapter four contributes knowledge to facilitate successful setting-up buyer-supplier collaborations for module developments.

Chapter five is built on chapter four and tests supplier characteristics in regards to grey-box and black-box supplier integrations for module developments. Four commonly applied assets for successful platform developments provide the structure of analysis, so that grey-box and black-box integrations are compared along the different assets.

Findings of chapter five imply that suppliers for black-box integrations need more capabilities than suppliers for joint grey-box developments. Thus, chapter five is the first that shows that increasing development responsibility of suppliers is directly linked to a higher need of supplier capabilities. Thereby, results enhance relational view understanding, since findings give reason to belief that the level of required resources depend on the interaction pattern between the stakeholders. At the same time, chapter five provides practitioners guidance on supplier capabilities needed for either grey-box or black-box supplier integration.

Chapter six builds on chapter four and five by taking a closer look at the interplay of product modularity and buyer-supplier collaborations. In detail, chapter six examines the interplay between modularity and buyer-supplier collaboration in relation to technical knowledge residing at the supplier site. Thereby, the analysis sheds light on the controversy if product modularity leads to less tightly coupled collaborations between buyers and suppliers or not. In detail, technical knowledge is divided in component and architectural knowledge and added to the relation of modularity and interfirm collaborations.

Chapter six contributes new insights to the debate if modularity leads to ‘loose’ or ‘thick’ organizational relations. By adding the supplier perspective and the differentiation of product knowledge in component and architectural knowledge, chapter six takes a novel perspective on the ongoing controversy. Findings imply that both theoretical positions appear to be relevant and that the firms’ scope of knowledge is a major influencing factor between the two proposed concepts. In view of the results, chapter six indicates that sometimes suppliers should ‘know more than they produce’ and what suppliers know matter for the inter-organizational relationship.

This dissertation contributes multiple aspects to literature and practice. On the theoretical site, current understanding of supplier integration is advanced by applying relational view throughout different perspectives. Moreover, results provide new inputs to the ongoing debate about loose and thick relations in modular product designs. Looking at managerial contributions, this dissertation delivers a broad range of aspects complemented with a practical check-list that help practitioners to realize more prosperous and effective buyer-supplier collaborations in an modular product environment.

2. Chapter - The agent role of purchasing for supplier integration

2.1. Introduction

For many firms, suppliers have become an increasingly important source of product and process innovation (Wagner & Bode, 2014). Various studies have shown that a supplier's involvement in a new product development (NPD) process of the buying firm can be very beneficial for the latter (Song & Di Benedetto, 2008; Wagner & Bode, 2014). This allows for the involvement of a supplier's resources, expertise and ideas which can result in improved product manufacturability, lower costs, higher profits, and increased innovation (Luzzini & Ronchi, 2011; Primo & Amundson, 2002; Tracey, 2004).

To successfully develop products with suppliers, firms need the ability to manage, maintain, and create knowledge (W. M. Cohen & Levinthal, 1990). Accordingly, the development of new products and services requires firms to integrate their different functional areas in order to bundle and leverage resources (Lovelace, Shapiro, & Weingart, 2001; Luca & Atuahene-Gima, 2007). With regard to cross-departmental integration, prior research has paid substantial attention to cross-functional collaboration in the NPD process (e.g. Sherman, Berkowitz, and Souder, 2005; Song, Thieme, and Xie (1998)). For example, the cross-functional integration between research and development (R&D) and marketing were observed to have a positive effect on the proficiency of prototype development, the effectiveness of R&D commercialization, and the proficiency of product launch (Souder, Sherman, & Davies-Cooper, 1998). Moreover, the integration of further functions such as pricing has also indicated relevance for NPD activities (Ingenbleek, Frambach, & Verhallen, 2010). When looking at the important empirical question of how to establish collaboration between buyer and suppliers (Ahuja, 2000; Argote, McEvily, & Reagans, 2003), research considers professionals in a firm's purchasing department in the key role as supplier involvement agents within cross-functional NPD teams (Ellegaard & Koch, 2012; Gupta & Wilemon, 1990; Luzzini & Ronchi, 2011; Schiele, 2010; Van Echtelt et al., 2008). Explanations for successful supplier integration have been provided employing variables drawn from transaction cost economics, e.g. relation specific investments (Song & Di Benedetto, 2008) or relational view literature, e.g. the length of the buyer-supplier relationship (Wagner & Bode, 2014). Nonetheless, there is limited understanding of the interaction effect between the integrative role of purchasing and the positive stimulus of the degree of supplier involvement on buying firms' performance. Hence, this study is the first that examines the relationship between the degree of supplier involvement and the buying firms' organizational performance and how this relationship is positively moderated by the degree to which purchasing is integrated into NPD. Assuming a positive contribution of purchasing to NPD, the question is how to involve purchasing. This research contributes by providing an explanation of how NPD processes should be organized to effectively involve the purchasing department in NPD (Lakemond, Berggren, & Weele, 2006). Schiele's (2010) review of 25 quantitative empirical studies on integration of purchasing professionals and suppliers in NPD revealed that none of the previous studies considers organizational aspects such as top management support or the presence of formalized processes for supplier involvement. Due to this lack of understanding it is challenging for firms to successfully operationalize purchasing integration in the NPD process, which might eventually cause a lack of competitiveness (Van Echtelt et al., 2008). Accordingly, the main organizational

factors that enable the integration of the purchasing department to support NPD processes need to be identified. Following the relational view as our theoretical framework, firms require not only internal resources but also resources located outside their boundaries. They can achieve competitive advantages if they can gain privileged access to these resources (Dyer & Singh, 1998; J. L. Johnson, 1999; Wagner & Hoegl, 2006). To allow for that, companies have to develop and sustain organizational factors like dedicated resources, routings and processes to permit involvement of suppliers through synergistic bundling of assets, knowledge, or capabilities. Presumably, purchasing professionals, involved in NPD processes, can facilitate those organizational determinants by, for instance, acting as a dedicated integration agent (Dowlatshahi, 1998; Lakemond, Echtelt, & Wynstra, 2001; Schiele, 2010).

Despite its relevance, empirical work on organizational antecedents for purchasing integration in NPD is very limited. Therefore, the aim of our study is to promote and extend the understanding by looking at the influence of supplier involvement on performance. We focus our research on the following questions:

a) Which role does purchasing integration play for the influence of supplier involvement on the buying firms' performance?

b) What are organizational antecedents for purchasing integration in the NPD process?

Drawing on theory from the relational view, we build and test a conceptual model of the antecedents and supplier involvement outcomes of purchasing integration in NPD processes. For this purpose we conduct a survey among 101 respondents from Germany and Austrian.

The results obtained support our model relating supplier involvement to performance of the buying organization as it is positively moderated by purchasing integration in NPD. Moreover, organizational and cultural antecedents for purchasing integration are identified. We also conduct a subgroup analysis and find evidence for the interaction effects of two of the antecedent variables of purchasing integration: top management support and collaborative corporate culture.

The findings of this study yield important scientific and managerial implications. With regard to theoretical contributions, this examination adds to the scientific literature on cross-functional and inter-organizational collaboration in NPD. In detail, the study provides a blueprint of how to establish cross-functional collaboration while looking at purchasing integration in NPD. Thereby, this is the first research project that considers organizational antecedents of cross-functional integration in terms of purchasing professionals by testing four key organizational variables: top management support, structural differentiation, process organization, and corporate cooperative culture. In addition, this study is the first to develop and test a model relating supplier involvement in NPD to performance by evaluating the role of purchasing representatives in NPD. Thereby, this study contributes to the relation view theory as well as to innovation literature by being the first to address the fundamental question of which conditions trigger benefits and positive results for firms in terms of inter-organizational collaboration.

As mentioned, the findings have also valuable managerial implications for firms, highlighting the importance of integrating purchasing professionals in the NPD process to enable supplier

involvement which advances the overall performance of the buying firm. These insights can also propel the somewhat stagnating research in involvement of suppliers in NPD. In particular, purchasing managers who want to increase their department's participation in NPD can benefit from our empirically tested blueprint in order to present a strong argument.

The remainder of this article proceeds as follows. We first (1) analyze recent literature dealing with the involvement of purchasing professionals and suppliers to better understand the antecedents of integrating these parties into NPD processes. We then (2) develop a theoretical framework to explain how the integration of purchasing professionals and suppliers into NPD teams can be facilitated by firms. Finally, we (3) test the model on a large-scale sample of firms, and (4) present and discuss the identified antecedents of purchasing integration and supplier involvement.

2.2. Theoretical Background

2.2.1. The relational view in the context of supplier involvement and purchasing inclusion

The relational view is used to explain performance improvement of relationship-specific capabilities and processes in different settings, including relational contracting, cross-licensing agreements, logistics processes and value co-creation (Morgan & Hunt, 1994; Rai et al., 2012). In the past, researchers linked the potential performance benefits in vertical alliances through the theoretical foundations of the resource-based view and its relationship specific approach, the relational view (I. J. Chen et al., 2004; Mesquita et al., 2008). Basically, the relational view of the firm is an extension of the resource-based view by integrating firm-external factors. These factors are critical to generate relational rents in order to enlarge performance benefits and to gain the competitive advantage (Porter, 2008). Particularly, in the purchasing context, the relational view explicitly considers the relevance of relationships between buyers and suppliers as a potential source for relational rents and competitive advantage.

By applying the relational view, suppliers acquire the character of firm-addressable valuable resources which should become accessible by purchasing professionals of the buying firm (Beers & Zand, 2014; Sanchez & Heene, 1997). Thus, a firm's purchasing function engaging in buyer-supplier relationships can gain relational rents through four sources: (i) effective governance, (ii) complementary resources and capabilities, (iii) (interfirm) knowledge-sharing routines, and (iv) relation-specific assets (Dyer & Singh, 1998). Effective governance attempts to provide structural protection for managing the relationship between the buying and the supplying firm. Interfirm knowledge-sharing routines reflect collaboration, information sharing, and interfirm communication. Complementary resources and/or capabilities emphasize that a firm's resources can be used in combination with the complementary resources and/or capabilities of the firm's supply chain partners. Finally, relationship-specific assets emphasize the specific investments (site specificity, process-specific knowledge, and physical specificity) that can be utilized to improve firm performance (Chou, Techatassanasoontorn, & Hung, 2015).

Current research findings indicate that the utilization of a firm's performance potential leads to a tighter involvement of suppliers (S. W. Kim, 2009). A higher level of supplier involvement in

e.g. NPD processes requires the integration of the purchasing function to handle the complexity within business relationships in supply chains, upstream and downstream (Jayaram, Tan, & Nachiappan, 2010; Schoenherr & Swink, 2012). Furthermore, close relationships lead to an integration of purchasing and e.g. NPD processes between buyers and suppliers enable firms to improve information exchange and better material and product flows throughout supply chains (Wiengarten, Humphreys, Gimenez, & McIvor, 2016). In addition, close buyer-supplier relationships allow buying firms to access various resources and/or capabilities in form of knowledge embedded within suppliers and subsequently increase their own innovativeness (Cao & Zhang, 2011; Craighead, Hult, & Ketchen, 2009; Wiengarten et al., 2016).

This seems to be of great relevance as firms in e.g. innovation-driven high-tech industries, in their pursuit of gaining competitive advantage through innovation and NPD, find it more and more difficult to achieve advantages through command on superior internal resources. Instead, they increasingly have to rely on their purchasing function to gain privileged access to external resources, i.e. most precious suppliers to obtain an adequate relational rent (Hunt & Davis, 2012; Markman, Gianiodis, & Buchholtz, 2009; Pulles, Veldman, Schiele, & Sierksma, 2014). This research focuses on the particular case of NPD through interfirm collaborative NPD as a type of relational rent (Lavie, 2006).

2.2.2. Involvement of suppliers in NPD

From a theoretical perspective, research on supplier involvement has become increasingly important since an operationalization of the relational view of the firm (Duschek, 2004; Dyer & Singh, 1998) signifies the involvement of suppliers in the NPD process, forward-targeted sourcing and an active role of suppliers within the process of developing parts and products (Van Echtelt et al., 2008).

Reflecting on the inter-organizational character of NPD, the “open innovation” paradigm has been put forward (Chesbrough, 2003; Gassmann, 2006). According to this model, firms commercialize internal and external ideas, using outside as well as inside pathways to the market. Four main factors have contributed to the shift from a closed (firm-centered) innovation model to an open (network-embedded) innovation model: (1) the increasing mobility of workers, (2) the advent of venture capital, (3) external options for ideas sitting on the shelf, and - of particular importance for this paper - (4) the increasing capability of suppliers (Chesbrough, 2003). To profit from external resources and expertise, firms must be open to innovations from suppliers and willing to structure optimal innovation networks within their supply base (Beers & Zand, 2014; Chang, 2003; Gassmann et al., 2010).

There has been extensive research on the benefits of including suppliers in NPD. For instance, researchers have highlighted the positive effect of integrating external knowledge into the NPD process on time-to-market, which can lead to a reduction in design changes (Clark, 1989; Langerak & Hultink, 2008; Van Echtelt et al., 2008). Supplier involvement can also improve the manufacturability of products (Birou & Fawcett, 1994; Clark, 1989). Other benefits include improved quality and design (Droege et al., 2000; Ragatz, Handfield, & Scannell, 1997; Wasti & Liker, 1997) and, increased innovation due to new knowledge and cutting-edge solutions

(Jaakkola & Hakanen, 2013; Tracey, 2004). All in all, supplier involvement can contribute to the sustainable competitiveness of firms (Jaakkola & Hakanen, 2013). The question is how could supplier participation in NPD be enabled?

According to previous research, a prerequisite for enabling involvement of suppliers is the integration of the purchasing department into NPD (Hillebrand & Biemans, 2004). As is generally argued, engineering personnel is reluctant towards increased supplier involvement as they fear that additional tasks might be outsourced. Thus, supplier involvement should not be left to engineering personnel alone, as this might result in a paucity of suppliers in NPD teams (Geishecker, 2008).

In contrast, including purchasing professionals in the NPD team has the opposite effect. Purchasers have a natural incentive to include suppliers in a NPD project to proactively elicit the associated benefits of supplier involvement. The existence of suppliers is the purchaser's reason for being. This could be an explanation for the finding that the probability of suppliers being involved in NPD increases when purchasers are part of the NPD team (Hillebrand & Biemans, 2004; Tracey, 2004).

2.2.3. Integration of purchasing professionals in NPD

Fast-changing technologies, general reliance on suppliers, increasing organizational size and complexity are all factors that demand greater involvement of the purchasing department in NPD activities (Van Echtelt et al., 2008; Wynstra, Van Weele, & Axelsson, 1999). Several studies have demonstrated the positive effects of including purchasing professionals as part of an NPD team (Droege, Jayaram, & Vickery, 2004; McGinnis & Vallopra, 2001; Tracey, 2004). Yet, what exactly does the role of the purchasing department in NPD comprise? The literature identifies a large set of activities which fall into two categories: those directed towards generating innovations and those that focus on optimizing costs (Burt & Soukup, 1985; Clark, 1989; Di Benedetto, Calantone, Van Allen, & Montoya-Weiss, 2003; Handfield et al., 1999; Langerak & Hultink, 2008; Luzzini & Ronchi, 2011). This dual role of purchasing professionals in NPD has been summarized as follows (Schiele, 2010): (1) generating innovations: introducing new technologies as a gatekeeper of suppliers, identifying sufficient numbers of innovative vendors, developing specifications, and managing the supplier interface and (2) cost control and company-wide integration: conducting cost and risk analyses of product concepts; promoting parts substitution and standardization, including make-or-buy considerations; choosing suppliers from comparable alternatives; tracking and ensuring supplier performance during the project; safeguarding supplier readiness; ensuring supply-base streamlining (e.g., through pooling among factories); and drafting contracts and monitoring costs.

At the same time, the purchasing department must continue its usual tasks such as communicating with the supply base and supplier development to ensure suppliers' readiness and availability. The purchasing department plays a strategic role in the design of the supplier structure and relation to individual suppliers (Gadde & Håkansson, 1994) and is a key in strategic supply chain management through successful supplier involvement (I. J. Chen et al., 2004; Ellram & Liu, 2002; J. L. Johnson, 1999). Indeed, a firm's supply chain fit, as established

through the activities of the purchasing department, directly impacts the return on assets of the firm (Wagner, Grosse-Ruyken, & Erhun, 2012).

Just as purchasing professionals' responsibilities extend beyond NPD projects, their overall perspective of NPD is supposed to widen. They are expected to develop a total cost of ownership approach which considers the entire life cycle of products (Berenson, 1967; Birou, Fawcett, & Magnan, 1997; Cousineau, Lauer, & Peacock, 2004; Ellram, 1995; Handfield & Pannesi, 1994; Rigby, 1996). The purchasing department's responsibilities evolve over the course of the product life cycle, with the baseline of procuring parts and ensuring competitiveness pervading all stages (Doha, Das, & Pagell, 2013; Rink & Fox, 1999). This long-term orientation requires a broad perspective concerning, for instance, the need to choose a supplier capable of guaranteeing spare parts for many years (Handfield et al., 1999).

Considering their multiple tasks and broader perspective, purchasing professionals can play a significant role within the NPD project team as well as for product life phases, among others. The next section proposes and operationalizes such a model, including the purchasing department's structural and process environment within the firm.

2.3. Research Model and Hypotheses

The relational view claims that firms combine external and internal resources to develop competitive advantages (Dyer & Singh, 1998), which improve the overall performance of the company (Porter, 2008). Consequently, integrating external resources, like suppliers, into NPD have a positive influence on the overall performance of a firm such as sales growth, return on assets, market share gain and cost position. Thus, our model relates supplier involvement in a NPD process to the overall performance of the buying firm. Nevertheless, the purchasing's role with regard to supplier involvement has been largely ignored in the main body of research on involving suppliers in NPD. Previous research has indicated that collaborating during NPD is a challenging task with more than 50% of collaborative efforts between suppliers and buyers being unsuccessful (Littler, Leverick, & Bruce, 1995). Researchers also consider the integration of purchasing professionals into NPD processes as a key supporting factor to successfully integrate suppliers (Hillebrand & Biemans, 2004). Yet, the possible effect of purchasing integration on supplier involvement has not been empirically addressed in previous research. The relational view proposes that parties have to identify complementary resources and need the organizational complementarities to benefit from external resources (Dyer & Singh, 1998). Purchasing professionals, included in NPD process, can potentially enable those determinants. Literature argues that the purchasing's dual role leads to an integration agent position of purchasing professionals which safeguards communication and knowledge sharing, promotes suppliers to a complementary level, creates and manages supplier interfaces and supports corporate governance (Dowlatsahi, 1998; Ellegaard & Koch, 2012; Lakemond et al., 2001; Luzzini & Ronchi, 2011; Schiele, 2010).

To determine how best to deploy the purchasing department to act as an integration agent by including suppliers in the NPD process, Schiele (2010) suggests analyzing the involvement of

purchasing professionals alongside the factors that explain successful NPD. However, most NPD research models feature limitations concerning certain aspects by focusing on specific issues rather than employing a comprehensive approach that incorporates operative antecedents. An exception is the conceptual model presented by Cooper and Kleinschmidt (1995). It has found wide application in NPD research (Ernst, 2002) and introduces organizational antecedents corresponding with determinants for the operationalization of the relational view, such as routines and processes (Dyer & Singh, 1998). In detail, Cooper and Kleinschmidt (1995) describe the results of a multi-firm benchmarking study and developed five critical success factors that characterize the majority of successful firms in NPD. Schiele (2010) has highlighted the relevance and applicability of the framework to the purchasing perspective. Accordingly, we acknowledge that top management support, structural differentiation, process organization, corporate culture, and strategic integration need to be considered as antecedents in examining the integration of purchasing professionals in NPD. Likewise, Van Echtelt et al. (2008) argue that both operative and strategic sets of activities are critical in achieving not only short-term objectives, but also long-term benefits of supplier involvement in NPD. Nevertheless, we exclude the strategic integration factor from our analysis in this study and instead center on the often-disregarded organizational and cultural antecedents of purchasing integration. To concentrate our analysis on organizational aspects, we focus on advanced sourcing activities of purchasing within structural differentiation. Our emphasis to focus on organizational antecedents is based on our choice of theory as well as our prior research area. The relational view theory specifically highlights organizational requirements to integrate external resources, which underlines the relevance of those often neglected factors. Moreover, even though theory underpins significant relevance, organizational influencing factors for purchasing integration in NPD processes have not been a field of research yet (Lakemond et al., 2006; Nijssen, Biemans, & De Kort, 2002). This significant gap of analysis has encouraged us to exclusively focus this study on organizational and cultural antecedents. To set the variables in the proper organizational perspective, we oriented them in relation to our dependent variable, namely the integration of purchasing professionals: We assigned (1) top management support, (2) structural differentiation, (3) process organization, and (4) cooperative corporate culture as antecedents to the integration of purchasing professionals into successful NPD projects. These factors are presumably direct enabling elements of purchasing integration through organizational adaptations. A detailed definition of the four independent variables can be found in Table 1. Figure 3 illustrates the research model.

Figure 3 - Research model (chapter 2)

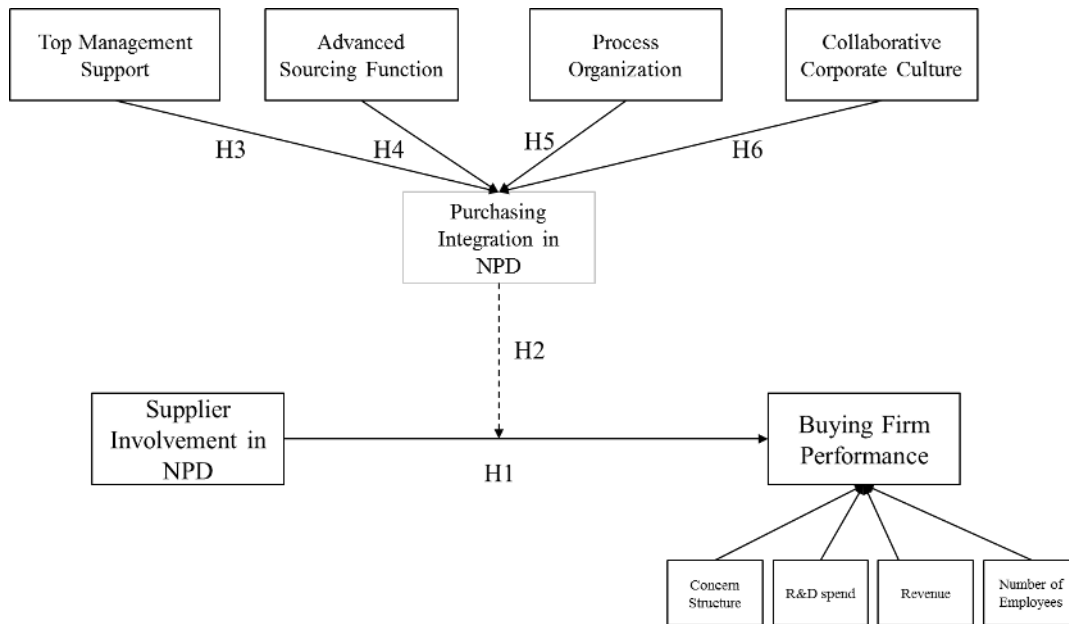


Table 1 - Definition of independent variables (chapter 2)

Top management support	Top management support stands for complete support, full appreciation and integral integration of purchasing by management, when it comes to innovation.
Advanced Sourcing Function	Structural differentiation refers to several specialized tasks of the purchasing department, such as serial procurement and advanced sourcing. This study is focused on advanced sourcing activities of purchasing within a differentiated structure (Burt & Soukup, 1985; Mendez & Pearson, 1994; Rendon, 2005; Trent & Monczka, 2005). Advanced purchasing activities can include for example supplier development, innovation identification, supplier quality assistance etc.
Process organization	A process organization represents the level of cross-functionally agreed processes for supplier selection, supplier development, NPD and supplier involvement in NPD.
Collaborative corporate culture	A collaborative corporate culture stands for easiness and chance to collaborate and communicate across hierarchical levels and functional boundaries.

2.3.1. Hypotheses

Research on the resource-based view has highlighted that the configuration of internal resources by firms drive organizational performance (Jay Barney, 2001; Eisenhardt & Martin, 2000). To foster competitive advantage and by that performance (Porter, 2008), the resource-

based view has “[...] evolved into a dynamic recipe explaining the process by which these ingredients (a firm’s resources) must be utilized.” (Newbert, 2007, p. 124) Based on this argumentation, the relational view claims that organizations have to extend a firm’s own boundaries by considering external resources (Wang and Li-Ying, 2015) as vital resources are often found outside the firm “[...] embedded in interfirm resources and routines.” (Dyer & Singh, 1998, p. 650) It is recognized that the type of linkage with partners outside the firm determines what kind of shared external resource influences the relational rent and, as a consequence, a firm’s performance (Chiaroni, Chiesa, and Frattini, 2010; Tsai and Wang, 2007). Resource sharing between supply chain partners brings complementary resources together, which create super-additive value (Tanriverdi, 2006). With regard to that, researchers have observed that supplier resources integrated in the NPD process show positive influence on the NPD performance of the buying firm (Song & Di Benedetto, 2008; Wagner & Bode, 2014). In detail, the involvement of supplier’s resources contributes complementary expertise and ideas, thus fostering improved product manufacturability, lower costs, higher profits and increased innovation (Luzzini & Ronchi, 2011; Primo & Amundson, 2002; Tracey, 2004). Accordingly, researchers argue that supply chain collaboration has a positive effect on performance by enabling firms to link external and internal resources for increased effectiveness and innovations (Cao & Zhang, 2011; Soosay, Hyland & Ferrer, 2008). Hence, we hypothesize:

H1: Greater supplier involvement leads to better performance of the buying firm.

The relational view proposes that parties have to identify complementary resources and need the organizational complementarities to benefit from external resources (Dyer & Singh, 1998). With regard to NPD, research on the relational view proves that a firm’s respective performance is related to (a) the number of collaborations with external partners and (b) the scope of collaboration partners (Wang and Li-Ying, 2015). A broad resource set of partners provides the firm with comprehensive knowledge that could increase the existing knowledge base (Foss, Lyngsie, and Zahra, 2013). This in turn allows firms to benefit from many opportunities of novel combinations of input factors, resources and capabilities (Fleming, 2001; Katila and Ahuja, 2002; Laursen and Salter, 2006; Li, 2010). As a result of organizational learning, firms may profit from complementary information and synergetic effects (Van Beers & Zand, 2014).

It is argued that the purchasing’s dual role leads to an integration agent position of purchasing professionals which creates and manages supplier interfaces, promotes suppliers and their competences to a complementary level and safeguards communication as well as knowledge sharing between internal and external stakeholders (Dowlatshahi, 1998; Ellegaard & Koch, 2012; Lakemond et al., 2001; Luzzini & Ronchi, 2011; Schiele, 2010).

Purchasing professionals, integrated in NPD, directly contribute to NPD during the supplier selection procedure (McGinnis & Vallopra, 1999), for instance, by supporting the evaluation of a particular supplier’s innovation potential (Schiele, 2006). The purchasing department not only supports the identification of most suitable supplier resources, but also executes supplier management activities related to NPD (Kraljic, 1983). For example, the purchasing department is responsible for controlling supplier involvement and initiating supplier development activities

(Handfield et al., 1999; Krause, Handfield, & Scannell, 1998; McGinnis & Vallopra, 1999). The purchasing department can thus advance supplier capabilities and adjust them based on the buying firm's needs, for instance, through selectively stimulating activities such as the initiation of knowledge exchange between suppliers and sub-suppliers (Fagerstroem & Jackson, 2002). The significance of these supplier management activities has been illustrated by benchmark studies showing that the purchasing department's commitment to innovation increases the overall innovation level of a firm's supply base (Goffre, Plaizier, & Schade, 2005).

As the purchasing department can be seen as an integration agent that stimulates internal and external cross-functionalization in NPD (McDermott & Handfield, 2000; McGinnis & Vallopra, 1999), it can assume a lead role in coordinating the internal collaboration within NPD by simultaneously including suppliers (Dowlatshahi, 1998; Hillebrand & Biemans, 2004).

Applying the relational view to the purchasing department's agent role, supplier management competencies and dual interest in generating innovation and managing costs, facilitates the identification of complementary resources and the organizational complementarities to benefit from external resources. Thus, the involvement of purchasing professionals acts as a key enabling factor that stimulates the involvement of external firm-addressable supplier resources (I. J. Chen et al., 2004; Clark, 1989; Ellram & Liu, 2002; Johnsen, 2009; Sanchez & Mahoney, 1996). Accordingly, previous research has found that involvement of the purchasing department in NPD projects leads to cross-functional collaboration and, in particular, supplier involvement (I. J. Chen et al., 2004; Droege et al., 2004; Ellram & Liu, 2002; Hillebrand & Biemans, 2004; Johnsen, 2009; Tracey, 2004; Van Echtelt et al., 2008). However, the purchasing's agent role might not only drive supplier involvement in general, but it provides knowledge of identifying, developing and integrating supplier resource effectively. We therefore hypothesize that purchasing integration does not only increase the level of supplier involvement, but also stimulates the positive influence of supplier involvement on corporate performance:

H2: The greater the integration of purchasing professionals in the NPD process, the greater supplier involvement positively affects corporate performance.

Purchasing departments have evolved from being primarily concerned with cost savings (Cousin & Spekamn, 2003) to comprising a more strategic function in firms (Carter & Narasimhan, 1996). In the context of managing and obtaining suppliers' innovations, the purchasing department of a buying firm acts as a gatekeeper for suppliers by developing specifications and identifying innovative vendors (Schiele, 2010). Further it engages in value-added activities inducing relational rents (Dyer and Singh, 1998), such as the introduction of supplier development programs (Krause et al., 1998; W. Li, Humphreys, Yeung, & Cheng, 2012; Trent & Monczka, 2005). Arguably, this re-definition of the role of purchasing departments requires support from top management (Cammish & Keough, 1991; Nijssen et al., 2002). The willingness of the top management to foster activities supporting collaboration within a firm depends on the long-term perspective it has. Only if top managers adopt this position it can value internal cooperation as an investment in a desirable lasting relation. The relational rents may refer to superior knowledge about supplier preferences, complementary resources and the capabilities

of suppliers (Harrison, Bosse, and Philips, 2010), or lower supplier search costs or more effective governance approaches (Dyer and Singh, 1998; Sawhney and Zabin, 2002; Vos and Achterkamp, 2015).

The significant influence of senior staff support operates not only at the strategic or corporate level, but also at the NPD project level (Howell, Shea, & Higgins, 2005), even though top managers generally take little interest in such operational projects (Clark, 1989; Langerak & Hultink, 2008; Wasti & Liker, 1997). Nevertheless, increasing competition and the need for competitive advantages presumably drives the interest of senior management, if project performance contributes most effectively to corporate governance at the top management level (Cooke-Davies, 2002; Young & Jordan, 2008). Accordingly, top management expects NPD projects to contribute to the firm's margin and competitiveness by adhering to timelines and budgets while generating innovative high-quality products (Clark, 1989; Langerak & Hultink, 2008; Wasti & Liker, 1997). The purchasing's dual role and the related intuitive motive to act as an integration agent for internal and external resources (Dowlatshahi, 1998; Lakemond et al., 2001; Schiele, 2010), can subsequently foster NPD contributions to corporate governance undertakings (Ellegaard & Koch, 2012; Luzzini & Ronchi, 2011; Schiele, 2010). Because of the need for efficiency, it can be assumed that top management will recognize the added value by having the purchasing department not merely involved, but actually acting as an integration agent within NPD.

Hence, we assume that top management support not only strengthens the purchasing's position on a corporate level (Hughes, Ralf, & Michels, 1998; Nijssen et al., 2002), but also enables purchasing integration into NPD by fostering the purchasing department's agent role at the NPD project level. Thus we hypothesize as follows:

***H3:** Top management support enables the integration of purchasing professionals into the NPD process.*

Previous studies considering the impact of structural organization on the integration of purchasing professionals in NPD have yielded mixed results (P. F. Johnson, Klassen, Leenders, & Fearon, 2002; P. F. Johnson, Leenders, & Fearon, 1998; Wynstra, Van Weele, & Weggemann, 2001). Ideally, the organizational structure should allow for interactions between engineering as the technical stakeholder, the purchasing department as the integrator, and the supply base as the source of external expertise. The individual organizational design of the stakeholder groups, however, can present challenges concerning the identification of appropriate cross-functional interfaces. In particular, the NPD project team structure and the organization of the purchasing department might be divergent and therefore pose difficulty for integration (Rozemeijer, Weele, & Weggeman, 2003; Wynstra et al., 2001). Engineering departments are often structured along technologies or product lines, following NPD project logic (Lakemond et al., 2006). Purchasing departments, on the other hand, tend to be focused on supply markets for sourcing and negotiation activities (Monczka, Handfield, Giunipero, & Patterson, 2008). If the purchasing department were to mirror the engineering structure and focus on technology fields, it would no longer have an adequate overview of the supply market nor be able to ensure benefits from

supplier pooling. Yet, an exclusive focus on commodity groups derived from a supply market logic may result in multiple purchasers being present in each NPD project, which also would be impractical.

A solution for this dilemma lies in structural differentiation that splits the traditional purchasing role into a strategic sourcing function and an advanced sourcing function (also called “procurement engineering”) (Burt & Soukup, 1985; Mendez & Pearson, 1994; Rendon, 2005; Trent & Monczka, 2005). The strategic sourcing function deals with serial sourcing activities that are structured in coordination with commodity groups based on supply markets. Such a commodity structure allows for the bundling of demands across regions as well as the realization of global strategic sourcing activities (Driedonks, Gevers, & van Weele, 2010). The advanced sourcing function, on the other hand, involves technically skilled purchasers building the interface between the NPD project team and the diverse commodity managers from the strategic sourcing departments. The allocation of dedicated advanced sourcing resources in alignment with the NPD project structure provides firms with the opportunity to actively integrate purchasing professionals. Such integration and the dedication of resources empower purchasing managers and R&D specialists to be able to jointly collaborate with important suppliers to discuss key topics and exchange knowledge (Wynstra et al., 1999). Thus our hypothesis is the following:

***H4:** A highly advanced sourcing function leads to greater integration of purchasing professionals into the NPD process.*

Littler et al. (1995) have shown that more than 50% of collaborative efforts between suppliers and buyers are unsuccessful. Well-defined organizational processes could improve this figure. For example, the implementation of a risk management process appears to be crucial in reducing supply risk (Hoffmann, Schiele, and Krabbendam, 2013). Similarly, the implementation of a cross-functional and cross-regional internal process was observed to intensify cross-departmental cooperation, which in turn improves NPD success rates (McGinnis & Vallopra, 1999; Petersen, Handfield, & Ragatz, 2005; Rendon, 2005; Tassarolo, 2007; Van Echtelt et al., 2008). Also the establishment of interfirm relationship and knowledge transfer processes between buying and supplying firms turned out to be essential for NPD success (Knudsen, 2007). Without well-defined processes, firms run the risk of impulsive and nonsystematic action (Ungan, 2006). Consequently, variability in individual skills, competencies, and behaviors can result in diverging, uncertain results for the same task (Ungan, 2006). With a defined process, comparability and consistency of attitudes, activities, or principles can be realized (David & Rothwell, 1996). When there is a clear and formalized NPD process description, purchasing integration would, for example, no longer depend on the benevolence of an individual project leader, but rather follow an objective and standardized process. Such a product development process would ensure continuous cross-functional development activities by safeguarding purchasing integration (Tassarolo, 2007). Moreover, a standardized NPD process application would guarantee that purchasing integration evolves into a routine with well-defined tasks (Ungan, 2006).

Due to the increasing relevance of suppliers in NPD, supplier relationship management has become crucial and comprises the development and maintenance of fruitful relationships with suppliers (Lambert & Schwieterman, 2012). Supplier selection and supplier development are considered to be two major steps for supplier relationship management (Rezaei, Wang, & Tavasszy, 2015). The purchasing department is regarded as the supplier relationship manager within organizations as it executes supplier relationship activities (Dowlatshahi, 1992). Thus, in order to apply supplier selection and supplier development activities, purchasing representatives need to be part of the NPD process. With regard to that supplier management processes presumably foster the integration of purchasing representatives since purchasing capabilities are needed to execute supplier management activities. Particularly, when suppliers are integrated to collaborate in NPD (S. W. Anderson & Dekker, 2005), purchasing capabilities become crucial (Gadde & Håkansson, 1994; Macbeth, 1994). As a result, processes aiming for early supplier involvement presumably support the integration of purchasing resources in NPD. We therefore assume that the definition and standardized application of NPD and supplier management processes foster successful purchasing integration and, ultimately, supplier involvement. Accordingly, we hypothesize:

***H5:** Well-defined NPD and supplier management processes are a prerequisite for the integration of purchasing professionals into the NPD process.*

A corporate culture openly committed to cross-functional collaboration and expressed through support of cross-functional teams as well as the involvement of all stakeholders, has been found to be a major distinctive feature concerning NPD between best-in-class firms and underperformers (Adams, Bessant, & Phelps, 2006; Chang, 2003; Cooper & Kleinschmidt, 1995; De Brentani & Kleinschmidt, 2004; Goffre et al., 2005). A firm's culture requires - within a framework of certain norms and attitudes - openness for knowledge exchange and collaboration across functions. The same applies for the integration of purchasing professionals within NPD projects (McGinnis & Vallopra, 2001; Petersen et al., 2005; Wei & Morgan, 2004). All team members - whether from engineering, logistics, manufacturing, or marketing and sales - have to be open and show willingness to cooperate beyond their functional origins (Dowlatshahi, 1998; Hillebrand & Biemans, 2004). The engineering representatives' amenability to purchasing input in particular should be ensured since the intention of purchasing professionals to incorporate external knowledge could seem threatening to the in-house engineers (Geishecker, 2008). Moreover, in the light of the historically weak position of the purchasing department as purely a support function (Ellram & Carr, 1994; L. Li, 2007), there may be limited acceptance of the purchasing professionals within the team. If the purchasing professionals have to fight for their position, then cross-functional collaboration could end up in self-oriented empire building and functional isolation (Wynstra et al., 2001). As a consequence, integration across stakeholder groups would decrease, which in turn would lead to a lower level of purchasing integration. Conversely, a firm where members from different departments have equivalent responsibilities and experience acceptance may find it easier to include additional departments for particular tasks, such as including purchasing professionals in an NPD project team (Rendon, 2005). We

therefore hypothesize:

H6: *A collaborative corporate culture supports the integration of purchasing professionals into the NPD process.*

2.3.2. Measures

To test the hypotheses in our conceptual model (figure 3), we used previously tested reflective scales to measure purchasing integration (McGinnis & Vallopra, 1999), supplier involvement (I. J. Chen & Paulraj, 2004), purchasing status with focus on top management support (Carr & Smeltzer, 2000; Cousins, Lawson, & Squire, 2006), corporate culture (Jaworski and Kohli, (1993), and performance of the buying firm (Peteraf, 1993; Tracey, 2004).

The purchasing integration measurement is based on McGinnis and Vallopra (1999), as the construct evaluates the purchasing's role in cross-functional NPD teams. Two items of the original construct were dropped as those refer to specific NPD projects, whereas this analysis looks at the general integration of purchasing in NPD. The measure supplier involvement originates from I. J. Chen and Paulraj (2004), since the construct was developed with a structured development approach by capturing the involvement of suppliers in crucial project and planning processes. Concerning top management support for purchasing, we followed Cousins et al. (2006) and Carr and Smeltzer (2000). They assessed the purchasing's status by looking at its positioning with regard to the scope of top management support, importance to strategy and its importance from the top managers' perspective. Further, the innovation aspect was added to the strategy to reflect the NPD aspect. In a last step, features of the interdepartmental connectedness measure from Jaworski and Kohli (1993) were added for the purchasing integration measurement applied here. The measurement examines cross-functional interactions with focus on individual employees from different departments, which, from our point of view, evaluates a collaborative corporate culture. The performance measure of the buying firm is based on Tracey (2004), since the original construct considers the organizational performance of a firm. Following the resource-based view and the argumentation by Peteraf (1993), the cost position of a firm was added to the construct with one item in order to enhance the scope of performance measurement.

In order to improve the reliability and validity of constructs, we dropped ten items from purchasing integration, supplier involvement, collaborative corporate culture and buying firm performance. Nonetheless, the underlying theoretical domain of all constructs was not significantly affected.

