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Innovation and its Impact on Firm Financial Performance:

Empirical Investigations in Buyer-Supplier Relationships

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Abstract

Firms increasingly seek to profit from the innovative capabilities of their customers and suppliers. Extant research on vertical relationships has thus focused extensively on the outcomes of collaborative innovation. Specifically, many studies explored the effects of involving customers and suppliers in product development on product quality, product costs, and development times. However, improvements in these measures need not necessarily lead to enhanced corporate financial performance. Collaborations with vertical partners entail the risk that valuable technological knowledge spills to competitors. Furthermore, collaborations can leave firms dependent on the assets and technologies of their partners. Hence, the focal firm might in fact lose out, while its partners and competitors capture most of the value from innovation. Further research is thus called for that focusses on financial outcomes, and that thereby advances our understanding of how firms can profit from their own and their partners' innovations.

The present dissertation addresses this gap. Through three distinct empirical investigations, it sheds light on the relationship between innovation and firm financial performance in the context of buyer-supplier relationships. The empirical investigations build on a large panel of buyer-supplier relationships obtained from Compustat North America and the U.S. Patent and Trademark Office (USPTO). The panel covers the period from 2000 to 2013 and contains, in total, 4306 buyer-supplier dyads from the U.S. In utilizing panel regressions, the investigations offer robust findings on (1) how firms can profit from their suppliers' innovations, (2) on whether and to which extent component suppliers depend on their buyers' innovative activities to earn returns on their own investments in innovation, and (3) on the implications of absorptive capacity for the value of supplier relations to buying firms. The obtained

findings on these three issues provide important contributions to the management literature and have relevant implications for practice.

Zusammenfassung

Unternehmen sind zunehmend daran interessiert von der Innovationsfähigkeit ihrer Kunden und Lieferanten zu profitieren. Die bisherige Supply Chain Management Forschung hat sich daher stark auf die Ergebnisse der Zusammenarbeit von Kunden und Lieferanten in Innovationsprojekten konzentriert. Insbesondere haben viele Studien die Auswirkungen von Kollaborationen in der Produktentwicklung auf Produktqualität, Produktkosten und Entwicklungszeiten untersucht. Verbesserungen in diesen Bereichen müssen jedoch nicht zwangsläufig zu einem grösseren finanziellen Erfolg des Unternehmens führen. Kooperationen mit Supply Chain Partnern bergen das Risiko, dass technologisches Wissen an Wettbewerber weitergegeben wird. Darüber hinaus können durch Kooperationen Abhängigkeiten entstehen, welche die Verhandlungsposition des Unternehmens schwächen. Daher ist es möglich, dass Partner und Wettbewerber von den durch Zusammenarbeit geschaffenen Innovationen profitieren, während diese nicht zu einem grösseren wirtschaftlichen Erfolg des Fokalunternehmens beitragen. Es bedarf daher weiterer Forschung, die sich auf finanzielle Ergebnisse konzentriert und dadurch unser Verständnis des Zusammenhangs zwischen Innovation und Unternehmenserfolg fördert.

Die vorliegende Dissertation adressiert diese Forschungslücke. In drei verschiedenen empirischen Untersuchungen wird der Zusammenhang zwischen Innovation und finanzieller Leistungsfähigkeit im Kontext von Kunden-Lieferanten-Beziehungen beleuchtet. Die empirischen Untersuchungen basieren auf Paneldaten, die durch die Datenbank Compustat North America und durch Daten des U.S. Patent and Trademark Office (USPTO) erhoben wurden. Die Paneldaten decken den Zeitraum von 2000 bis 2013 ab und enthalten insgesamt 4306 Kunden-Lieferanten-Dyaden aus den USA. Durch die Verwendung von Panel-Regressionen bieten die Untersuchungen robuste Erkenntnisse darüber, (1) wie Unternehmen von den Innovationen ihrer Zulieferer

profitieren können (2) ob und in welchem Umfang Komponentenlieferanten von der Innovationsaktivität ihrer Kunden abhängen, um Erträge aus ihren eigenen Investitionen in Innovation zu erzielen, und (3) wie die Absorptionsfähigkeit den Wert von Lieferantenbeziehungen für Unternehmen beeinflusst. Die gewonnenen Erkenntnisse zu diesen drei Themen liefern wichtige Beiträge zur Managementliteratur und haben relevante Implikationen für die Praxis.

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Chapter 1 Introduction and overview of the research

1 Introduction

In today’s competitive environment, firms must innovate continuously in order to survive and to maximize their financial performance (Bettis & Hitt, 1995; Roberts, 1999; Teece, Pisano, & Shuen, 1997). Many firms therefore invest heavily in research and development. However, not all innovations lead to success for the innovator. In many cases, the latter loses out, while imitators, suppliers, and customers capture most of the rents generated by the innovation (Teece, 1986). An understanding of the relationship between innovation and financial performance is thus of great importance for businesses. In order to sustain high levels of financial performance, businesses need to understand how both innovations that are developed internally and those that emerge from outside can be translated into commercial successes.

As noted by the literature (e.g., Adner, 2006; Teece, 1986), the relationship between innovation and financial performance often depends on vertical partners such as customers or suppliers. Since many firms possess assets such as manufacturing and sales capabilities, they can potentially capture rents from the innovations of their upstream or downstream partners (Teece, 1986). A prominent example of such a case is the pharmaceutical industry after the emergence of biotechnology. Following the scientific breakthrough of genetic engineering in the 1970s, new biotechnology firms sought to enter the market for pharmaceuticals (Ceccagnoli & Rothaermel, 2008). The latter, however, was controlled by a few incumbent firms that, as opposed to the biotechnology firms, possessed important assets and capabilities in large-scale manufacturing, clinical trial, regulatory management and sales (Ceccagnoli & Rothaermel, 2008). In order to gain access to these assets, biotechnology firms had to enter strategic alliances, joint ventures, and licensing agreements with incumbents

(Ceccagnoli & Rothaermel, 2008). Consequently, many biotechnology and pharmaceutical firms became vertical partners. Even in 2001, several top-selling biotechnology drugs were still commercialized by incumbent pharmaceutical companies (Ceccagnoli & Rothaermel, 2008). Due to their complementary assets, pharmaceutical firms were able to capture considerable value from their suppliers' innovations in biotechnology (Ceccagnoli & Rothaermel, 2008).

Furthermore, innovations are frequently systemic and require other, complementary innovations in order to create value (Adner, 2006; Adner & Kapoor, 2016; Teece, 2006). In some cases, firms may therefore only profit from their own innovations if their customers or suppliers develop complementary technologies and solutions. Consider for instance the introduction of fourth-generation wireless systems (4G) by network operators. In order for these systems to create value, mobile phone manufacturers had to develop compatible handsets. From the viewpoint of network operators, the commercial success of the innovation thus hinged on the success of their handset suppliers in developing complementary technology.

These examples illustrate that how much firms profit from innovation often depends on customers and suppliers. However, despite the importance of customers and suppliers for the relationship between innovation and firm financial performance, the literature on vertical relationships has devoted little attention to studying the financial outcomes of innovation. Most empirical research on innovation in this domain is focused on product development outcomes. For instance, many studies explored the effects of involving customers or suppliers in product development on product quality, product costs, and development times (Fang, 2008; Handfield, Ragatz, Petersen, & Monczka, 1999; Hoegl & Wagner, 2005; Primo & Amundson, 2002; Wagner, 2010, 2012). Yet, improvements in these measures that are achieved through collaborations with vertical partners need not necessarily lead to enhanced financial performance. Collaborations entail the risk that valuable technological knowledge spills to competitors (Hamel, 1991). Furthermore, collaborations can leave firms dependent on the assets and technologies of their partners (Hamel, 1991). Imitators, customers, and suppliers might thus capture a considerable share of the generated value at the expense of the focal firm (Teece, 1986). Hence, while the aforementioned studies certainly produced valuable insights on how firms can develop more and better innovations, they contributed little to our knowledge on how firms can turn these into financial gains.

This dissertation seeks to fill this gap. The purpose of this dissertation is to advance our understanding of the relationship between innovation and firm financial performance in the context of vertical relationships.

The remainder of this dissertation is structured as follows. In the subsequent sections of chapter 1, important theoretical concepts and ideas on the relationship between innovation and firm financial performance are presented. Then, the employed empirical methodology is outlined, and summaries of the three essays included in this dissertation are provided. The last section concludes chapter 1 by discussing limitations and avenues for future research. Finally, chapters 2, 3, and 4 provide full versions of the essays of this dissertation.

2 Innovation and firm financial performance

This section provides an overview of concepts and ideas that are relevant for understanding the relationship between innovation and firm financial performance. It briefly elaborates on the term innovation, on the profiting-from-innovation (PFI) framework, on the resource-based view (RBV) and on the role of complementary innovations.

2.1 Innovation

According to Thompson's (1965, p. 2) classic definition, innovation is the "generation, acceptance, and implementation of new ideas, processes, products or services." Similarly, Amabile, Conti, Coon, Lazenby, and Herron (1996, p. 1155) define innovation as the "successful implementation of creative ideas within an organization." Hence, in essence, innovation relates to the implementation of something that is novel or creative.

An important distinction can be made between an innovation and an invention. Scholars define the latter as a new idea or piece of knowledge that stems from a recombination of existing knowledge elements (Fleming, 2001; Schumpeter, 1939). An invention, in contrast to an innovation, has not yet been successfully implemented. As such, it can become an innovation if it is introduced commercially as a new or improved product or process (Maclaurin, 1953). However, not all inventions must necessarily become innovations (Maclaurin, 1953).

2.2 The profiting-from-innovation (PFI) framework

In his seminal article, Teece (1986) addressed the relationship between innovation and corporate financial performance. He developed a framework – the profiting-from-innovation (PFI) framework – that explicates the determinants of an innovator's ability to capture value from innovation. The framework identifies three major determinants: the appropriability regime, complementary assets and market entry timing. The role of these determinants is explained in the subsequent paragraphs.

To appropriate value from their innovations, firms usually aim at protecting them from being imitated. The appropriability regime relates to whether such protection is easy or difficult (Teece, 1986). In a "tight" appropriability regime, protection is easy due to legal impediments such as patents, copyrights and trademarks, due to trade secrets, or due to tacit knowledge (Teece, 1986). In contrast, a "weak" appropriability regime offers little protection because these factors are either absent or ineffective (e.g., patents can sometimes be "invented around") (Teece, 1986). Whether the appropriability regime is tight or weak co-determines the ability of innovators to capture returns: In a tight regime, innovators will usually be able to profit as competition from imitators is limited (Teece, 1986). However, in a weak regime, innovators often face intense competition from imitators (Teece, 1986). According to Teece (1986), their ability to profit thus hinges on their complementary asset position.

Complementary assets such as other technologies, products or services are important since most innovations depend on them in order to yield value to the user/ consumer (Teece, 1986). For example, hardware requires software (and vice versa), mobile phones need mobile phone networks (and vice versa), and airlines require airports (and vice versa) (Teece, 2010). Most technical innovations also depend on complementary services such as marketing, competitive manufacturing and after-sales

(Teece, 1986). Innovators rarely own and control all required complementary assets; some of them are often owned by other firms (Teece, 1986). If such “external” complementary assets are in limited supply and cannot be replicated by the innovator, the owners are likely in a strong bargaining position relative to the innovator (Teece, 1986). This can allow them to capture significant shares of the surplus generated by the innovation at the expense of the innovator (Teece, 1986). However, conversely, if “internal” complementary assets – i.e., assets owned by the innovator – are rare and difficult to replicate, they can strengthen the innovator’s bargaining power (Teece, 1986). Furthermore, by controlling important complementary assets, innovators can prevent imitators from competing in the market (Teece, 1986). Hence, the ownership of complementary assets can potentially compensate for a weak appropriability regime and enable the innovator to appropriate returns (Teece, 1986).

Besides the appropriability regime and complementary assets, market entry timing also influences an innovator’s ability to capture returns (Teece, 1986). Following Abernathy and Utterback (1978) and Dosi (1982), Teece (1986) divides the technological evolution of an industry into two consecutive stages: the preparadigmatic stage and the paradigmatic stage. The initial, preparadigmatic stage is characterized by a high level of competition amongst designs (Teece, 1986). Through trial and error, a dominant design – i.e., a design that is most promising – will eventually emerge, marking the transition to the paradigmatic stage (Teece, 1986). In this transition, competition shifts to price away from design, and consequently, process improvements and economies of scale gain importance (Teece, 1986). According to Teece (1986), the probability that an innovator enters the first stage with the dominant design is low. Instead, it is likely that imitators will build upon the initial innovation and develop the dominant design (Teece, 1986). In the preparadigmatic stage, imitators and complementary assets holders might thus often capture most of the rents generated by the innovation – especially if the appropriability regime is weak (Teece, 1986).

In essence, Teece’s (1986) framework recognizes that innovators must occupy a “bottleneck” position in the value chain/ system through which the innovation is commercialized in order to capture value. They can secure such a position either through a tight appropriability regime or through ownership of complementary assets.

Furthermore, innovators might often lose out in the early phases of a technology cycle, as the probability of entering the market with the dominant design is low.

2.3 The resource-based view (RBV)

In contrast to Teece's (1986) framework, which specifically addresses the relationship between innovation and firm financial performance, the resource-based view more broadly addresses firm performance, and in particular, firm performance differentials. Nevertheless, the resource-based view can still be employed as a theoretical lens for understanding the link between innovation and firm financial performance.

A main assumption of the resource-based view is that firms are heterogeneous with respect to the resources they control (Barney, 1991; Wernerfelt, 1984). Hence, firms are regarded as bundles of resources consisting of their assets, capabilities, organizational processes, firm attributes, information, and knowledge (Barney, 1991). Based on this assumption, the resource-based view postulates that resources can be a source of competitive advantage if they are valuable and rare (Barney, 1991). A valuable resource is one which "enables a firm to conceive of or implement strategies that improve its efficiency and effectiveness" (Barney, 1991, p. 106). A rare resource is one which is not possessed by many competing or potentially competing firms (Barney, 1991). Thus, according to the logic of the resource-based view, an innovation can be a source of competitive advantage and thereby contribute to firm financial performance if the associated knowledge is valuable and rare. Among these two criteria, the first is fulfilled, since innovations imply a certain amount of commercial value. The second, however, is not always fulfilled.

This logic is similar to Teece's (1986) PFI theory, which emphasizes the need of the innovator to protect its innovation from being imitated. Indeed, since the PFI framework focuses on firms' assets and their characteristics, it can be viewed as an early application of the resource-based view (Teece, 2006). Yet, in considering the interplay between rareness (i.e., the appropriability regime), complementary assets and market entry timing, the PFI framework offers a more granular account of the relationship between innovation and firm financial performance than the resource-based view. Specifically, the PFI theory accounts for the possibility that firms, as owners of complementary assets, can profit from external innovations even if they do not possess the innovation-related knowledge resources. The resource-based view, in contrast, assumes that firms need to own and control knowledge resources in order for those to represent a source of competitive advantage (Lavie, 2006). Thus, the RBV-logic is limited in the sense that it can only explain firms' profits from external innovation that accrue from the transfer of knowledge.

2.4 Complementary innovations

The PFI framework assumes that an innovation has a fixed amount of value, and that the appropriability regime, complementary assets and market entry timing determine how this amount is distributed between the innovator and other actors. However, the value of an innovation need not be fixed, but can depend on complementary innovations (Adner, 2006; Teece, 2006). For instance, as noted by Adner and Kapoor (2010), the A380 aircraft required innovations from Airbus, from component suppliers and from complementors in order to deliver value to consumers.

In such cases, it is important to consider that the impact of an innovation on firm financial performance not only depends on the distribution of value, but also on the total value available. Recent literature therefore proposes a distinction between value creation and value capture (Bowman & Ambrosini, 2000; Brandenburger & Stuart, 1996; Jacobides, Knudsen, & Augier, 2006; Lepak, Smith, & Taylor, 2007; Priem, 2007). Value creation refers to the generation of a surplus, whereas value capture refers to its division (Brandenburger & Stuart, 1996; Wagner, Eggert, & Lindemann, 2010). Based on this distinction, the relationship between innovation and firm financial performance can be viewed as a two-step process in which an innovation, together with other complementary innovations, creates a surplus, and, depending on the factors identified by the PFI framework, this surplus is then distributed among innovators, owners of complementary assets and imitators.

3 Empirical basis

The three essays of this thesis develop theory-driven models and test these on a large panel data set of buyer-supplier relationships. This section elaborates on the data sources used, the data collection procedure, and on the employed methods of statistical analysis.

3.1 Data sources

All three essays build on data from Compustat North America and on patent data from the United States Patent and Trademark Office (USPTO). Following previous studies (Cohen & Frazzini, 2008; Fee & Thomas, 2004; Hertzel, Li, Officer, & Rodgers, 2008; Mackelprang & Malhotra, 2015), Compustat North America was used to collect information on buyer-supplier relationships. Compustat North America contains this information since publicly traded firms in the U.S. are required to report their major customers (i.e., customers that represent at least 10 percent of the respective firm's sales). Yet, since company names are not standardized, firms may sometimes report customers with slightly different spellings and abbreviations. Following Fee and Thomas (2004) and Hertzel et al. (2008), a string matching algorithm was employed in order to match the disclosed customer names to firm names in Compustat. Furthermore, each obtained buyer-supplier link was manually inspected subsequent to string matching in order to exclude potential errors. This procedure yielded a panel of 4306 buyer-supplier dyads from the U.S. (i.e., all firms in this panel are U.S.-incorporated). In total, the panel comprises 11311 dyad-year observations from the period between 2000 and 2013.

Patent data from the USPTO, provided by PatentsView, was used in order to obtain information on firms' innovative activities. Patent portfolios were thus collected for each firm and year of the buyer-supplier panel. Links between patents and firms were obtained through approximate string matching. However, as some firms assign patents to their subsidiaries (Sampson, 2007), patents were carefully aggregated to the firm level. As such, not only matches of patent assignee names with a firm's name but also matches with the names of its subsidiaries were taken into account. Data on subsidiaries came from the Directory of Corporate Affiliations, Thomson ONE, Mergerstat M&A, and from the open data source, CorpWatch API.

In addition to these two sources, industry concentration data and benchmark industry input-output tables from the U.S. Department of Commerce were used in Essay 1 in order to operationalize the main independent variables. No additional data sources were employed in Essays 2 and 3.

3.2 Method of statistical analysis

Panel data offers several advantages over cross-sectional data. It gives more information, more variability, less collinearity among the variables, more degrees of freedom and more efficiency (Baltagi, 2005). Its main advantage, however, is that it allows to control for individual heterogeneity (Baltagi, 2005; Wooldridge, 2010). In almost any statistical analysis, the dependent variable is influenced by unobserved effects, which can contribute to individual heterogeneity and potentially lead to an omitted variable bias (Wooldridge, 2010). Panel data regressions mitigate against the risk of such a bias since they control for all time-invariant unobserved effects (Wooldridge, 2010).

Among panel data regressions, two common types of models can be distinguished: fixed-effects and random-effects models. The main difference between these two is that, in contrast to fixed-effects models, random-effects models assume that the unobserved effects are uncorrelated with the independent variables (Wooldridge, 2010). In other words, they assume exogeneity of all regressors with the unobserved effects (Wooldridge, 2010). In order to decide between both types of models, the Hausman test is commonly employed (Wooldridge, 2010). For the estimations of Essays 1, 2, and 3, this test suggested that the independent variables might be correlated with the unobserved effects. Consequently, all essays in this dissertation employ a fixed-effects panel regression as method of statistical analysis.

Furthermore, the hypotheses tests in each essay are based on cluster-robust standard errors that allow for cross-sectional dependence. This is necessary, because the buyer-supplier panel exhibits a nested structure. Specifically, the panel comprises several buyer-supplier dyads that share the same buyer or the same supplier. Observations of these dyads thus cannot be assumed statistically independent. In order to allow for dependencies between such observations, two-way cluster-robust standard errors were calculated that cluster around the buyer and the supplier. In addition to allowing for cross-sectional dependence, these two-way cluster-robust standard errors also account for arbitrary heteroscedasticity and serial correlation (Cameron & Miller, 2015). The calculation of the standard errors followed the procedure proposed by Cameron and Miller (2015).

4 Summaries of essays

This section provides a summary for each essay of this dissertation. Each summary addresses the motivation, the research gap, the research setting, main findings, key contributions, and managerial implications of the respective study. An overview of the essays that comprise this dissertation is offered in Table 1.

4.1 Essay 1

4.1.1 Motivation and research gap

Interdependence is an essential feature of vertical relationships. In any such relationship, the two involved firms – i.e., the buyer and the supplier – are at least to some extent dependent on each other. For instance, the buyer usually depends on the supplier's products or services as inputs to its own business processes. The supplier, in turn, depends on the buyer as a source of revenue. According to Casciaro and Piskorski (2005), vertical relationships are thus characterized by two dimensions of interdependence: mutual dependence and power imbalance.

The first dimension captures bilateral dependencies and can be defined as the sum of dependencies between the buyer and the supplier (Casciaro & Piskorski, 2005). The second dimension captures asymmetric dependencies and can be defined as the absolute difference of their dependencies on each other (Casciaro & Piskorski, 2005). Both dimensions have important implications for the nature of vertical relationships (Gulati & Sytch, 2007). They influence knowledge sharing and relative bargaining power, and as a result, affect the processes of value creation and value capture (i.e., how much value is created in the relationship, and how value is distributed between both partners) (Gulati & Sytch, 2007). Value creation and value capture, in turn, determine the relationship between innovation and firm financial performance (Jacobides et al., 2006; Teece, 2010). Specifically, they determine the extent to which the buyer can profit from the supplier's innovations. Hence, mutual dependence and power imbalance can be expected to affect the contribution of supplier innovation to buyer financial performance.

An understanding of whether and to which extent firms profit from their suppliers' innovations is important for both businesses and policy. Business managers are looking for sources of high returns, while policy makers need to understand the distribution of returns from innovation in order to design policies that incentivize innovation and growth. Nevertheless, extant research has not yet addressed the influence of interdependence on the link between supplier innovation and buyer financial performance.

4.1.2 Objectives and research setting

Essay 1 seeks to fill this gap. Its purpose is to investigate the implications of interdependence for the relationship between supplier innovation and buyer financial performance.

To examine these implications, Essay 1 draws upon a panel of buyer-supplier dyads from the U.S. The latter was obtained from Compustat North America and complemented with patent data from the United States Patent and Trademark Office (USPTO). The two main independent variables, mutual dependence and power imbalance, were operationalized following Casciaro and Piskorski (2005) who utilize industry input-output patterns and concentration ratios. Data on these came from the Bureau of Economic Analysis (BEA) and the Census Bureau of the U.S. Department of Commerce. The dependent variable, buyer financial performance, was measured by Tobin's q and the independent variable, supplier innovation, by citation-weighted patent counts. The final sample of Essay 1 encompasses 841 dyads and 3291 dyad-year observations of the period from 2000 to 2010.

4.1.3 Findings and contributions

The results of Essay 1 indicate a positive effect of mutual dependence, and a negative effect of power imbalance on the relationship between supplier innovation and buyer financial performance. Hence, as expected, interdependence seems to influence how much firms profit from their suppliers' innovations. Furthermore, the results suggest that supplier innovation is not associated with a general positive effect on buyer financial performance. Instead, the direction of the effect seems to depend on mutual dependence and power imbalance.

These results contribute to our understanding of the conditions under which firms benefit from their supplier's innovations. In revealing the implications of mutual dependence and power imbalance, they advance our knowledge on the financial outcomes of innovation in vertical relationships. Furthermore, they carry forward the debate on whether using suppliers as sources of innovation may have adverse effects on the buying firm (e.g., Azadegan & Dooley, 2010).

These results also contribute to resource dependence theory, and particularly to research on interdependence in vertical relationships (e.g., Casciaro & Piskorski, 2005; Gulati & Sytch, 2007). They support the beneficial effects of joint dependence on value creation that have been proposed by Gulati and Sytch (2007). They also confirm Gulati and Sytch's (2007) empirical results, which suggest that a manufacturer's power-advantage diminishes its performance in a procurement relationship.

