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Leading Knowledge Creation Across Boundaries

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"And so, my fellow Americans:
Ask not what your country can do for you,
ask what you can do for your country."

—John F. Kennedy, inauguration address, January 1961.

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Thomas Gersdorf

Abstract

To innovate, firms in knowledge-intensive industries increasingly collaborate with other organizations, such as universities, start-ups, and other firms, in knowledge creation. This dissertation advances the theoretical understanding of collaborative knowledge creation between firms and partnering organizations, and investigates managerial levers that facilitate work in such collaboration *across* the firm boundary.

Collaborative knowledge creation projects that span the firm boundary entail multiple boundary complexities, which potentially affect the functioning of these projects. The goal of this dissertation is to illuminate how these boundary complexities impact the outcomes of collaborative knowledge creation projects by identifying the underlying mechanisms at play. In addition, the dissertation seeks to identify managerial levers that help to counter the potentially negative impacts of these boundary complexities and enhance the performance of such collaborative projects. This dissertation thus provides new insights into the functioning and effective management of collaborative knowledge creation.

This dissertation consists of seven introductory chapters and three co-authored essays based on data from 187 collaborative research projects of a global pharmaceutical firm and its partnering academic organizations. The first two essays develop and test new theory about the impact of two specific complexities – (1) diversity of expertise and (2) diversity of goals among team members of collaborative projects – on the functioning and the outcomes of collaborative projects. The third essay categorizes all challenges present in such collaborative projects using an inductive qualitative analysis and tests the impact of those challenges on project performance.

The implications of this research are relevant for both theory and practice. The findings from the three essays point to the fact that knowledge creation of firms in knowledge-intensive industries is far from confined within the firms' boundaries. Rather, the collaboration of a firm with other organizations also serves as a vehicle for knowledge creation. By examining collaborative knowledge creation projects in which the partnering organizations *create* knowledge together, this dissertation moves beyond previous perspectives that typically focus on knowledge transfer. Moreover, given that many managerial mechanisms, such as hierarchical control or financial incentives, are largely absent in collaborative knowledge creation, the role of leadership in driving collaborative knowledge creation is elevated. Finally, collaborative knowledge creation requires significantly different management than does intra-organizational knowledge creation and requires extra efforts from both project members and managers.

Zusammenfassung

Unternehmen in wissensintensiven Branchen arbeiten zunehmend mit anderen Organisationen wie Universitäten, Start-ups und anderen Unternehmen in der Wissenserzeugung zusammen, um neue Produkte, Services und Prozessverbesserungen zu erzeugen. Diese Dissertation bringt das theoretische Verständnis über die Funktionsweise der gemeinsamen Wissenserzeugung von Unternehmen und deren Partnerorganisationen voran und untersucht Managementmethoden, die die Zusammenarbeit zwischen Unternehmen und Partnerorganisationen über Unternehmensgrenzen hinweg erleichtern.

Kollaborationsprojekte zur Wissenserzeugung, die sich über die Unternehmensgrenzen hinweg erstrecken, haben mehrere Komplexitäten zur Folge. Das Ziel dieser Dissertation ist es, aufzuzeigen, wie sich diese Komplexitäten auf die Ergebnisse von Kollaborationsprojekte auswirken, indem die zugrundeliegenden Mechanismen identifiziert werden. Darüber hinaus identifiziert diese Dissertation Steuerungshebel, die dazu beitragen, die potenziell negativen Auswirkungen dieser Komplexitäten entgegenzuwirken und die Leistung solcher Kollaborationsprojekte zu verbessern. Damit gibt diese Dissertation neue Einblicke in die Funktionsweise und das effektive Management von wissenserzeugenden Kollaborationen.

Diese Dissertation besteht aus sieben einleitenden Kapiteln und drei zusammen mit Koautoren verfassten Essays, die auf der Auswertung von Daten von 187 kollaborativen Forschungsprojekten eines globalen Pharmaunternehmens und seiner Partnerorganisationen basieren. Die ersten beiden Essays entwickeln und testen neue Theorie über die Auswirkungen zweier spezifischer Komplexitäten – (1) die Diversität des Wissens und (2) der Diversität in den Zielsetzungen der Teammitglieder von Verbundprojekten – auf die Funktionsweise und die Ergebnisse von Kollaborationsprojekten. Das dritte Essay kategorisiert alle Herausforderungen, die in solchen Verbundprojekten auftreten, mithilfe einer induktiven qualitativen Analyse und testet den Einfluss dieser Herausforderungen auf den Projekterfolg.

Die Implikationen dieser Forschung sind sowohl für die Theorie als auch für die Praxis relevant. Die Ergebnisse der drei Essays streichen heraus, dass die Wissenserzeugung von Unternehmen in wissensintensiven Branchen bei weitem nicht nur innerhalb des Unternehmens stattfindet. Vielmehr dient die Zusammenarbeit eines Unternehmens mit anderen Organisationen ebenso zur Wissenserzeugung. Durch die Untersuchung von kollaborativen Projekten zur gemeinsamen Wissenserzeugung entwickelt diese Dissertation die existierende Literatur, dies sich auf den Wissenstransfer zwischen Organisationen konzentriert, weiter. In Anbetracht der Tatsache, dass viele Managementmechanismen wie hierarchische Strukturen oder finanzielle Anreize bei der kollaborativen Wissenserzeugung weitgehend fehlen, wird die Rolle der Führung für die Förderung der kollaborativen Wissenserzeugung wichtiger. Schließlich unterscheidet sich das Management der kollaborativen Wissenserzeugung erheblich von der organisationsinternen Wissenserzeugung und erfordert zusätzliche Anstrengungen von Projektteilnehmern und Managern.

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IP	Intellectual property
KBV	Knowledge-based view of the firm
MTA	Material transfer agreement
NIBR	Novartis Institutes for BioMedical Research
R&D	Research and development
RBV	Resource-based view of the firm
TFL	Transformational leadership
TTO	Technology Transfer Office
SEM	Structural equation modeling

1. Introduction

As both technological change and globalization accelerates and competition among firms becomes increasingly fierce, it is inevitable that firms will innovate at a rapid pace to remain competitive and relevant (Dobbs, Manyika, & Woetzel, 2016; Govindarajan & Srivastava, 2016). Consequently, the average lifespan of large firms has dropped significantly in recent decades (e.g., George, 2016; Reeves & Pueschel, 2015). The accelerated competition involved in acquiring and creating new knowledge plays an important role in these developments. Firms increasingly obtain their strategic advantages from knowledge creation (Grant, 1996a; Kogut & Zander, 1992; Nonaka, 1994) – which increasingly occurs exclusively in the digital space (e.g., Dougherty & Dunne, 2012; Nambisan, Lyytinen, Majchrzak, & Song, 2017) – while at the same time, physical assets are becoming less and less relevant to obtaining a strategic advantage (Grant, 2009; McGrath & Kim, 2014).

Advancements in science and technology challenge firms competing in knowledge-intensive industries to accumulate, create, and retain all relevant knowledge internally (Powell & Snellman, 2004). Therefore, many firms increasingly collaborate with other organizations or individuals in knowledge creation. While early innovation research recognized that the "ability of a firm to recognize the value of new, external information, assimilate and apply it […] is critical to its innovative capabilities" (Cohen & Levintbal, 1990), scholars have since described new forms of collaboration with organizations and individuals. Grant and Baden-Fuller argue that instead of absorbing as much external knowledge as possible, firms increasingly seek to access external knowledge through collaborative partnerships based on the demand of the organizational knowledge creation process (Grant & Baden-Fuller, 2004).

Moreover, firms increasingly collaborate with other organizations or individuals to *create* new knowledge that none of the collaborating organizations already possesses (Dougherty & Dunne, 2011; Gulati, 1999; Hardy, Phillips, & Lawrence, 2003; Powell, Koput, & Smith-Doerr, 1996). However, *how firms optimally organize and lead such knowledge creation in collaboration with other organizations* remains poorly understood. The goal of this dissertation is to advance the understanding of the functioning and effective management of collaborative knowledge creation across the firm boundary.

Prior studies describe different ways in which firms collaborate with external actors for the purpose of innovation. User innovation research has described how firms can harness users of their products and services as an important source of ideas for new products and services or the improvement of existing ones (Bogers, Afuah, & Bastian, 2010; von Hippel, 1986). Other scholars have coined the paradigm of open innovation, in which firms obtain valuable knowledge from other organizations such as suppliers, other firms, and universities to accelerate innovation and expand market opportunities for new products or services (Chesbrough & Bogers, 2014; Chesbrough, 2003). Open innovation entails processes by which a firm either in-sources external knowledge to use in the internal innovation process (e.g., obtaining scientific knowledge from a university for internal product development), outsources internal knowledge for external exploitation (e.g., out-licensing of intellectual property), or collaborates with partnering organizations or individuals in creating knowledge (Gassmann & Enkel, 2004). Research on the search processes by which

firms in-source external knowledge has empirically documented the positive impact of open innovation on firm performance. By examining the patterns by which firms search for external knowledge, scholars have identified specific search strategies that increase a firm's innovation performance significantly (Laursen & Salter, 2006), depending on the firm's internal resources and the abundance of external knowledge (Garriga, von Krogh, & Spaeth, 2013).

Innovation scholars have recognized that a firm's collaboration with other organizations or individuals is not limited to knowledge transfer across the firm boundary but often includes knowledge *co-creation* (Chesbrough & Bogers, 2014), which has the potential to create significant value for the firms involved (Faems, De Visser, Andries, & Van Looy, 2010; Garriga et al., 2013; Laursen & Salter, 2006). A recent definition of open innovation by Chesbrough and Bogers (2014) as "distributed innovation processes based on purposively managed knowledge flows across organizational boundaries, using pecuniary and non-pecuniary mechanisms in line with the organizations' business model" explicitly suggests that the locus of innovation spans *across* the firm boundary.

Similarly, organizational theorists have argued that both a firm's internal and external knowledge bases are critical inputs to knowledge creation and thereby key to the innovation activities of firms (Kogut & Zander, 1992; Nonaka & Toyama, 2005). According to the knowledge-based view of the firm (Kogut & Zander, 1992; Nonaka, 1994; Wang & Xiong, 2010), knowledge creation takes place as a result of interactions between individuals, and yields valuable knowledge that can potentially constitute a source of sustainable competitive advantage for the firm (Grant, 1996b; Nonaka & Takeuchi, 1995; von Krogh, Ichijo, & Nonaka, 2000). By recognizing that firms create knowledge through interaction with their environment – i.e., by synthesizing internal knowledge and knowledge held by other organizations or individuals including customers, suppliers, competitors, or universities – scholars of the knowledge-based view readily accepted that the knowledge creation of firms spans across the firm boundary (Nonaka & Toyama, 2005).

Moreover, scholars have argued that the activities through which a firm collaborates with other organizations or individuals are the driving forces behind the development of organizational knowledge (Tsoukas & Vladimirou, 2001). Given that firms operate in environmental and technical contexts that are subject to change and therefore require continuous adaptation to novel situations, organizational knowledge is always incomplete and requires a constant inflow of new knowledge (Tsoukas & Vladimirou, 2001). Collaboration between firms and external actors is therefore a key activity that keeps the organizational knowledge up to date (Tsoukas & Vladimirou, 2001). As many scholars – such as Polanyi, Nonaka, and Tsoukas – outline, these processes take place through interactions between individuals (Nonaka, 1994; Polanyi, 1962; Tsoukas & Vladimirou, 2001). Consequently, collaboration between individuals from different organizations plays a key role in explaining the functioning of collaborative knowledge creation.

However, existing research in organizational theory cannot adequately explain the functioning of collaborative knowledge creation (Fjeldstad, Snow, Miles, & Lettl, 2012). For example, the famous study by Lawrence and Lorsch (1967) explains that the absorption and integration of knowledge from the firm's

environment takes place within the different departments and subunits of a firm, such as research & development, manufacturing and marketing. Lawrence and Lorsch suggest that to effectively integrate knowledge, firms need to implement organizational mechanisms to exchange knowledge between departments and units (Lawrence & Lorsch, 1967b). However, this perspective does not accommodate the phenomenon that knowledge creation occurs as part of collaboration with other organizations (Gulati, 1999; Powell, 1990, 1996). Similarly, the literature on absorptive capacity (Cohen & Levintbal, 1990) focuses on the processes within the organization that are responsible for the *integration* of external knowledge rather than the processes that facilitate the *creation* of new knowledge. Consequently, there is a need to advance organizational theories to explain knowledge creation that spans across the firm boundary.

Scholars have outlined a number of areas where findings from research on interorganizational collaboration (Hardy et al., 2003) and, more generally, new forms of organizing (Puranam, Alexy, & Reitzig, 2014), challenge previous organizational theory (Fjeldstad et al., 2012). These findings particularly concern the role of (1) incentives (e.g., Lerner & Tirole, 2002), (2) governance (e.g., O'Mahony & Ferraro, 2007), (3) coordination (e.g., Kellogg, Orlikowski, & Yates, 2006; von Hippel & von Krogh, 2003), and (4) leadership (e.g., von Krogh, Nonaka, & Rechsteiner, 2012). An important observation about collaborative knowledge creation is that actors – individuals and groups of individuals – from different organizations dynamically form collaborative relationships (Fjeldstad et al., 2012) that can be described neither as markets nor as hierarchies (Hardy et al., 2003; Powell, 1990).

Given the increasing prevalence of knowledge creation across the firm boundary and the inadequacy of traditional management and organizational theory in explaining these phenomena (Fjeldstad et al., 2012; Gulati, Puranam, & Tushman, 2012; Powell, 1990), new theory is needed. Three aspects of knowledge creation across the firm boundary deserve specific attention. First, knowledge creation spanning across the firm boundary is characterized by the collaboration of individuals from different organizations, who largely self-organize their work and rely on local decision making that is typically not backed by hierarchical control structures (Dougherty & Dunne, 2011; Fjeldstad et al., 2012). Hence, effective managerial influence and leadership mechanisms could potentially differ from those used within organizations. While it is reasonable to expect that both centralized and distributed leadership will play major roles in collaborative knowledge creation (von Krogh, Nonaka, et al., 2012), the leadership structures that form in such settings and their influence on teams could be different due to the absence of the organizational hierarchy (Gulati, Puranam, et al., 2012). Because expertise and knowledge are important precursors of leadership influence, especially in the absence of hierarchy-backed authority (Yukl, 2010), the distribution of expertise could have a significant influence on leadership structures in collaborative knowledge creation.

Second, cooperation and coordination are more complex in a collaboration between different organizations than within organizations, because the collaborating individuals generally have different goals and interests (Gulati, Wohlgezogen, & Zhelyazkov, 2012). For example, in university-industry collaboration, firms collaborate with universities and other academic institutions that have different the goals and objectives from those of firms (Cyert & Goodman, 1997; De Fuentes & Dutrénit, 2012; Perkmann et al., 2013).

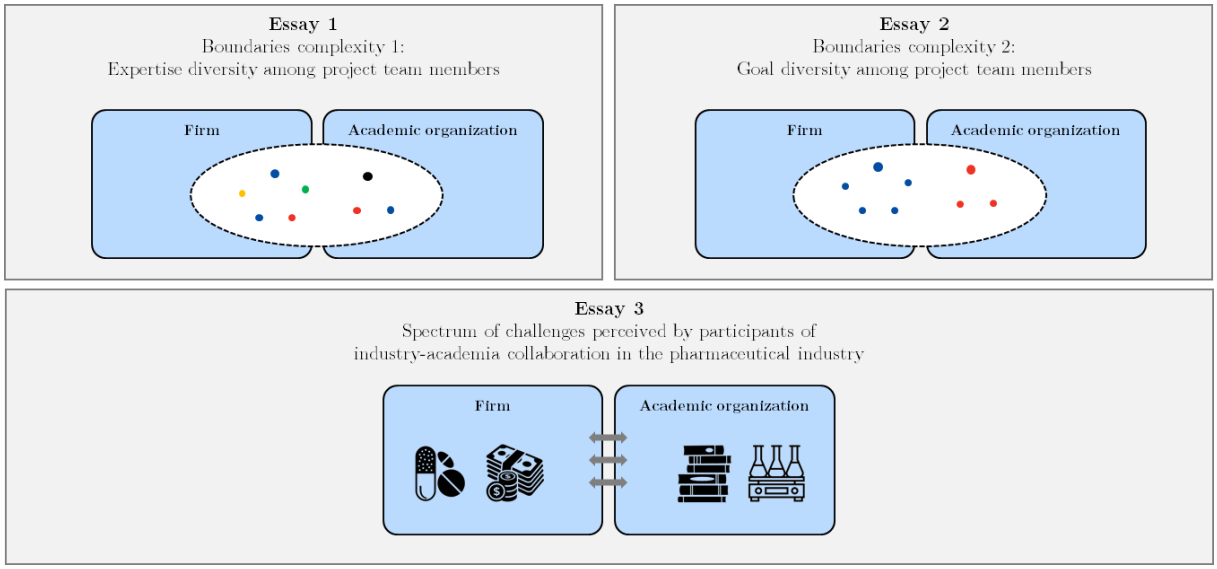

Figure 1.1: Research framework of this dissertation

Therefore, participants in collaborative projects must overcome the potential negative effects of free-riding (Hardin, 1982) and the tragedy of the commons (Hardin, 1968). For example, a firm might not be able to share some knowledge with a partnering organization if there is the fear that the partner might exploit this knowledge for its own purposes. Moreover, because individuals from different organizations possess different types of knowledge and are part of different communities of practice (Brown & Duguid, 2001), knowledge sharing is more complicated compared to within organizations (Kellogg et al., 2006).

Third, collaborative knowledge creation requires that members of collaborative projects mobilize resources from within their organization for the collaborative project (Hardy et al., 2003; Ostrom, 1990). While organizational hierarchies effectively facilitate resource allocation within organizations (Bower, 1970), the mobilization of resources in collaborations between organizations will likely be comparatively more complex.

To advance the understanding of the functioning and effective management of collaborative knowledge creation, the research in this dissertation develops new theory and analyses a unique dataset from 187 teams of industry-academia collaboration projects (Perkmann et al., 2013) working on drug discovery research. Collaborative knowledge creation between firms and other organizations is often organized in collaborative project teams (Fjeldstad et al., 2012), similar to the knowledge work in modern organizations that is typically organized in teams or projects (Kozlowski & Bell, 2003; Lanaj, Hollenbeck, Ilgen, Barnes, & Harmon, 2013). The author collected both qualitative and quantitative data from the collaborative research projects of a global pharmaceutical company, Novartis AG, and its academic partners. A three-wave survey of all participants in these projects serves as the major data source for all essays in this dissertation.