In prior research, the measurement of structural differentiation has often been limited to issues of centralization versus decentralization with little consideration given to departmental structure. In their pioneering "Aston studies", Pugh and Hickson (1976) tallied the number of different departments in particular firms to construct a variable on horizontal differentiation. In this study, we refine this measure by asking respondents to indicate the percentage of time spent on particular activities. Thus the measure becomes insensitive to firm size, as only large firms may set up a special department for a particular task. In practice, respondents were asked to indicate the percentage split of time - of a total of 100 percent - they spent on each of the aspects given. By this means, the degree of horizontal structural differentiation of the purchasing department

could be measured. Since aspects by items are not consecutive or related, a formative design for the measure was applied. The measure examines the time spent for advanced purchasing activities. To evaluate the proportion of advanced purchasing activities, the percentages of time spent for operative activities were subtracted from the total of 100. As a result in average 12 percent of available time is spent for advanced activities. Thus, the construct represents exclusively the percentage of advanced purchasing activities.

Furthermore, we assessed process organization using a model proposed by Daugherty, Droege, and Germain (1994) that gathers information about the existence of documented processes. Based on Takeuchi and Nonaka (1986), we transferred four key aspects of new product developments into items by relating them to processes of NPD and supplier management. It was our purpose to capture a comprehensive spectrum of collaborative NPD processes by including supplier management aspects. The processes under scrutiny are not related to each other since each process can run independently. Thus, we opted for a formative design illustrating the independency of items.

A detailed illustration of the measurement items for each construct can be found in the appendix of this dissertation.

2.3.3. Method

In reaction to increasing concerns about the relevance of management research (Brennan & Ankers, 2004), we paid particular attention to ensuring a high level of applicability and practicality in this research. Accordingly, we combined the input of industrial and academic stakeholders (Hatchuel, 2001; Schiele & Krummaker, 2010; Starkey & Madan, 2001; Tranfield et al., 2004; Vermeulen, 2007) during the development of our conceptual model at the beginning of this project (Forza, 2002; Sekaran; Wacker, 1998). The aim was to test previously defined aspects in a new context and empirically verify them (Filippini, 1997; Forza, 2002; M. K. Malhotra & Grover, 1998; Pinsonneault & Kraemer, 1993).

A survey instrument was developed, pretested with seven expert professionals and five academic experts and then distributed among members of German and Austrian purchasing associations as well as members from the mailing list of h&z, a consulting firm specialized in supply management. From a total of 101 usable responses nine are from Austria. Four responses from other countries were deleted in order to avoid any cross-cultural influences. Potential respondents were invited, via direct emails and notices in association newsletters and magazines, to participate voluntarily in the survey on a web-based panel (Callegaro & DiSogra, 2008; Couper, 2000). Employing the opt-in approach allowed us to capture our desired target population, given that firms visiting the purchasing association web sites are presumably conversant and actively involved in purchasing (Couper, 2000). Yet, due to the voluntary nature of participation in the survey, we are unable to define a denominator for the respondent pool (Callegaro & DiSogra, 2008; Fricker & Schonlau, 2002).

As stated above, the collected data comprises information from 101 respondents representing firms across the German and Austrian industry structure, with particular emphasis on engineering and electronics: 31% were from mechanical engineering and machine building firms, 27% from

electronic and electrical engineering firms, 14% from the chemical industry, and 11% from vehicle building firms. The remaining 17% of respondents indicated that they worked in service industries. The profile of the sample is as follows: 45% of the respondents were purchasing managers; 39% purchasers; and 16% other, including senior management. The firms represented in our sample are of notable size and considered high-tech with an average turnover of €840 million, 2,988 employees, and 7.9% of turnover invested in R&D. No significant industry differences could be found in the responses, either between services or production industries. We also set controls for firm size but no significant influence was detected.

Based on Atinc, Simmering, and Kroll (2011), four control variables were introduced which potentially affect the model from a theoretical rationale and previous evidence. Following the resource-based view's understanding that resources drive performance (Jay Barney, 2001; Eisenhardt & Martin, 2000), we include group structure, R&D spending, revenue and number of employees as control variables in the conceptual model. All four variables refer to resource availability which potentially influences buyer performance.

Group structure stands for legally independent firms which merge into one economic entity or group that is under single management (Heidenhain, 2000). Firms with a reasonable group structure are likely to integrate and leverage different sets of resources since they purchase more on a multinational scope. Thereby, they can collaborate with most potential stakeholders by balancing or leveraging regional characteristics. Accordingly, diversified product and industry sections, as realized by concerns, can potentially give firms a greater ability to perform more successfully (Geringer, Beamish, & DaCosta, 1989).

High R&D spending in relation to revenue can be characteristic of a firm's ability and focus with regard to innovation and technical advantage, which can influence the overall performance of a company. For example, Morbey (1988) identifies a strong association between R&D spending and subsequent growth in sales.

The revenue level of a firm can potentially influence the general performance of a company since more financial resources are available within the organization. A corporation with high revenues - and so potentially higher financial resources - might invest more than firms with lower revenues. Investments, for example in machinery, labor or efficiency programs, can positively influence the overall performance of the company. The number of employees of a firm represents the firm size and presumably indicates maturity, professionalism, and resource availability within. Thereby a large number of employees might enhance performance, given that the firm provides sufficient resources. An analysis of 7,000 US publicly-held firms during the period of 1987–2006 showed that firm size is nonlinear positively correlated with profit levels (Lee, 2009). We therefore control for the number of employees of the buying company.

2.4. Data Analysis and Results

2.4.1. Construct validation

To evaluate our constructs, we followed Hair et al. (2011) who stated that formative measures, a complex structural model, and a medium sample size are all necessary for the application of structural equation modeling (SEM) based on partial least squares (PLS). Although PLS is a

regression-based SEM approach that tends to overestimate the measurement model and underestimate the relationships in the structural model (Hair, Hult, Ringle, & Sarstedt, 2014), in comparison to covariance-based SEM software, it has a significantly better capability to deal with formative constructs (Esposito Vinzi, Chin, Henseler, & Wang, 2010) and predict variables (Hair et al., 2011). Covariance-based SEM techniques also have certain restrictions regarding model complexity, which is not the case for PLS (Wetzels, Odekerken-Schroder, & Van Oppen, 2009). Additionally, Monte Carlo simulations have shown that for samples smaller than 250, as in our case, PLS offers more accurate estimates (Reinartz, Haenlein, & Henseler, 2009). We therefore used the SmartPLS software (Ringle et al., 2015) to evaluate our measures and test our hypotheses.

We assessed the internal reliability of our variables by calculating the composite reliabilities (Cronbach, 1951; Tabachnick & Fidell, 2001). All reflective measures have an composite reliability above 0.7 which indicates high reliability. Next, convergent validity was demonstrated with average variance extracted (AVE) values above 0.5 (Fornell & Larcker, 1981). These results are reported in Table 3.

For the assessment of discriminant validity we evaluated the cross-loading values within a cross-correlation matrix. Table 4 shows that each indicator's loading on its own construct is larger than its cross-loading with other constructs. Thus, findings provide evidence for high discriminant validity between constructs. Moreover, the square root of AVE of each construct is higher than the highest correlation with any other construct, which underscores the evidence of discriminant validity (Hair et al., 2014). In our analysis, missing values were dealt with by using mean replacement. The significance of the path coefficients was determined with a bootstrapping procedure (101 cases, 5,000 samples). We calculated a goodness of fit measure in SmartPLS by running the PLS algorithm. The measure uses standardized root mean square residual (SRMR) to provide a result for the composite factor. A value between 0.05 and 0.08 indicates fair fit, 0.08 and 0.10 for a mediocre fit and above 0.10 for a poor fit (Hu & Bentler, 1998). The composite factor model indicates a reasonable fit (0.082). Thus results imply that PLS-SEM is a suitable technique to analyze our proposed model (Henseler et al., 2014).

It is argued that survey data that originate from a single informant with a self-assessment approach, as our data set does, may lead to common method bias effects (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003; Podsakoff & Organ, 1986; Richardson, Simmering, & Sturman, 2009). We therefore followed Venkatesh, Thong, and Xu (2012) and applied two statistical analysis methods to test for a potential effect of common method bias. As suggested by Liang, Saraf, Hu, and Xue (2007), we performed an unmeasured latent methods factor test (Podsakoff et al., 2003) by adding a common method variance factor that covers all principal constructs' indicators. Hence, we estimated the substantive variance that describes the loading between the main construct and the indicator construct as well as the average method-based variance, which stands for the loading of the common factor on the indicator construct. The results (Table 2) show that the substantive variance was on average 0.66 and the average method-based variance is 0.02. Since the substantive variance represents a value 30 times higher than the method variance and most of the method factor loadings are insignificant, results indicate that a common method bias

is unlikely to be a critical factor for this study. Moreover, we followed Richardson et al. (2009) and applied the confirmatory factor analysis marker technique that involves the addition of a theoretically less relevant marker variable (Lindell & Whitney, 2001; N. K. Malhotra, Kim, & Patil, 2006). As described by Malhotra et al. (2006), we opted for the second-smallest positive correlation between two manifest variables as a conservative estimate. After the deduction of this value from all correlations, we ran the model again. No significant difference between the original and adjusted correlation estimates was observed. In consequence, the marker technique confirms the indication that common method bias is less problematic for this analysis.

Table 2 - Common method bias test

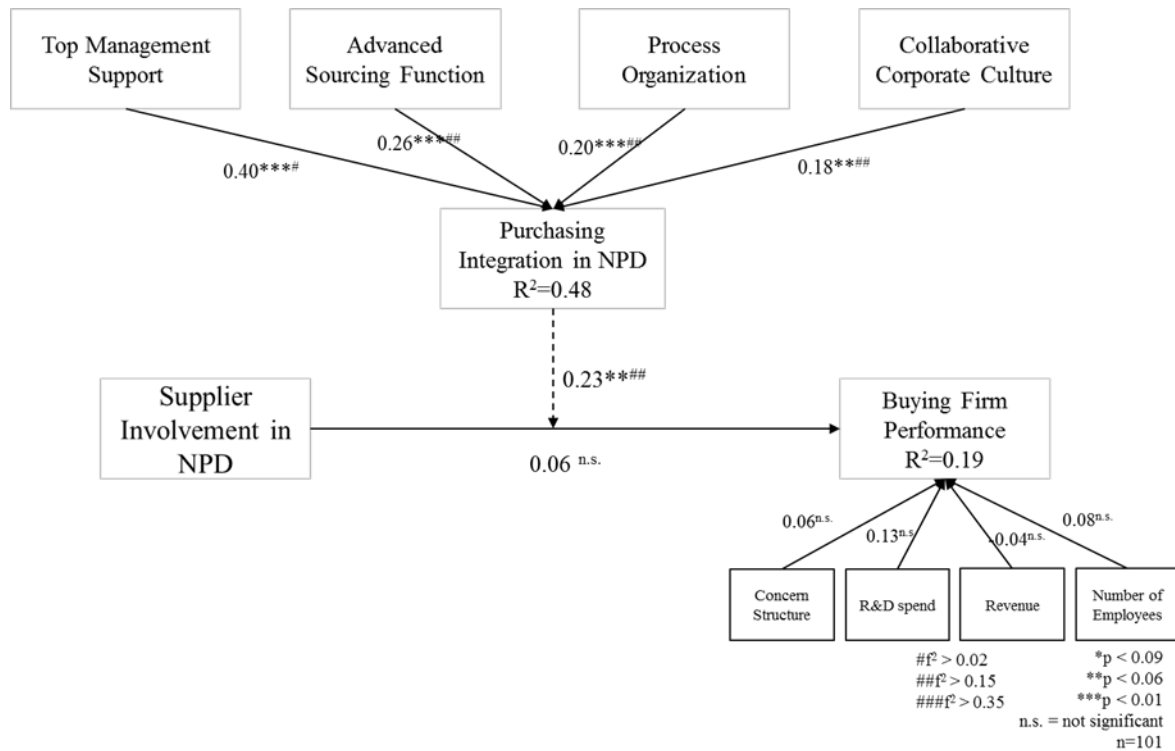
	Construct Loading (CL)	CL ²	Method Factor (MFL)	MFL ²
Top management support				
tms1	0.99	0.97	0.09	0.01
tms2	0.83	0.69	0.13	0.02
tms3	0.95	0.89	0.04	0.00
Advanced Sourcing Function				
HDP1	1.00	1.00	0.00	0.00
Process organization				
pro 1	0.84	0.70	0.15	0.02
pro 2	0.87	0.75	0.03	0.00
pro 3	0.79	0.63	0.04	0.00
pro 4	0.64	0.40	0.20	0.04
Corporate culture				
C1	0.82	0.68	0.10	0.01
C2	0.85	0.72	0.02	0.00
C3	0.79	0.62	0.10	0.01
Purchasing integration				
Pi2	0.67	0.45	0.22	0.05
Pi3	0.91	0.82	0.19	0.03
Pi4	0.86	0.74	0.08	0.01
Supplier involvement				
Si1	0.71	0.50	0.15	0.02
Si2	0.77	0.60	0.19	0.04
Si3	0.83	0.69	0.00	0.00
Performance				
P1	0.73	0.53	0.10	0.01
P2	0.84	0.70	0.11	0.01
P4	0.78	0.61	0.01	0.00
P6	0.53	0.28	0.22	0.05
Average	0.81	0.662	0.10	0.02

Note: * p < 0.05; **p < 0.01; ***p < 0.001 (one-sided).

2.4.2. Hypothesis testing

Figure 4 displays an overview of the path coefficients, highlighting the results per individual relationship. The model shows an R^2 of 19% for performance and 46% for purchasing integration, which underpins the theoretical and managerial relevance of our model (Combs, 2010).

Figure 4 - Research model with results (chapter 2)

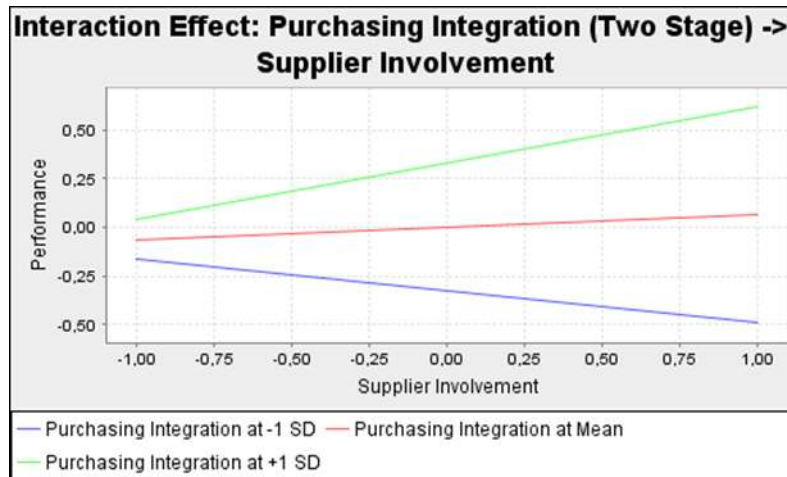


To evaluate the impact of the independent variables on the dependent variables, we calculated the effect size (Cohen's f^2) of each variable by determining the change in R^2 . The f^2 indication level ranges from small (0.02) and medium (0.15) to large (0.35) (Chin, 2010; J. Cohen, 1988). Table 5 reports results with confidence intervals (J. Cohen, Cohen, West, & Aiken, 2013). Top management shows a moderate effect on purchasing integration with an f^2 of 0.24, while advanced purchasing function ($f^2 = 0.05$), process organization ($f^2 = 0.07$), and corporate culture ($f^2 = 0.04$) imply minor influence on the integration of purchasing professionals. This means that top management support has a strong relationship with purchasing integration as opposed to the other three antecedents. The sampling distribution calculation illustrates a bootstrap distribution for the coefficients, so that those can be used to evaluate the hypotheses (Hair, Hult, Ringle, and Sarstedt, 2014). The results obtained support hypotheses: H2, H3 path coefficient = 0.40, ($p < 0.06$, $f^2 > 0.15$), H4 path coefficient = 0.26, ($p < 0.01$, $f^2 > 0.15$), H5 path coefficient = 0.20 ($p < 0.01$, $f^2 > 0.15$), and H6 path coefficient = 0.18 ($p < 0.06$, $f^2 > 0.15$).

Moreover, the results reject H1 and confirm H2. The results show a significant and positive interaction effect between the degree of purchasing integration in NPD and the degree of supplier involvement on buyer performance, this finding confirms H2 (path coefficient = 0.23 ($p < 0.06$, $f^2 > 0.15$)). To facilitate its interpretation, we plotted the interaction effect in figure 5, the regression lines show a positive effect of higher supplier involvement on buyer performance when purchasing professionals are integrated in the NPD process. However, in contrast to what H1 suggests we find that when purchasing professionals are not integrated in the NPD process a

higher supplier involvement will decrease the buyer's performance. Clearly the effect of supplier involvement in NPD on buyer performance can be positive and negative and is conditional on the degree of purchasing integration in NPD.

Figure 5 - Interaction effect between purchasing integration and supplier involvement

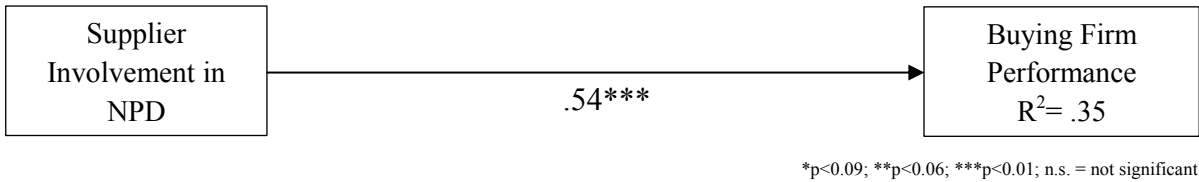


To verify the observed effects, we applied a PLS-based multi-group analysis using Henseler's (2012) nonparametric approach. A multi-group analysis compares the basic model under diverse conditions. We formed two comparison groups by splitting the initial sample at the median of the variable loadings of purchasing inclusion (Henseler & Fassott, 2010). The group with high loadings represented high purchasing inclusion (n = 37) and the group with low loadings represented low supplier involvement (n = 64). This allowed us to test for group-specific characteristics fostering the positive effect of supplier involvement on performance in the basic model (Henseler, 2012).

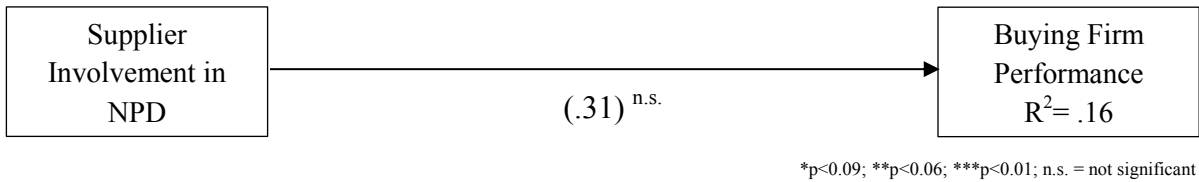
For the operationalization we followed Henseler (2012) and ran our model separately for each group. Results of the group analysis can be found in Figure 6 for both the high and low loading groups. The comparison of the path coefficients for the two groups show substantial difference, which underline the significant moderating effect of purchasing inclusion: the group of high supplier involvement indicates a stronger positive effect of supplier involvement (.54; p-value 0.00) on buying firm performance. In contrast, the group of low purchasing inclusion imply a negative effect of supplier involvement on buying firm performance (-.31; p-value 0.44). By comparing the mean and standard deviations (+1 and -1) of purchasing inclusion, the simple slope analysis (Figure 4) underlines the enabling effect of purchasing inclusion in relation to supplier involvement and buying firm performance.

Figure 6 - Sub-group analysis purchasing inclusion

High purchasing inclusion (n=37)



Low purchasing inclusion (n=64)



2.5. Discussion and Conclusion

2.5.1. Theoretical implications

This study contributes to literature on cross-functional collaboration in NPD with the focus on purchasing integration and supplier involvement. In general, this analysis advances previous conceptual research on cross-functional collaboration in NPD (e.g. Jassawalla and Sashittal (1998)). The identification of organizational and cultural aspects generates new insights into the debate of how to establish aforementioned cross-functional collaboration in NPD. By examining inter-organizational collaboration, this study provides evidence that firms which want to establish external relationships need to align internally first (Horn, Scheffler, & Schiele, 2014). In detail, this study identifies purchasing integration as a key enabling factor to implement supplier involvement with positive influence on buying firms' performance. Hence, this study also contributes to the understanding of the purchasing's agent role by highlighting the significant enabling effect of purchasing professionals on supplier involvement (I. J. Chen et al., 2004; Ellram & Liu, 2002; Johnsen, 2009). As in previous research (Droege et al., 2004; Gupta & Wilemon, 1990; Wynstra, Weggeman, & Van Weele, 2003), purchasing integration shows positive effects on supplier involvement. Nevertheless, this study advances current knowledge by looking at the interaction effect of purchasing integration and supplier involvement in relation to buying firm's performance. Empirical results provide evidence that purchasing integration can trigger the positive effect of supplier involvement on buying firm's performance. Moreover, the executed slope analysis further confirms that purchasing representatives need to be integrated into NPD in order to realize a positive effect of supplier involvement on corporate performance. If purchasing professionals are not part of NPD activities, supplier involvement can have no or even negative effects. Thus, the purchasing's agent role is further promoted by being identified as a necessary enabling factor for positive influences of supplier involvement on buying firms' performance. Applying the relational view to the observation, purchasing professionals integrated in NPD aids the identification of complementary resources, i.e. suppliers with the necessary

competences. and facilitates organizational structures enabling relational rents in form of innovations co-developed with suppliers. Consequently, firms, which do not include their purchasing department in NPD projects, are likely to fail with supplier involvement activities. For example, those firms might include too few suppliers or ‘wrong’ suppliers and thus miss the benefits associated with supplier involvement in NPD. Consequently, supplier involvement without purchasing integration has limited effects or potentially negative influence on the overall performance of the buying firm.

After identifying the relevance of purchasing integration in NPD for effective supplier involvement, this study is the first to test organizational antecedents for purchasing integration, which constitutes the second major contribution. To highlight how firms can integrate purchasing into NPD, we examined four factors that previous NPD research has revealed to be effective in NPD projects (Cooper & Kleinschmidt, 1995; Ernst, 2002), namely, top management support, structural differentiation, process organization, and cooperative corporate culture.

First, our results illustrate that top management support not only increases the strategic role of purchasing professionals within a firm (Carter & Narasimhan, 1996; Ellram & Carr, 1994; L. Li, 2007) and overall project success (Crawford, 2005; Thomas, Dellsie, Jugdev, & Buckle, 2002; Young & Jordan, 2008), but it also leads to purchasing integration in NPD projects and, indeed, emphasizes the relevance of the purchasing department with regard to the firm’s innovation activities. Moreover, top management support for purchasing professionals also implies enabling effects for supplier involvement. By means of the group analysis, we observed that companies with a high supplier involvement level show high top management support, whereas firms with low supplier involvement have low top management support for purchasing. Accordingly, top management support seems to be the driving force for the successful implementation of the purchasing’s dual role, namely incorporating input from outside sources (I. J. Chen et al., 2004; Ellram & Liu, 2002; Johnsen, 2009; Schiele, 2010).

Second, we show that structural differentiation has a substantial positive effect on purchasing integration by demonstrating a possible approach to overcome the cross-functional collaboration challenges that may exist among engineering, purchasing, and suppliers within NPD (Wynstra et al., 2001). Our results indicate that a differentiated purchasing structure with advanced sourcing activities (Burt & Soukup, 1985; Mendez & Pearson, 1994; Rendon, 2005; Trent & Monczka, 2005) can lead for example to the development of cross-functional touch points between engineering and purchasing during the NPD process. Consequently, structural differentiation and the introduction of advanced sourcing activities enable purchasing integration from an organizational point of view.

Third, our findings go beyond previous NPD studies by showing that a clear business process not only is a highly relevant key factor for success in NPD projects (Page & Schirr, 2008; Petersen et al., 2005; Tessarolo, 2007). Moreover, we demonstrate that a clear business process can also lead to the integration of purchasing professionals into NPD. Defining standardized processes, roles, and responsibilities enables the purchasing department to be actively integrated in NPD teams (Tessarolo, 2007; Wynstra et al., 2001). Furthermore, creating an explicit approach to including purchasing professionals aids to mitigate opposition of engineering personnel and

makes it unnecessary for purchasing personnel to rely on individual project leaders' favor to be included.

Fourth, our results support previous research findings that collaborative corporate culture is an antecedent to purchasing integration in NPD (Rendon, 2005; Van Echtelt et al., 2008). We show that the possibility to communicate easily and across functions and hierarchies is vital for promoting cross-functionalization and, consequently, the integration of the purchasing department. Further, organizational aspects, such as the spatial proximity between purchasing and engineering, can also foster an integrative and cooperative approach between the two functions. This way, our results advance current knowledge by illustrating that a lack of collaborative corporate culture can be compensated by top management support in order to facilitate purchasing integration and the other way around

By relating our findings to the relational view, we can highlight further theoretical contributions as well as identify explanations for our results. Our findings extend the current understanding of the relational view by showing that integrating purchasing professionals in the NPD process is one possible way to operationalize relational rents with suppliers. The integration of purchasing in NPD, by incorporating the attitude of purchasing professionals, facilitates relational rents. For example, the structural differentiation of purchasing permits dedicating purchasing resources to NPD in order to promote supplier involvement and trigger specific supplier development activities. Thereby, complementary resources of suppliers are either identified or proactively developed by purchasing professionals. The purchasing's dual role also fosters the integration agent position of purchasing professionals. The interest in the reduction of costs by simultaneously stimulating innovation requires purchasing to enable cross-functional and cross-company communication. Thereby, purchasing established organizational complementarities which allows for the use of complementary resources between organizations. In other words, purchasing fosters knowledge sharing and manages supplier interfaces so that complementary resources are exchanged with the best possible outcome for the buying firm (Dowlatshahi, 1998; Ellegaard & Koch, 2012; Lakemond et al., 2001; Luzzini & Ronchi, 2011; Schiele, 2010).

Overall, our results indicate that without internal collaboration, external relationships with suppliers can have a negative influence on the organizational performance of the buying firm. Moreover, without top management support and adjustments of the structural, procedural, and cultural aspects of firms, cross-functional collaboration in NPD such as purchasing integration is less likely to occur. Given these striking findings with regard to organizational aspects, we expect that the future theoretical debate will be redirected to focus on the prominent role of organizational issues. Our results also suggest that research on NPD could be revitalized by examining more intensely sustainable organizational structures rather than predominantly concentrating on project management issues.

2.5.2. Managerial implications

Our aim in this study was to provide firms with insight into the relevance of purchasing integration with regard to supplier involvement. Second, we intended to spotlight organizational

antecedences of purchasing integration in order to determine the decisive factors in achieving supplier involvement in the NPD process. Indeed, our results suggest answers to our research questions as well as practical guidance for managers.

a) What role does purchasing integration play for performance improvement through supplier involvement in NPD?

According to our results, the positive influence of supplier involvement on the corporate performance of the buying firm is a prerequisite for the purchasing integration into NPD. In fact, our data go even further, indicating that firms with weak purchasing integration had only 4.1% innovative suppliers in their portfolio, as compared to more than twice as many (9.1% of their A and B supplier) for firms with successful purchasing integration (Hillebrand & Biemans, 2004; Johnsen, 2009; Tracey, 2004). Thus, this study is the first to present broad evidence that firms which facilitate purchasing integration on an operational level are likely to have a higher and more efficient supplier involvement than those that, for instance, rely purely on engineering personnel for the integration of external expertise. In other words, this study shows that integrating purchasing personnel in NPD is crucial with respect to the integration of external knowledge since it can boost the buying firm's performance. As highlighted by our results, neglecting purchasing integration can have negative influence on supplier involvement.

b. What are organizational antecedents for purchasing integration in the NPD process?

In addition to the all-important top management support, our study demonstrates that the often-neglected structural, procedural, and cultural aspects of a firm are highly relevant antecedents for purchasing integration into NPD. Specifically, our results indicate that the structure of the purchasing department needs to be adapted to facilitate integration into the NPD process, for instance, by applying a structural differentiation approach using an advanced sourcing (sub-) department or, in case of a smaller firm, at least one person executing (ideally) only that specific function. Moreover, a clearly defined NPD process framework facilitates purchasing integration into the NPD process. Therefore, a corporate-wide process description that finds constant application can be a useful tool for ensuring the establishment of a stable process environment for NPD. The reluctance that is often found in formulating and enforcing detailed process descriptions should not be tolerated. Additionally, a cooperative culture can act as an important influential factor for purchasing integration by encouraging the willingness and ability to cooperate and communicate internally.

To sum up, in order to achieve integration of purchasing professionals into the NPD process, our findings suggest to first convince the top management to provide appropriate support. The next step entails an explicit purchasing integration process with clearly defined steps in the NPD process which would encourage its continuous and systematic execution. Then the purchasing department may want to adapt their organizational structure by introducing a group of dedicated senior sourcing purchasers. Finally, a collaborative work ethic across functions would ensure effective integration of purchasing staff into the NPD project teams. If a firm lacks in cooperative corporate culture, top management support can prove effective for compensate debilitating effects, which gives managers an instrument to foster purchasing integration into NPD projects in the short-run. In the long-term, top management back-up combined with a clear process

framework and dedicated senior purchasing resources would promote the development of a cooperative work ethic. For example, spatial proximity between purchasing and engineering can offer excellent opportunities for the development of an integrative and collaborative corporate, if located in the same building and sharing certain facilities. Similarly, a process framework with cross-functional and cross-regional scope would intensify the cross-departmental work relations.

2.6. Limitations and Future Research

As stated above, this research presents the first comprehensive and empirically tested blueprint for purchasing managers to successfully integrate their departments into the NPD process. However, there are some limitations that have to be acknowledged and call for further investigation.

One limitation concerns the dependent variables, purchasing integration and supplier involvement, which were assessed using subjective items. For example, we asked respondents whether their purchasing department holds an important role in NPD projects and is able to assume a leading role in projects. Although such perceptual measures are considered to be satisfactory in operations management research (Ketokivi & Schroeder, 2004a), collecting more objective and transparent data, for example, the number of projects with reasonable purchasing integration in comparison to the total number of projects, would add validity to the findings.

A second limitation relates to functional origin of the responses. Most of the participants work in the purchasing department, which could lead to an overestimation of the effect of their actions as well as limited understanding of corporate results (e.g. sales growth of the company). To avoid a potential overestimation, it was clearly communicated to participants that survey results are anonyms, so that participants had no motive to overrate their influence. In addition, prior research underlines the identified effect of purchasing involvement as a key enabling factor for cross-functional collaboration and, in particular, supplier integration in NPD (I. J. Chen et al., 2004; Droege et al., 2004; Ellram & Liu, 2002; Hillebrand & Biemans, 2004; Johnsen, 2009; Tracey, 2004; Van Echtelt et al., 2008). However, input from other departments could have added further insights to the analysis.

Second, potential respondents were invited via an opt-in approach which allowed us to capture a target population that volunteered to participate. Thereby, it can be assumed that people with special motivation took the time to participate in the survey. This special interest might have driven the commitment to obtain the information. Moreover, the high number of mid to senior management participants (61 percent of the whole sample) imply that corporate related facts were either know or accessible for participants.

A third limitation to our study is that all respondents share the same cultural background, so cross-cultural differences could not be considered. However, innovation issues and willingness to cooperate could be subject to culturally influenced value systems (Hofstede, 1993) and thus analyzing the integration of purchasing in NPD from an international perspective may yield further insights. For example, reliance on clearly defined and well-documented processes may be particularly successful in a German cultural environment, which is characterized by high uncertainty avoidance and adherence to process rules. A third challenging aspect is the relatively

small sample size which signifies that this study was exploratory in nature (Forza, 2002; Nunnally & Bernstein, 1978). Fourth, most of our survey respondents are employed at large firms, thus, a study focusing on small and medium-sized firms may report different observations (Pressey, Winklhofer, & Tzokas, 2009).

We have several suggestions for extending our study through future research. First, because of the focus on purchasing integration, we did not check for organizational antecedents for the integration of other functional areas such as manufacturing or logistics. The analysis of other functions could enhance the understanding of successful cross-functional collaboration in NPD and provide more detailed insight for practitioners to answer the question of how to promote cross-functional collaboration in NPD.

Second, although we focused on the specific target spectrum of organizational antecedents of purchasing integration, future research should also consider the strategic aspects (Van Echtelt et al., 2008) of successful NPD projects. Analysis of strategic aspects, such as the influence of strategic purchasing integration, could yield interesting and highly relevant outcomes that would lead to a holistic understanding of antecedents for purchasing integration. Third, due to the high complexity and failure potential in NPD (Littler et al., 1995) as well as the organizational identity-building potential of cross-organizational cooperation (Croom, 2001), a dyadic capabilities view, including the perspective of suppliers, could increase the efficiency of organizational and process adaptations by the buying firm (J. C. Anderson, Håkansson, & Johanson, 1994; I. D. Ford, Hakansson, & Johanson, 1986). A dyadic analysis approach that combines the buying and supplying perspective could be beneficial for both academia and practitioners.

2.7. Appendices

Table 3 – Results of Reliability Analysis, Variables and Operationalization (chapter 2)

<i>Variable</i>	<i>Items</i>
<p><i>Top management support</i> (reflective)</p> <p>(i) $\alpha = 0.91$ (ii) CR = 0.94 (iii) AVE = 0.84</p>	<p><i>TMS1</i> The management completely supports our efforts to tie purchasing more strongly to the innovation process.^(a)</p> <p><i>TMS2</i> In our firm purchasing is an integral part of the innovation strategy.^(a)</p> <p><i>TMS3</i> The opinion of purchasing is highly appreciated by the management when it comes to innovation.^(a)</p>
<p><i>Advanced Sourcing Function</i> (formative)</p>	<p>How much time do members of staff spend on the functions listed below?</p> <p><i>HDP1</i> <i>Advanced Purchasing Activities</i></p>
<p><i>Process organization</i> (formative)</p>	<p>We have an explicitly documented and cross-functionally agreed-on process for:</p> <p><i>PRO1</i> Supplier selection.^(a)</p> <p><i>PRO2</i> Supplier development.^(a)</p> <p><i>PRO3</i> New product development.^(a)</p> <p><i>PRO4</i> Early supplier involvement in new product development.^(a)</p>
<p><i>Collaborative Corporate culture</i> (reflective)</p> <p>(i) $\alpha = 0.75$ (ii) CR = 0.86 (iii) AVE = 0.67</p>	<p><i>C1</i> In our organization, it is easy to communicate with virtually anyone you need to, regardless of their rank or position.^(a)</p> <p><i>C2</i> There is ample opportunity for informal 'corridor chats' among individuals from different departments in our organization.^(a)</p> <p><i>C3</i> In our organization, employees from different departments feel comfortable contacting each other when the need arises.^(a)</p>
<p><i>Purchasing integration</i> (reflective)</p> <p>(i) $\alpha = 0.73$ (ii) CR = 0.84 (iii) AVE = 0.64</p>	<p><i>PI1</i> Purchasing plays an important role in new product development in cross-functional teams and continuous improvement efforts.^(a)</p> <p><i>PI2</i> Purchasing takes a leadership role in new product development in cross-functional teams and continuous improvement efforts.^(a)</p> <p><i>PI3</i> Purchasing plays an important role in identifying suppliers who offer technologies that give our business competitive advantages.^(a)</p>
<p><i>Supplier involvement</i> (reflective)</p> <p>(i) $\alpha = 0.64$ (ii) CR = 0.79 (iii) AVE = 0.55</p>	<p><i>SI1</i> We involve key suppliers in the product design and development stage.^(a)</p> <p><i>SI2</i> We have key supplier membership/participation in our project teams.^(a)</p> <p><i>SI3</i> Our key suppliers have major influence on the design of new products.^(a)</p>
<p><i>Performance by buying firm</i></p> <p>(i) $\alpha = 0.71$ (ii) CR = 0.80 (iii) AVE = 0.51</p>	<p><i>P1</i> Our growth in sales is very good.^(a)</p> <p><i>P2</i> Our return on assets is very good.^(a)</p> <p><i>P3</i> In general we are satisfied with our competitive position.^(a)</p> <p><i>P4</i> Our cost position is very good.^(a)</p>

Control Variables		
<i>Concern Structure</i>	<i>G1</i>	Our department belongs to a big multinational concern with a lot of sub companies. ^(a)
<i>Revenue</i>		
<i>Number of Employees</i>	<i>G2</i>	Revenue of company.
	<i>G3</i>	Number of employees.
<i>R&D Spend</i>	<i>G4</i>	R&D spend in percentage in relation to the turnover of the company. ^(a)
<p>^(a) Item measured on five-point scale: 1 = fully disagree, 5 = fully agree.</p> <p>^(b) Item measured in percentage.</p> <p>⁽ⁱ⁾ Cronbach's Alpha should be $\alpha > 0.6$ (Cronbach, 1951).</p> <p>⁽ⁱⁱ⁾ Composite Reliability should be $CR > 0.7^*$.</p> <p>⁽ⁱⁱⁱ⁾ Average Variance Extracted should be $AVE > 0.5^*$.</p> <p>* Referring to Nunally (1978), Fornell and Larcker (1981), Bagozzi and Yi (1988), Henseler, Ringle, and Sinkovics (2009).</p>		

Table 4 - Cross-correlation matrix (chapter 2)

	<i>Mean</i>	<i>Sd</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>	<i>9</i>	<i>10</i>	<i>11</i>
1.Top Management	3.35	1.07	.92										
2.Process organization	3.63	0.99	.36	-									
3.Advanced Sourcing Function	12.66	4.67	.25	.27	-								
4. Corporate culture	3.83	0.78	.37	.30	.1	.82							
5.Purchasing integration	3.15	0.86	.59	.41	.42	.41	.80						
6. Supplier involvement	3.16	0.90	.38	.29	.37	.29	.54	.74					
7. Performance by buying firm	3.74	0.62	.27	.31	.24	.16	.34	.22	.71				
8. Concern Structure	3.51	1.689	.11	.18	.2	(.19)	.17	(.01)	.08	-			
9. Revenue.	841.9	1383	.04	.04	.09	(.13)	.12	.02	.03	.7	-		
10. Number of employees.	2968	5702	.07	.18	.36	(.19)	.17	(.01)	.09	.24	.68	-	
11. R&D spend	7.87	5.001	(.02)	.11	(.07)	.15	.08	.12	.14	.24	(.16)	(.07)	-

^a Values on the diagonal are shared values within a construct (square root of AVE)

Table 5 - Cohen's f2 analysis (chapter 2)

Independent variable	Depended variable: Purchasing Integration	
	f ²	Confidence intervals
Top Management Support	0.24	99%: 0.025 ≤ f2 ≤ 0.601
Advanced Sourcing		95%: 0.073 ≤ f2 ≤ 0.498
Function		90%: 0.098 ≤ f2 ≤ 0.451
Process Organization	0.05	99%: -0.051 ≤ f2 ≤ 0.176
Collaborative Corporate Culture		95%: -0.029 ≤ f2 ≤ 0.142
		90%: -0.017 ≤ f2 ≤ 0.126
	0.07	99%: -0.049 ≤ f2 ≤ 0.223
		95%: -0.023 ≤ f2 ≤ 0.182
		90%: -0.009 ≤ f2 ≤ 0.162
	0.04	99%: -0.051 ≤ f2 ≤ 0.151
		95%: -0.030 ≤ f2 ≤ 0.121
		90%: -0.020 ≤ f2 ≤ 0.107
	Dependent variable: Performance	
Supplier involvement	0.003	99%: -0.024 ≤ f2 ≤ 0.031
		95%: -0.017 ≤ f2 ≤ 0.024
		90%: -0.014 ≤ f2 ≤ 0.020
Purchasing Inclusion	0.09	99%: -0.047 ≤ f2 ≤ 0.272
		95%: -0.016 ≤ f2 ≤ 0.222
		0%: -0.000 ≤ f2 ≤ 0.198
Interaction Effect	0.06	99%: -0.052 ≤ f2 ≤ 0.203
		95%: -0.032 ≤ f2 ≤ 0.164
		90%: -0.014 ≤ f2 ≤ 0.146

Note: f² > 0.02 = small
f² > 0.15 = medium
f² > 0.35 = large

3. Chapter – Supplier innovation through supply chain collaboration

3.1. Introduction

Technological leadership by offering innovative solutions is considered to be one of the best ways to achieve competitive advantages (Faems et al., 2005; Zhou & Li, 2012). However, in today's complex technological environment, internal resources of a company are barely sufficient to develop innovative products (Corso et al., 2001; Grant & Baden-Fuller, 2004). Since the first studies on Japanese manufacturing practices, the importance of the integration of suppliers in new product development processes has been highlighted (Clark, 1989; Narasimhan & Kim, 2002). The same holds true for the supplier's capability to integrate its own suppliers, in turn, i.e. the second-tier suppliers from an original equipment manufacturer's perspective. Knowledge and expertise residing at the supply chain are an increasingly important resource trapped by OEMs, for instance, in regards to new product developments (NPD) (Phelps, 2010; Zaheer & Bell, 2005).