Finally, the results contribute to the value-based literature (e.g., Bowman & Ambrosini, 2000; Brandenburger & Stuart, 1996; Lepak et al., 2007). Scholars increasingly argue that a firm's ability to create and appropriate value depends on organizational interdependencies in the industry architecture or business ecosystem in which it operates (Adner & Kapoor, 2010; Jacobides et al., 2006; Teece, 2007). Although the importance of such interdependencies is widely recognized, the mechanisms through which they affect organizational performance are not yet fully understood. Essay 1 enhances our knowledge of those mechanisms by showing that interdependencies determine whether and to which extent innovation by vertical partners contributes to organizational performance.

From a practical perspective, Essay 1 suggests that firms can profit the most from supplier innovation in relationships that are characterized by high bilateral dependence and low power asymmetry. Businesses could possibly foster such relationships by preferring two-sided to one-sided relationship-specific investments with existing suppliers, or by aiming for constellations of high bilateral dependence and low power asymmetry when selecting new suppliers.

4.2 Essay 2

4.2.1 Motivation and research gap

Scholars commonly distinguish between two types of innovation: autonomous innovations and systemic innovations (e.g., Brusoni & Prencipe, 2001; Chiesa & Frattini, 2011; Helfat & Campo-Rembado, 2016; Kapoor, 2013; Langlois & Robertson, 1992; Teece, 1996; Wolter & Veloso, 2008). Autonomous innovations can be introduced without modifying other components or items of equipment of the system in which they are introduced (Teece, 1996). As such, they "fit comfortably into existing systems" (Teece, 1996, p. 217). Systemic innovations, on the other hand, require significant adaptations of other parts (Teece, 1996).

The difference between autonomous and systemic innovations has implications for buyer-component supplier relationships – i.e., for vertical relationships in which the supplier develops and manufactures components for the buyer's products. From the viewpoint of the supplier, both types of innovation are associated with different mechanisms of value creation. If the supplier's innovations are autonomous, they can be readily integrated in the buyer's products. Hence, they can deliver value directly. Yet, if the innovations are systemic, the buyer has to readjust other parts of its products. Whether and how much value the innovations deliver then hinges on the buyer's success in making suitable readjustments – that is, on the buyer's innovative output.

Since suppliers seek to earn returns on their investments in innovation, such dependencies associated with systemic innovations pose a considerable risk and thus need to be managed (Adner, 2006). With regard to suppliers' ability to manage systemic innovations, prior research highlights the role of common knowledge as a facilitator of communication and coordination (Brusoni, Prencipe, & Pavitt, 2001; Helfat & Campo-Rembado, 2016). Accordingly, prior research proposes that whether buyer-component supplier relationships hold common knowledge corresponds to the type of innovation: relationships that experience mainly systemic innovations likely exhibit a high degree of common knowledge, while those that experience mainly autonomous innovations likely exhibit a low degree of common knowledge (Brusoni et al., 2001). However, this proposition has not yet been tested.

4.2.2 Objectives and research setting

Essay 2 addresses this gap. It seeks to investigate whether buyer-component supplier relationships of different knowledge base overlaps exhibit different mechanisms of value creation, and thus, experience different types of innovations.

Essay 2 relies upon a panel of buyer-supplier dyads from the U.S. The panel was obtained from Compustat North America and complemented with patent data from the United States Patent and Trademark Office (USPTO). To ensure that the panel captures dyads in which the supplier produces technical components and the buyer higher-level technical systems, it was restricted to firms in machinery manufacturing; computer and electronic product manufacturing; electrical equipment, appliance and component manufacturing; and transportation equipment manufacturing. Furthermore, to ensure that suppliers produce product components instead of production machines or other manufacturing equipment, suppliers operating in machinery manufacturing were pre-emptively excluded. The final sample of Essay 2 comprises 435 unique dyads and 2006 dyad-year observations from the period 2000-2013.

4.2.3 Findings and contributions

The analysis reveals that varying degrees of knowledge base overlap correspond to different value creation mechanisms in buyer-component supplier relationships. In relationships of a high knowledge base overlap, innovative output by the buyer is required in order for the supplier's component innovations to deliver value. The supplier's returns-to-innovation thus hinge on the buyer's innovative output. In contrast, in relationships of a low knowledge base overlap, the supplier's component innovations can create and deliver value independently. Taken together, these results suggest that relationships of a high knowledge base overlap experience significantly more systemic and significantly less autonomous innovations than relationships of a low knowledge base overlap. As such, the analysis indicates a match between the division of knowledge and the type of innovation in vertical relationships.

Essay 2 contributes to the literature in at least two ways. First, in examining a large panel of buyer-supplier relationships from several manufacturing industries, it provides large-scale evidence for a link between innovation type and knowledge partitioning. This evidence lends support to research proposing that common knowledge facilitates coordination and communication and thus enables firms to manage systemic innovations (Brusoni et al., 2001; Helfat & Campo-Rembado, 2016). Furthermore, the identified link between innovation type and knowledge partitioning indicates that, for firms who mainly experience autonomous innovations, the costs of developing and maintaining common knowledge may often outweigh its benefits. Hence, consistent with the analysis of Helfat and Campo-Rembado (2016), the findings suggest that whether firms choose to develop and maintain common knowledge depends on the prevalence of systemic innovations.

Second, extant evidence on systemic and autonomous innovations is either anecdotal, case study-based (e.g., Brusoni et al., 2001; Langlois & Robertson, 1992) or limited to specific industries (e.g., Adner & Kapoor, 2010; Kapoor, 2013). In showing that the prevalence of systemic and autonomous component innovations varies significantly across vertical relationships, Essay 2 provides large-scale evidence for the presence of both types of innovations in various industries. Furthermore, from the perspective of a focal firm having to manage systemic innovations in ecosystems, extant research has focused on the interdependence risks of coordinating with complementors and suppliers (Adner & Kapoor, 2010). In contrast, Essay 2 examines the interdependence risks of coordinating with buyers, and suggests that these seem to play an equally important role for component suppliers – that is, for firms whose products are embedded in larger systems.

4.3 Essay 3

4.3.1 Motivation and research gap

Firms increasingly collaborate with their suppliers in new product development. Since such collaborations are characterized by iterative problem solving, they usually require two-sided knowledge transfers (Baldwin & Clark, 2000; Clark & Fujimoto, 1991; von Hippel, 1994). Accordingly, both partners in such a collaboration should be able to absorb knowledge from each other – that is, both should possess a certain level of absorptive capacity. If one of them lacks absorptive capacity, product development outcomes may be unsatisfactory – even if the other's absorptive capacity is sufficient.

Despite the relevance of two-sided knowledge transfers and absorptive capacities, extant research has adopted a one-sided approach. Specifically, extant research has focused solely on the performance implications of the buyer's absorptive capacity (e.g., Azadegan, 2011; Wagner, 2012). Unsurprisingly, results on these implications are mixed: while Azadegan (2011) found a positive effect of the buyer's absorptive capacity, Wagner (2012) found no effect.

4.3.2 Objectives and research setting

Contrary to extant research, Essay 3 adopts a two-sided approach in examining the performance implications of absorptive capacity. Essay 3 therefore distinguishes between two distinct constructs: mutual absorptive capacity and the absorptive capacity gap. Mutual absorptive capacity can be defined as the sum of the buyer's and the supplier's partner-specific absorptive capacities. It reflects the ability of both firms to engage in mutual learning and joint problem solving. The absorptive capacity gap, on the other hand, can be defined as the difference between the buyer's and the supplier's partner-specific absorptive capacities. In contrast to mutual absorptive capacity, it reflects differences in the rates at which the buyer and the supplier are able to absorb knowledge from each other, and thus, is related to the potential ability of the buyer to outlearn the supplier.

The purpose of Essay 3 is twofold. First, it aims to examine how mutual absorptive capacity and the absorptive capacity gap influence the financial value of supplier relations to buying firms. Second, it seeks to investigate whether and how these effects are moderated by the knowledge base overlap in the buyer-supplier relationship.

Essay 3 draws upon Compustat North America and data from the United Stated Patent and Trademark Office (USPTO) in order to obtain a panel of buyer-supplier relationships from the U.S. Patent data was used to measure the main independent variables. To enhance the validity of these measures, the sample was restricted to industries characterized by a high propensity to patent. Based on the 2008 Business Research and Development and Innovation Survey of the U.S. Census Bureau, the following industries were selected: chemicals; machinery; computer and electronic products; electrical equipment, appliances and components; medical equipment and supplies; and scientific R&D services. The obtained sample consists of 360 buyer-supplier dyads and 1445 dyad-year observations from the years 2001 through 2013.

4.3.3 Findings and contributions

The empirical results indicate that mutual absorptive capacity enhances, while an absorptive capacity gap decreases the buyer's financial performance. This suggests that mutual absorptive capacity facilitates joint problem solving, and that an absorptive capacity deters suppliers from engaging in collaborations. Furthermore, the results show that the knowledge base overlap attenuates both effects. Specifically, the overlap negatively moderates the effect of mutual absorptive capacity, and positively moderates the effect of the absorptive capacity gap. A possible interpretation of the negative moderation effect is that a large overlap limits technological diversity, and thus the potential of the relationship to create new recombinations of knowledge. An interpretation of the positive moderation effect is that a large overlap makes it more likely that the buyer and the supplier compete in the development of new technologies, which makes the ability of the buyer to outlearn the supplier more valuable.

These findings contribute to research that links absorptive capacity to firm performance. Scholars have long recognized that learning in interfirm relationships involves both collaborative and competitive elements (i.e., joint problem solving with the partner vs. outlearning the partner) (Hamel, 1991; Khanna, Gulati, & Nohria, 1998). However, despite these insights, the distinct constructs of mutual absorptive capacity and the absorptive capacity gap that relate to these two elements have not been studied empirically. Prior empirical research on firm performance almost exclusively adopted a one-sided approach and investigated only the role of the absorptive capacity of one partner (Azadegan, 2011; Chang, Gong, & Peng, 2012; Lane, Salk, & Lyles, 2001; Rothaermel & Alexandre, 2008; Wagner, 2012). Essay 3 suggests that both constructs have distinct implications, and can thus jointly offer a refined understanding of the link between absorptive capacity and firm performance.

From a practical standpoint, Essay 3 suggest that buying firms can gain from favoring mutual learning in their supplier relations over learning unilaterally. Specifically, by promoting mutual learning (i.e., by focusing not only on their own ability to learn from suppliers but also on their suppliers' ability to learn from them), buying firms facilitate joint problem solving, which increases the success of collaborations in new product development. By favoring mutual learning, buying firms can also avoid asymmetries (i.e., absorptive capacity gaps) that potentially reduce their suppliers' willingness to collaborate.

Table 1: Overview of essays

Essay Nr.	Title	Authors[1]	Research Question	Empirical Setting and Methods	Key Findings
1	Supplier Innovation and Firm Performance: The Moderating Role of Interdependence	Dennis M. Schuler Stephan M. Wagner	How does interdependence affect the relationship between supplier innovation and buyer financial performance?	Country: United States Sample: 3291 obs., 2000-2010 Method: Fixed-Effects Panel Regression	Whether and how much firms profit from their suppliers' innovations depends on interdependence: mutual dependence shows a positive, power imbalance a negative effect.
2	Knowledge Partitioning in Vertical Relationships: How the Type of Innovation affects Firms' Knowledge Boundaries	Dennis M. Schuler Stephan M. Wagner	Is there a match between knowledge partitioning and the type of innovation (i.e., systemic vs. autonomous) in buyer-supplier relationships?	Country: United States Industry: Manufacturing Sample: 2006 obs., 2000-2013 Method: Fixed-Effects Panel Regression	Buyer-component supplier relationships exhibit a match between knowledge base overlap and type of innovation: high knowledge base overlaps co-occur with systemic innovations, low knowledge base overlaps with autonomous innovations.
3	Gaining from Vertical Partnerships: Mutual Absorptive Capacity, Absorptive Capacity Gap, and Knowledge Base Overlap	Dennis M. Schuler Stephan M. Wagner	How does absorptive capacity affect the value of supplier relations to buying firms?	Country: United States Industry: Manufacturing and R&D Services Sample: 1445 obs., 2001-2013 Method: Fixed-Effects Panel Regression	Mutual absorptive capacity enhances, an absorptive capacity gap decreases buyer financial performance. Both, the positive effect of mutual absorptive capacity and the negative effect of an absorptive capacity gap are attenuated by the knowledge base overlap in the supplier relation.

[1] Contribution by Dennis M. Schuler to Essays 1, 2 and 3: lead the project, research design, literature review, data extraction and quality control, econometric analysis, manuscript preparation.

5 Concluding remarks

5.1 Limitations

Naturally, the research conducted as part of this dissertation has limitations that need to be noted. First, the procedure of collecting buyer-supplier relationships from Compustat results in a panel of asymmetric relationships, which limits generalizability. Since suppliers are only required to report their major customers, buyers in the panel are, on average, larger than suppliers. Generalizability is also limited because of restrictions on the samples and the use of a fixed-effects panel estimation. In all three essays, the samples are restricted to firms in the U.S., to firms in certain industries, and to certain periods. Furthermore, in fixed-effects estimations, interference is restricted to the specific set of firms in the sample (Baltagi, 2005). Care must thus be taken in generalizing the results to other settings and to relationships in which both firms are of equal size.

Second, this dissertation employs patents as indicators of firms' innovative activities. Several studies suggest that patents reflect these activities. For instance, patents have been shown to strongly correlate with new products (Comanor & Scherer, 1969; Hagedoorn & Cloodt, 2003), non-patentable innovations (Patel & Pavitt, 1997), and literature-based invention counts (Basberg, 1982). Empirical studies on innovation thus commonly employ patent-based measures. Nevertheless, such measures can only serve as approximations of actual innovative activities because the propensity to patent varies across firms, not all innovations are patented, and not all patents are commercialized (Santarelli & Piergiovanni, 1996).

Finally, although this dissertation employs fixed-effects panel models, endogeneity problems cannot be completely ruled out. Fixed-effects panel models have many advantages over cross-sectional models (Ketokivi & McIntosh, 2017). In particular, they mitigate unobserved heterogeneity and alleviate endogeneity arising from omitted variables (Ketokivi & McIntosh, 2017). However, like cross-sectional models, they still require the assumption that all regressors are uncorrelated with the error term (Ketokivi & McIntosh, 2017). Since this assumption cannot be tested, the analyses might still be affected by endogeneity.

5.2 Future research

How firms can profit from innovation is an enduring question. In order to advance our knowledge on innovation and its financial outcomes, we need to develop a better understanding of the processes of value creation and value capture. As noted, a firm's innovations often require complementary innovations from ecosystem members such as customers, suppliers and complementors in order to create value. Although this dissertation and other extant research (Adner, 2006; Adner & Kapoor, 2010) attend to this matter, our knowledge on how firms can manage their dependencies on complementary innovations is limited. Future research could thus investigate how firms can get their ecosystem members to develop required complementary innovations – for instance by examining factors that determine their willingness and ability to engage in such efforts. Their willingness might be determined by incentives such as value-sharing agreements (i.e., agreements that warrant a certain percentage share of value to the partner). Their ability, on the other hand, could potentially be managed by knowledge sharing and by development programs that increase their partners' innovativeness. It would be interesting to see if such development programs, similar to the established practice of supplier development programs (Krause & Ellram, 1997; Wagner et al., 2010; Wagner & Krause, 2009), pay off for firms.

Future research could also address interdependencies between value creation and value capture. In choosing a strategy for profiting from innovation, firms often face a trade-off between capturing a large share of a small value pie and capturing a small share of a large value pie. Essay 1 of this dissertation is a first step in understanding such trade-offs. It suggests that, while a buyer's power-advantage vis-à-vis its supplier enables it to capture a larger share of the pie, it also diminishes the pie to an extent that offsets any gains. Hence, in sum, a power-advantage seems to reduce the amount of value appropriated by the buyer. Measures such as value-sharing agreements and knowledge sharing, however, also exhibit such a trade-off. For instance, value-sharing agreements might increase a partner's willingness to develop complementary innovations and thereby enhance value creation; but they also require the focal firm to forgo a large percentage share. Similarly, knowledge sharing might lead to better development outcomes and more value creation in the ecosystem (Alexy, George, & Salter, 2013; Nickerson & Zenger, 2004). Yet, at the same time, knowledge sharing can potentially erode a firm's competitive advantage and thus impair its position to claim value (Nickerson & Zenger, 2004; Teece, 1986). Research on these trade-offs could yield valuable insights on how firms can balance value creation and value capture in order to profit the most from innovation.

5.3 Conclusion

This dissertation investigates the relationship between innovation and firm financial performance in the context of buyer-supplier relationships. It offers new insights on (1) how firms can profit from their suppliers' innovations, (2) on whether and to which extent component suppliers depend on their buyers' innovative activities to earn returns on their own investments in innovation, and (3) on the implications of absorptive capacity for the value of supplier relations to buying firms. The findings of this dissertation provide important contributions to the management literature and have relevant implications for practice.

Chapter 2 Supplier innovation and firm performance: The moderating role of interdependence

1 Introduction

Scholars have long suggested that firms may benefit financially from the innovations of their suppliers. For instance, in his influential article “Profiting from technological innovation,” Teece (1986) argued that innovating firms often fail to reap significant returns from their innovations. Instead, their customers, suppliers or imitators might appropriate large shares (Teece, 1986). Another explanation has been put forward by Griliches (1979), who investigated the effects of research and development on productivity growth. He noted that the productivity achieved by a firm depends not only on its own research efforts but also on the pool of accessible external knowledge. Thereby, knowledge created by supplier innovation might increase a buyer’s productivity (Griliches, 1979), and thus, contribute to its financial performance.

The results of several empirical studies indeed point to a link between supplier innovation and buyer financial performance. For example, Petersen, Handfield, and Ragatz (2005) find that firms can improve their financial performance by involving suppliers in product development. McGahan and Silverman (2006) show that innovation by industry outsiders (which may include suppliers) increases the market value of incumbent firms. Similarly, Kafouros and Buckley (2008) find that research and development efforts by industry outsiders enhances a firm’s productivity. Azadegan and Dooley’s (2010) results indicate that supplier innovativeness is positively related to multiple dimensions of buyer performance such as cost, quality, product development, delivery and flexibility. Finally, Brachtendorf, Bode, and Wagner (2016) show that a supplier’s research and development expenditures contribute to the market value of its buyers.

Those studies provide valuable support for a potential relationship between supplier innovation and buyer financial performance. Yet so far, we have not reached a comprehensive understanding of the mechanism that undergirds this relationship. In our view, this lack of understanding results from the diverging theoretical perspectives that have been employed, which by themselves only offer a partial account of this complex phenomenon. Prior explanations of the link between supplier innovation and buyer financial performance have either been based on Teece's (1986) framework or on R&D spillover arguments originating from Griliches (1979). While the former focuses on bargaining and value capture (Jacobides et al., 2006), the latter emphasizes knowledge spillovers, and thus, value creation. Although, depending on the scope of the respective study, those approaches might be sufficient, we argue that, to comprehensively understand this relationship, both value creation and value capture need to be taken into account. Supplier innovations create value and buyer financial performance is determined by value capture (Lepak et al., 2007). Hence, their relationship necessarily involves both processes.

We therefore conceptualize the link between supplier innovation and buyer financial performance as a process of "value slippage" – a term introduced by Lepak et al. (2007). According to the latter, value slippage occurs when value created by one source or entity is captured by another (Lepak et al., 2007). The concept of value slippage reflects Teece's (1986) insight that, instead of the innovator, others might reap most of the rents generated by an innovation. In addition, it accounts for value creation dynamics, and enables us to incorporate the effects of knowledge and information exchange. Consequently, the concept of value slippage allows for a comprehensive analysis that encompasses both value creation and value capture.

In conceptualizing the relationship between supplier innovation and buyer financial performance as a value slippage process, we obtain novel insights on how its strength depends on the interdependencies in the dyad. The latter characterize each interorganizational relation, wherefore scholars have devoted considerable attention to studying their implications. Much of the early research on interdependence focused on the role of power imbalance, meaning the difference in actors' dependencies on each other (Pfeffer, 1972; Stolte & Emerson, 1976); more recent research highlighted the importance of mutual dependence, meaning the sum of dependencies between actors in the relationship (Casciaro & Piskorski, 2005; Gulati & Sytch, 2007). Hence, interdependence in a buyer-supplier dyad is now commonly viewed as two-dimensional – comprising both mutual dependence and power imbalance. Accordingly, we examine how both dimensions influence the relationship between supplier innovation and buyer financial performance.

Investigating the moderating role of interdependence is motivated by prior research. Teece (1986) argues that interdependencies between innovators and complementary asset holders (e.g., between suppliers and buyers) have a major influence on how returns to innovation are distributed. Additionally, prior research suggests that power imbalance affects a firm's willingness to share knowledge and information, and thus, the amount of knowledge spillover between a buyer and a supplier (Chen, Zhao, Lewis, & Squire, 2015; Inkpen & Tsang, 2005). Finally, Gulati and Sytch (2007) show that mutual dependence and power imbalance have distinct implications for value creation and value capture in buyer-supplier relationships. Taken together, both dimensions can thus be expected to affect value slippage, and consequently, the contribution of supplier innovation to buyer financial performance.

Our empirical analysis confirms this expectation. In a panel of 841 buyer-supplier relationships from 2000-2010, we find strong moderating effects of mutual dependence and power imbalance. Specifically, we find mutual dependence to enhance, and power imbalance to decrease value slippage. Through these findings, our study makes several contributions to the literature. First, we improve our understanding of the effect of supplier innovation on buyer financial performance. We show that, due to potential competence-destroying disruptions, there seems to be no general positive effect. Instead, our results indicate that whether the effect of supplier innovation is positive or negative depends strongly on interdependence. Second, we add to the value-based literature by examining the process of value slippage – a phenomenon that prior research has largely ignored. Our findings suggest that value slippage occurs in buyer-supplier relationships, and that it may contribute significantly to the buyer's financial performance. Furthermore, in investigating the moderating roles of mutual dependence and power imbalance, we contribute to resource dependence theory, and especially to research on interdependence in vertical exchange relationships. Similar to Gulati and Sytch's (2007) findings, our results indicate that mutual dependence increases value creation in the relationship, while power imbalance decreases value creation to an extent that outweighs potential value capture gains of the power-advantaged firm.

2 Theory and hypotheses

2.1 Value slippage

In the value-based literature, value creation and value capture are regarded as two distinct processes (Lepak et al., 2007). This distinction is important because value created by one entity may be captured by another – a process which Lepak et al. (2007) term "value slippage." For instance, firms that create value through innovation might have to share this value with buyers, and perhaps also with other stakeholders such as employees, competitors or society (Lepak et al., 2007). Although value slippage might occur among various stakeholders and on several levels of analysis (Lepak et al., 2007), this paper focuses on value slippage in buyer-supplier relationships, and specifically, on value "slipping" from a supplier to a buyer.

In order to understand how value slippage is determined, one first has to look at the underlying processes of value creation and value capture. The latter can be illustrated using the value, price and cost (VPC) framework – a bargaining model introduced by Tirole (1988) and later adopted by others (Crook & Combs, 2007; Hoopes, Madsen, & Walker, 2003; Priem, 2007). The framework models a transaction of a good that contributes value (V) to the buyer, incurs production costs (C) at the supplier, and, as a result of bargaining, is exchanged for a certain price (P) (Hoopes et al., 2003). By conceptualizing both value and price, the framework reflects Bowman and Ambrosini's (2000) distinction between use and exchange value. Use value refers to the specific qualities of the good perceived by the buyer (Bowman & Ambrosini, 2000). In monetary terms, it can be defined as the maximum price a buyer is willing to pay absent competing products or services (Bowman & Ambrosini, 2000). Importantly, as noted by Bowman and Ambrosini (2000), the perception of use value applies to all purchases and not only to those of final consumers. Exchange value is equal to the price at which the good is actually sold (Bowman & Ambrosini, 2000).