Early-stage drug discovery research is a context ideally suited to the investigation of collaborative knowledge creation. Firms in the pharmaceutical industry spend more on research and development (R&D)

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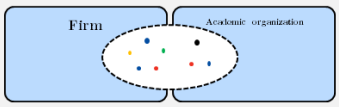
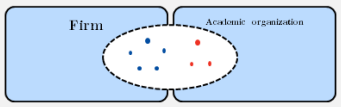
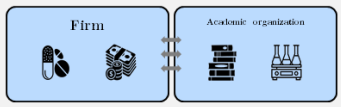
			
	Folding under Uncertainty? Exploring the Link between Expertise Diversity and Performance of Knowledge Teams *Revise & Resubmit at Journal of Applied Psychology*	**The impact of orientation-based dissimilarities in university–industry collaboration on project outcomes: Investigating the critical roles of conflict and transformational leadership** *Revise & Resubmit at Research Policy*	**Demystifying Industry-Academia Collaboration** *Accepted for publication in Nature Reviews Drug Discovery*
	How does expertise diversity affect knowledge creation in teams for different levels of uncertainty?	How do orientation-based dissimilarities (OBD) affect the outcomes of university-industry collaboration? What managerial levers exist to overcome such dissimilarities?	What are the challenges perceived by participants of university-industry collaboration in drug discovery? How do these challenges relate to project success?
	▪ Team level	▪ Team level	▪ Individual level & team level
	▪ Expertise and functional diversity (Van der Vegt & Bunderson, 2005) ▪ Knowledge teams (Carlile, 2004; Faraj & Sproull, 2000) ▪ Functional leadership (Morgeson et al., 2010) ▪ Social identity (Ashforth & Mael, 1989; Turner, 1985)	▪ University-industry collaboration (Cohen et al., 2002; Perkmann et al., 2013) ▪ Dissimilarities in UIC (Bruneel et al., 2010; Estrada et al., 2016; Tartari et al., 2012) ▪ Workgroup conflict (Jehn et al., 1999; Pelled et al., 1999) ▪ Transformational leadership (Bass, 1985; Podsakoff et al., 1990)	▪ University-industry collaboration in the pharmaceutical industry (Barnes et al., 2009; Melese et al., 2009)
	▪ The positive effect of expertise diversity on team performance vanishes for high task uncertainty ▪ Team leadership asymmetry mediates this moderating effect ▪ Team identification reduces the emergence of team leadership asymmetry and thereby the overall negative effect	▪ Orientation-based dissimilarities have an overall negative and non-nonlinear impact on project performance and negative impact on intention to repeat collaboration ▪ Conflict within the project team mediates the effect of OBD on project performance ▪ Transformational leadership reduces the emergence of project team conflict	▪ Resource constraints, legal & administrative process constraints are the most frequently observed types of challenges ▪ Except for two types of challenges, the presence of challenges relates to lower levels of project success 6 months later
	▪ Teams with high expertise diversity are not always optimal, especially in the case of high task uncertainty ▪ Team identification mitigates the emergence of team leadership asymmetry	▪ Orientation-related dissimilarities are indeed "barriers" to collaboration, except for very low levels ▪ Transformational leadership is a managerial lever to foster collaboration between participants with different goals and expectations	▪ Collaboration between firms and universities in drug discovery bears challenges, but they appear manageable ▪ Participants of collaborative projects should pro-actively address these challenges to achieve project success

Figure 1.2: Overview of the essays in this dissertation

than firms in almost any other industry (Jaruzelski, Staack, & Chwalik, 2017). Yet, pharmaceutical research has become so complex that not even the largest pharmaceutical companies are able to accumulate all relevant knowledge internally (Pammolli, Magazzini, & Riccaboni, 2011; Schachter, 2012; Simpson & Reichman, 2014).

The average costs to bring a single drug to the market in the United States total 2.6 billion U.S. Dollars according to recent estimates (PhRMA, 2016), with a trend towards even higher costs (Scannell, Blanckley, Boldon, & Warrington, 2012). Given the inherent uncertainty and high complexity of early-stage pharmaceutical research (e.g., Ben-Menahem, von Krogh, Erden, & Schneider, 2016), pharmaceutical companies frequently collaborate with academic institutions (Melese, Lin, Chang, & Cohen, 2009; Schachter, 2012).

The pharmaceutical industry has a long history of extended partnering between companies and public organizations in the research and development of new drugs (Melese et al., 2009). For example, the vast majority of the most impactful drugs of the last 25 years were developed with contributions from both the private and the public sectors (Chakravarthy, Cotter, DiMasi, Milne, & Wendel, 2016). University-industry collaboration projects entail knowledge creation (Perkmann et al., 2013) and differ from transactive activities such as contract research (Chapman, 2003) and in-/out-licensing (Ashburn & Thor, 2004). The outcomes of these collaborative projects include tangible results such as new assays, methods, chemical and biological compounds (Schachter, 2012) as well as intangible learning, and knowledge transfer (Denee et al., 2012). Because these collaborative projects indeed create new knowledge, they provide an ideal empirical context for this dissertation.

Three co-authored essays form the main contribution of this cumulative dissertation. Figure 1.1 presents the research framework of this dissertation. The first two essays conceptually explore two different boundary complexities that arise in collaborative knowledge creation: the diversity of expertise and the diversity of the goals of project team members. The first essay investigates how expertise diversity – the differences in team members' knowledge and background expertise (Bunderson & Sutcliffe, 2002; Van Der Vegt & Bunderson, 2005) – affects the knowledge creation performance of collaborative projects for different levels of task uncertainty. The second essay investigates how goal diversity arising from differences in the goals and expectations of project members from the partnering organizations impacts project performance (i.e., goal attainment) and the project members' intentions to collaborate again.

Essay 3 provides an overall view by analyzing the spectrum of challenges – including those arising from the two boundary complexities discussed in the first two essays – as perceived by the members of collaborative projects. This essay employs a qualitative methodology to categorize all challenges reported by the project team members who have engaged in collaborative knowledge creation projects. Furthermore, this essay quantitatively assesses the impact of different types of challenges on project success. Targeting a practitioner audience, the essay concludes with practical recommendations on how to manage university-industry collaboration. Thus, essay 3 gives a concrete empirical example of the relevance of boundary complexities in collaborative knowledge creation projects. All three essays differ substantially in their theoretical perspectives and do not share the same dependent variable, as Figure 1.2 summarizes.

Taken together, the insights from these essays advance the theoretical understanding of the functioning of collaborative knowledge creation between firms and other organizations. Finally, the essays reveal important findings on how such collaboration can be optimally organized and led.

This dissertation proceeds in four parts. Part One summarizes the theoretical foundations of management theory relevant to this dissertation and briefly reviews the literature streams that the essays build upon. Part Two introduces the empirical context and the research methodology. Part Three summarizes the three essays and concludes with a discussion of the implications for theory and practice. Part Four comprises the essays themselves.

Part One: Literature Review

2. Theoretical Foundations

Three major theoretical foundations form the perspective through which this dissertation investigates the overarching research question of *how firms can effectively organize and lead collaborative knowledge creation with other organizations or individuals across the firm boundary*. These are the knowledge-based view of the firm in strategic management, essential elements of organizational theory, and leadership theory. This chapter reviews these theoretical foundations briefly before chapter 3 reviews recent research relevant to the three essays in the dissertation.

2.1. Strategic management and the knowledge-based view of the firm

Strategic management at its core is about explaining differences in the economic performance of firms and understanding how managers should act to achieve the firm's objectives. Michael Porter shaped the field of strategic management with his seminal work focused on the idea that differences in performance between firms can be explained by the characteristics of the industry in which the firm operates, giving rise to the *Five Forces* framework (Porter, 1979).

While this perspective was highly influential, the focus soon shifted to the analysis of specific firms (Porter, 1980, 1985). Porter suggested that firms could enhance their profits further by successfully pursuing one of three "generic strategies": *cost leadership*, *differentiation* and *focus* (Porter, 1980). Firms adopting a *cost-leadership* strategy aim at earning above-average profits by obtaining an industry-wide cost advantage. By contrast, firms adopting a differentiation strategy aim at achieving above-average profits by creating products or service offerings that are unique industry-wide and can be sold at higher prices. Firms adopting the *focus* strategy target a specific customer group, product line or geographical market and achieve above-average profits because they can meet the needs of the target market more effectively than competitors, serve the target market at lower costs, or both.

Another school of thought – the *resource-based view of the firm* – emerged in parallel to the industry-focused perspective of Porter. The core argument of the resource-based view is that strategic resources are heterogeneously distributed across firms and that the properties of the resource bundle of a firm predicts the firm's performance (Barney, 1991; Wernerfelt, 1984). Firms can obtain a sustained competitive advantage (i.e., above-average economic performance over a long time) when they possess rare resources that are valuable inputs for the firm's products and are difficult for competing firms to imitate or substitute (Barney, 1991).

Scholars developed the resource-based view further by recognizing knowledge as the most important resource of firms in the knowledge-based economy (Powell & Snellman, 2004), leading to the development of the *knowledge-based view of the firm* (Kogut & Zander, 1992; Nonaka, 1994; Wang & Xiong, 2010). A core foundation of the knowledge-based view is the distinction between *explicit* and *tacit* knowledge. While explicit knowledge can be codified and therefore transferred easily between individuals, tacit knowledge

(including skills, know-how, and contextual knowledge) manifests only in application (Polanyi, 1969) and is therefore costly to transfer (Grant, 2009; Kogut & Zander, 1992; Nonaka, 1994).

Kogut and Zander (1992) paved the way for the "knowledge-based view of the firm" by portraying the firm as an organization that can share and transfer knowledge more efficiently than can markets. Kogut and Zander proposed that firms combine the knowledge held by different individuals within the firm into new knowledge. The combination of existing knowledge into new knowledge through both internal and external learning processes leads to the creation of new products and services (Kogut & Zander, 1992).

Nonaka's (1994) theory of organizational knowledge creation then suggested that knowledge creation takes place through the social interaction processes between individuals, in which individuals articulate and amplify their knowledge. However, knowledge transfer between individuals is costly and slow due to the tacit nature of knowledge (Kogut & Zander, 1992; Nonaka, 1994). The role of the firm is therefore to facilitate the social interaction processes between individuals, as those are the processes by which individuals create knowledge. For example, Grant (1996) proposed a set of coordination mechanisms that explain how firms effectively integrate the knowledge of different specialists.

The early literature on the knowledge-based view of the firm underscored the importance of external knowledge sources for a firm's knowledge creation processes (e.g., Kogut & Zander, 1992; Nonaka & Toyama, 2005). At the same time, decades of alliance research in the strategy literature has acknowledged the importance of different forms of alliances (including strategic alliances, joint ventures, and buyer-supplier partnerships) for knowledge creation within firms (Grant & Baden-Fuller, 2004). In addition, both the strategy and innovation literature point to the fact that firms might not only engage in strategic alliances with other firms but also engage in different forms of both formal and informal collaboration with other firms or external individuals to source new knowledge (Chesbrough & Bogers, 2014; Chesbrough, 2003; Fjeldstad et al., 2012; von Hippel, 1986).

In summary, research in the knowledge-based view explains knowledge creation within firms and points to the critical role of external sources of knowledge for the knowledge creation process within firms. Understanding how firms interact and collaborate with their environment for knowledge creation is therefore an important debate among strategy researchers, who seek to understand how firms obtain a sustainable competitive advantage. However, the current understanding in the literature on how knowledge creation *across* the firm boundary functions and what managerial and organizational mechanisms facilitate collaborative knowledge creation is still at an early stage and thus forms an important departure point for this dissertation.

2.2. Organizational theory

A fundamental question for organizational theorists is why firms exist in the first place (Coase, 1937). Over the course of the last century, economists and management scholars have developed a range of theories that attempt to answer this question and explain the conditions under which firms outperform markets.

The core argument of the *transaction cost economics theory* is that firms exist to minimize transaction costs that arise due to prevailing imperfections in markets (Williamson, 1975, 1979). Transaction costs arise from both human factors (e.g., bounded rationality or opportunism) and transactional factors (e.g., uncertainty, small numbers, and information asymmetry). When the transaction costs outweigh the administrative costs of internal organization, it is feasible to complete a transaction within an organization (Williamson, 1975). The theory then suggests optimal organizational structures and governance modes depending on the characteristics of the transaction; for example, prescribing firms to vertically integrate in the case of high asset specificity and high transaction uncertainty (Williamson, 1979).

The *behavioral theory of the firm* (Cyert & March, 1963) is one of the most influential developments in organizational and management theory. This theory introduced the perspective that the psychological aspects of decision making have a profound influence on the functioning of the firm (Gavetti, Greve, Levinthal, & Ocasio, 2012). In particular, the behavioral theory of the firm builds on the core proposition of *bounded rationality* coined by March and Simon; bounded rationality refers to the limits of rationality in the decision making of individuals (March & Simon, 1958; Simon, 1947). The perspective of bounded rationality argues that decision makers have imperfect information and argues against the rational-agent model of economic theory. The main assumptions of this perspective can be summarized in three central postulates (Gavetti et al., 2012).

First, individuals satisfice instead of maximize; that is, they choose the first alternative they find to be satisfactory. Second, the search for the optimal solution is constrained by the fact that it is rarely possible for individuals to have "complete knowledge and anticipation of the consequences that will follow on each choice" (Simon, 1947: 81), meaning that individuals might not always uncover the optimal alternative when making a decision. Third, firms usually counter uncertainty and lack of information in decision making by using rules and standard operating procedures, which build on previous experience and therefore constrain the selection of choices by remaining similar to previous trajectories (Cyert & March, 1963; Gavetti et al., 2012).

Four "relational concepts" form a core insight of the behavioral theory of the firm, postulating how firms function (Cyert & March, 1963; Gavetti et al., 2012: 5). The *quasi-resolution of conflict* (1) suggests that organizations resolve goal conflicts through compromises that typically satisfy a fraction of all goals because a full consensus among actors is often not possible. Furthermore, *uncertainty avoidance* (2) postulates that decision makers favor short-term planning over long-term planning in which planning heavily depends on the prediction of uncertain events. In this way, firms avoid and control uncertainty. The postulate of *problemistic search* (3) suggests that decision makers' search for knowledge and solutions is motivated by specific problems and the goal of overcoming performance shortfalls, and that search is also directed by simple models of causality and biased by personal experience and goals (Gavetti et al., 2012). Last, the postulate about *organizational learning* (4) suggests that organizational learning takes place in an iterative process in which firms search for new knowledge and solutions, and subsequently adapt their organizational goals and their rules for search processes depending on what they interpret as having caused an improvement (Gavetti et al., 2012).

The behavioral theory of the firm has had a tremendous influence on organizational and management theory. The perspective on individual decision makers and their *behaviors*, which can only be explained by expanding economic rational-agent theories to include psychological factors, constituted a major departure from previous theories. That perspective paved the way to future research in strategic management, organizational learning, organizational innovation and many other areas of research, especially studies adopting the knowledge-based view of the firm.

The *evolutionary theory of economic exchange* (Nelson & Winter, 1982a, 1982b) recognized that economic theories have limited power to explain the dynamics caused by technological development and competition among firms. Analogous to the theory of evolutionary biology and particularly the idea that the most adaptive species survive, Nelson and Winter suggest that firms continuously search for ways to improve profits. Those firms that are most able to innovate and adapt to changing market demands are the most successful and therefore drive the less successful firms out of business (Nelson & Winter, 1982a).

Taking inspiration from Schumpeter's work on innovation, Nelson and Winter emphasize the role of firms in creating knowledge: "In electronics, pharmaceutical and many other industries, it is plain that competition among firms centrally involves their R&D policies, successes and failures." (Nelson & Winter, 1982b: 114). By accumulating knowledge, particularly tacit knowledge, organizations assemble valuable repertoires of competences (Nelson & Winter, 1982a), which cannot be explained by neoclassical economic theory. Because skills and knowledge are hard to transfer and costly to develop due the tacit nature of knowledge (e.g., Polanyi, 1962), there is significant inertia and path dependency in the strategy development of firms. The implication of this theory for strategic management is that firms need to develop and expand existing competences in a way that leverages their existing assets while still developing new competences through their own knowledge creation and benchmarking of the competition.

The *resource dependence theory* (Pfeffer & Salancik, 1978; Thompson, 1967) extends the behavioral theory of the firm by suggesting that firms pro-actively engage in exchange relationships with other organizations to obtain resources that they depend on. An important departure from previous theory was the argument that one party in an exchange relationship can possess power over the other party, particularly when they possess resources or expertise that the other organization needs but does not possess. Firms can reduce their dependence on their environment by different strategies, such as vertical integration, joint ventures, or political action (Pfeffer & Salancik, 1978). The resource dependence theory shifted the focus from the firm itself to the external actions of the firm and has thus been a cornerstone for the understanding of a firm's interaction with its environment.

A related theory in strategic management and one of the precursors to the knowledge-based view is the *resource-based view of the firm*, which extends the concept of resource dependence and assumes that a firm's resource bundle is the core determinant of its ability to obtain a sustainable competitive advantage (Barney, 1991). Firms must identify, obtain and retain resources with specific properties (i.e., they must be rare, valuable, difficult to imitate, and difficult to substitute) to achieve superior performance (Wernerfelt, 1984). As scholars increasingly recognized knowledge as the strategically most relevant resource of firms (e.g., Grant, 1996; Leonard-Barton, 1992), the knowledge-based view was developed.

The *organizational learning theory* builds on the assumption that firms need to constantly adapt and improve the knowledge that they possess, which goes back to the behavioral theory of the firm, and the assumptions of problemistic search and the adaptation of routines and procedures (Cyert & March, 1963). Scholars have studied the learning of individuals, groups of individuals, and organizations (Fiol & Lyles, 1985) and distinguished different types of learning processes: incremental innovation and radical innovation (March, 1991). The ground-breaking work by March (1991) suggests that firms need to balance incremental improvement (i.e., exploitation) with radical innovation (i.e., exploration) for effective organizational learning.

These theories about organizations form an important foundation for this dissertation, because they provide fundamental explanations for why firms exist, how they function, how they interact with the environment, and how they are different from market mechanisms. However, as the boundaries of contemporary firms are becoming increasingly porous (Tell, Berggren, Brusoni, & Van de Ven, 2017), the traditional model of organizations is becoming increasingly inadequate. In particular, there is a need to extend previous theories and to advance the understanding of the functioning of collaborative knowledge creation *across* the firm boundary.

The processes by which firms engage in collaborative knowledge creation with other organizations or individuals, processes that are governed neither by market mechanisms nor by hierarchical organizing principles (Hardy et al., 2003; Powell, 1990), provide an ideal setting to examine the limits of traditional organizational theory and thereby advance it (Fjeldstad et al., 2012).

2.3. Leadership theory

Managerial leadership is an interpersonal influence process that is particularly relevant in organizations (Yukl, 2010). Yukl defines leadership in organizations as the "process of influencing others to understand and agree about what needs to be done and how to do it, and the process of facilitating individual and collective efforts to accomplish shared objectives" (Yukl, 2010: 26). Leadership research has studied the impact of leadership behaviors on the performance of individuals (e.g., Cole, Walter, & Bruch, 2008; Derue, Nahrgang, Wellman, & Humphrey, 2011), groups (e.g., Burke et al., 2006; Morgeson, DeRue, & Karam, 2010; Zaccaro, Rittman, & Marks, 2001) and organizations (e.g., Bruch & Vogel, 2011).

From a phenomenological viewpoint, researchers often distinguish leadership from management (e.g., Kotter, 1990; Mintzberg, 1973), yet controversies exist regarding whether leadership and management are mutually exclusive (e.g., Zaleznik, 1977). Many scholars view leadership and management as different behaviors or activities that can, but do not necessarily have to, overlap (Bass, 1990; Kotter, 1990; Mintzberg, 1973; Yukl, 2010). Historically, many leadership and organizational theories are often based on the implicit assumption that only individuals with a formal role or responsibility, for example, managers legitimatized by the hierarchical structure of an organization, carry out leadership (von Krogh, Nonaka, et al., 2012; Yukl, 2010).