Scholars in supply chain management documented the benefits of integrating supplier resources in NPD. Research showed for example that innovation ability of suppliers build a key source for technical leadership and innovation performance of buying firms (Azadegan & Dooley, 2010; Tödting et al., 2009; Von Hippel, 1988; Wagner, 2009). Accordingly, supplier related topics like supplier selection (Choi & Hartley, 1996), early supplier involvement (Petersen et al., 2005), supply base management (Choi & Krause, 2006), supplier integration (Wong, Boon-Itt, & Wong, 2011) and technological diversity in supplier networks (Gao, Xie, & Zhou, 2015) were identified to positively influence supplier value contributions for OEMs.

Even though previous research has analyzed antecedents of supplier innovativeness in buyer-supplier collaborations (Pulles, Veldman, & Schiele, 2014; Wagner & Bode, 2014), limited attention has been paid to up-stream and down-stream interactions in supply chains and its influence on innovativeness (Roy & Sivakumar, 2010). In addition, recent studies call for more empirical studies to develop a deeper understanding of supplier-supplier-buyer relationships (Wu & Choi, 2005). This study looks into the process of how inter-relationships among suppliers work and tests for the interplay in conjunction with innovativeness as proposed by previous scholars (e.g. Choi & Krause, 2006). In detail, this study focuses on up-stream interactions by considering collaborations between sub-suppliers and first-tier suppliers and their influence on first-tier supplier innovativeness at the OEM level.

Recent studies promote the relational view as a useful theoretical lens to analyze supply chain collaborations and to examine the partners individual and joint impacts on relational outcomes (D. Q. Chen et al., 2013; Zhou et al., 2014). Resource based view explains the limitation of assets by companies with the natural constraint of resources (Eisenhardt & Schoonhoven, 1996). To overcome natural limitations, the relational view introduces the phenomenon of relational exchange resulting from sharing of resources between companies (Dyer & Singh, 1998). The paradigm of collaborative advantage adds the supply chain perspective to the theoretical lens of relational view and argues that combining resources from different supply chain stakeholders creates new capabilities within the value chain (Dyer, 1996, 2000; Dyer & Nobeoka, 2000; Kanter, 1994).

Likewise, innovation generation is increasingly viewed as a multidisciplinary activity including several organizations like a supply chain (Corsaro, Ramos, Henneberg, & Naudé, 2012; Håkansson, 1987; Lundvall, 1985; Roy et al., 2004; Von Hippel, 1994). Although scholars agree that a substantial part of innovation creation occurs in the supply chain between buyers and suppliers, analysis of open innovation literature shows that the supplier perspective of innovation competences is less intensively researched (Gassmann et al., 2010; Roy et al., 2004). Similarly, relationship characteristics present a critical dimension, as it can influence the degree of sharing and openness of suppliers in buyer-supplier collaborations (Pulles, Veldman, & Schiele, 2014; Schiele, 2006). Therefore, this study performs an empirical analysis of a dyadic data set to compare technical characteristics with relationship characteristics while checking the relevance of supply chain collaboration for supplier innovativeness in buyer-supplier collaborations. The main questions driving this paper are the following: (1) how do relationships within supplier networks influence supplier innovativeness for OEMs? (2) what are the contingent effects of first-tier supplier characteristics for the relationship between sub-supplier integration and supplier innovations for OEMs? (3) which role do technical characteristics play in contrast to relationship characteristics for the innovation collaboration between buyers and suppliers?

Building on relational view, this study examines supplier capabilities of innovative suppliers by reflecting on technical and relational characteristics. Thereby, this study contributes three important aspects to supply chain management literature. First, this study provides a model helping buying firms to identify innovative suppliers. In view of that, this study addresses the critical question of which supplier capabilities enhance innovation development within buyer-supplier collaborations.

Second, a few studies indicate that innovation is created through the interplay of multiple organizations within a business network (Corsaro et al., 2012; Håkansson, 1987; Lundvall, 1985; Roy et al., 2004; Von Hippel, 1994), but understanding is limited about the role of supply chain collaboration in regards to first-tier supplier innovations. Thus, this study examines how second-tier supplier integration by first-tier suppliers impacts the innovation output for the OEM.

Third, prior research like Pulles, Veldman, and Schiele (2014) and Wagner and Bode (2014) among others have mainly tested antecedents and dynamics of dyadic buyer-suppliers relations either from the buyer or the supplier perspective, but rarely from both sites (Terpend et al., 2008). This study employs a dyadic approach by compiling responses from both sites which can build a role model for further research

This paper will proceed with the following structure: First recent literature regarding supplier innovation and buyer-supplier relations will be analyzed. We then develop a theoretical research framework to empirically identify supplier characteristics that explain the innovation potential of suppliers and examine how collaborations with sub-suppliers influence the abilities of first-tier suppliers. Finally, we test the model on a dyadic sample of responses from suppliers and a buying firm in order to present and discuss the findings.

3.2. Literature

3.2.1. *Innovations as relational rents*

Multiple scholars argue that collaborations between organizations develop distinctive capabilities, which form the basis for core competencies that provide an organization with enduring competitive advantages (Jay Barney, 1991; Hamel & Prahalad, 1990). Innovation is considered to be a distinctive capability that provides one of the best ways to achieve competitive advantages (Faems et al., 2005; Hoonsopon & Ruenrom, 2012). To create innovations, previously detached pieces of knowledge need to be integrated and recombined into new combinations of products, concepts, and practices that create value (Schumpeter, 1934). From a theoretical perspective, relational view (Dyer & Singh, 1998) and the paradigm of collaborative advantages (Dyer, 2000) consider the exchange of resources as source of competitive advantage. Thereby, collaborations between companies do not only facilitate the exchange of existing knowledge, but the exchange of resource creates capabilities that none of the organizations could have developed internally (Dyer & Nobeoka, 2000). In accordance, literature about alliances and networks for innovation claims a significant relevance of combining resources in order to create innovative capabilities (Ahuja, 2000; Sampson, 2007). For example, resource-rich external partners provide firms access to complementary knowledge that combined with internal knowledge result in novel and unique resources (Ahuja & Lampert, 2001; Dyer & Singh, 1998; Mouzas & Ford, 2009). In particular, the paradigm of collaborative advantage considers up-stream and down-stream supply chain connections as key in value creation from a multi-tier perspective (Dyer, 2000).

3.2.2. *Supplier innovation through supply chain collaboration*

From theory, we know that relational rents in supply chains enable firms to pool internal and external resources to create competitive advantages (Dyer & Singh, 1998). Referring to developed competences of suppliers, Chesbrough (2003) highlights the advantages of involving external resources in the context of “open innovation”. Integrating external competences is considered as a valuable source of competitiveness for companies (Beers & Zand, 2014; Dyer & Singh, 1998). For example, literature shows evidence that the innovation ability of suppliers is a key source for technical leadership and innovative performance of buying firms (Azadegan & Dooley, 2010; Jaakkola & Hakanen, 2013; Tödtling et al., 2009; Von Hippel, 1988). Despite recognized relevance, scholars agree that the understanding of innovation competences of supplier has been less intensively researched (Gassmann et al., 2010; Roy et al., 2004). This paper focuses on supply chain collaboration as basis for innovative supplier inputs within buyer-suppliers collaborations.

Supply chains are considered to be a key source for firms to obtain valuable external knowledge (Choi & Krause, 2006; Y. Kim, Choi, Yan, & Dooley, 2011; J. J. Li, Poppo, & Zhou, 2010). Sub-suppliers, thereby, acquire the character of supplier-addressable resources for first-tier suppliers (Beers & Zand, 2014; Sanchez & Heene, 1997). Vertical integration of sub-suppliers might influence the innovation capabilities of first-tier suppliers, since sub-suppliers with distinctive technological backgrounds provide different and novel resources to the first-tier suppliers which increases the possibility of creative learning and innovation (Choi & Krause,

2006; Sampson, 2007). Therefore, to further advance the understanding of innovative suppliers, this study examines the antecedents of relational view not only in the direct buyer-supplier relation, but also in respect to sub-supplier integration to analyze characteristics of innovative suppliers. The more the supply chain comes into focus, the more novel problems arise for OEMs for example with which of its customers a multi-tier supply chain is going to collaborate and how OEMs can most efficiently benefit from supply chain resources.

3.2.3. The struggle for privileged treatment in buyer-supplier relationship

To utilize supplier competences most effectively, recent works have indicated that analysis should not be limited to supplier competences, but aspects of the supplier's attitude towards the collaboration with the buyer should also be considered (Croom, 2001; Pulles, Veldman, & Schiele, 2014; Schiele, 2006). Integrating external resources has become an important way for buying firms to access complementary resources that enrich their own innovation capabilities. For example, previous research has shown that suppliers are the second important source of innovation for organizations (Enkel et al., 2009). In consequence, buyer-supplier collaborations have become a central strategic element for many firms (Lavie, 2007). The explanation provided by the resource based concept points out that suppliers have naturally restricted resources (Eisenhardt & Schoonhoven, 1996), so that only a limited number of buyers can be satisfied by suppliers (Gulati, Zaheer, & Nohria, 2000). As buying firms from the same industry environment are trying to collaborate with identical innovative suppliers, it becomes challenging for these buyers to receive unique resources from the suppliers by creating an advantage over competitors (Ellegaard & Koch, 2012). In consequence, relationship characteristics like financial attractiveness and supplier satisfaction were observed to determine which buying firm gets access to innovative resources of the supplier (Baxter, 2012; Schiele, Calvi, & Gibbert, 2012).

3.3. Conceptual model & hypothesis

3.3.1. Conceptual model

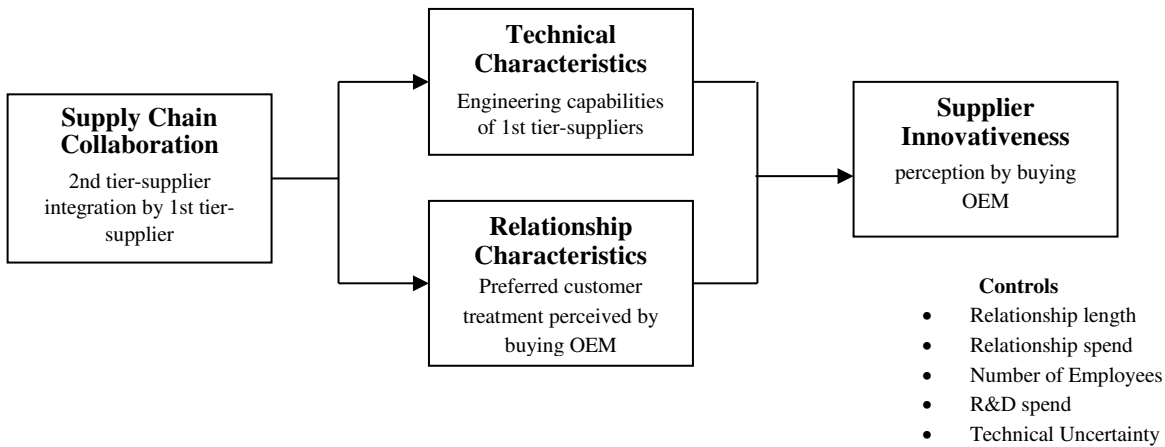
In business networks physical and social interactions permit firms to create new knowledge from the exchange and rearrangement of existing knowledge (Mouzas & Ford, 2009). This paper has its focus on buyer-supplier collaborations with special emphasis on characteristics of innovative suppliers in buyer supplier collaborations. To examine characteristics of innovative suppliers, we take the theoretical lense of relational view and the paradigm of collaborative advantage.

We follow the paradigm of collaborative advantage which claims that combining resources from different supply chain stakeholders creates new capabilities within the value chain (Dyer, 2000; Dyer & Nobeoka, 2000). Accordingly, we assume that resource exchange among suppliers as well as between buyers-suppliers foster innovation creation. To look into the process how the exchange between sub-suppliers, suppliers and the OEM work, we apply relational view as theoretical lense to examine antecedents for supplier innovativeness. Relational view considers complementary resources, knowledge-sharing routines, effective governance and relation-specific assets as driving factors for successful relationships (Dyer & Singh, 1998). Complementary

resources stand for synergy-sensitive resources from a relationship partner (Dyer & Singh, 1998). With the intention to receive innovative input, technical competences of suppliers symbolize synergy-sensitive resources complementing buying firms (Monczka, Handfield, Frayer, Ragatz, & Scannell, 2000; Wognum, Fisscher, & Weenink, 2002). Thus, this study signifies technical characteristics of suppliers in respect to complementary resources in the conceptual model. Knowledge-sharing routines refer to transparency and reciprocity that lead to greater potential for relational rents (Dyer & Singh, 1998). NPD project processes establish transparency and absorptive capabilities (Lenox & King, 2004) that presumably enable innovative contributions by suppliers (W. M. Cohen & Levinthal, 1990; Salomo, Weise, & Gemünden, 2007). Relationship characteristics of the buyer–supplier relationship relate to effective governance as mentioned by relational view (Dyer & Singh, 1998). To reflect willingness and frankness to cooperatively exchange innovative resources, the customer status of the buyer is taken into account in order to evaluate the role of effective governance (Croom, 2001; Pulles, Veldman, & Schiele, 2014; Schiele, 2006). Relation-specific assets are described by the duration and volume of the relationship (Dyer & Singh, 1998).

The conceptual model combines both relational view and the paradigm of collaborative advantage by looking into the process of how inter-relationships among suppliers work in collaborative archetypes (Wu & Choi, 2005). Thereby, the model is testing the interplay of supply chain relationships in conjunction with innovativeness as proposed by previous scholars (e.g. Choi & Krause, 2006). Supply chain literature examining the inter-relationships between suppliers claims that suppliers can manage their relationship with other suppliers which refers to a so called ‘relationship capability’ (Wu & Choi, 2005). However, an individual case analysis has indicated that not every supplier is equally capable of managing the relationship with other suppliers to provide best solutions to buyers (Wu & Choi, 2005). The conceptual model, therefore, tests if supplier characteristics act as enabling factors of a ‘relationship capability’ that facilitates the passing-on of second-tier supplier resources to OEMs. To examine supplier characteristics which potentially act as mediator, the conceptual model takes relational view as theoretical lense. Accordingly, technical and relationship characteristics of first-tier suppliers are tested to be a mediating effect between supply chain collaboration and supplier innovativeness at the OEM level. Knowledge-sharing routines and relationship-specific assets work as control variables. The conceptual model is illustrated in Figure 7.

Figure 7 - Conceptual model (chapter 3)



3.3.2. Sub-supplier integration as condition for first-tier supplier innovativeness

Innovation generation is increasingly viewed as a multidisciplinary activity involving different organizations along a supply chain (Håkansson, 1987; Lundvall, 1985; Roy et al., 2004; Von Hippel, 1994). Across the supply chain, manufacturers form inter-organizational collaborations with its external partners like customers and suppliers to create supply chain collaborations (Flynn, Huo, & Zhao, 2010; Stank, Keller, & Daugherty, 2001). Resource sharing between supply chain partners bring complementary resources together, which create super-additive value (Tanriverdi, 2006). As described by the paradigm of collaborative advantage (Dyer, 2000; Kanter, 1994), the innovation level of first-tier suppliers presumably benefit from the integration of sub-suppliers.

First, suppliers collaborating with sub-suppliers get access to diverse knowledge which can lead to a higher innovation level (Ahuja, 2000; Laursen & Salter, 2006). The diversified sub-supplier resources enable first-tier suppliers to dissimilar knowledge, which increases the number and variety of potential novel knowledge combinations (Fleming & Sorenson, 2001). Therefore, sub-supplier integration can enable the absorption of knowledge which leads to innovative solutions (Cao & Zhang, 2011; Soosay, Hyland, & Ferrer, 2008).

Second, first-tier suppliers can use sub-suppliers for flexibility and resource purposes (Fagerstroem & Jackson, 2002). In view of that sub-suppliers acquire the character of supplier-addressable resources (Beers & Zand, 2014; Sanchez & Heene, 1997). First-tier suppliers can allocate non-value adding activities to their supply base, which releases resources and capacities for innovation related activities. Sub-suppliers can, therefore, foster indirectly value adding activities, which imply a reasonable influence of sub-suppliers on first-tier suppliers' innovativeness (Doran, Hill, Hwang, & Jacob, 2007; Prajogo, Chowdhury, Yeung, & Cheng, 2012). Thus, high integration of sub-suppliers can foster the innovation ability of first-tier suppliers.

H1: *The more first-tier suppliers actively collaborate with their sub-supply base, the higher the innovation level of first-tier suppliers.*

3.3.3. Sub-supplier collaboration, engineering capabilities and supplier innovativeness

We hypothesize that sub-supplier collaboration can benefit the innovation level of first-tier suppliers; however, the positive effects for buying firms might depend on the engineering capabilities of first-tier suppliers. First, to create innovations, firms need to assimilate and recombine knowledge from various sources to a novel combination (Phelps, 2010). Relational view proposes that “the greater the partner-specific absorptive capacity is, the greater the potential will be to generate relational rents through knowledge sharing” (Dyer & Singh, 1998, p. 666). Absorptive capacity of a firm describes that innovative companies need to have a certain level of specific knowledge in-house (Azadegan & Dooley, 2010; W. M. Cohen & Levinthal, 1990; Prabhu, Chandy, & Ellis, 2005; Volberda, Foss, & Lyles, 2010). Absorptive capacity is a dyadic paradigm, which means that the partner who receives the knowledge must be able to assimilate and apply that knowledge to its products. In the context of supply chain collaborations, sub-suppliers might offer resources and knowledge to first-tier suppliers, but technological knowledge is tacit in nature and difficult to be codified and communicated (J. J. Li et al., 2010). Thus, first-tier suppliers need prior engineering capabilities to fully understand and successful processes the acquired information to valuable and innovative outcomes for buying firms.

Second, advanced engineering capabilities allow first-tier suppliers to better leverage sub-supplier resources in accordance to technical trends of the buying firm. Supplier engineering capabilities refer to the ability of a supplier to create and respond to emerging technologies (LaBahn & Krapfel, 2000). For example, first-tier suppliers with strong engineering capabilities can better anticipate customer needs of new products and integrate multiple sub-suppliers to develop novel concepts. Based on the advanced engineering abilities, those concepts can be moved along faster and with more innovative solutions for the buying firm (Zhang, Vonderembse, & Cao, 2009). Therefore, engineering capabilities reflect a key relational characteristic through which sub-supplier integration contributes to innovation performance of first-tier suppliers.

H2: Engineering capabilities of first-tier suppliers fully mediate the positive effect of sub-supplier integration on supplier innovativeness for buying firms.

3.3.4. Sub-supplier collaboration, preferred customer treatment and supplier innovativeness

We posit that preferred customer treatment of first-tier suppliers fully mediates the value of sub-supplier integration on supplier innovativeness for buying firms. As described by relational view, the more the relationship partner invest in the relationship, the larger the potential for successful collaborations (Dyer & Singh, 1998). However, suppliers might not be willing to invest and cooperate as desired by the buying firm (Essig & Amann, 2009). Due to multiple customers eager to collaborate with a limited number of suppliers, suppliers resources cannot serve every buyer, so that suppliers prioritize between buying firms (Mitsubishi & Greve, 2009). Thus, buying firms experience a competition for supplier resources and preferred customer status (Schiele, Veldman, & Hüttinger, 2011). Based on cost-benefit thinking, suppliers favor the buying firms who show highest attractiveness to the supplier (Ellegaard, Johansen, & Drejer, 2003; Ramsay & Wagner, 2009; Thibaut & Kelley, 1959). Consequently, a buying firm that embodies a higher attractiveness to suppliers than their competitors can be expected to access

supplier resources with greater ease. Preferred customers are more likely to, for example, get the best personnel for a joint development from a supplier or innovations that are not available to the buying firm's competitors (Hüttinger, Schiele, & Veldman, 2012). Previous research also imply that a preferred customer status may result in better access to supplier's innovative resources (Pulles, Veldman, & Schiele, 2014). In view of that we expect that preferred customers of first-tier suppliers might have a better access on benefits of sub-supplier integration.

First, suppliers might have a higher motivation to develop and create innovative recombinations of sub-supplier knowledge for preferred customers. The sub-supply base provides technologically diverse solutions that embody novel and unique knowledge (Choi & Krause, 2006; Sampson, 2007). However, technical knowledge is generally complex, tacit and challenging to integrate and absorb (Phelps, 2010). First-tier suppliers have the highest interest to engage knowledge from sub-suppliers in accordance to the interests of their preferred customers. Moreover, strong relations between stakeholders foster a higher absorptive capacity to transfer information and knowledge (Podolny, 2001). First-tier suppliers are, therefore, more likely to identify and absorb sub-supplier knowledge relevant for their preferred customers, leading to greater supplier innovativeness for preferred customers.

Second, first-tier suppliers are more open to share sub-supplier knowledge with preferred customers. Knowledge sharing can be risky. The relationship partner offering exclusive and sensitive knowledge can have a disadvantage, when the receiving party acts unscrupulously. Trusting the other party can improve the confidence of suppliers that buying firms will not take advantage of its openness (Oke, Idiagbon-Oke, & Walumbwa, 2015; Villena, Revilla, & Choi, 2011). In order to acquire preferred customer status, buying firms have to become more attractive than their competitors to their core suppliers which foster the interest of buying firms to be a trustworthy partner. In consequence, suppliers are more willing to exchange genuine, novel sub-supplier knowledge with their preferred customers which increase the innovation level for 'preferred' buying firms.

H3: *Preferred customer treatment of first-tier suppliers fully mediates the positive effect of sub-supplier integration on supplier innovativeness for buying firms.*

3.4. Method & Measures

3.4.1. Data collection

Data for this study was obtained from supplying firms of the agricultural equipment industry. In detail, survey responses were collected from direct material first-tier suppliers of a focal agriculture equipment OEM with headquarter in the U.S. Similar to the automotive industry, suppliers of the agriculture industry have the tendency to supply goods to multiple OEM's (Dyer & Singh, 1998; Ellis et al., 2012). Accordingly, this study can be considered to represent the broader agriculture equipment industry.

The use of sample firms working in the same industry context ensures that industry-level differences in the dyadic buyer-supplier relationships are excluded (Liu et al. 2009). This survey includes sample firms from a global scope with a wide diversity of material groups.

In preparation to the survey, 5 workshops with randomly selected practitioners were organized to ensure academic and practical relevance of the questionnaire. During, the workshops the questionnaire was answered together with one researcher, so that questions were discussed and suggestions were made. After the workshops, the questionnaire was transformed into an online survey tool and send out to 100 randomly selected first-tier suppliers in order to test the research instrument under real-life conditions. 58 suppliers participated in the survey pre-test, which provided a good sample to test for statistical validity. The pre-testing ensured that items were clear and understandable by providing simultaneously face validity for the constructs examined. Minor wording adjustments were done to the questionnaire after the pre-testing before it was converted in the final online survey. Afterwards, the final survey was sent out to the remaining sample of 335 first-tier suppliers of the OEM.

Including the responses from the pre-testing, in total 196 first-tier suppliers participated, which gives a response rate of around 45 percent from the total sample of 435 suppliers. Based on the 196 supplier responses, the buyers at the OEM were asked to evaluate the suppliers who related to their commodities. The survey instrument completed by the buyers included identical questions as for the suppliers, only wording adjustments were made due to the different perspective of the relationship. In total, 93 suppliers were evaluated by the buyers. In consequence, this study is based on a dyadic data set that includes 93 responses from the first-tier supplier level and the OEM.

In regards to data collection, based on the support from the agriculture equipment OEM, suppliers' key accounts were invited to participate in the survey by an e-mail sent by the OEM. The e-mail pointed out that suppliers' participation is voluntary by providing a link to the online survey hosted by the university. After collection of the supplier data, OEM's buyers were contacted via e-mail from the university to evaluate suppliers from their commodity. Buyers represent commodity buyers, who are responsible for managing one or more commodities at the OEM. Buyers were asked to evaluate the suppliers relating to their commodities. Thereby, buyers had the knowledge to evaluate the corresponding suppliers. In some cases, buyers also consulted other functions for their opinion, which further increased validity of the responses. .

Table 6 shows the geographic locations, the industry breakdown and the size of companies of the sample. The data collection shows a heterogeneous structure covering a broad range of manufacturing industry sectors and geographic locations. The sample represents the industry and product structure of a vehicle manufacturer by representing the supply base structure of a globally operating European OEM. Thereby, the collected data represents a valuable and well-balanced sample. The firms represented in our sample are of notable size, averaging USD 1,322 million turnover, 9,153 employees, and 5.1% of turnover invested in R&D.

Table 6 - Descriptive information of the sample

Geographic locations of suppliers	Number of suppliers	Percentage
Geographic location		
EU	60	65%
Asia	12	13%
North America	10	11%
South America	11	12%
Total	93	100%

Industry sector	Number of suppliers	Percentage
Castings and metal fabrications	20	21%
Engine and engine components	17	18%
Hydraulics	13	14%
HVAC	9	10%
Electrics, Electronics	5	5%
Tires, Wheels	6	6%
Axles	4	4%
Transmission	2	2%
Others	19	20%
Total	93	100%

Supplier Size	Number of suppliers	Percentage
Large Size (>2000)	29	31%
Middle Size (300-2000)	25	27%
Small Size (<300)	39	42%
Total	93	100%

Profile of respondents	Number of suppliers	Percentage
Key Account Manager	35	38%
Manager of sales department	24	29%
Other functions (e.g. engineering)	19	18%
Senior Management	14	14%
Total	93	100%

The majority of respondents from the supplier site comes from the sales area (67%). In addition, other functions like engineering (18%) and senior management (14%) represent the profiles of the respondents. On the OEM site, all responses originate from the responsible commodity buyers. On both the supplier and the OEM site, respondents were asked to evaluate capabilities in relation to the competition. Thereby, the group of sales and purchasing experts should be enabled to provide adequate input as market and technology understanding is a key competence for both sales and purchasing experts. Nevertheless, to ensure the ability to answer the survey instrument, respondents had to acknowledge their confidence to be able to answer the

questions. Moreover, around 25% of the respondents from the supplier site also indicated that they included other functions in answer the survey. A cross-checking between cases when respondents answered by themselves and those cases with cross-functional input showed no significant differences. In case of the analyzed OEM, a random sample of responses was also cross-checked with perceptions from other departments. Again, findings showed no significant deviation.

3.4.2. Measures

Multi-item scales with a five-point Likert scale with end points of ‘strongly disagree’ and ‘strongly agree’ (Likert, 1932) were used to operationalize the variables of this study. The dyadic data set compiles responses from both sites of the buyer-supplier relationship. Data regarding supplier innovativeness and preferred customer treatment were collected at the buying site. Thereby, we intended to ensure the ‘objective’ customer perception of supplier characteristics in respect to innovativeness and customer treatment. The construct engineering capabilities and sub-supplier collaboration originate from the supplier site, since both constructs refer to internal supplier capabilities that can be best evaluated by the supplier itself. Intentionally, we adopted measurement items from previous studies, only if needed existing items were slightly modified with minor wording changes. Table 8 in the appendix provides the scale items and the exploratory factor analysis (EFA) with factor loadings of the items utilized in this study.

Sub-supplier Collaboration

The measure sub-supplier collaboration looking at the interaction of first-tier and second-tier suppliers mainly draws on existing items that initially refer to buyer-supplier collaborations (Hoegl & Wagner, 2005). First, to reflect resource exchange between sub-suppliers and first-tier suppliers, four items were taken from the 11 existing items. Four selected items were identified as most applicable for the analysis of NPD collaborations between first-tier suppliers and their sub-suppliers. The other items refer to the project level of a specific NPD project, which is not the level of analysis of this study. Second, in accordance to supply chain literature claiming that suppliers can collaborate with second-tier suppliers (Wu & Choi, 2005), the four items were modified to test for the degree of interaction between first-tier suppliers and their supply-base. In particular, the wording was adapted, so that the items refer to the collaboration between the supplier and its sub-suppliers. Thereby, the measure follows the paradigm of collaborative advantage by looking at integrating supply-chain resources by first-tier suppliers (Dyer, 2000; Dyer & Nobeoka, 2000; Kanter, 1994). Third, the following systematic validation steps were executed to ensure validity and applicability of the modified items: (1) Content validity was ensured with an extensive literature review, (2) in-depth focus group discussions with five purchasing managers and five key account managers from randomly selected suppliers facilitated relevance and understandability, (3) one pre-test of the survey with overall 100 suppliers’ sales representatives as described above safeguarded the practical applicability.

Engineering Capabilities

The measure for engineering capabilities is based on an existing measurement which sets engineering capabilities in relation to the competitive environment of the analyzed organization (LaBahn & Krapfel, 2000). We have chosen this measure in order to facilitate a comparison

between the supplier and its peers in regards to technical capabilities. By this means, the measure allows the comparison of technical competences, which is the complementary resource with synergy-sensitive meaning for buying firms (Dyer & Singh, 1998; Monczka et al., 2000; Wognum et al., 2002).

Preferred Customer Treatment

In accordance to relational view, relationship partners need to be willing to engage in value creation initiatives. In detail, Dyer and Singh (1998) introduce self-enforcing agreements, in which “no third party intervenes to determine whether a violation has taken place” (Telser, 1980). Third party enforcement represents for example a contractual agreement that regulates resource allocations between alliance partners. Scholars, however, have suggested that self-enforcing agreements, which can be “informal safeguards”, are most effective and least costly for specialized investments and complex exchange (Dyer & Singh, 1998; Hill, 1995; Sako, 1991; Uzzi, 1997). The preferred customer measure takes the perspective of informal safeguards and evaluates the informal resource contributions of suppliers. We therefore have chosen the measure from Schiele et al. (2011).

Supplier Innovativeness

We have chosen the existing measures for supplier innovativeness from Schiele et al. (2011), since items of this measure evaluate the ability of suppliers to add innovative offerings to supplier and buyer collaborations which represented the intended point of analysis.

3.4.3. Control variables

We controlled for additional supplier characteristics related to the levels of firm, theory and industry: (1) R&D spend, (2) number of employees, (3) relationship length, (4) relationship spend, (5) NPD process maturity, (6) technical uncertainty.

First, for the firm-level, we measured R&D expenses and the number of employees. Previous research showed that R&D investments influence the number and the level of collaboration between organizations (Becker & Dietz, 2004). Thus, we included R&D expenses by the ratio of R&D expenditures in relation to company sales. Moreover, companies might need a reasonable number of resources to contribute innovative solutions to customers. Therefore, we included the number of employees as an indication of available resources. Due to presumable differences in culture (Hofstede, 1993), we controlled for differences in regards country of origin. No significant differences in accordance to the country of origin could be found in the responses.

Second, in accordance with relation view, we included controls of relation-specific assets and knowledge-sharing routines. Relation-specific assets work as determinates of relational rents and involve the duration of safeguards as well as the volume of interfirm transactions (Dyer & Singh, 1998, p. 663). This paper, therefore, controls for relationship length and the spend volume between the buyer and supplier.

Knowledge-sharing routines are included by means of NPD process maturity. Absorptive capacity claims that benefits of relational rents increase for firms with strong internal capabilities in comparison to firms that lack internal capabilities (W. M. Cohen & Levinthal, 1990). Transforming this notion of absorptive capacity to the supplier perspective, suppliers need

internal capabilities to contribute innovations to buyer-supplier collaborations. In particular, a collaborative working behavior across internal functions represents a stimulus for collaborations with external supply chain stakeholders (Gimenez & Ventura, 2005; Horn et al., 2014; Schoenherr & Swink, 2012; Zhao, Huo, Selen, & Yeung, 2011). Mature NPD project processes facilitate aligned actions across functions and projects by providing a common language and framework to enhance communication between NPD activities (Engwall, Kling, & Werr, 2005). Thus, we control for mature NPD processes representing knowledge-sharing routines. In accordance to the discussion of Amaral, Rozenfeld, and de Araujo (2007) about NPD process maturity, new items were developed and applied to measure NPD project process maturity. Systematic validation, following the previous explained logic, was executed for this new construct.

Third, on the industry-level, we measured technical uncertainty as potential influencing factor of supplier innovativeness. Technological uncertainty is defined as the likelihood of unforeseen technological changes in the product. Technological uncertainty was calculated using a two-item measure adopted from Walker and Weber (1984) plus one item taken from the technological uncertainty measure of Jaworski and Kohli (1993). The analysis of further industry characteristics in form of commodity differences showed no results.

3.4.4. Measurement validation

To estimate the interaction effects, we employ ordinary least squares regression (OLS) by estimating a multiple regression which examines many-to-one relationships and indicates how much each variable contributes to the relationship. OLS presents a rather simple analysis method, which has no distributional assumptions and is computationally robust (Shah & Goldstein, 2006). Negative points of OLS are scale invariance and absence of fit indices or standard errors for estimates (Shah & Goldstein, 2006). Results of the regression analysis with engineering capabilities and supplier innovation in buyer-supplier collaborations as the dependent variable are shown in Table 9 in the appendix of this chapter.

Before finally testing the research model, we assessed the reliability and validity of the multiple-item constructs and checked for multicollinearity issues that pose a threat to the validity of the OLS analyses. First, we applied a confirmatory factor analysis (CFA) to assess the reliability and validity of the constructs measured by multiple-item scales. The results indicate a good fit ($\chi^2=240.203$, $p < .001$; comparative fit index=.91, incremental fit index=.92). All factor loadings are significant at $p < .001$ level. For all constructs, cronbach's alpha, the composite reliability and the average variance (AVE) are higher than the .60, .70 and .50 minimum levels respectively (Table 8) (Cronbach, 1951; Fornell & Larcker, 1981; Hair et al., 2014; Henseler, Ringle, & Sinkovics, 2009; Nunnally & Bernstein, 1978). Thus, the measures demonstrated adequate convergent validity and reliability.

Second, to assess multicollinearity we computed the variance inflation factors (VIFs). All VIF values are below 2.5 (Table 7), which is significantly less than the threshold of 10 that is commonly viewed as indication of multicollinearity (O'Brien, 2007). The results thus suggest that multicollinearity is not an issue within this study. Third, we use a cross-correlation matrix to check

the cross-loading values in order to assess discriminant validity for the reflective constructs by applying Fornell–Larcker criterion. Discriminant validity between the constructs appears to be implied, since for all items, an indicator’s loading on its own constructs are higher than all of its cross-loadings with other constructs (Table 7) (Hair et al., 2014). Moreover, each constructs’ square root of AVE is higher than the highest correlation with any other construct, which underscores the evidence of discriminant validity (Hair et al., 2014). According to Podsakoff et al. (2003), survey data that originate from a single informant may lead to common method bias effects. As the data set of this study originates from two different sources, thus a common method bias is not threatening our analysis.

Table 7 - Construct cross-correlation matrix (chapter 3)

	Mean	Sdf	VIF	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. Sub-Supplier Integration	4.19	0.76	1.00	.88									
2. Engineering Capabilities	4.51	0.60	1.45	.57	.85								
3. Preferred Customer Treatment (Buyer Perspective)	3.56	0.81	1.02	.21	.11	.88							
4. Supplier Innovation (Buyer Perspective)	3.60	0.86	-	.30	.34	.00	.89						
5. NPD Project Process Maturity	4.26	0.89	1.96	.50	.51	(.02)	.06	.89					
6. Technical uncertainty	2.91	0.85	1.11	.21	.26	.05	.06	.09	.91				
7. Relationship length	20.26	19.6	1.12	(.09)	(.02)	.21	.04	(.09)	.01	1.00			
8. Spend volume	6.29	8.04	1.25	.09	(.08)	.15	.14	(.18)	.13	.07	1.00		
9. R&D spend by suppliers	5.12	5.45	1.29	.21	.15	(.09)	.13	.15	.09	(.04)	.29	1.00	
10. Number of employees	9153	33529	1.10	.13	.13	.09	.14	.13	.03	.09	(.16)	.10	1.00

3.5. Results

We followed a multistep approach to test for mediating effects of engineering capabilities (H2) and preferred customer treatment (H3) (Baron & Kenny, 1986). First, we examined the effect between the independent variable (sub-supplier integration) to the dependent variable (supplier innovativeness) illustrated by Model 1 in Table 9. The effect of sub-supplier integration on supplier innovativeness shows a positive and significant result ($\beta = .37, p < .01$) implying strong support for H1.

Second, we established the effect of the independent variable (sub-supplier integration) on the first mediating effect (engineering capabilities). Model 2 in Table 9 shows that the effect on engineering capabilities is positive and significant ($\beta = .29, p < .01$). Third, the first mediator is related to the dependent variable, which indicates a significant positive effect. Model 3 in Table 9 shows that engineering capabilities has a positive and significant influence on supplier innovativeness ($\beta = .61, p < .01$). In the last step, both the independent variable (sub-supplier integration) and the first mediator (engineering capabilities) are added to the regression. Model 4 in Table 9 shows that the relation between the independent variable (sub-supplier integration) and

the dependent variable (supplier innovativeness) became non-significant ($\beta = .23$, p -value = .19) by adding the first mediator (engineering capabilities) to the model. Thereby, findings provide evidence that engineering capabilities fully mediate the positive effects of sub-supplier integration on supplier innovativeness.

Additionally, we tested for the second mediating effect of preferred customer treatment (H3). First, we started again with direct effect of the independent variable (sub-supplier integration) on the dependent variable (supplier innovativeness) ($\beta = .37$, $p < .01$) Model 1 in Table 9. Second, we tested the relation between the independent variable (sub-supplier integration) and the second mediator (preferred customer treatment). Model 5 in Table 9 emphasizes a significant positive effect ($\beta = .31$, $p < .05$). Third, Model 6 in Table 9 illustrates the relation between the second mediator (preferred customer treatment) and the dependent variable (supplier innovativeness) which implies a significant effect ($\beta = .59$, $p < .01$). Last, adding the second mediator and the independent variable results in a non-significant relation between sub-supplier integration and supplier innovativeness ($\beta = .19$, p -value = .13) (Model 7 in Table 9), while other relationships between constructs remained robust. Based on the relative small sample size, we applied nonparametric bootstrapping (5000 sample) of the direct effect and indirect effects to assess statistical significance of the indirect effects (Bollen & Stine, 1990; Shrout & Bolger, 2002). The 95 percent confidence interval for the indirect effects did not contain value zero, which supports the significance of the indirect effects (Table 10). In conclusion, findings show evidence that engineering capabilities and preferred customer treatment fully mediate the relationship between sub-supplier integration and supplier innovativeness in buyer-supplier collaborations.

Looking at technical and relationship characteristics in relation to supplier innovativeness, Model 8 in Table 9 shows that preferred customer treatment ($\beta = .58$, $p < .01$) and engineering capabilities ($\beta = .46$, $p < .01$) have a significant positive effect on supplier innovativeness in buyer-supplier collaborations.

3.6. Discussion and implications

3.6.1. Theoretical contribution

This study investigates the role of supplier characteristics in relation to supplier innovativeness in buyer-supplier collaborations. The findings advance current supply chain literature in multiple aspects.

First, this study develops a model of how buying firms can increase the innovation level of supplier within buyer-supplier collaborations. Although scholars have recognized the important role of suppliers for innovation (Gao et al., 2015; Wagner & Bode, 2014), open innovation literature shows a limited understanding of supplier characteristics driving innovation creation (Gassmann et al., 2010; Roy et al., 2004). In consequence, this paper examines critical aspects which foster innovative supplier contributions in collaborative actions between buyers and suppliers. Moreover, recent studies call for research on up-stream and down-stream relationships including supplier-supplier as well as supplier-buyer relationships (Choi & Krause, 2006; Roy & Sivakumar, 2010; Wu & Choi, 2005). In this manner, this study adds to supply chain literature by

advancing the understanding of inter-supplier relationships in regards to supplier innovativeness at the OEM level. The integrative view of up-stream and down-stream relationships in context of innovation generation provides novel insights to current understanding.

Supply chain collaboration fosters the ability of suppliers to contribute innovative inputs to buying firms. Nonetheless, our findings indicate that potential benefits for buying firms depend on characteristics of first-tier suppliers. With respect to inter-supplier relationships, first-tier suppliers seem to act as a filter through which sub-suppliers capabilities have to be passed-on to the OEM level.