Based on the VPC framework, a transaction generates a surplus (V-C), which is divided between buyer surplus (V-P) and supplier surplus (P-C) (Hoopes et al., 2003). Hence, a transaction creates an amount of value equal to the surplus V-C, of which certain shares are captured by the buyer and the supplier. While the amount of value created by a transaction is determined by the buyer's perceived use value and the supplier's production costs, the amounts of value captured are determined by the price – as a result of competition and isolating mechanisms (Lepak et al., 2007).

As transactions between buyer and supplier reoccur over time, the amount of value created might change. Supplier innovations can both reduce production costs and enhance the buyer's perceived use value through the introduction of a new, better-performing product or service (Hoopes et al., 2003). Hence, innovations create incremental value by increasing the surplus V-C. In case the supplier is unable to fully appropriate the created incremental value, a certain fraction "slips" to the buying firm. Figure 1 illustrates this process based on an innovation that reduces production costs (the surplus increases from V-C to V-C').

Applying the VPC framework to the process of value slippage reveals that the magnitude of value slippage in buyer-supplier relationships depends on two factors: (1) incremental value creation, which determines the size of the additional surplus available to be distributed between buyer and supplier, and (2) the share of value captured by the buyer. In the following sections, we examine the relationship between interdependence, represented by the dimensions of mutual dependence and power imbalance, and the magnitude of value slippage, that is, the contribution of supplier innovation to buyer financial performance. Therefore, we relate both mutual dependence and power imbalance to each of the two identified determinants in order to draw conclusions on their overall expected effects.

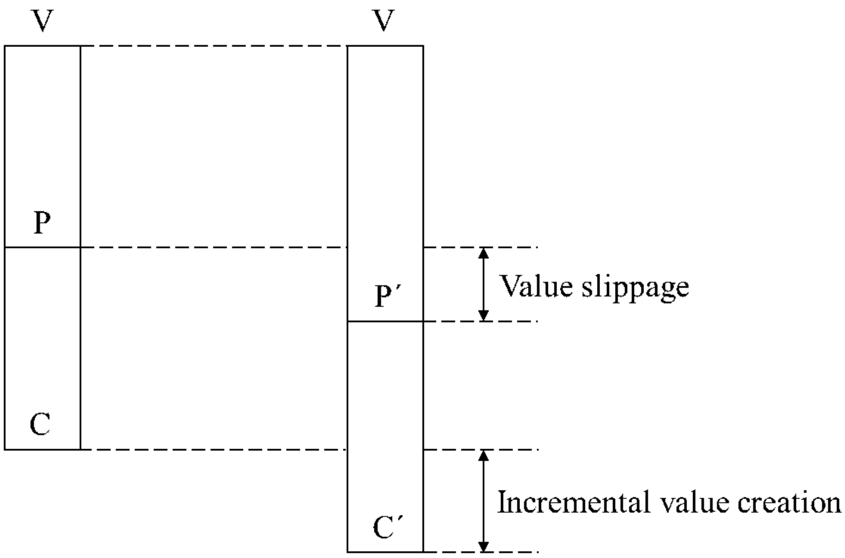

Figure 1: Value slippage illustrated with the value, price and cost framework

2.2 Interdependence

Interdependence is a core concept of resource dependence theory (Pfeffer & Salancik, 1978). The latter views organizations as embedded in networks of interdependencies that stem from their need to maintain or acquire resources by exchanging with actors in their environment (Pfeffer & Salancik, 1978). The nature of interdependence in dyadic interfirm relationships can be described by two dimensions introduced by Casciaro and Piskorski (2005): mutual dependence and power imbalance.

Building on Emerson’s (1962) theory of power-dependence relations, Casciaro and Piskorski (2005) argue that dyadic interdependence can only be exhaustively described by considering the reciprocal nature of interdependence, that is, in an A-B relation, the simultaneous presence of actor A’s dependence on actor B and actor B’s dependence on actor A. Casciaro and Piskorski’s (2005) first dimension, mutual dependence, captures bilateral dependencies and can formally be defined as the sum of both dependencies (Casciaro & Piskorski, 2005). Their second dimension, power imbalance, captures asymmetric dependencies and can be defined as the absolute difference of both dependencies (Casciaro & Piskorski, 2005). For any given value of power imbalance, a dyad can be characterized by varying levels of mutual dependence and vice versa (Casciaro & Piskorski, 2005).

2.3 The role of mutual dependence

According to Gulati and Sytch (2007), mutual dependence has implications for buyer-supplier relationships. Due to increased depth of economic interaction, mutual dependence is related to relationship characteristics such as heightened attention to the responses and attitudes of the partner, enhanced trust, joint action, preference for non-coercive over coercive strategies, relational tactics, and extensive exchange of knowledge and information (Gulati & Sytch, 2007). Those relationship characteristics affect the ability of supplier innovations to create incremental value. In particular, through extensive knowledge and information exchange, the supplier can identify the buyer's needs, and thus, develop products that yield higher perceived use value (Narver & Slater, 1990). Furthermore, extensive knowledge and information exchange facilitates the integration of supplier innovations in the form of new component designs into the buyer's product (Takeishi, 2001). A better integration of new component designs, in turn, increases the functionality of the buyer's product (Takeishi, 2001), and enhances perceived use value. Hence, the extensive knowledge and information exchange associated with high mutual dependence can be expected to increase use value, and consequently, incremental value created by supplier innovations.

Next to knowledge and information exchange, mutual dependence affects the degree to which a supplier targets its innovations at a buyer. As noted above, supplier innovation may create incremental value by increasing a buyer's perceived use value (V) or by reducing costs (C). Supplier innovations, however, are usually not only targeted at one specific buyer, but also at other buyers or customer segments. A certain share of a supplier's innovations may create value only for other buyers. We argue that, the greater the mutual dependence in a buyer-supplier dyad, the higher the degree to which supplier innovations are targeted at the buyer. This is because, under conditions of high mutual dependence, the supplier is specialized towards the buyer (Teece, 1986), which reflects the supplier's past strategic orientation and decision making (Schreyögg & Kliesch-Eberl, 2007). Self-reinforcing processes cause the supplier to replicate this pattern of past decision making (Sydow, Schreyögg, & Koch, 2009) and to pursue innovation projects targeted at the buyer. Hence, mutual dependence is likely positively related to value creation since it both increases supplier innovation targeted at the buyer and the amount of knowledge and information exchange in the dyad.

While mutual dependence can be expected to enhance incremental value creation, it is probably unrelated to the share of value captured by the buyer. According to Emerson (1962), mutual dependence between two actors results from both rewards that can be obtained through the relationship and low availability of those rewards outside the relation, i.e., through other relations. Low availability of rewards outside the relation implies that both actors possess rather strong isolating mechanisms, which limit competition (Lepak et al., 2007). Mutual dependence therefore relates to the strength of isolating mechanisms on both sides, and hence leaves their relative strength unaffected. In other words, mutual dependence does not influence the bargaining power in the dyad. Consequently, we expect no association between mutual dependence and the share of value captured by the buyer.

Our propositions are summarized in Table 2. Taken together, we argue that mutual dependence enhances incremental value creation and is unrelated to the share of value captured by the buyer. Hence, we predict that mutual dependence increases value slippage, and thus, positively moderates the relationship between supplier innovation and buyer financial performance:

H1. The level of mutual dependence in a buyer-supplier dyad positively moderates the relationship between supplier innovation and buyer financial performance.

2.4 The role of power imbalance

Scholars suggest that not only mutual dependence, but also power imbalance affects buyer-supplier relationships. According to Blau (1964), power imbalance makes it possible for the power-advantaged firm to act opportunistically by exercising coercion. As the power imbalance grows, the power-advantaged firm will increasingly resort to adversarial tactics to capture greater value in the relationship at the expense of the weaker actor (Blau, 1964; Gulati & Sytch, 2007). Such coercive and opportunistic behavior undermines trust within the relationship (Barney & Hansen, 1994; Ireland &

Webb, 2007), thereby reducing the weaker actor's willingness to exchange knowledge and information (Inkpen & Tsang, 2005). A recent study by Chen et al. (2015) lends empirical support to this argument. They show that a buyer's coercive behavior decreases the motivation of its suppliers to share knowledge. Yet, as noted previously, knowledge and information exchange is important for incremental value creation as it is required for the supplier to identify the buyer's needs as well as for integrating supplier innovations in the form of new components into the buyer's product. Therefore, the loss of knowledge and information exchange associated with power imbalance can be expected to impede incremental value creation.

Power imbalance is, however, not related only to knowledge and information exchange, but also to the degree to which a supplier targets its innovations at a buyer. This is because, in unbalanced exchange relationships, the weaker firm exhibits unmitigated dependencies on the stronger firm, which limit its organizational autonomy (Oliver, 1990, 1991; Pfeffer & Salancik, 1978). Under such circumstances, the stronger firm can control the weaker firm's resource allocation and innovation programs (Christensen & Bower, 1996). The study by Christensen and Bower (1996) supports this argument by showing that powerful customers influence the way that firms allocate their resources to innovation projects. The influence of power on organizational autonomy implies that, if the buyer is power-advantaged, power imbalance increases the degree to which supplier innovation is targeted at the buyer. This then contributes to incremental value creation, and counteracts negative effects resulting from impeded knowledge and information exchange. Hence, given the buyer is power-advantaged, the implication of power-imbalance for incremental value creation is ambiguous. In contrast, if the supplier is power-advantaged, the power imbalance is associated with higher organizational autonomy, which may reinforce adverse effects resulting from impeded knowledge and information exchange. Accordingly, under the condition of a power-advantaged supplier, power imbalance is likely negatively related to incremental value creation.

In addition to incremental value creation, power imbalance affects value capture, and thus, a buyer's appropriated share. As is commonly argued, the power-advantaged actor in a relationship may exploit its power in order to capture greater value at the expense of the weaker actor (Blau, 1964; Bowman & Ambrosini, 2000; Gulati & Sytch, 2007). As such, if the buyer is power-advantaged, greater power imbalance implies that the buyer can capture a greater share of the generated surplus. In contrast, if the supplier is power-advantaged, greater power imbalance implies that the buyer can only capture a smaller share.

Since the implications of power imbalance depend on which partner is power-advantaged, we state separate hypotheses for each case. Under the condition of a power-advantaged supplier, power imbalance is negatively related to both incremental value creation and to the share of value captured by the buyer. Accordingly, we expect power imbalance to decrease value slippage, and consequently, to negatively moderate the relationship between supplier innovation and buyer financial performance:

H2. The level of power imbalance in a buyer-supplier dyad negatively moderates the relationship between supplier innovation and buyer financial performance, if the supplier is power-advantaged.

Under the condition of a power-advantaged buyer, the effect of power imbalance on value slippage is ambiguous. While we can expect power imbalance to enhance the share of value captured by the buyer, a conclusion on its effect on incremental value creation cannot be drawn. As the overall effect of power imbalance might be positive, negative or null, we state three competing hypotheses:

H3a/ b/ c. The level of power imbalance in a buyer-supplier dyad positively moderates/ negatively moderates/ is unrelated to the relationship between supplier innovation and buyer financial performance, if the buyer is power-advantaged.

Table 2: Proposed relationships

	Mutual dependence	Power imbalance (Supplier advantage)	Power imbalance (Buyer advantage)
Incremental value created	+	–	+/ – / 0
Share of value captured by the buyer	0	–	+
Overall effect on value slippage	*Positive (H1)*	*Negative (H2)*	*Positive/Negative/Zero (H3a/b/c)*

3 Empirical analysis

3.1 Empirical design, data and sample

In our empirical analysis, we measure buyer financial performance as a function of supplier innovation, mutual dependence, power imbalance and relevant control variables. The unit of analysis is the buyer-supplier dyad. In order to isolate the effect of supplier innovation and its interaction effects with mutual dependence and power imbalance as much as possible, we include strong buyer-level controls. Specifically, we utilize panel data, which allows us to control for all unobserved, time-invariant factors that may contribute to buyer financial performance.

In order to obtain panel data on buyer-supplier relationships, we draw on Compustat North America which contains information on firms' major customers. Under the U.S. accounting regulation FAS 131 (1997), publically traded U.S. firms are required to report their major customers: those buying at least 10 percent of the firm's sales. The information on firms' self-reported customers is available in the Compustat customer segment files, which therefore constitute a potential and increasingly utilized data source of buyer-supplier relationships (Cohen & Frazzini, 2008; Fee & Thomas, 2004; Hertzel et al., 2008; Lanier, Wempe, & Zacharia, 2010; Mackelprang & Malhotra, 2015). However, since there is no standard method for firms to report their customers' names, the same customers can be identified with slightly different spellings or abbreviations. Like others (Fee & Thomas, 2004; Hertzel et al., 2008), we rely on approximate string matching to match reported customer names to firm names in Compustat. Subsequently, we visually inspect each match in order to ensure accuracy (Hertzel et al., 2008). In total, we obtain a panel of 1598 buyer-supplier dyads and 6076 dyad-year observations from 2000 to 2010. All buyer and supplier firms in this panel are incorporated in the U.S. Next to identifying buyer-supplier relationships, we use Compustat as a source of financial data for our dependent variable and control variables.

For our innovation-related variables, we draw on patent data from the United States Patent and Trademark Office (USPTO) provided by PatentsView. We select all granted patents, applied at the USPTO from 1995 to 2010, and match those to all firms (buyers and suppliers) in our data set. We link patents to firms using an approximate string matching algorithm that compares patent assignee names to company names. Because firms often assign patents to their subsidiaries, we consider not only matches with a firm's name but also matches with names of its subsidiaries. Data on subsidiaries comes from the Directory of Corporate Affiliations, Thomson ONE (formerly SDC Platinum), and CorpWatch API. We use the Directory of Corporate Affiliations to identify all divisions, subsidiaries and joint ventures of our sample firms as of 2015, and then use information on M&A deals from Thomson ONE to trace back the firms' subsidiaries for our study period. In order to identify the M&A deals of our sample firms, we link deals to firms based on CUSIP codes. Additionally, we complement the obtained lists of subsidiary names with those reported in firms' 10-K filings provided by CorpWatch API.

For our mutual dependence and power imbalance variables, we retrieve data from the Bureau of Economic Analysis (BEA) and the Census Bureau of the U.S. Department of Commerce. We follow Casciaro and Piskorski (2005) who utilize industry input-output patterns and concentration ratios to operationalize mutual dependence and power imbalance. Since their approach requires both partners to be classified in separate industries, we restrict our sample to buyer-supplier dyads in which both partners exhibit different six-digit North American Industry Classification

System (NAICS) codes. Data on industry input-output patterns comes from the Benchmark Input-Output (I-O) accounts provided by the Bureau of Economic Analysis (BEA). Like Casciaro and Piskorski (2005), we match the six-digit I-O codes of the Benchmark I-O accounts with our firms' six-digit NAICS codes based on the concordance provided by the BEA in its Survey of Current Business. Data on industry concentration comes from the Census Bureau of the U.S. Department of Commerce. Both Benchmark I-O tables and concentration ratios are released every five years. For our study, we use the latest available publications, which are those of 1997, 2002 and 2007. In order to obtain annual measures, we adopt Casciaro and Piskorski's (2005) approach and linearly extrapolate the data over the three available years. Furthermore, as industry concentration data for 1997 is unavailable for certain industries (NAICS codes beginning with digits 4, 5 and 6), we also follow Casciaro and Piskorski's (2005) approach and linearly extrapolate the available concentration ratios across the missing time period. Our findings do not change whether we include or exclude these extrapolated observations (see Table 5).

A further issue that needs to be addressed is common ownership. In some dyads, the buyer and the supplier are subsidiaries of a common parent firm or one of them is the parent firm of the other. In these cases, the process of value slippage can differ from that in dyads of independent ownership due to different governance modes (i.e., hierarchy vs. market). Since we focus our analysis on value slippage between independent organizations as opposed to value slippage within an organization, we exclude dyads in which both the buyer and the supplier are under common ownership. In order to obtain information on the parent firms of buyers and suppliers, we draw on the Directory of Corporate Affiliations and Thomson ONE. We first identify the parent firms as of 2015 based on the Directory of Corporate Affiliations. Subsequently, we trace back changes in ownership based on M&A deals from Thomson ONE. This is possible, since Thomson ONE lists the target firm's parent firm from before and after an M&A deal. Using this data, we are able to assign parent firms to observations, to manually compare the assigned parents, and to exclude those under common ownership.

Our final sample encompasses 3291 dyad-year observations of the period from 2000 to 2010. It consists of 841 buyer-supplier dyads that we observe on average over a time span of 3.9 years, with the minimum and maximum observed time periods being 2 and 11 years, respectively. The sample comprises, in total, 798 unique firms of which 37 occur both as a buyer and a supplier.

3.2 Dependent variable: buyer financial performance

We employ the natural logarithm of buyer Tobin's q as our dependent variable. Tobin's q is defined as the ratio of market value to the replacement cost of the firm (Wernerfelt & Montgomery, 1988). It indicates corporate financial performance because it reflects future firm rents (van Reenen, 1996) and a firm's ability to earn above a competitive return (Lindenberg & Ross, 1981). A main advantage of Tobin's q compared to other measures of firm performance is its combination of market-based and accounting-based data. As a result of this combination, it uses the correct risk-adjusted discount rate, accounts for disequilibrium effects and minimizes tax law and accounting convention distortions (Wernerfelt & Montgomery, 1988). In contrast, pure accounting rates of return may differ considerably from true economic rates of return due to biases in their calculation (Benston, 1985), differences in tax laws and latitude in interpreting accounting regulations (Wernerfelt & Montgomery, 1988).

In practice, Tobin's q can be measured by approximating the replacement cost of the firm by the book value of its total assets (Wernerfelt & Montgomery, 1988), and by estimating its market value as the sum of its nominal value of outstanding debt and its market capitalization (Hall & Oriani, 2006; Sandner & Block, 2011). We follow this approach, which has been applied in many previous studies (Hall, Jaffe, & Trajtenberg, 2005; Humphery-Jenner, 2014; Sandner & Block, 2011). The year in which we measure buyer Tobin's q is the year in which the supplier reported the buyer as major customer (year t). Furthermore, we use a log transformation of Tobin's q in order to reduce skewness.

3.3 Independent variables

3.3.1 Supplier innovation

We operationalize supplier innovation by a five-year average of citation-weighted patent counts. Patent counts are reliable indicators of innovative performance since they strongly correlate with new products (Comanor & Scherer, 1969; Hagedoorn & Cloodt, 2003), literature-based invention counts (Basberg, 1982) and non-patentable innovations (Patel & Pavitt, 1997). Furthermore, citation-weighted patent counts take account of the heterogeneity in patent value and thus provide a more accurate measure of innovative output than simple patent counts (Hall et al., 2005).

When using patent citations as proxies for the value or quality of patented innovations, it is necessary to correct for the truncation bias that is inherent to patent citations (Hall, Jaffe, & Trajtenberg, 2001). The number of citations received by a given patent is truncated because patents accumulate citations over time, wherefore older patents have, on average, more forward citations than recent patents (Hall et al., 2001). We correct for this truncation bias with the fixed-effects approach detailed in Hall et al. (2001). The fixed-effect approach removes truncation effects, effects due to any systematic changes over time in the propensity to cite, and effects due to changes in the number of patents making citations (Hall et al., 2001).

For each observation in our sample, we calculate our measure of supplier innovation as the sum of citation-weighted patent counts in the five-year window preceding the year of observed buyer financial performance (t-5 to t-1). In order to link patents to years, we use the priority date, which is closest to the time of invention (Hall et al., 2005). Furthermore, we use a scaling factor of 1/1000.

3.3.2 Mutual dependence and power imbalance

We follow Casciaro and Piskorski (2005) who developed measures of mutual dependence and power imbalance based on Burt’s (1983) seminal formulation of constraint. Their measures are based on inter-industry input-output patterns and industry concentration ratios, and are consistent with Emerson’s (1962) theory of power-dependence relations. The latter states that the dependence of actor A upon actor B is directly proportional to (1) the motivational investment in goals mediated by B and (2) inversely proportional to the availability of alternatives outside the relation A-B (Casciaro & Piskorski, 2005). Since their measures are consistent with Emerson's (1962) theory, they can be expected to yield better approximations of interorganizational dependence than measures based on direct firm-to-firm transactions (Casciaro & Piskorski, 2005).

Casciaro and Piskorski's (2005) general measure of dependence of a firm in industry y on a firm in industry x ($C_{x \to y}$) is formulated in equation 1. This dependence is high to the extent that firms in industry y sell a large fraction of their goods and services to firms in industry x. Furthermore, this dependence is high to the extent that firms in industry y buy a large fraction of their inputs from firms in industry x. In addition, dependence increases with concentration of industry x (a high industry concentration indicates a low availability of alternatives).

$$C_{x \to y} = \left[p_{yx} + s_{yx}\right] O_x \tag{1}$$

$$p_{yx} = \frac{z_{xy}}{\sum_q z_{qy}} \tag{2}$$

$$s_{yx} = \frac{z_{yx}}{\sum_q z_{yq}} \tag{3}$$

z_{yx}:	Value of goods and services sold by industry y to industry x.
$\sum_q z_{yq}$:	Total value of goods and services sold by industry y.
z_{xy}:	Value of goods and services purchased by industry y from industry x.
$\sum_q z_{qy}$:	Total value of goods and services purchased by industry y.
O_x:	Four-firm concentration ratio of industry x.

Based on equation 1, we obtain the dependencies between suppliers k and buyers j ($C_{k \to j,t}$ and $C_{j \to k,t}$) for the years 1997, 2002 and 2007 using inter-industry flows from the Benchmark I-O tables and four-firm concentration ratios from the Census Bureau of the U.S. Department of Commerce. We then linearly extrapolate the measures in order to obtain annual values. In order to ensure nonnegative dependence values, we constrain potentially negative values from the extrapolation to a minimal value of zero.

Following Casciaro and Piskorski (2005), we specify our measure of mutual dependence as the sum of $C_{k\rightarrow j}$ and $C_{j\rightarrow k}$. In order to measure mutual dependence during the observed period of supplier innovative output, we take a five-year average of this sum from the period preceding the year of observed buyer financial performance (from t-5 to t-1). In addition, we follow Casciaro and Piskorski (2005) and log-transform the variable using Stata's lnskew0 function due to its non-normal and skewed distribution. The lnskew0 function calculates the natural logarithm, ln(x + k), of the original variable x and chooses an exponent k such that the skewness of the resulting distribution is minimized. The following equation details our specification:

$$Mutual\ Dependence_{it} = \ln\left(k + \frac{1}{5}\sum_{n=1}^{5} C_{j\rightarrow k,t-n} + \ C_{k\rightarrow j,t-n}\right) \quad (4)$$

Like Casciaro and Piskorski (2005), we specify our measure of power imbalance as the absolute difference of $C_{k\rightarrow j}$ and $C_{j\rightarrow k}$. Again, we take a five-year average from the period preceding the year of observed buyer financial performance (from t-5 to t-1) and log-transform the variable using Stata's lnskew0 function. The following equation details our specification:

$$Power\ Imbalance_{it} = \ln\left(k + \frac{1}{5}\sum_{n=1}^{5}\left|C_{j\rightarrow k,t-n} - C_{k\rightarrow j,t-n}\right|\right) \quad (5)$$

3.3.3 Binary indicators of buyer-power and supplier-power

In order to distinguish observations with a power-advantaged buyer from observations with a power-advantaged supplier, we construct two binary indicators: *Buyer advantage* and *Supplier advantage*. Together, they enable us to differentiate the following cases:

(1) A power-advantaged buyer (*Buyer advantage* = 1, *Supplier advantage* = 0),

(2) A power-advantaged supplier (*Buyer advantage* = 0, *Supplier advantage* = 1),

(3) Balanced power (*Buyer advantage* = 0, *Supplier advantage* = 0).