Early leadership research was highly influenced by the "great man" theories, which suggest that leadership influence is carried out by leaders who possess exceptional characteristics and skills (Borgatta, Bales, & Couch, 1954; Weber, 1947). Consequently, leadership researchers have focused on the behaviors and leadership styles of individual leaders within an organization and tried to answer the questions of why these individuals emerged as leaders and how and when their influence over other individuals – the followers – is most effective. Over many decades, scholars have researched numerous leadership traits and skills to determine when a person will engage in leadership and under what conditions that person's leadership influence will be effective (Yukl, 2010).

A key topic in leadership theory is to explain what makes leadership influence effective – that is, when does the influence of the leader yield the intended action of the follower? Leadership research has studied the characteristics of the leader (e.g., traits, skills, influence tactics), the characteristics of the followers (e.g., traits, attributions about the leader, satisfaction with the leader) and the characteristics of the situation (e.g., task characteristics, power structure, organizational culture) to deduce factors that explain effective leadership, focusing especially on the mechanisms by which leadership influence emerges and how it impacts the followers (Yukl, 2010).

Power is tightly connected to leadership theory, because the concept of power helps us to understand when people are successful in influencing others (Mintzberg, 1983; Pfeffer, 1992; Yukl, 2010). French and Raven distinguish five different types of power depending on its source (French & Raven, 1959; Yukl, 2010). Reward power (1) and coercive power (2) describe a situation in which the target person follows the agent to obtain rewards or avoid punishment, respectively. Legitimate power (3) is the power arising from the perception that the agent has the right to make the request and thus the target person has to follow. Expert power (4) describes the influence of the agent on the target person because the target person believes that the agent has special knowledge about the way to do something. Finally, referent power (5) is the influence that takes place because the target person admires or identifies with the agent and wants to gain the agent's approval. In knowledge-creation contexts such as research and development projects or academic science, expert power plays a particularly important role because hierarchical leadership based on reward and coercive power is weak and the role of knowledge in effective leadership influence is heightened (von Krogh, Nonaka, et al., 2012).

Starting from early work in psychology that examined specific behaviors of leaders, a large part of leadership research is devoted to analyzing the leadership styles of leaders (i.e., types of leadership behaviors) and their efficacy in influencing followers (Yukl, 2010). While there is a plethora of leadership styles, leadership researchers have contrasted two major leadership styles: *transactional* and *transformational leadership* (Avolio, Bass, & Jung, 1999; Bass, 1985, 1990; Burns, 1978). *Transactional leadership* is a leadership style that is based on an exchange relationship in which the leader employs the provision of resources, rewards and disciplinary action to promote the compliance of followers (Avolio et al., 1999; Bass, 1990).

Transformational leadership is a style of leadership that transforms followers to rise above their self-interest by altering their morale, ideals, interests, and values, motivating them to perform better than initially

expected (Bass, 1985; Yukl, 2010). Scholars have described transformational leadership as "the most effective form of leadership" (Bass, 1985; van Knippenberg & Sitkin, 2013: 2) and provide ample evidence that transformational leadership inspires followers to pursue better performance (Judge & Piccolo, 2004; Podsakoff, Mackenzie, Moorman, & Fetter, 1990). The transformational leadership literature typically conceives of transformational leadership as a four-dimensional leadership style, entailing the following components: idealized influence, inspirational motivation, intellectual stimulation and individual consideration (Bass, Bernard & Riggio, Ronald, 2006). Bass (1985) noted that leadership styles are not mutually exclusive and that leaders can employ multiple leadership styles (e.g., transactional and transformational leadership) at the same time.

Scholars have identified leadership as an important driver of knowledge creation (Nonaka & Toyama, 2005; von Krogh, Nonaka, et al., 2012) and innovation within organizations (Crossan & Apaydin, 2010; Jung, Chow, & Wu, 2003; Mumford & Licuanan, 2004; West et al., 2003). Because transformational leaders motivate individuals by promoting a long-term vision, transformation and change (Bass, Bernard & Riggio, Ronald, 2006; Bass, 1985), transformational leadership drives creativity and innovative behavior, behaviors that largely rest on the motivation of individuals (Amabile, 1988). Consequently, the leadership literature portrays transformational leadership as a leadership style with exceptional potential to engender creativity and innovative behavior, thereby driving innovation (Bass, 1985; Eisenbeiss, van Knippenberg, & Boerner, 2008; Jung et al., 2003; Pieterse, Knippenberg, Schippers, & Stam, 2010).

In general, leadership theory concerns leaders at every level of the organization. While some scholars focus on leaders at the higher levels of an organization, as seen in the upper-echelon theory (Hambrick & Mason, 1984) and the strategic leadership theory (Vera & Crossan, 2004), researchers have also explored the leadership influence exercised by leaders at other levels of the organization. For example, scholars have emphasized that leadership theories such as transformational leadership are important to explain not only upper-echelon leadership but also the leadership influence of middle managers (e.g., Bruch & Walter, 2007) and the effect of leadership on cross-functional project teams such as new product development (NPD) teams (e.g., Barcxk & Wilemon, 1989; Berson, Nemanich, Waldman, Galvin, & Keller, 2006).

More recently, leadership research has departed from the assumption that leadership is exercised only by selected individuals and described leadership in groups or teams as a distributed influence process in which every group or team member can take part (Carson, Tesluk, & Marrone, 2007; Gronn, 2002). The shared leadership perspective suggests that leadership responsibility can be shared within a team (Carson et al., 2007; DeRue, Nahrgang, & Ashford, 2015; Wang, Waldman, & Zhang, 2014) and measures, for example, the degree to which teams "rely" on each team member "for leadership" (Carson et al., 2007: 1225). Similarly, functional leadership scholars have theorized that leadership functions in a group can be distributed among team members (Gibb, 1954; Gronn, 2002; Pearce & Conger, 2003). Because teams focused on knowledge-intensive tasks often include members with diverse knowledge and task-relevant expertise, scholars have suggested that shared or distributed forms of leadership are particularly important for orchestrating work in those teams (von Krogh, Nonaka, et al., 2012).

The functional leadership theory takes the perspective that the role of leadership in a group is to identify the needs of the group and to ensure that those needs are taken care of (McGrath, 1962; Morgeson et al., 2010). Scholars have applied functional leadership theory mainly in team contexts (Zaccaro et al., 2001) and provided different typologies of the leadership behaviors that team members engage in (Fleishman et al., 1991; Hiller, Day, & Vance, 2006; Klein, Ziegert, Knight, & Xiao, 2006). Recent work on functional leadership takes up findings from shared and distributed leadership research to suggest that leadership functions in a team can be fulfilled by both formal (i.e., vertical or centralized leadership) and informal (i.e., shared or distributed leadership) leadership (Morgeson et al., 2010).

The *creative leadership* perspective aims to understand how leadership impacts creative work and innovation (Mainemelis, Kark, & Epitropaki, 2015; Mumford & Licuanan, 2004; Mumford, Scott, Gaddis, & Strange, 2002). In this perspective, creative leadership relates to the efforts of leaders to lead their followers towards the attainment of a creative outcome (Mainemelis et al., 2015). Mainemelis and colleagues suggest that three major theoretical conceptualizations of creative leadership can be distinguished. In the first conceptualization, the creative leadership of leaders *facilitates* the followers' creativity by providing direction, structuring idea generation processes and providing a climate supportive of creativity (Mainemelis et al., 2015). In the second conceptualization, the creative leadership of leaders is the major source of creative thinking and behavior and therefore *directs* followers to achieve creative outcomes. In the third conceptualization, creative leadership *integrates* the creative contributions of other members of a group with the leader's own creative work. Each conceptualization describes a slightly different form of creative leadership, yet these forms are interrelated and contribute to the understanding of the profound and manifold influence of leadership on the creative efforts of individuals and the development of new ideas (Mainemelis et al., 2015).

Taken together, leadership theories form an important building block in this dissertation because they provide the fundament for explaining the processes that *facilitate* knowledge creation across the organizational boundary. In interorganizational settings, managerial control based on organizational hierarchy is largely absent (Fjeldstad et al., 2012), which elevates the role of leadership as a managerial lever for knowledge creation in interorganizational settings.

2.4. Social identity theory

Social identity theory suggests that individuals categorize themselves according to social categories and perceived membership in social groups (Ashforth & Mael, 1989; Tajfel & Turner, 1985; Turner & Oakes, 1986). Individuals seek a positive self-identity by "comparing in-groups favorably with out-groups" (Turner & Oakes, 1986: 240). That is, individuals treat others better if they perceive them to be in the same "in-group".

Social categorization processes are closely related to motivational underpinnings of how individuals interact and behave towards others in teams, groups, and organizations (Ashforth & Mael, 1989). An important consequence of these social categorization processes is that individuals prefer to interact with those

individuals who share similar sociodemographic, behavioral and intrapersonal characteristics (McPherson, Smith-Lovin, & Cook, 2001).

Building on insights from social identity theory, scholars have described team identification – the psychological state in which individuals perceive themselves as psychologically intertwined with the fate of the team (Ashforth & Mael, 1989) – as an important antecedent of an individual's willingness to contribute to team work (van Knippenberg, 2000). When individuals identify strongly with the team, they identify less with the different subgroups within a team, thereby reducing counter-productive team processes that would otherwise inhibit team performance, for example, conflict and coalition-forming (Jehn & Bezrukova, 2010). Especially in teams with high diversity, a high team identification is an important lever that fosters the exchange of knowledge and enables faster learning within teams (Van Der Vegt & Bunderson, 2005).

Given these links between identification with a team and individual behavior, social identity theory provides important explanations of what causes individuals in diverse teams (e.g., teams with expertise diversity) to contribute to teamwork. In particular, because engagement in leadership behavior rests on both an individual's skill and motivation (Chan & Drasgow, 2001; Lord & Hall, 1992), motivational processes could possibly help explain leadership engagement in groups.

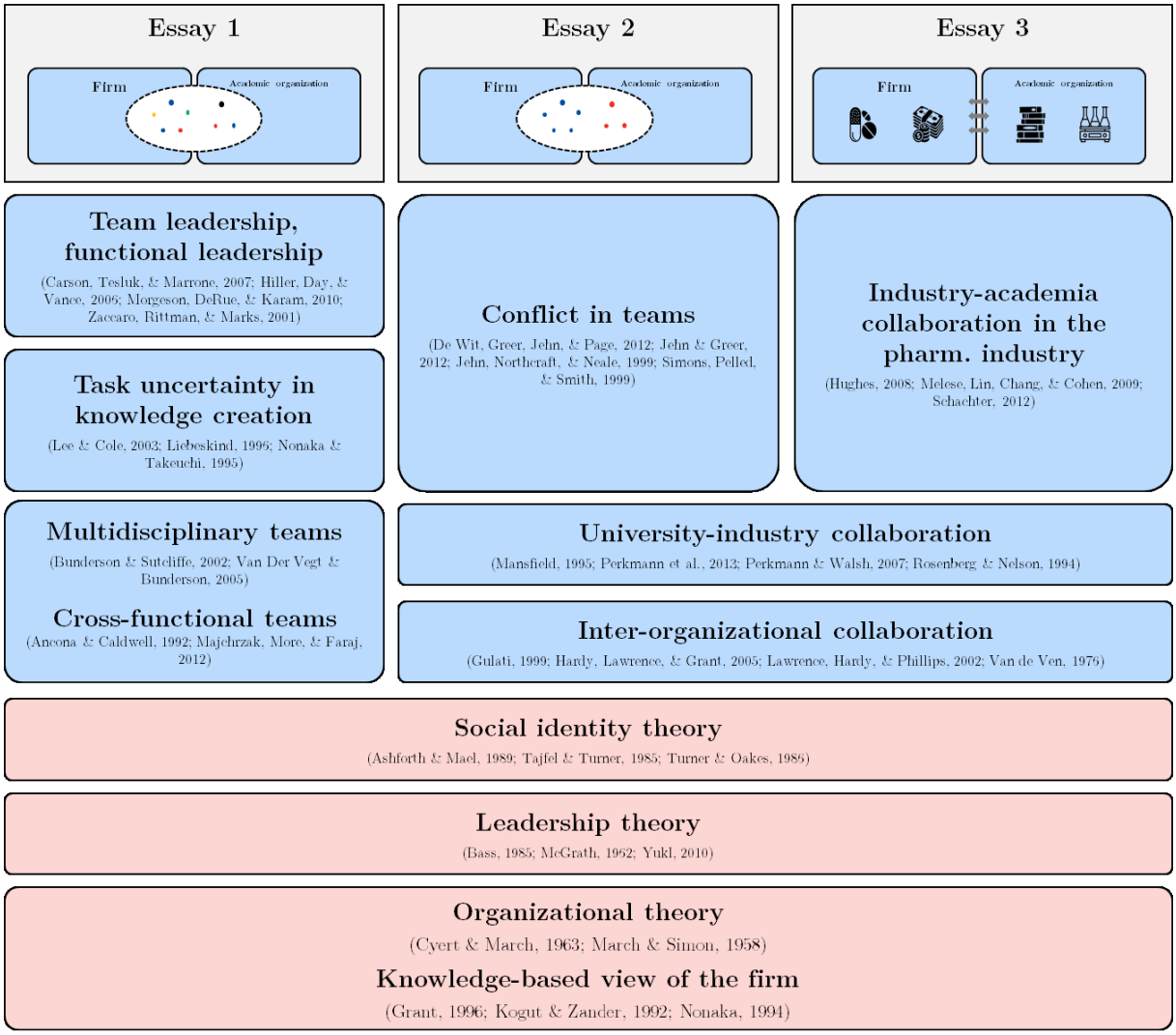


Figure 2.1: Relevant theoretical foundations and selected literature streams in this dissertation

3. Selected Literature

This chapter briefly reviews seven relevant literature streams, summarizes the status quo, and outlines how the three essays link and contribute to these literature streams. Figure 2.1 provides an overview of how the theoretical foundations reviewed in the previous chapter and the selected literature streams reviewed in this chapter relate to the three essays in this dissertation.

According to the knowledge-based view of the firm, firms provide the basis for the interactive processes between individuals that articulate and amplify the knowledge of these individuals, thereby yielding new knowledge (Nonaka, 1994). To understand how knowledge creation takes place in collaborative project teams, this dissertation employs two different perspectives. First, by building on research on teams that feature high expertise diversity among team members – i.e., multidisciplinary and cross-functional teams – essay 1 examines the features of the team context and the team members' behaviors that enable collaborative teams to synthesize new knowledge in the absence of organizational control mechanisms. Second, based on the literature on interorganizational collaboration and university-industry collaboration, essays 2 and 3 zoom in on the peculiarities that arise from the fact that individuals from different organizations work together.

3.1. Multi-disciplinary and cross-functional teams

The literatures on multi-disciplinary (Van Der Vegt & Bunderson, 2005) and cross-functional teams (Ancona & Caldwell, 1992; Majchrzak, More, & Faraj, 2012) study teams with a high expertise diversity – i.e., the differences in team members' knowledge and background expertise (Van Der Vegt & Bunderson, 2005). Expertise diversity can arise from diversity of educational backgrounds (Shin & Zhou, 2007), current and previous functions within organizations (Bunderson & Sutcliffe, 2002) and industry experience (Horwitz & Horwitz, 2007).

Diversity researchers conceive of high expertise diversity in teams as a double-edged sword. On the one hand, high expertise diversity facilitates knowledge creation by providing a larger and more diverse reservoir of task-relevant information and knowledge (Huang, Hsieh, & He, 2014; Singh & Fleming, 2010; Taylor & Greve, 2006). Moreover, high expertise diversity prompts mutual learning and critiques among team members, both of which increase the quality of problem-solving and decision-making in teams (Hoever, van Knippenberg, van Ginkel, & Barkema, 2012; Jehn, Northcraft, & Neale, 1999; van Knippenberg & Schippers, 2007).

On the other hand, higher expertise diversity complicates the interactions between team members (e.g., Carlile, 2004; Kotha, George, & Srikanth, 2013; Van Der Vegt, Bunderson, & Oosterhof, 2006), and those interactions are essential for knowledge creation (Nonaka, 1994). Diverse expertise gives rise to differences in team members' terminology, their understandings of each other, and their interests (Bechky, 2003; Carlile, 2004; Cummings & Kiesler, 2005). Carlile (2002, 2004) has labeled these differences "knowledge boundaries", implying that they hinder collaboration between team members. These differences complicate

teamwork in particular, because they lead to misunderstandings and conflicts between team members (Cronin & Weingart, 2007).

Recent research points to a number of mechanisms that enable teams to capitalize on expertise diversity, such as team learning (Van Der Vegt & Bunderson, 2005), team reflection (Somech, 2006), information processing mechanisms (van Knippenberg, De Dreu, & Homan, 2004) and specific dialogue practices (Majchrzak et al., 2012). Scholars have also started to explore managerial processes that facilitate these mechanisms within teams, such as transformational leadership (Kearney & Gebert, 2009). All these studies contribute to the mounting evidence suggesting that the processes within a team are critical to converting expertise diversity into new knowledge and ideas.

Overall, this literature conceives of multi-disciplinary and cross-functional teams as a major vehicle for knowledge creation within organizations (Kearney, Gebert, & Voelpel, 2009; Lovelace, Shapiro, & Weingart, 2001; Van Der Vegt & Bunderson, 2005). Depending on how it is managed, expertise diversity can be beneficial or detrimental to performance (Kearney & Gebert, 2009; van Knippenberg & Mell, 2016).

The potential benefits and caveats of diverse teams in pursuit of knowledge creation form a central theme of this thesis. Essay 1 builds on the literature on expertise-diversity teams directly and studies the effect of expertise diversity on the knowledge creation performance of collaborative teams that are exposed to varying levels of task uncertainty. Essay 2 studies a related effect: the impact of diverse goals among participants on the functioning and outcomes of the work of collaborative teams. Goal diversity is tightly linked to expertise diversity because individuals with different goals also develop different expertise over time and focus on different aspects of the task when they work together in a team (Carlile, 2004). Therefore, Essays 1 and 2 investigate two salient boundary complexities that result when collaborative project teams span organizational boundaries.

3.2. Uncertainty in knowledge creation

Knowledge creation is an inherently uncertain process (Lee & Cole, 2003; Liebeskind, 1996; Nonaka & Takeuchi, 1995), which has important consequences for teams when they are pursuing knowledge creation.

The uncertainty of knowledge creation impacts the work of teams because it gives rise to task uncertainty– the difference between the information needed for a task and the information available (Argote, Turner, & Fichman, 1989). For knowledge-intensive tasks, task uncertainty entails incomplete information about the target outcome (e.g., the scientific knowledge created in research teams; a product created by product development teams) and cause-and-effect relationships in the knowledge relevant for the task (Dougherty & Dunne, 2012; Liebeskind, 1996).

Uncertainty in knowledge creation can emerge from different sources depending on the knowledge creation task of the team. For example, scholars have described scientific uncertainty in multidisciplinary research teams pursuing scientific research (Ben-Menahem et al., 2016) and technological uncertainty in new product development teams (Song & Montoya-Weiss, 2001).