In particular, technical capabilities of suppliers were identified to fully mediate the effect of supply chain collaboration on supplier innovativeness. Thus, our findings provide novel evidence that engineering capabilities of first-tier suppliers act as an enabling factor for buying firms to profit from sub-tier supply chain capabilities. Thereby, this study enhances previous knowledge that engineering capabilities facilitate innovative inputs by suppliers (Cabral & Traill, 2001; Monczka et al., 2000; Wognum et al., 2002) while showing that engineering capabilities also fosters access to supply chain resources for OEMs.. Moreover, relational characteristics of suppliers were identified as another full mediator between supply chain collaboration and innovative supplier contributions in buyer-supplier collaborations. Therefore, suppliers need to be willing to share information and resources with the buying firm, so that the buying firm can benefit from resources alongside the up-stream value chain. Findings of this study provide evidence that relationship characteristics work as a facilitator for buying firms to benefit from supply chain resources, which extends current understanding that relationship characteristics influences access to first-tier supplier resources (Pulles, Veldman, & Schiele, 2014; Schiele, 2006). Our findings imply relational aspects are equal or even more important for innovative collaborations between buyers and suppliers than technical and organizational characteristics (Pulles, Veldman, & Schiele, 2014). Thus, if an OEM wants to fully profit from the resources of its supply chain, the OEM needs to work with competent first-tier suppliers who have, in turn, 'relationship capabilities' to integrate second-tier suppliers and who award the OEM with preferred customer status.

Second, this study contributes to supply chain literature by highlighting the role and relevance of supply chain collaboration in regards to supplier innovativeness. Previous studies have indicated that the interplay of multiple organizations within a business network drive innovation creation (Corsaro et al., 2012; Håkansson, 1987; Lundvall, 1985; Roy et al., 2004; Von Hippel, 1994); however the understanding of the role of lower-tier supplier integration remained limited. Following the theoretical argumentation of relational view and the paradigm of collaborative advantage (Dyer, 2000; Dyer & Nobeoka, 2000; Kanter, 1994), this study adds new insights about the creation of innovation through the combination of resources from different supply chain stakeholders. Accordingly, our findings give reason to belief that if a supplier is not able to collaborate with its sub-suppliers, this firm might be a less attractive partner for OEMs.

Third, this paper adds to supply chain literature with the first empirical test of dyadic data compiling buyer and supplier responses in regards to supplier innovation in buyer-supplier collaborations. Until now, antecedents and dynamics of buyer-supplier relations have been tested

mainly either from the buyers or the suppliers perspective, but rarely between buyers and suppliers in the same relationship (O'Toole & Donaldson, 2002). Scholars have acknowledged that a lack of dyadic perspective can build a limitation of supply chain research (Monczka et al., 1995; O'Toole & Donaldson, 2002). In consequence, this study provides one potential role model for future supply chain literature.

3.6.2. Managerial contribution

This study identifies several managerial contributions for buying and supplying firms. Looking at buying firms, our results provide clear guidance to identify most innovative suppliers for buyer-supplier collaborations. In the past, scholars and practitioners often followed the limited conjecture to merely select suppliers with the “best” technical and organizational characteristics in order to receive innovative contributions (Ho, Xu, & Dey, 2010; Le Dain, Calvi, & Cheriti, 2011). This study extends previous perceptions and highlights that buying companies should invest as much if not more attention to relationship characteristics of the supplier. Accordingly, in addition to checking technical and organizational characteristics of suppliers, buying firms should ensure that suppliers are willing to share resources with them rather than its competitors (Pulles, Veldman, & Schiele, 2014; Schiele et al., 2011). Our findings underline that a preferred customer perception enhances access to supply chain resources via the first-tier suppliers as well as supports supplier innovativeness for buying firms.

Second, buying firms need to understand that technical capabilities of first-tier supplier act as facilitator for positives effects of supply chain collaborations on supplier innovativeness. Until now, previous research has argued that suppliers with existing in-house engineering capabilities can be trusted to develop parts, or subassemblies (Koufteros, Cheng, & Lai, 2007) and that engineering capabilities are essential to for innovative suppliers in product development activities (Cabral & Traill, 2001; Monczka et al., 2000; Wognum et al., 2002). Findings of this study indicate that practitioners should think and act beyond this current understanding to get innovative solutions for the supply chain. To identify most innovative suppliers, buying firms should, first, evaluate, if first-tier suppliers integrate lower-tier suppliers in their NPD activities. But second, buying firms should ensure that first-tier suppliers have the engineering capability to translate and integrate the lower-tier resources. Firms should understand that the value of supply chain collaboration is depending on the first-tier supplier characteristics both relational, but also technical wise.

Our study suggests adding a new item when OEMs decide to contract a supplier: buyers may explicitly stimulate supplier initiatives to integrate (sub-) supplier integration early on. Practically, this could inquire that the purchasing officers of the OEM may not only talk to their key accounts, but also talk to suppliers' purchasing function in order to understand suppliers' relationship capabilities to fully leverage its own supply chain.

Considering the supplier side, our results offer guidance to supplying firms in order to increase their own innovation potential. Integrating sub-suppliers improves the engineering capabilities of suppliers as well as the innovation ability of suppliers, since sub-supplier can act as a source of flexibility and resources (Fagerstroem & Jackson, 2002). Consequently, suppliers who want to

improve their innovation level should screen their sub-supply base in order to identify resources that would increase their own engineering capabilities.

3.6.3. Limitations and further research

This research presents a comprehensive and empirically tested blueprint for purchasing managers on what to look for at the supplier site in order to identify innovative suppliers. To pinpoint towards future research opportunities, we would like to acknowledge some limitations and options for further research activities.

One limitation of our study is that all respondents originate from the same industrial sector, so that other industrial characteristics cannot be considered. However, supply chain characteristics and the influence of preferred customer status could be an industry related topic. Therefore, analyzing the perception of different industries may create further insights.

Based on our results, some opportunities for future research appeared to us. First, looking at additional theoretical backgrounds, future research could evaluate the relevance of the mutual hostage model (Williamson, 1996) and the resource investment view (Morias, Dorsch, & Backman, 2004). Both claim that when a party invests resources, this action will be returned in a similar manner by the other party. Accordingly, future research could analyze, if innovation sharing by the buying firm stimulates in reaction innovation sharing by suppliers or sub-suppliers. Second, future research should analyze the direct interaction between the OEM and second-tier suppliers in order to develop innovation. Existing literature shows that buying firms can generally manage and approach sub-suppliers. Hewlett-Packard (HP) gives a practical example of an OEM that has dedicated sub-supplier initiatives in place. Initiatives with HP sub-suppliers have the focus on sustainability and include assessments like sub-supplier site visits and audits as well as collaboration actions like trainings and workshops (Grimm, Hofstetter, & Sarkis, 2014). Future research should examine instruments, structures and antecedents regarding the creation of innovation based on the direct relation between OEMs and sub-suppliers.

Third, we suggest that future research should look into other supplier-supplier relation archetypes and checks for the implications on innovativeness. Wu and Choi (2005) formulated different archetypes of supplier-supplier-buyer triad relationships. This study builds on collaborative supplier-supplier relation archetype; future research needs to consider other relationship structures in order to enhance current knowledge.

3.7. Conclusion

This study looks at the effect of sub-supplier integration by first-tier suppliers on supplier innovations in buyer-supplier collaborations. Our findings provide evidence to belief that the benefits of sub-supplier integration for buying firms in form of supplier innovations are carried through characteristics of first-tier suppliers. Technical and relational characteristics of first-tier suppliers act as facilitator for the positive effects of sub-supplier integration. This study adds to supply chain literature by providing buying firms with relevant insights on how to more efficiently manage buyer-supplier collaborations to enhance supplier innovations.

3.8. Appendices

Table 8 - Results of Reliability Analysis, Variables and Operationalization (chapter 3)

<i>Variable</i>	<i>Items</i>	<i>Loadings</i>
Sub-Supplier Integration by Supplier (based on Hoegl & Wagner, 2005) (reflective) (i) $\alpha = 0.78$ (ii) CR = 0.93 (iii) AVE = 0.90	<i>SSI1</i> Important ideas and information are exchanged openly with technical relevant suppliers of your company within NPD projects. ^(a)	0.85
	<i>SSI2</i> General atmosphere is cooperative with technical relevant suppliers of your company within NPD projects. ^(a)	0.88
	<i>SSI3</i> Communication between your suppliers and your company is frequent within NPD projects. ^(a)	0.89
	<i>SSI4</i> Communication between your suppliers and your company is intensive within NPD projects. ^(a)	0.90
Engineering Capabilities (LaBahn & Krapfel, 2000) (reflective) (i) $\alpha = 0.73$ (ii) CR = 0.93 (iii) AVE = 0.91	<i>Relative to the competition ...</i>	
	<i>EC1</i> ... our engineers are proficient with the latest technology. ^(a)	0.87
	<i>EC2</i> ...our engineers are skilled at creating technological innovations. ^(a)	0.92
	<i>EC3</i> ...we can incorporate the latest technology in our new products ^(a)	0.85
	<i>EC4</i> ...we can offer a high degree of engineering support to our customers ^(a)	0.83
<i>EC5</i> ...we are able to respond quickly to technological changes ^(a)	0.76	
Preferred Customer Treatment (Schiele et al. (2011)) (Buyer Perspective) (reflective) (i) $\alpha = 0.77$ (ii) CR = 0.94 (iii) AVE = 0.92	<i>PC1</i> This supplier has made sacrifices for us in the past. ^(a)	0.86
	<i>PC2</i> This supplier cares for us. ^(a)	0.89
	<i>PC3</i> In case of shortages, this supplier has gone out on a limb for us. ^(a)	0.85
	<i>PC4</i> We feel this supplier is on our side. ^(a)	0.90
	<i>PC5</i> The best resources of this supplier work for us. ^(a)	0.89
Supplier Innovativeness (Schiele et al. (2011)) (Buyer Perspective) (reflective) (i) $\alpha = 0.79$ (ii) CR = 0.94 (iii) AVE = 0.91	<i>SI1</i> The supplier possess innovative and unique technology capabilities. ^(a)	0.87
	<i>SI2</i> The supplier is willing to share key technology with OEM. ^(a)	0.89
	<i>SI3</i> The supplier is capable of bringing new technical aspects to the table. ^(a)	0.89
	<i>SI4</i> The supplier is frequently proactive in approaching the OEM with innovations. ^(a)	0.90
Controls		
NPD Project Process Maturity New measure (reflective) (i) $\alpha = 0.79$ (ii) CR = 0.95 (iii) AVE = 0.94	<i>NPD1</i> Our company has detailed NPD project management processes (e.g. milestones, resources planning etc.). ^(a)	0.91
	<i>NPD2</i> Our NPD project process is practiced cross functionally. ^(a)	0.90
	<i>NPD3</i> NPD project management processes are continuously improved within our organization. ^(a)	0.87
	<i>NPD4</i> NPD project management processes are supported and backed-up by a control system. ^(a)	0.90
	<i>NPD55</i> NPD project performance is continuously measured against pre-defined goals and targets. ^(a)	0.90

<p>Technical Uncertainty (Bernard J Jaworski and Ajay K Kohli (1993); Gordon Walker and David Weber (1984) (reflective) (i) $\alpha = 0.77$ (ii) CR = 0.86 (iii) AVE = 0.67</p>	<p>TC1 Specifications for your components / subsystems change frequently. TC2 Future technological improvements for your components and subsystems are very likely. TC3 The technologies used in your components / subsystem are changing rapidly.</p>	<p>.87 .78 .90</p>
<p>Relationship length Spend volume by relationship R&D spend by suppliers Number of Employees</p>	<p>G1 For how long do you work with this supplier? G2 Spend volume with this supplier in relation to your overall spend (%) G3 Spend for basic research (% of revenue) G4 Number of employees</p>	
<p>(a) Item measured on five-point scale: 1 = fully disagree, 5 = fully agree. (b) Item measured in percentage. (i) Cronbach's Alpha should be $\alpha > 0.6$ (Cronbach, 1951). (ii) Composite Reliability should be CR > 0.7*. (iii) Average Variance Extracted should be AVE > 0.5*. * Referring to Nunally (1978), Fornell and Larcker (1981), Bagozzi and Yi (1988), Henseler et al. (2009).</p>		

Table 9 - Regression Analysis (chapter 3)

Variables	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6		Model 7		Model 8	
	Supplier Innovativeness		Engineering Capabilities		Supplier Innovativeness		Supplier Innovativeness		Preferred Customer		Supplier Innovativeness		Supplier Innovativeness		Supplier Innovativeness	
	B	s.e.	β	s.e.	β	s.e.	β	s.e.	β	s.e.	β	s.e.	β	s.e.	β	s.e.
<i>Controls</i>																
R&D spend by suppliers	.03	.01	.01	.01	.01	.02	.01	.02	(.03)	.02	.03	.01	.02	.01	.02	.01
Number of employees	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Relationship length	.00	.00	.00	.00	.00	.00	.00	.00	.01	.00	.00	.00	.00	.00	.00	.00
Spend volume by relationship	.00	.01	(.01)	.02	.02	.01	.01	.01	.02	.01	.00	.01	.00	.01	.00	.01
NPD process maturity	(.11)	.12	.18***	.07	(.14)	.12	(.20)	.12	(.10)	.11	.03	.09	(.06)	.10	(.06)	.10
Technical uncertainty	(.03)	.10	.12*	.06	(.07)	.10	(.08)	.10	(.01)	.09	.00	.09	(.02)	.09	(.02)	.09
<i>Main effect</i>																
Sub-supplier integration	.37***	0.14	.29***	.08			.23	.15	.31**	.13			.19	.12	.06	.12
<i>Mediations</i>																
Engineering capabilities					.61***	.16	.51***	.18							.46***	.15
Preferred customer											.64***	.10	.59***	.10	.58***	.09
Constant	2.40***	0.59	2.14***	.34	1.46**	.69	1.32*	.69	2.51***	.55	1.13**	.54	.90	.56	(.04)	.62
F value	1.78		8.24***		2.67**		2.67**		2.23**		7.35***		6.82***		7.67***	
R2	.13		.40		.18		.20		.16		.38		.39		.45	
Adjusted R2	.06		.36		.11		.13		.09		.33		.34		.39	

$p \leq .01$ ***; $p \leq .05$ **; $p \leq .09$ *

; β = unstandardized

Table 10 - Bootstrapping of mediation effects (chapter 3)

I.V.	Mediator	D.V.	Estimates	95% CI's	
				Lower bound	Upper bound
Sub-supplier integration	ENG	Supplier Innovativeness	.16**	.01	.33
Sub-supplier integration	PC	Supplier Innovativeness	.13**	.02	.31

Notes: I.V. = independent variable; D.V. = dependent variable; ENG = engineering capabilities. Confidence intervals (CI's) are based on 5000 bootstrap samples. ***p>0.01, **p>0.05

4. Chapter – Identifying the ,right‘ supplier for module developments: A cross-industrial case analysis

4.1. Introduction

Increasing customer demands drive product complexities, so that single firms can barely cope with the full spectrum of resources required for new product developments (NPD) (Corso et al., 2001; Grant & Baden-Fuller, 2004). Based on resource based view (Eisenhardt & Schoonhoven, 1996), relational view argues that external resources can be rented to overcome those natural constraints (Dyer & Singh, 1998). Accordingly, previous research has observed that buying firms are incorporating external competences in order to realize competitive advantages (Bonaccorsi & Lipparini, 1994; Droege et al., 2000; Howard & Squire, 2007; Jaakkola & Hakanen, 2013; Koufteros et al., 2007). Modular product architecture is expected to aid the integration of supplier resources. The decoupled structure of modular product architectures enables outsourcing of development activities to suppliers, since decoupled modules have no interfering with other modules of the end product (Baldwin & Clark, 2003; Baldwin & Von Hippel, 2011; Campagnolo & Camuffo, 2009; Howard & Squire, 2007; Nepal et al., 2012; Sako & Murray, 1999). Accordingly, OEMs increasingly use suppliers to perform development activities of supplementary modules, so that they can focus on core activities (Helander & Möller, 2008; Langlois & Robertson, 1992; Sako & Murray, 1999), which results in generally improved NPD performance (Das & Teng, 2000). The automotive and aircraft industry can be seen as examples, where modularization of products has given buying firms the lead in product development, while a large share of the actual development work is delegated to suppliers (Frigant & Talbot, 2005; Gadde & Jellbo, 2002). Specialized technical knowledge, long-term experience and most of the time cross-industrial familiarity with technologies allow suppliers to leverage knowledge and to develop specific modules and sub-systems faster, cheaper and with better performance (Koufteros et al., 2007). As a result, the innovation level of the buying firms and the likelihood of developing commercially successful products increase significantly (Faems et al., 2005; Rosell & Lakemond, 2012; Von Hippel, 1988). Even though scholars agree on the relevance of supplier resources for innovation creation in supply chains, reviewing open innovation literature shows that the supplier perspective of competences is less intensively researched (Gassmann et al., 2010; Roy et al., 2004). There has been first conceptual and empirical work on supplier identification (Croom, 2001; Pulles, Veldman, & Schiele, 2014), however not for module suppliers.

Since results on supplier characteristics are limited in literature, we consider possible threats to find foregoing results for required supplier characteristics. Previous research has indicated that integrating suppliers in NPD projects is always associated with technical and performance risk (Handfield et al., 1999). Module suppliers, in particular, are exposed to both risk perspectives. The long-term orientation and impact across product families rises the importance and reliance on supplier input which increases both technical as well as performance risk for the buying firm (Giunipero & Eltantawy, 2004). Moreover, due to complexity and required investments, modules are most likely developed and sourced from a single supplier, which increases the dependency and relevance of module suppliers significantly. To find module suppliers with the 'right' resources, therefore, symbolizes a critical success factor for companies. The analyses of three leading OEMs from different four wheel vehicle industries will be used to identify supplier

competences for module developments. Thereby, this paper tries to answer the following research questions:

*Which supplier characteristics are critical for module developments with suppliers?
How to integrate suppliers in module developments in accordance to their supplier characteristics?*

In order to answer the introduced research questions, this paper gives a short literature review, which outlines the theoretical background of the topic. In the following, the paper will present the results of the three case studies to identify competence criteria for module suppliers. Based on the findings, a practical oriented model will be developed and provide guidance on how suppliers should be integrated in module development in accordance to their competences. Thereby, this paper adds to relational view as well as helps practitioners to prevent potential supplier risks.

4.2. Theoretical Background

4.2.1. Suppliers as module developing resource

A modular product structure represents a type of product architecture, which follows the idea that design and components are shared across different products and product families by introducing modules and platforms as well as part commonality (Halman et al., 2003; Utterback & Meyer, 1993). The significant level of standardization and flexibility enables companies to improve production and procurement performance by for instance leveraging technologies into new markets with reduced per-unit costs (Frattini, Bianchi, Massis, & Sikimic, 2014; Meyer & Mugge, 2001). The decoupling of modules enables efficient and effective outsourcing of development activities, so that external resources like suppliers can be integrated more easily (Baldwin & Clark, 2003; Baldwin & Von Hippel, 2011; Nepal et al., 2012; Sako & Murray, 1999). Consequently, a modular product architecture enables the transfer of certain value-adding tasks to upstream suppliers (Doran et al., 2007; D. Ford, Gadde, Håkansson, & Snehota, 2003). In accordance to Wagner and Hoegl (2006) the interest of buying firms to integrate suppliers can differ between know-how projects and capacity projects:

- Know-how projects relate to high innovative products with firms' intention to utilize the specialized technical knowledge of suppliers. Suppliers get, therefore, responsibility for more critical and comprehensive modules or systems.
- Capacity projects have the intention to compensate shortages of internal R&D resources or to increase firms R&D flexibility. Since the buying firm defines interfaces in regards to product and task, the involvement of suppliers is limited when it comes to time and scope.

Applying relational view to both interests, suppliers need relevant and complementary resources to add to development activities of the buying firm (Dyer & Singh, 1998). Supplier competences are of highest relevance for successful supplier integration in NPD projects (Handfield et al., 1999). Specifically, module developments are seen as highly critical, since a modular product architecture combines a high level of complexity by containing technical, supply chain and service aspects (Novak & Eppinger, 2001; Salvador et al., 2002b). Thus, module suppliers need specialized resources (Doran et al., 2007; Momme & Hvolby, 2002; Wolters,

2002). For example, modularization brings high technical complexity (Handfield et al., 1999; Wasti & Liker, 1997), which requires suppliers to have advanced development flexibility, module understanding and engineering competences (Oh & Rhee, 2010). Therefore, suppliers contributing to module development activities in NPD need to provide advanced capabilities, which extend the profile of a single component supplier (Monczka et al., 2000; Wognum et al., 2002). Two risk dimensions illustrate the need for sophisticated supplier competences in regards to module developments, namely (1) technical supplier risk and (2) supplier performance risk (Handfield et al., 1999):

- Technical risk related to the extent to which a supplier is able to provide the desired technical functionality and performance (Handfield et al., 1999). For example, a module can contain a significant number of parts and functionalities, which would need to be developed and managed by the module supplier.
- Performance risk is associated with the threat that suppliers are not capable of executing the assigned task, which would result in bad performance of the supply chain (Wagner & Bode, 2008). For example, suppliers could fail to adapt to technological or product design changes which could have detrimental effects on the customer's costs and competitiveness (Zsidisin & Ellram, 2003).

Both technical as well as performance risk become more crucial with increased importance and reliance on the supplier input (Giunipero & Eltantawy, 2004). Next to potential risks associated with supplier integration, buying firms can also realize significant benefits by integrating capable suppliers (Handfield et al., 1999). For example, selecting the right supplier can lead to an increased reliability of the module, so that the same module can be reused in the design of multiple products over time. Consequently, suitable module suppliers need to have a special profile of qualifications, which covers technical and performance capabilities.

4.3. Method and sampling

To explore supplier competences for successful module development within its real-life context (Yin, 2013), we have chosen a multiple case analysis which is explicitly applicable for purchasing related research (Stuart et al., 2002). Case analysis allows the focus on cause and effect relationships by asking for how and why (Yin, 2013), which enable us to capture the motivation as well as the perception of supplier competences. To ensure comparable results, we applied the replication logic, so that all cases are analyzed in the same standardized manner (Yin, 2013).

Our unit of analysis is the original equipment manufacturer (OEM) perspective. In all cases central functions with global responsibilities, for example for a specific product group, were the point of analysis. We selected three leading OEMs from different four wheel vehicle industries namely automotive, agricultural equipment and rail vehicles. Even though product structures are similar, the case industries show significant differences in some general characteristics like production volumes and product life cycles. Therefore, the focus on four wheel vehicle industries allows a cross-industrial analysis with industry and product differences. Please find in table 11 some key characteristics of the selected case companies.

Table 11 - Selected companies and their key characteristics

Company Label	Industry	Turnover Category in m Euro ¹	Number of employees ¹	Ownership	HQ Location
M1	Rail	5,000-10,000	>10,000	Publicly traded	Canada
M2	Agricultural machinery	5,000-10,000	>10,000	Publicly traded	North America
M3	Automotive	>10,000	>10,000	Publicly traded	Germany

¹The turnover and number of employees are given in categories to guarantee anonymity

To overcome common weaknesses of case analysis in form of external validity (Cook et al., 1979; Kidder & Fine, 1987) and the threat of paradox sampling (Kaplan, 1964), we have selected our research sample based on two principles: theoretical sampling and criterion sampling. Following theoretical sampling, we have limited the sample to companies, which produce tangible products focusing on four wheel vehicle industries (Eisenhardt & Graebner, 2007). We concentrated on tangible products, since research has shown that 85 percent of companies acting in a producing industry involve suppliers in their product development projects (Roberts, 2001; Wagner, 2009). Moreover, previous research has reported a high level of modularity for four wheel vehicle industries (Gavioli, 2005; Mikkola, 2003; Pandremenos, Paralikas, Salonitis, & Chryssolouris, 2009). Taking both dimensions into account, we acknowledged the four wheel vehicle industries as information rich cases.

Second, we have applied a criterion sampling approach, which increases the probability to select information-rich cases that highlight the issues under study significantly (Patton, 2005). Thus, we considered multinational industry leaders for each of the industries. We assume that industry leader have a reasonable firm size presenting a sufficient level of maturity, professionalism, market position and resources to successfully employ product platform architecture and supplier integration. We used the parameters of number of employees, revenue and market share as indication for industry leadership.

4.3.1. Data collection

Within the each case company, individual expert interviews were realized, so that the data could be gathered in a moderate way of openness and structure (Lamnek, 2002). Detailed instruments included face-to-face and telephone interviews in combination with archival data from the internet. All interviewees were employees with a significant level of involvement in new product development activities like product development engineers, which allowed a reliable overview of the analyzed organization. To represent the variety of perspectives relating to supplier integrations in module developments, 22 interviews were conducted at case companies. The selection of individual interviewees within the chosen case companies followed the approach of seeking ‘intensity’ (Miles & Huberman, 1994) which looks for intense but not necessarily extreme manifestations of the phenomenon under study (Marshall & Rossman, 2014). As the supplier selection involves many stakeholders and especially engineering and purchasing within a buying company (Pearson & Ellram, 1995), it is advisable to include more than one business

function in the target group of the proposed study (Sánchez-Rodríguez & Martínez-Lorente, 2004). Thus, this research included representatives from the purchasing and engineering function as interviewees. The unequal split of interviews across the case companies is grounded on a sequential narrowing of the analysis focus on a case-by-case basis. Thus, a higher number of interviews were conducted in case M1 in order to collect comprehensive input and to identify most relevant aspects. Within case M2, the focus was further itemized, so that even a lower number of interviews in M3 allowed the comparison between the cases. Table 12 illustrates the split of interviewees along the case companies as well as the functions.

Table 12 - Selected companies, functions and list of interviews

Company Label	Interviewees		
	Purchasing	Engineering	Total
M1	2	14	16
M2	2	2	4
M3	1	1	2

Data for the study was collected through semi-structured (Rubin & Rubin, 2011) or standardized open-ended (Patton, 2005) interviews. Thereby respondents have the chance to express their comments and perceptions openly which can lead to in-depth data and a ‘thick description’ (Geertz, 1973). The interview protocol consisted of six main sections and is primarily based on the assets of successful platform developments as proposed by Robertson and Ulrich (1998). The first section aimed at obtaining general information about the interviewee as well as his background. Sections two, three, four and five represent the four assets for successful platform developments namely process, component, knowledge and relationship (Robertson & Ulrich, 1998). Section two stands for process and investigates ‘how’ suppliers are integrated for module developments. The third section refers to component and looks at the product part designs as well as the fixtures and tools needed to make them. Fourth, knowledge signifies the knowledge about product technologies and design know-how. Section five stands for relationship which characterizes relations among team members and well as interfirm activities. Section six reflects on positive and negative experiences of the interviewee. Thereby, we aimed to identify key factors for successful supplier integrations. A shortened version of the interview protocol can be seen in Table 13.

To ensure reliability and external validity, a second set of data was collected at a purchasing conference of a leading German automotive OEM, who is a direct competitor to case company M3. Thereby, a random sample as a second independent source was collect to support the reliability of the case findings (Ellram, 1996). Conference participants were drawn from the OEM and suppliers of the OEM. In total, the input from 20 random participants could be compiled for this paper. 12 responses originate from the OEM and 8 from representatives of suppliers. Suppliers of the automotive industry often supply simultaneously to multiple automotive OEMs, which thereby give insights to the industry understanding. Moreover, due to similarity of components, automotive suppliers also work with other industries like agriculture equipment and rail vehicles. Furthermore, these industries all increasingly focus on the development and use of

modular product architectures that can function as a platform for their product family (Gavioli, 2005; Hofer & Halman, 2004; Zirpoli & Becker, 2011). By this means, the group of participants can be considered to be independent but supplementary to the selected case company sample.

Looking at the data collection, the following three steps were applied: First, participants were given a short presentation introducing the topic of supplier integration for module developments. Second, a panel discussion between researchers and the audience was initiated addressing the questions mentioned in Table 14. Third, during and after the discussion, participants documented their opinion on the topic in reference to the questions in a provided questionnaire. The addressed questions as outlined in Table 14 were based on the theoretical foundation of supplier integration approaches (Petersen et al., 2005) and assets for module developments (Robertson & Ulrich, 1998).

4.3.2. Data analysis

To analyze and transcribe the collected data, we applied a three step approach of data reduction, data display and conclusion drawing (Miles & Huberman, 1994). First, data reduction started with the decision of research questions, initial research framework, cases selection and data collection methods. Within the decided setting, conducted interview transcripts as the main source of evidence were read several times to increase familiarity with the topic (Miles & Huberman, 1994). Next, coding of the transcribed interviews fostered the data reduction. The coding 'start list' (Miles & Huberman, 1994) encompasses the concepts which in our case were grounded on literature and theory (Araujo, 1995) in form of the relational view (Dyer & Singh, 1998) and the assets of successful platform developments (Robertson & Ulrich, 1998). To reduce and refine information, the coding process was repeated for two times.

Second, data was displayed with the attempt to draw conclusions from the 'clusters'. Accordingly, the coded data was transferred into a large 'thematic conceptual matrix' (Miles & Huberman, 1994). Within the matrix, cases can be contrasted and content can be divided by themes and their categories. As a result interview statements could be 'clustered' under individual labels representing a specific theme or typology.

In the final step of data analysis, patterns of the utilization and perceptions on supplier characteristics were detected. Thereby, the three dimensions of technical, organizational and relational factors could be identified as individual labels.

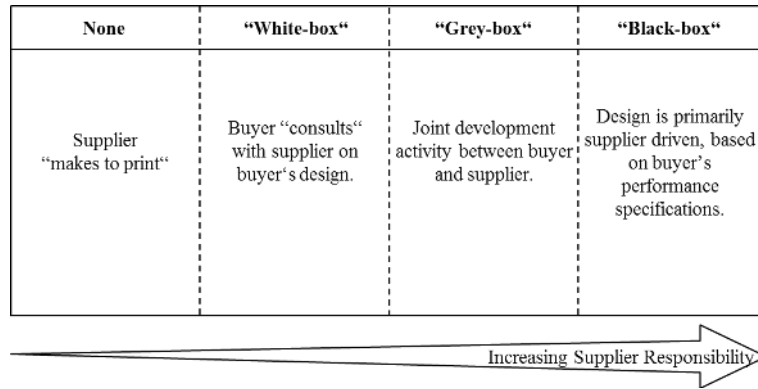
We analyzed the responses from the purchasing conference by following a three step approach again (Miles & Huberman, 1994). First, we reduced data while defining a framework with areas of interest. Second, we checked the stated competences and grouped them in a matrix (Miles & Huberman, 1994). Third, we identified clusters representing key labels. Afterwards, we compared the identified categories with labels from the cases. In the next step, we evaluated the numerical result from the conference and calculated the average per competence. Thereby, we got an indication for each competence and could compare it with the outlined relevance from the cases.

4.4. Results

To ensure comparability between the three cases, we first checked the motivation to integrate suppliers of all case companies. The underlying motive can influence the way of acting with

suppliers as described in the supplier integration model by Petersen et al. (2005). The model introduces 4 steps of interacting with suppliers, while each of the four steps comes with a different level of supplier involvement (Figure 1).

Figure 8 - Model of supplier integration



Source: Petersen et al. (2005)

The first step ‘none’ refers to no supplier integration. The supplier builds to print by bringing no value adding input with very limited development responsibility. ‘White box’ integration stands for an informal integration of suppliers, when suppliers give advice on designs relating to limited responsibility. Grey-box integration describes a structured and formalized integration of suppliers for joint development activities. In this case, suppliers take an equal stage of development responsibility. Black-box integration assigns the highest development responsibility to suppliers. In this scenario, suppliers develop components individually in accordance to the specifications of the buyer.

Grey-box and black-box integration approaches address reasonable or major development responsibility to suppliers. In contrast, the other 2 integration steps symbolize limited supplier integration by leaving the main development responsibility to the buying firm. All cases mentioned in this paper apply grey-box and black-box integration, so that suppliers are integrated for value adding activities with high development responsibility. In accordance with the defined interests from Wagner and Hoegl (2006), case companies include suppliers to first rent detailed technical knowledge and second to reduce development complexity. Thereby, technical and organizational factors as well as buyer-supplier relationship aspects show high relevance by driving successful module development with suppliers. Technical factors stand for the technical understanding of the suppliers. Organizational factors discuss operative and managerial aspects within the organization of the supplier. Last but not least, the buyer-supplier relationship talks about soft and inter-personal aspects, which were highly emphasized by all case companies. Table 15 provides an overview of key findings along the three identified dimensions.

4.4.1. Technical factors

Our results highlight that technical knowledge is a crucial aspect for module suppliers, since suppliers need to be able to develop the assigned part from a technical point of view. However, technical knowledge differs in accordance to the development responsibility of the supplier. In accordance to Petersen et al. (2005), results show difference of knowledge between joint development, grey-box integration, and self-contained developments by suppliers, black-box integration.

Looking at joint developments, suppliers are seen as technical experts, who bring specialized technical knowledge to the development project. Thus, a supplier should embody high expertise regarding the technology that is linked to the development. Especially for complex modules or new technologies, suppliers are expected to add special technical knowledge, whereas the OEM remains the system integrator. To give an example, one case company reported from a development project in which a module was developed representing a new, highly innovative technology. For both, the case company and the supplier the technology was totally new. Thus, both parties had to work closely together, while learning from each other during the project. Due to the high complexity and the high investment level of money and resources, the case company needed a value adding partner, a technical expert, for the project. The case company pointed out that the level of detail and in-depth knowledge could only be provided by a supplier with specialized technical knowledge on the component level. The case company itself acted as a system integrator and ensured that the new develop module fit the final end-product. Thus, the supplier and the case company acted in symposia together.

In case a supplier develops a module by himself, the technical understanding by the supplier should not be limited to the module itself. Due to multiple physical and functional interfaces with adjacent product parts, black-box module suppliers should have interface knowledge and architectural understanding. Thereby, module suppliers can ensure the fit of the module in the customers' end product. One case company described the occasion, when one of his black-box suppliers approached another supplier of a related module to highlight potential problems and challenges related to the interface between both modules. Thereby, a problem relating to customers overall end-product was prevented. Architectural knowledge allows suppliers to obtain a system integrator role, so that the buying firm can allocate resources to core activities. Black-box projects were mentioned as not primarily innovation driven, but more capacity oriented, so that the case companies could focus on core elements. Therefore, suppliers for black-box integration need to act as a technical specialized and system integrator.

4.4.2. Organizational factors

In addition to technical characteristics, all cases emphasized the relevance of supplier attitudes relating to organizational competences, which represent firm characteristics and managerial competences.

Firm characteristics, namely financial stability and geographical proximity to the buying firm, were declared as necessities for successful developments by the cases. Due to the fact that module developments are associated with significant investments from both the buying and

supplying firm, suppliers have to bring a robust level of financial stability. Otherwise, there is the threat that suppliers accept a module development, but cannot cope with the needed human and financial resources. If a supplier goes out of business within a module development, it causes significant trouble and costs for the OEM. The long-term orientation of module projects and the impact on various product families point toward the high criticality for buying firms.

Geographical proximity was stated as another crucial aspect with specific focus on grey-box collaboration. If a module is jointly developed with a supplier, presumably supplier representatives need to frequently interact with counterparts from the buying firm in person. Thus, geographical proximity of the supplier can be a critical factor, so that personal meetings can be easily arranged. Moreover, proximity implies a similar cultural background which can be another success factor for joint developments. When the supplier has to develop a module self-contained proximity plays a subordinate role, as interaction between suppliers and buyers is less frequent.

Managerial aspects build the second dimension of organizational factors that appear to be enabling factors for suppliers to fulfill project targets like quality levels, in-time delivery and project deliverables. Managerial aspects can be broken down in engineering capabilities and procedures.

Module suppliers need engineering competences as well as sufficient and dedicated resources for product development projects. A supplier might have the technical understanding of a module, but the capability to develop a new innovative technology is depending on the engineering capabilities of the supplier. Accordingly, suppliers need to be able to provide adequate degree of engineering support. For example, suppliers need engineers, who are proficient with the latest technologies who can respond quickly to technological changes. However, to transcribe the competences, suppliers need sufficient engineering resources that can be allocated to development projects. If the supplier embody great engineering abilities, but has limited number of people who can implement knowledge, the operative employment of engineering capabilities will be limited. For example, one case company mentioned that within one development project 2 development engineers from his site were involved, whereas the supplier had 30 development engineers working on the project. The buying firm defined the interfaces and was safeguarding the development project, while the specialized supplier provided comprehensive technical knowledge to develop the high complex module. Thus, module suppliers need to have engineering resources from a technical and operational point of view.

As a substitute to competences available at the supplier, case companies report the case that module suppliers and especially black-box suppliers shift activities to their own supply base as pool of resources and expertise. Value creation by sub-suppliers, thereby, increases and resource availability at the first-tier supplier level rises. Nevertheless, first-tier suppliers need to manage the integration of upstream resources in form of n-tier suppliers.

To utilize internal as well as supply chain resources most efficiently, case companies highlighted the relevance of mature processes at the supplier. Special emphasis was indicated for NPD and quality management processes. From the case company understanding, the NPD process is supposed to facilitate cross-functional working like concurrent engineering in a

systematic and structured way. Thereby activities and principles are comparable and consistent, so that impulsive and nonsystematic actions by suppliers are prevented. This allows case companies to integrate suppliers in their product development activities more easily, since activities and processes can be aligned. Moreover, case companies perceive quality processes as safeguards of a standard quality level by the suppliers. An example from one case company illustrates the relevance of processes with special emphasis on cross-functionality and quality. Within a new product development project of a complex module, the case company wanted to integrate a new supplier. Until this point, the case company had only one supplier, since the module had a significant complexity level and knowledge requirements. To increase competition, the case company has chosen to integrate a new supplier who had no previous relation to the company. During the development project, the case company requested parts for quality and geometry testing from the new supplier. The delivered components had bad quality, so that the parts were not applicable for testing purposes. The case company investigated the cause of the bad quality and it turned out that the supplier had no dedicated quality manager as well as standardized process for quality testing within new product development projects. Due to the lack of cross-functionality and process existence, components were not previously checked by the supplier which caused the problems. As a result, the project costs increased and the project had difficulties to meet the anticipated time line.

4.4.3. Relationship factors

All cases highlighted that relationship factors are the third driving factor for successful module developments with suppliers, since people and the buyer-supplier relationship are considered as determining factors for successful execution of module development projects. In detail, trust to the supplier, proactivity by the supplier and willingness to adapt to customer needs by the supplier could be identified as key factors for success.

Trust to the supplier is referring to the belief of the buying firm that the supplier can successfully handle the addressed task. The aspect of trust was stressed, since case companies explained that suppliers tend to be overconfident in their abilities in order to make business. Therefore, it is sometimes a challenge to rely on suppliers, especially by taking into account that a module development represents a high criticality and relevance for the buying firm. In consequence, buying firms have pinpointed to trust a supplier plays a critical role. Especially in regards to trust, the related people play a special factor. How well people relate to each other and interpret their role within the project was stated as potential differentiating factor.

Proactivity and willingness of adapting to customer needs are particularly relevant for module developments. To give an example, one of the case companies described a project, where the OEM and the supplier entered a development project for a totally new technology. The goal was to create a new technology which would have given both parties a competitive advantage. The case company reported that the supplier took a driving role within the project by showing proactively the will to reach the anticipated goal together with remarkable learning efforts by taking significant responsibilities. The supplier significantly identified himself with the project and considered the project relevant and critical for his own reputation and business.

Consequently, the supplier showed great initiative for instance he suggested proactively improvement ideas to the buying firm. Moreover, the supplier offered access to his newest development activities and provided his best development resources to the project. The supplier made significant sacrifices like taking development costs beyond agreements with the intention to succeed with the development project. All in all, the supplier considered the project as his own and did a lot to ensure success.

In order to validate the findings from the case companies, we compared the responses from the case findings with findings collected at a purchasing conference of a global automotive OEM. The cross-checking of findings with responses from the separate purchasing conference indicate that major findings of the case companies are supported. The collected key words show a high similarity to the key findings from the cases. Moreover, looking at the numerical indication, all competences for module developments have a value above 3.5 out of 5, which underlines the relevance highlighted by the case companies. Table 16 summarizes the major findings from the conference participants. The cross-checking gives reason to believe that a replication of the case studies would create similar results, which supports the reliability of the case data (Ellram, 1996).

4.5. Discussion

Within this study, we follow relational view and argue that suppliers need relevant resources to add value to activities of the buying firm (Dyer & Singh, 1998). Assuming a nested modular product architecture representing a product architecture that consists of modules that, by themselves, can be further broken down into components, the contribution of each supplier can differ accordingly (Von Hippel, 1988). As a result, if a company wants to allocate the development of a supplementary module, like an engine, to a supplier, the supplying firm would need sufficient technical and managerial capabilities to execute the development. Otherwise, the anticipated module would cause problems in the end-system resulting in low NPD project performance for the buying firm (Zsidisin & Ellram, 2003). To identify critical supplier competences for module developments, we follow the concept of relational rents (Dyer & Singh, 1998). To evaluate potential drivers for relational rents in regards to module developments, the findings of the case studies are discussed along three determinants of relations rents.