We construct the indicators based on the five-year average of the difference of $C_{j\to k}$ and $C_{k\to j}$ from t-5 to t-1. Positive values indicate a power-advantaged buyer since in this case the supplier is more dependent on the buyer than the buyer is on the supplier. Accordingly, negative values indicate a power-advantaged supplier, and values of zero indicate balanced power. Equations 6 and 7 detail our construction of the binary indicators. It is important to note that, for the case of balanced power, our measure of power imbalance is, by construction, constant and takes on its minimum value. In contrast, the level of power imbalance is not predefined in the other two cases.

$$Buyer\ advantage_{it} = \begin{cases} 1, & if\ \frac{1}{5}\sum_{n=1}^{5} C_{j\to k,t-n} - C_{k\to j,t-n} > 0 \\ 0, & if\ \frac{1}{5}\sum_{n=1}^{5} C_{j\to k,t-n} - C_{k\to j,t-n} \leq 0 \end{cases} \quad (6)$$

$$Supplier\ advantage_{it} = \begin{cases} 0, & if\ \frac{1}{5}\sum_{n=1}^{5} C_{j\to k,t-n} - C_{k\to j,t-n} \geq 0 \\ 1, & if\ \frac{1}{5}\sum_{n=1}^{5} C_{j\to k,t-n} - C_{k\to j,t-n} < 0 \end{cases} \quad (7)$$

3.4 Control variables

We use a fixed-effects panel model that allows us to control for any time-constant influences on buyer financial performance. However, since this does not fully exclude the possibility of an omitted variable bias, we include the following time-varying controls. First, we control for buyer innovation, as innovative output is a major driver of firm performance. We measure buyer innovation using citation-weighted patent counts measured in the five-year window from t-5 to t-1. We construct this variable analogously to the construction of our measure of supplier innovation. Furthermore, firms making capital investments may have superior resources, which can affect their corporate financial performance (Ray, Xue, & Barney, 2013). As such, we control for the buyer's capital intensity measured by the ratio of capital expenditures to assets, and for the buyer's age of capital stock measured by the ratio of depreciation expense to net property, plant, and equipment (following Dezsö & Ross, 2012), both measured in year t-1. Furthermore, since a firm's capital structure may affect corporate financial performance, we also include the buyer's leverage, measured as the ratio of debt to assets from the year t-1. In addition, we take account of the influence of the buyer's size by including its number of employees from the year t-1, and control for general economic trends and business cycles by including year fixed-effects. We log-transform the control variables buyer size, buyer leverage and buyer capital intensity using Stata's lnskew0 function due to their skewed and non-normal distributions.

3.5 Statistical method

Since we seek to conduct a panel data analysis, we perform the Hausman test to decide between a random- and a fixed-effects model. The test strongly rejects the null hypothesis of uncorrelated effects (χ^2 (20) = 229.4, $p < 0.001$). Hence, we use a fixed-effects model. Another issue that needs to be addressed is the nested structure of our data in which several buyer-supplier dyads may share a buyer or supplier. As a result, not all disturbances are independent. To correct for this lack of independence, we calculate two-way cluster-robust standard errors that cluster around the buyer and the supplier. The latter allow disturbances within the defined clusters to be correlated, and thereby, allow for both cross-sectional and serial correlation (Cameron & Miller, 2015). We obtain the two-way cluster-robust standard errors based on the calculation procedure detailed in Cameron and Miller (2015).

We estimate six models in a step-wise procedure. Model 1 is our base model and includes all control variables. Model 2 extends model 1 by the variable *Supplier innovation*. Model 3 extends model 2 by the variables *Mutual dependence* and *Power imbalance*. Model 4 extends model 3 by the interaction terms *Supplier innovation X Mutual dependence* and *Supplier innovation X Power imbalance*. Model 5 adds the dummy variable *Supplier advantage* and the interaction terms *Supplier innovation X Buyer advantage*, *Power imbalance X Buyer advantage* and *Power imbalance X Supplier advantage*. Finally, model 6 adds the two three-way interaction terms *Supplier innovation X Power imbalance X Buyer advantage* and *Supplier innovation X Power imbalance X Supplier advantage*. These allow the moderation effect of power imbalance to vary depending on whether the buyer or the supplier is power-advantaged. According to Hayes (2013), a model that contains three-way interaction terms should also include all their constituents as single terms and all their constituents' possible two-way interactions to maximize the flexibility of the model and to avoid biased results. These are the terms that we add in model 5. However, since power imbalance is constant and takes on its minimum value for observations with balanced power (see section 3.3.3.), including all terms would lead to perfect collinearity and preclude the estimation of our model. In order to circumvent perfect collinearity, it is necessary to omit the single term *Buyer advantage* and the two-way interaction term *Supplier innovation x Supplier advantage*. As, in this case, these terms do not add any information, omitting them does not limit the flexibility of the model.

3.6 Results

Table 3 and Table 4 report descriptive statistics and regression results, respectively. *H1* proposes a positive moderation effect of mutual dependence on the relationship between supplier innovation and buyer financial performance. We test this hypothesis based on the coefficient of the interaction term *Supplier innovation X Mutual dependence* in model 4. This coefficient is estimated at a value of 0.096 with a standard error of 0.032 and a p-value of 0.003 based on a two-sided *t*-test, which supports *H1*. The interaction graph in Figure 2 illustrates this result.

H2 proposes a negative moderation effect of power imbalance on the relationship between supplier innovation and buyer financial performance for the case of a power-advantaged supplier, while *H3a/b/c* propose a positive/negative/zero moderation effect for the case of a power-advantaged buyer. The coefficient of the interaction term *Supplier innovation X Power imbalance* in model 4 is estimated at a value of -0.086 with a standard error of 0.026 and a p-value of 0.001 based on a two-sided *t*-test. This indicates a general negative moderation effect of power imbalance, which supports *H2* and *H3b*. However, since we stated separate hypotheses for the case of a power-advantaged supplier and a power-advantaged buyer, we test for a difference in the moderation effects of both cases in model 6. To do so, we estimate the difference between the coefficients of the two three-way interaction terms *Supplier innovation X Power imbalance X Buyer advantage* and *Supplier innovation X Power imbalance X*

Supplier advantage in model 6. The estimated value of the difference is 0.022 with a standard error of 0.033 and a p-value of 0.515 based on a two-sided *t*-test. Based on this result, we cannot reject the null hypothesis of equal moderation effects. Hence, there seems to be no difference in strength or direction of the moderation effects of power imbalance between both cases. Together with the result of model 4, this supports *H2* and *H3b*, and consequently, rejects *H3a* and *H3c*. The interaction graph in Figure 3 depicts the negative moderation effect of power imbalance.

A noticeable finding is that our analysis does not support a general positive effect of supplier innovation on buyer financial performance. As indicated by the 95% confidence intervals in Figure 2 and Figure 3, high mutual dependence and low power imbalance correspond to a significant positive effect, while low mutual dependence and high power imbalance correspond to a significant negative effect. More specifically, the marginal effect of supplier innovation given high mutual dependence (its mean plus one standard deviation) and low power imbalance (its mean minus one standard deviation) is estimated at a value of 0.297 with a standard error of 0.103 and a p-value of 0.004 based on a two-sided *t*-test. This effect can be interpreted as a semi-elasticity according to which an increase in supplier innovation by one standard deviation (0.612) results in an increase in buyer Tobin's q by about 18 percent ($100 \times 0.612 \times 0.297 \approx 18$), holding other factors fixed. In contrast, the marginal effect given low mutual dependence (its mean minus one standard deviation) and high power imbalance (its mean plus one standard deviation) is estimated at a value of -0.510 with a standard error of 0.157 and a p-value of 0.001. According to this marginal effect, an increase in supplier innovation by one standard deviation results in a reduction in buyer Tobin's q by about 31 percent ($100 \times 0.612 \times (-0.510) \approx -31$), holding other factors fixed. We provide an explanation for these findings in the subsequent discussion and conclusion section.

Table 3: Summary statistics for main variables

Variable	Mean	Std. Dev.	Min	Max
Buyer financial performance	0.706	0.468	-0.649	2.796
Buyer size	4.332	0.562	3.388	5.449
Buyer leverage	0.310	0.171	-0.183	1.869
Buyer capital intensity	-3.390	0.677	-6.548	-1.228
Buyer age of capital stock	0.235	0.235	0.019	8.900
Buyer innovation	1.062	1.956	0	15.850
Supplier innovation	0.075	0.612	0	15.694
Mutual dependence	0.309	2.137	-2.714	4.685
Power imbalance	-0.660	2.299	-3.878	4.127
Buyer advantage	0.480	0.500	0	1
Supplier advantage	0.413	0.492	0	1

Notes: *Buyer advantage* is a dummy variable indicating if the buyer is power-advantaged. *Supplier advantage* is a dummy variable indicating if the supplier is power-advantaged. All other variables are continuous variables.

Table 4: Estimation results

Variables	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
Constant	3.785***	(0.75)	3.604***	(0.66)	3.601***	(0.67)	3.632***	(0.65)	3.622***	(0.66)	3.615***	(0.66)
Buyer size	-0.659***	(0.17)	-0.629***	(0.15)	-0.625***	(0.15)	-0.630***	(0.15)	-0.636***	(0.15)	-0.636***	(0.15)
Buyer leverage	0.140	(0.16)	0.162	(0.16)	0.166	(0.15)	0.161	(0.15)	0.158	(0.15)	0.161	(0.15)
Buyer capital intensity	0.066*	(0.03)	0.064*	(0.03)	0.063	(0.03)	0.061	(0.03)	0.062*	(0.03)	0.060	(0.03)
Buyer age of capital stock	-0.074	(0.07)	-0.074	(0.07)	-0.075	(0.06)	-0.075	(0.06)	-0.074	(0.07)	-0.074	(0.06)
Buyer innovation	-0.015	(0.01)	-0.015	(0.01)	-0.017	(0.01)	-0.015	(0.01)	-0.015	(0.01)	-0.016	(0.01)
Supplier innovation			-0.068***	(0.01)	-0.068***	(0.01)	-0.193***	(0.06)	-0.184***	(0.05)	-0.155**	(0.05)
Mutual dependence					-0.032	(0.03)	-0.034	(0.02)	-0.029	(0.02)	-0.029	(0.02)
Power imbalance					0.004	(0.02)	0.007	(0.02)	-0.011	(0.02)	-0.014	(0.02)
Supplier innovation X Mutual dependence							0.096**	(0.03)	0.083*	(0.04)	0.079*	(0.04)
Supplier innovation X Power imbalance							-0.086***	(0.03)	-0.062	(0.05)	0.216	(0.15)
Supplier advantage									0.064	(0.06)	0.064	(0.06)
Supplier innovation X Buyer advantage									-0.051	(0.06)	-0.080	(0.05)
Power imbalance X Buyer advantage									0.008	(0.01)	0.011	(0.02)
Power imbalance X Supplier advantage									0.018	(0.02)	0.021	(0.02)
Supplier innovation X Power imbalance X Buyer advantage											-0.274	(0.14)
Supplier innovation X Power imbalance X Supplier advantage											-0.296*	(0.14)
Dyad fixed effects	Yes		Yes		Yes		Yes		Yes		Yes	
Year fixed effects	Yes		Yes		Yes		Yes		Yes		Yes	
No. of observations	3291		3291		3291		3291		3291		3291	
No. of groups	841		841		841		841		841		841	
Within-group R^2	0.298		0.304		0.307		0.310		0.312		0.313	

See next page for notes.

Table 5: Robustness check: Results without extrapolating industry concentration ratios

Variables	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
Constant	3.641***	(0.75)	3.413***	(0.62)	3.355***	(0.60)	3.403***	(0.58)	3.388***	(0.60)	3.376***	(0.61)
Buyer size	-0.638***	(0.18)	-0.600***	(0.15)	-0.588***	(0.15)	-0.597***	(0.14)	-0.600***	(0.14)	-0.599***	(0.15)
Buyer leverage	0.058	(0.17)	0.082	(0.16)	0.099	(0.16)	0.092	(0.15)	0.097	(0.15)	0.099	(0.15)
Buyer capital intensity	0.047	(0.03)	0.045	(0.03)	0.044	(0.03)	0.041	(0.03)	0.042	(0.03)	0.041	(0.03)
Buyer age of capital stock	-0.064	(0.06)	-0.064	(0.06)	-0.063	(0.06)	-0.063	(0.06)	-0.062	(0.06)	-0.062	(0.06)
Buyer innovation	-0.018	(0.02)	-0.017	(0.02)	-0.019	(0.02)	-0.016	(0.02)	-0.017	(0.02)	-0.018	(0.02)
Supplier innovation			-0.073***	(0.01)	-0.073***	(0.01)	-0.249**	(0.09)	-0.244*	(0.10)	-0.288*	(0.14)
Mutual dependence					-0.001	(0.03)	-0.004	(0.03)	-0.004	(0.03)	-0.003	(0.03)
Power imbalance					-0.024	(0.02)	-0.021	(0.02)	-0.030	(0.03)	-0.035	(0.03)
Supplier innovation X Mutual dependence							0.122*	(0.05)	0.107	(0.06)	0.118	(0.07)
Supplier innovation X Power imbalance							-0.102**	(0.04)	-0.070	(0.06)	0.219	(0.19)
Supplier advantage									0.070	(0.06)	0.071	(0.06)
Supplier innovation X Buyer advantage									-0.069	(0.06)	-0.003	(0.11)
Power imbalance X Buyer advantage									-0.005	(0.02)	-0.000	(0.02)
Power imbalance X Supplier advantage									0.011	(0.02)	0.015	(0.02)
Supplier innovation X Power imbalance X Buyer advantage											-0.309	(0.17)
Supplier innovation X Power imbalance X Supplier advantage											-0.277	(0.17)
Dyad fixed effects	Yes		Yes		Yes		Yes		Yes		Yes	
Year fixed effects	Yes		Yes		Yes		Yes		Yes		Yes	
No. of observations	2686		2686		2686		2686		2686		2686	
No. of groups	694		694		694		694		694		694	
Within-group R^2	0.311		0.319		0.322		0.326		0.328		0.329	

See next page for notes.

Notes on Table 4 and Table 5: The dependent variable is buyer financial performance, measured as the natural logarithm of Tobin's q. Standard errors are robust to arbitrary heteroscedasticity and allow for both serial and cross-sectional correlation through two-way clustering around buyers and suppliers. Buyer advantage is a dummy variable indicating if the buyer is power-advantaged. Supplier advantage is a dummy variable indicating if the supplier is power-advantaged. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ (two-tailed).

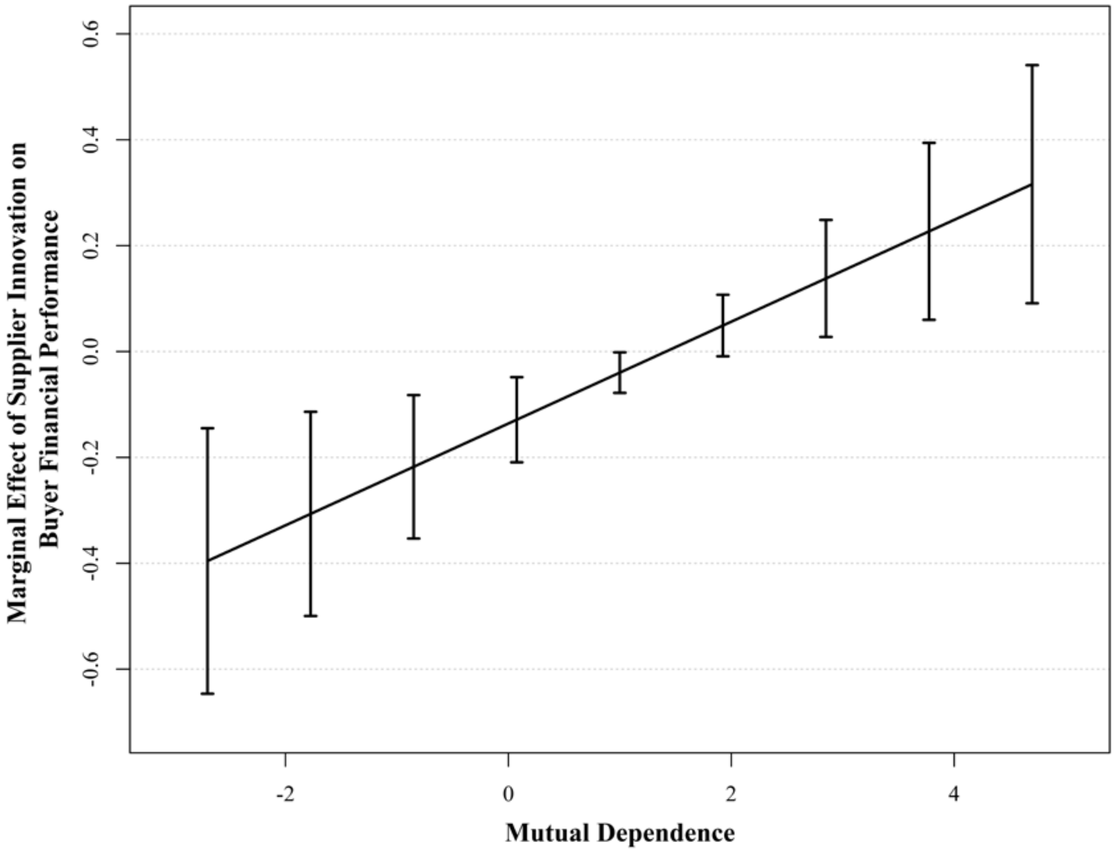

Figure 2: Moderation effect of mutual dependence

Notes: For plotting the moderating effect of mutual dependence, power imbalance was set at its mean (-0.660). Predictive margins with 95 percent confidence intervals.

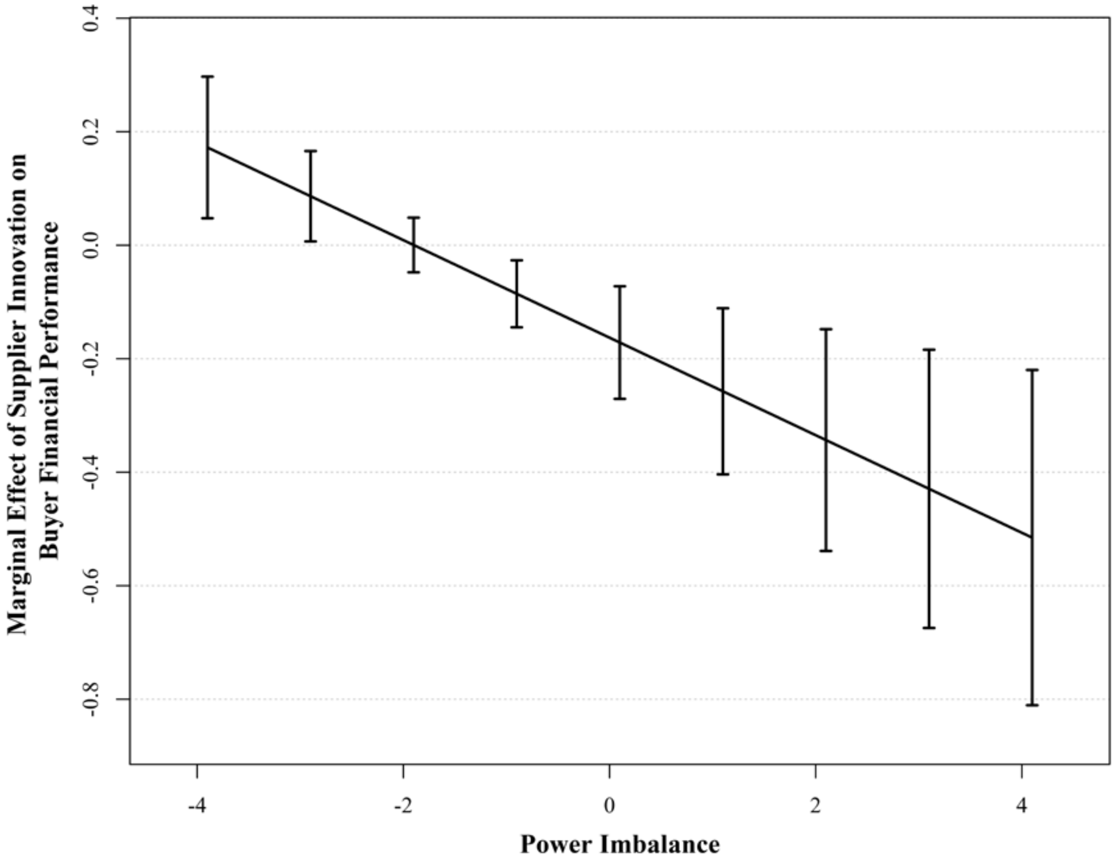

Figure 3: Moderation effect of power imbalance

Notes: For plotting the moderating effect of power imbalance, mutual dependence was set at its mean (0.309). Predictive margins with 95 percent confidence intervals.

4 Discussion and conclusion

In this paper, we investigate the relationship between supplier innovation and buyer financial performance. We conceptualize the latter as a value slippage process that involves both value creation and value capture (Lepak et al., 2007). Based on this conceptualization, we state and test propositions on how the magnitude of value slippage is determined by interdependence in the buyer-supplier dyad. Following Casciaro and Piskorski (2005), we view the latter as a two-dimensional construct comprised of mutual dependence and power imbalance. The first dimension, mutual dependence, captures bilateral dependencies in the dyad (i.e., the sum of dependencies between both firms), while the second dimension, power imbalance, captures asymmetric dependencies in the dyad (i.e., the absolute difference in firms' dependencies on each other).

For mutual dependence, our estimation results suggest a strong positive moderation effect on value slippage. This finding is consistent with our theoretical analysis: Mutual dependence can be expected to facilitate knowledge and information exchange in the dyad and increase the degree to which supplier innovations are targeted at the buyer. In this way, it enables supplier innovations to create more incremental value in transactions with the buyer, which then enhances their contribution to buyer financial performance. Hence, the greater the mutual dependence in a buyer-supplier relationship, the greater the contribution of supplier innovation to buyer financial performance.

For power imbalance, the estimation results suggest a strong negative moderation effect. Importantly, the latter seems to prevail independent of which partner is power-advantaged. This supports the proposition that power imbalance impedes knowledge and information exchange in the dyad, which limits incremental value creation and, ultimately, the contribution of supplier innovation to buyer financial performance. The finding of a negative effect also indicates that, if the buyer is power-advantaged, an increase in power imbalance reduces incremental value creation to an extent that outweighs value capture gains resulting from an increase in bargaining power. Hence, more power does not imply that buyers benefit more from supplier innovation. Instead, more power seems to prevent supplier innovations from developing their full value creation potential.

An interesting finding is that the magnitude of the negative effect of power imbalance does not seem to depend on whether the buyer or the supplier is power-advantaged. One possible explanation for this finding is that suppliers capitalize less on their power-advantage. According to Gulati and Sytch (2007), suppliers often have neither the desire nor the resources to leverage their structural power-advantage. Hence, even though suppliers might possess power, they often may not use it. For a power-advantaged supplier, this would imply a limited negative impact of power imbalance on the share of value captured by the buyer, and a limited detrimental effect of power imbalance on value creation. Conversely, for a power-advantaged buyer, power imbalance would have a strong positive influence on the share of value captured by the buyer, and an even stronger detrimental influence on value creation. Since, in this case, both effects work in opposite directions, the overall effect of power imbalance on value slippage could reach a magnitude similar to the effect given a power-advantaged supplier. While this explanation does not seem unlikely, it is important to notice that other reasons might also be responsible for the observed similarity in effect sizes.

Another interesting finding of our analysis is that supplier innovation is not associated with a general positive effect on buyer financial performance. Instead, the direction of the effect seems to depend on mutual dependence and power imbalance (Figure 2 and Figure 3). While high mutual dependence and low power imbalance correspond to a positive effect, low mutual dependence and high power imbalance correspond to a negative effect. One explanation for this finding is that, besides the potential for value slippage, supplier innovation entails risks that may diminish the financial performance of the buying firm, and thus, decrease its Tobin's q. In the context of innovation, such a risk is competence-destroying disruption (Tushman & Anderson, 1986). Supplier innovation can be disruptive and devalue a buyer's current tangible and intangible assets (or, at worst, render them obsolete). This may lead to a negative effect of supplier innovation on buyer financial performance if the positive contribution of value slippage does not outweigh the risk of asset devaluation.