An important insight of the cross-functional teams literature is that uncertainty – which some scholars have conceptualized as the *novelty* of the knowledge created (Carlile & Rebentisch, 2003) – complicates the work of teams because it increases the requirements for the team to exchange and process knowledge (Carlile, 2002; Majchrzak et al., 2012). This situation occurs because a higher degree of uncertainty or novelty of the task renders previously obtained knowledge less useful and therefore requires team members to integrate more knowledge from other team members as they go about a task (Carlile & Rebentisch, 2003; Majchrzak et al., 2012).

In summary, the inherent uncertainty of knowledge creation is an important contextual factor that likely influences the dynamics of project teams in knowledge-intensive environments (Gibson, 2016). Because organizations often employ teams with high expertise to tackle complex tasks with high uncertainty (Faraj & Yan, 2009; Gardner, Gino, & Staats, 2012; Majchrzak et al., 2012), task uncertainty is an important contingency factor to consider for such teams.

Essay 1 builds on this literature and studies the moderating effect of task uncertainty on the relation between expertise diversity and the knowledge creation performance of collaborative project teams, thereby incorporating the implications of task uncertainty into the research on multidisciplinary teams.

3.3. Interorganizational collaboration

An interorganizational collaboration is a relationship between two (or more) organizations that act collectively to solve complex problems and attain joint goals that they cannot achieve on their own; the organizations accomplish this goal by leveraging differences in their knowledge, skills and resources (Gulati, 1999; Hardy, Lawrence, & Grant, 2005; Lawrence, Hardy, & Phillips, 2002; Van de Ven, 1976). While research on interorganizational collaboration usually begins at the organizational level, scholars emphasize the relevance of individuals who work collectively with individuals from the partnering organizations – often in clearly defined collaborative project teams – while still representing the interests of their own organization (Hardy et al., 2005; Lawrence et al., 2002).

There are manifold forms of interorganizational collaboration, including strategic alliances (Mowery, Oxley, & Silverman, 1996), joint ventures (Kogut, 1988) and research and development (R&D) alliances and partnerships (Perkmann et al., 2013; Sampson, 2007). Prior studies consistently report high failure rates for many types of interorganizational collaboration, thereby hinting that such collaboration is challenging (Gulati, Wohlgezogen, et al., 2012).

Gulati and colleagues (2012) suggest that there are two important requirements for successful collaboration between organizations: *cooperation* and *coordination*. These requirements have been addressed by different scholarly works. Research adopting the *cooperation* perspective investigates the factors that enable

cooperation between the partnering organizations. Scholars portray[1] interorganizational collaborations as relationships between partnering organizations that rely on neither market nor hierarchical mechanisms to ensure cooperation (Lawrence et al., 2002; Powell, 1990). Therefore, scholars adopting this perspective view cooperation as the primary problem in interorganizational collaboration because the partnering organizations have conflicting interests and are driven by different goals and self-interests that can lead to opportunism (Doz, 1996; Gulati, Wohlgezogen, et al., 2012; Williamson, 1985). Researchers adopting this perspective suggest that partnering organizations can foster cooperation by selecting potential partners carefully and by using formal structures and contractual agreements to exercise control and remedy cooperation failures (Gulati, Wohlgezogen, et al., 2012). In addition, trust plays an important role in promoting a good relationship and thereby driving the success of interorganizational collaboration (Zaheer, McEvily, & Perrone, 1998).

By contrast, research on *coordination* in interorganizational collaboration focuses on the challenges of carrying out work inside interorganizational collaboration (Gulati, Wohlgezogen, et al., 2012). As collaboration between organizations inherently involves the division of labor, which implies some level of task interdependence, successful collaboration requires sufficient coordination between organizations to ensure the timely exchange of information and knowledge, the provision of resources for the collaboration, and the synchronization of tasks between the partnering organizations (Gulati, Wohlgezogen, et al., 2012). Scholars have analyzed various mechanisms that are effective at coordinating work within interorganizational collaboration. These mechanisms include formal organizing principles based on the definition of clear authority relations, informal mechanisms such as shared informal norms, and relational mechanisms such as boundary-spanning managers (Gulati, Wohlgezogen, et al., 2012; Kale, Singh, & Perlmutter, 2000). Lawrence and colleagues (2002) view these mechanisms as "structuration" processes that establish new institutions in the interorganizational space. Contrasting these two perspectives, Gulati and colleagues (2012) argue that explaining the functioning of interorganizational collaboration requires taking both cooperation and coordination issues into account.

The strategy literature has recognized the relevance of a firm's engagement in collaboration with other organizations as an important source of sustained competitive advantage and has devoted much attention to the question of how firms can employ interorganizational collaboration as a source of new knowledge (Dyer & Singh, 1998; Hamel, 1991; von Krogh & Roos, 1996). Scholars have developed different models of the competitive dynamics inside interorganizational collaboration, including the possibility that the partnering organizations will compete. For example, Hamel (1991) suggested that alliances between competing firms often lead to asymmetrically distributed benefits for the partnering organizations because one partner might try to exploit the collaboration at the expense of the other partner by internalizing skills and proprietary knowledge of the partner. However, other scholars suggest that alliances can indeed have outcomes that are of equal benefit to both partners, for example R&D alliances that produce new

[1] This view applies to a large variety of collaborative arrangements, but excludes buyer-supplier relationships in which "cooperation is purchased" (Hardy et al., 2005: 58) and arrangements in which the collaborative relationship is coined by ownership, such as the collaboration between subsidiaries (e.g., Srikanth & Puranam, 2014).

knowledge. In such alliances, each partner intends to maintain their distinct and specialized knowledge but incorporates the jointly created knowledge (Schulze, Brojerdi, & von Krogh, 2014). Similarly, Grant and Baden-Fuller (2004) suggested in their knowledge-accessing theory of strategic alliances that firms merely profit from accessing the partner's knowledge when they need it instead of absorbing and exploiting all the partner's knowledge.

Recent research has moved on and suggested that interorganizational collaboration might not be limited to collaboration between organizations. Rather, firms can also collaborate with a whole group of organizations (Fjeldstad et al., 2012) or with other groups of individuals that may not be part of the same organization, as seen when firms collaborate with open-source software development communities during the innovation process (von Hippel & von Krogh, 2003). Moreover, organizational design scholars speak of the emergence of meta-organizations when collaboration between partnering organizations intensifies and reaches a level where the partnering organizations pursue an overarching goal (Fjeldstad et al., 2012; Gulati, Puranam, et al., 2012).

Taken together, the extensive research on interorganizational collaboration provides an important foundation for the analysis of the functioning of collaborative knowledge creation between a firm and other organizations. Essay 2 specifically addresses the topic of cooperation in interorganizational collaboration by analyzing the potential of transformational leadership to achieve cooperation among members of collaborative project teams by reconciling those team members' diverse goals and providing an overall vision. Furthermore, by conceptualizing collaborative projects between firms and universities as team environments in which individuals contribute their unique expertise to achieve a joint outcome, Essay 1 builds on the notion that collaborating organizations can combine their expertise to achieve a joint outcome.

3.4. University-industry collaboration

A special case of interorganizational collaboration – the collaboration of a firm with an academic institution for the purposes of research and development – has attracted the interest of many scholars, particularly in policy research (Perkmann et al., 2013). Early on, the literature provided ample evidence that university-industry collaboration benefits both academic and industrial research and therefore constitutes a driving force of innovation in societies (Cohen, Nelson, & Walsh, 2002; Etzkowitz & Leydesdorff, 2000; Mansfield, 1995; Salter & Martin, 2001). For example, university-industry collaboration facilitates the translation of academic research results into commercial products and services (Perkmann et al., 2013). Therefore, many innovation scholars view university-industry collaboration as an important instance of open innovation (Garriga et al., 2013; Perkmann & Walsh, 2007).

A large part of this literature stream investigates the question of when universities and firms engage in collaboration (for a review, see Perkmann et al., 2013) and how such collaboration is fostered, particularly from the perspective of policymaking. An important feature of university-industry collaboration is the different economic and intellectual benefits that the partnering organizations aim for when engaging in

collaboration (De Fuentes & Dutrénit, 2012; Perkmann et al., 2013). While firms typically aim to obtain a different perspective on how to solve problems and to receive valuable inputs on their internal product and process innovations (De Fuentes & Dutrénit, 2012; Rosenberg & Nelson, 1994), universities aim to acquire new sources of funding, obtain access to proprietary resources of the firm, and acquire new ideas for future research (De Fuentes & Dutrénit, 2012; Meyer-Krahmer & Schmoch, 1998).

Recently, scholars have devoted more attention to the functioning of university-industry collaboration and have particularly highlighted the *dissimilarities* between the partnering organizations (Estrada, Faems, Martin Cruz, & Perez Santana, 2016; Tartari, Salter, & D'Este, 2012) that could potentially represent "barriers" to successful collaboration (Bruneel, D'Este, & Salter, 2010). Given the different motives of private- and public-sector institutions, scholars have described *orientation-based dissimilarities* – the differences in goals and expectations between organizations when they engage in collaboration – as a major obstacle that inhibits collaboration (Estrada et al., 2016). However, research in this domain is at an early stage, and there is much more to learn regarding when dissimilarities in university-industry collaboration impact the outcomes of collaborative projects and what managerial levers help to reduce the potentially negative consequences.

Because this thesis investigates the knowledge creation activities of pharmaceutical companies with academic partners, the literature on university-industry collaboration is of particular importance. This literature stream provides the basis for explaining how the inherent differences between firms and universities, which become visible in the different goals of participants from universities and firms, affect the processes within and the outcomes of collaborative projects, as discussed in Essay 2. Essay 3 picks up the perspective that collaboration between universities and firms – while promising beneficial outcomes to the collaborating organizations – is replete with challenges that can potentially harm project success. Essay 3 then provides an overall account of all challenges perceived by team members of collaborative projects, categorizes them and thereby helps to provide a new perspective on the importance of the challenges arising from goal diversity in collaborative teams.

3.5. Team leadership and functional leadership

In addition to traditional leadership theories that focus on the leadership styles and behaviors of individual leaders in organizations (e.g., transformational leadership theory; Bass, 1985), scholars have developed new theories centering around leadership functions in teams (Morgeson et al., 2010; Zaccaro et al., 2001). This emerging stream of literature recognizes that the leadership of team members performs a critical function in teams and should therefore be considered an important mechanism driving team performance (Morgeson et al., 2010; Zaccaro et al., 2001).

Research on functional leadership theory builds on the observation of McGrath that the role of leadership is "to do, or get done, whatever is not being adequately handled for group needs" (McGrath, 1962: 5). This view perceives leadership as highly instrumental for collaborative teams, thus underlining its core role in driving team effectiveness, without specifying exactly who carries out particular leadership functions

(Morgeson et al., 2010). Morgeson and colleagues suggest that both team members and formal team leaders can carry out almost all leadership functions. According to Zaccaro and colleagues (2001), the influence of leadership behaviors on team effectiveness occurs via cognitive, motivational, effective and coordination processes. Hence, the functional leadership and team leadership literature focus on *what* leadership functions need to be fulfilled for teams to function successfully rather than *who* fulfills these leadership functions.

A key contribution of the functional leadership literature is the development of taxonomies that categorize different leadership behaviors by their function in a team. Going back to the first taxonomic efforts to systematically characterize the leadership behaviors of formal leaders (e.g., Fleishman et al., 1991), team and functional leadership scholars typically describe a set of leadership dimensions that are presumed to facilitate team performance or team effectiveness (Hiller et al., 2006; Morgeson et al., 2010; Zaccaro et al., 2001). For example, Hiller and colleagues (2006) identify four dimensions planning/organizing, problem solving, support/consideration and developing/mentoring.

A related literature starts from the assumptions that leadership roles in a team can be *shared* or *distributed* among a team (Carson et al., 2007; Pearce & Conger, 2003). Therefore, this literature stream analyzes *who* is responsible for leadership in a team but, in most cases, without examining *what* leadership functions these individuals fulfill. Scholars in this literature often employ social network approaches to identify who influences whom in a team (Nicolaides et al., 2014; Wang et al., 2014) or what causes individuals to engage in leadership behavior (DeRue & Ashford, 2010; DeRue et al., 2015).

Overall, the shared leadership and functional leadership literatures provide complementary perspectives about *who* engages in leadership in the team (shared leadership literature) and *what* leadership functions the individuals who engage in leadership fulfill (functional leadership literature). Taken together, both perspectives help us to understand the role of leadership in facilitating the work of teams, particularly in multidisciplinary and cross-functional teams. However, many phenomena are not yet understood, such as the link between expertise diversity in a team and the resulting leadership structure within the team (van Knippenberg & Mell, 2016).

Essay 1 builds on this literature to explain how expertise diversity links to the knowledge creation performance of a team by suggesting that expertise diversity conditions the leadership structure within a team.

Essay 2 takes a different perspective by analyzing the extent to which transformational leadership exercised by the two formal leaders of a collaboration project between two organizations helps to prevent the emergence of conflict from divergent goals within a project team.

While Essay 1 analyzes the functional leadership structure emerging across *all* team members, Essay 2 focuses specifically on the leadership influence of formal team leaders. This approach is in line with the central assumption in the literature that formal and informal leadership fulfill different but complementary roles in a team (Morgeson et al., 2010; von Krogh, Nonaka, et al., 2012). Whereas aligning team members

under a common vision of the knowledge task is a key leadership task of formal leaders (von Krogh, Nonaka, et al., 2012), facilitating teamwork within a team is a leadership task that can be fulfilled by all team members (Morgeson et al., 2010; von Krogh, Nonaka, et al., 2012).

3.6. Conflict in teams

The literature on conflict in teams within organizations suggests that conflict is an important mechanism that explains how the diversity of a team impacts the team's outcomes, including team performance and team member satisfaction (Jehn & Greer, 2012; Jehn et al., 1999). Conflict within a team relates to "the process arising from perceived or real incompatibilities among group members" (Jehn & Greer, 2012: 180) and has a profound impact on the functioning of teams (De Dreu & Weingart, 2003; De Wit, Greer, Jehn, & Page, 2012).

While scholars often study conflict arising from different sources within a team – e.g., task conflict, process conflict and relationship conflict, these different types of conflict often correlate strongly (Bendersky et al., 2014; Simons & Peterson, 2000) and reinforce each other (Jehn & Greer, 2012; Jehn, Greer, Levine, & Szulanski, 2008). Consequently, scholars often start by examining the effects of the overall mean level of "team conflict" before examining the effects of the different conflict types separately (e.g., Jehn & Greer, 2012; Jehn, Rispens, & Thatcher, 2010; Klein, Knight, Ziegert, Lim, & Saltz, 2011).

Conflict researchers suggest that conflict can either unleash beneficial interactions within a team or destroy team dynamics and thereby inhibit teamwork (Bradley, Anderson, Baur, & Klotz, 2015; De Wit et al., 2012). Specifically, previous research argues that small levels of conflict – characterized as situations of "cooperative negotiation" – can have positive effects on team performance (De Dreu & Weingart, 2003: 742). However, high levels of conflict – that is, situations of "hostile negotiation" – have been consistently found to negatively affect team performance (De Dreu & Weingart, 2003: 742; De Wit et al., 2012).

Thus, the literature on conflict in teams within organizations provides important explanations of the processes that take place in collaborative teams, especially those processes that arise as a consequence of diversity among the team members (Jehn & Greer, 2012). Essay 2 builds on this literature to suggest that conflict within a collaborative project team is an important mechanism that explains when differences in the goals of participants from the collaborating parties are of consequence in a collaborative project.

3.7. Industry-academia collaboration in the pharmaceutical industry

The pharmaceutical industry has a long history of collaboration between pharmaceutical firms and academic institutions (Melese et al., 2009). Authors of articles about collaboration in the pharmaceutical industry usually refer to such collaboration as "industry-academia collaboration" (e.g., Melese et al., 2009; Schachter, 2012). Due to the prevalence of industry-academia collaboration in this industry, many authors have published articles about the topic in science journals such as *Nature Reviews Drug Discovery* or *Drug Discovery Today.*

The authors of these articles identify a trend towards increased collaboration and suggest that this trend is, at least partially, a response to the ever-increasing complexity of pharmaceutical research (Eastgate, Schmidt, & Fandrick, 2017; Munos, 2009; Scannell et al., 2012). Several articles highlight how large-scale projects, including long-term institutional arrangements and research consortia, have mushroomed in recent years (Barnes et al., 2009; Hughes, 2008; Vrueh & Crommelin, 2017). For example, the number of research consortia launched per year grew from 1 in 1995 to 46 in 2013 (Lim, 2014). At the same time, bilateral collaborative projects are on the rise. A bibliographic analysis of the publications co-authored by scientists at large pharmaceutical companies showed that the percentage of joint publications with academic partners increased from 62.1% in 1998 to 71.7% in 2009 (Rafols et al., 2014). Scholars further suggest that the intention of pharmaceutical companies to strengthen their ties with academic research can also be observed in the increasing co-location of industrial research centers close to famous universities, for example, in the science hub around Harvard and MIT (Schuhmacher, Gassmann, & Hinder, 2016).

Furthermore, this literature also identifies new collaboration models that extend the "traditional" bilateral collaboration model, in which several researchers from the R&D unit of a pharmaceutical company collaborate with an academic research group (Melese et al., 2009; Schachter, 2012). Many companies have launched company-wide initiatives and have engaged in institutional-level alliances to harness the potential of external R&D even more than before (Wang, Plump, & Ringel, 2015). At the same time, research has described pre-competitive industry consortia[2] and private-public partnerships[3] as "tighter" collaboration models (Wang et al., 2015). Moreover, collaborative projects often not only explore novel scientific phenomena but also aim specifically at co-developing medicines (French et al., 2014; Schachter, 2012).

Many articles argue that the trend towards closer collaboration between industry and academia constitutes a paradigm shift in the way the pharmaceutical industry innovates. Strong links to academic research have become indispensable for firms seeking to stay at the cutting edge of scientific knowledge because the advancement of biopharmaceutical research requires research efforts and knowledge accumulation on a scale and scope that one organization cannot tackle alone (Wagner et al., 2010) Many companies have also reduced their investments in basic research and early-stage discovery (Ladbury, Hall, & Skidmore, 2014; Simpson & Reichman, 2014), which increases their reliance on academic collaboration as a way to obtain the scientific knowledge that is critical for drug development. In particular, many companies focus only on the targets with the strongest validation and commercial potential and hope to source novel targets through external partnerships (Ladbury et al., 2014; Simpson & Reichman, 2014). To secure access to critical knowledge, many pharmaceutical companies pursue strategic investments to ensure tight links with academic research communities (Hughes, 2008; Ledford, 2011; Schuhmacher et al., 2016). Consequently, the need for companies to collaborate with academic institutions is unprecedentedly high as companies continue to conduct less and less scientific research internally (Arora, Belenzon, & Patacconi, 2017).

[2] Partnerships between companies that typically aim at developing resources or research input that is not directly marketable but is nevertheless useful to all participating companies.

[3] Partnerships that include both companies and public research institutes, often facilitated by government incentives (PPPs).

At the same time, governments are providing more incentives for industry and academia to collaborate. This includes monetary incentives to collaborate in public-private partnerships to work on topics in new and neglected areas of research (Frail et al., 2015). Such setups aim to exploit synergies between the public and private sectors by pooling knowledge and resources from the partnering organizations (Lim, 2014; Vrueh & Crommelin, 2017). In addition, governments demand a stronger focus on "translational science" with a high relevance for human health from public research institutions, to justify their public funding (Wang et al., 2015). In summary, the literature points to the growing prominence of industry-academia collaboration in the pharmaceutical industry.