Supplier characteristics are the primary focus of this study. Therefore, relation-specific assets are excluded from the analysis as those do not represent primarily supplier related aspects. For example, the volume of interfirm transactions is significantly influenced by buying firms. We, therefore, excluded relational specific assets from our perspective of analysis. In consequence, knowledge sharing routines, complementary resources and effective governance illustrate the level of discussion:

- Knowledge sharing routines related to absorptive capacity of the supplier, as well as the transparency and consistency of information exchange.
- Complementary resources stand for resources like competence and knowledge that is complement to the desire of the other relationship partner.
- Effective governance represents enforcement mechanisms within the relationship.

In the following, specific competences related to module suppliers are discussed along the three determinants of relational rents.

4.5.1. Knowledge sharing routines

Module development requires suppliers to potentially coordinate simultaneous development tasks related to higher responsibility and work load (Von Hippel, 1990). Accordingly, failure risk and complexity increases, since different components have to be integrated into one final module (Olausson & Berggren, 2010; Tatikonda & Rosenthal, 2000). To ensure successful coordination of components, a module supplier should have stable and consistent processes in place (Eppinger & Chitkara, 2006; Henderson & Clark, 1990). In detail, modules suppliers have to either deal with development responsibilities solely by their own or suppliers can share development activities with its supply base. In case, the whole module is developed with in-house resources of the supplier, module suppliers need next to technical competences also a process landscape which is capable to cope with related complexity. Therefore, suppliers need a reasonable management concept throughout the whole process chain including project and quality management processes. From the conducted case studies we learn that NPD process is supposed to facilitate cross-functional working like concurrent engineering in a systematic and structured way. Thereby activities and principles are comparable and consistent, so that impulsive and nonsystematic actions by suppliers are prevented. Thus, project management skills represent an essential capability for complex NPD projects (Schiele, 2010; Schiele, Contzen, & Zachau, 2008). Especially, black-box suppliers are considered to have mature processes by the case companies. To lead a module development such as a global module development project is a complex activity which becomes more challenging with every new stakeholder (Eppinger & Chitkara, 2006). Therefore, module suppliers, especially black-box suppliers, should have strong project management capabilities to manage and monitor the project in terms of milestones, technical work quality and cost. Case companies indicated quality processes as safeguard to ensure standard quality level by the suppliers. Accordingly, certified quality management is a suitable method for designing complex products (Clark & Fujimoto, 1991). Following quality management, suppliers can satisfy customer by ensuring quality at each stage of the product development process with less time in development, fewer start-up problems and lower start-up costs (Akao & Mazur, 2003). Pekovic and Galia (2009) argue that a company in a manufacturing industry should scout for suppliers with mature quality management systems.

All case companies outlined that module suppliers and especially black-box suppliers can shift activities to their own supply base as pool of resources and expertise. In this case, the module supplier has to coordinate development activities of his supply base during the NPD process (Sanchez & Mahoney, 1996; K. Ulrich, 1995). Module suppliers, therefore, need a supplier management approach which comes with supplier selection and supplier development processes as well as procedures for early integration of suppliers. All cases highlight that both grey-box and black-box developments are associated with higher process complexity for module suppliers, but due to the higher responsibility and higher complexity, black-box suppliers have a higher urgency

for process maturity. In general, module suppliers should have the following managerial competences:

- Cross-functionally driven new product development process
- Mature and stable quality management process
- Active sub-supplier integration capabilities

4.5.2. Complementary resources

Modular product architecture enables the decentralization of product development activities (Sanchez & Mahoney, 1996; K. Ulrich, 1995), so that companies can delegate a large share of the actual development work to suppliers (Frigant & Talbot, 2005; Gadde & Jellbo, 2002). In accordance, suppliers can take a coordinating role within the development of modules, which can mean responsibility for the development process and coordination across involved subsystem developers (Pittaway, Robertson, Munir, Denyer, & Neely, 2004; Prencipe, 2003). The complexity of modules, however, requires a sophisticated technical understanding by suppliers that can be divided in component knowledge and architectural understanding (Henderson & Clark, 1990; Takeishi, 2002). Looking at the results, case companies apply a similar distinction of knowledge, which underlines the relevance of component and architectural knowledge within supplier and buyer collaborations. Component knowledge relates to design and manufacturing of single components or modules (e.g., the fuel tank) for the final product of the buying firm (e.g., an automobile). Architectural knowledge, on the other hand, stands for the capability to integrate, manage and manufacture tasks beyond the module level. Architectural knowledge is a specific aspect for module suppliers, since mainly in modular product designs different subsystems are linked together in a well-functioning end-system (Henderson & Clark, 1990). Interfaces are an important aspect as those combine the decoupled modules to a functional end-product. Thus, understanding and developing physical and functional interfaces between modules build a distinctive characteristic of module suppliers.

Cases have shown that the component and architectural knowledge potentially differs in accordance to the integration approach. Black-box suppliers need a technical understanding around their module and of interfaces, since the module has to fit the final product of the buying firm. Due to multiple physical and functional interfaces with adjacent product parts, general interface understanding represents a key success factor for black-box suppliers. All in all, potential module supplier should bring the following competence in regards to complementary resources:

- Component knowledge
- Architectural knowledge

4.5.3. Effective governance

Modular product architectures are associated with vertical and horizontal inter-organizational relationships with special emphasis on interaction patterns within NPD projects (Campagnolo & Camuffo, 2009; Henderson & Clark, 1990; Muffatto, 1999). For example, modularization requires a certain level of collaboration in order to reduce interface constraints. This suggests that successful outsourcing involves cooperative buyer-supplier relations (Jacobs et al., 2007). To

overcome potential barriers between supplier and buying firm, Ragatz et al. (1997) suggest a broad concept call relationship structure, which considers risk/reward sharing agreements and joint agreement on performance measurements. To ensure consistent and effective collaboration, both parties should be willing to enter such agreements. Interviewed companies have strongly indicated that suppliers need to be willing to invest resources on an equal level ideally in form of a preferred customer status (Schiele, 2012; Schiele et al., 2012). Cases indicated that mutual agreements can set boundaries for collaboration, but communication between parties fosters successful operationalization in NPD. Frequent and operative communication with the NPD team of the buying firm can be a critical factor in order to exchange and align knowledge (Swink, 1999; Wasti & Liker, 1997). For example, to solve potential interface constraints a team problem solving approach with functional specialists from all stakeholders can be an appropriate approach (Van de Ven, Delbecq, & Koenig Jr, 1976).

The case companies have indicated that geographic proximity can be a key point that allows frequent in person meetings. Thereby, communication and operationalization is fostered which can help to successfully collaborate in joint developments. Such as being member of the same regional industry cluster can help to engage in collaborative activities (Steinle & Schiele, 2008). For black-box developments of suppliers, case companies indicated that mutual agreements have to be formulated at the beginning of the project. However, after the beginning frequent meetings and geographic proximity are less relevant. Effective communication is not only key between the supplier and the buyer also internally suppliers should apply cross-functional collaboration. For example, best practice firms in NPD performance explicitly support their people and drive team communication (Barczak, Griffin, & Kahn, 2009). Consequently, module suppliers should have communications settings across functional boundaries like cross-functional development teams. Case companies mentioned that concurrent engineering in a systematic and structured way presents curial competences, which is the result of a collaborative internal working style at the supplier. Based on the previous observations, we argue that module suppliers should be evaluated along the following criteria in regards to people and relationship resources:

- Resource allocation
- Preferred customer status
- Geographical proximity
- Internal cross-functional collaboration

4.6. Conclusion

In reference to the formulated research questions, this paper identified supplier characteristics for module developments and developed a framework for supplier roles in module developments. Based on the identified gap in literature that supplier characteristics of collaborations is less intensively researched (Gassmann et al., 2010; Roy et al., 2004), this study fills the gap by recognizing supplier characteristics and providing supplier roles for buyer-supplier collaborations. In detail, the analysis identified significant theoretical and practical implications. On the theoretical site, understanding of relational view could be further expanded. Looking at

the practical contribution, this study provides practitioners with a model and evaluation scheme helps to find the best interaction pattern for each supplier.

4.6.1. Theoretical implications

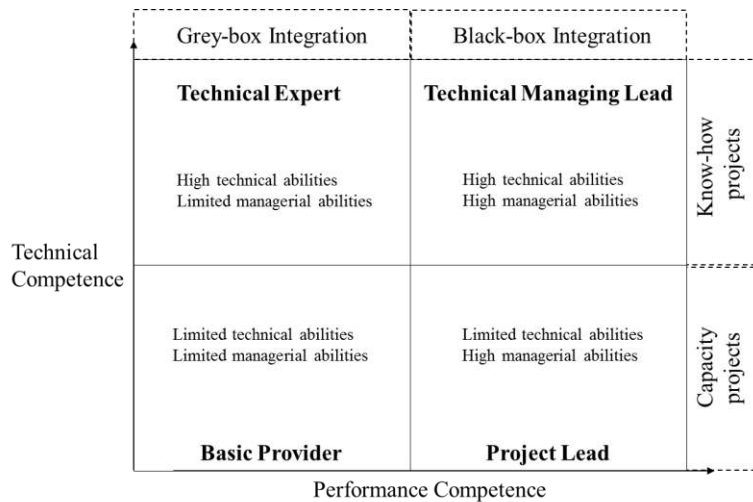
First, this paper contributes to relational view by focusing on successful operationalization of relation rents between suppliers and buyers for module developments. As described by relational view, companies rent resources from suppliers in order to create competitive advantages. Likewise, we learn from literature that modular product architecture foster those relational rents between buying firms and suppliers. However, the kind of competences needed by suppliers in order to be a valuable and interesting source of rentable resource within a modular architecture was not field of research yet. Thus, this study is the first that identifies supplier characteristics for module developments with suppliers. In detail, the paper implies that suppliers need mature processes for NPD, quality and sub-supplier integration. Moreover, technical competence especially component and architectural knowledge as well as collaborative working style are also considered to be crucial along the dimensions of knowledge sharing routines, complementary resource and effective governance (Dyer & Singh, 1998).

Second, this study adds to relational view by illustrating that different interaction levels between suppliers and buyers require different levels of supplier characteristics. In detail complementary resource, knowledge sharing routines and effective governance differ in relation to possible roles of module suppliers. Based on the integration model of Petersen et al. (2005), this study identified that joint collaboration, grey-box integrations, have different implications for suppliers, than a self-contained black-box development by suppliers. In detail, grey-box suppliers need to bring component knowledge, whereas architectural knowledge can be limited. In contrast black-box suppliers should offer both knowledge types. Similarly, mature processes in regards to project, quality management and sub-supplier management are considered to be more relevant for black-box suppliers. Considering the introduced supplier risks from Handfield et al. (1999), risks levels and associated supplier competences differ in relation to the supplier integration approach. Findings imply that buying firms need to differentiate and define the role of a supplier first by then looking for a suitable supplier. In consequence, relational view was further developed, as it was shown that resources differ in relation to the integration pattern between suppliers and buyers.

Based on the finding that different supplier interaction levels require different supplier characteristics in order to prevent supplier risks and to realize potential benefits (Handfield et al., 1999), four possible supplier roles for successful supplier collaborations could be formulated. Following Handfield et al. (1999), we claim that a grey-box or black-box integration can have either know-how focus or capacity emphasis. Accordingly, our findings underline that the main types of supplier integrations projects are technical or capacity oriented as described by Wagner and Hoegl (2006). Bringing the two projects types, the two integration approaches and the identified supplier characteristics together, four possible roles of module suppliers can be identified namely (1) basic provider, (2) project lead, (3) technical expert and (4) technical managing lead. The competence level of suppliers is split in accordance to the two risk

dimensions namely technical and performance risk (Handfield et al., 1999). Thereby the model provides a systematic approach to match the project type with available supplier characteristics by providing an answer on which supplier integration approach fits best which supplier. Figure 9 illustrates the model in detail.

Figure 9 - Supplier roles for module developments



Source: Own illustration

Performance competence represents the orientation of one axis of the model looking at the performance risk. In association with Handfield et al. (1999), we argue that high managerial or performance competences point toward a low performance risk level of potential module suppliers. In other words, with mature processes, strong business knowledge as well as good people and relationships resources, the supplier can most likely perform self-contained module development activities from a managerial perspective. Therefore, we argue that supplier's ability to handle module development tasks is indicated by the performance competence. Consequently, buying firms should use the performance indicator to determine the scope of supplier responsibility. To give an example, a supplier with a low managerial score will not be able to successfully develop a module, since the company lacks the required process maturity level. Aiming for successful operationalization of relational view, buying firms should exactly know which activities the supplier can perform and which not. It has to be mentioned that we assume that a supplier who is evaluated for modular development activities, anyway is a well performing supplier. Therefore, low performance competences are not associated with low operational performance, but imply lower entrusting of activities by the buying firm. This means, in case a modules supplier shows lower performance competences, the buying firm should take an approach with higher control and responsibility for itself, a so called joint development or grey-box integration (Clark & Fujimoto, 1991; Petersen et al., 2005). In contrast, a module supplier with high performance competences will most likely have the toolkit to work in a self-contained

or autarkic setting with an autonomous ‘black-box’ role. For that reason buying firms should check the project management expertise of suppliers. For example, having an experienced project manager on the supplier selection team could help to access the project management proficiencies of suppliers.

Technical competence stands for the second axis of the model and represents technical knowledge of a supplier. The technical knowledge includes component and architectural knowledge of the supplier. In accordance to technical risks described by Handfield et al. (1999), suppliers with limited technical understanding will have difficulties to execute development activities associated with complex components. Technical competences, therefore, characterize the second fundamental supplier characteristic, when it comes to project goals and integration approaches.

4.6.2. Managerial implications

Along the theoretical contributions, also practical contributions can be drawn from the findings of this study. On the one hand, interaction patterns between suppliers and buyers could be conveyed from the potential roles of suppliers. On the other hand, based on the findings an evaluation scheme is proposed that helps practitioners to make better sourcing decision for module developments.

First, the formulated supplier roles exemplify four interaction patterns for buying firms. In the following, the four patterns are described in more detail:

(1) Suppliers falling in the category basic providers are considered to have limited resources in regards to technical and managerial competences. Nevertheless, buying firms can integrate those suppliers for clearly defined tasks and products with a simplified structure. An example would be a module with industry standards which need to be produced in an effective and cost efficient manner. As described by a case company, one supplier had significant more engineers working on the project in comparison to the buying firm. Thereby, the buying company could use supplier resources for his aims. In accordance buying firms can use basic providers as a source of resources, when capacity shortages need to be compensated.

(2) Project lead suppliers have a clear strength in managerial aspects, which make them a valid partner for buying firms within NPD projects. However, due to limitations of technical capabilities, suppliers operating as a project lead are more capacity oriented. Buying firms can allocate simple or supplementary module to the suppliers in order to reduce development and coordination complexity and to finally expose in-house resources. Since technical competences are limited, project leads take a more consulting or project lead oriented role. Nevertheless, due to the managerial competences, OEMs can allocate components with limited need for technical expertise as a black-box development to project lead suppliers.

(3) Technical experts are high potential tech-firms, which have a lack of managerial competences. An example could be a traditional family owned business with significant technical potential, but simultaneously organizational weaknesses. Complex and innovative technologies can be addressed by the supplier, but buying firms would need to assist with supporting activities

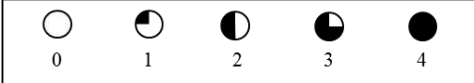
like project management skills. Due to the weaknesses, the buying firm will need to apply a joint development in order to support and assist the supplier.

(4) Technical managing lead represents a full capable module supplier who can execute developments in form of black-box developments. Technical and managerial resources are available and buying firms can use those organizations in order to create innovative products which can results in competitive advantages as described by relation view.

Second, in addition to describing potential interaction pattern with suppliers, this paper provides practitioners with guidance how to classify suppliers to the most suitable development role for the supplier. Thereby, this study helps practitioners to make better sourcing decisions for module developments. First buying firms should use the proposed criteria of module suppliers to assess potential module suppliers. Figure 10 shows a possible evaluation scheme that uses supplier capabilities, which were identified within this study, as evaluation parameter. For each capability, the buying firm can assess the competence level of a supplier on a scale from zero (very low) to four (very high). Thereby, managers from buying firms can get an overview of relevant supplier capabilities for module developing. In the given example, supplier A shows high knowledge sharing routines, high component knowledge and high governance structures. Only architectural knowledge is resented with a limited competence level.

Figure 10 - Example of evaluation scheme

Category	Capability	Competence Level
Knowledge sharing routines	New product development process	●
	Quality management process	●
	Sub-supplier integration process	●
Complementary resources	Component knowledge	●
	Architectural knowledge	○
Effective governance	Resource allocation	●
	Preferred customer status	●
	Geographical proximity	●
	Internal cross-functional collaboration	●



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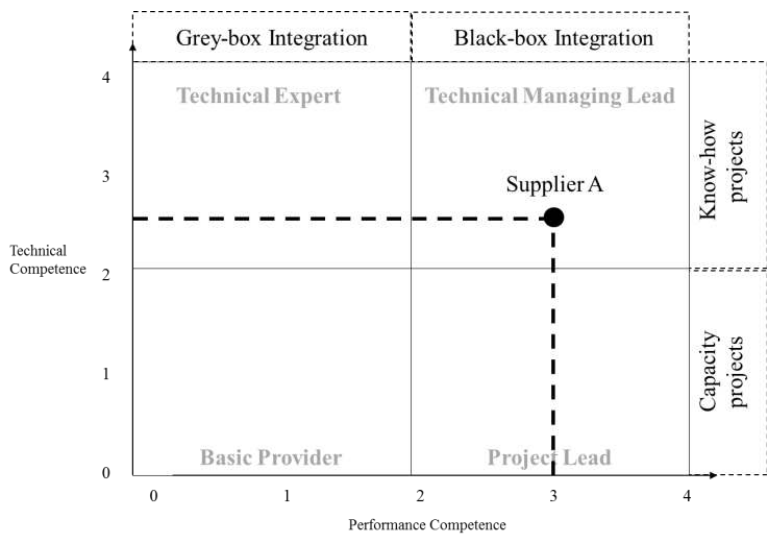
Source: Own illustration

Second, the buying OEM can use the assessment of each supplier capability to identify the best suited role for suppliers. Performance competence represented by one axis of the supplier model for module developments considers mature knowledge sharing routines like process and effective governance like people and relationships to ensure a good performance by module suppliers. In accordance, we take the average of knowledge sharing routines and effective

governance to determine the performance competence level of potential module suppliers. Following the given example, supplier A has an average score of three for both knowledge sharing routines and effective governance. As a result, the supplier has a total score of three for performance competences.

The second axis stands for technical competence and is supposed to represent the technical knowledge of a supplier. Since, technical knowledge for module developments includes component and architectural knowledge, the technical competence level is the average of component and architectural knowledge. Referring to the example, supplier A has an average of two point five for the technical competence.

Figure 11 - Supplier scoring and supplier role for module developments



Source: Own illustration

By using the same scale (zero to four) on the axis of the supplier role model, the results of the evaluation scheme can be used to illustrate the best role of a supplier. Thereby buying firms can get a visual indication which role a supplier can potential best fulfill. Taking on the previous example, Figure 11 demonstrates that supplier A shows potential to be a black-box supplier by contributing to knowledge driven projects. However, due to the limited architectural knowledge, the buying firm should consider if supplier A is capable to develop a module with a high number of interfaces by himself.

With the proposed supplier roles and the related evaluation scheme, this paper provides buying firms a tool to assess a supplier and to understand the most suitable interaction pattern with the supplier. As a result, buying firms can match the supplier role with their own requirements to make better sourcing decision for module developments.

Considering the supplier site, this study provides guidance which capabilities suppliers need to get focus on in order to get more development responsibility from their customers within module developments. To increase attractiveness, potential module suppliers should advance their

knowledge sharing routines, complementary resources and effective governance structures. By this means, suppliers might receive more development responsibility from customers.

4.7. Limitations and future research

There are limitations to the findings and conclusions of this study. First, we limited ourselves to three case companies from four wheel vehicle industries. While our theoretical sampling approach aid generalizability (Rosenthal & Rosnow, 1991), our findings may have limited applicability to other industries or service types. Second, while we study the buying site, we excluded the supplier perspective on the topic. Scholars of buyer-supplier relationships have acknowledged that a lack of dyadic responses is a limitation of research (Monczka et al., 1995; O'Toole & Donaldson, 2002). Therefore, this study might have a limited scope as the supplier perspective was excluded.

Based on the presented result, we would like to show some opportunities for future research. First, future research could apply an empirical analysis approach to investigate, if identified supplier characteristics differ in relation to the integration approaches of grey-box and black-box. Second, other industries could be included in future qualitative analysis. Thereby, potential industry or product related difference could be acknowledged. Third, the inclusion of suppliers would create a dyadic research methodology that would further advance the understanding of driving forces for buyer-supplier collaborations.

4.8. Appendices

Table 13 - Interview protocol (shortened version)

Section	Question module	Examples of questions
1	Introduction & personal information	<ul style="list-style-type: none"> • <i>What is your current position within your company?</i> • <i>How long do you occupy this position already?</i> • <i>How many years of work experience do you have in total?</i> • <i>Which function do you relate to?</i> • ...
2	Process	<ul style="list-style-type: none"> • <i>Can you please describe how you involve suppliers in product development activities?</i> • <i>Can you please describe how you involve suppliers in the development of modules / platforms?</i> •
3	Component	<ul style="list-style-type: none"> • <i>Why are you integrating suppliers on modular product structures?</i> • <i>Can you please explain on which areas of the modular product architecture you integrate suppliers?</i> • <i>Can you please explain how you manage interfaces between modules in regards to supplier integration?</i> •
4	Knowledge	<ul style="list-style-type: none"> • <i>What kind of skills and competences do suppliers need to be involved in your company as co-developer?</i> • <i>What kind of skills and competences do suppliers need to be involved in your company as module/system developer?</i> • <i>How do you deal with risk of reliance, e.g. if a supplier takes a system development role which so that the supplier knows more than you?</i> • ...
5	Relationship	<ul style="list-style-type: none"> • <i>Can you please explain why and under which circumstances you apply co-development (grey-box development) with a supplier?</i> • <i>Can you please explain why and under which circumstances you apply main development (black-box development) by supplier?</i> • ...
6	Experience	<ul style="list-style-type: none"> • <i>What is your experience concerning success factors of supplier taking the leading position of a module or system development?</i> • <i>Why has a system development by a supplier failed?</i> • ...

Table 14 - Guide for discussion and questions to be answered by participants

Section	Question module	Question
1	Supplier Integration approaches	<i>What competences does a supplier need to develop a module in collaboration with an OEM? What competences does a supplier need to develop a module independently from the OEM?</i>
2	Assets for module developments	<i>Please indicate your opinion about the following statements on a scale from 1 (strongly disagree) to 5 (strongly agree): In general suppliers involved in module development needcomponent competence (e.g. knowledge about design, material, specifications). ...mature processes (e.g. new product development and quality processes). ...knowledge capacities (e.g. sufficient engineering capabilities). ...interconnected people & relationships (e.g. internal collaboration preferred relationship).</i>
3	General information	<i>What kind of business are you working for? (OEM or supplier) What is your position at your company?</i>

Table 15 - Main findings per case

Perspective	Major Findings
Technical factors	<ul style="list-style-type: none"> • Suppliers need technical expertise on components, since complexity of products cannot be reflected by internal resources (M1, M2, M3) • Particularly suppliers for close collaborations are supposed to be technical specialists for their component/module (M1, M2, M3) • Black-box suppliers ideally understand component as well as interfaces and main concepts of adjacent components to ensure architectural fit (M1, M3)
Organizational factors	<ul style="list-style-type: none"> • Suppliers need the ability to interact along the supply chain (down and up-stream) (M1, M2, M3) • Organizational structure (e.g. key account, cross-functional team) and internal collaboration across functions is essential for project stability and compliance (M1, M2, M3) • Supplier should show resource capacity to ensure product development, quality and manufacturability (M1, M3) • Process maturity aids quality and project stability (M1, M2, M3) • Suppliers should embody NPD project management proficiency with process and structure (cross-functional team) especially for black-box developments (M1, M2, M3) • Suppliers have a duty to have supplier management expertise with n-tier suppliers (M1, M3)

Relationship factors	<ul style="list-style-type: none"> • Supplier needs to be willing to invest and share profits (royalty) for joint activities (M1, M2, M3) • Willingness to share capabilities and ideas openly are key prerequisite for close collaborations with suppliers (M1, M2, M3) • Trust and commitment for long-term partnerships with and by suppliers are critical for module developments (M2, M3) • Geographical proximity to supplier helps to meet in person and to collaborate closely (M2, M3) • People are key factor, since everything can be checked but people need to execute (M2, M3) • Suppliers with highest development responsibility should show learning attitude and proactivity like communication of threats, alignment on interfaces with other suppliers or providing ideas for final end-product (M1, M3)
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Table 16 - Main findings from conference participants

Section	Question module	Key findings
1	Supplier Integration approaches	Supplier competences for joint development between supplier & buyer: <ul style="list-style-type: none"> • Technical knowledge • Technical competence (Module competence) • Willingness to share • Process and project competence
		Supplier competences for independent development by supplier: <ul style="list-style-type: none"> • Full product knowledge (product design) • Technical knowledge • Resource Capacity • Sub-supplier management competence
2	Assets for module developments	<ul style="list-style-type: none"> • Component 4.5 • Processes 4.1 • Knowledge 3.6 • Interconnected people 4.1

5. Chapter - Module suppliers: Competence differences between grey-box and black-box collaborations

5.1. Introduction

Differentiated customer demands and a related increase of product complexities make it challenging for single firms to cope with the full spectrum of resources required for new product developments (NPD) in today's business world (Corso et al., 2001; Grant & Baden-Fuller, 2004). Resource based theory explains this phenomena with natural limitations of resources by companies (Eisenhardt & Schoonhoven, 1996). To overcome natural constraints, relational view theory argues that external resources are firm addressable assets, which can be rented from external stakeholders like suppliers (Dyer & Singh, 1998). Those external resource are ideally complementary to the buying firms' set of resources (Dyer & Singh, 1998; Lavie, 2006). Accordingly, firms incorporate external competences and pool it with internal resources to benefit from its partner's assets in order to realize competitive advantages (Bonaccorsi & Lipparini, 1994; Droege et al., 2000; Howard & Squire, 2007; Jaakkola & Hakanen, 2013; Koufteros et al., 2007). Previous research has formulated a integration model that defines a latter of integration stages (Petersen et al., 2005). Along the level of development responsibility, the model introduces the terms grey-box and black-box integration. Grey-box integration represents formalized joint development activities between the supplier and the buying firm. In contrast, black-box integration stands for a self-contained and independent development role of the supplier.

Modular product architecture presumably aids intentions to integrate supplier resources. The decoupled product structure enables outsourcing of development activities to suppliers, since outsourced modules are not interfering with other modules of the product (Baldwin & Clark, 2003; Baldwin & Von Hippel, 2011; Campagnolo & Camuffo, 2009; Howard & Squire, 2007; Nepal et al., 2012; Sako & Murray, 1999). The automotive and aircraft industry provide examples where the modularization of products has given buying firms the lead in product development, while a large share of the actual development work was delegated to suppliers (Frigant & Talbot, 2005; Gadde & Jellbo, 2002). Thereby, companies use supplier knowledge for supplementary development activities, so that the buying firm can assimilate internal resources to their core competences (Langlois & Robertson, 1992; Sako & Murray, 1999). Technical competences, long-term experience and most likely cross-industrial familiarity with technologies allow suppliers to leverage knowledge and to develop specific modules and sub-systems faster, cheaper and with better performance (Koufteros et al., 2007). As a result, the innovation level of the buying firms is positively influenced (Rosell & Lakemond, 2012; Von Hippel, 1988) and the likelihood of developing commercially successful products increases (Faems et al., 2005).

Previous research on supplier performance has indicated that integrating suppliers in NPD projects is associated with various risks referring to technical and performance aspects (Handfield et al., 1999). Accordingly, buying firms have to ensure that supplier have sufficient technical and performance resources in order to prevent associated risks of supplier integration. However, the needed resources might differ in accordance to the applied supplier integration approach. A joint grey-box development between the buying and supplying company might require a different set of resources from the supplier than a black-box development by a supplier. For example, the communication pattern differs between both approaches as well as increasing development

responsibility might require more supplier resources. Even though the different integration approaches imply the need for individual supplier resource levels, potential differences in supplier competences were not field of research yet. In view of that, this paper tries to answer the following research question:

How do supplier competences differ between grey-box and black-box supplier integrations for module developments?

To answer the introduced research question, this paper will continue as follows. After a (1) short literature review which shows the theoretical background of suppliers as module development resource, the paper will continue with a (2) theoretical research framework to explain the antecedents for grey-box and black-box supplier integration. Finally, we (3) test the model on a large-scale sample of supplier by (4) presenting and discussing the identified antecedents of supplier integration.

To the best of our knowledge, this study is the first to develop and test a model of antecedents for grey-box and black-box module development by suppliers. The four categories of antecedents originate from Robertson and Ulrich (1998) and function as complementary resources described by Dyer and Singh (1998) within relational view. In detail, we look at component and architectural knowledge, quality processes maturity, engineering capabilities, and supply chain collaboration. This study adds to supplier integration literature by being the first to specifically test for competences of supplier regarding different integration approaches for module developments. The outcome show valuable conclusions for firms highlighting the importance to fine-tune the assessment of supplier competences individually to the integration approach.

5.2. Theoretical Background

5.2.1. Supplier as Module Developing Resource

Companies use modular product architectures to balance product standardization versus strategic flexibility by simultaneously integrating supplier resources to create competitive advantages (Gadde & Snehota, 2000; Krishnan & Gupta, 2001; Meyer & Lehnerd, 1997; Nepal et al., 2012; Skoeld & Karlsson, 2007). To realize competitive advantages, relational view theory argues that suppliers need relevant resources to add value to product development activities of the buying firm (Dyer & Singh, 1998). This stands in line with observation that the more valuable and rare resources, the greater the advantage the firm may obtain (Jay Barney, 1991; Dierickx & Cool, 1989). Research on resource based view has highlighted that the configuration of resources by firms drive distinctive performance (Jay Barney, 2001; Eisenhardt & Martin, 2000). To foster competitive advantage, resource based view has therefore “evolved into a dynamic recipe explaining the process by which these ingredients [a firm’s resources] must be utilized” (Newbert, 2007, p. 124). Based on this argumentation, relational view claims that the organizing process has to extend firm’s own boundaries by considering external stakeholders, because vital resources are often found outside the firm — ”embedded in interfirm resources and routines” (Dyer & Singh, 1998, p. 650). The decoupled arrangement of modular product architecture permit design changes within very limited influence on other modules in the product system (Baldwin & Von Hippel, 2011; Henderson & Clark, 1990; Muffatto & Roveda, 2002; K. Ulrich,

1995). Changes within a module require limited coordination between different modules during the NPD process (Baldwin and Clark, 1998), so that external resources, like suppliers, can be integrated more easily (Baldwin & Clark, 2003; Baldwin & Von Hippel, 2011; Nepal et al., 2012; Sako & Murray, 1999). Consequently, within a modular product architecture certain value-adding tasks can be transferred to up-stream suppliers. Thus, resource limitations at the buying firm can be compensated with the integration of supplier resources (Doran et al., 2007; D. Ford et al., 2003). For example, a reasonable number of automotive suppliers develop not only discrete parts but also whole systems (Womack, Jones, & Roos, 1990). Such value transfers lead to reduced costs, higher quality, and faster speed of product development for buying firms, since the expertise of the supplier are driving economies of scale and scope (Koufteros et al., 2007).

5.2.2. Supplier Integration

In accordance to the theoretical foundation of relational view, the availability of supplier competences determine if a supplier integration in NPD projects is successful and brings value add (Handfield et al., 1999). Supplier contributions differ related to the component characteristics (Von Hippel, 1988), supplier integration in module developments are, therefore, considered as highly critical, since a modular product development represents a high level of complexity (Novak & Eppinger, 2001; Salvador et al., 2002b). For example, modularization brings high technical complexity (Handfield et al., 1999; Wasti & Liker, 1997), which requires suppliers to have advanced development flexibility, technical understanding and engineering competences (Oh & Rhee, 2010). Therefore, suppliers contributing to module development activities in NPD need to provide advanced capabilities, which extend the profile of a single component supplier (Monczka et al., 2000; Wognum et al., 2002). On the other hand, modularization is associated with commonly shared parts, since mutual parts find application in multiple platforms across different products (Muffatto, 1999; Robertson & Ulrich, 1998). Thus, the relevance of module development activities increases significantly as problems affect not only one product of a company, but most likely a wide portion of products. To coordinate the challenging task of integrating suppliers, the supplier integration model of Petersen et al. (2005) conceptualizes a latter of supplier integration along the level of development responsibility of suppliers. Accordingly, the terms grey-box integration and black-box integration were introduced. Grey-box represents joint development activities with the supplier, whereas black-box integration stands for independent development tasks for the supplier (Petersen et al., 2005). Both grey-box and black-box integration imply high development responsibility for suppliers (Petersen et al., 2005), which lead to special requirements for potential module suppliers (Doran et al., 2007; Momme & Hvolby, 2002; Wolters, 2002). This paper is first that focus on potential difference of supplier competences in accordance to the supplier integration approach.

5.3. Research Framework

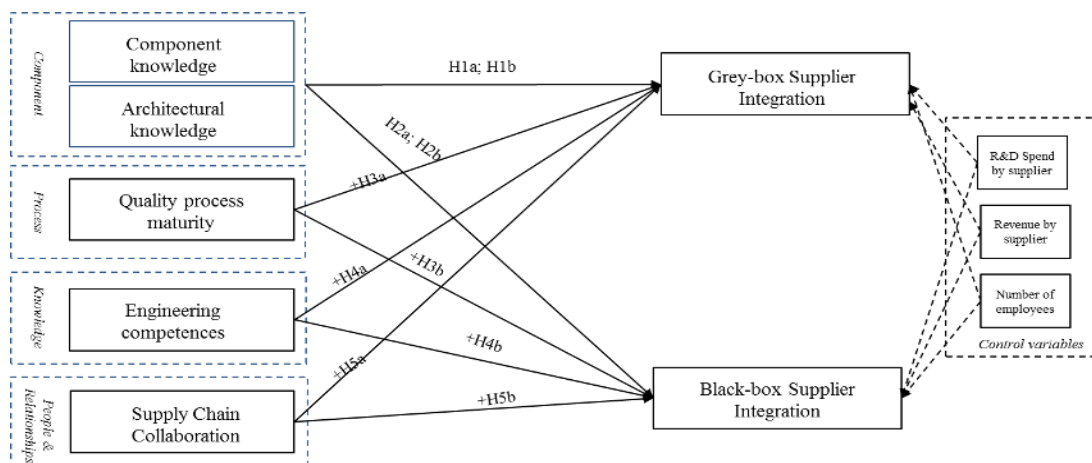
In accordance to relational view theory, suppliers need complementary resources to the OEM to be attractive for relational rents (Dyer & Singh, 1998). Since complementarity implies correspondence to OEM resources, we investigated, if literature advises general competences that are associated with successful module developments. In this regard, we found a model that

defines successful platform development as a collection of commonly applied assets that can be gathered in four categories (1) component, (2) process, (3) knowledge and (4) people and relationships (Robertson & Ulrich, 1998). Due to the fact that modules are an incremental part of product platforms, we presume that modules inherit development assets of platform development as suggested by Robertson and Ulrich (1998). The general relevance was shown by Chai et al. (2012), who have empirically demonstrated that the suggested assets of platforms by Robertson and Ulrich (1998) are antecedents for platform based product development activities. Applying the idea of complementary resources (Dyer & Singh, 1998), we consider the four assets as potential complementarities to OEMs, which want to get either unique assets for innovative developments or supplementary resources from suppliers (Wagner & Hoegl, 2006). Consequently, we propose the following aspects as antecedents for supplier integration for module developments:

- 1) In reference to component assets, technical knowledge considers the availability of part and module design abilities like interface understanding, component know-how and system design knowledge. In detail, we differentiate between component knowledge and architectural knowledge, since these two levels talk cover most relevant aspects of module components aspects.
- 2) Regarding process assets, quality process maturity is main focus of analysis in this study. Quality process maturity refers to managerial capabilities of quality management ensuring that the provided product or service consistently meet or exceed customer's expectations (Brunsson & Jacobsson, 2000; Holjevac, 2008).
- 3) Engineering capabilities stands for the knowledge asset. It reflects supplier's ability to conduct research and development in a competitive manner for relevant design work, which directly support the execution of the assigned task (Wasti & Liker, 1999).
- 4) Supply chain collaboration takes external relationships with sub-suppliers into account. Based on a paradigm of collaborative advantage (Dyer, 2000; Kanter, 1994), the level of interaction between first-tier and the tier-two supplier network can create super-additive value (Tanriverdi, 2006).

Since, previous analysis has indicated that all assets are relevant for platform based product development (Chai et al., 2012), we propose to use all four assets as evaluation perspectives for module suppliers. We relate the identified assets for module developments to supplier integration approaches by doing that we can check, if the relevance of assets differ between grey-box and black-box supplier integration. To set the variables in the right relation, we linked the four defined assets (1) component and architectural knowledge, (2) quality process maturity, (3) engineering capabilities and (4) supply chain collaboration to the dependent variables called grey-box supplier integration and black-box supplier integration. We control for the influence of R&D spend, revenue and number of employees by the supplier. Figure 12 illustrates the research model.

Figure 12 - Research model (chapter 5)



5.3.1. Component and architectural knowledge

From previous literature we know that modular product architecture introduces decoupled physical components and architectural interfaces as well as functions (Sanchez & Mahoney, 1996; K. Ulrich, 1995). In view of that, this study proposes technical knowledge of module suppliers has to be separated into component and architectural knowledge (Brusoni & Prencipe, 2001b; Henderson & Clark, 1990). Each component within a platform architecture, irrespective of the cluster type, is a “physically distinct portion of a product that embodies a core design concept” (Henderson & Clark, 1990, p. 2). The independency of modules enables the transfer of certain value-adding tasks to up-stream suppliers (Doran et al., 2007; D. Ford et al., 2003). With increasing value-adding tasks for suppliers, complexity and responsibility increases simultaneously for suppliers. Thus, module suppliers need advanced technical competences to ensure technical functionality of the developed component (Henderson & Clark, 1990; Takeishi, 2002). In other words, the supplier needs to fully understand the internal working concept of the components like modeling, material and specifications. To give a practical example, a module supplier, who is asked to develop a component (e.g. the fuel tank) for the final product of the buying firm (e.g. an automobile), would need to develop the component with the best design and highest efficiency. Hartley et al. (1997) have indicated that suppliers with well-known technical capabilities reduce supplier-related problems for buying firms in new product developments. Irrespectively of the development responsibility level, a supplier has to understand the component related to his development activities in order to successfully execute the development task related to his component. Consequently, we presume that component knowledge fosters the integration of suppliers in module development activities, both grey-box and black-box. Accordingly, we hypothesis:

H1a: Suppliers with high component knowledge are more likely integrated in black-box developments.

H1b: Suppliers with high component knowledge are more likely integrated in grey-box developments.

5.3.2. Architectural Knowledge

To ensure the fit of components in the final product, one of the involved development parties have to actively safeguard the integration of components. Either the buying or the supplying firm can take this role of a ‘system integrator’, which stands for the management and coordination across subsystems boundaries (Pittaway et al., 2004; Prencipe, 2003). To ensure successful system-level interactions on the component and system level, the system integrator need detailed understanding of the whole end-system so called architectural knowledge (Henderson & Clark, 1990; Takeishi, 2002). We consider architectural knowledge as thorough understanding of the end-product’s architecture by knowing how to integrate subsystems in the customer’s final product. Thereby, architectural knowledge allows predicting the effect of changes in one subsystem on other subsystems and vice versa by enabling the end products functionality.