4.1 Contributions to literature

Our research contributes to the literature in several ways. First and foremost, it enhances our understanding of the relationship between supplier innovation and buyer financial performance. We introduce value slippage as a conceptual model and thereby promote a deeper understanding of the mechanism that undergirds this relationship. In particular, the value slippage framework incorporates both Teece's (1986) value capture and Griliches' (1979) knowledge spillover arguments, and thus facilitates a more comprehensive analysis. Furthermore, we show that, due to potential competence-destroying disruptions, there seems to be no general positive effect of supplier innovation on buyer financial performance. Instead, our results indicate that whether the effect is positive or negative depends on mutual dependence and power imbalance. This contributes to the debate on whether using suppliers as sources of innovation may have adverse effects on the buying firm, and complements Azadegan and Dooley’s (2010) finding of a general positive effect.

Second, our study adds to the value-based literature. While prior research has devoted little attention to the process of value slippage, we show that it may occur in buyer-supplier relationships and contribute significantly to the buyer’s financial performance. Moreover, our results on the moderating effects of mutual dependence and power imbalance show that the magnitude of value slippage is strongly influenced by organizational interdependence. Scholars increasingly argue that a firm’s ability to create and appropriate value depends on organizational interdependencies in the industry architecture or business ecosystem in which it operates (Adner & Kapoor, 2010; Jacobides et al., 2006; Teece, 2007). Although the importance of such interdependencies is widely recognized, the mechanisms through which they affect organizational performance are not yet fully understood. We enhance our knowledge of those mechanisms by showing that value slippage is an important path through which interdependencies affect organizational performance.

Finally, our study contributes to resource dependence theory, and particularly to research on interdependence in vertical exchange relationships (Casciaro & Piskorski, 2005; Gulati & Sytch, 2007). In showing that mutual dependence positively moderates the link between supplier innovation and buyer financial performance, we provide additional support for the beneficial effects of joint dependence on value creation in vertical relationships proposed by Gulati and Sytch (2007). Additionally, our finding of a negative moderation effect of power imbalance indicates that power imbalance decreases value creation to an extent that outweighs the value capture gains of the power-advantaged firm. This is consistent with Gulati and Sytch’s (2007) empirical results, which show that a manufacturer’s power-advantage diminishes its performance in a procurement relationship.

4.2 Managerial implications

An important result of this study is that buying firms do not always seem to gain from supplier innovation. Instead, whether and how much they benefit is likely influenced by mutual dependence and power imbalance. In order to profit the most from supplier innovation (and to avoid potential losses), buying firms should thus establish relationships with their suppliers that are characterized by a high level of bilateral dependence and a low level of power asymmetry. These characteristics can be expected to enhance knowledge exchange in the dyad and the degree to which a supplier targets its innovative activity at the buying firm. In practice, buying firms could foster such relationships by emphasizing reciprocal relationship-specific investments with their suppliers as well as by aiming for high mutual dependence and low power imbalance constellations when selecting new suppliers. Our result might also have implications for investors. Since, according to our findings, supplier innovation can have both strong positive and strong negative effects on firm financial performance, taking the innovativeness of a firm's suppliers and their prevailing structural interdependencies into account could help investors to forecast a firm's financial performance and market value more accurately.

4.3 Limitations and future research

Naturally, this research has important limitations. Although our measures of mutual dependence and power imbalance are consistent with Emerson's (1962) theory of power-dependence, their operationalization based on industry input-output patterns and concentration ratios serves only as an approximation. Similarly, citation-weighted patent counts only partially reflect a firm's innovative output since the propensity to patent varies across firms, not all innovations are patented, and not all patents are commercialized (Santarelli & Piergiovanni, 1996). In addition to these limitations stemming from construct measurement, care must be taken in generalizing our findings to other settings. Our sample is restricted to buyer-supplier dyads in which both firms are incorporated in the U.S., classified in different industries, and not owned by the same parent firm. Therefore, our sample may not reflect the total population of buyer-supplier relationships. Moreover, generalizability is limited by our use of a fixed-effects panel model. The latter yields unbiased estimators, but inference is restricted to the behavior of the specific set of firms in the sample (Baltagi, 2005).

Future work could extend this study by examining the factors that mediate between interdependence and value slippage. For instance, based on our theoretical analysis, we expect mutual dependence and power imbalance to influence value slippage through their effects on knowledge exchange as well as on the extent to which the supplier targets its innovations at the buyer. Yet so far, we know little about the relative strength of those mediating factors. Investigating them independently would enhance our knowledge of the detailed processes through which interdependence affects value slippage. Another interesting path for future research would be to study the implications of power imbalance on value slippage by distinguishing structural power from actual power use. These are distinct constructs as firms that possess structural power can decide whether or not to use it (Brass & Burkhardt, 1993). Looking at these two constructs independently could thus reveal if firms can alleviate the negative effects of power imbalance by simply not using their power or if it is necessary for them to change the actual power structure. Finally, as value slippage is not restricted to buyer-supplier relationships (Lepak et al., 2007), future research could study it in other contexts, for instance, between a focal firm and its complementors. Research in this area would contribute to our knowledge on the circumstances in which value slippage occurs and on whether there are systematic differences in the magnitude of value slippage between different contexts.

Chapter 3 Knowledge partitioning in vertical relationships: How the type of innovation affects firms' knowledge boundaries

1 Introduction

Researchers have commonly argued that firms' ability to manage technological change is affected by the ways in which they are organized with respect to upstream components (Afuah, 2001; Kapoor & Adner, 2012; Teece, 1996; Wolter & Veloso, 2008). While scholars have long proposed a match between firms' vertical integration choices and the type of innovation (Teece, 1988, 1996; Wolter & Veloso, 2008), a recent stream of research also proposes a match between firms' knowledge boundaries and the type of innovation (Brusoni et al., 2001; Takeishi, 2002). With regard to the latter, two types of innovation are commonly distinguished: systemic innovations and autonomous innovations (e.g., Brusoni & Prencipe, 2001; Chiesa & Frattini, 2011; Helfat & Campo-Rembado, 2016; Kapoor, 2013; Langlois & Robertson, 1992; Teece, 1996; Wolter & Veloso, 2008). Systemic innovations require considerable readjustment of other parts of the system in which they are embedded (Teece, 1988, 1996). Autonomous innovations, on the other hand, can be implemented without changing other parts of the system (Teece, 1988, 1996).

In a case study of firms in the aerospace industry, Brusoni et al. (2001) found that, if component innovations create technological imbalances and have cascade effects on other parts– i.e., if the innovations are systemic, firms' keep component knowledge in-house. Furthermore, they found that firms retain less component knowledge if component innovations do not create such imbalances – i.e., if the innovations are autonomous. Hence, their results indicate a match between innovation type (systemic vs. autonomous) and knowledge partitioning. However, beyond Brusoni et al.’s (2001) initial case study, research has not yet empirically investigated whether such a match actually prevails. This lack of empirical evidence is somewhat surprising, given the longstanding interest in the relationship between firm organization and the nature of technological change (e.g., Chesbrough & Kusunoki, 2001; Chesbrough & Teece, 1996; Helfat & Campo-Rembado, 2016; Kapoor, 2013; Kapoor & Adner, 2012; Teece, 1988; Teece, 1996; Tushman & O'Reilly, 1996).

In this study, we draw on a panel of buyer-component supplier relationships from the period 2000-2013 obtained from Compustat North America. The panel covers several U.S. manufacturing industries and comprises in total 435 buyer-component supplier dyads. Consistent with the distinction between systemic and autonomous innovations, we differentiate between systemic and autonomous component innovations. Given a buyer-component supplier relationship, systemic component innovations are those innovations developed by the supplier that require the buyer to readjust other parts of its products, while autonomous component innovations can be implemented without changes in other parts of the buyer’s products. From the viewpoint of the supplier, both types of innovations exhibit different mechanisms of value creation. Systemic component innovations depend on the buyer’s innovative output in order to deliver value. Autonomous component innovations, in contrast, can yield value independent from the buyer’s innovative output.

We utilize patent data from the United States Patent and Trademark Office (USPTO) in order to measure the division of knowledge in buyer-component supplier relationships and to measure firms’ innovative outputs. Furthermore, we draw on financial data from Compustat in order to quantify the component suppliers’ financial performance. Through a fixed-effects panel regression, we are able to show that different degrees of knowledge base overlap in buyer-component supplier relationships correspond to different value creation mechanisms, and thus, seem to be dominated by different types of innovation. Specifically, we find that, the greater the knowledge base overlap, the greater the effect of the buyer’s innovative output on the supplier’s returns to innovation. Furthermore, we find that, the smaller the knowledge base overlap, the greater the supplier’s “stand-alone” returns to innovation. The latter refer to the supplier's returns absent innovative output from the buyer. Hence, different degrees of knowledge base overlap seem to exhibit significant differences in the relative prevalence of systemic and autonomous component innovations.

These findings provide large-scale empirical support for a match between knowledge partitioning and the type of technological change. In line with arguments on firms' integrative or systems integration capabilities (Brusoni et al., 2001; Helfat & Campo-Rembado, 2016), they suggest that common knowledge facilitates coordination and communication, and thereby enables firms to manage systemic innovations. The findings also suggest that, for firms who mainly experience autonomous innovations, the costs of developing and maintaining common knowledge may often outweigh its benefits. Thus, the findings are consistent with the analysis of Helfat and Campo-Rembado (2016), which predicts that whether firms choose to develop and maintain integrative capabilities depends on the prevalence of systemic innovations. In addition, the analysis adds to the evidence on systemic and autonomous innovations, which has thus far been based on case studies (e.g., Brusoni et al., 2001; Langlois & Robertson, 1992) or restricted to specific industries (e.g., Adner & Kapoor, 2010; Kapoor, 2013). Finally, by investigating the role of innovation type, the study complements prior research on the determinants of the division of knowledge in vertical relationships (Brusoni et al., 2001; Lee & Veloso, 2008; Takeishi, 2002).

The remainder of this paper is organized as follows. In the next section, we discuss differences in the value creation mechanisms of systemic and autonomous component innovations. We then derive propositions on how these affect the relationship between the buyer's innovative output and the component supplier's returns to innovation – contingent on the knowledge base overlap. This is followed by a detailed account of the empirical analysis and its results. We conclude by discussing the study's findings, contributions and limitations.

2 Theory and hypotheses

2.1 Autonomous vs. systemic component innovations

The analysis in this paper focuses on buyer-component supplier relationships. The latter are vertical, business-to-business relationships in which suppliers are specialized in developing, manufacturing and marketing technical components. Technical components, in turn, are physically distinct portions of higher-level technical systems (Henderson & Clark, 1990). Thus, in buyer-component supplier relationships, the suppliers' products are subsystems of their buyers' products. Furthermore, we focus on specialized component suppliers whose innovative activity can be expected to revolve mainly around components as opposed to higher-level technical systems.

Innovation research commonly distinguishes between two types of innovation: autonomous innovations and systemic innovations. Autonomous innovations can be introduced without modifying other components of the system they are part of (Teece, 1988, 1996). As such, they fit "comfortably into existing systems" (Teece, 1996, p. 217). Systemic innovations, on the other hand, require a significant readjustment of other components (Teece, 1988, 1996).

In accordance with these definitions, we propose a distinction between autonomous and systemic component innovations. Given a buyer-component supplier relationship, autonomous component innovations are those innovations developed by the supplier that can be implemented without changes in other parts of the buyer's products. Such innovations are most likely to occur in modular systems in which interface standards ensure compatibility (Brusoni & Prencipe, 2001; Langlois & Robertson, 1992). An example is "a new turbocharger to increase horsepower in an automobile engine, which can be developed without a complete redesign of the engine or the rest of the car" (Chesbrough & Teece, 1996, p. 67). Systemic component innovations, in contrast, are those that require the buyer to readjust other components of its products. An example is provided by Chesbrough and Kusunoki (2001), who argue that hard disk drives (HDDs) experienced a shift in disk drive head technology, which trigged changes in other disk components. Specifically, the transition from ferrite to thin film head technology required significant complementary changes in the head-disk interface, in the disk media and in the methods of error correction (Chesbrough & Kusunoki, 2001).

From the viewpoint of a component supplier, autonomous and systemic component innovations exhibit different mechanisms of value creation. The value of systemic component innovations depends on modifications of other components, and as such, on the buyer's innovative activity. Whether and how much the component supplier profits from its innovation thus hinges on the buyer's success in innovation. Autonomous component innovations, on the other hand, can yield value by improving the buyer's products without other parts of the system changing. Accordingly, the component supplier's returns to innovation do not necessarily depend on the buyer's innovative activity.

These differences between autonomous and systemic component innovations can be condensed to two main distinctions. First, systemic component innovations exhibit greater complementarity with the buyer's subsequent innovative output than autonomous innovations (given that the buyer decides to integrate the component innovations in its products). The reason for different levels of complementarity lies in differences in synergistic specificity. According to Schilling (2000, p. 316), synergistic specificity relates to "the degree to which a system achieves greater functionality by its components being specific to one another." Given a systemic component innovation, the buyer has to redesign other parts, thereby making them specific to the component innovation. This results in synergistic specificity and a greater contribution of the component innovation to system functionality. Given an autonomous component innovation, the buyer might also innovate and improve other parts. However, since these improvements are not specific to the component innovation, they result in lower synergistic specificity, and hence a smaller amplification of the component innovation's contribution to system functionality.

Second, autonomous component innovations yield greater "stand-alone" value than systemic component innovations. "Stand-alone" value refers to the value the component technologies can deliver absent subsequent innovation from the buyer. By definition, autonomous component innovations can be introduced and improve the buyer's products without modifications of other parts (Langlois & Robertson, 1992). Hence, they can create value without innovation from the buyer. Systemic component innovations, on the other hand, require the buyer to modify other parts of the system, and thus to innovate.

2.2 The role of common knowledge

In contrast to autonomous innovations, systemic innovations require communication and coordination of activities, investments and objectives in different stages of the value chain (Helfat & Campo-Rembado, 2016). Organizations therefore depend on common knowledge and shared understandings as enablers of communication and coordination in order to adapt to and introduce systemic innovations (Helfat & Campo-Rembado, 2016). According to Grant (1996, pp. 115-116), common knowledge "permits individuals to share and integrate aspects of knowledge which are not common between them." Furthermore, common knowledge enables individuals to anticipate and adapt to one another's actions and needs, and thereby facilitates coordination (Bechky, 2003). Buyer-supplier relationships in which systemic innovations are common are thus likely to exhibit an overlap of knowledge bases in order to facilitate the required levels of communication and coordination.

However, the ability to adapt to and introduce systemic innovations is costly to develop and maintain (Helfat & Campo-Rembado, 2016). Firms can advance their knowledge (and thus develop common knowledge with others), by absorbing existing knowledge or by creating new knowledge (Nickerson & Zenger, 2004; von Krogh, Nonaka, & Aben, 2001). Both activities are costly since they involve action and commitment by individuals (Nickerson & Zenger, 2004; Nonaka, 1994; von Hippel, 1994). Furthermore, as once acquired knowledge deteriorates if it is unused (Argote, Beckman, & Epple, 1990; Darr, Argote, & Epple, 1995; de Holan & Phillips, 2004), retaining common knowledge requires constant effort (de Holan & Phillips, 2004). Buyers and suppliers must therefore weigh the benefits of enhanced communication and coordination against the costs of developing and maintaining common knowledge.

If autonomous innovations are significantly more prevalent than systemic innovations, the costs may outweigh the benefits. The degree of knowledge base overlap in a buyer-supplier dyad may thus correspond to whether systemic or autonomous innovations dominate.

Indeed, extant empirical research suggest that the division of knowledge in vertical relationships depends on the type of innovation. Brusoni et al. (2001) found that the extent to which firms retain knowledge on upstream components depends on whether innovations in these components cause technical imbalances and have cascade effects on other parts of the system (i.e., on whether they are systemic or autonomous). Specifically, Brusoni et al.'s (2001) results suggest that a prevalence of autonomous component innovations corresponds to decoupled vertical linkages with low degrees of knowledge base overlap, while a prevalence of systemic component innovations corresponds to loosely coupled vertical linkages with high degrees of knowledge base overlap. Similarly, Takeishi (2002) found that firms in the Japanese automotive industry are more likely to retain knowledge on upstream components in projects that feature a high level of technological newness – i.e., that require significant changes to existing solutions.

Based on these findings, we assume that the degree of knowledge base overlap in buyer-component supplier relationships corresponds to the type of innovation. In particular, we assume systemic component innovations to dominate in relationships of a high knowledge base overlap, and autonomous component innovations to dominate in relationships of a low knowledge base overlap. Furthermore, we assume that component innovations are likely to be adopted by buyers. Buyers may often have to implement component innovations in order to avoid falling behind competitors (e.g., Teece, 2007). In addition, even without such competitive pressure, buyers may choose to adopt component innovations in order to enhance their financial performance.[2]

[2] Due to imperfect appropriability conditions, firms are rarely able to capture the total value created by their innovations (Teece, 1986). A certain share of value is thus often appropriated by owners of complementary assets such as buyers and suppliers (Teece, 1986).

Given these assumptions, we expect buyer-component supplier relationships with different knowledge base overlaps to exhibit differences in complementarity and "stand-alone" value. As noted, systemic component innovations exhibit greater complementarity with the buyer's subsequent innovative output than autonomous component innovations. Consequently, we expect a greater effect of the buyer's subsequent innovative output on the component supplier's returns to innovation in relationships of a greater knowledge base overlap.[3]

H1. The greater the knowledge base overlap in a buyer-component supplier relationship, the greater the effect of the buyer's subsequent innovative output on the supplier's returns to innovation.

Furthermore, autonomous component innovations yield greater "stand-alone" value than systemic component innovations. As such, we expect the supplier to capture greater "stand-alone" returns to innovation in relationships of a lower knowledge base overlap.

H2. Absent subsequent innovative output from the buyer, the component supplier's returns to innovation increase with decreasing knowledge base overlap in the buyer-component supplier relationship.

3 Empirical analysis

3.1 Empirical design, data and sample

In our empirical investigation, we measure the returns to innovation of a component supplier by the marginal effect of its innovative output on its financial performance. As such, the dependent variable in our regression is the component supplier's financial

[3] The buyer's total innovative output can have both competence-enhancing and competence-destroying effects on the supplier (Tushman & Anderson, 1986). Since either may dominate, it is not possible to predict a specific direction of the effect of the buyer's subsequent innovative output on the supplier's returns to innovation. We therefore confine our argument to relative differences in effects between cases of a high and a low knowledge base overlap.

performance, and the independent variables are the component supplier's innovative output, the buyer's innovative output, the knowledge base overlap and relevant control variables. The unit of analysis is the buyer-component supplier dyad. We utilize strong controls in order to isolate the effect of the component supplier's innovative output on its financial performance as much as possible. Specifically, we conduct a fixed- effects panel regression through which we are able to control for all unobserved, time-invariant factors.

In order to collect panel data on buyer-supplier dyads, we draw on Compustat North America's segment files. The U.S. regulation FAS 130 (1997) requires publically traded firms to report their major customers defined as those with which they generate at least 10 percent of their revenue. The segment files contain these reports, and can thus be used to collect observations of buyer-supplier links. The reporting firms, however, specify their major customers with varying spellings and abbreviations. To identify the reported names as firms, we follow prior studies (Fee & Thomas, 2004; Hertzel et al., 2008) and link the names to firms listed in Compustat through approximate string matching. Subsequent to string matching, we visually inspect each match in order to ensure accuracy (Hertzel et al., 2008). Because firms are only required to report their major customers, collecting buyer-supplier dyads from Compustat yields dyads in which buyers are, on average, larger than suppliers. Specifically, in our sample, the buyers' average number of employees exceeds that of suppliers by a factor of 9.6. Hence, compared to buyers, suppliers are on average rather small and specialized.

Since we seek to study suppliers that produce technical components and buyers that produce corresponding higher-level technical systems, we limit our sample to firms in the following industries defined by 3-digit NAICS codes: machinery manufacturing (333); computer and electronic product manufacturing (334); electrical equipment, appliance and component manufacturing (335); and transportation equipment manufacturing (336). In order to ensure that the suppliers in our sample produce product components instead of production machines or other manufacturing equipment, we pre-emptively exclude all observations in which suppliers operate in machinery manufacturing (333). Through the procedure of collecting buyer-supplier dyads from Compustat and selecting firms based on industry codes, we obtain a panel of 724 dyads and 3318 dyad-year observations from the period 2000-2013. All firms in this panel are incorporated in the U.S.

For the innovation- and knowledge-related variables, we draw on patent data from the United States Patent and Trademark Office (USPTO) provided by PatentsView. We select all granted patents that companies applied at the USPTO in the period from 1995 to 2012. U.S. patents are a suitable data source due to the reputation of the United States to provide effective protection for intellectual property, and the fair and rigorous granting process (Pavitt, 1988). Furthermore, using patents from a single country enhances consistency, reliability, and comparability across firms (Griliches, 1990).

We link patents to the buyer and supplier firms in our sample through approximate string matching. Because patents are often assigned to subsidiaries, we carefully aggregate patents to the firm level. We use the Directory of Corporate Affiliations and identify all divisions, subsidiaries and joint ventures of our sample firms as of 2015. Subsequently, we trace each firm’s history to account for name changes and M&A deals. Through this process, we obtain a master list for each firm that comprises its subsidiaries during the period in which the firm occurs in our sample. In addition, we complement these lists with data on firms’ subsidiaries reported in their 10-K filings provided by CorpWatch API. In order to link patents to the firms on our sample, we then match patent assignee names to company and subsidiary names in the master lists.

Because we construct our key independent variables with patent data, we exclude observations in which neither the supplier nor the buyer did patent. In addition, we exclude observations for which Compustat data for the dependent variable and control variables is not available. This reduces the panel to 2006 dyad-year observations from the period 2000 to 2013. The final panel comprises, in total, 435 unique buyer-supplier dyads that, in turn, comprise 284 unique firms. On average, we follow each dyad over a period of 4.6 years, with the minimum observed period being 2, and the maximum observed period being 13 years.

3.2 Dependent variable

We employ Tobin's q as our measure of a component supplier's corporate financial performance. Tobin's q is defined as the ratio of market value to the replacement cost of the firm (Wernerfelt & Montgomery, 1988). It is commonly used as a measure of corporate financial performance since it indicates future firm rents (van Reenen, 1996) and a firm's ability to earn above a competitive return (Lindenberg & Ross, 1981). Tobin's q combines both market-based and accounting-based data, which allows for minimal tax law and accounting convention distortions, ensures use of the correct risk-adjusted discount rate, and accounts for disequilibrium effects (Wernerfelt & Montgomery, 1988). Unlike Tobin's q, pure accounting rates of return may strongly deviate from true economic rates of return due to biases in their calculation (Benston, 1985), differences in tax laws, and latitude in interpreting accounting regulations (Wernerfelt & Montgomery, 1988).

In practice, the replacement cost of a firm can be approximated by the book value of its total assets (Wernerfelt & Montgomery, 1988). Furthermore, a firm's total market value can be approximated by the sum of its market capitalization and the nominal value of its outstanding debt (Hall & Oriani, 2006; Sandner & Block, 2011). We employ this approach to calculating Tobin's q that has been widely applied in previous studies (Hall et al., 2005; Humphery-Jenner, 2014; Sandner & Block, 2011). For each dyad-year observation, we measure supplier financial performance in year t, that is, in the year in which the supplier reported the buyer as one of its major customers. We use a log transformation of Tobin's q in our analysis in order to reduce skewness.

3.3 Independent variables

3.3.1 Supplier innovative output

We measure the supplier's innovative output by citation-weighted patent counts. Patents exhibit a strong correlation with new products (Comanor & Scherer, 1969; Hagedoorn & Cloodt, 2003), literature-based invention counts (Basberg, 1987), and non-patentable innovations (Patel & Pavitt, 1997). As such, patent measures can serve as reasonably reliable indicators of innovative activity (Griliches, 1990). Simple patent counts, however, do not account for differences in the quality or value of the underlying innovations (Griliches, 1990). We therefore employ citation-weighted patent counts. The latter weigh each patent with the number of its accumulated forward citations as a measure of its quality or value (Hall et al., 2001; Harhoff, Narin, Scherer, & Vopel, 1999).