Furthermore, the literature on industry-academia collaboration in the pharmaceutical industry also suggests that this form of collaboration is challenging. Authors of many articles on the topic suggest that the differences between the public and private sectors are the most significant roadblock to successful collaboration (Bruneel et al., 2010; Schachter, 2012; Wang et al., 2015). The literature speaks of "incompatible approaches" (Paul et al., 2010), "clash of cultures" (Birnbaum, 2016), "conflicting goals" (Wellenreuther, Keppler, Mumberg, Ziegelbauer, & Lessl, 2012) and "conflicting incentive structures" (Altshuler et al., 2010), suggesting that the differences between the public and private sector are a major obstacle to collaboration. Yet, while many articles point at different complications within collaborative projects, empirical evidence on those challenges remains scarce.

This practice-oriented literature provides the departure point for Essay 3, which aims to provide a categorization of all challenges and their relevance to industry-academia collaboration. Essay 3 therefore provides an overview of the topics relevant in industry-academia collaboration and thereby puts Essays 1 and 2 into perpsective, which focus on specific aspects. Finally, Essay 3, with its focus on the pharmaceutical industry, provides an important basis for discussion of the practical implications of this dissertation, which are directed to practitioners in that industry.

Part Two: Empirical Approach

4. Context and Data Source

All essays in this dissertation are based on data collected from Novartis AG (henceforth: Novartis) and its academic collaboration partners. The author collected both quantitative and qualitative data from 209 research collaborations at Novartis' research division. The author used a three-wave survey[4] as the main data source for this dissertation and also conducted 32 exploratory interviews before the launch of the survey.

The first two essays in this dissertation employ formal *hypothesis testing* research (Edmondson & McManus, 2007) in a deductive research design. State-of-the-art psychometric analyses of quantitative data provide rigorous empirical evidence to test theoretical propositions. The third essay identifies themes in participants' responses to an open-ended question using an inductive qualitative methodology and subsequently tests the impact of the themes on project performance using quantitative analyses of variance.

4.1. Drug discovery research

The research in this dissertation studies collaborative project teams pursuing drug discovery research – the first step in pharmaceutical research. The development of a new drug is a process that spans 10-15 years and usually involves the following steps (Ding, 2014): (1) drug discovery (3–6 years), (2) clinical trials (6–7 years), and (3) Food and Drug Administration (FDA) review (0.5–2 years).

Pre-clinical drug discovery research is about identifying potential drug candidates up to a "proof of concept" and typically entails three major steps (Blass, 2015; Gassmann, Reepmeyer, & Zedtwitz, 2008). First, during the *target identification and validation* phase, scientists identify the disease-causing biological agent – typically a molecule such as a protein or a nucleic acid – as "the target" using various biomedical research methods. Subsequently, scientists verify the target by testing whether the target is indeed responsible for causing the disease, for example, by modulating the target and examining the effect on the disease. Second, in the *screening and lead-finding* phase, scientists employ various strategies to find a suitable drug candidate that is active against the target – a process including both focused screening techniques (that is, testing a few drug candidates based on previous knowledge) and large-scale high-throughput screening techniques against compound libraries. Third, in the *lead optimization* phase, the scientists optimize the identified drug candidate by tuning and changing its structure and properties to yield better characteristics, such as higher efficacy, better receptivity or improved safety in the human body. Subsequently, the drug candidate enters large-scale testing in clinical trials.

Drug discovery research is characterized by the explorative nature of scientific discovery, such that scientific uncertainty is omnipresent in the daily work of scientists (Dougherty & Dunne, 2011). Thus,

[4] The three-wave survey consisted of one questionnaire to all project team members at time T1, a second follow-up questionnaire to all project team members at T2 (approximately 6 months after T1), and separate questionnaire to senior managers at time T3 (about 2 months after T2) to probe the dependent variables separately.

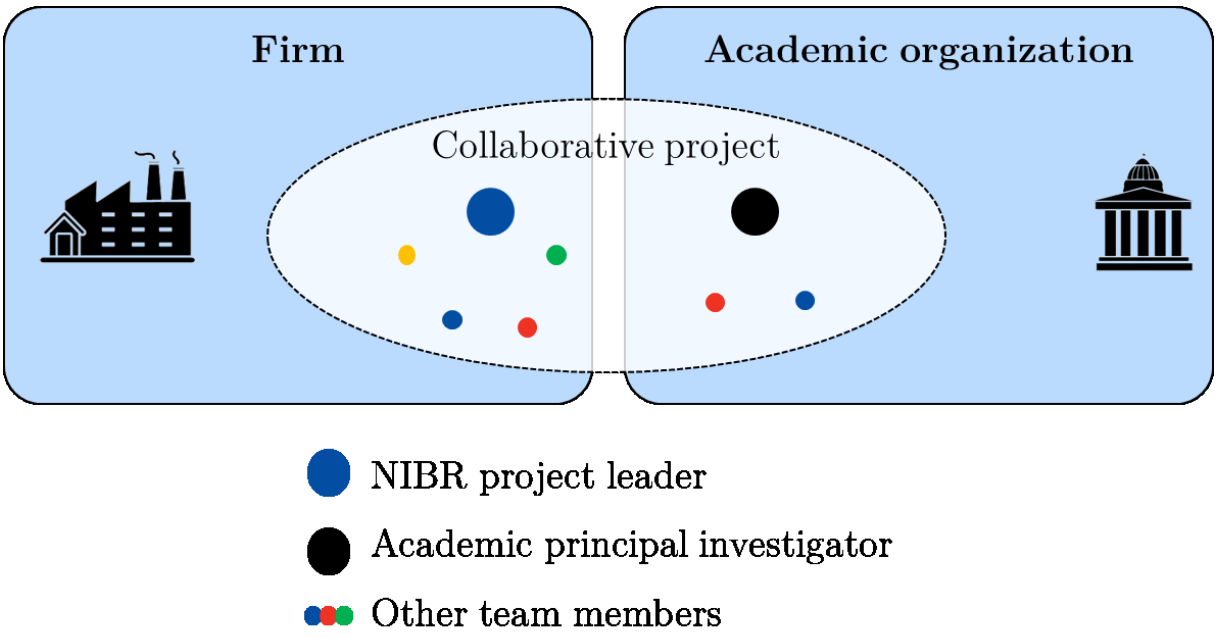


Figure 4.1: Typical set-up of a collaborative project in the sample

drug discovery teams constitute an ideal context for exploring the link between expertise diversity and the performance of knowledge teams under different levels of task uncertainty (Essay 1).

4.2. The pharmaceutical industry

The pharmaceutical industry is one of the most research-intensive industries (Jaruzelski et al., 2017) with a long and costly product development cycle. For every compound that reaches the market as an approved drug in the United States, researchers test between 5,000 to 10,000 compounds, which takes on average about 10-15 years (Ding, 2014) and costs about 2.6 billion U.S. Dollars according to recent estimates (PhRMA, 2016).

Given this complex development process requiring significant scientific expertise (Gassmann et al., 2008), pharmaceutical companies frequently collaborate with other academic institutions such as research institutes, universities, and hospitals (Tralau-Stewart, Wyatt, Kleyn, & Ayad, 2009). The omnipresence of collaboration makes this industry especially suitable for exploring the consequences of diverse goals inside a collaborative knowledge creation project team (Essay 2).

4.3. Research context

Research collaboration projects between Novartis and its academic partners, such as universities and hospitals, constitute the main data sample for all three essays in this dissertation. Novartis is a global pharmaceutical company with sales operations in 155 countries, a revenue of 48.5 billion U.S. Dollars and a headcount of more than 123,000 employees worldwide in 2016 (Novartis AG, 2017). Novartis concentrates

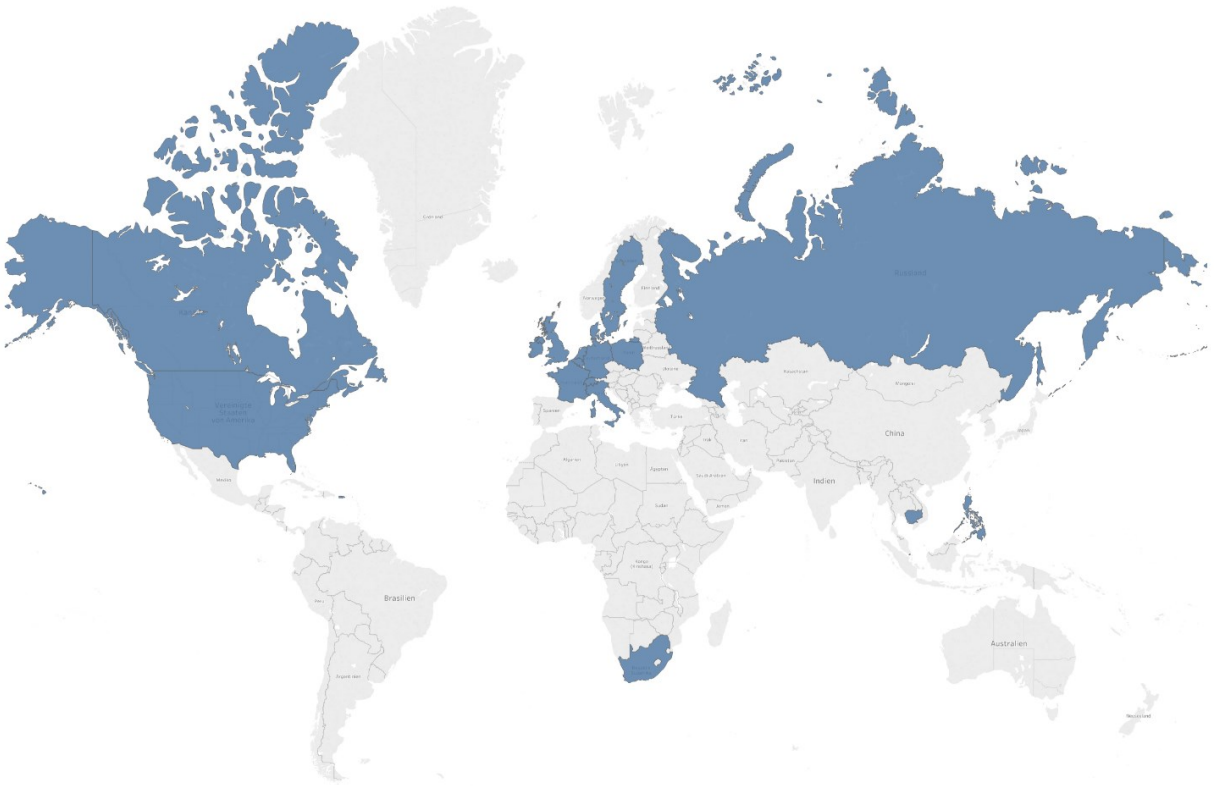


Figure 4.2: Countries (in blue) in which the partnering academic institutions are located

its global research activities at *The Novartis Institutes for Biomedical Research* (NIBR), a cross-country research sub-organization with more than 6000 scientists, physicians and business professionals (Novartis AG, 2016).

Scientists at the NIBR frequently collaborate with biotech firms and academic collaborators in collaborative projects to support internal research activities. These collaborative projects are based on formal contracts that regulate the appropriation of economic returns and, at times, the procedural details of the project (e.g., the resource commitment of collaborating organizations, confidentiality, etc.).

In a typical project (see Figure 4.1 for an illustration), there is one person from each organization responsible for the collaboration: a project leader from Novartis (called "the project champion" among Novartis scientists) and a principal investigator from the academic partner (usually a professor, senior researcher, or post-doc). The project leaders and other members of the collaboration project have roles and responsibilities within their respective organizations in addition to those associated with the collaboration. Their formal roles may be situated at different levels of the organizational hierarchy. For example, a project team may consist of a laboratory head and several scientists at Novartis as well as a full professor and several assistant professors from a university.

4.4. Data access and data collection

A research collaboration with the senior management of the Novartis Institutes for Biomedical Research (NIBR) allowed the collection of data from Novartis' collaborative research projects under a research agreement with confidentiality terms. The research collaboration took place from September 2014 to September 2016 and entailed both exploratory qualitative research and a large-scale quantitative survey.

Before the start of the main data collection, the author conducted exploratory semi-structured interviews to facilitate the contextualization of the theoretical phenomena and aid the development of suitable measures. Some of the interviewees were gatekeepers at NIBR, who later provided critical access to projects within their responsibility.

In the main data collection, the author collected quantitative data from 209 research collaboration projects in multiple steps. First, the *Operational Alliances* unit[5] of NIBR provided a list of all contracts that have been signed with external partners within the last ten years. In collaboration with two senior managers from the *Program Office*[6] of NIBR, the author assembled a list of all projects that fit the sampling criteria of the study. These two senior managers had extensive experience in managing collaborative projects and oversaw NIBR's collaboration activities with external partners.

Because this dissertation focuses on knowledge creation in collaborative project teams, only those collaborative projects that involved joint knowledge creation or some form of intellectual exchange were selected. Projects that involved only transactive activities between organizations (i.e., the main purpose of the project was the transfer of a good or intellectual capital, such as technology transfer, purchase of technology, in-licensing and out-licensing; De Clercq & Dimov, 2008; Gambardella, Giuri, & Luzzi, 2007) were excluded. In addition, to ensure that projects lasted until the second survey was administered, the sample was restricted to projects that (i) were active in September 2015 and (ii) were expected to run for at least another six months. This procedure yielded a final sample of 209 projects.

Subsequently, the author obtained additional information about these projects from the *Operational Alliances*; this information included the project title, the agreement type, the department within NIBR, the subject, the name and contact information of the project leader at NIBR and of the principal investigator at the collaborating academic institution, among other details. To identify the project members, the first survey asked the project leader from NIBR and the principal investigator from the academic organizations to identify the other members of the project team from their organization by providing their email. The author followed up via email or phone if the project leaders did not provide the contact details in the survey.

[5] A headquarter unit in charge of handling the legal matters with external partners, except strategic alliances with financial investments above 500 000 USD.

[6] A headquarter unit in charge of planning and supporting internal research activities.

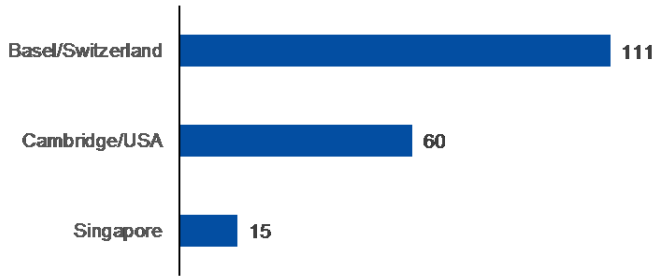


Figure 4.4: Projects in the sample by the NIBR research site

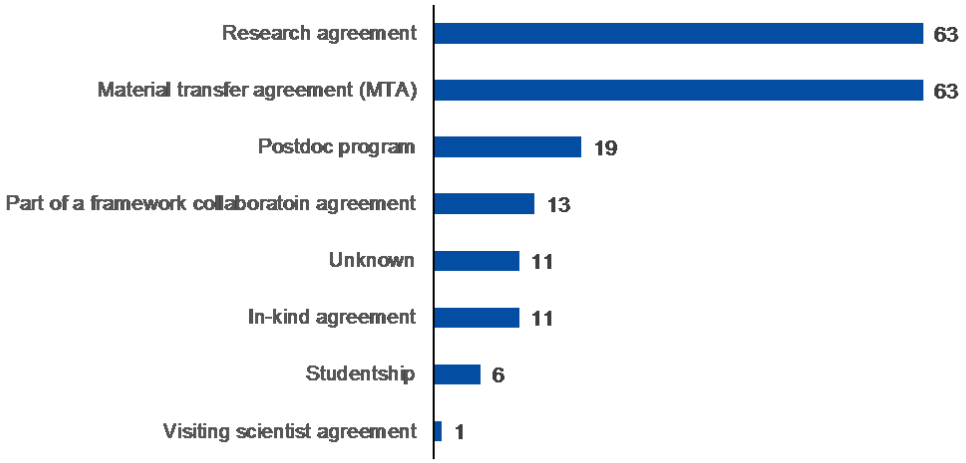


Figure 4.3: Projects by legal agreement type

The author administered three questionnaires using the browser-based survey software Qualtrics (Snow, 2018). The questionnaires included predominantly quantitative questions plus a qualitative question for Essay 3. Questionnaires 1 and 2 were sent to all project team members, including the project leaders, with an interval of 6 months. In both questionnaires, project members were stratified into formally appointed project leaders (i.e., the project leader from NIBR and the principal investigator from the academic partner) and project members. Project leaders and project members received slightly different question sets. For example, project members rated the transformational leadership of the formal project managers, and project leaders reported specific project-level data, such as contractual details or the start date of the project.

Approximately 2 months after the respondents returned questionnaire 2, the author administered a third questionnaire to senior managers at NIBR who were not part of the project teams in the sample. The purpose of the third questionnaire was to obtain an external rating of project performance.

All survey participants received invitations to take the survey via personalized emails, which included a personalized greeting and a description of the collaborative project that is the subject of the survey. The

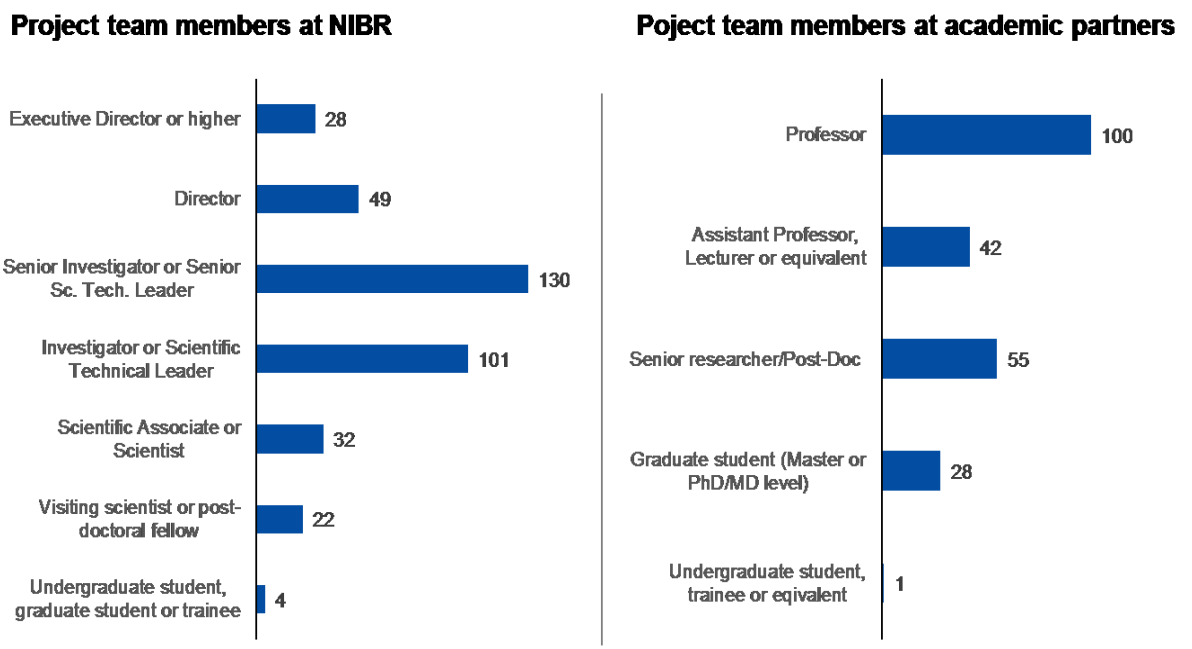


Figure 4.5: Job titles of the project members in the sample

author developed a database-based tracking system that allowed the automatic administration of personalized emails to the participants and the tracking of the survey responses. With this system, the author and a senior manager at NIBR sent out the email invitations via personal email accounts to make them appear as personalized rather than automatically generated emails. This approach also allowed participants to reply directly to the invitation email if they had questions or concerns about the survey.