In case of black-box developments, module suppliers have to develop a module self-contained by safeguarding the fit of the module in the final product. Consequently, suppliers need to understand the interfaces, so that the module can be developed in accordance to the interfaces and functions of the final product. Accordingly, black-box suppliers probably demonstrate high architectural knowledge. When both the buying firm and the supplier execute the development jointly within a grey-box development, buying firms will remain the system integrator, but suppliers will need to have architectural understanding. Prior research indicates that despite product modularity the lead-firm’s knowledge base should remain broader than that strictly needed to manage the internal design and production activities (Brusoni & Prencipe, 2001a; Brusoni, Prencipe, & Pavitt, 2001; Furlan, Cabigiosu, & Camuffo, 2014; Zirpoli & Becker, 2012). Thus for joint developments, the buying firm is expected to remain the ‘system integrator’, since the buying firm leads the merge of different parts of the end-product. However, a close collaboration between buyer and supplier like grey-box integration is mainly applied for activities with high uncertainty (Kouvelis & Milner, 2002; Wasti & Liker, 1999). For example, innovative projects with high technical uncertainty foster close collaboration between development partners with an overlap of knowledge between supplier and buyer (Takeishi, 2002). The overlap of knowledge gives both parties the opportunity to contribute on the same level to the development activities. In consequence, it can be assumed that both buying firms and suppliers embody architectural knowledge in grey-box collaborations. Accordingly, we formulate the following hypotheses:

H2a: *Suppliers with high architectural knowledge are more likely integrated in black-box developments.*

H2b: *Suppliers with high architectural knowledge are more likely integrated in grey-box developments.*

5.3.3. Quality process maturity

Mature quality procedures are enabling factors of suppliers to develop modules, since quality processes ensure a constant performance level throughout all ensure all steps of a NPD project (Akao & Mazur, 2003). Defined quality processes prevent companies from impulsive and nonsystematic actions, so that tasks performed are certain, comparable and consistent (David &

Rothwell, 1996; Urgan, 2006). In detail, product standardization, reliability, conformity to rules and procedures, and attention-to-detail are facilitated by quality procedures (Detert, Schroeder, & Mauriel, 2000; Prahalad & Krishnan, 1998). Mature quality procedures ensure core competences to provide a product or service that consistently meet or exceed customer's expectations (Brunsson & Jacobsson, 2000; Holjevac, 2008). By this means, quality processes play a significant role for buying firms, for example, quality was found to be the most popular supplier selection criteria for buying firms (Ho et al., 2010). The high complexity of modules implies a reasonable failure risk for new developments of modules (Oh & Rhee, 2010; Salvador et al., 2002b). Therefore, it can be expected that the majority of modules benefit from standardization like quality procedures, since failures and unexpected actions are prevented. We, therefore, hypothesize that for both integration approach quality procedures are favorable:

***H3a:** Suppliers with higher quality process maturity are more likely involved in black-box developments.*

***H3b:** Suppliers with higher quality process maturity are more likely involved in grey-box developments.*

5.3.4. Engineering Capabilities

As described by relational view, when suppliers show complementary resources, buying firms integrating complementary resources will create competitive advantages (Dyer & Singh, 1998). Engineering capabilities represent a principal competence for module supplier as those can directly complement buyers resources by directly contributing to development activities of the buying firm (Monczka et al., 2000; Wognum et al., 2002). Suppliers with high engineering capabilities can better understand customer needs and develop multiple concepts for those needs, so that concepts can be moved along with parallel development design alternatives (Zhang et al., 2009). Suppliers with potent product engineering capabilities can be trusted to develop parts, or subassemblies for their customers (Koufteros et al., 2007). In view of that previous research shows that suppliers with existing in-house engineering capabilities appear to be essential for buying firms that desire to integrate suppliers in product development activities (Cusumano & Takeishi, 1991; Petersen et al., 2005). Moreover, suppliers with leading engineering capabilities in specialized fields are perceived as excellent source of technical knowledge which can lead to better development performance (Koufteros et al., 2007). As for both grey-box and black-box integration, the suppliers has to perform sophisticated engineering activities (Koufteros et al., 2007; Petersen et al., 2005), we hypothesis that suppliers should have a high level of in-house design knowledge for both grey-boy and black-box developments:

***H4a:** Suppliers with higher engineering capabilities are more likely involved in black-box developments.*

***H4b:** Suppliers with higher engineering capabilities are more likely involved in grey-box developments.*

5.3.5. Supply Chain Collaboration

Along a supply chain, companies enter inter-organizational collaborations to create supply chain collaborations (Flynn et al., 2010; Stank et al., 2001). The notion of supply chain collaboration is based on a paradigm of collaborative advantage (Dyer, 2000; Kanter, 1994) which is a relational view of joint competitive advantage (Dyer & Singh, 1998). Companies create those relations to advance their own capabilities as well as their value creation like effectiveness and innovation (Cao & Zhang, 2011; Soosay et al., 2008). Studies have shown that modular product architectures are associated with inter-organizational collaboration within NPD projects (Campagnolo & Camuffo, 2009; Henderson & Clark, 1990; Muffatto, 1999). A module is related to several sub-components that require management and alignment of individual development tasks (Von Hippel, 1990). Consequently, a module supplier can be exposed to a wide spectrum of development activities within a module development. The required resources are most likely broad and complex, so that the module supplier will be challenged to provide an overwhelming level of knowledge. Like described by relation view theory, an effective firm uses its own core competencies but also mobilizes the resources available controlled by other firms (Dyer & Singh, 1998). Accordingly, effective module suppliers presumably use their sub-suppliers to successfully complete their assigned development task (Culley, 1999). For example, Fagerstrom and Jackson (2002) illustrate that main suppliers use sub-suppliers for flexibility, innovation, and resource purposes. In this view, sub-suppliers acquire the character of supplier-addressable resources (Beers & Zand, 2014; Sanchez & Heene, 1997). We, therefore, argue that first-tier supplier who collaborate with their supply base empower successful module development which is why there are more likely to be integrated in module developments. Looking at the integration type, we consider both as positively driven by supplier collaboration. On the one hand black-box integration requires advanced resources, which most likely are reached through sub-supplier collaboration. On the other hand, grey-box might be even more influenced by supply chain collaboration, because companies that collaborate with sub-suppliers might also be more willing and able to collaborate with the other end of the supply chain, their customers. Consequently, supply chain capabilities are considered as antecedents for grey-box and black-box development integration:

H5a: Suppliers showing advanced supply chain collaboration are more likely integrated in black-box developments.

H5b: Suppliers showing advanced supply chain collaboration are more likely integrated in grey-box developments.

5.4. Research Methodology

5.4.1. Sampling and data collection

Data of the study were collected from direct material suppliers of an American based focal agriculture equipment OEM. The use of sample firms working in the same industry context excludes industry-level differences in the dyadic buyer–supplier relationships (Liu et al. 2009). Like in other industries (e.g. automotive industry), suppliers of the agriculture equipment industry have the tendency to supply goods to multiple OEM's within the industry (Dyer &

Singh, 1998; Ellis et al., 2012). For that reason, it can be assumed that suppliers who participated in this study also supply to other market participants of the agriculture equipment industry. By this means, this study can be perceived as representative sample for an OEM producing agricultural equipment.

This survey includes sample firms from a global scope with a wide diversity of material groups. To avoid sample biases, suppliers were randomly selected grounded on the global commodity strategies from the OEM. All direct material commodities of the OEM were included, so that the sample represented a heterogeneous and representative group of suppliers with different industry, product and technology backgrounds. The sample represents the industry and product structure of a vehicle manufacturer by representing the supply base structure of a globally operating European OEM.

In preparation to the survey, 5 workshops with randomly selected practitioners were organized to ensure academic and practical relevance of the questionnaire. During, the workshops the questionnaire was answered together with one researcher, so that questions were discussed and suggestions were made. After the workshops, the questionnaire was transformed into an online survey tool and send out to 100 randomly selected suppliers in order to test the research instrument under real-life conditions. The selected suppliers represent a heterogeneous and representative sample covering a broad range of subsystems, manufacturing industry sectors and geographic locations. 58 suppliers participated in the survey pre-test, which provided a good sample to test for statistical validity. The pre-testing ensured that items were clear and understandable by providing simultaneously face validity for the constructs examined. Minor adjustments were done to the questionnaire after the pre-testing before it was converted in the final online survey. Including the pre-testing, in total 196 suppliers participated which provides a response rate of 45% percent from the total sample.

In regards to data collection, based on the support from the agriculture equipment OEM, suppliers' key accounts were invited to participate in the survey by an e-mail send by the OEM. The e-mail pointed out that suppliers' participation was voluntary and provided a link to the online survey hosted by the university.

The final sample includes direct material suppliers of the agricultural equipment OEM from different industry sectors: 21% are related to castings and metal fabrications, 18% to engine and engine components, 14% to the hydraulic, cylinders and bearing systems, 10% to heating, ventilation and air conditioning. The remaining suppliers belong to other product parts like transmissions, axles, wheels, rubber etc.

The responses illustrate a global origin of responses with an European focus: 66% of responses originate from Europe; 14 % from Asia; 12% from North America and 9% from South America. Major countries of origin are Germany (36%), Italy (13%), United States (12%), Brazil (9%) and China (8%). The remaining responses are coming from Taiwan, UK, and other European countries. The sample symbolizes the supply base structure of a globally operating OEM based in the EU.

The profiles of the respondents are distributed as follows: 37% were key account managers; 24% managers of the sales department; 14% senior management and 18% other positions, including

engineering. Around 25% of the respondents have included another function in order to complete the survey instrument. A cross-check between the different groups of respondent profiles as well as a comparison between cases with and without cross-functional input show no significant deviation. The firms represented in our sample are of notable size, averaging USD 811 million turnover with 7,617 employees, and 4.9% of turnover invested in R&D.

5.4.2. Measures

The introduced variables of this study were operationalized with multi-item scales in a five-point Likert scale with end points of ‘strongly disagree’ and ‘strongly agree’ (Likert, 1932). By intention previously developed measures were adopted from previous studies. Accordingly, the measure engineering capabilities is based on previous research (LaBahn & Krapfel, 2000). Only minor wording changes were made to the existing item to reflect the supplier focus of this study. The measures grey-box and black-box integration (Koufteros et al., 2007), process maturity (Schiele, 2007) and sub-supplier integration (Hoegl & Wagner, 2005) are based on previous work, but include new single items. Looking at grey-box and black-box integration measures we have added items for a stronger link to the theoretical concept of Petersen et al. (2005). Moreover, we again rephrased the measure to analyze the supplier perspective. In regards to process maturity we applied the logic from Schiele (2007) and related the maturity items to quality processes. The sub-supplier integration measurement is based on the previous work, but was modified to fit the context of supplier collaboration. Totally, new items had to be developed for the constructs of component and architectural knowledge. Systematic validation steps were executed for the new constructs. The following steps were accomplished: (1) Content validity was ensured with an extensive literature review, (2) in-depth focus group discussions with eight purchasing managers and eight key account managers from randomly selected suppliers facilitated relevance and understandability, (3) one pre-tests of the survey with overall 100 suppliers’ sales representatives as described above safeguarded the practical applicability.

5.4.3. Control variables

Based on Atinc et al. (2011) three control variables were introduced that potentially affect the model from a theoretical rationale and previous evidence. The organizational size of suppliers might influence possibilities and likelihood of supplier integration for module developments. Due to the high complexity of modules (Novak & Eppinger, 2001; Salvador et al., 2002b), the size in form of number of employees and revenue can influence the availability of needed resource to handle the amount of work associated with a module development. Moreover, R&D expenses by the supplier could increase the ability to contribute innovative input by suppliers, since previous research showed that the internal R&D investments influence the number and the level of collaboration between organizations (Becker & Dietz, 2004). Thus, R&D expense by suppliers was introduced as third control variable.

Due to presumable differences in industry and culture (Hofstede, 1993), we controlled for differences in regards to commodity and country of origin. No significant differences in accordance to commodity or country of origin could be found in the responses. We also controlled for firm size, but no significant influence was detected.

5.5. Data Analysis and Results

This study uses partial least squares structural equation modeling (PLSSEM) to test the formulated hypothesis model (Fornell & Cha, 1994). In recent years, PLS has been widely and increasingly employed in operational management research with promise for the assessment of success factors of certain target constructs (Hair et al., 2011; Hair et al., 2012; Peng and Lai, 2012). Although PLS has the so called “PLS-bias” to slightly overestimate the measurement model and underestimate the relationships in the structural model (Hair et al., 2014), in comparison to covariance-based SEM software, it shows more accurate results for smaller sample sizes ($n < 250$) (Reinartz et al., 2009) and more complex models (Wetzels et al., 2009). Moreover, Hair et al. (2011) argue that in situations when the research objective is not theory confirmation, but theory development and prediction, like in this study, PLS-SEM is the preferred method because of its prediction orientation. To validate the fit of smartPLS as leading technique, we calculated a goodness of fit measure in SmartPLS by running the PLS algorithm. The measure uses standardized root mean square residual (SRMR) to give a result for the composite factor. A value between 0.05 to 0.08 indicates fair fit, 0.08 to 0.10 show mediocre fit and above 0.10 stands for poor fit (Hu & Bentler, 1998). With a value of 0.054 results indicate smartPLS as a good methodology to analyze the given data (Henseler et al., 2014). We therefore used SmartPLS software for our analysis (Ringle et al., 2015).

5.5.1. Construct validation

Before testing the defined research model, we checked statistical validity of constructs by calculating cronbach’s alpha, the composite reliability and the average variance extract (AVE). All constructs indicate statistical validity, by exceeding required level of cronbach’s (0.6), reliability (0.71) and a AVE (0.5) (Cronbach, 1951; Fornell & Larcker, 1981; Hair et al., 2014; Henseler et al., 2009; Nunnally & Bernstein, 1978). The exact results can be found in Table 18. In addition, we use a cross-correlation matrix to check the cross-loading values in order to assess discriminant validity for the reflective constructs by applying Fornell–Larcker Criterion (Table 19). Discriminant validity between all the constructs can be shown, since for all items, an indicator’s loading on its own constructs are higher than all of its cross-loadings with other constructs (Hair et al., 2014). Moreover, each constructs’ square root of AVE is higher than the highest correlation with any other construct, which underscores the evidence of discriminant validity (Hair et al., 2014).

The heterotrait-monotrait (HTMT) ratio of correlations underlines the validity of results, since all figures are below the most conservative critical value of 0.85 in combination with a smaller value than 1 for the HTMT inference model. Therefore discriminant validity is indicated (Henseler, Ringle, & Sarstedt, 2015). According to Podsakoff et al. (2003), survey data that originate from a single informant may lead to common method bias effects. As suggested by Liang et al. (2007), we performed an unmeasured latent methods factor test by adding a common method variance factor that covers all principal constructs’ indicators (Podsakoff et al., 2003). In the following, we estimated the substantive variance that describes the loading between the main construct and the indicator construct as well as the average method-based variance, which stand

for the loading of the common factor on the indicator construct. The results (Table 20) show that the substantive variance was on average 0.85 and the average method-based variance is 0.00. Because the substantive variance represents a value 85 times higher than the method variance and most of the method factor loadings are insignificant, the results indicate that no common method bias could be identified for this study.

5.5.2. Hypothesis testing

Table 17 displays an overview of the path coefficients, highlighting the results per individual path. The model shows an R^2 of 43% for black-box supplier integration and 33% for grey-box inclusion, which underpins the theoretical and managerial relevance of our model (Combs, 2010).

Table 17 - Path coefficients (chapter 5)

	Path	Path Coefficient	P Values	f ²	Result
H1a	Component Knowledge -> Black-box development	0.207	0.008***#	0.041 [#]	Supported
H1b	Component Knowledge -> Grey-box development	0.186	0.96	0.027 [#]	X
H2a	Architectural Knowledge -> Black-box development	0.270	0.000***#	0.087 [#]	Supported
H2b	Architectural Knowledge -> Grey-box development	0.199	0.041**#	0.039 [#]	Supported
H3a	Quality Process Maturity -> Black-box development	-0.228	0.001***#	0.065 [#]	Reversed
H3b	Quality Process Maturity -> Grey-box development	-0.128	0.040**#	0.018	Reversed
H4a	Engineering Capabilities -> Black-box development	0.235	0.023**#	0.049 [#]	Supported
H4b	Engineering Capabilities -> Grey-box development	0.054	0.599	0.002	X
H5a	Supply Chain Collaboration -> Black-box development	0.263	0.003***#	0.081 [#]	Supported
	Supply Chain Collaboration -> Grey-box development	0.373	0.001***#	0.134 [#]	Supported
H5b					
H6a	R&D Spend by supplier -> Black-box development	-0.020	0.770	-	X
H6b	R&D Spend by supplier -> Grey-box development	0.041	0.404	-	X
H7a	Number of employees -> Black-box development	0.060	0.072	-	Supported
H7b	Number of employees -> Grey-box development	0.044	0.176	-	X
H8a	Revenue -> Black-box development	0.001	0.977	-	X
H8b	Revenue -> Grey-box development	-0.002	0.957	-	X

#f² > 0.02
 ##f² > 0.15
 ###f² > 0.35
 *p < 0.09
 **p < 0.05
 ***p < 0.01
 n.s. = not significant
 n=196

Two hypotheses were not confirmed by our results: H1b path coefficient = 0.19, (not significant), H4b path coefficient = 0.05, (not significant). In addition, H2b (path coefficient = 0.199; $p < 0.05$, $f^2 > 0.02$) shows opposite results by indicating that grey-box suppliers need architectural knowledge. In contrast, results show with H1b and H4b that supplier involved in joint developments do not show in-depth component knowledge as well as extended engineering capabilities.

Quality related hypotheses show opposed results by being significant negative: H3a path coefficient = -0.23 ($p < 0.01$, $f^2 > 0.02$), H3b path coefficient = -0.13 ($p < 0.01$, $f^2 > 0.02$). Thus,

firms with mature quality processes seem to be less attractive to be integrated in module developments for both integration approaches.

The results of the controls show only a significant positive influence for the number of employees in regards to black-box developments. To cope with the complexity of self-contained module development, supplier size in terms of human resources seems to enable suppliers to execute a black-box development. Other constructs show no significant influence which implies no effect of revenue and R&D spend.

To evaluate the impact of the independent variables on the dependent variables, we calculated the effect size (Cohen's f^2) of each construct by determining the change in R^2 . The f^2 indication level ranges from small (0.02) and medium (0.15) to large (0.35) (Cohen, 1988; Chin, 2010). Table 17 shows all independent variables indicate a small influence on grey-box and black-box integration. The sampling distribution calculation illustrates a bootstrap distribution for the coefficients, so that those can be used to evaluate the hypotheses (Hair et al., 2014). The results support most of our hypotheses: H1a path coefficient = 0.20 ($p < 0.01, f^2 > 0.02$), H2a path coefficient = 0.27 ($p < 0.01, f^2 > 0.02$), H4a path coefficient = 0.24, ($p < 0.01, f^2 > 0.02$), H5a path coefficient = 0.26, ($p < 0.01, f^2 > 0.02$) and H5b path coefficient = 0.37, ($p < 0.01, f^2 > 0.02$).

5.6. Discussion

This study contributes to research on supplier inclusion with an empirical analysis of antecedents for black-box and grey-box supplier integration for new module developments. In detail, we examined factors that previous research proposed to be necessary for successful module developing (Chai et al., 2012; Robertson & Ulrich, 1998), specifically, technical knowledge, quality process maturity, engineering competence, and sub-supplier integration. By applying the pre-defined antecedents for module developments, this study contributes with valuable input for theory and practice.

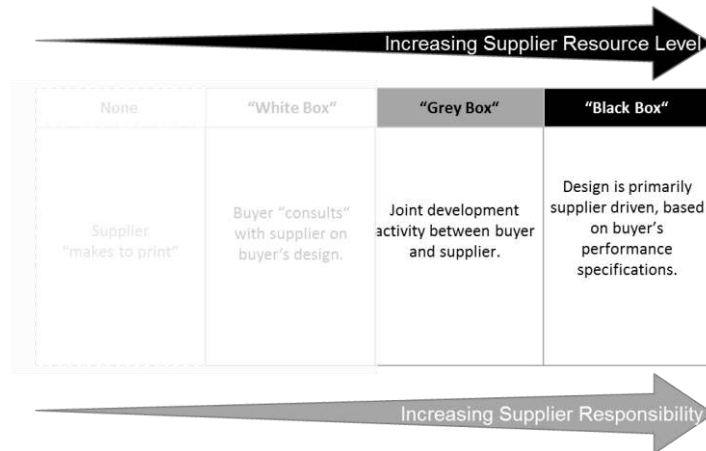
5.6.1. Theoretical implications

First, our results further expand the theoretical concept of relational view between buyers and suppliers. By this means, this study is the first that empirically applied the relational view concept with focus on complementary resources to suppliers-buyer collaborations for module developments. Results indicate complementary resources differ in accordance to the supplier integration approach. Thereby, this study expands operational understanding of relational view theory by showing that integration approach has to fit complementary resources at the supplier site.

Second, our results extend the supplier integration concept formulated by Petersen et al. (2005) by showing that the resource level of the supplier increases concurrently with the development responsibility of suppliers. The original supplier integration concept claims that more supplier integration results in an increase of suppliers' development responsibility. For example, when a supplier develops a component with the customer, the supplier has the responsibility for a limit number of tasks and content. On the other hand, a supplier who develops a component for a customer has the full responsibility for the entire module including all tasks and content. In accordance to the model of Petersen et al. (2005), our results indicate that higher

development responsibility results in higher resource level of the supplier. Thereby, this study advances theoretical understanding by claiming that a higher integration level requires a higher resource level at the supplier site. Comparing black-box and grey-box supplier integration, black-box suppliers embody a higher level of capabilities. For example, grey-box suppliers do not show advanced component knowledge and engineering capabilities. Figure 13 shows the modified supplier integration model based on Petersen et al. (2005).

Figure 13 - Modified supplier integration model



Source: Based on Petersen et al. (2005)

Third, this study is the first indicating that future research should differentiate technical knowledge in component knowledge and architectural knowledge. Different results for the two knowledge levels in regards to the supplier integration approach imply a significant dissimilarity, so that component and architectural knowledge should be evaluated separately for module developments. Moreover, this study shows that suppliers integrated in joint developments embody architectural knowledge, whereas component knowledge shows limited influence. We argue that suppliers acting in joint developments need an understanding of the customer's end-product to contribute to joint developments, whereas the component itself is developed in joint efforts. Grey-box suppliers, therefore, do not need specific component knowledge.

Fourth, this study is the first that empirically confirms separate functional systems as hurdle for relational rents (Dyer & Singh, 1998). In detail, results adds to relational view understanding by showing that relational rents between suppliers and buyers are negatively influenced by mature quality processes of suppliers. As described by Dyer and Singh (1998) separate functional systems can lead to lower levels of relational rents between companies. Results imply that mature quality procedures support the obstacle of close collaboration. Mature quality processes come with product standardization, conformity to rules and procedures and attention-to-detail (Detert et al., 2000; Prahalad & Krishnan, 1998). To ensure those characteristics, companies create a separate functional system for quality management. Thereby, information exchange, interfaces and joint activities of collaborations can decline to a minimum level, which leads to reduced relational rents between buyers and suppliers.

5.6.2. Managerial implications

This study had the intention to analyze grey-box and black-box supplier integration for module developments in regards to potential difference of required supplier competences. In that way, this study is the first showing that supplier competences differ between grey-box and black-box integrations. Both integration approaches require special supplier competences, which were not yet clearly identified. This study shows a detailed blueprint advising practitioners on which supplier competences to focus on when they either want to jointly develop with a supplier or when the supplier is asked to develop self-conducted for the customer.

Regarding joint developments, practitioners should focus on architectural knowledge and a collaborative attitude symbolized by an active interaction with sub-suppliers. Our results show that suppliers need architectural understanding within a grey-box development by understanding the functional and physical interactions of component. Specific component knowledge turned out to be less relevant for suppliers of joint developments. The nature of joint developments with high technical uncertainty and knowledge overlap (Takeishi, 2002) imply that specific component knowledge is developed throughout the joint development. In consequence, grey-box suppliers need to bring a general understanding of the end-product in form of architectural knowledge, but do not need specific component knowledge as component expertise might be developed during the project. To successfully perform such a joint development, the buying firm should look for a supplier who interacts actively with its supply base. Collaboration with sub-suppliers indicates a collaborative attitude, which is driven by information exchange and openness. When a collaborative attitude is applied to sub-suppliers, it can be assumed that the supplier will also work collaborative with its customers. Consequently, practitioners can use the treatment of sub-suppliers as an indication, if a module supplier is suitable for a joint development.

When practitioners want to allocate a module development to suppliers in form of a black-box developments, our results indicate that the required level of supplier resources increases in comparison to joint developments. In addition to architectural understanding and sub-supplier integration, black-box suppliers should provide component knowledge and engineering capabilities. Due to value-adding tasks of black-box module suppliers, technical competences play a more significant role. The black-box supplier needs architectural knowledge to drive the fitting into the final end-product, whereas component knowledge ensures the technical functionality of the developed component (Henderson & Clark, 1990; Takeishi, 2002). To ensure the performance of a black-box development, our results underline previous research by showing that engineering capabilities appear to be a significant competence. A development of a module represents a high level of complexity (Novak & Eppinger, 2001; Salvador et al., 2002b), which rises the complexity of the task of supplier (Von Hippel, 1988). Suppliers need, therefore, advanced engineering competences (Oh & Rhee, 2010). Consequently, managers should evaluate engineering capabilities and component knowledge of suppliers, when allocating a self-contained module development to a supplier.

Besides the identified supplier competence, this study shows the negative role of quality processes on supplier integration of module developments. Results illustrate that mature quality

processes have a negative influence on both grey-box and black-box integrations. We argue that this impact is caused by the trade-off relationship between flexibility and routine, which advocates 'rule infringements,' versus 'strict rules' by quality process (Quinn & Rohrbaugh, 1983). As described by Amabile, Hadley, and Kramer (2002) "when creativity is under the gun, it usually ends up getting killed", suppliers integrated in module developments seem to need a degree of flexibility to fulfill customer needs, which explains a limited level of quality process maturity. Practitioners should, therefore, check if suppliers demonstrate the right degree of quality processes balancing flexibility and standardization for module developments.

5.7. Limitations and future research

This research presents the first comprehensive and empirically tested outline for purchasing managers to successfully integrate suppliers in module development activities. Nevertheless, we would like to acknowledge some limitations and highlight possible avenues for further research.

One limitation concerns the dependent variables, grey-box and black-box integration, which were assessed using subjective items. For example, we asked respondents whether their company is involved in NPD projects of their customers. Although such perceptual measures are considered to be satisfactory in operations management research (Ketokivi & Schroeder, 2004a), collecting more objective and transparent data, for example, the number of projects with reasonable integration in comparison to the total number of projects, would add validity to the findings. A second limitation of our study is that all respondents came from the same industrial and product area. However, supplier competences for collaboration can differ between industries. Thus, evaluating supplier competence for module developments in NPD from another industry perspective may generate further insights. Third, due to complexity, we had to limit our scope of analysis to a certain number of competences. However, additional perspectives like internal collaboration, new product development process maturity etc. might add further insights to the understanding of antecedents for supplier integrations for module developments.

For further research, we would like to highlight prospects for future research activities. First, following the idea that sub-suppliers represent a critical source of resources for module suppliers. A value chain analysis might create new understanding for buying firms, since purchasing managers are not only dealing with the first-tier suppliers, but rather with the whole value chain of the module supplier. Thus, it can be claimed, if buying firms should still select a module supplier or if they should rather focus on selecting a value chain.

Second, buying firms probably should not only focus on supplier competence in order to integrate a supplier, but should also consider the business relationship to the supplier. For example, a supplier could be highly capable, but the relationship to the supplier is bad, so that the buyer should not enter in such a complex and critical relationship like a module development. Therefore, adding the relationship perspective to the analysis would broaden the analysis perspective.

5.8. Appendices

Table 18 - Results of Reliability Analysis, Variables and Operationalization (chapter 5)

<i>Variable</i>	<i>Items</i>
Architectural Knowledge (reflective) (i) $\alpha = 0.63$ (ii) CR = 0.92 (iii) AVE = 0.90	AK1 Your company fully understand subsystem core design concepts (e.g. arrangement of subcomponents, design specifications etc.). ^(a) AK2 Your company fully understands how our subsystem interfaces with subsystem supplied by other parties. ^(a) AK3 Your company well understands effective development processes for our subsystems. ^(a) AK4 Your company has thorough concept design and systems integration resources in-house. ^(a) AK5 Your company fully understands how to integration our subsystems in the customers final product. ^(a) AK6 Your system knowledge allows us to predict the effect of changes in our subsystem on other subsystems in our customers' end product and vice versa. ^(a) AK7 Your company has a thorough understanding of the architecture of our customers' end-product. ^(a) AK8 Your company fully understands how our subsystems interact with other subsystems in fulfilling the end-products function. ^(a)
Component Knowledge (reflective) (i) $\alpha = 0.76$ (ii) CR = 0.94 (iii) AVE = 0.92	CK1 Your company fully understands the internal working concept of our components (e.g. modeling, material, specifications etc.) ^(a) CK2 Your company has full understanding to predict which varieties of a component (e.g. material, design, specification etc.) to use in order to improve performance. ^(a) CK3 Your company well understands effective development processes for components. ^(a) CK4 Your company has thorough component design resources in-house. ^(a) CK5 Your company can explain why using certain varieties of component results in specific performance characteristics. ^(a)
Engineering Competence (reflective) (i) $\alpha = 0.76$ (ii) CR = 0.93 (iii) AVE = 0.89	<i>Relative to the competition...</i> EC1 ... our engineers are proficient with the latest technology. ^(a) EC2 ...our engineers are skilled at creating technological innovations. ^(a) EC3 ...we can incorporate the latest technology in our new products ^(a) EC4 ...we can offer a high degree of engineering support to our customers ^(a) EC5 ...we are able to respond quickly to technological changes ^(a)
Quality process maturity (reflective) (i) $\alpha = 0.75$ (ii) CR = 0.94 (iii) AVE = 0.92	Q1 Your company has detailed quality management processes (e.g. milestones, resources planning etc.). ^(a) Q2 Your quality processes are practiced cross functionally. ^(a) Q3 Quality processes are continuously improved within your organization. ^(a) Q4 Quality processes are supported and backed-up by a control system. ^(a) Q5 Quality performance is continuously measured against pre-defined goals and targets. ^(a)
Supply Chain Collaboration (reflective) (i) $\alpha = 0.81$ (ii) CR = 0.94 (iii) AVE = 0.92	SI1 Important ideas and information are exchanged openly with technical relevant suppliers of your company within NPD projects. ^(a) SI2 General atmosphere is cooperative with technical relevant suppliers of your company within NPD projects. ^(a) SI3 Communication between your suppliers and your company is frequent within NPD projects. ^(a) SI4 Communication between your suppliers and your company is intensive within NPD projects. ^(a)

<i>Grey-box development</i> (reflective) (i) $\alpha = 0.81$ (ii) CR = 0.87 (iii) AVE = 0.85	<i>GBI1</i>	Your company is involved in early stages of product development of our customers
	<i>GBI2</i>	Your company provides our input on the design of the component parts of our customers.
	<i>GBI3</i>	Your company provides our expertise in the development of products of our customers
	<i>GBI4</i>	Your company enters in joint development efforts with our customers, which include joint decision making.
<i>Black-box development</i> (reflective) (i) $\alpha = 0.91$ (ii) CR = 0.92 (iii) AVE = 0.89	<i>BBI1</i>	Your company develops component parts for our customers (self-contained).
	<i>BBI2</i>	Your company does product engineering of component parts for our customers.
	<i>BBI3</i>	Your company develops whole subassemblies for our customers (self-contained).
	<i>BBI4</i>	Your company is informed of customer requirements and then get almost complete development responsibility for the purchased item.
	<i>BBI5</i>	Your company involves our sub-suppliers in development activities for our customers on our own choice.
(a) Item measured on five-point scale: 1 = fully disagree, 5 = fully agree. (b) Item measured in percentage. (i) Cronbach's Alpha should be $\alpha > 0.6$ (Cronbach, 1951). (ii) Composite Reliability should be CR > 0.7*. (iii) Average Variance Extracted should be AVE > 0.5*. * Referring to Nunally (1978), Fornell and Larcker (1981), Bagozzi and Yi (1988), Henseler et al. (2009).		

Table 19 - Construct cross-correlation matrix (chapter 5)

	Mean	SD	1.	2.	3.	4.	5.	6.	7.
1. Architectural Knowledge	3.89	0.79	0.79						
2. Component Knowledge	4.49	0.79	0.55	0.87					
3. Engineering Competence	4.45	0.61	0.46	0.62	0.86				
4. Quality process maturity	4.64	0.56	0.25	0.35	0.46	0.86			
5. Supply Chain Collaboration	4.14	0.81	0.34	0.33	0.50	0.49	0.90		
6. Grey-box development	4.15	0.86	0.42	0.41	0.39	0.19	0.46	0.83	
7. Black-box development	3.66	1.13	0.53	0.51	0.52	0.15	0.43	0.43	0.83

Table 20 - Common Method Bias Test (chapter 5)

	Construct Loading (CL)	CL ²	Method Factor (MFL)	MFL ²
Architectural Knowledge				
AK1	0.71	0.84	0.08	0.29
AK2	0.82	0.91	0.03	0.16
AK3	0.73	0.85	0.07	0.26
AK4	0.77	0.88	0.02	0.13
AK5	0.89	0.94	-0.08	-0.28
AK6	0.91	0.95	-0.10	-0.31
Component Knowledge				
CK1	0.79	0.89	0.03	0.16
CK2	0.86	0.93	0.04	0.19
CK3	0.94	0.97	-0.05	-0.22
CK4	0.84	0.91	0.00	0.06
CK5	0.93	0.96	-0.02	-0.12
Engineering Capabilities				
EC1	0.93	0.96	-0.06	-0.24
EC2	0.96	0.98	-0.06	-0.24
EC3	0.80	0.89	0.06	0.24
EC4	0.75	0.87	0.12	0.35
EC5	0.85	0.92	-0.06	-0.25
Quality Process Maturity				
Q1	0.79	0.89	0.05	0.21
Q2	0.88	0.94	0.00	0.05
Q3	0.85	0.92	0.05	0.22
Q4	0.87	0.93	0.02	0.14
Q1	0.94	0.97	-0.12	-0.34
Supply Chain Collaboration				
SI1	0.94	0.97	-0.10	-0.32
SI2	0.87	0.93	0.03	0.18
SI3	0.90	0.95	0.03	0.18
SI4	0.89	0.94	0.04	0.19
Grey-box Integration				
<i>GBI1</i>	0.71	0.84	-0.03	-0.18
<i>GBI2</i>	0.90	0.95	-0.04	-0.19
<i>GBI3</i>	0.88	0.94	-0.01	-0.09
<i>GBI4</i>	0.82	0.90	0.07	0.26
Black-box Integration				
BB11	0.91	0.95	-0.06	-0.24
BB12	0.88	0.94	-0.05	-0.22
BB13	0.94	0.97	-0.11	-0.33
BB14	0.76	0.87	0.13	0.36
BB15	0.68	0.82	0.06	0.25
	0.85	0.92	0.00	0.01

6. Chapter - Should my suppliers know more than they produce?

6.1. Introduction

Buyer-supplier collaboration in relation to modular product architectures has received significant scholarly attention (Cabigiosu, Zirpoli, & Camuffo, 2013; Danese & Filippini, 2010; Howard & Squire, 2007). A stream of the modularity literature has dealt with the across-firm mirroring hypothesis predicting that firms benefit from isomorphism between the “thickness” of their interfirm relationships and the technical patterns of dependency in the system under development (Cabigiosu & Camuffo, 2012a; Colfer & Baldwin, 2010; Sanchez & Mahoney, 1996). In this way a modular (integral) product design would reduce (increase) the need for close supply relationships and result in a modular (integral) inter-organizational design (Baldwin, 2008; Colfer & Baldwin, 2010; Sanchez & Mahoney, 1996).

An alternative view proposes that product modularity and high levels of buyer-supplier integration are complements (Cabigiosu & Camuffo, 2012a; Hsuan, 1999; Jacobs et al., 2007). Modularization is unlikely to fully eliminate interdependencies between subsystems and companies (Cabigiosu & Camuffo, 2012a; Colfer & Baldwin, 2010; Staudenmayer, Tripsas, & Tucci, 2005). Therefore prior research indicates that despite product modularity the lead-firm’s knowledge base should remain broader than that strictly needed to manage the internal design and production activities (Brusoni & Prencipe, 2001a; Brusoni et al., 2001; Furlan et al., 2014; Zirpoli & Becker, 2012). In this respect prior research differentiates between component knowledge and architectural knowledge (Brusoni & Prencipe, 2001b; Henderson & Clark, 1990). Higher levels of both types of knowledge would allow the systems integration firm to better cope with technical uncertainty and uneven rates of change at the subsystem level and effectively integrate subsystems that are produced by suppliers with which they share loose inter-organizational relationships. To develop this deep knowledge, firms would need to make to know (Parmigiani & Mitchell, 2009) or engage in hand in glove relationships with their subsystem suppliers.

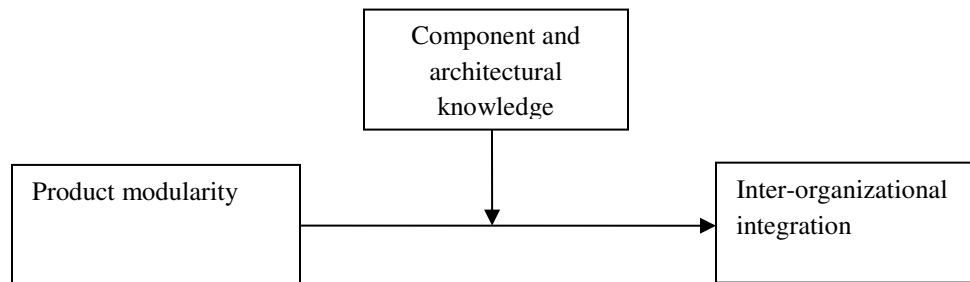
No study, however, has addressed conditions under which buyers decide to combine product modularity with loose or tight buyer-supplier integration. Furthermore, very limited empirical research has focused how knowledge residing at the *supplier* side influences the relationship between product modularity and the degree of inter-organizational integration in the buyer-supplier relationship. This research aims to enhance this currently limited understanding in literature. For this purpose we conducted a quantitative study among 193 suppliers of a American systems integration firm in the agricultural industry. Our findings reveal that the two types of knowledge - component and architectural have a significant and contrasting moderation effect. Specifically we find that higher architectural knowledge on part of the supplier positively moderates the relationship between the degree of product modularity and the degree of buyer-supplier integration and, we find that higher component knowledge on part of the supplier negatively moderates this relationship. These findings add empirical insight to recent studies that indicated the need for a more nuanced theory on the relationship between product modularity and the degree of *inter-organizational* integration (Cabigiosu & Camuffo, 2012a; Colfer & Baldwin, 2010; Kalaignanam, Kushwaha, & Nair, 2015) and in particular on the relevance of the *suppliers’* component and architectural knowledge for effective innovation in inter-organizational settings

(Brusoni & Prencipe, 2001a). Managers can use our findings to assess the degree of component and architectural knowledge of their suppliers and accordingly optimize the level of integration with their suppliers given the degree of product modularity in their product-system. The paper is organized as follows. In the next section, we provide a brief overview of the theory and develop our hypotheses. This is followed by our data analysis and results section. Finally we discuss our findings and highlight some limitations and suggestions for future research.

6.2. Theoretical background & hypotheses

The underlying research model of this study is summarized in Figure 14. Our theoretical model assumes that modular product design affects the degree of inter-organizational integration between a buyer and its subsystem suppliers. Furthermore it presumes that this relationship is influenced by the supplier's scope of product knowledge in the form of component and architectural knowledge.

Figure 14 - Research model (chapter 6)



6.2.1. Product modularity and the degree of buyer-supplier integration

Product architectures can be described by its level of modularity which refers to the degree to which a system can be decomposed into relatively independent subsystems that each perform one or a few functions in the end-system (Baldwin & Clark, 2000; K. T. Ulrich, 1995). This relative independence between subsystems implies that a design change within one subsystem does not require compensating changes in the design of the other subsystems (Schilling, 2000). Another feature linked to modularity are interface standards that describe how subsystems connect and interact by specifying for example the amount and type of energy and information exchange between the subsystems (Henderson & Clark, 1990; Sanchez, 1995; Sanchez & Mahoney, 1996; Sosa, Eppinger, & Rowles, 2003).

Prior studies have highlighted the importance of the selected product architecture for managerial decision making (Baldwin & Clark, 1997; Sanchez & Mahoney, 1996; Schilling, 2000; K. T. Ulrich, 1995). For example a product architecture is known to affect the technical performance of products, but it can also facilitate (or inhibit) the recombination of subsystems in various products affecting both the degree of subsystem carry-over and the ease with which users can customize their individual products (Baldwin & Clark, 1997; M. Fisher, Ramdas, & Ulrich, 1999; Schilling, 2000). Moreover and central to this paper, it is argued that modularity has a

significant impact on the way development and production is managed within and across organizational boundaries (Baldwin & Clark, 1997; M. Fisher et al., 1999; Sanchez & Mahoney, 1996).