Yet, forward citations suffer from an inherent truncation bias (Hall et al., 2001). The number of citations received by a given patent is truncated because patents accumulate citations over time, wherefore older patents have, on average, more forward citations than recent patents (Hall et al., 2001). We employ the fixed-effects approach suggested by Hall et al. (2001) in order to correct for this bias. The fixed-effects approach removes truncation effects, effects due to any systematic changes over time in the propensity to cite, and effects due to changes in the number of patents making citations (Hall et al., 2001).

For each dyad-year observation, we measure the supplier's innovative output as the sum of citation-weighted patent counts in the three-year window from t-6 to t-4. Consistent with the literature, we use the date of application, specifically, the priority date, to link patents to years. This date is closest to the time of invention (Hall et al., 2005), and thus, the most appropriate choice for measuring innovative output over time. In addition, we multiply our measure by a factor of 1/1000 in order to align its scale with the scales of other variables.

3.3.2 Buyer innovative output

Analogous to measuring the supplier's innovative output, we measure the buyer's innovative output by citation-weighted patent counts. However, since we seek to capture the buyer's innovative output in response to the emergence of new component innovations, we measure the sum of the buyer's citation-weighted patent counts in the six-year window from t-6 to t-1. Similar to our measure of supplier innovative output, we use a scaling factor of 1/1000.

3.3.3 Knowledge base overlap

In order to measure the knowledge base overlap in a buyer-supplier dyad, we follow prior research (Fleming & Sorenson, 2001; Yayavaram & Ahuja, 2008) and assume that technology classes assigned to a firm's patents (3-digit USPTO classes) capture the knowledge elements that constitute its knowledge base. We approximate the stock of common technical knowledge in the buyer-supplier dyad by considering both the buyer's patents that match to the supplier's technology classes and the supplier's patents that match to the buyer's technology classes. Specifically, we count the number of buyer patents from t-6 to t-1 that are assigned to at least one technology class associated with the supplier's patents from t-6 to t-1 plus the number of supplier patents from t-6 to t-1 that are assigned to at least one technology class associated with the buyer's patents from t-6 to t-1.

Thereby, we obtain values of knowledge base overlap that range from 0 to 22377 (the distribution of these values is highly skewed). We divide our sample into a high knowledge base overlap and low knowledge base overlap group. The high knowledge base overlap group includes 617 observations and captures the range of values from 1130 to 22377 ($1130 < x \leq 22377$). The low knowledge base overlap group includes the remaining 1389 observations and captures the range of values from 0 to 1130 ($0 \leq x \leq 1130$). We choose 1130 as the cutoff point because it ensures that there are sufficiently many observations in the high knowledge base overlap group. For higher cutoff points, the number of observations decreases rapidly due to the skewed distribution, which reduces the statistical power for estimating group differences. Our results hold for all cutoff points in the interval between 910 and 1130.

3.4 Control variables

By utilizing a fixed-effects panel regression, we are able to control for any time-constant influences on the component supplier's financial performance. However, we additionally include the following time-varying controls in order to exclude the possibility of an omitted variable bias as much as possible. We control for the *supplier's innovative output* during the three-year window from t-3 to t-1 since our independent variable captures only the innovative output from t-6 to t-4. Like our independent variable, innovative output subsequent to t-4 can potentially affect corporate financial performance in year t. We measure this control variable analogously to the independent variable.

Furthermore, a firm's capital structure may influence agency costs and thereby affect its financial performance (Berger & Bonaccorsi di Patti, 2006; Jensen & Meckling, 1976). We therefore control for the *supplier's leverage*, measured as the ratio of debt to assets from the year t-1. Next to capital structure, capital investments, as indicators of superior resources, may affect corporate financial performance (Ray et al., 2013). Hence, we control for the *supplier's capital intensity* measured by the ratio of capital expenditures to assets, and for the *supplier's age of capital stock* measured by the ratio of depreciation expense to net property, plant, and equipment (following the approach of Dezsö and Ross (2012)), both measured in year t-1. In addition, we control for the *supplier's size* by its number of employees (in thousands) from the year t-1, and for business cycles through *year fixed-effects*.

Another factor that may influence a firm's financial performance is the asset mobility in its industry segment (Jacobides et al., 2006). More specifically, a firm's ability to capture value is likely contingent on the relative asset mobility in vertically adjacent segments (Jacobides et al., 2006). Accordingly, we control for the *supplier's industry concentration* and the *buyer's industry concentration* measured in year t-1. Furthermore, we control for the *relative industry concentration* between both, measured as the supplier's industry concentration divided by the buyer's industry concentration in year t-1. We quantify industry concentration as the ratio of the total sales of the top four firms in an industry to total industry sales. Following Ray et al. (2013), we calculate these industry-level controls using the Compustat segment database. For each multisegment firm, we weight the industry concentration values by sales across all the industries in which a firm participates.

Finally, a firm's ability to appropriate value also affects its returns to innovation – that is, the effect of its innovative output on its financial performance (Jacobides et al., 2006). Consequently, we control for the impact of asset mobility on the supplier's returns to innovation by adding interaction terms between the supplier's innovative output and the supplier's industry concentration, the buyer's industry concentration, and the relative industry concentration, respectively.

3.5 Statistical method

Since we use panel data, we perform the Hausman test in order to decide between a random- and a fixed-effects panel model. The test strongly rejects the null hypothesis of uncorrelated effects (χ^2 (31) = 177, $p < 0.001$). Hence, we test our hypotheses based on a fixed-effects model. Furthermore, we test our hypotheses using cluster-robust standard errors in order to account for cross-sectional dependence. The sample exhibits a nested structure in which several buyer-supplier dyads may share the same buyer or the same supplier. As a result, not all of the observations' disturbances can be assumed statistically independent. In order to allow for correlation between disturbances, we employ two-way cluster-robust standard errors that cluster around the buyer and the supplier. Thereby, we account for dependencies between observations sharing the same dyad, for dependencies between observations that share only the same buyer or supplier, as well as for arbitrary heteroscedasticity and serial correlation (Cameron & Miller, 2015). The calculation of the two-way cluster-robust standard errors follows the procedure detailed in Cameron and Miller (2015).

We perform the estimation in three stages. First, we estimate model 1 by regressing supplier financial performance on all independent and control variables.

Subsequently, we estimate model 2, which extends model 1 by an interaction term between supplier innovative output and buyer innovative output, and an interaction term between supplier innovative output and the binary indicator for knowledge base overlap. Finally, we estimate model 3, which extends model 2 by the three-way interaction term between supplier innovative output, buyer innovative output, and the binary indicator for knowledge base overlap. Following Hayes (2013), we ensure that, for each two-way interaction term, all of its constituents also occur in the model as single terms in order to avoid biased results. For the same reason, we ensure that, for the three-way interaction term, the model contains all of its constituents as single terms as well as all of their possible pairs as two-way interaction terms (Hayes, 2013).

3.6 Results

In Table 6, we provide descriptive statistics for the model covariates used in our analysis. In Table 7, we report the estimates of our fixed-effects panel models. *H1* states that the effect of the buyer's subsequent innovative output on the component supplier's returns to innovation increases with increasing knowledge base overlap. Testing this hypothesis corresponds to testing for a positive sign of the coefficient for the three-way interaction *Supplier innovative output X Buyer innovative output X High knowledge base overlap* in model 3. We estimate this coefficient at a value of 0.20 with a standard error of 0.10 and a *p*-value of 0.039 (based on a two-sided *t*-test). Hence, *H1* is supported.

H2 states that, absent subsequent innovative output from the buyer, the component supplier's returns to innovation increase with decreasing knowledge base overlap. Testing this hypothesis corresponds to testing for a negative sign of the coefficient for the two-way interaction term *Supplier innovative output X High knowledge base overlap* in model 3. We estimate this coefficient at a value of -1.35 with a standard error of 0.44 and a *p*-value of 0.002 (based on a two-sided *t*-test). Hence, *H2* is supported.

Next to support for our hypotheses, the estimation yields a noticeable finding on the effect of the buyer's subsequent innovative output on the supplier's returns to innovation for the case of a low knowledge base overlap. In model 3, this effect is indicated by the coefficient for the two-way interaction term *Supplier innovative output X Buyer innovative output*. With an estimated coefficient value of -0.20 and a standard error of 0.10, our analysis provides support for a negative relationship (p = 0.044, based on a two-sided t-test). We discuss potential reasons for the latter in the next section. Figure 4 displays the expected values of the component supplier's returns to innovation depending on the knowledge base overlap and the buyer's innovative output.

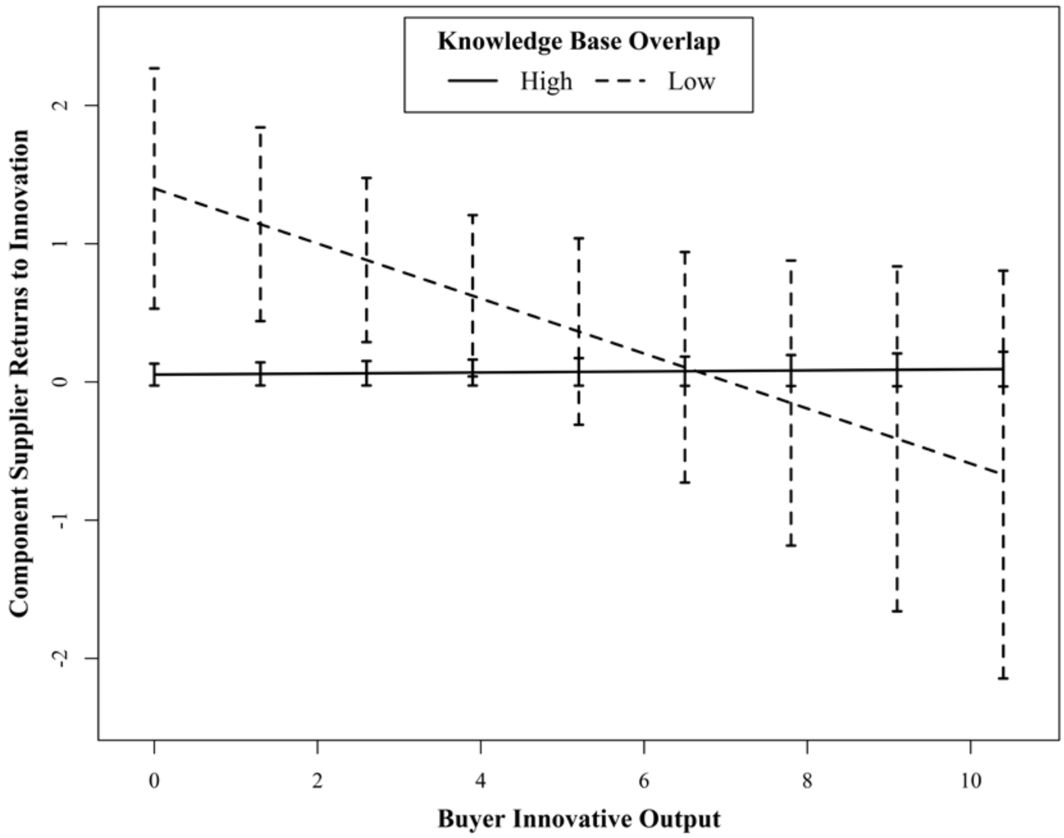

Figure 4: Interaction between buyer innovative output and knowledge base overlap

Notes. Predictive margins with 95 percent confidence intervals. The plotted values of buyer innovative output correspond to the range from its minimum to its 99th percentile. In estimating component supplier returns to innovation, median values for all control variables were assumed.

Table 6: Descriptive statistics

Variables	1	2	3	4	5	6	7	8	9	10	11	12
1. Supplier financial performance												
2. ln(Supplier size)	-0.18											
	0.00											
3. ln(Supplier leverage)	-0.13	0.52										
	0.00	0.00										
4. ln(Supplier age of capital stock)	0.23	-0.40	-0.17									
	0.00	0.00	0.00									
5. ln(Supplier capital intensity)	-0.02	0.37	0.26	-0.35								
	0.45	0.00	0.00	0.00								
6. Supplier innovative output (control)	0.11	0.29	-0.03	0.02	0.22							
	0.00	0.00	0.22	0.42	0.00							
7. Supplier industry concentration	0.07	-0.05	0.12	-0.01	-0.10	-0.10						
	0.00	0.03	0.00	0.68	0.00	0.00						
8. Buyer industry concentration	0.00	0.18	0.20	-0.09	0.03	0.01	0.25					
	0.93	0.00	0.00	0.00	0.13	0.69	0.00					
9. Relative industry concentration	0.06	-0.21	-0.08	0.07	-0.15	-0.09	0.64	-0.54				
	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00				
10. Buyer innovative output	-0.05	0.02	-0.05	0.09	-0.05	0.16	-0.07	0.03	-0.04			
	0.02	0.35	0.02	0.00	0.02	0.00	0.00	0.21	0.10			
11. High knowledge base overlap	0.06	0.24	0.01	0.11	0.03	0.28	-0.01	0.06	-0.04	0.57		
	0.01	0.00	0.84	0.00	0.16	0.00	0.83	0.01	0.06	0.00		
12. Supplier innovative output	0.04	0.23	-0.02	0.00	0.17	0.77	-0.09	-0.02	-0.06	0.20	0.24	
	0.07	0.00	0.49	0.94	0.00	0.00	0.00	0.45	0.01	0.00	0.00	
Mean	0.41	0.80	-1.02	-1.25	-3.42	0.16	0.46	0.58	0.84	2.49	0.31	0.11
Median	0.34	0.70	-0.87	-1.40	-3.38	0.01	0.44	0.62	0.83	1.49	0.00	0.00
Minimum	-1.20	-4.20	-3.78	-3.94	-7.36	0.00	0.27	0.27	0.30	0.00	0.00	0.00
Maximum	2.98	5.39	1.28	2.72	-1.22	6.42	0.99	1.00	2.82	39.29	1.00	6.42
s.d.	0.47	1.93	0.77	0.69	0.80	0.61	0.15	0.14	0.32	2.85	0.46	0.52

Notes. *n*(observations) = 2006. Significance levels appear below correlations.
The variable “supplier innovative output (control)” measures supplier innovative output during t-3 to t-1 whereas the variable “supplier innovative output” measures supplier innovative output during t-6 to t-4.
The variable “high knowledge base overlap” is a dummy variable that takes on a value of 1 for observations in the high knowledge base overlap group and a value of 0 for those in the low knowledge base overlap group.

Table 7: Estimation results

Variables	Model 1		Model 2		Model 3	
Constant	0.87*	(0.40)	0.87*	(0.40)	0.87*	(0.40)
ln(Supplier size)	-0.29***	(0.04)	-0.29***	(0.04)	-0.29***	(0.04)
ln(Supplier leverage)	0.10***	(0.03)	0.10***	(0.03)	0.10***	(0.03)
ln(Supplier age of capital stock)	-0.01	(0.04)	-0.01	(0.04)	-0.01	(0.04)
ln(Supplier capital intensity)	0.03	(0.02)	0.03	(0.02)	0.03	(0.02)
Supplier innovative output (control)	0.02	(0.02)	0.02	(0.02)	0.02	(0.02)
Supplier industry concentration	-0.11	(0.56)	-0.13	(0.56)	-0.18	(0.55)
Buyer industry concentration	-0.09	(0.30)	-0.09	(0.30)	-0.06	(0.29)
Relative industry concentration	0.35	(0.19)	0.36	(0.19)	0.37*	(0.19)
Buyer innovative output	-0.01*	(0.01)	-0.02*	(0.01)	-0.00	(0.01)
High knowledge base overlap	0.05	(0.05)	0.07	(0.05)	0.09*	(0.04)
Supplier innovative output	1.66***	(0.41)	2.38***	(0.58)	3.05***	(0.61)
Supplier innovative output x Supplier industry concentration	4.00***	(1.04)	4.31***	(1.13)	4.38***	(1.14)
Supplier innovative output x Buyer industry concentration	-2.83***	(0.68)	-2.93***	(0.73)	-2.97***	(0.74)
Supplier innovative output x Relative industry concentration	-2.27***	(0.58)	-2.42***	(0.64)	-2.44***	(0.64)
Supplier innovative output x Buyer innovative output			0.00	(0.00)	-0.20*	(0.10)
Supplier innovative output x High knowledge base overlap			-0.70*	(0.35)	-1.35**	(0.44)
Buyer innovative output x High knowledge base overlap					-0.01	(0.01)
Supplier innovative output x Buyer innovative output x High knowledge base overlap					0.20*	(0.10)
Dyad fixed-effects	Yes		Yes		Yes	
Year fixed-effects	Yes		Yes		Yes	
Within-group R^2	0.39		0.39		0.39	

Notes. *n*(dyads) = 435; *n*(observations) = 2006. The dependent variable is supplier financial performance in year t, measured as the natural logarithm of supplier Tobin's q. Standard errors are robust to arbitrary heteroscedasticity and allow for both serial and cross-sectional correlation through two-way clustering around buyers and suppliers.
The variable "supplier innovative output (control)" measures supplier innovative output during t-3 to t-1 whereas the variable "supplier innovative output" measures supplier innovative output during t-6 to t-4.
The variable "high knowledge base overlap" is a dummy variable that takes on a value of 1 for observations in the high knowledge base overlap group and a value of 0 for those in the low knowledge base overlap group.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ (two-tailed *t*-tests).

4 Discussion and conclusion

Research suggests that the division of knowledge in buyer-component supplier relationships depends on whether component innovations are systemic or autonomous (Brusoni et al., 2001). However, beyond Brusoni et al.'s (2001) case study of firms in the aerospace industry, research has not yet empirically investigated whether a match between knowledge partitioning and the type of component innovation actually prevails. We test for such a match by drawing on a panel of buyer-component supplier relationships obtained from Compustat North America and by drawing on patent data from the United States Patent and Trademark Office (USPTO).

From the vantage point of a component supplier, systemic and autonomous component innovations imply different mechanisms of value creation. Systemic component innovations require changes in other parts of the system in which they are introduced, and hence, depend on innovative output from the buyer in order to deliver value. Autonomous component innovations, on the other hand, can be implemented without other parts of the system changing, and thus, can deliver value independent from the buyer's innovative output.

Our empirical results on buyer-component supplier relationships characterized by different degrees knowledge base overlap are consistent with these different mechanisms of value creation.

Specifically, they show that, the greater the knowledge base overlap, the greater the effect of the buyer's innovative output on the supplier's returns to innovation. Furthermore, they indicate greater "stand-alone" returns to innovation for a lower knowledge base overlap. "Stand-alone" returns to innovation refer to the supplier's returns absent innovative output from the buyer. Taken together, these results suggest that relationships of a high knowledge base overlap experience significantly more systemic component innovations and significantly less autonomous component innovations than relationships of a low knowledge base overlap. As such, our analysis indeed indicates a match between knowledge partitioning and type of innovation.

A noticeable finding is that, in relationships of a low knowledge base overlap, the buyer's innovative output has a negative effect on the supplier's returns to innovation. This suggests that competence-destroying effects on the supplier exceed competence-enhancing effects in these cases (e.g., Abernathy & Clark, 1985; Tushman & Anderson, 1986). A reason for this might be that autonomous innovations exhibit a small potential for being augmented by the buyer's innovative output due to low synergistic specificity (e.g., Schilling, 2000).

The current study makes at least two distinct contributions to the literature. First, in examining a large panel of buyer-supplier relationships from several manufacturing industries, it provides large-scale evidence for a link between innovation type and knowledge partitioning. Thereby, the study lends support to research proposing that common knowledge facilitates coordination and communication and thus enables firms to manage systemic innovations (Brusoni et al., 2001; Helfat & Campo-Rembado, 2016). For instance, Helfat and Campo-Rembado (2016) argue that common knowledge is an important component of firms' integrative capabilities – that is, their abilities to adapt to and create systemic innovations. Similarly, Brusoni et al. (2001) argue that firms' maintain common knowledge with their component suppliers in order to strengthen their systems integration capabilities. The identified link between innovation type and knowledge partitioning also indicates that, for firms who mainly experience autonomous innovations, the costs of developing and maintaining common knowledge may often outweigh the benefits of enhanced integrative or systems integration capability. Hence, consistent with the analysis of Helfat and Campo-Rembado (2016), the findings suggest that whether firms choose to develop and maintain such capabilities depends on the prevalence of systemic innovations.

Second, extant evidence on systemic and autonomous innovations is either anecdotal, case study-based (e.g., Brusoni et al., 2001; Langlois & Robertson, 1992) or limited to specific industries (e.g., Adner & Kapoor, 2010; Kapoor, 2013). In showing that the prevalence of systemic and autonomous component innovations varies significantly across vertical relationships, our analysis provides large-scale evidence for the presence of both types of innovations in various industries. Furthermore, from the perspective of a focal firm having to manage systemic innovations in ecosystems, extant research has focused on the interdependence risks of coordinating with complementors and suppliers (Adner & Kapoor, 2010). In contrast, our study examines the interdependence risks of coordinating with buyers, and suggests that these seem to play an equally important role for component suppliers – that is, for all firms whose products are embedded in larger systems.

The study has a number of limitations that we hope will be addressed by future research. First, the analysis assumes that the observed differences between cases of a high and a low knowledge base overlap stem from differences in value creation as opposed to differences in the supplier's appropriability conditions. This assumption seems reasonable, considering that the empirical analysis focuses on patented technologies. Since the supplier's component innovations are patented, its knowledge on these innovations is publically available, and the distribution of knowledge in the buyer-supplier relationship thus unlikely to affect the supplier's appropriability conditions. Furthermore, by focusing on patented innovations and by including proxies for the supplier's, the buyer's and their relative asset mobility in the regression, the empirical analysis at least partially controls for appropriability conditions. The estimated coefficients of these proxies are highly significant and thus likely capture determinants of the supplier's returns to innovation. Nevertheless, we cannot fully exclude the possibility that our results are confounded by influences on the supplier's appropriability conditions.

Second, patents as indicators of firms' knowledge bases and innovative activities have limitations. Patents only partially reflect firms' knowledge bases since firms may not always be willing to disclose their knowledge. Furthermore, patents only partially reflect innovative activities because not all innovations are patented, not all patents are commercialized (Santarelli & Piergiovanni, 1996), and since the propensity to patent varies across firms (Basberg, 1987). Nevertheless, patent counts have been shown to strongly correlate with new products (Comanor & Scherer, 1969; Hagedoorn & Cloodt, 2003), literature-based invention counts (Basberg, 1982), and non-patentable innovations (Patel & Pavitt, 1997).

Finally, the use of a fixed-effects panel model restricts interference to the specific set of firms in the sample (Baltagi, 2005). Hence, care must be taken in generalizing our findings to buyer-component supplier relationships in other industries, countries and periods.

Despite these limitations, our analysis suggests that vertical relationships between firms and their component suppliers exhibit a match between the type of innovation and the division of knowledge. Systemic component innovations seem to dominate in relationships of a high knowledge base overlap, while autonomous component innovations seem to dominate in relationships of a low knowledge base overlap. These results contribute to our understanding of the determinants of firms' knowledge boundaries and of how the ways in which firms are organized with respect to upstream components affects their ability to manage technological change.

Chapter 4 Gaining from vertical partnerships: Mutual absorptive capacity, absorptive capacity gap, and knowledge base overlap

1 Introduction

Prior research has paid considerable attention to the effects of supplier relations on buyers' competitive advantage and financial performance. Studies have shown that by involving suppliers in new product development, buyers can reduce the time needed for development, save development costs, and increase end-product quality (Clark, 1989; Clark & Fujimoto, 1991; Cusumano & Takeishi, 1991; Eisenhardt & Tabrizi, 1995; Koufteros, Cheng, & Lai, 2007; Petersen et al., 2005). Studies have also argued that, in order to obtain such benefits from supplier relations, buyers need to be able to learn from suppliers – that is, they need a certain level of absorptive capacity (Azadegan, 2011; Malhotra, Gosain, & Sawy, 2005; Wagner, 2012). However, empirical results on the role of absorptive capacity are mixed: while Azadegan (2011) found a positive effect, Wagner (2012) found no effect.