To further encourage participants to take the survey, participants received a supportive email from the senior management of NIBR, stressing the importance of the survey. Furthermore, all survey participants received an offer to obtain an electronic gift voucher (value: ca. 10 USD, depending on the country) upon completion of the survey. In case of non-response, the author followed with up to three reminding emails (4 weeks, 6 weeks, and 8 weeks later). In case a participant did not respond after the reminding emails, the author followed up via telephone to encourage the participation in the survey.

4.5. Data sample

Out of all 209 projects that fulfilled thr sampling criteria, the author received survey responses from 187 projects (an 89% response rate) and from 669 project team members (an 85% response rate).

The projects in the sample were located at the three major sites of Novartis and covered different cultural contexts. At NIBR, projects were spread over its three major research sites in Cambridge/USA, Basel/Switzerland and Singapore, as Figure 4.4 outlines. The academic partners were spread over 18 different countries, as shown in Figure 4.2.

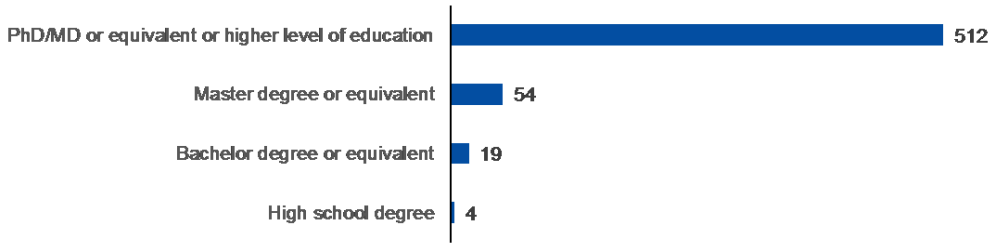


Figure 4.6: Educational background of the project team members in the sample

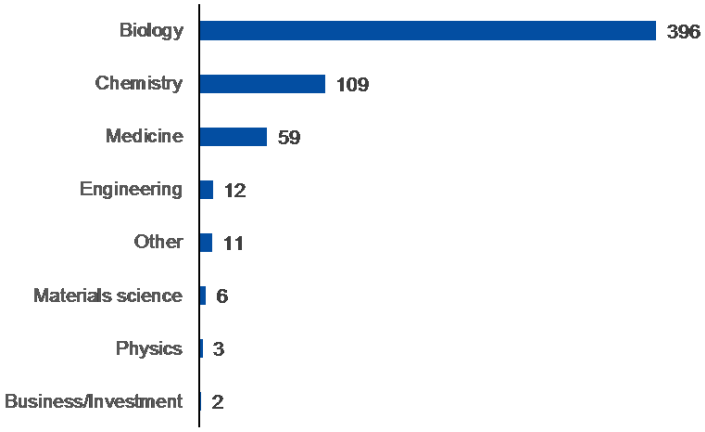


Figure 4.7: Scientific backgrounds (main disciplines) of the project team members in the sample

The projects in the sample were also based on different contractual agreements as shown in Figure 4.3. Note that although the contract type called "material transfer agreement" suggested a purely transactive project, the explorative interviews with industry-academia liaison professionals at NIBR and with technology transfer office (TTO) professionals at two public universities suggest that this category is often used also for collaborative, knowledge-creating projects. One reason for this is that material transfer agreements (MTAs) usually take less time and effort to process and are often handled expediently. Explorative interviews with senior managers at NIBR with extensive collaboration experience confirmed that MTAs often include extensive collaboration projects with significant knowledge production. Therefore, all projects based on MTAs were included as potential knowledge creation projects. To confirm that all projects in the sample are indeed collaborative projects featuring knowledge creation, all project leaders were asked to confirm that their project was "a collaborative interaction or intellectual exchange with [Novartis/the academic partner]".

In total, 669 individual project team members, distributed among 187 of the 209 projects in the sample, completed the first survey. Project team members occupied different roles at NIBR or at their academic

institutions as reported in Figure 4.5[7] and were highly educated, with 87% holding a PhD/MD or equivalent degree (see Figure 4.6). As Figure 4.7 illustrates, the project team members had diverse backgrounds, with a majority having a background in biology or related disciplines.

The resulting data sample opens up an unprecedented opportunity to research the functioning and management of the collaborative knowledge creation of a firm with partnering organizations. The data sample covers different research areas within Novartis, spans different cultural contexts and involves many different partnering organizations, thus yielding a high degree of representativity.

[7] The numbers in the figures do not add up to the total number of 699 responses, because some participants have not answered the corresponding question (a response was not required to conclude the survey).

5. Methodological Approach

This chapter provides an overview of the quantitative methodology employed in Essay 1 and 2 and the mixed methodology employed in Essay 3.

5.1. Empirical challenges and research design

Essays 1 and 2 employ formal hypothesis testing using state-of-the-art quantitative methods. Empirical quantitative research is constrained by the possibility that the observed relationships could be inflated due to different sources of potential biases, most notably *common method* and *common source bias* (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003).

To mitigate potential bias, the research design employs three remedies. First, a three-wave survey design allows for *temporal separation* between key criterion and predictor variables, which possibly reduces bias by decreasing the respondent's ability or motivation to recall answers to previous questions and by lowering the risk of reverse causality (Podsakoff, MacKenzie, & Podsakoff, 2012).

Second, the main theoretical concepts have been measured using *different methodological approaches*. Some variables in this study are measured by quantitative questions that probe the participant's perception of the group or their own behaviors using Likert scales, whereas other variables, such as expertise diversity, are calculated from the configuration of the team members' backgrounds within a team.

Third, the dependent variables and the predictors are probed using data from *different sources* to reduce potential common source bias (Podsakoff et al., 2012). Senior managers, who were not part of the project team, rated the dependent variables for Essays 1 and 2 (i.e., knowledge creation performance and goal attainment) and the moderator variable (i.e., task uncertainty) in Essay 1. The project team members rated the remaining variables. Overall, because the research design includes state-of-the-art methodological remedies against method bias, such bias is unlikely to affect the reliability of the results in this thesis.

5.2. Statistical analysis

To test the theoretical models that were developed deductively based on previous theory, essays 1 and 2 employ a formal hypothesis testing approach using quantitative methods (Edmondson & McManus, 2007). For most of the constructs used in the theoretical models in essays 1 and 2, psychometric tests already existed and were employed.

For these two essays, the unit of analysis is the team. Yet, the data were collected from the questionnaires collected from individual team members (except the dependent variables, which were assessed using one external senior manager per team), which requires an aggregation of the data. Depending on the concept, different methods of aggregation have been employed. If a team-level variable is conceptualized as the summation of the individual-level contribution regardless of the variance at the individual level (e.g., the

total amount of leadership behaviors within a team), the team-level variable can be calculated by taking the mean of the individual level (Chan, 1998). In contrast, if the team-level variable is conceptualized as the consensus of the lower-level units (e.g., the overall level of conflict within a team), the computation of the average level per team requires testing the validity of the aggregation (Chan, 1998), for example, using the intra-class correlation coefficients (ICCs; Bliese, 2000).

The quantitative data analysis for the first two essays proceeded in multiple steps. As a first step, the data were cleaned, aggregated and prepared for analysis in STATA. Then, two different analytical procedures were used. In the first essay, only two variables were latent variables[8]; the other variables (i.e., expertise diversity and team leadership asymmetry) were measured on a continuous scale. Therefore, the statistical analysis was carried out using the PROCESS macro by Hayes (2013) for the program IBM SPSS, which provides state-of-the-art testing of moderation and mediating effects using a series of ordinary linear regressions.

In Essay 2, all except one variable were latent variables, making a structural equation modeling (SEM) approach feasible. Thus, Essay 2 analyses the theoretical model using SEM with the program Mplus 8.0 (Muthén & Muthén, 2017). Mplus is the only program featuring the computation of interactions between latent variables and the estimation of overall conditional indirect effects.

In both essays 1 and 2, the analysis entails the estimation of interaction effects computed by product terms between two variables. The estimates for these product terms could be inflated if the two variables are not normally distributed (Hayes, 2013). As a remedy, Hayes' recommendation to use the bootstrapping resampling technique is used in both the PROCESS macro for Essay 1 and the Mplus software for Essay 2.

5.3. Qualitative data analysis

Essay 3 aims at identifying and categorizing the whole spectrum of challenges present in university-industry collaboration and employs a mixed method. First, the essays analyze the qualitative data obtained from the answers of the project members to an open-ended question in questionnaire 1. To analyze these qualitative data, Essay 3 employs a qualitative methodology based on thematic analysis (Braun & Clarke, 2006) and the "Gioia method", an established technique for analyzing qualitative data (Gioia, Corley, & Hamilton, 2012; Miles, Huberman, & Saldana, 2014).

Second, this essay tests the impact of different categories of challenges on project performance six months later by assigning previously measured factors to the challenge categories obtained from the qualitative analysis. By conducting an analysis of variance (ANOVA) of these factors and project performance, the

[8] A latent variable is a variable that is not directly observed or measured, but constructed from a set of variables such as, for example, a set of Likert-type questions that probe the same construct.

Essay	Dependent variable	Method	Sample[9]
Essay 1	Knowledge creation performance (evaluated by external senior managers)	Linear regression analysis, PROCESS macro to test moderated mediation effects (Hayes, 2013)	Project teams with ≥ 3 team members (128 project teams)
Essay 2	Project success (goal attainment; evaluated by external senior managers)	Structural equation modelling (SEM)	Project teams with ≥ 3 team members, at least 1 team member from NIBR and 1 team member from the academic partner (120 project teams)
Essay 3	*In the quantitative analysis*: Perceived project performance (evaluated by project team leaders)	Qualitative analysis of responses to an open-ended questions; quantitative analysis using ANOVAs	*Qualitative analysis*: All projects teams in the sample (187 project teams) *Quantitative analysis*: Project teams with ≥ 3 team members (128 project teams)

Table 5.1: Dependent variables, methodical approaches and samples in the essays in this dissertation

essays tests whether projects that exhibit challenges to a higher degree also exhibit lower average project performance. The details of this methodology are described in the method appendix to Essay 3.

5.4. Data stratification

The empirical analysis in all three essays in this dissertation is based on data from the same population. However, all three essays investigate different research questions, have different dependent variables and employ different methodologies (see Table 5.1 for an overview). Because all essays have a different focus in both the theoretical and empirical analysis, a separate analysis of different research questions is justified (Kirkman & Chen, 2011).

[9] The number in brackets indicates the sample size *before* the analysis procedure. During the course of the analysis, missing variables led to further reduction of the sample size as described in the individual essays. For examples, because there were missing values in the mediating or dependent variables for some project teams, these projects teams have been automatically excluded from the analysis.

Part Three: Overview of the Essays in this Dissertation

6. Essay Summaries

This dissertation investigates the functioning and management of collaborative knowledge creation between firms and partnering organizations based on three co-authored essays. These essays take different perspectives as Figure 6.1 illustrates. The first two essays each investigate one specific boundary complexity relevant in boundary-spanning knowledge work in depth: (1) diversity of expertise within a collaboration team and (2) diversity of goals between the partnering organizations. The third essay takes a more general perspective by categorizing all challenges present in industry-academia collaboration and investigating their impact on project performance.

All three essays have been published in or submitted to peer-reviewed journals and form the main contribution of this dissertation. Whereas the first two essays contribute mainly to management theory, the last essay focuses on the pharmaceutical industry and is therefore particularly relevant both to the industry-specific literature and to practitioners. Table 6.1 provides an overview of the publication status of all essays and the contributions of the author to each essay.

6.1. Summary of Essay 1: Folding under Uncertainty? Exploring the Link between Expertise Diversity and Performance of Knowledge Teams

6.1.1. Goal and research question

The first essay examines how expertise diversity within teams impacts knowledge creation performance. Because knowledge creation is typically carried out in project teams that include specialists with diverse knowledge and skills, such teams exhibit high expertise diversity (Van Der Vegt & Bunderson, 2005). Knowledge teams are omnipresent within organizations (e.g., multidisciplinary teams; Ben-Menahem et al., 2016; cross-functional-teams, Majchrzak et al., 2012) and in interorganizational collaboration (e.g., industry-academia collaboration, Perkmann & Walsh, 2007).

At the same time, knowledge-intensive tasks often feature a significant degree of uncertainty (Liebeskind, 1996; Song & Montoya-Weiss, 2001). Organizations often compile teams with high expertise diversity to tackle knowledge-intensive tasks that feature a high degree of uncertainty (e.g., Ben-Menahem et al., 2016). However, the precise impact of expertise diversity on the knowledge creation performance of a team when uncertainty is high is unknown. So far, scholars have argued for both beneficial and counterproductive effects of expertise diversity on the team performance of knowledge teams; yet, the theoretical understanding of the mechanism by which expertise diversity impacts team performance remains poorly understood (van Knippenberg & Mell, 2016; van Knippenberg & Schippers, 2007).

The goal of this essay is to develop a new theory on the mechanism by which expertise diversity impacts the team performance of knowledge teams, contingent on the level of task uncertainty. Specifically, the essay builds on the team leadership literature to suggest that the leadership distribution within the team – a form of behavioral diversity (van Knippenberg & Mell, 2016) – mediates the effect of expertise diversity

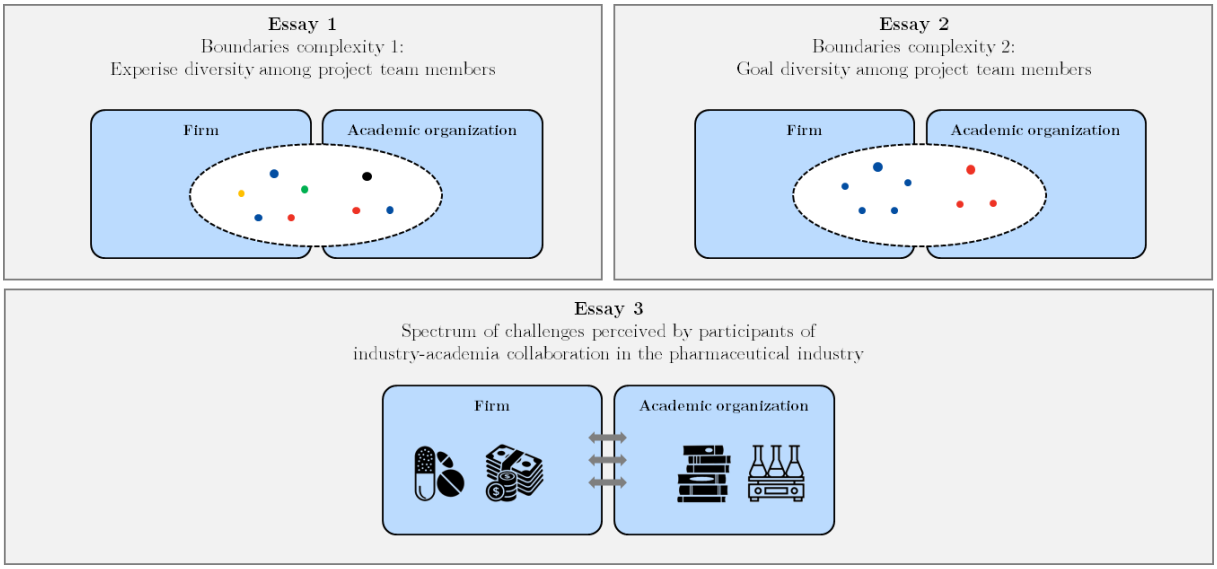


Figure 6.1: Different boundary complexities investigated by the three essays in this dissertation

on team performance, contingent on the level of task uncertainty. The research question guiding this essay is *how expertise diversity impacts team performance under different levels of task uncertainty.*

6.1.2. Methodological approach

This essay develops a new theoretical model based on the team diversity and team leadership literature and validates this model using empirical data from 99 drug discovery research teams, staffed by researchers from both Novartis and its academic collaboration partners. The author collected data from both the project members and external senior managers in three survey waves, as chapter 4 explains in detail.

Using the PROCESS macro of Hayes (2013), this essay tests a mediated moderation model and computes boot-strapped estimates of the overall indirect effects.

6.1.3. Findings and contributions to theory and practice

Essay 1 reveals how the configurational characteristics of knowledge teams affect the team outcomes via the behavioral dynamics that develop inside these teams. The findings suggest that team leadership asymmetry mediates the moderation of task uncertainty on the relationship between expertise diversity and a team's knowledge creation performance. While for high levels of task uncertainty, expertise diversity had a negative effect on knowledge creation performance, this effect is positive for low levels of task uncertainty. Moreover, the analysis revealed that team identification decreases the emergence of team leadership asymmetry and thereby reduces the negative indirect effect of expertise diversity on team performance at high levels of task uncertainty.

Essay 1 contributes to the literature by putting a spotlight on the behavioral processes that *indirectly* facilitate knowledge creation within a team. To date, team researchers have mainly focused on the processes

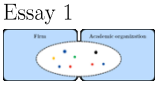
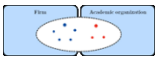
Essay	Title	Co-authors	Contribution of the author	Publication status
Essay 1 	Folding under Uncertainty? Exploring the Link between Expertise Diversity and Performance of Knowledge Teams	Vivianna Fang He, **Thomas Gersdorf,** Georg von Krogh	Theoretical development, data collection, data analysis, preparation of the manuscript	*Revise and Resubmit (1st round)* at ***Journal of Applied Psychology***
Essay 2 	The impact of orientation-based dissimilarities in university–industry collaboration on project outcomes: Investigating the critical roles of conflict and transformational leadership	**Thomas Gersdorf,** Vivianna Fang He, Georg von Krogh	Theoretical development, data collection, data analysis, preparation of the manuscript	*Revise and Resubmit (1st round)* at **Research Policy**
Essay 3 	Demystifying industry–academia collaboration	**Thomas Gersdorf**, Vivianna Fang He, Ann Schlesinger, Guido Koch, Dominic Ehrismann, Hans Widmer, Georg von Krogh	Theoretical development, data collection, data analysis, preparation of the manuscript	Published in ***Nature Reviews Drug Discovery*** (forthcoming)

Table 6.1: Contribution of the author and publication status for the essays in this dissertation

that *directly* facilitate knowledge creation by helping the team members of knowledge teams process information, e.g., studies have examined information elaboration or knowledge sharing (Hoever et al., 2012; Huang et al., 2014). Essay 1 augments this perspective by suggesting a set of facilitating leadership processes that facilitate teamwork and thereby drive knowledge creation performance in collaborative teams.

Furthermore, Essay 1 contributes to the literature on workgroup diversity by drawing on recent developments on the topic of emergent diversity (van Knippenberg & Mell, 2016). The essays answer a call to examine the emergent diversity (the diversity of emergent team states and team behaviors) in addition to the configurational diversity (the diversity of team members' stable characteristics) of teams. By teasing out how configurational diversity (i.e., expertise diversity) affects emergent diversity (i.e., team leadership asymmetry) within a team, this essay provides a representative example of when emergent diversity has important consequences for team outcomes.