However, theories on modularity raise contrasting arguments on how product design and organizational architectures interrelate to each other. The first concept maintains that product modularity reduces interfirm interdependence which fosters 'loose' buyer-supplier integration (Baldwin, 2008; Sanchez & Mahoney, 1996; Sosa, Eppinger, & Rowles, 2004). As long as a subsystem supplier adheres to the standard interfaces that determine the range of possible interactions between subsystems, they can modify their subsystem without the need to involve in co-development practices with other subsystem suppliers or the coordinating system integration firm (Baldwin & Clark, 2000; Cabigiosu & Camuffo, 2012a). So interface standards do not eliminate interdependencies between subsystems, but they do reduce the need for extensive coordination between organizations throughout the development process (Sanchez & Mahoney, 1996; Schilling, 2000). In this way interface standards facilitate the concurrent and autonomous development of subsystems by loosely coupled organization structures (Sanchez and Mahoney, 1996). Following this rationale a widespread assumption in the modularity literature is that modularity in product design associates with loose inter-organizational integration between a lead firm and its suppliers, this is also known as the 'mirroring hypothesis' (Cabigiosu & Camuffo, 2012a; Colfer & Baldwin, 2010; MacCormack, Baldwin, & Rusnak, 2012).

In contrast, the second concept proposes a complementarity between product modularity and tighter buyer-supplier integration (Cabigiosu & Camuffo, 2012a; Hsuan, 1999; Jacobs et al., 2007). This idea posits that for effective product modularization and subsequent integration of complementary subsystems in an end-system, the buyer needs to maintain an in-depth understanding of the outsourced subsystems (Brusoni et al., 2001). Hsuan's (1999) case study on Chrysler Jeeps indicated that higher opportunity for modularization is possible when a more collaborative form of partnership is shared between the parties. Modularity requires companies to understand products at a deep level and, to define proper interface standards one should be able to predict how modules will evolve over time. Prior research suggests that firms need to make subsystems in order to fully understand their inner working and their possible interactions with other subsystems (Parmigiani & Mitchell, 2009). Next to producing subsystems in-house, firms can also chose to develop their component-specific knowledge via intense supply relationships (Hsuan, 1999; Zirpoli & Camuffo, 2009). In view of that products can be modularized only if buyers "know more than they make" (Brusoni et al. 2001, p. 597) buying firms need to engage suppliers in collaborative relationships which may eventually facilitate component modularity (Hoetker, 2006). The modular product is than the result of inter-organizational co-development which depends on intensive interaction by buyers and suppliers (Hsuan 1999)

A buying firm can use different supplier integration strategies in the development of their subsystems. Two relevant strategies that describe the partitioning of NPD responsibilities among the buyer and suppliers include the grey-box and black-box integration modes (Koufteros et al., 2007; Petersen et al., 2005). With black-box integration, a supplier bears complete development responsibility for certain subsystems of their customer and bases their design choices on the

customer's product requirements. In contrast, with grey-box integration the development efforts require that the suppliers become involved in an early stage of the development process to share their expertise and engage in joint decision making in subsystem development. Thereby, black-box integration can be seen as equivalent to loose interfirm relations as described by 'mirroring', whereas grey-box integration stands for tighter integration as proposed by 'complementarity'. We take the perspective of the mirroring hypothesis to connect the degree of modularity with the two supplier integration strategies. We, thus, hypothesize the following:

When the level of modularity of supplier components increases there is less need for inter-organizational integration between the systems integration firm and component suppliers, this implies a higher level of black-box integration (H1a) and a lower level of grey-box integration (H1b).

6.2.2. Architectural and Component Knowledge moderating the product modularity – organizational integration relationship.

Prior research that adopted the architectural view on products and innovation have stressed the relevance of two types of knowledge for the development of individual subsystems and their effective integration in the end-system: component knowledge and architectural knowledge (Henderson & Clark, 1990; Sanchez & Mahoney, 1996). Component knowledge involves a deep understanding on the underlying technical working concepts of individual subsystems and can be used to faster achieve new functions and designs that can be accommodated in the existing product architecture (Henderson & Clark, 1990; Sanchez & Mahoney, 1996). Architectural knowledge involves a deep understanding about the ways in which subsystems are linked together and allows a firm to integrate the multiple subsystems in a well-functioning end-system (Henderson & Clark, 1990).

Several empirical studies indicate that knowledge plays an important role in the relationship between product modularity and the degree of inter-organizational integration (Brusoni et al., 2001; Cabigiosu et al., 2013; Sanchez & Mahoney, 1996). In this respect Brusoni et al's study (2001) in the aircraft industry shows that systems integration firms that maintain a knowledge base that covers the whole product system are more effective in coordinating the design and manufacturing activities within their network of specialized subsystem suppliers. Prencipe (2000) also argued that a deep understanding of components' inner working helped manufacturers of aircraft engine control systems to specify, assess, test and integrate components that are externally sourced. Later studies found that in many cases modularity (in the form of standard interfaces) did not per se eliminate the need for buyer-supplier integration (Cabigiosu & Camuffo, 2012a; Cabigiosu et al., 2013; Colfer & Baldwin, 2010). Despite attempts to modularize systems, modularization is unlikely to fully eliminate and/or codify all the interdependencies between subsystems and companies ex ante (Cabigiosu & Camuffo, 2012a; Colfer & Baldwin, 2010; Ethiraj & Levinthal, 2004; Staudenmayer et al., 2005). Therefore, tight buyer-supplier integration (i.e. grey-box integration) may complement modularity as a means to coordinate the interdependencies that tend to emerge ex post after definition of the modular design interfaces (Staudenmayer et al., 2005). A study in the air conditioning industry suggests

that buyer–supplier coordination was indeed facilitated through interface stability only at high levels of component and architectural knowledge held by the OEM as this improved its ability to predict the technical interdependences characterizing the design of the product (Cabigiosu et al., 2013).

Following these arguments, we expect that higher levels of component and architectural knowledge on part of the supplier allows a firm to more effectively integrate externally produced subsystems as it allows the supplier to better anticipate to potential architectural changes that are triggered by changes within modules (Brusoni et al., 2001; Furlan et al., 2014; Staudenmayer et al., 2005).

H2a: Component knowledge positively moderates the positive relationship between product modularity and black-box integration.

H2b: Architectural knowledge positively moderates the positive relationship between product modularity and black-box integration.

H3a: Component knowledge negatively moderates the positive relationship between product modularity and grey-box integration.

H3b: Architectural knowledge negatively moderates the positive relationship between product modularity and grey-box integration.

6.3. Data & sample

Data of this study was collected from direct material suppliers of an American based focal agriculture equipment OEM. The use of sample firms working in the same industry context excludes industry-level differences in the dyadic buyer–supplier relationships (Liu et al. 2009). Like in other industries (e.g. automotive industry), suppliers of the agriculture equipment industry have the tendency to supply goods to multiple OEM’s within the industry (Dyer & Singh, 1998; Ellis et al., 2012). For that reason, this study and its results can be perceived as representative for the broader agricultural equipment industry.

This survey includes sample firms from a global scope with a wide diversity of material groups. To avoid sample biases, suppliers were randomly selected grounded on the global commodity strategies from the OEM. Thereby, active suppliers with realistic level of relevance were included. All direct material commodities of the OEM were involved, so that the sample represented a diversified group of suppliers with different industry, product and technology backgrounds.

In preparation to the survey, 5 workshops with randomly selected practitioners were organized to ensure academic and practical relevance of the questionnaire. During, the workshops the questionnaire was answered together with one researcher, so that questions were discussed and suggestions were made. After the workshops, the questionnaire was transformed into an online survey tool and send out to 100 randomly selected suppliers in order to test the research instrument under real-life conditions. 58 suppliers participated in the survey pre-test, which provided a good sample to test for statistical validity. The pre-testing ensured that items were clear and understandable by providing simultaneously face validity for the constructs examined. Minor adjustments were done to the questionnaire after the pre-testing before it was converted in

the final online survey. Including the pre-testing, in total 196 suppliers participated which provides a response rate of 45% percent from the total sample.

In regards to data collection, based on the support from the agriculture equipment OEM, suppliers' key accounts were invited to participate in the survey by an e-mail send by the OEM. The e-mail pointed out that suppliers' participation was voluntary and provided a link to the online survey hosted by the university.

The final sample includes direct material suppliers of the agricultural equipment OEM from different industry sectors: 21% are related to castings and metal fabrications, 18% to engine and engine components, 14% to the hydraulic, cylinders and bearing systems, 10% to heating, ventilation and air conditioning. The remaining suppliers belong to other product parts like transmissions, axles, wheels, rubber etc. The diversification of suppliers represents the composition of a final product of the OEM.

The responses illustrate a global origin of responses with a European focus: 66% of responses originate from Europe; 14 % from Asia; 12% from North America and 9% from South America. Major countries of origin are Germany (36%), Italy (13%), United States (12%), Brazil (9%) and China (8%). The remaining responses are coming from Taiwan, UK, and other European countries. The sample symbolizes the supply base structure of a globally operating OEM based in the EU.

The profile of the respondents are distributed as follows: 37% were key account managers; 24% managers of the sales department; 14% senior management and 18% other positions, including engineering. The firms represented in our sample are of notable size, averaging USD 811 million turnover with 7,617 employees, and 4.9% of turnover invested in R&D.

6.4. Measures

The main effect between product modularity and buyer-supplier collaborations is measured with previously existing measures. Only minor wording changes from prior work were done to the measures of product modularity, grey-box integrations and black-box integrations. In contrast, new measures were defined for measuring the degree of component knowledge and architectural knowledge.

Product Modularity. The degree of product modularity is measured using five items which originate from Antonio, Yam, and Tang (2007). The measure considers decoupling, standardization, usability on other products and carry-over potential as perspectives to evaluate the degree of modularity of a product.

Supplier Collaborations. Petersen et al. (2005) define buyer-supplier collaborations in grey-box integrations and black-box interactions. In accordance with Petersen et al. (2005), Koufteros et al. (2007) have formulated measures to capture different degrees of buyer-supplier collaborations which are applied in this study. Grey-box collaboration is about close collaboration between suppliers and buyers, when suppliers provide value adding input on an eye-to-eye level to the buying firm. Black-box collaboration describes the case, when suppliers develop for buying firms by providing majority of development input.

Product Knowledge. New measures were formulated for the two knowledge levels within modularity: Namely component knowledge and architectural knowledge. Previous scholars have argued that product knowledge in context of product modularity should be divided in component knowledge and architectural knowledge (Henderson & Clark, 1990). To reflect the proposed concept of two knowledge types from literature, individual measures were defined for each of the knowledge levels. On the one hand, component knowledge refers to the internal core concept of an individual subsystem (Clark, 1985; Henderson & Clark, 1990). The decoupled structure of a modular product gives subsystems a specific and predefined range of components, which have increases the internal connection and decreases external relations. Thus, the measure for component knowledge is a four item measure that talks about specific knowledge like design and performance for components within a subsystem (Brusoni & Prencipe, 2001b; Henderson & Clark, 1990; Sanchez & Mahoney, 1996). Architectural knowledge, on the other hand, discusses the understanding about integrating and linking subsystems within a coherent whole, so that value is added through the design and integration of subsystems into an embedded end-product (Davies, 2004; Henderson & Clark, 1990; Hobday, Davies, & Prencipe, 2005). The measure includes eight items and reflects among others on system design knowledge, interface understanding and end-product understanding.

To ensure the applicability and relevance of new measures, the formulation followed a systematic validation process: (1) Content validity was safeguarded with an extensive literature review, (2) in-depth focus group discussions with five purchasing managers and five key account managers from randomly selected suppliers facilitated relevance and understandability, (3) one pre-tests of the survey with overall 100 suppliers' sales representatives safeguarded the practical applicability. During the pre-test and the original survey, responses were asked to answer in a five-point Likert scale with end points of 'strongly disagree' and 'strongly agree' (Likert, 1932). A detailed overview of measures can be found in the appendix of this chapter.

6.4.1. Control variables

Design Standards. The four distinct categories of design rules include: *product architecture*, the *interfaces*, *integration protocols* and the *testing standards* that will be used (Baldwin & Clark, 2000). These four categories are transferred into a scale consisting of four items that together tap into a complete set of design rules.

Technological Change. Technological uncertainty is defined as the likelihood of unforeseen technological changes in the product. *Technological uncertainty* was calculated using a two-item measure adopted from Walker and Weber (1984) plus one item taken from the technological uncertainty measure of Jaworski and Kohli (1993).

Supplier resources. The relationship between firm resources and development capabilities of firms is widely discussed (Eisenhardt & Schoonhoven, 1996). Firms with higher resources levels like financials or human capital might be able to more frequently enter product developments with other supply chain stakeholders. Conversely, small firms may also have an advantage in being more flexible and faster to recognize innovative opportunities (Bower & Christensen,

1995). To control for both economies and diseconomies of scale, firm resources are included with number of employees, revenue and R&D spend.

6.5. Analysis & results

Descriptive statistics of variables (means, standard deviations, and correlations between variables) are presented in Table 21. For hypotheses testing hierarchical regression analysis is applied to examine the interactions between product modularity and product knowledge in regards to buyer-supplier collaboration approaches. The procedure followed the outline provided by Aiken, West, and Reno (1991) and Jaccard and Turrisi (2003). First, we averaged the items of each construct and mean centered the values of variables included in the interaction terms. Second, we computed linear interaction terms between product modularity and both knowledge levels as well as component and architectural knowledge. Third, we developed a three way interaction term between product modularity and the two knowledge levels. Fourth, we executed the hierarchical regression analysis by consecutively adding the following blocks of variables: control variables, individual main variables, two-way interaction terms and three way interaction term.

Table 21 - Descriptive Statistics (chapter 6)

Variable	Mean	S.D.	1	2	3	4	5	6	7	8	9	10
1 Product Modularity	3.08	.99	.77									
2 Grey-box collaboration	4.15	.87	.3	.82								
3 Black-box Collaboration	3.67	1.13	.45	.43	.83							
4 Component Knowledge	4.5	.73	.37	.4	.5	.86						
5 Architectural Knowledge	3.89	.79	.36	.41	.55	.59	.78					
6 Technological Change	2.91	.85	.44	.15	.23	.15	.32	.91				
7 Design Standards	3.55	1.01	.47	.26	.42	.31	.41	.24	.82			
8 R&D expenses	4.73	5.15	.05	.07	.16	(.03)	.08	.05	.07	-		
9 Number of employees	7798	25832	.04	.13	.16	.14	.09	(.01)	.17	.2	-	
10 Revenue	14.13	27.32	(.01)	(.02)	.01	(.08)	(.03)	(.02)	(.04)	.2	(.14)	-

n=196 ^a Values on the diagonal are shared values within a construct (square root of AVE)

Table 22 and 23 show the results of the hierarchical regression analysis for grey-box collaborations (table 22) and black-box collaborations (table 23). In both cases we tested successive regression models for product modularity, component knowledge and architectural

knowledge. The variance inflation factors (VIF) among the independent variables (including interaction variables) indicate for both dimensions values below the threshold of 1, which suggests that multicollinearity did not distort our regression results (J. Cohen et al., 2013).

For grey-box collaboration, Model 1 includes the control variables, Model 2 adds the main variables product modularity, architectural knowledge and component knowledge, Model 3 includes the two way interaction terms between product modularity and each of the knowledge types as well as between the knowledge types. Model 4 represents the full model that also contains the three way interaction term between product modularity, component knowledge and architectural knowledge. Models 5, 6, 7 and 8 follow a similar logic by applying successive regression models for black-box collaborations.

We began with examining the improvement in model fit of our control and main variables, linear interaction terms and three way interaction terms. For both Table 22 and Table 23, model comparison follows partial *F*-tests. Results presented in Table 22 and 23 indicate that successive models provided a significant improvement in explanatory power over the previous model, but adding three way interactions in Model 4 and 8 show no change in explanation of R^2 . Regression models 2 and 3 highlight that including the main variables increases R^2 by .14, and linear interaction terms improves R^2 by .15. Similarly, Model 6 and 7 indicate that main variables improve R^2 by .22 and linear interaction terms also led to a significant improvement in the regression model with an R^2 change of 0.02. Finally, the inclusion of three way interactions in Model 4 and 8 show no significant effect on R^2 .

Table 22 shows for grey-box collaborations that the main effect of component knowledge is significant positive in Model 2 ($\beta = .25$; $p < .01$), whereas the main effect of architectural knowledge is positive and significant in Model 2, 3 and 4 (model 2: $\beta = .24$; $p < .01$; model 3: $\beta = .23$; $p < .01$; model 4: $\beta = .23$; $p < .05$). Likewise, the interaction term between product modularity and architectural knowledge shows positive effects (model 3: $\beta = .29$; $p < .01$; model 4: $\beta = .29$; $p < .01$), whereas the interaction between product modularity and component knowledge imply a significant and negative effect (model 3: $\beta = -.57$; $p < .01$; model 4: $\beta = -.56$; $p < .01$). Results suggest no effect by the introduced control variables.

Table 23 highlights a positive and significant effect of component knowledge (model 6: $\beta = .36$; $p < .01$; model 7: $\beta = .50$; $p < .01$; model 8: $\beta = .50$; $p < .01$), architectural knowledge (model 6: $\beta = .39$; $p < .01$; model 7: $\beta = .37$; $p < .01$; model 8: $\beta = .36$; $p < .01$) and product modularity (model 6: $\beta = .24$; $p < .01$; model 7: $\beta = .22$; $p < .01$; model 8: $\beta = .22$; $p < .01$) among Models 6, 7 and 8 for black-box integrations. The linear interaction term between component and architectural knowledge imply a further positive influence in Model 7 (model 7: $\beta = .27$; $p < .01$). Other interaction terms show no significance for black-box collaborations. The control variables R&D spend (model 6: $\beta = .03$; $p < .05$; model 7: $\beta = .03$; $p < .05$; model 8: $\beta = .03$; $p < .05$), design standards (model 7: $\beta = .16$; $p < .05$; model 8: $\beta = .16$; $p < .05$) and technological change (model 5: $\beta = .19$; $p < .05$) have a significant and positive impact on black-box collaborations.

Figure 15 - Slope analysis for knowledge levels of suppliers

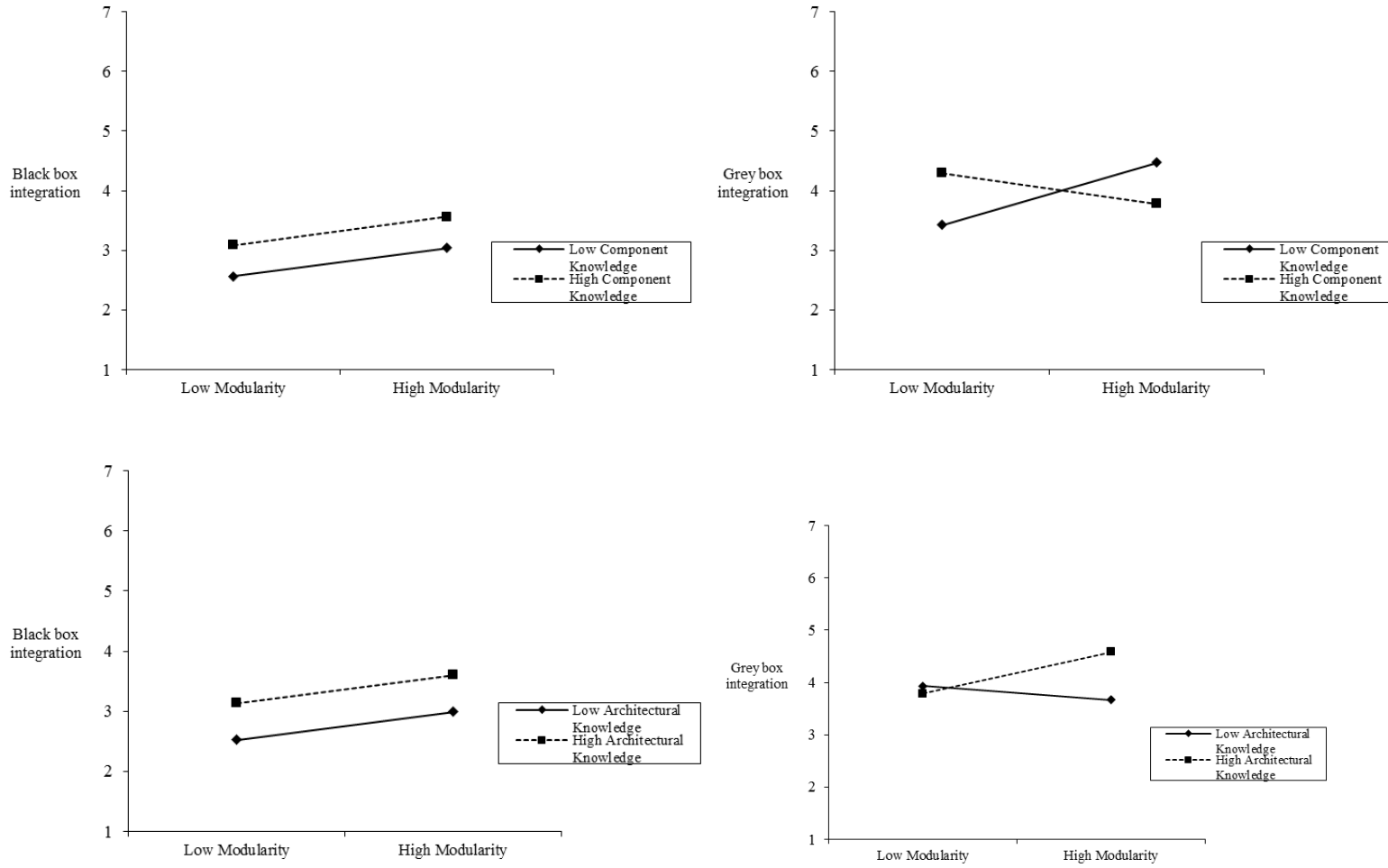


Table 22 - Hierarchical regression results for grey-box integration

Variables (Constant)	Grey-box															
	Model 1				Model 2				Model 3				Model 4			
	<i>B</i>	s.e.		VIF	β	s.e.		VIF	β	s.e.		VIF	β	s.e.		VIF
	3.13	0.28	**		4.03	.33	**		3.93	.30	**		3.93	.30	**	
Technological Change	.10	.07		1.07	(.01)	.07		1.32	(.02)	.07		1.35	(.02)	.07		1.35
Design Standards	.19	.06	**	1.10	.03	.07		1.42	.06	.06		1.44	.06	.06		1.44
R&D expenses	.01	.01		1.06	.01	.01		1.08	.01	.01		1.08	.01	.01		1.09
Number of employees	.00	.00		1.06	.00	.00		1.07	.00	.00		1.08	.00	.00		1.08
Revenue	.00	.00		1.07	.00	.00		1.07	.00	.00		1.08	.00	.00		1.14
Architectural Knowledge					.24	.09	**	1.81	.23	.09	**	1.82	.23	.09	*	2.13
Component Knowledge					.25	.10	**	1.66	.16	.11		2.62	.17	.12		3.06
Product Modularity					.11	.07		1.61	.12	.06		1.64	.12	.07		1.80
Product Modularity*Architectural Knowledge									.29	.08	**	1.87	.29	.08	**	1.97
Product Modularity*Component Knowledge									(.57)	.09	**	2.31	(.56)	.11	**	3.57
Component Knowledge*Architectural Knowledge									.17	.08	*	2.93	.19	.12		6.16
Product Modularity*Component Knowledge*Architectural Knowledge													.01	.08		7.05
Adjusted R ²	.06				.20				.34				.34			
ΔR^2	.08				.14				.15				.00			
ΔF	3.65		**		11.68		**		14.66		**		.03			

N=193; β = unstandardized coefficient. s.e. = standard error. * $p < .05$. ** $p < .01$

Significance levels are two-tailed.

Table 23 - Hierarchical regression results for black-box integration

Variables	Black-box															
	Model 5				Model 6				Model 7				Model 8			
(Constant)	β	s.e.		VIF	β	s.e.		VIF	β	s.e.		VIF	β	s.e.		VIF
Technological Change	.19	.09	*	1.07	(.02)	.08		1.32	(.02)	.08		1.35	(.02)	.08		1.35
Design Standards	.41	.08	**	1.10	.14	.07		1.42	.16	.07	*	1.44	.16	.07	*	1.44
R&D expenses	.03	.01		1.06	.03	.01	*	1.08	.03	.01	*	1.08	.03	.01	*	1.09
Number of employees	.00	.00		1.06	.00	.00		1.07	.00	.00		1.08	.00	.00		1.08
Revenue	.00	.00		1.07	.00	.00		1.07	.00	.00		1.08	.00	.00		1.14
Architectural Knowledge					.39	.11	**	1.81	.37	.10	**	1.82	.36	.11	**	2.13
Component Knowledge					.36	.11	**	1.66	.50	.14	**	2.62	.50	.15	**	3.06
Product Modularity					.24	.08	**	1.61	.22	.08	**	1.64	.22	.08	**	1.80
Product Modularity*Architectural Knowledge									(.02)	.09		1.87	(.02)	.09		1.97
Product Modularity*Component Knowledge									(.19)	.11		2.31	(.18)	.13		3.57
Component Knowledge*Architectural Knowledge									.27	.10	**	2.93	.28	.15		6.16
Product Modularity*Component Knowledge*Architectural Knowledge													.01	.09		7.05
Adjusted R ²	.20				.42				.43				.43			
ΔR^2	.22				.22				.02				.00			
ΔF	1.70 **				24.35 **				2.59 **				.01			

N=193; β = unstandardized coefficient, s.e. = standard error, * $p < .05$. ** $p < .01$
 Significance levels are two-tailed.

6.6. Discussion

The aim of this paper is to shed light on the controversy if product modularity leads to less tightly coupled collaborations between buyers and suppliers or not. As such, this study is the first that asks: Should my suppliers know more than they produce? By trying to answer this question, this study contributes valuable insights by adding the supplier perspective and the differentiation between component and architectural knowledge to the discussion. This paper has theoretical and managerial contributions.

6.6.1. Theoretical implications

The first contribution of this study is to increase insight and provide explanation on the ongoing controversy about the “mirroring hypothesis” (Cabigiosu & Camuffo, 2012a; Colfer & Baldwin, 2010; Sanchez & Mahoney, 1996). Modularity literature often refers to the rational of mirroring hypothesis that product architecture drives organizational architecture (Colfer & Baldwin, 2010; Sanchez & Mahoney, 1996). But two different theoretical positions have emerged and build a controversy on the topic in literature. One stream claims that modularity in product design minimizes the need for close relationships between buyer and suppliers, because decoupling of subsystems lowers interfirm interdependence as well as coordination and control needs (Baldwin, 2008; Sanchez & Mahoney, 1996; Sosa et al., 2004). The second stream considers modularity in product design to increase the need for tight integration between buyers and suppliers (Hsuan, 1999). In view of that modularity can only work, if buyers “know more than they make” (Brusoni & Prencipe, 2001b) and engage suppliers in collaborative relationships that component modularity may eventually only facilitate (Hoetker, 2006). In light of this controversy, this study provides an explanation under which conditions there are mirroring effects and under which not.

Our findings confirm our first hypothesis (H1a) that high modularity of supplier components leads to loose inter-organizational integration in form of black-box collaborations. Thereby, the general idea of mirroring is confirmed. In contrast our results reject the second hypothesis (H1b) by showing that higher modularity can also bring higher buyer-supplier collaboration in case of grey-box collaborations. Thereby, this study underlines the ongoing discussion that not in all cases modular design replaces high-intensive collaboration mechanisms between companies. Our results provide empirical evidence that firm’s scope of knowledge is a major influencing factor in determining, if mirroring happens or if “thick” interfirm collaborations emerge. Thereby, this study contributes a key aspect to explain the interplay of modularity and inter-organizational relationships.

Knowledge sitting at the supplier site appears to have a direct impact on the type of inter-organizational collaborations. Moreover, the type of knowledge appears to matter, since component and architectural knowledge infer different effects on inter-organizational collaborations. Looking at loose collaborations in the form of black-box collaborations, component and architectural knowledge at the supplier site promote loose collaborations under the condition of high modularity (H2a and H2b). By this means our results support the mirroring hypothesis, when product scopes are defined and suppliers have high component and

architectural knowledge the interaction between parties is reduced. The results of the simple slope analysis (Figure 15) illustrate the positive relation between product modularity, the two knowledge types and lower interfirm collaborations in the form of black-box collaborations. Architectural knowledge seems to have a larger positive effect than component knowledge on the degree of black-box integration. Apparently, suppliers that ‘know more than they produce’ understand how changes within their subsystem may require compensating changes in other subsystems can more independently work on their subsystems.

Interestingly, effects of knowledge contradict with mirroring hypothesis when grey-box collaborations are concerned. Our results show that low component knowledge by the supplier fosters close collaboration between the buyer and supplier within highly modular product structures (rejection of H3a). Brusoni and Prencipe (2001b) claim that product modularization brings greater specialization involving greater division of work across firms. However, if suppliers lack component-specific knowledge, suppliers are inhibited to address and perform all possible development activities. Thus, the OEM and the supplier work closely together to develop the dedicated subsystem together, when the boundaries of the subsystem are defined. In that way, this study identifies a lack of component knowledge as the first condition under which product modularity can lead to high-intensive interfirm collaborations.

Our results also show that in highly modular product structures, high-interactive grey-box collaborations can increase, when suppliers have a great level of architectural knowledge (reject of H3b). The findings of the simple slope analysis (Figure 2) show that the inter-organizational collaboration in form of grey-box collaboration increases, when architectural knowledge as well as product modularity is high. Cabigiosu et al. (2013) argued studying the automotive industry, the knowledge level held by the OEM and its ability to predict the technical interdependences characterizing the design of the product fosters buyer–supplier coordination within product modularity. Similar phenomenon appears to be relevant when architectural knowledge resides at the supplier. A explanation could be that high modularity increases the system integration role of buying firms (Brusoni & Prencipe, 2001b), which results in greater efforts for the buying firms to coordinate and manage the integration of different subsystems. Thus, suppliers with architectural knowledge are more intensively integrated in the form of grey-box collaborations, since suppliers with architectural knowledge can assist the buying firm with their system integrator activities. Thereby, our results present the second condition under which product modularity can stimulate intensive inter-organizational collaborations between buyers and suppliers.

Following up on the ongoing debate in literature, if product modularity leads to ‘loose’ or ‘thick’ buyer-supplier relationships, this study finds evidence to belief that the degree of mirroring (Colfer & Baldwin, 2010), and the concept of a direct link between product structures and related organizational structures (Sanchez & Mahoney, 1996) is depending on the knowledge levels of firms. Moreover, the knowledge levels of suppliers appear to have an influence on the nature of collaborations. In accordance with Brusoni and Prencipe (2001b), a suppliers’ knowledge scope can fundamentally differ from the scope of the subsystem the supplier has to develop. The knowledge level of the suppliers can impact the nature of inter-organizational

collaborations independent of the degree of product modularity. In consequence, sometimes your suppliers should ‘know more than they produce and what your suppliers know matter for you’.

The second contribution of this study is the first empirical differentiation between component and architectural knowledge. Our results show that the two knowledge dimensions affect the relationship between product modularity and inter-organizational collaboration. Previous scholars have argued that product knowledge in a modular product environment should be divided in component and architectural knowledge (Henderson & Clark, 1990; Sanchez & Mahoney, 1996). This study has put the theoretical discussion into application and defined different measures for each knowledge dimension. The results show evidence that knowledge should be differentiated, when looking at product modularity and inter-organizational interactions. Component knowledge and architectural knowledge show dissimilar impacts in our results, which imply the relevance of distinction in future research.

The third contribution builds the analysis of the supplier perspective in context of product modularity and interfirm collaborations. The role of suppliers is ignored by most of the research on product and organizational design, as the buying site is commonly considered as driving stakeholder defining organizational interfaces and acting as system integrator (Brusoni & Prencipe, 2001b; Cabigiosu & Camuffo, 2012b). However, inter-organizational collaborations are dyadic by nature and involve buyers and supplier by allocating a major part of development activities to suppliers (Frigant & Talbot, 2005; Gadde & Snehota, 2000). Suppliers, therefore, need to embody all the knowledge relevant to the development of the component or subsystem itself. Thus, the supplier site represents a highly relevant perspective in the topic of product and organizational design. To our knowledge, this study is the first that takes the supplier site into consideration, which is often neglected by previous research. Thereby, this study adds a new perspective to the debate which has been documented and argued convincingly by several scholars.

6.6.2. Managerial implications

Based on the findings, clear managerial implications can be formulated. First, practitioners working at buying firms should consider the knowledge level of suppliers, when deciding for a collaboration approach with suppliers. A well-defined modular product design does not automatically facilitate loose supply relationships, but the interplay of modularity and product knowledge enables both ‘loose’ or ‘thick’ buyer-supplier relationships. Indeed, we found that modularization requires component and architectural knowledge at the suppliers to establish loose relationships in form of black-box collaborations, but findings also imply certain knowledge domains can intensify the collaboration between buyer and supplier. Thus, buying firms should carefully evaluate the knowledge levels of suppliers, so that they can most benefit. For example, practitioners could intensively integrate suppliers with high architectural knowledge in form of grey-box collaborations in order to use the supplier as additional resource for systems integrator activities. To give a practical example, the supplier could contribute to the buying firm in defining and managing interfaces of the subsystem through joint decision making.

6.7. Limitations & future research

While our study offers novel and complementary insights regarding product modularity and inter-organizational collaborations, we would like to acknowledge some limitations and highlight possible avenues for further research.

First, the subjective measurement of the dependent variables, grey-box and black-box integration, represent a limitation. Respondents were asked whether their company is involved in NPD projects of their customers. Although such perceptual measures are considered to be satisfactory in operations management research (Ketokivi & Schroeder, 2004a), collecting more objective and transparent data like the number of projects with reasonable integration in comparison to the total number of projects, would add validity to the findings.

Second, while we asked respondents about their interaction pattern with customer over a period of three years, potentials evolvments of knowledge and the implications on relationships couldn't be captured. For example, suppliers' architectural knowledge could increase though out a development project, which potentially influence the organizational coupling between the supplier and the buyer. Future research could benefit from studying how patterns of learning and knowledge gain over time influence inter-organizational collaborations.

Third, another potential limitation relates to the single industry orientation of this study. Nonetheless, the industry segment studied is characterized by a wide variety of products (e.g. castings and metal fabrications, engine components and hydraulic and cylinders etc.), country of origins (Europe, North America, Asia etc.) and a diversity of respondents profiles (key account, management, C-level management.) the generalization of these results awaits further research support.

We hope future studies will continue to address the ongoing controversy about product modularity and organizational coupling. Scholars of buyer-supplier relationships have acknowledged that dyadic data samples advance the scope of analysis significantly (Monczka et al., 1995; O'Toole & Donaldson, 2002). Thus, future research focusing on dyadic or network relations by collecting data from multiple stakeholders could help to further understand the interplay of modularity, product knowledge and inter-organizational collaborations.

6.8. Appendices

Items measuring constructs

For all items with no other scale indicated, the response scale was 1 = ‘strongly disagree’ to 5 ‘strongly agree’.

Main variables

Product modularity

PM1 Your products can be decomposed into separate modules.

PM2 We can make changes in key component of our products without redesigning other parts.

PM3 Your product components can be reused in various products.

PM4 Your product has high degree of component carry-over.

PM5 Your product components are standardized.

Architectural knowledge

AK1 We fully understand subsystem core design concepts (e.g. arrangement of subcomponents, design specifications etc.)

AK2 We fully understand how our subsystem interfaces with subsystem supplied by other parties.

AK3 We well understand effective development processes for our subsystems.

AK4 We have thorough concept design and systems integration resources in-house.

AK5 We fully understand how to integrate our subsystems in the customers final product.

AK6 Our system knowledge allows us to predict the effect of changes in our subsystem on other subsystems in our customers‘ end product and vice versa.

AK7 We have a thorough understanding of the architecture of our customers' end-product.

AK8 We fully understand how our subsystems interact with other subsystems in fulfilling the end-products function.

Component knowledge

CK1 We fully understand the internal working concept of our components (e.g. modeling, material, specifications etc.)

CK2 We have full understanding to predict which varieties of a component (e.g. material, design, specification etc.) to use in order to improve performance.

CK3 We well understand effective development processes for components.

CK4 We have thorough component design resources in-house.

CK5 We can explain why using certain varieties of component results in specific performance characteristics.

Grey-box collaboration

Please rate the following points in accordance to the level of appearance at our company during the last 3 years.

GB1 We are involved in early stages of product development of our customers

GB2 We provide our input on the design of the component parts of our customers.

GB3 We provide our expertise in the development of products of our customers

GB4 We enter in joint development efforts with our customers, which include joint decision making.

Black-box collaboration

Please rate the following points in accordance to the level of appearance at our company during the last 3 years.

BB1 We develop component parts for our customers (self-contained).

BB2 We do product engineering of component parts for our customers.

BB3 We develop whole subassemblies for our customers (self-contained).

BB4 We are informed of customer requirements and then get almost complete development responsibility for the purchased item.

BB5 We involve our sub-suppliers in development activities for our customers on our own choice.

Design rules

For the products in your industry, a complete set of design rules is available that fully describes the following categories of design information. Please choose the appropriate response for each item:

DR1 Design rules for the architecture (i.e., what subsystems will be part of the architecture system, and what the roles of the subsystems will be in the architecture system)

DR2 Design rules for the interfaces among the different subsystems (i.e., detailed descriptions of how the different subsystems will interact, including how they will fit together, connect, communicate and so forth).

DR3 Design rules for integrations protocols (i.e. procedures that will allow designers to assemble the architecture system)

DR4 Design rules for testing standards (i.e. standards that will allow designers to determine how well the architecture system works, whether a particular (sub-) system conforms to the design rules, and how one version of a subsystem performs relative to another.

Control variables

Technical Change

TC1 Specifications for your components / subsystems change frequently.

TC2 Future technological improvements for your components and subsystems are very likely.

TC3 The technologies used in your components / subsystem are changing rapidly.

Design Standards

DS1 Design rules for the architecture are available.

DS2 Design rules for the interfaces among the different subsystems are available.

DS3 Design rules for integrations protocols are available.

DS4 Design rules for testing standards are available.

Single item control variables:

Please provide the following information related to your company. In case you are part of a group structure, please indicate the information for your location.

- Spend for basic research (% of revenue)
- Number of employees
- Annual sales of your company (in Mio. €)

7. Discussion

7.1. Introduction

The aim of this research was to understand supplier integration in NPD with special emphasis on supplier characteristics within modular product designs. This dissertation consists of five research papers each presenting a different perspective on supplier integration in NPD. In the following concluding section, key findings of earlier chapters will be highlighted and contributions for research and practice will be outlined. Finally, limitations and possible paths for future research will be discussed.

7.2. Main Findings

To address the topic of supplier integration in modular product designs, this research first looked at OEMs and analyzed antecedents at the buying site. Thereby, the first secondary research question about antecedents for supplier integration in NPD is addressed. Findings indicate that purchasing representatives need to be involved in NPD in order to realize a positive effect of supplier integration on the OEM performance (chapter two). Results provide strong empirical support for the notion that purchasing inclusion is a major driving and enabling factor for successful supplier integration (Hillebrand & Biemans, 2004; Johnsen, 2009; Tracey, 2004). In detail, findings imply that firms who include their purchasing employees in NPD are likely to have supplier integrations with better effects than those who for example purely rely on engineering personnel for the integration of external expertise. To facilitate purchasing inclusion, chapter two provides explanation on organizational antecedents. Findings identified top management support, existence of an advanced sourcing function, a process organization and a collaborative corporate culture as organizational antecedents driving purchasing inclusion within an OEM organization.

After the analysis of antecedents for supplier integration in general, this dissertation studied the second secondary research question of which supplier capabilities enhance supplier innovations in buyer-supplier collaborations (chapter three). Thereby, this study contributes to supply chain literature by highlighting that sub-supplier integration by first-tier suppliers fosters the innovativeness of first-tier suppliers at the OEM level. Nonetheless, findings indicate the novelty that potential benefits of sub-supplier integration are depending on technical and relational characteristics of first-tier suppliers. In particular, engineering capabilities and preferred customer treatment fully mediate the effect of sub-supplier integration on supplier innovativeness for OEMs. First-tier suppliers seem to act as a filter through which sub-suppliers capabilities have to be passed-on to the OEM level. Thus, if an OEM wants to fully profit from the resources of its supply chain, the OEM needs to work with competent first-tier suppliers who have, in turn, 'relationship capabilities' to integrate second-tier suppliers and who award the OEM with preferred customer status.

After the analysis of antecedents for innovative supplier contributions, this dissertation elaborates on supplier characteristics of module developments. Research showed that product modularity is considered to have an influence on supplier integration (e.g. Campagnolo & Camuffo, 2009) and specially on characteristics of module suppliers (Oh & Rhee, 2010). By considering the third secondary research question, this research has identified critical supplier

characteristics for module developments through three case studies in four wheel industries (chapter four). Mature processes for NPD, quality and sub-supplier integration were detected as relevant supplier capabilities. Moreover, technical competences especially component and architectural knowledge as well as a collaborative working style along the supply chain were considered to be crucial for successful module developments with suppliers. Considering different interaction levels between suppliers and buyers as proposed by Petersen et al. (2005), qualitative (chapter four) and quantitative (chapter five) analysis addressed the fourth and fifth secondary research question. Both analyses give reason to belief that supplier capabilities differ between joint developments (grey-box) and self-dedicated developments by suppliers (black-box). Accordingly, the empirical analysis of supplier capabilities in relation to grey-box and black-box collaboration indicates that increasing development responsibility of suppliers goes hand in hand with an increase of required supplier capabilities (chapter five).