A reason for those mixed findings might be that looking only at a buyer's absorptive capacity (i.e., at its ability to learn from its suppliers) is not enough. Joint product development is characterized by iterative problem-solving cycles in which knowledge flows not only from suppliers to the buyer, but also from the buyer to suppliers (Baldwin & Clark, 2000; Clark & Fujimoto, 1991; von Hippel, 1994). Hence, the absorptive capacity of suppliers is likely equally important. Due to the iterative nature of product development, and problem solving in general, a lack of supplier absorptive capacity can lead to inferior outcomes – independent of the level of buyer absorptive capacity. This suggests that, contrary to prior research, both buyer and supplier absorptive capacity should be taken into account in examining the performance benefits that buyers can obtain from supplier relations.

In this study, we therefore view absorptive capacity as a dyadic, two-dimensional construct. Specifically, we differentiate between mutual absorptive capacity and the absorptive capacity gap. The first dimension, mutual absorptive capacity, can be defined as the sum of the buyer's and the supplier's partner-specific absorptive capacities. It reflects the ability of both firms to engage in mutual learning and joint problem solving. The second, the absorptive capacity gap, can be defined as the difference between the buyer's and the supplier's partner-specific absorptive capacities. In contrast to mutual absorptive capacity, it reflects differences in the rates at which the buyer and the supplier are able to absorb knowledge from each other, and thus, is related to the potential ability of the buyer to outlearn the supplier. Hence, both dimensions can be expected to influence the value of supplier relations to buying firms.

Accordingly, we investigate how these two dimensions affect the buying firm's financial performance. In a panel of 360 buyer-supplier dyads from the period 2001-2013, we find significant effects associated with both dimensions. Our results indicate that mutual absorptive capacity increases, while the absorptive capacity gap decreases financial performance. Furthermore, we examine how these effects vary with the knowledge base overlap in the buyer-supplier relation. We find that the effect of mutual absorptive capacity becomes smaller (less positive), while the effect of the absorptive capacity gap becomes greater (less negative) with increasing knowledge base overlap.

These findings provide several contributions to research. First, they enhance our knowledge on absorptive capacity in buyer-supplier relationships, and contribute to the literature on supplier involvement in new product development. Specifically, our findings suggest that, instead of the buyer's absorptive capacity, mutual absorptive capacity is needed in order for buyers to gain from supplier relations. Furthermore, our findings suggest that both mutual absorptive capacity and the absorptive capacity gap have distinct performance implications, and can thus jointly offer a refined understanding of how absorptive capacity determines firm performance. Finally, our findings on the moderating role of knowledge base overlap add to our knowledge on its relationship with mutual absorptive capacity. They show that, while the knowledge base overlap is an important determinant of mutual absorptive capacity (Cohen & Levinthal, 1990), it also moderates its contribution to performance.

2 Theory and hypotheses

2.1 Absorptive capacity in buyer-supplier relationships

In their seminal paper, Cohen and Levinthal (1990) defined a firm's absorptive capacity as its ability to recognize the value of new knowledge, assimilate it, and apply it to commercial ends. This definition has later been extended by Zahra and George (2002), who argue that absorptive capacity should also encompass a firm's ability to transform knowledge, which they note is essential for problem solving, and thus, for commercial exploitation. A further important refinement has been proposed by Lane and Lubatkin (1998). They argue that a firm's absorptive capacity is partner-specific since it not only depends on the firm's own knowledge base, but also on the knowledge bases of its partners.

In line with these previous works, we view absorptive capacity in buyer-supplier relationships as a dyadic, partner-specific construct. In any buyer-supplier relationship, the buyer exhibits a certain ability to recognize, assimilate, transform and exploit knowledge from the supplier (i.e., the buyer's partner-specific absorptive capacity). However, the supplier, in turn, also exhibits a certain ability to recognize, assimilate, transform and exploit knowledge from the buyer (i.e., the supplier's partner-specific absorptive capacity). This leads to two distinct dimensions of absorptive capacity in a buyer-supplier dyad: (1) mutual absorptive capacity, which we define as the sum of the buyer's and the supplier's partner-specific absorptive capacities, and (2) the absorptive capacity gap, which we define as the difference between the buyer's and the supplier's partner-specific absorptive capacities.

2.2 The value of mutual absorptive capacity and an absorptive capacity gap

Having defined these two dimensions, we now turn to examining how both affect the value of supplier relations for buying firms. For our analysis, we draw on the knowledge-based literature, and in particular, on Nickerson and Zenger's (2004) problem-solving perspective. According to the latter, the fundamental knowledge-based goal of firms is to sustain above-normal profits by continually discovering valuable solutions to problems (Nickerson & Zenger, 2004). More specifically, through problem solving, firms create new and unique combinations of knowledge, which enable them to either improve or develop new products or services, or to reduce production costs (Nickerson & Zenger, 2004).

However, specialization often causes firms to differ in their ability to solve problems. For instance, a pharmaceutical company can be expected to achieve better results in drug development than a car manufacturer. Specialization leads to such differences because of two reasons: First, in problem solving, firms often need to rely on simplified, cognitive representations of the solution space under exploration – i.e., on heuristics (Nickerson & Zenger, 2004). Second, in order to build heuristics, firms have to rely on their available knowledge (Nickerson & Zenger, 2004). Hence, the knowledge that is available to a firm determines whether its heuristics are well-developed, and thus whether it can efficiently discover high-value solutions to a particular problem (Nickerson & Zenger, 2004; Walsh, 1995). The pharmaceutical firm's advantage over the car manufacturer in drug development is thus related to differences in their available and accumulated knowledge.

In order to enhance their problem solving ability and to maximize value creation, firms increasingly seek to broaden their range of available knowledge by engaging in joint problem solving with other firms (Brown & Eisenhardt, 1995; Takeishi, 2001). This means that firms collectively search for solutions to a particular problem by sharing the efforts of problem solving and by exchanging intermediate problem-solving outputs (i.e., new combinations of knowledge) (von Hippel, 1994). By engaging in such joint problem solving, firms are able to pool their distinct knowledge bases and to develop better heuristics, which increases search efficiency and the chances of finding valuable solutions (Nickerson & Zenger, 2004). Hence, joint problem solving can allow for superior value creation.

Theoretically, firms could also seek to maximize value creation by simply absorbing knowledge from other actors without sharing the efforts of problem solving. This, however, is often infeasible because other actors are not always willing to reveal their knowledge, and even if they are, transferring knowledge can be too costly (von Hippel, 1994). Joint problem solving also requires a certain amount of knowledge transfer, but is usually more economical than fully absorbing others' knowledge (von Hippel, 1994). This results from the fact that only knowledge on intermediate problem-solving outputs needs to be exchanged instead of having to transfer all knowledge that is relevant to the problem (von Hippel, 1994). As a consequence, firms often need to share the efforts of problem solving if they seek to increase value creation with reasonable efficiency.

This also holds for buyer-supplier relationships. It is now more and more common for buying firms to involve suppliers in joint problem solving, which has been shown to result in higher-quality products, lower development costs and shorter development times (Clark, 1989; Clark & Fujimoto, 1991; Cusumano & Takeishi, 1991; Eisenhardt & Tabrizi, 1995; Koufteros et al., 2007; Petersen et al., 2005). Yet, obtaining such benefits necessitates mutual absorptive capacity. This is because the nature of joint problem solving is often iterative: In joint problem solving, both the buyer and the supplier usually develop intermediate problem solving outputs and iteratively exchange those with each other (Carlile & Rebentisch, 2003; von Hippel, 1994). These iterative exchanges enable them to identify and resolve critical trade-offs in their search for solutions (Carlile & Rebentisch, 2003), and to effectively pool their knowledge bases to develop better heuristics. As such, knowledge flows in joint problem solving are often bidirectional. This, in turn, implies that the buyer and the supplier should be able to learn from each other in order for them to create value through joint problem solving. Hence, the supplier relation should be characterized by mutual absorptive capacity. Consequently, we expect supplier relations of high mutual absorptive capacity to, on average, contribute more to the buyer’s financial performance than supplier relations of low mutual absorptive capacity.

H1. Mutual absorptive capacity in a supplier relation is positively related to buyer financial performance.

Although joint problem solving – that is, collaboration in innovation – is increasingly common in buyer-supplier relationships, competition in innovation is not completely excluded. Consider for example the case of Samsung and Apple. Samsung is one of Apple’s major suppliers, but at the same time, both firms compete in developing smart phones and other electronic devices ("Slicing an Apple: Apple and Samsung’s Symbiotic Relationship," 2011). Another example is the automotive industry in which traditional OEMs (e.g., Daimler and Toyota) are now competing with their 1-st tier suppliers (e.g., Bosch and Johnson Controls) in the market for electric vehicle batteries (Dinger et al., 2010).

In such situations of competition in innovation, an absorptive capacity gap may benefit the buyer. This is because, for the buyer, an absorptive capacity gap allows learning from the supplier whilst limiting knowledge spillovers to the supplier (Hamel, 1991; Yang, Zheng, & Zaheer, 2015). Thereby, the buyer can likely develop a superior solution since it can draw on its own and the supplier’s problem solving output while the supplier can only draw on its own problem solving output (Baldwin & Clark, 2000). Hence, in case of competition in innovation, an absorptive capacity gap is valuable to the buyer. Furthermore, an absorptive capacity gap might benefit the buyer independent of problem solving. According to Hamel (1991), asymmetric learning capabilities affect how bargaining power in the dyad evolves over time. If one partner has superior learning capabilities, it can internalize knowledge and competences from the other and thereby reduce its dependence (Hamel, 1991). Due to inferior learning capabilities, the other, however, cannot reduce its dependence at the same rate (Hamel, 1991). An absorptive capacity gap may thus gradually shift bargaining power towards the buyer, thereby allowing it to capture an increasing share of value at the expense of the supplier (Bowman & Ambrosini, 2000). Taking both arguments together, we expect that supplier relations of a large absorptive capacity gap, on average, contribute more to buyer financial performance than supplier relations of a small absorptive capacity gap.

H2. The absorptive capacity gap in a supplier relation is positively related to buyer financial performance.

2.3 The moderating role of knowledge base overlap

As noted, buying firms increasingly engage in joint problem solving with their suppliers in in order to discover new and valuable recombinations of knowledge. However, the potential of joint problem solving to yield such recombinations varies. In particular, it depends on the knowledge base overlap. In case of a high knowledge base overlap, the buyer and the supplier possess similar capabilities, which limits the potential to create new recombinations of knowledge by pooling their distinct perspectives (i.e., the buyer and the supplier have little to learn from each other) (Sampson, 2007). Conversely, if the knowledge base overlap is low, the capabilities of the buyer and the supplier contrast strongly, wherefore pooling can likely yield many new recombinations (Sampson, 2007). The knowledge base overlap in a buyer-supplier relationship thus determines the value of pooling or integrating knowledge through joint problem solving. Because mutual absorptive capacity allows for the latter, we expect the value of mutual absorptive capacity to depend on the knowledge base overlap. Consequently, we hypothesize:

H3. The relationship between mutual absorptive capacity and buyer financial performance is negatively moderated by the knowledge base overlap in the supplier relation.

Similar to the value of mutual absorptive capacity, the value of the absorptive capacity gap depends on the knowledge base overlap. As argued previously, the knowledge that a firm possesses determines its expected success in solving a particular problem (Nickerson & Zenger, 2004). Accordingly, if the knowledge base overlap is low, the buyer and the supplier have widely different problem-solving abilities, which limits the chances of both trying to independently solve the same problem (i.e., to compete in innovation) (Nickerson & Zenger, 2004). In contrast, given a high knowledge base overlap, the buyer and the supplier have similar problem-solving abilities, which makes it more likely that both compete in innovation (Nickerson & Zenger, 2004). Since the value of the absorptive capacity gap depends on competition in innovation, we expect a moderation effect of the knowledge base overlap. Specifically, we expect the absorptive capacity gap to, on average, contribute more to the buyer's financial performance for a higher knowledge base overlap. We hypothesize:

H4. The relationship between the absorptive capacity gap and buyer financial performance is positively moderated by the knowledge base overlap in the supplier relation.

3 Empirical analysis

3.1 Empirical design, data and sample

The dependent variable, buying firm financial performance, is determined by various influencing factors. This can potentially lead to an omitted variable bias in our empirical analysis if those factors are not controlled for. We therefore seek to conduct a panel estimation, which enables us to control for all unobserved, time-invariant determinants. In addition, we seek to include several time-varying controls in order to further isolate the effects of our independent variables.

We collect panel data on buyer-supplier relationships from Compustat North America. The U.S. accounting regulation FAS 131 (1997) requires any publically traded U.S. firm to report its major customers, which are defined as customers that buy at least 10 percent of its sales. This information is accessible in the Compustat customer segment files, which can thus be used as a data source of buyer-supplier dyads (Cohen & Frazzini, 2008; Fee & Thomas, 2004; Hertzel et al., 2008; Mackelprang & Malhotra, 2015). Yet, firms may report their customers' names with slightly different spellings due to a lack of standardized company names. Following Fee and Thomas (2004) and Hertzel et al. (2008), we thus use approximate string matching in order to match the reported customer names to firm names in Compustat. In addition, we carefully inspect each buyer-supplier link subsequent to string matching in order to exclude potential errors (Hertzel et al., 2008). In total, we obtain a panel of 4306 buyer-supplier dyads and 11311 dyad-year observations from the period between 2001 and 2013. All firms in this panel (both buyers and suppliers) are incorporated in the U.S.

For our independent variables, we draw on patent data from the United States Patent and Trademark Office (USPTO) provided by PatentsView. We select all granted patents, applied at the USPTO in the period from 1996 to 2013, and match those to the buyers and suppliers in our data set. In order to link patents to firms, we utilize an approximate string matching algorithm that compares patent assignee names to company names. However, as firms may assign patents to their subsidiaries, we carefully aggregate subsidiaries to the firm level (i.e., we not only consider matches with a firm's name but also matches with the names of its subsidiaries). Information on subsidiaries comes from the Directory of Corporate Affiliations, Thomson ONE, and from the firms' 10-K filings provided by CorpWatch API. Based on the Directory of Corporate Affiliations we first identify all divisions, subsidiaries and joint ventures of our sample firms as of 2015, and then use the information on M&A deals from Thomson ONE to trace back the firms' subsidiaries for our study period (we identify M&A deals based on the firms' CUSIP codes). In addition, we then supplement the obtained lists of subsidiary names with those reported in their 10-K filings.

In order to enhance the validity of our patent-based measures, we restrict our sample to industries that are characterized by a high propensity to patent (i.e., to industries in which firms patent a large fraction of their inventions). This ensures that the patenting activities of the firms in our sample reflect their actual inventive activities (Basberg, 1987). Based on the 2008 Business Research and Development and Innovation Survey of the U.S. Census Bureau, we select the following industries, classified by NAICS codes, in which firms place importance on patents: chemicals (325); machinery (333); computer and electronic products (334); electrical equipment, appliances and components (335); medical equipment and supplies (3391); and scientific R&D services (5417).

Furthermore, we restrict our sample to buyer-supplier dyads in which the buyer and the supplier do not belong to the same parent firm. In other words, we exclude dyads in which the buyer and the supplier are under common ownership – either because both are owned by a third party or because one of them owns the other. This is necessary as common ownership can influence both mutual absorptive capacity and the buyer's financial performance. As such, common ownership might lead to an omitted variable bias (i.e., endogeneity). Since only a minor fraction of the observations in our sample are characterized by common ownership (~0.3 percent), we choose to omit these observations as opposed to including a control variable. We draw on the Directory of Corporate Affiliations and Thomson ONE in order to retrieve the ownership structures of buyers and suppliers. Specifically, we first identify their parent firms as of 2015 based on the Directory of Corporate Affiliations and then trace back changes in ownership based on M&A deals from Thomson ONE. This is possible, since any M&A deal in Thomson ONE contains information on the target firm's parent from before and after the transaction. With this information, we assign parent firms to buyer-supplier-year observations, manually compare the assigned parents of buyers and suppliers, and exclude those observations characterized by common ownership.

In addition to taking common ownership into account, we omit observations for which data on our dependent, independent and control variables is unavailable. Our final panel consists of 1445 dyad-year observations from the years 2001 through 2013. It comprises 360 buyer-supplier dyads, observed on average over a time span of 4 years (the minimum and maximum observed time spans are 2 and 12 years, respectively). The panel includes, in total, 308 unique firms of which 29 occur both as a buyer and a supplier.

3.2 Dependent variable

We employ Tobin's q as our measure of buyer financial performance. A firm's Tobin's q is defined as the ratio of its market value to its replacement cost (Wernerfelt & Montgomery, 1988). This ratio indicates the firm's ability to earn above a competitive return and thus reflects financial performance (Lindenberg & Ross, 1981). A main advantage of Tobin's q compared to other measures of financial performance is its combination of market-based and accounting-based data. This combination ensures that it uses the correct risk-adjusted discount rate, accounts for disequilibrium effects and minimizes tax law and accounting convention distortions (Wernerfelt & Montgomery, 1988). A further advantage is that Tobin's reflects the present value of expected future profits, and is thus able to indicate long-run future financial performance (Salinger, 1984).

In order to calculate Tobin's q, we follow previous studies (Hall et al., 2005; Humphery-Jenner, 2014; Sandner & Block, 2011) and approximate the replacement cost of the firm by the book value of its total assets, and the firm's market value by the sum of its outstanding debt and its market capitalization. We measure Tobin's q in year t – that is, in the year in which the supplier listed the buyer as a major customer. Additionally, we log-transform the variable to reduce skewness.

3.3 Independent variables

3.3.1 Mutual absorptive capacity and absorptive capacity gap

In order to construct the mutual absorptive capacity and absorptive capacity gap variables, we first measure each firm's (i.e., both the buyer's and the supplier's) partner-specific absorptive capacity. We follow Yang et al. (2015) and measure the partner-specific absorptive capacity of Firm A by calculating its citations to partner Firm B's patents divided by the total citations Firm B received, excluding self-citations, in a five year period from t-5 to t-1. This measure indicates Firm A's share of Firm B's knowledge spillovers (Yang et al., 2015), and thus reflects Firm A's capacity to absorb knowledge from Firm B. The measure is detailed in equation 1. Similar to Yang et al. (2015), we standardize the citation data by the average citation value for patents in the same technical class and granted in the same year. This is necessary as patents accumulate citations over time, and as the fecundity rate in each technical area may influence this accumulation (Hall et al., 2001; Srivastava & Gnyawali, 2011). To obtain our measure of mutual absorptive capacity, we take the sum of the buyer's and the supplier's partner-specific absorptive capacity. To obtain our measure of the absorptive capacity gap, we take the difference between the buyer's and the supplier's partner-specific absorptive capacity.

$$\text{Partner-specific absorptive capacity}_{A \rightarrow B} = \frac{\sum_{t-5}^{t-1} \text{A's citations to B's patents}}{\sum_{t-5}^{t-1} \text{Total citations B received}} \quad (1)$$

3.3.2 Knowledge base overlap

In order to measure the overlap between the buyer's and the supplier's knowledge bases, we follow prior research (Fleming & Sorenson, 2001; Yayavaram & Ahuja, 2008) and assume that the technology classes assigned to their patents (3-digit USPTO classes) reflect the knowledge elements that constitute their knowledge bases. In order to approximate a firm's knowledge base (i.e., either the buyer's or the supplier's), we select its set of unique technology classes from its granted patents, applied in the five-year window from t-5 to t-1. We then calculate the knowledge base overlap between the buyer and the supplier by counting the number of their shared technology classes (found in both firm's knowledge bases), and dividing this value by the total number of non-shared technology classes (found only in either the buyer's or the supplier's knowledge base). Equation 2 details this specification.

$$\text{Knowledge base overlap} = \frac{\sum_{t-5}^{t-1} \text{Number of shared technology classes}}{\sum_{t-5}^{t-1} \text{Number of non-shared technology classes}} \quad (2)$$

3.4 Control variables

As mentioned above, we conduct a panel data analysis, which enables us to control for unobserved, time-invariant influences on buyer financial performance. Next to controlling for these time-invariant influences, we include the following time-varying controls. First, capital investments may indicate superior resources, and may thus be related to corporate financial performance (Ray et al., 2013). We therefore control for *the buyer's capital intensity* measured by the ratio of capital expenditures to assets, and for *the buyer's age of capital stock* measured by the ratio of depreciation expense to net property, plant, and equipment (following the approach of Dezsö and Ross (2012)), both measured in year t-1.

Second, a firm’s capital structure may affect agency costs and thereby exert influence on its financial performance (Berger & Bonaccorsi di Patti, 2006; Jensen & Meckling, 1976). As such, we control for *the buyer’s leverage*, measured as the ratio of debt to assets from the year t-1.

Third, firms may profit from their innovations (Teece, 1986). Hence, we control for *the buyer’s innovative output* measured by citation-weighted patent counts from the period between t-5 to t-1. Specifically, we consider the buyer’s granted patents that were applied in this five-year window and calculate their weighted sum based on forward citations. Similar to our construction of the absorptive capacity variables, we standardize the citation data by the average number of citations for patents in the same technical class and granted in the same year.

Fourth, a firm’s ability to appropriate value may depend on the asset mobility in its segment (Jacobides et al., 2006). We therefore control for *the buyer’s industry concentration* from the year t-1. Following the method of Ray et al. (2013), we quantify the latter as the ratio of the total sales of the top four firms in an industry to total industry sales using data from the Compustat segment database. Like Ray et al. (2013), we take into consideration that firms might be active in multiple segments. Thus, for each multisegment firm, we weight the industry concentration values by sales across all the industries in which it participates.

Fifth, we control for *the buyer’s size* measured by its number of employees (in thousands) from the year t-1 in order to take account of economies of scale, and further include *year fixed effects* in order to control for economic trends and business cycles.

Next to the buyer-level characteristics that we mentioned so far, supplier-level characteristics such as the supplier’s resources (Lavie, 2006), its innovative output (Azadegan & Dooley, 2010), and the asset mobility in its segment (Jacobides et al., 2006) may also affect buyer financial performance. To control for these influences, we include the above listed variables also on the supplier level. In particular, we control for *the supplier’s capital intensity*, *the supplier’s age of capital stock*, *the supplier’s* *leverage*, *the supplier's innovative output*, *the supplier's industry concentration* and *the supplier's size*. We quantify each variable analogously to the calculation of the corresponding buyer-level variable. In addition, we control for *the supplier's financial performance* from the year t-1 measured by its Tobin's q.

Finally, innovations can impact the asset mobility in industry segments and thereby change the distribution of bargaining power (Jacobides et al., 2006). Differences in the innovative outputs of the buyer and the supplier may thus shift their relative bargaining power and affect their performance. We therefore control for *the innovative output gap* measured as the difference between the buyer's and the supplier's innovative output in the five-year window from t-5 through t-1.

We log-transform all control variables due to their skewed and non-normal distributions. Since *the innovative output gap* in our sample takes on both positive and negative values, we apply the log-modulus transformation $sign(x)log(|x|+1)$. Furthermore, since *the buyer's innovative output* and *the supplier's innovative output* are not greater than zero for all observations, we employ the log transformation $log(x+1)$. For all other control variables we use the standard log transformation $log(x)$.

3.5 Statistical method

Given that our sample is a panel of buyer-supplier dyads, we use the Hausman test in order to compare random-effects models to fixed-effects models. The test prefers the latter ($\chi^2(31) = 94.11$, p-value = 0.000), wherefore we test our hypotheses based on fixed-effects panel estimations. Furthermore, we employ cluster-robust standard errors in order to allow for potential cross-sectional dependence. Several buyers and suppliers in our sample occur in multiple dyads wherefore the disturbances of their observations cannot be assumed statistically independent. As such, we use two-way cluster robust standard errors that cluster around the buyer and the supplier. This accounts for dependencies between observations that share either the same buyer or the same supplier, as well as for serial correlation and arbitrary heteroscedasticity (Cameron & Miller, 2015). We follow the instructions provided by Cameron and Miller (2015) in order to calculate the two-way cluster robust standard errors.