Moreover, by building on the functional and team leadership literature, Essay 1 also contributes to those literature streams in two ways. First, it shows that team members' engagement in functional or shared leadership is not necessarily homogeneous; rather, asymmetric leadership contributions have important consequences for team outcomes. Second, the findings suggest that team members' engagement in leadership is a function of both their skills and their motivation to engage. A higher team identification increases leadership engagement and thereby smooths the differences in leadership engagement that emerge in a team as a result of expertise diversity.

Last, Essay 1 carries important implications for the management of knowledge teams. In particular, because the essay finds that the benefits of expertise diversity sharply decline under high task uncertainty, teams faced with highly uncertain tasks (e.g., explorative research) benefit from lower levels of expertise diversity. Team leaders should limit expertise diversity within teams exposed to high task uncertainty, for example, by breaking large project teams down into sub-teams or by including team members with specialized expertise dynamically depending on the project's demands (Ben-Menahem et al., 2016).

6.1.4. Contribution of the author

The author collected data for this essay and carried out the data analysis. Together with the two co-authors, the author developed the theory in this essay and prepared the manuscript for publication.

6.2. Summary of Essay 2: The impact of orientation-based dissimilarities in university–industry collaboration on project outcomes: Investigating the critical roles of conflict and transformational leadership

6.2.1. Goal and research question

The second essay investigates the impact of so-called *orientation-based dissimilarities* – the differences in goals and interests of the members of a project team – on the functioning of collaborative projects between firms and universities.

The university-industry collaboration literature assumes that orientation-based dissimilarities constitute "barriers", i.e., they have negative consequences for the functioning and outcomes of collaborative projects (Bruneel et al., 2010). However, most studies, except for one qualitative study of two collaborations (Estrada et al., 2016), assume these negative implications without empirically testing the effects of orientation-based dissimilarities or identifying the underlying mechanisms that could give rise to potentially negative effects. Moreover, although it is possible that orientation-related dissimilarities will indeed turn out to be barriers to project success, scholars have not yet identified managerial mechanisms that could help lower these barriers and facilitate team performance when orientation-related dissimilarities are high.

The goal of this essay is to develop and test a new theory that explains the effect of orientation-related dissimilarities on two important project outcomes: project performance and the project team members' intention to collaborate again. Therefore, this essay addresses the research question of *how orientation-based dissimilarities affect the project outcomes of university-industry collaboration projects*. Based on team research, this essay theorizes a moderated mediation model in which the impact of orientation-based dissimilarities on project performance and on the project team members' intention to collaborate again occurs via the level of conflict in the project. The effect of project team conflict on project performance is first positive and then decreases with increasing levels of orientation-based dissimilarities; the effect of project team conflict on the intention to collaborate again is generally negative. Moreover, the essay

identifies transformational leadership as an important managerial lever that attenuates the emergence of conflict resulting from the presence of orientation-based dissimilarities.

6.2.2. Methodological approach

Essay 2 uses data from the same data source as Essay 1 but focuses on university-industry collaboration projects – that is, projects composed of at least 3 project team members that include at least one project team member at a partnering academic organization.

Because the variables in this essay are mostly latent variables, the essay employs structural equation modeling (SEM) and the program Mplus (Muthén & Muthén, 2017) to test the theorized moderated mediation model.

6.2.3. Findings and contributions to theory and practice

The findings of Essay 2 make important contributions to the university-industry collaboration literature by shedding light on the processes that take place inside collaborative projects *after* the involved parties agreed to collaborate. Specifically, the findings show that orientation-based dissimilarities affect project outcomes via the level of project team conflict, and that this effect depends on the level of transformational leadership of the project leaders. For weak transformational leadership, orientation-based dissimilarities have a negative indirect effect on both project performance and the intention to collaborate again. Strong transformational leadership mitigates these effects. These findings extend the existing literature, which has mainly focused on the configuration of a collaborative project and the question of when universities and industry collaborate but has rarely examined the dynamics within collaborative projects.

By identifying transformational leadership as a managerial lever that prevents the emergence of conflict in collaborative projects, Essay 1 contributes to both the university-industry collaboration literature and to the interorganizational collaboration literature. This finding suggests that collaborative projects can function with almost any level of goal diversity among the project team members as long as the level of transformational leadership is sufficiently high to unite the project team members under a common vision.

Essay 2 also advances the university-industry collaboration literature from a methodological point of view. Scholars have repeatedly called for more studies that collect data from all partnering organizations within a collaboration (Perkmann et al., 2013). This essay answers these calls and provides an unprecedented, in-depth investigation of 118 university-industry collaboration projects.

At the same time, the findings from Essay 2 carry important implications for both policy makers and managers of collaborative projects. The findings underline the importance of developing and selecting project leaders for collaborative projects. By recognizing the critical role of the project leaders' transformational leadership in collaborative projects, firms and universities engaged in university-industry collaboration, as well as governments incentivizing collaboration, could potentially increase the success of collaborative projects by investing in leadership development.

Moreover, Essay 2 reveals an important trade-off in the management of collaborative projects: while small levels of project team conflict sparked by the different goal orientations of the project team members are valuable for project performance, such conflicts reduce the project team members' intentions to repeat the collaboration. To foster a good relationship and secure future collaborative projects, project managers should very carefully manage collaborative projects with new partners. In particular, they should try to reduce the amount of conflict as much as possible.

6.2.4. Contribution of the author

The author collected the data for this essay and carried out the data analysis. Together with the two co-authors, the author developed the theoretical model in this essay and prepared the manuscript for publication.

6.3. Summary of Essay 3: Demystifying industry–academia collaboration

6.3.1. Goal and research question

While Essay 1 and Essay 2 investigate the effects of two specific boundary complexities arising within collaborative project teams (i.e., diversity of expertise and diversity of goals among team members), Essay 3 takes a broader perspective on the challenges that arise in collaborative knowledge creation projects in the pharmaceutical industry. Thus far, there has been a gap between management research and the industry-specific literature that discusses the challenges of collaborative projects in the pharmaceutical industry. On the one hand, management researchers focus on understanding specific phenomena in a detailed and rigorous way, for example, by studying the impact of one or a few project characteristics on the outcome. On the other hand, scholars writing about collaborative projects in the pharmaceutical industry[10] – often labeled industry-academia collaboration in that literature – usually provide only anecdotal evidence rather than a thorough empirical analysis.

The goal of this essay is to bridge this gap by providing an overall account of the challenges that members of university-industry collaboration projects face, categorizing them and analyzing their impact on project performance. Based on a rigorous analysis of empirical data using management research methods, this essay investigates all issues present in collaborative projects as well as their impact on project success. The research questions in this essay are as follows: What are the challenges *perceived* by the members of collaborative research projects? How do these challenges impact project performance, as evaluated by the team?

[10] Articles on this topic are typically published in journals covering pharmaceutical research, for example *Nature Reviews Drug Discovery*, *Nature Biotechnology*, *Drug Discovery Today*, *Nature Medicine*, and *Science Translational Medicine*.

6.3.2. Methodological approach

Essay 3 employs a research approach based on both quantitative and qualitative data analysis methods. The author collected the qualitative and quantitative data for this essay in the same survey as that used to study the collaborative projects between Novartis and its academic collaboration partners, as described in chapters 4 and 5. However, unlike the other essays that are based on quantitative data from project teams with at least three project team members responding to the survey, this essay primarily uses qualitative data from all 699 survey responses in 187 projects to provide an overall account of the challenges perceived by participants.

Using qualitative methods, this essay analyses – in an inductive way – the answers to an open-ended question about the challenges that occur within a collaborative project (Miles et al., 2014). By grouping challenges in themes and higher-order categories using an approach inspired by thematic analysis and the Gioia method (Braun & Clarke, 2006; Gioia et al., 2012), the analysis reveals seven major categories of challenges and the frequency by which survey respondents mentioned them.

Subsequently, the essay analyses the impact of each challenge category on project success by associating the qualitatively identified categories with quantitative indicators that have been selected and measured a priori. Analyses of variance (ANOVAs) test the extent to which these challenges – measured by the associated quantitative factor – impact project success as perceived by project leaders in the second survey wave.

6.3.3. Findings and contributions to theory and practice

The findings in Essay 3 are of great relevance to practitioners and scholars. The findings in this essay contrast with those of the previous literature, which discusses "incompatible approaches" (Paul et al., 2010), "clash of cultures" (Birnbaum, 2016), "conflicting goals" (Wellenreuther et al., 2012), and "conflicting incentive structures" (Altshuler et al., 2010), arguing that the differences between the public and private sectors are a major complication in industry. The analysis in this essay reveals that the most commonly mentioned challenges are not related to the fundamental differences between industry and academia. Rather, the most commonly mentioned challenges are organizational challenges that fall within the control of the project team remembers. These challenges include resource constraints, legal and administrative process complexity, and coordination challenges.

Moreover, Essay 3 shows that most challenges identified in the qualitative analysis indeed have a negative impact on project performance when they are present in a project, except for challenges due to legal matters or due to explorative technology. These findings highlight the need for members and managers of collaborative projects to address these challenges, which can potentially hamper project success. For example, those projects that report a high coordination quality also report a significantly higher level of project success.

Essay 3 distills advice for practice that could help members and managers of collaborative projects to address the identified challenges. Overall, this essay suggests that industry-academia collaboration is not inherently difficult, but rather comes with a number of solvable challenges that need to be addressed.

6.3.4. Contribution of the author

The author collected the data and led the data analysis, which was carried out by the author and three research assistants. Further, the author led the development of the storyline of the essay and prepared the manuscript for submission together with all co-authors.

7. Conclusion

This dissertation set out to advance our understanding of the functioning and effective management of collaborative knowledge creation, in which firms collaborate with other organizations to jointly create knowledge. In collaborative knowledge creation, different boundary complexities occur when employees from a firm collaborate with other organizations across the firm boundary. The three essays in this dissertation analyze the consequences of two boundary complexities, specifically the diversity of expertise (Essay 1) and the diversity of goals (Essay 2) among the team members of collaborative projects, and provide an overall account of the spectrum of challenges perceived by the team members (Essay 3).

This chapter integrates the findings from these three essays to summarize the theoretical implications, discuss the implications for management practice and outline the limitations of this research.

7.1. Theoretical implications and future research

The research in this dissertation provides a number of theoretical implications that contribute to different literatures. First, the first two essays contribute to research on diversity in teams by articulating the role of team processes; through these processes, different types of diversity affect team outcomes. Diversity researchers have long examined various diversity-performance relationships, but have only recently articulated the importance of the underlying mechanism and the contingency factors of these relationships (van Knippenberg & Mell, 2016). By explicating the mechanisms (team leadership asymmetry and project team conflict) that link expertise diversity (Essay 1) and goal diversity (Essay 2) to team outcomes, these essays answer the calls to theorize and empirically test the mechanisms underpinning diversity-performance relationships (e.g., van Knippenberg & Mell, 2016). Additionally, by highlighting the role of team members' identification with the team (Essay 1) and the influence of transformational leadership (Essay 2), these essays reveal managerial levers that can be used to improve project performance. Future research could build on these findings and research additional managerial levers that help teams to capitalize on diversity.

Second, the findings in this dissertation suggest that high-diversity knowledge teams – often discussed as an effective way to solve complex knowledge tasks due to the extensive repertoire of skills among the diverse team members (e.g., Van Der Vegt & Bunderson, 2005) – are not always per se the most effective way to tackle highly complex and uncertain tasks. This lack of effectiveness may result because high task uncertainty (e.g., the scientific uncertainty in research projects; Essay 3) imposes higher requirements for team members to process information and knowledge within the team and renders asymmetric leadership structures less effective (Essay 1). As a consequence, task uncertainty is an important contingency factor for the suitability of high-diversity teams. Unless accompanied by strong motivational forces (e.g., high team identification, Essay 1), there is a negative effect of expertise diversity on team performance in cases of high task uncertainty. Moreover, a high level of transformational leadership is required to prevent the conflicts within the project team that arise from diverse goals among the members of high-diversity teams (Essay 2).

Third, the first two essays tease out the key role of formal and informal leadership in driving collaborative knowledge creation. So far, researchers have mentioned, yet rarely researched in-depth, the role of leadership in driving knowledge work in interorganizational collaboration (e.g., Gulati, Wohlgezogen, et al., 2012). Even for teams within organizations, scholars have only recently explored the role of leadership in orchestrating knowledge work (e.g., Mainemelis et al., 2015; von Krogh et al., 2012). The findings suggest that the leadership of leaders with formal responsibility (i.e., transformational leadership, Essay 2) and team leadership (i.e., leadership functions carried out by all team members, Essay 1) fulfil critical functions in collaborative knowledge creation. While the project leader's transformational leadership is important in uniting participants with diverse goals under a common vision and in motivating them to contribute to the project (e.g., Atwater & Bass, 1994), the team members' leadership contributions facilitate knowledge work in collaborative project teams by fulfilling critical team functions (e.g., planning work, solving problems, and mentoring other team members). Unlike previous research that has described team processes that *directly* facilitate knowledge creation (for example, information elaboration or knowledge sharing; Hoever et al., 2012; Huang et al., 2014), the leadership behaviors of team members *indirectly* facilitate team performance by exercising influence on other team members along the four functional dimensions evaluated (planning/organizing, problem solving, supporting/consideration, developing/mentoring; Hiller et al., 2006).

While previous research suggests that team members could share leadership functions within a team (e.g., Carson et al., 2007; Hiller et al., 2006), the findings from Essay 1 show that team members' engagement in leadership functions critically depends on both their expertise and their motivation. Taken together, the findings from both essays paint the picture of a domino effect of leadership in collaborative projects: The project leaders' transformational leadership exerts motivational influence on the project members, who in turn increasingly engage in leadership functions for the team. Because the essays in this dissertation only study formal and informal leadership in separate essays, future research could explore the interaction of these two leadership sources to determine whether these two types of leaders are complementary or additive for project performance.

Fourth, the findings from the first two essays advance leadership theory in two ways. On the one hand, previous leadership research, including studies researching what form of leadership influence drives creativity and innovative behavior (Mainemelis et al., 2015; Mumford & Licuanan, 2004), follows the traditional paradigm of explicitly distinguishing between leaders and followers. Essay 1 suggests that it is not the team leader who solely *facilitates* knowledge creation but rather the team as whole. Given that the leadership structure (e.g., the degree of asymmetry in team members' leadership contributions; Essay 1) has a profound impact on the performance of knowledge-creating teams, this dissertation suggests that creative leadership theory could be augmented by including the degree to which leadership responsibility is distributed among team members (ranging from highly asymmetric = one leader, to completely homogenous = all team members contribute equally) as a third dimension in the framework of Mainemelis and colleagues (2015). These findings also contribute to the literature on shared and distributed leadership, which has studied the emergence of asymmetric structures in teams (e.g., DeRue et al., 2015) but put less emphasis on uncovering the performance implications of different leadership structures in teams.

Fifth, the findings in this dissertation collectively call for advancing the knowledge-based view of the firm in strategic management. Although a core element of this theory is that firms learn from external sources (Kogut & Zander, 1992) and the knowledge creation theory has long recognized that knowledge creation might span different organizational boundaries and social practices (e.g., Nonaka & von Krogh, 2009), the center of gravity of organizational knowledge creation is implicitly assumed to be located within organizations. The essays in this dissertation provide a new perspective, suggesting that knowledge creation might take place fully within collaborative projects *between* organizations and that we need new explanations of how such projects function. Future research could expand this type of theoretical inquiry in other contexts beyond the university-firm collaboration projects that form the basis of this thesis. For example, scholars have posited that knowledge creation might take place not only in bilateral collaboration between two organizations but also in multiparty collaboration networks and meta-organizations consisting of multiple firms or individuals (Fjeldstad et al., 2012; Gulati, Puranam, et al., 2012).

Sixth, the research in this dissertation contributes to organizational theory by delineating an important pillar of that theory. So far, scholars have taken for granted that organizations and firms are systems with a clearly identifiable and stable boundary that demarks which knowledge, resources and employees belong to the organization (Pfeffer & Salancik, 1978; Williamson, 1975). The findings from this dissertation's analysis of collaborative knowledge creation projects suggest that this picture might no longer be fully appropriate in contemporary organizations. Rather, as knowledge creation takes place inside a firm's collaborations with partnering organizations, the knowledge is created neither within the firm nor by the partnering organization but instead via the collaboration of individuals from these two organizations (Hardy et al., 2003; Powell, 1990, 1996). Furthermore, collaborative knowledge creation relies on different organizing principles such as self-mobilizing leadership instead of hierarchical control (Fjeldstad et al., 2012). Essays 1 and 2 are clear illustrations of the fact that collaborative projects that span the firm boundary feature similar characteristics as those of knowledge-creating teams within organizations, but rely on new forms of governance and leadership (Fjeldstad et al., 2012), for example, to mobilize resources. Future research should further integrate these findings from research on interorganizational collaboration and develop new theory that can describe such collaboration, as Fjeldstad and colleagues (2012) suggest.

Seventh, the findings from the essays in this dissertation have implications for the literature on interorganizational collaboration. Specifically, while the findings from Essays 2 and 3 confirm that cooperation and coordination are critical issues that need to be addressed for effective collaboration (Gulati, Wohlgezogen, et al., 2012), the first two essays indicate that different forms of leadership can serve as coordination and cooperation mechanisms. Specifically, the discussion of team members' functional leadership behaviors in Essay 1 also shows that such team leadership might serve coordination functions, such as planning and organizing the work inside the project team (Hiller et al., 2006). Moreover, as transformational leadership helps to align team members who have different goals (Essay 2), transformational leadership serves as a mechanism with which to achieve cooperation. Therefore, especially in interorganizational collaboration, where traditional organizational control mechanisms are absent, the relevance of both formal and informal leadership for archiving cooperation and coordination among team members is heightened. Future research might further explore the degree to which different types of

leadership can replace traditional mechanisms of coordination and cooperation in achieving collaboration performance.

7.2. Implications for practice

The research in this dissertation has numerous implications for managing collaborative projects in practice. First and foremost, the findings suggest that managers in firms and public research organizations should lead collaborative projects differently than projects within their own organizations. In collaborative projects, the role of leadership is elevated because other managerial mechanisms, such as organizational control, are less effective or absent. Therefore, project managers should engage in transformational leadership and foster functional leadership within the team – a combination of leadership influence that can be labeled *collaborative leadership*. Whereas transformational leadership aligns team members towards a joint vision and fosters their commitment to and engagement in a collaborative project, the team members' functional leadership facilitates the work inside the project team.

To foster transformational leadership in collaboration projects, organizational managers should train potential project leaders in transformational leadership. For example, firms and academic organizations should develop training programs tailored to train suitable individuals in transformational leadership (Barling, Weber, & Kelloway, 1996) and the leadership of collaboration teams. To ensure participation, such programs should be incentivized and should constitute a requirement for career advancement. In addition, senior leaders – especially in organizations where less hierarchical authority exists, such as in academic organizations – should convince the members of their organization to take part in leadership trainings and project management to reduce the failure rate of projects. Moreover, because transformational leadership is a set of leadership behaviors that cannot be "learned" quickly but require long-term development, organizations might set up mentoring programs in collaborative leadership, in which star collaborators (i.e., seasoned individuals with significant collaboration experience) mentor project leaders during their first collaboration projects. Given the importance of strong transformational leadership within a collaborative project to unite participants with diverse goals under a common team vision (Essay 2), organizations should select suitable individuals with particularly strong leadership skills as formal leaders of knowledge creation projects that span across organizational boundaries.