By elaborating on the interaction between product modularity, technical supplier knowledge and buyer-supplier collaborations, this study contributes to the fifth secondary research question by adding to the knowledge which supplier should be integrated for module developments. Findings provide evidence that the degree of technical knowledge residing at the supplier site influences the kind of buyer-supplier collaborations within product modularity (chapter six).

Moreover, the type of knowledge appears to matter, since component and architectural knowledge infer different effects on inter-organizational collaborations. Looking at loose collaborations in the form of black-box collaborations, component and architectural knowledge at the supplier site promote loose collaborations under the condition of high modularity. In contrast our results also show that in highly modular product structures, high-interactive grey-box collaborations can increase, when suppliers have a great level of architectural knowledge. Findings provide explanation under which conditions a supplier should be loosely integrated (black-box) or should be integrated with high-interaction (grey-box).

In sum, this dissertation sheds light on the question which suppliers should be integrated for module developments. Since this dissertation intends to provide a great level of applicability and practicality, we have formulated a check-list that translates the major findings of this dissertation into a practical format (Figure 16).

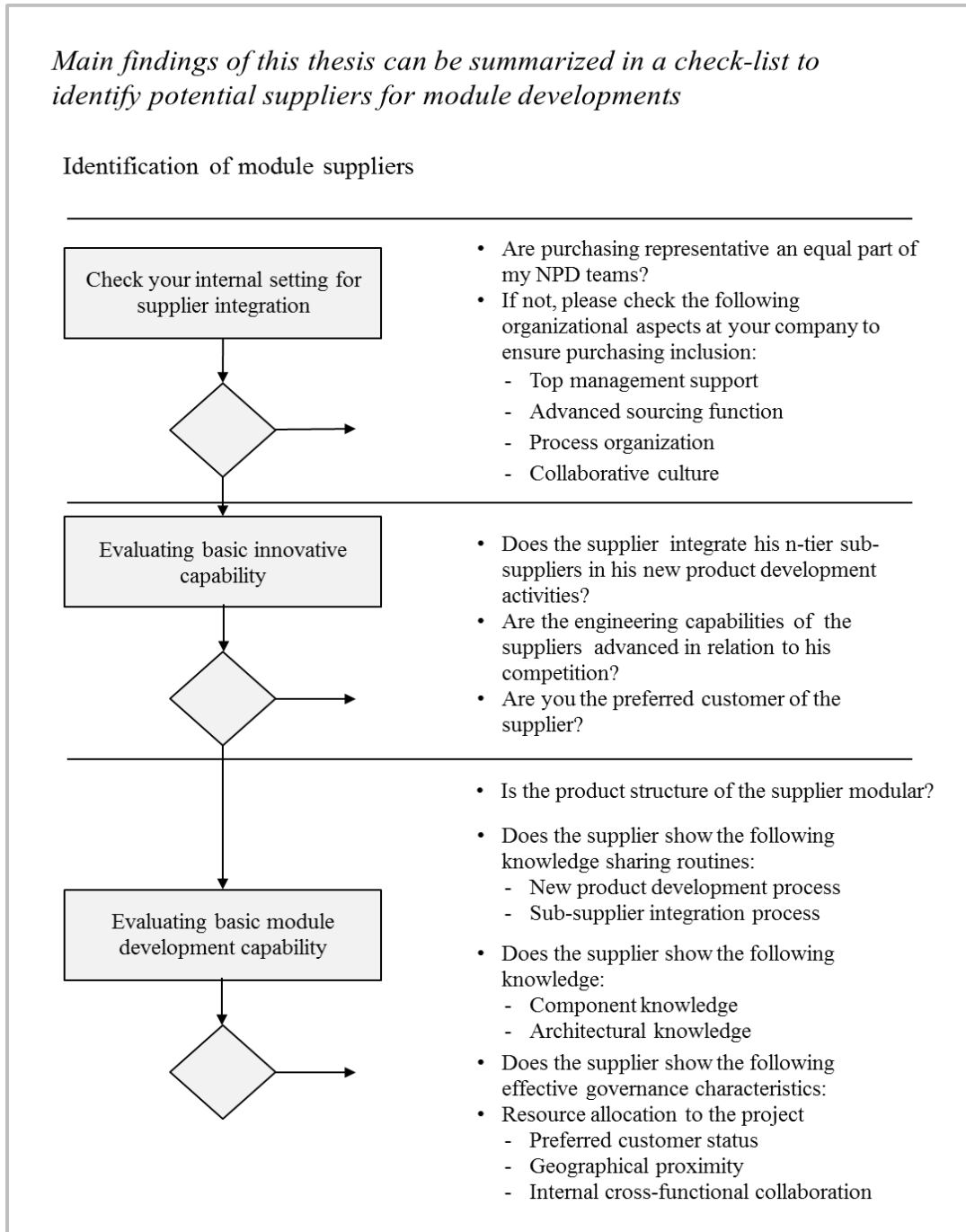
First, to ensure supplier integration in the first place, practitioners should check if their own organization is capable to integrate suppliers. Thus, practitioners should analyze if purchasing is part of their NPD team structure since the purchasing stakeholders work as integration agent for suppliers in NPD. If purchasing is not an equal part, the four organizational aspects driving the inclusion of purchasing representative in NPD should be evaluated. Thereby practitioners can identify potential root causes for ineffective purchasing inclusion and can in consequence foster successful supplier integration.

Practitioners should then assess the basic innovation capability of suppliers. In doing so, practitioners can ensure that a potential supplier can bring innovative contributions. The supplier should in particular show interaction with n-tier sub-suppliers, technical and relational capabilities. Practically, this could inquire that the purchasing officers of the OEM may not only

talk to their key accounts, but also talk to suppliers' purchasing function in order to understand suppliers' relationship capabilities to fully leverage its own supply chain.

After the assessment of more general aspects, practitioners are supposed to assess the basic module development capabilities of suppliers in order to prevent technical and performance risks (Handfield et al., 1999). Therefore, module suppliers should be evaluated on multiple dimensions referring to technical and organizational capabilities of suppliers.

Figure 16 - Check-list to identify module suppliers



To ensure supplier performance for module developments, practitioners are advised to match the identified supplier characteristics with the anticipated supplier integration approach. This dissertation has focused on two supplier integration approaches: Joint developments between buyers and suppliers (grey-box) and self-dedicated developments by suppliers (black-box). Based on the finding of this dissertation supplier profiles with necessary supplier characteristics for grey-box and black-box collaboration are outlined in Figure 17.

Figure 17 - Supplier profiles for module developments

Identification of module supplier profiles	
Module suppliers for grey-box collaboration	Module suppliers for black-box collaboration
<ul style="list-style-type: none"> • Component Knowledge • NPD project management process • Sub-Supply Chain Collaboration • Resource allocation • Preferred customer status • Geographic proximity • Internal cross-functional collaboration 	<ul style="list-style-type: none"> • High product modularity • Component Knowledge • Architectural Knowledge • Advanced engineering capabilities in relation to competition • NPD project management process • Sub-Supply Chain Collaboration • Resource allocation • Preferred customer status • Internal cross-functional collaboration • Number of employees

7.3. Implications and contributions per chapter

This dissertation consists of five research articles represented in the different chapters. All contributions and implications of the articles can be found in the respective discussion section of each chapter. The following concluding section will summarize the key implications and contributions for theory and practice.

7.3.1. Purchasing as integration agent who fosters positive effects of supplier integration

Chapter two addresses antecedents for supplier integration in NPD and discusses the role of purchasing professionals and their positive influence on supplier integration in relation to buying firms performance.

Core elements:

- Positive impacts on buying firms performance by supplier integration depends on the inclusion of purchasing representatives in NPD

- Involvement of purchasing representatives in NPD can be fostered through four organizational factors
- Managers can assure positive effects of supplier integration on buying firm's performance through purchasing inclusion

Theoretical contribution. The first major theoretical contribution of this research builds the identification of purchasing inclusion as enabling factor for positive impacts of supplier integration in NPD. Thus, firms who want to establish external relationships need to first align internally (Horn et al., 2014). Findings provide evidence that purchasing inclusion enables supplier involvement by building relationships between internal and external stakeholders. This study contributes to the understanding of purchasing's agent role by highlighting the significant enabling effect of purchasing professionals on supplier involvement (I. J. Chen et al., 2004; Ellram & Liu, 2002; Johnsen, 2009). The positive effect of purchasing inclusion was addressed by many scholars before (Droege et al., 2004; Gupta & Wilemon, 1990; Wynstra et al., 2003), but findings of this study enhance current knowledge by illustrating the significant moderating effect of purchasing inclusion. If purchasing is involved in NPD, its supplier management competencies and its dual interest in generating innovation and managing costs, facilitates the identification and integration of valuable suppliers. The enabling role of purchasing follows the prerequisite that the involved purchasing representatives have the knowledge to identify, develop and integrate supplier resource effectively.

Second, our findings provide indication that organizational aspects drive purchasing inclusion in NPD. We examined four factors that previous NPD research has revealed to be effective in NPD projects (Cooper & Kleinschmidt, 1995; Ernst, 2002), namely top management support, structural differentiation, process organization, and collaborative corporate culture. Findings of this dissertation highlight that these four organizational aspects stimulate purchasing inclusion in NPD teams. In consequence, supply chain literature is enhanced by highlighting that analysis of often neglected organizational aspects should be revitalized for buyer-supplier related research.

Managerial contributions. Chapter two indicates that involving purchasing personnel in NPD is crucial for supplier integration. Accordingly, if managers want to ensure positive effects of supplier integration on buying firm's performance, involving purchasing representatives in NPD appears to be obligatory. Findings show that buying firms who lack involvement of purchasing do not only miss opportunities to integrate supplier, but can also experience a negative effect of supplier integration on their performance.

In order to assist managers to ensure purchasing involvement, chapter two provides explanation on how to organize a company in order to realize successful purchasing involvement in NPD. In addition to the all-important top management support, findings demonstrate that the often-neglected structural, procedural, and cultural aspects of a firm are highly relevant. Specifically, our results indicate that the structure of the purchasing department needs to be adapted to facilitate the integration into the NPD process. For instance, companies should apply a structural differentiation approach using an advanced sourcing (sub-) department or, in case of a

smaller firm, at least one person executing (ideally) only that specific function. Moreover, a clearly defined NPD process framework facilitates the purchasing integration into the NPD process. Therefore, a corporate-wide process description that finds constant application can be a useful tool to ensure the establishment of a stable process environment for NPD. The reluctance that is often found in formulating and enforcing detailed process descriptions should not be tolerated. Additionally, a cooperative culture can act as an important influential factor for purchasing integration by encouraging the willingness and ability to cooperate and communicate internally. All in all, findings provide practitioners guidance about the relevance and implementation of purchasing involvement in NPD.

7.3.2. Technical and relational characteristics as driving factors for supplier innovativeness

Chapter three addresses supplier characteristics that drive innovative supplier contributions in buyer-supplier collaborations. Thereby, our findings identify sub-supplier integrations under the condition of technical and relational characteristics of first-tier suppliers as driver of innovative supplier contributions in buyer-supplier collaborations. The analysis was realized in form of a dyadic analysis by consolidating responses from a multinational OEM and its international supply base.

Core elements:

- Sub-supplier integration by first-tier suppliers foster the innovation level of (first-tier) suppliers at the buying firm level
- Benefits of sub-supplier integration depend on technical and relational characteristics of first-tier suppliers
- Dyadic research might build a role model for future supply chain research

Theoretical contributions. First, chapter three presents a model of how buying firms can increase the innovation level of suppliers within buyer-supplier collaborations. Findings show that supply chain collaboration fosters the ability of first-tier suppliers to contribute innovative inputs to buying firms. However, findings imply that OEMs only receive the benefits of sub-supplier integration, when first-tier suppliers show advanced technical capabilities and favorable relational characteristics.

Until now engineering capabilities by suppliers were perceived as facilitator for innovative inputs by suppliers (Cabral & Traill, 2001; Monczka et al., 2000; Wognum et al., 2002). Findings of chapter three enhance the current understanding by showing that advanced engineering capabilities of first-tier suppliers also act as an enabling factor for buying firms to profit from sub-tier supply chain capabilities.

Relational characteristics of suppliers were identified as another full mediator between supply chain collaboration and innovative supplier contributions to OEMs. Thereby, a preferential customer treatment is identified as a facilitator for buying firms to benefit from supply chain resources. Previously, relationship characteristics in form of preferred customer treatment were

only identified to facilitate access to first-tier supplier resources (Pulles, Veldman, & Schiele, 2014; Schiele, 2006). Likewise, findings of chapter three imply that relational aspects are equal or even more important for innovative collaborations between buyers and suppliers than technical and organizational characteristics (Pulles, Veldman, & Schiele, 2014).

Second, this study contributes to supply chain literature by highlighting the relevance of supply chain collaborations in regards to supplier innovativeness. Previous studies have indicated that the interplay of multiple organizations within a business network drive innovation creation (Corsaro et al., 2012; Håkansson, 1987; Lundvall, 1985; Roy et al., 2004; Von Hippel, 1994); however the understanding of the role of lower-tier supplier integration in regards to innovation creation remained limited (e.g. Choi & Krause, 2006). This study adds new insights by showing that the integration of sub-suppliers in NPD activities by first-tier suppliers results in a higher innovation level at the OEM. Sub-suppliers are thereby identified as a source of innovation within supply chains.

Third, this paper adds to supply chain literature with the first empirical test of dyadic data compiling buyer and supplier responses in regards to supplier innovation in buyer-supplier collaborations. Until now, antecedents and dynamics of buyer-supplier relations have been tested mainly either from the buyers or the suppliers perspective, but rarely between buyers and suppliers in the same relationship (Terpend et al., 2008). Scholars have acknowledged that a lack of dyadic perspective can build a limitation of supply chain research (Monczka et al., 1995; O'Toole & Donaldson, 2002). In consequence, this study provides one potential role model for future supply chain literature.

Managerial Contributions. First, looking at buying firms, findings provide guidance to identify most innovative suppliers for joint development activities. In the past, scholars and practitioners often followed the limited conjecture to merely select suppliers with the “best” technical and organizational characteristics in order to receive innovative contributions (Ho et al., 2010; Le Dain et al., 2011). This study corrects previous perceptions and highlights that buying companies should invest as much if not more attention to relationship characteristics of the supplier.

Second, buying firms need to understand that technical capabilities of first-tier supplier act as facilitator for positives effects of supply chain resources on supplier innovativeness. Until now, previous research has argued that suppliers with existing in-house engineering capabilities can be trusted to develop parts, or subassemblies (Koufteros et al., 2007) and that engineering capabilities are essential for innovative suppliers in product development activities (Cabral & Traill, 2001; Monczka et al., 2000; Wognum et al., 2002). Findings of this study indicate that managers should think and act beyond this current understanding. Buying firms should foster and ensure advanced engineering capabilities of their first-tier suppliers in order to benefit from sub-supplier capabilities. In consequence, practitioners should consider the different sources of innovation within the supply chain.

Third, considering the supplier site, our results offer direction for supplying firms to increase their innovation potential. Integrating sub-suppliers within NPD activities was identified to foster

engineering capabilities as well as the innovation ability of suppliers. Thus, chapter three highlights that first-tier suppliers can advance their own capabilities by using sub-suppliers as a source of flexibility and resources (Fagerstroem & Jackson, 2002).

7.3.3. Module supplier embody special characteristics along for possible roles

Chapter four considers the interplay of supplier integration and modular product design in order to identify supplier characteristics for module developments. During three case studies, capabilities of suppliers that are involved in module developments were analyzed and grouped in relation to different degrees of interaction. Thus, chapter four presents a novel research perspective that provides a detailed picture on supplier characteristics of module suppliers.

Core elements:

- Increasing development responsibilities by suppliers simultaneously require higher supplier resource levels
- Engineering capabilities and component knowledge are less relevant for joint development activities than for self-dedicated developments by suppliers
- Supplier roles for successful collaborating in module developments can be put in four supplier roles

Theoretical contributions. At first, findings of chapter four identify supplier characteristics for module developments. In particular, mature processes for NPD, quality and sub-supplier integration, technical understanding and a collaborative working style were identified to be crucial characteristics of module suppliers. The identification of supplier characteristics for module developments adds new aspects to the theoretical understanding of successful buyer-supplier collaborations. As a result, findings help to find competent suppliers for module developments to avoid complications such as project disruptions (Flynn et al., 2000; Hartley et al., 1997; Primo & Amundson, 2002; Zsidisin & Smith, 2005).

Second, this study advances the understanding of relational view in context of supply chain collaborations. Findings give reason to belief that the interaction level between supplier and buyer is influenced by characteristics of suppliers. Based on the integration model of Petersen et al. (2005), findings provide evidence that supplier integrated for a joint collaboration (grey-box) need other capabilities than a supplier who is asked to develop a module self-contained (black-box). Black-box suppliers are identified to have more capabilities in comparison to suppliers for joint grey-box developments. Chapter four uses the perspectives of relational view to present the differences between black-box and grey-box collaborations in detail. Accordingly, black-box suppliers need more complementary resources in form of technical knowledge and knowledge sharing routines like mature processes than grey-box suppliers. The variances between grey-box and black-box integrations imply that supplier integration approaches for module developments need to be matched with the available supplier characteristics. The link between relation view

(available characteristics) and potential supplier integration approaches (grey-box and black-box) enhances the theoretical understanding of buyer-supplier collaborations.

Third, findings about supplier characteristics and supplier integration approaches were translated in a guideline that links supplier integration approaches and supplier characteristics with project interests. Four possible supplier roles for successful buyer-supplier collaborations concerning module developments were identified. Suppliers can be a basic provider, a project lead, a technical expert or a technical managing lead. The individual role of a supplier depends on the technical and managerial capabilities of each individual supplier.

Managerial contributions. First, chapter four identifies crucial supplier characteristics for successful module developments with suppliers. Second, findings provide guidance to practitioners on how to find the best integration approach for potential suppliers. Based on the formulated model of potential module supplier roles, chapter four presents an evaluation scheme that directly supports the right supplier decision for module developments. This evaluation scheme takes supplier characteristic and evaluates their competences level for each characteristic. Thereby, practitioners can evaluate potential suppliers in a structured way and get an indication of the best suitable role for each supplier.

7.3.4. Supplier resources differ in accordance to the supplier integration approach for module developments

Chapter five builds on findings of chapter four and empirically investigates the identified supplier characteristics in relation to grey-box and black-box supplier integration approaches.

Core elements:

- Empirical evidence that supplier resources differ in accordance to the supplier integration approach
- Increasing development responsibilities for suppliers require more capabilities at the supplier site
- Quality processes can represent a hurdle for buyer-supplier collaborations

Theoretical contributions. First, chapter five enriches the theoretical concept of relational view while looking at collaborations between buyers and suppliers. By this means, to best of our knowledge, this study is one of the first taking relational view as theatrical concept to analyze suppliers-buyer collaborations for module developments. Findings provide empirical evidence that supplier resources differ in accordance to the supplier integration approach. Suppliers acting as a module developer in form of black-box suppliers show more capabilities than supplier who participate in a joint (grey-box) development with OEMs. On the hand, grey-box supplier should embody architectural knowledge and supply chain collaboration capabilities. In addition to capabilities of grey-box suppliers, black-box suppliers are characterized by a high number of employees, component knowledge and advanced engineering capabilities. The empirical evidence that supplier capabilities differ in accordance to interfirm collaboration designs adds to the operational understanding of relational view.

Second, findings enhance the proposed supplier integration concept by Petersen et al. (2005). Petersen et al. (2005) claim that the higher the supplier integration level, the higher the supplier development responsibility. The analysis of supplier characteristics gives reason to believe that the resource level of suppliers concurrently increases with the development responsibility of a supplier. In accordance to the concept of Petersen et al. (2005), findings indicate that higher supplier integration results in higher development responsibility and higher resource level at the supplier. Thereby, chapter five advances theoretical understanding of supplier integrations by claiming that a higher integration level requires a higher resource level at the supplier site.

Third, chapter five enhances the understanding of buyer-supplier collaborations by empirically indicating that mature quality processes of suppliers can act as hurdle for buyer-supplier collaborations. In doing so, findings advance the understanding of relational view by signifying mature quality processes as a negative influencer of relational rents between suppliers and buyers. It can be argued that mature quality processes can be considered as a separate functional system that represent a roadblock for relational rents (Dyer & Singh, 1998). Therefore, suppliers with mature quality processes could be unable to synchronize with buying firm's processes which can harm interfirm collaborations.

Managerial contributions. Chapter five is the first stating that supplier competences differ between grey-box and black-box integrations. Both integration approaches require special supplier competences, which were not yet clearly identified. In accordance, findings of chapter five provide explanation to practitioners on which supplier characteristics are relevant for grey-box and black-box collaborations. Thereby, this study advises practitioners on which supplier competences to focus on when they either want to jointly develop with a supplier or when the supplier is asked to develop self-conducted for the customer. With respect to joint developments, practitioners should focus on architectural knowledge and a collaborative attitude symbolized by an active interaction with sub-suppliers. When practitioners want to allocate a module development to suppliers in form of a black-box development, our results indicate that the required level of supplier resources increases in comparison to a joint development. In addition to architectural understanding and sub-supplier integration, black-box suppliers should also provide component knowledge and engineering capabilities. Due to value-adding tasks of black-box module suppliers, technical competences play a more significant role.

7.3.5. Technical knowledge residing at the supplier influence buyer-supplier collaboration within modular product designs

Chapter six refines the question which supplier to integrate for module developments by looking at the interplay of product modularity and buyer-supplier collaborations in relation to technical knowledge of suppliers. Thereby, findings contribute to the debate if product modularity mirrors to organizational structures or not. Even though the subject has been discussed and argued several times by previous scholars, this chapter offers unique contributions to theory and practice.

Core elements:

- The link between modular product structures and interfirm collaborations depends on the knowledge levels of firms
- Knowledge residing at the supplier site influences buyer-supplier collaborations with modular product designs
- Technical knowledge should be differentiated in component knowledge and architectural knowledge

Theoretical contributions. The first theoretical contribution of this study is to shed light on the ongoing controversy about the “mirroring hypothesis” (Cabigiosu & Camuffo, 2012b; Colfer & Baldwin, 2010; Sanchez & Mahoney, 1996). Until now, it is debated if and under which conditions product modularity leads to ‘loose’ (Baldwin, 2008; Sanchez & Mahoney, 1996; Sosa et al., 2004) or ‘thick’ (Hsuan, 1999; Jacobs et al., 2007) interfirm relations. In respect to this controversy, this study finds empirical evidence to belief that the degree of mirroring (Colfer & Baldwin, 2010), and the concept of a direct link between product structures and related organizational structures (Sanchez & Mahoney, 1996) is depending on the knowledge levels of firms. Knowledge sitting at the supplier site appears to have a direct impact on the type of inter-organizational collaborations. Moreover, the type of knowledge appears to matter, since component and architectural knowledge imply different effects on inter-organizational collaborations. Looking at loose collaborations in the form of black-box collaborations, component and architectural knowledge at the supplier site promote loose collaborations under the condition of high modularity. Interestingly, effects of knowledge contradict with mirroring hypothesis when grey-box collaborations are concerned. Our results show that low component knowledge by the supplier fosters close collaboration between the buyer and supplier within highly modular product structures.

The second contribution of chapter five is the first empirical differentiation between component and architectural knowledge. Previous scholars have argued that product knowledge in a modular product environment should be divided in component and architectural knowledge (Henderson & Clark, 1990; Sanchez & Mahoney, 1996). This study has put the theoretical discussion into application and defined different measures for each knowledge dimension.

Third, using the supplier perspective as level of analysis builds a novelty in context of product modularity and interfirm collaborations. The role of suppliers is ignored by most of the research on product and organizational design, as the buying site is commonly considered as driving stakeholder defining organizational interfaces and acting as system integrator (Brusoni & Prencipe, 2001b; Cabigiosu & Camuffo, 2012a). To our knowledge, this study is the first that takes the supplier site into consideration, which is often neglected by previous research. Thereby, this study adds a new perspective to the debate which has been documented and argued convincingly by several scholars.

Managerial contributions. First, findings imply that practitioners working at buying firms should consider the knowledge level of suppliers, when deciding for a collaboration approach. A well-defined modular product design does not automatically facilitate loose supply relationships,

but the interplay of modularity and product knowledge enables both ‘loose’ or ‘thick’ buyer-supplier relationships. We found that modularization requires component and architectural knowledge at the suppliers to establish loose relationships in form of black-box collaborations. Findings also imply certain knowledge domains can intensify the collaboration between buyer and supplier. Thus, buying firms should carefully evaluate the knowledge levels of suppliers, so that they can most benefit.

Second, practitioners at supplying firms should reflect that the level of their technical knowledge has a major influence on the interaction pattern with customers. This insight can give managers at the supplier site the chance to influence the nature of customer collaborations within modular product designs. In view of that, suppliers who want to increase their responsibility and relevance for customers, either by being involved in joint development activities or by being an autonomous system developer, can apply the findings of this study to actively manage their customer relationships.

7.4. Limitations and future research

This study has some limitations that have to be acknowledged. First, apart from chapter two, data was gathered in the supply base of the agriculture equipment industry. In consequence, external validity of the study could be reduced. Due to similarity of components, however, suppliers of the agriculture equipment industry often supply in parallel components to other industries like the automotive industry. Moreover, the industry segment studied is characterized by a wide variety of components (e.g. castings and metal fabrications, engine components, hydraulic and cylinders etc.), country of origins (Europe, North America, Asia etc.) and a diversity of respondent profiles (key account, management, C-level management.). All aspects increase external and general validity.

Second, this dissertation has its focus on supplier selection for module developments. Thereby, the attention paid to the role of product families and the involvement of suppliers in product family development is limited. Supplier integration in product family development builds a general setting of this research. However, by intention, aspects like the potential reuse of modules in different products that belong to the same product family are excluded in order to focus on supplier characteristics driving active supplier collaboration for module developments. The circumstance that supplier integration in NPD is still less intensively researched than the integration of customers (Gassmann et al., 2010) has caused the emphasis on the supplier site of buyer-supplier collaborations in NPD.

Third, dependent variables of the quantitative parts of this dissertation were assessed using subjective measures. For example, we asked respondents about the company performance or the degree of interaction. Perceptual measurement instruments have been widely used in the extant of recent operations management literature (Danese & Romano, 2011; Lau, Tang, & Yam, 2010) and operations management scholars have witnessed that “objective” measures may not yield data that is any more objective than data obtained by perceptual measures (Ward, McCreery, Ritzman, & Sharma, 1998). Thus, perceptual measures are considered to be satisfactory in operations management research (Ketokivi & Schroeder, 2004a). However, current literature (e.g.

van der Vaart & van Donk, 2008) discusses possible limitations of perceptual measures which have to be acknowledged. In accordance, perceptual measures can be exposed to error effects (Ketokivi & Schroeder, 2004b). For example, respondents can have a unique understanding that is not in any way consistent across informants. Moreover, the individual respondent could have limited knowledge to answer and cannot decide between a 4 and a 5 etc. To minimize the risk of error effects, a definition of key aspects was provided to ensure common understanding by the respondents. The measurement instrument included two questions referring to the knowledge level of the respondent as well as to the involvement other functions. In detail, respondents were asked if they were well and enough informed to answer the questions. Moreover, if respondents perceived themselves as not knowledgeable enough to answer the questions, respondents were encouraged to involve internal specialists from other functional areas and to note this in the survey instrument. Nevertheless, previous research has indicated that subjective and objective performance measures show a high correlation (Dess & Robinson, 1984; Song & Parry, 1997). Thus, it can be claimed that using subjective performance data did not harm the reliability and validity of the empirical findings represented in this dissertation.

Fourth, the functional origin of the responses can be considered as another potential limitation of this dissertation. Most of the respondents worked either in the sales department of a first-tier supplier or in the purchasing department of an OEM. Both groups might be experts in their field of profession, but they could have limited understanding of other functional areas for example engineering capabilities. Respondents, however, were asked to evaluate the engineering capabilities in relation to the competition, which should be possible as market and technology understanding is a key part for both sales and purchasing experts. Nevertheless, each respondent had to confirm his ability to answer the survey questions. Moreover, respondents were asked to involve an internal expert, if they uncertain about the correct answer. Around 25% of the respondents indicated that they consulted an internal expert in order to answer the survey instrument. Findings show no significant differences between cases when respondents answered by themselves and those cases with cross-functional input. In case of the analyzed OEM, a random sample of responses was cross-checked with perceptions from other departments. Again, findings showed no significant deviation.

Fifth, this dissertation has its focus on centralized networks by mainly considering the relation between first-tier suppliers and a lead firm. Only chapter two enlarges the perspective by looking at the influence of the first-tier sub-supply base on the one-to-one buyer-supplier relationship. Nevertheless, buying firms are connected indirectly to a wider business network, including the connections to customers, sub-suppliers, competitors, and other horizontal actors (Choi & Kim, 2008; Gadde, Håkansson, & Persson, 2010). Those other parties of a business network affect many of the potential benefits and constraints of a company's supplier relationships (Roseira, Brito, & Ford, 2013). Therefore, it has to be acknowledged that the scope of this dissertation is focused on centralized networks primarily.

Looking at directions for future research, we would like to highlight four main paths. First, future research could further operationalize the paradigm of collaborative advantage in relation to a modular product environment with the focus on NPD. As the paradigm of

collaborative advantage claims that combining resources from different supply chain stakeholders creates new capabilities within the value chain (Dyer, 2000; Dyer & Nobeoka, 2000), future research could investigate the roles of first-tier and n-tier sub-suppliers in a modular product design. For example, based on higher complexities of modules, first-tier suppliers responsible for module developments have to manage a higher number of development activities, which potentially influence the integration and contribution of sub-suppliers. Future research could examine if and how modular product design by OEMs impacts the upstream supply chain collaborations.

Second, future research could investigate how modularity influences value contributions along the upstream supply chain. Again, referring to the parading of collaborative advantage, modularity might influence the contribution level of supply chain stakeholders in a reasonable way. If first-tier suppliers take module development activities, how does the contribution of the n-tier supply base adapt. Moreover, findings of this dissertation imply that sub-suppliers have a direct influence on the innovation level of first-tier supplier for OEMs. Guided by this findings, future research could study which level of the multi-tier supply chain creates innovation and how OEM can better access and incorporate those resources in the end-product.

Third, it would be interesting to see how supplier integration in NPD is evolving over an extended period of time. While such longitudinal studies are difficult to operationalize, they would add significantly to the understanding of the important phenomenon. Especially, upcoming trends of further technology developments like digitalization (e.g. industry of things / industry 4.0) will shape interfirm collaborations in future. For example, current company strategies already acknowledge a few interfaces to smart items, but with further advanced computational and communication technologies, the development of business networks will further advance (Haller, Karnouskos, & Schroth, 2008). Intelligent mechanisms for data aggregation, filtering, fusion and conversion will be deployed and will most likely transform the supply chain towards supply networks which bring new ways of interfirm collaborations. Thus, one direction of future research could analyze the development of supplier integration over time by considering the influence of megatrends like digitalization.

Fourth, future research in the area of operations management could address the on-going debate in recent literature about the present role and interpretation of the p-value in science. The American Statistical Association (ASA) has formulated a statement on p-values by referring to the context, process, and purpose of p-values (Wasserstein & Lazar, 2016). The statement makes several practical points on the use of p-values in empirical scientific inquiry. In reaction, several authors (e.g. Gelman, 2016; Goodman, 2016; Ionides, Giessing, Ritov, & Page, 2016) have responded on the statement from ASA. Both, ASA and the further comments, encourage researchers to better contextualize their measurement and analysis to improve statistical interpretations. In view of that researchers should follow methodological authorities such as Nunnally (Nunnally & Bernstein, 1994) and Fisher (R. A. Fisher, 1956) to consider a broader context of statistical reasoning before interpreting p-values to draw conclusions. For example, researchers should take into account the design of their study, the quality of the measurements, the external evidence for the phenomenon under study, and the validity of assumptions that

underlie their analysis before formulating statistical conclusions (Gelman, 2016; Goodman, 2016; Ionides et al., 2016). In consequence, researchers should prevent drawing conclusions from observations that imply statistical significance by considering p-values as general and standardized indication for significant findings (Wasserstein & Lazar, 2016). For example, looking at other fields of research like the field of genomics implies that evidential thresholds are changeable within disciplines and circumstances with $P \leq 10^{-8}$ now sought for claiming relations derived from genomewide scanning (R. A. Fisher, 1956; Goodman, 2016). However, future research activities will need to show, if such thresholds can or should be modified by design, by discipline, or by individual study for operations management research.

In the meantime, researchers are advised to apply further methods like the Bayes factors (e.g. Goodman, 1999), which might add supplementary insights to enhance scientific reasoning. Future research in the area of operation management could build on the on-going discussions by further bring contextual factors into play to derive scientific inferences.

Despite some general limitations and the overall agenda of possible future research, each respective chapter is related to some limitations and directions for future research. Data from **chapter two**, originates from the same cultural background, so that cross-cultural differences could not be considered. However, innovation issues and willingness to cooperate could be subject to culturally influenced value systems (Hofstede, 1993) and thus analyzing the integration of purchasing in NPD from an international perspective may yield further insights. Moreover, the data set is relatively small of size which signifies that this study was exploratory in nature (Forza, 2002; Nunnally & Bernstein, 1978). Last but not least, most of the survey respondents are employed at large firms, thus, a study focusing on small and medium-sized firms may report different observations (Pressey et al., 2009).

A future research direction could build the analysis of other functions enhancing the understanding of successful cross-functional collaboration in NPD to promote the integration of suppliers. Thereby, practitioners would get a more detailed understanding of how to promote internal collaboration in order to realize external integration of suppliers. Second, although we focused on the specific target spectrum of organizational antecedents of purchasing integration, future research should also consider the strategic aspects (Van Echtelt et al., 2008) of successful NPD projects. Analysis of strategic aspects could add interesting insides that would lead to a better understanding of antecedents for purchasing integration.

With regards to limitations of **chapter three**, the consideration of additional theoretical backgrounds like the mutual hostage model (Williamson, 1996) and the resource investment view (Morias et al., 2004) could enhance the understanding of innovation sharing between buyers and suppliers. Both models claim that when one party invests resources, this action will be returned in a similar manner by the other party. Accordingly, future research could analyze, if innovation sharing by the buying firm stimulates in reaction innovation sharing by suppliers. Second, future research should analyze the direct interaction between the OEM and second-tier suppliers in order to develop innovation. Existing literature shows that buying firms can generally manage and approach sub-suppliers (Grimm et al., 2014). Future research should examine instruments, structures and antecedents regarding the creation of innovation based on the direct relation

between OEMs and sub-suppliers. Third, we suggest that future research should look into other supplier-supplier relation archetypes and examines the implications on innovativeness. Wu and Choi (2005) formulated different archetypes of supplier-supplier-buyer triad relationships. Future research needs to consider other relationship structures in order to enhance current knowledge.

Chapter four is associated with the following limitations: First, while our theoretical sampling approach aids generalizability (Rosenthal & Rosnow, 1991), the focus on three case companies from four wheel vehicle industries may result in limited applicability to other industries or service types. Second, since we solely study the buying site, the supplier perspective is excluded. However, scholars of buyer-supplier relationships have acknowledged that a lack of dyadic responses is a limitation of research (Monczka et al., 1995; O'Toole & Donaldson, 2002). Therefore, chapter four might represent a limited scope as the supplier perspective was excluded.

A future path of research could be the analysis of other industries. Thereby, potential industry or product related difference could be acknowledged. Second, qualitative analysis of dyadic relationships under the condition of product design and project goal would further advance the understanding of driving forces for buyer-supplier collaborations in modular product designs.

Due to complexity, **chapter five** can address a limited number of competences which restricts the scope of analysis. Additional perspectives like internal collaboration, new product development process maturity among others might add further insights to the understanding of antecedents for supplier integrations for module developments.

A prospect for future research activities builds the integration of sub-suppliers as technical enabling factor for module suppliers. To enhance the current understanding, future research should consider inter-organizational collaboration along the value chain as driving factors for module suppliers. It should be evaluated, if buying firms should still select a module supplier or if they should rather focus on selecting a value chain for module developments.

Last but not least, **chapter six** brings some limitations which we would like to acknowledge. While we asked respondents about their interaction pattern with customer over a period of three years, potentials evolvments of knowledge and the implications on buyer-supplier relationships couldn't be captured. For example, suppliers' architectural knowledge could increase throughout a longer period of time, which potentially influences the organizational coupling between the supplier and the buyer. Future research could benefit from studying how patterns of learning and knowledge influence inter-organizational collaborations gain over time.

Possible avenues for future research represent further contributions to the ongoing controversy about product modularity and organizational coupling. Scholars of buyer-supplier relationships have acknowledged that dyadic data samples advance the scope of analysis significantly (Monczka et al., 1995; O'Toole & Donaldson, 2002). Thus, future research focusing on dyadic or network relations by collecting data from multiple stakeholders could help to further understand the interplay of modularity, product knowledge and inter-organizational collaborations.

8. Academic output per chapter

Each chapter included in this dissertation was either presented at scientific conferences or submitted to a scientific journal. Final version of chapter two, three and four are under review in internal refereed journals. Below, we provide a brief overview.

Chapter two

This chapter is based on: Schiele, H, Eggers, J, Song, M; Zunk, B.M.; Hofman, E.(2016)

“The Agent Role of Purchasing - Antecedents and Implications of Integrating Purchasing Professionals into New Product Development Processes”

- The paper is under second-round review at the “Journal of Product Innovation Management”
- ISI impact factor 2015: 2.086; Scopus impact factor SJR (2015): 2.337

An earlier version was presented at the following peer reviewed conference:

- 24th European Doctoral Summer School on Technology Management, Leuven (Belgium), 2014.

Chapter three

This chapter is based on: Eggers, J; Schiele, H; Hofman, E (2016)

“Supplier innovation through supply chain collaboration: the OEM, the first-tier suppliers and its sub-supplier”

- The paper is under revision at the “Journal of Supply Chain Management”
- ISI impact factor 2015: 4.571; Scopus impact factor SJR (2015): 5.343

An earlier version was presented at the following peer reviewed conference:

- 25th IPSERA conference in Dortmund (Germany), 2016.

Chapter four

This chapter is based on: Eggers, J; Hofman, E; Schiele, H; Holschbach, E (2016)

“Identifying the ,right‘ supplier for module developments – A cross-industrial case analysis”

- The paper is accepted for publication at the “International Journal of Innovation Management”
- Scopus impact factor SJR (2015): 0.412

Earlier versions of the chapter were presented at the following conferences:

- 24th IPSERA conference in Amsterdam (The Netherlands), 2015.
- Autouni Research Symposium 2015, Wolfsburg, Germany

Chapter five

This chapter is based on: Eggers, J; Hofman, E; Schiele, H; (2016)

“Module Development with Suppliers - Differences between Grey-Box and Black-Box Collaborations”

Earlier versions of the chapter were presented as well as accepted at the following conferences:

- 25th IPSERA conference in Dortmund (Germany), 2016
- Academy of Management Meeting in Anaheim (United States), 2016

A revised version of this article is part of this dissertation and is ready to be submitted to an international journal.

Chapter six

This chapter is based on: Hofman, E; Eggers, J; Schiele, H; (2016).

“Should My Suppliers Know More Than They Produce? Knowledge Specialization In Inter-Organizational Settings”

An earlier version of the chapter was presented at the following conference:

- 23rd Innovation and Product Development Management Conference (IPDMC) in Glasgow (Scotland), 2016

A revised version of this article is part of this dissertation and is ready to be submitted to an international journal (ISI: 3.470; SJR: 3.536, 2015).

Note:

The supervisor Prof. dr. habil. H. Schiele and the Co-Supervisor Dr. ir. E. Hofman confirm that contributions on chapter two and six has been sufficiently intensive to include the papers as chapters in this dissertation.

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Original Equipment Manufacturers (OEMs) increasingly integrate supplier resources in new product development (NPD) activities to overcome bottlenecks of resources and to create competitive advantages. Simultaneously, OEMs react to new market challenges by implementing modular product designs. Despite the significant relevance, previous research has paid limited attention to the area of supplier integration in NPD. This dissertation looks at antecedents that facilitate the integration of suppliers in NPD with special emphasis on modular product designs.