3.6 Results

Table 8 reports descriptive statistics and Table 9 reports our regression results. In total, we estimate four models. Model 1 is the baseline model that includes only the control variables. Model 2 extends model 1 by the two independent variables *Mutual absorptive capacity* and *Absorptive capacity gap*. Model 3 extends model 2 by the independent variable *Knowledge base overlap*. Finally, model 4 extends model 3 by the two interaction terms *Mutual absorptive capacity X Knowledge base overlap* and *Absorptive capacity gap X Knowledge base overlap*.

H1 states that mutual absorptive capacity is positively related to the buyer's financial performance. The coefficient of *Mutual absorptive capacity* in model 2 is estimated at a value of 1.655 with a standard error of 0.740 and a p-value of 0.026, thus supporting *H1*. Furthermore, *H2* states that the absorptive capacity gap is positively related to the buyer's financial performance. However, the coefficient of *Absorptive capacity gap* in model 2 is estimated at a value of -1.554 with a standard error of 0.700 and a p-value of 0.026, which suggests a negative effect. Hence *H2* is rejected.

H3 asserts that knowledge base overlap negatively moderates the effect of mutual absorptive capacity on financial performance. The coefficient of the interaction term *Mutual absorptive capacity X Knowledge base overlap* in model 4 is estimated at a value of -1.391 with a standard error of 0.683 and a p-value of 0.042, thus supporting *H3*. Finally, *H4* states that knowledge base overlap positively moderates the effect of the absorptive capacity gap on financial performance. The coefficient of the interaction term *Absorptive capacity gap X Knowledge base overlap* in model 4 is estimated at a value of 1.502 with a standard error of 0.751 and a p-value of 0.046. Hence, *H4* is supported. Figure 5 and Figure 6 depict our results on the moderated effects of mutual absorptive capacity and the absorptive capacity gap.

Table 8: Summary statistics for main variables

Variable	Mean	Std. Dev.	Min.	Max.
Buyer financial performance	0.709	0.443	-0.584	2.493
Buyer size	3.380	1.535	-4.510	5.783
Buyer leverage	-0.801	0.460	-3.026	0.468
Buyer age of capital stock	-1.315	0.512	-3.066	1.816
Buyer capital intensity	-3.532	0.777	-8.164	-1.230
Buyer innovative output	6.742	1.726	0	9.804
Buyer industry concentration	0.502	0.151	0.268	1
Supplier financial performance	0.672	0.644	-1.202	4.282
Supplier size	-0.202	1.818	-4.828	4.949
Supplier leverage	-1.194	0.809	-3.650	2.913
Supplier age of capital stock	-1.018	0.857	-3.936	4.661
Supplier capital intensity	-3.673	1.028	-9.278	-1.022
Supplier innovative output	3.734	1.833	0	9.092
Supplier industry concentration	0.449	0.157	0.268	0.973
Innovative output gap	5.715	3.848	-8.986	9.803
Mutual absorptive capacity	0.030	0.088	0	1.003
Absorptive capacity gap	0.023	0.081	-0.163	1
Knowledge base overlap	0.241	0.355	0	5

Table 9: Estimation results

Variables	Model 1		Model 2		Model 3		Model 4	
Constant	1.974***	(0.57)	1.950***	(0.54)	1.945***	(0.54)	1.935***	(0.53)
Buyer size	-0.213**	(0.08)	-0.210**	(0.08)	-0.212**	(0.08)	-0.212**	(0.08)
Buyer leverage	0.018	(0.07)	0.018	(0.07)	0.016	(0.07)	0.015	(0.07)
Buyer age of capital stock	-0.094	(0.06)	-0.087	(0.06)	-0.085	(0.06)	-0.083	(0.06)
Buyer capital intensity	0.014	(0.03)	0.014	(0.03)	0.013	(0.03)	0.015	(0.03)
Buyer innovative output	0.010	(0.10)	0.013	(0.10)	0.014	(0.10)	0.015	(0.09)
Buyer industry concentration	-0.151	(0.45)	-0.126	(0.44)	-0.104	(0.43)	-0.082	(0.43)
Supplier financial performance	-0.014	(0.02)	-0.018	(0.02)	-0.018	(0.02)	-0.018	(0.02)
Supplier size	-0.035	(0.03)	-0.044	(0.03)	-0.047	(0.03)	-0.048	(0.03)
Supplier leverage	0.000	(0.02)	-0.000	(0.02)	0.001	(0.02)	0.002	(0.02)
Supplier age of capital stock	0.059**	(0.02)	0.057**	(0.02)	0.055**	(0.02)	0.054**	(0.02)
Supplier capital intensity	0.019	(0.01)	0.019	(0.01)	0.019	(0.01)	0.018	(0.01)
Supplier innovative output	-0.009	(0.02)	-0.011	(0.02)	-0.010	(0.02)	-0.010	(0.02)
Supplier industry concentration	-0.120	(0.12)	-0.115	(0.13)	-0.124	(0.13)	-0.126	(0.13)
Innovative output gap	-0.006	(0.00)	-0.008	(0.01)	-0.008	(0.01)	-0.008	(0.01)
Mutual absorptive capacity			1.655*	(0.74)	1.595*	(0.74)	2.705*	(1.10)
Absorptive capacity gap			-1.554*	(0.70)	-1.500*	(0.70)	-2.613*	(1.07)
Knowledge base overlap					-0.041	(0.04)	-0.030	(0.05)
Mutual absorptive capacity X Knowledge base overlap							-1.391*	(0.68)
Absorptive capacity gap X Knowledge base overlap							1.502*	(0.75)
Dyad fixed effects	Yes		Yes		Yes		Yes	
Year fixed effects	Yes		Yes		Yes		Yes	
No. of observations	1445		1445		1445		1445	
No. of groups (dyads)	360		360		360		360	
Within-group R^2	0.442		0.446		0.447		0.448	

Notes: The dependent variable is buyer financial performance, measured as the natural logarithm of Tobin's q. Standard errors are robust to arbitrary heteroscedasticity and allow for both serial and cross-sectional correlation through two-way clustering around buyers and suppliers. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ (two-tailed tests).

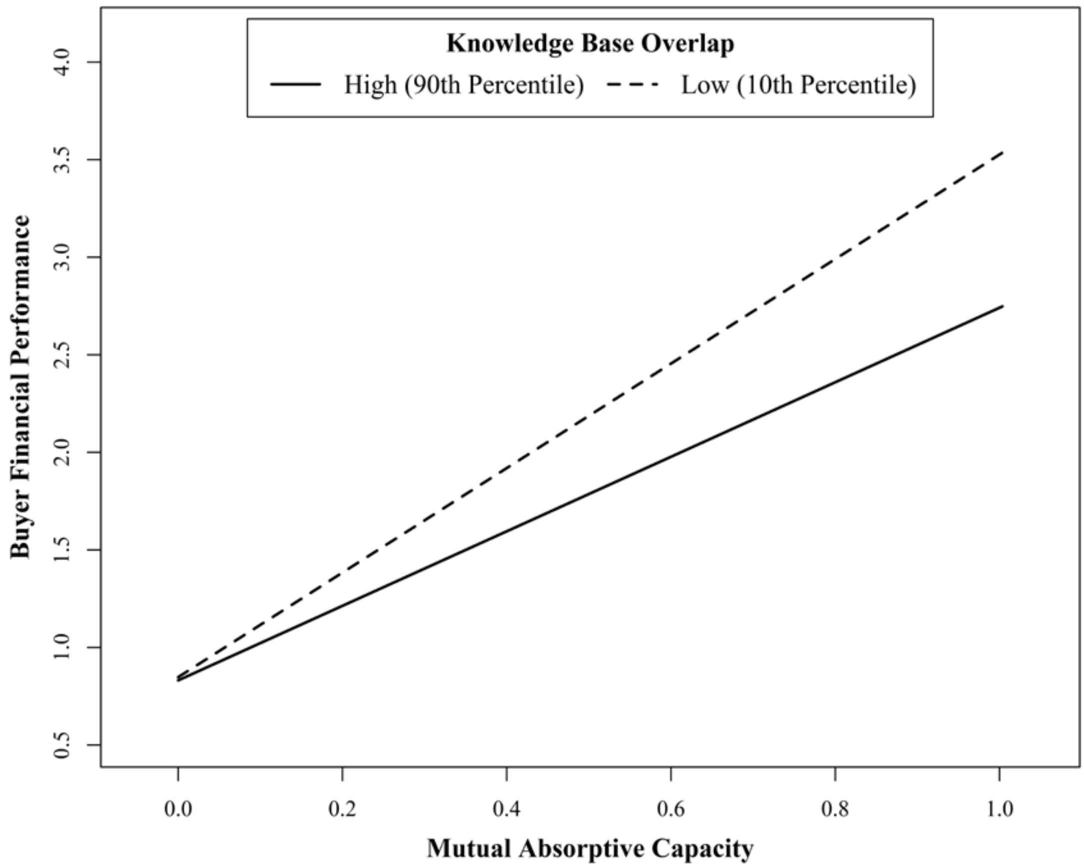

Figure 5: Buyer financial performance as a function of mutual absorptive capacity and the knowledge base overlap

Notes: For plotting the effect of mutual absorptive capacity, the absorptive capacity gap was set at its median (0) and all control variables were set at their mean. Furthermore, as indicated in the graph, the effect was plotted for two levels of knowledge base overlap: its 90th percentile (0.571) and its 10th percentile (0.019).

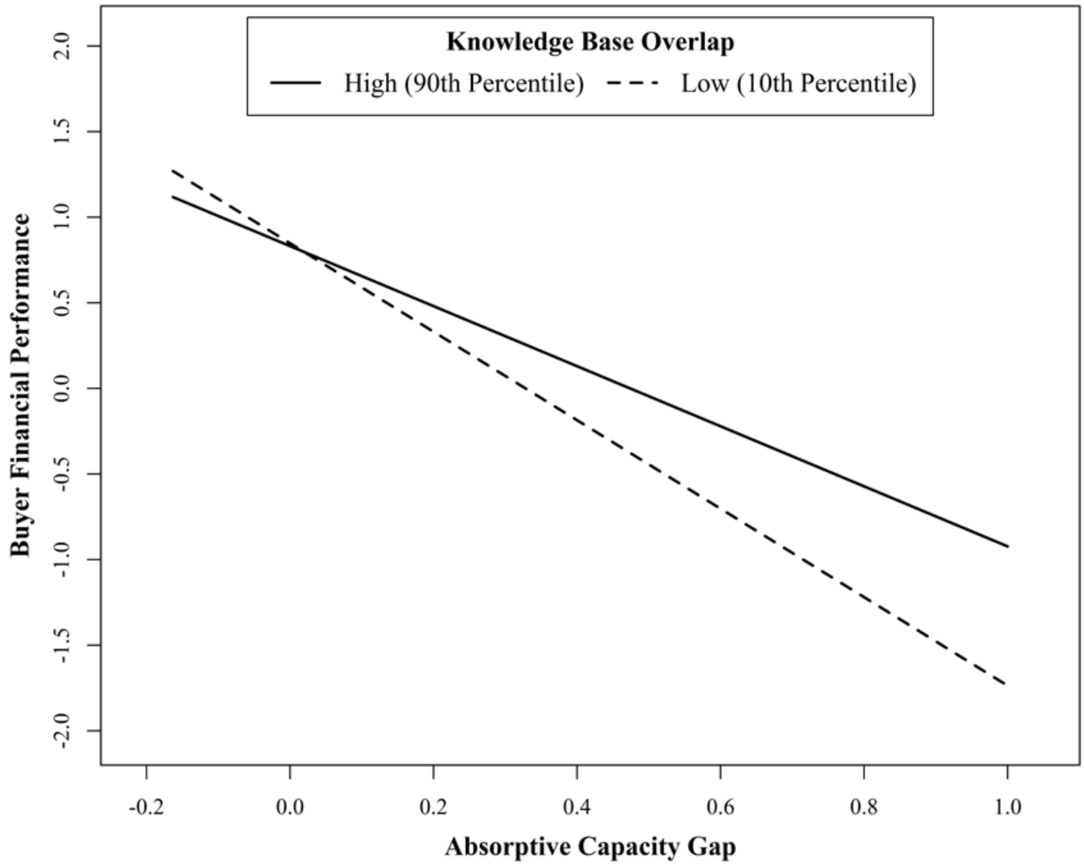

Figure 6: Buyer financial performance as a function of the absorptive capacity gap and the knowledge base overlap

Notes: For plotting the effect of the absorptive capacity gap, mutual absorptive capacity was set at its median (0) and all control variables were set at their mean. Furthermore, as indicated in the graph, the effect was plotted for two levels of knowledge base overlap: its 90th percentile (0.571) and its 10th percentile (0.019).

4 Discussion and conclusion

The aim of this study was to provide a new understanding of how absorptive capacity in supplier relations affects the buyer's financial performance. We conceptualized absorptive capacity as a dyadic, two-dimensional construct comprised of mutual absorptive capacity and the absorptive capacity gap. We defined mutual absorptive capacity as the sum of the buyer's and the supplier's partner-specific absorptive capacities, and the absorptive capacity gap as the difference between the buyer's and the supplier's partner-specific absorptive capacities.

Our empirical results indicate that mutual absorptive capacity enhances the buyer's financial performance. This is in line with our theoretical analysis, which predicts that mutual absorptive capacity allows for joint problem solving and thus for superior value creation. Specifically, mutual absorptive capacity enables both the buyer and the supplier to learn from each other, which seems to facilitate the iterative and bidirectional exchanges of knowledge that are essential to joint problem solving (e.g., to collaboration in new product development).

In addition to our prediction for mutual absorptive capacity, we predicted that an absorptive capacity gap increases the buyer's financial performance. An absorptive capacity gap may contribute to the latter as it allows the buyer to strengthen its bargaining power vis-à-vis the supplier and to potentially outlearn the supplier in case both firms compete in innovation. However, contrary to our prediction, our results indicate that an absorptive capacity gap reduces the buyer's financial performance. A potential explanation for this result is that an absorptive capacity gap may deter the supplier from collaborating with the buyer. In particular, fears of being outlearned might decrease the supplier's willingness to engage in joint problem solving, and thus decrease overall value creation. Scholars have long noted that such fears of being vulnerable to the partner's opportunistic behavior are a significant obstacle to collaboration (Chung, Singh, & Lee, 2000; Gulati, 1995; Gulati, Khanna, & Nohria, 1994). Yet, a consensus on whether they actually prevent partners from collaborating has not yet been reached. For instance, Yang et al. (2015) list several reasons why firms may collaborate despite asymmetric learning capabilities (e.g., the need to access complementary resources, to manage mutual competitive interdependence, to gain network advantages, to absorb meta-learning routines, and limited firm-specific foresight).

Besides these findings on the two main effects of mutual absorptive capacity and the absorptive capacity gap, our results show that both are moderated by the overlap of knowledge bases in the buyer-supplier relationship. Specifically, we find that the knowledge base overlap negatively moderates the effect of mutual absorptive capacity. This indicates that a large overlap limits technological diversity, and thus the potential of the relationship to jointly create new recombinations of knowledge. Furthermore, we find that the knowledge base overlap positively moderates the effect of the absorptive capacity gap. This suggests that a large overlap makes it more likely that the buyer and the supplier compete in the development of new technologies. Both of these findings on the moderating role of the knowledge base overlap are in line with our theoretical predictions.

4.1 Contributions to literature

Our study provides several contributions to research. First, we add to the literature on supplier involvement in new product development. Prior work in this domain has solely focused on the role of the buyer's absorptive capacity as an enabler of successful collaboration with suppliers (Azadegan, 2011; Wagner, 2012). In contrast to these prior works, our findings suggest that, instead of the buyer's absorptive capacity, mutual absorptive capacity is needed in order for buyers to gain from supplier relations. This is because successful supplier involvement often depends on bilateral as opposed to unilateral knowledge exchanges. Our results also suggest that an absorptive capacity gap likely reduces the supplier's willingness to collaborate due to fears of being outlearned. Hence, the buyer's absorptive capacity can potentially have no or a negative effect on its performance if the supplier's absorptive capacity is too low. This may explain the mixed results of prior research on the role of the buyer's absorptive capacity (e.g., Azadegan, 2011; Wagner, 2012).

Besides these contributions to the literature on supplier involvement in new product development, we contribute to the more general research that links absorptive capacity to firm performance. Scholars have long recognized that learning in interfirm relations involves both collaborative and competitive elements (i.e., joint problem solving with the partner vs. outlearning the partner) (Hamel, 1991; Khanna et al., 1998). However, despite these insights, the distinct constructs of mutual absorptive capacity and the absorptive capacity gap that relate to these two elements have not been studied empirically. Prior empirical research on firm performance almost exclusively investigated the role of the focal firm's absorptive capacity (Chang et al., 2012; Lane et al., 2001; Rothaermel & Alexandre, 2008). An exception is a recent study by Yang et al. (2015), which examines the influence of asymmetric learning capabilities (i.e., absorptive capacity gaps) in alliances. Yet, they leave the role of mutual absorptive capacity unexplored. Our findings suggest that both mutual absorptive capacity and the absorptive capacity gap have distinct implications, and can jointly offer a refined understanding of how absorptive capacity affects firm performance.

The analysis of the moderating role of the knowledge base overlap also adds to the literature. It has long been argued that the knowledge base overlap between two actors is an important determinant of their mutual absorptive capacity (Cohen & Levinthal, 1990). However, our results indicate that, while the knowledge base overlap may affect the level of mutual absorptive capacity, it also moderates its contribution to corporate financial performance. Hence, firms might gain more from mutual absorptive capacity if it is based on factors other than common knowledge. For instance, mutual absorptive capacity might be particularly valuable in supplier relations of a low knowledge base overlap where the ability of the buyer and the supplier to learn from each other does not stem from their common technological knowledge but from other factors such as cultural compatibility, organizational similarity and trust (van Wijk, van den Bosch, & Volberda, 2011).

Finally, the positive moderating effect of the knowledge base overlap on the link between the absorptive capacity gap and buyer financial performance suggests that competition in innovation may play a more important role in buyer-supplier relationships than previously assumed. Extant research on innovation in vertical relationships has mainly focused on supplier involvement and collaboration in new product development. Yet, the knowledge domains of buyers and suppliers often overlap, which may lead to competition in innovation. This might be particularly relevant in industries that undergo considerable technological change such that a clear division of labor in the development and production of new products has not yet emerged. For instance, as noted earlier, OEMs in the automotive industry are now competing with their 1-st tier suppliers in the market for electric vehicle batteries (Dinger et al., 2010).

4.2 Managerial implications

From a practical standpoint, our findings suggest that buying firms can gain from favoring mutual learning in their supplier relations over learning unilaterally. Specifically, by promoting mutual learning (i.e., by focusing not only on their own ability to learn from suppliers but also on their suppliers' ability to learn from them), buying firms facilitate joint problem solving, which increases the success of collaborations in new product development. By favoring mutual learning, buying firms can also avoid larger asymmetries (i.e., absorptive capacity gaps) that potentially reduce their suppliers' willingness to collaborate. Furthermore, our results indicate that mutual learning can yield the highest returns in supplier relations in which the buyer and the supplier possess widely different technological knowledge. This is because, in such cases, collaborations can result in more and better innovations due to the high potential to recombine knowledge in new ways. Although a lack of common knowledge might make it difficult to promote mutual learning in such supplier relations (Sampson, 2007), our findings suggest that it can yield higher returns than in those in which the buyer's and the supplier's technological knowledge is similar.

4.3 Limitations and future research

A main limitation of this study pertains to construct measurement. Since a firm's patenting activity only partially reflects its learning and its knowledge base, the patent-based variables such as mutual absorptive capacity, the absorptive capacity gap and the knowledge base overlap can only approximate their underlying constructs. The same holds for our dependent variable. Although Tobin's q is a well-established measure in the literature (Bharadwaj, Bharadwaj, & Konsynski, 1999; David, O'Brien, Yoshikawa, & Delios, 2010; Humphery-Jenner, 2014), it can only serve as an approximation of corporate financial performance. Additionally, it should be noted that our sample does not reflect the total population of buyer-supplier relationships as it is restricted to relationships in the U.S., in specific industries, in a specific time period, and in which the buyer is a major customer of the supplier. Thus, care must be taken in generalizing our findings to other settings.

A further limitation is that we cannot distinguish between vertical partnerships in which the buyer and the supplier collaborate in new product development and such in which they do not. As a consequence, we can only speculate about whether the absorptive capacity gap deters suppliers from collaborating. Future research may thus further investigate this relationship. Another path for future research would be to examine how buyers and suppliers can build mutual absorptive capacity. Our findings suggest that building the latter is most valuable in dyads characterized by a low knowledge base overlap. Yet, our current understanding of the antecedents of mutual absorptive capacity is still limited (van Wijk et al., 2011). Finally, future research could investigate whether and to which extent buyers and suppliers actually compete in innovation. As noted, extant research on buyer-supplier relationships has strongly focused on collaboration in product development, while competition received little attention. Studies that examine competition in innovation, and in particular the conditions under which it may occur, would thus greatly contribute to the buyer-supplier relationship literature.

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Appendix

1 Matching patents to firms

This section details the process of matching patents to firms that was employed in Essays 1, 2, and 3.

As firms often assign patents to their subsidiaries, we carefully aggregated patents to the firm level. Following the approach of Phelps (2010), we gathered each firm's subsidiaries listed for 2015 in the Directory of Corporate Affiliations, and subsequently traced its history of M&A deals to reconstruct subsidiary lists for the period of study. We obtained data on M&A deals from Thomson ONE and Mergerstat M&A (Essays 1 and 3 draw on Thomson ONE, Essay 2 on Mergerstat M&A). In order to further enhance the completeness of our reconstructions, we additionally used subsidiary information from U.S. Securities and Exchange Commission (SEC) filings. The firms in the sample are publically traded entities and thus required to disclose their major subsidiaries to the SEC (as specified by the Code of Federal Regulations, 17 CFR 229.601). Data on those reported subsidiaries came from CorpWatch API, which covers the period from 2003 to 2015.

As a first step in the procedure of collecting subsidiaries, we created linkages between the sample firms and the firms listed in each of the three employed data sources: (1) For the Directory of Corporate Affiliations, we obtained linkages manually by comparing company names, industry classifications, and CUSIP codes. We took account of changes in company names since some firms occur under a new name in the Directory of Corporate Affiliations. (2) For Thomson ONE and Mergerstat M&A, we created linkages based on CUSIP codes, and if those were not available, based on company names. (3) For CorpWatch API, we obtained linkages by matching company names. In order to avoid matching errors, we harmonized the company names of the sample firms and the company names in CorpWatch API, Thomson ONE and Mergerstat M&A by the following rules:

- Capitalized letters were changed to lowercase.
- The symbols “.”, “,”, “ ' ”, “?”, “(”, “)”, “!”, “-”, “/” were dropped.
- The symbols “&” and “+” were treated as the word “and”.
- Suffixes indicating the same type of business entity were assumed as equal (e.g, “incorporated” and “inc”, “company” and “co”, “limited” and “ltd“, “corporation” and “corp”).
- Abbreviations and their long forms were assumed as equal (e.g. “international” and “intl”, “holding” and “hldg”, “group” and “grp”).
- The word “the” was dropped.

With the collected data on firms’ subsidiaries as of 2015 and prior M&A deals, we gradually traced back their subsidiary portfolios for the prior years. In addition, we complemented those with information on subsidiaries from annual SEC reports. Based on the reconstructed subsidiary portfolios, we compiled a master portfolio for each firm that covers all of its subsidiaries from its period of observation.

In order to assign patents to the firms in the sample, we employed an approximate string matching algorithm. The latter compares company and subsidiary names with the names of patent assignees. The algorithm is based on the “stringdist”-package for R and uses the Jaro-Winkler metric in order to compare strings, which has been specifically designed for short, human-typed strings such as company names (van der Loo, 2014). In order to identify an appropriate threshold value for the algorithm, we conducted a test based on 500 random matches. We manually counted changes in the number of errors (i.e., false positives and false negatives) for changing threshold values, and found that a value of 0.03 minimizes the total number of errors. Thus, we selected the latter as the threshold value in the algorithm. Importantly, we harmonized all company and patent assignee names based on the above listed rules prior to running the string matching algorithm.