The contents of these leadership-training programs should embrace the fact that the role of transformational leadership is elevated in collaborative projects, as nurturing the motivation of project members is often the only lever with which to ensure their contributions to a project. For example, steering project members towards project outcomes with true win-win results (i.e., both collaborating organizations benefit more from the project compared to if they worked on the project themselves) and clearly communicating the benefits to all team members will likely increase their commitment to and engagement in the project because of the visible benefit from the win-win outcomes. This is particularly important because previous research on online communities has shown that both short-term rewards and long-term visions are critical motivational forces that drive team member engagement in projects relying on voluntary participation (von Krogh, Haefliger, Spaeth, & Wallin, 2012).

Project leaders of collaborative projects should also foster leadership engagement among project team members. Given that leadership engagement depends on both motivation and expertise, project leaders can drive motivation by making collaborative projects a core priority of the organization. In this way, team members are more likely to go "the extra mile" for a project and commit extra time that they would otherwise commit to other projects (especially those that are part of their performance review process).

Furthermore, fostering informal interactions among team members is a lever to increase team identification. One approach is to spend time with the project team outside the formal interactions and meetings required of a collaboration. This could be achieved, for example, via a common retreat to socialize and exchange ideas outside of the project. While most companies organize events and retreats for their employees, these approaches could work equally well for collaborative projects.

However, organizations should not restrict leadership development to those individuals with formal project responsibilities. Rather, given the importance of team leadership exercised by *all* members of a project team (Essay 1), all members of an organization who potentially participate in collaborative projects should take part in leadership trainings. In these leadership trainings, individuals should learn essential tools to engage in functional leadership behaviors, such as brainstorming methodologies to facilitate problem solving. Through such trainings, project members should learn to move from passive roles in which they carry out the work commissioned by the project leader to pro-active roles in which they are all collectively in charge of driving the collaborative project.

Second, the findings provide insights into the effective setup of knowledge creation teams. Specifically, managers of collaborative projects should recognize expertise diversity as an important team design factor and match the team's structure to the task requirements. As expertise diversity proves to be detrimental for team performance under high task uncertainty, project managers should break down large high-diversity teams that tackle complex and uncertain challenges. For example, project leaders might form sub-teams or include certain specialists only when their input is required (e.g., Ben-Menahem et al., 2016). For example, the common intuition is that when teams composed of highly skilled specialists engage in brainstorming, typically a few individuals dominate the process, especially when they possess superior knowledge about the topic. Breaking down brainstorming teams can often increase the participation of non-dominant group members and thereby harness the creativity of groups even more effectively.

Third, project leaders should manage collaborative projects carefully given the trade-off in the effect of project-team conflict on project outcomes. Because low levels of project-team conflict give rise to performance advantages, but simultaneously hamper the project team's intention to collaborate again with the same partner, managers of collaborative projects should decide about the priorities of the outcomes. If a long-term collaboration is desired, project leaders should take exceptional care in avoiding conflict by all means necessary in order to ensure the continuation of the collaborative relationship. Project leaders should monitor the teamwork carefully and both preempt conflict and intervene when necessary. For example, by conducting a detailed analysis that contrasts the partner's needs and expectations at every planning step with their own needs and expectations, leaders can avoid potential conflicts. Only once a relationship with a collaboration partner is established, project leaders can allow low levels of conflict to yield constructive

discourse beneficial to team performance (Essay 2). Moreover, frequent interactions such as regular email exchanges, meetings of the whole project team or steering committees can further help conflicts to surface quickly.

Fourth, senior managers in firms and public organizations should manage the portfolio of collaborative projects in their organizations strategically. Because collaborative projects demand significant resources, organizational leaders should consider the effort required to lead a collaborative project to success. This includes making detailed plans and budgets about the resources required – while also allowing for updates of the project plan once the demands of the project change in response to scientific uncertainty. Explorative interviews with project leaders of the collaborative projects in the data sample revealed that many projects do not have any formal budget, but rather rely on capitalizing on leftover resources (especially labor and equipment) that can be channeled from other projects. Stopping projects early is key to spending resources most effectively.

7.3. Limitations

Like any other research, the research presented in this dissertation is not without limitations. All three essays have some common limitations that future research might address. First, all three essays are based on data from Novartis and its collaboration partners. Although the sample includes collaborative projects on three different continents and those projects cover all major research departments at Novartis, there might be characteristics of the research context that are specific to Novartis or the pharmaceutical industry. Future research should conduct similar studies in other organizations and other industries.

Second, the dependent variables in the essays in this dissertation rely on perceptual data. Although sophisticated methodological considerations provide remedies against potential method bias (e.g., by probing the dependent variables in a separate questionnaire given to external senior managers as a different source, Podsakoff et al., 2012), a potential method bias cannot be fully excluded with these remedies. Future research could probe the dependent variables using more objective outcome measures, such as patents and publications, as soon as these data become available.

Third, the study design that forms the basis of all three essays offers only limited causal inference. Although the essays develop the theoretical model based on strong theoretical foundations and take significant efforts to rule out alternative explanations and reverse causality, future studies could further triangulate the findings, e.g., by using experimental methods.

The essays in chapters 8-10 discuss further specific limitations in the corresponding discussion section. Future research should triangulate the findings in this dissertation and address these limitations.

7.4. Outlook

Given that work is becoming increasingly knowledge-intensive, digitalized and globalized (Faraj, von Krogh, Monteiro, & Lakhani, 2016; Manyika et al., 2014), the orchestration of knowledge work is a key challenge for modern organizations.

As the knowledge economy advances at breathtaking speed, with new industries and ecosystems emerging within decades (McGrath & Kim, 2014), management scholars are tasked with providing necessary explanations of how contemporary organizations and meta-organizations function. While many traditional theories about organizations have remained relevant for decades, fundamental shifts in the economy and society require scholars to make significant updates to previous theories (Fjeldstad et al., 2012; Puranam et al., 2014). The research focus of this dissertation is a case in point: it has been only approximately 15 years since the first scholars fully recognized that the innovation process of a firm might span across organizational boundaries (e.g., Chesbrough, 2003; von Hippel & von Krogh, 2003) – the current literature is therefore only the beginning.

Companies and organizations must adapt swiftly to the new realities. The importance of orchestrating knowledge work across boundaries will most likely increase given the increasing connectedness among economic actors and the advancement of digitalization and globalization (Manyika et al., 2014). These developments will require organizations to organize work more dynamically, increasingly across organizational boundaries and more often than ever before in the digital space (Colbert, Yee, & George, 2016; Repenning, Kieffer, & Repenning, 2018).

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Part Four: Essays

8. Essay 1 - Folding under Uncertainty? Expertise Diversity and Performance of Knowledge Teams

Revise & Resubmit (1st round) at Journal of Applied Psychology

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Abstract

Against common organizational practice of assembling diverse knowledge teams to tackle uncertain tasks, expertise diversity may not always benefit team performance. In this study, we show that the relationship between expertise diversity and team performance becomes increasingly negative as task uncertainty increases. Building on functional leadership theory, we explain how team leadership asymmetry—variance in members' engagement in leadership functions—mediates this moderation effect. Moreover, incorporating social identity theory, we explain how team identification—the emotional significance that members attach to their team membership—influences the relationship between expertise diversity and team leadership asymmetry. We test these relationships using survey data from drug discovery teams facing various levels of task uncertainty. We find that while teams with high expertise diversity gravitate towards high leadership asymmetry, this tendency is partially attenuated by team identification. In turn, team leadership asymmetry relates differently to team performance, contingent on the level of task uncertainty. We discuss the implications of our findings for the research on and design of work teams.

Keywords: expertise diversity, functional leadership, task uncertainty, team identification, team performance.

8.1. Introduction

Organizations increasingly resort to knowledge teams—teams that are composed of experts with heterogeneous educational backgrounds and work experience, and that are expected to create new knowledge—for solving complex problems and tackling uncertain tasks (Faraj & Sproull, 2000; Faraj & Yan, 2009; Van Der Vegt & Bunderson, 2005). For example, pharmaceutical and chemical companies often rely on knowledge teams for research and development (e.g., Kearney & Gebert, 2009; Richter et al., 2012; Van Der Vegt & Bunderson, 2005). Similarly, computer hardware and software manufacturers alike regularly assemble cross-functional teams to develop new products (e.g., Faraj & Yan, 2009; Lovelace, Shapiro, & Weingart et al., 2001). This growing prominence of knowledge teams in practice often rests on the assumption that expertise diversity—a core feature of such teams (Bunderson & Sutcliffe, 2002)—provides a remedy for uncertainty (Faraj & Yan, 2009; Gardner, Gino, & Staats, 2012).

However, expertise diversity may not always be ideal for the effective collaboration of knowledge teams (e.g., Carlile, 2004; Faraj & Sproull, 2000), especially under high uncertainty. On one hand, expertise diversity creates an extensive reservoir of information and knowledge, promoting the cross-fertilization of ideas (Richter, Hirst, van Knippenberg, & Baer, 2012; van Knippenberg, De Dreu, & Homan, 2004). On the other hand, expertise diversity complicates the integration of knowledge (Carlile, 2004; Majchrzak, More, & Faraj, 2012) and the collaboration among different experts (Carlile, 2004; Rico, Sánchez-Manzanares, Antino, & Lau, 2012). Such complication is more pronounced when teams face highly uncertain tasks, which make information sharing, knowledge integration, and coordination more challenging (Crawford & Lepine, 2013; Faraj & Yan, 2009). Indeed, as task uncertainty increases, the net effect of expertise diversity on team performance becomes unclear. Therefore, scholars need to further explore the nature of this association, and examine whether the commonly assumed positive effect of expertise diversity still holds under high task uncertainty.

The primary objective of this paper is to advance theory on the impact of expertise diversity on team performance under different levels of task uncertainty. We develop a theoretical model (see Figure 1) in which the relationship between expertise diversity and team performance becomes increasingly negative as task uncertainty escalates. Given that behavioral diversity offers an important link between compositional diversity and team performance (van Knippenberg & Mell, 2016), we draw on functional leadership theory (Morgeson, DeRue, & Karam, 2010) to explain how the moderation effect of task uncertainty takes place through team leadership asymmetry (i.e., the variance in team members' leadership behaviors). Moreover, because leadership behaviors are not only determined by individuals' expertise but also by their motivation (Chan & Drasgow, 2001), we incorporate social identity theory (Ashforth & Mael, 1989; Turner, 1985) to explain how team identification (i.e., the emotional significance that members attach to their team membership) influences the relationship between expertise diversity and team leadership asymmetry. We argue that while knowledge teams with higher expertise diversity generally gravitate towards higher team leadership asymmetry, team identification can attenuate this tendency.

INSERT FIGURE 1 HERE

Our study contributes to research on knowledge teams in two fundamental ways. First, we establish task uncertainty as an important boundary condition for the performance benefits of expertise diversity in knowledge teams. Second, we answer the question of how the multiplex effect of expertise diversity on team performance takes places via team members' engagement in leadership functions—and, by doing so, we connect the functional leadership and diversity literatures in a novel and valuable way. In addition, we contribute to the functional leadership literature by explaining how team identification provides the additional motivation for individual members to fulfill team needs.

8.2. Theory and Hypotheses

8.2.1. The Expertise Diversity-Team Performance Relationship under Uncertainty

Expertise diversity—the differences in team members' knowledge and background expertise (Van Der Vegt & Bunderson, 2005)—is a design element with major implications for the functioning and performance of knowledge teams (Huang, Hsieh, & He, 2014; van Knippenberg & Schippers, 2007). Expertise diversity describes the within-team *variety* (i.e., differences in kind or category; Harrison & Klein, 2007) of knowledge that can arise from the team members' different educational backgrounds (Shin & Zhou, 2007; Van Der Vegt & Bunderson, 2005), industry experiences (Horwitz & Horwitz, 2007), specialized knowledge domains (Taylor & Greve, 2006), or current and previous functions within an organization (Bunderson & Sutcliffe, 2002).

Scholars recognize that expertise diversity can be beneficial for the performance of knowledge teams. The generation of new ideas and knowledge within teams relies on the availability of diverse, non-redundant knowledge among team members (Amabile, 1988; Huang et al., 2014; Milliken, Bartel, & Kurtzberg, 2003; van Knippenberg et al., 2004). Higher expertise diversity means team members can draw from a more diverse collection of task-relevant knowledge, skills, and abilities (Huang et al., 2014; van Knippenberg & Mell, 2016). A greater diversity in team members' perspectives prompts team members to evaluate, critique, and learn from one another's approaches (Jehn, Northcraft, & Neale, 1999; Pelled, Eisenhardt, & Xin, 1999). This cross-fertilization of ideas increases the quality of problem-solving and decision-making within teams (e.g., Hoever et al., 2012; Roberson et al., 2017; van Knippenberg & Schippers, 2007). Consequently, members of teams with higher expertise diversity may be better able to generate novel and useful ideas (Hülsheger, Anderson, & Salgado, 2009; West, 2002), ultimately enhancing team performance in knowledge-intensive tasks (Gardner et al., 2012; Horwitz & Horwitz, 2007).

Yet high expertise diversity also poses challenges in knowledge teams. First, high expertise diversity complicates the integration of task-relevant information and knowledge (Cronin & Weingart, 2007; van Knippenberg & Schippers, 2007). Experts from distinct knowledge domains may inhabit unique "thought worlds" (Dougherty, 1992; Faraj & Yan, 2009)—systems of underlying beliefs and assumption rooted in both their education and their practices (Cronin & Weingart, 2007; Srikanth, Harvey, & Peterson, 2016). They may also develop a unique understanding of the task and the associated team needs (Cronin & Weingart, 2007; Dougherty, 1992; van Ginkel & van Knippenberg, 2008). Scholars have referred to such

situations as "representational gaps" (Cronin & Weingart, 2007) of the task environment among highly specialized experts. The higher the expertise diversity, the more likely the existence of such gaps and the complications they bring in integrating diverse information in the team (Huang et al., 2014).

Second, high expertise diversity complicates both collaboration and communication within knowledge teams. Because individuals tend to like and trust others who are similar to them, they feel more comfortable interacting with team members with similar expertise (McPherson, Smith-Lovin, & Cook, 2001; Tajfel & Turner, 1985; van Knippenberg et al., 2004; Williams & O'Reilly, 1998). Moreover, team members with expertise in distinct domains are likely to develop their own language and terminology of the tasks at hand, have different interests and priorities, and even subscribe to different values (Carlile, 2004), All of these give rise to misunderstandings and potentially brew conflicts as the team tries to accomplish its tasks (Jehn et al., 1999; Lau & Murnighan, 2005; Li & Hambrick, 2005; van Knippenberg & Schippers, 2007).

Given its potential benefits and drawbacks, whether high expertise diversity will always predict high performance in knowledge teams remains unclear. Building on work group diversity literature, we argue that the relationship between expertise diversity and team performance hinges on task features (Horwitz & Horwitz, 2007; van Knippenberg & Schippers, 2007). For knowledge teams, task uncertainty constitutes one of the most important features (Faraj & Yan, 2009; Liebeskind, 1996). Generally, task uncertainty refers to the difference between the information needed for completing a task and the information available (Argote, Turner, & Fichman, 1989; Gardner et al., 2012). However, for knowledge-intensive tasks, uncertainty means incomplete information about the target outcome and the cause-and-effect relationships (Dougherty & Dunne, 2012; Liebeskind, 1996). In this case, task uncertainty may arise from either technological (Song & Montoya-Weiss, 2001) or scientific elements (Liebeskind, Oliver, Zucker, & Brewer, 1996).

We argue that because task uncertainty not only reduces the advantages but also amplifies the disadvantages of expertise diversity, the relationship between expertise diversity and team performance becomes more negative as task uncertainty increases. Task uncertainty makes the repertoire of information and knowledge accruing from expertise diversity less accessible to team members. Highly uncertain tasks require team members to discern and process a large amount of potentially valuable information (Gladstein, 1984; Kozlowski, Gully, Nason, & Smith, 1999). Without enough prior knowledge or established procedures, highly uncertain tasks make determining precisely what information or knowledge is needed highly challenging (if not impossible) in the first place (Galbraith, 1977; Van De Ven, Delbecq, & Koenig Jr., 1976).

Moreover, task uncertainty creates two additional barriers to the integration of diverse knowledge and the collaboration among different experts. First, task uncertainty increases the effort needed for that integration. Information-processing requirements become more onerous as task uncertainty increases, thereby requiring each team member to invest more effort in making his or her specialized knowledge both available and understandable to other team members (Faraj & Yan, 2009). Second, with high task uncertainty, team members find it difficult both to anticipate future events affecting the team processes and to predict the consequences of one another's actions (Carlile, 2004; Colquitt, LePine, Piccolo, Zapata,

& Rich, 2012; Weick, Sutcliffe, & Obstfeld, 1999). Such unclear dependencies among team members (a) widen the representational gaps and (b) exacerbate the language differences that prevent effective communication and collaboration in teams with expertise diversity (Littlepage & Silbiger, 1992). Therefore, we hypothesize:

Hypothesis 1: Task uncertainty moderates the relationship between expertise diversity and performance, making this relationship more negative as task uncertainty increases.

8.2.2. Leadership Functions in Teams

We argue that a deeper understanding of team performance requires a closer look at team members' engagement in leadership functions in team processes. Team processes include activities for defining specific team goals and performing activities that directly or indirectly contribute to attaining those goals (Marks, Mathieu, & Zaccaro, 2001). As these processes unfold, teams likely encounter various challenges, which in turn give rise to various needs that team members must fulfill to achieve the team goals (Morgeson et al., 2010). Functional leadership theory posits that leadership behaviors are oriented towards satisfying these needs, thereby facilitating team performance (Hiller, Day, & Vance, 2006; McGrath, 1962; Morgeson et al., 2010).

Hiller and colleagues (2006) synthesized various types of team needs into four categories, arguing that, to meet those needs, team members engage in the four corresponding types of leadership functions. These four categories are (1) planning and organizing, which involves setting goals and allocating resources; (2) problem solving, which involves identifying, diagnosing, and solving task-related problems; (3) support and consideration, which includes caring for other members; and (4) development and mentoring, which includes offering career-related advice and being a role model to other members.

In contrast to other leadership perspectives that focus on a few designated leaders within a team (e.g., transformational or transactional leadership; Bass, Avolio, & Atwater, 1996), the functional perspective contends that any team member who acts to satisfy a team need can be viewed as taking on a leadership function (McGrath, 1962; Morgeson et al., 2010). However, acknowledging that any team member could potentially engage in all leadership functions does not imply that all team members would actually engage in these functions to the same extent. A critical assumption of functional leadership theory is that, to satisfy various team needs, individuals *consciously* engage in leadership functions (Morgeson et al., 2010). Therefore, individuals' leadership behaviors will be a result of their distinct cognition (i.e., their evaluation of the team needs) and motivation (i.e., significance of the team needs to them).

Similarly, much accumulated team research has shown that individuals' engagement in leadership varies substantially (Aime, Humphrey, DeRue, & Paul, 2014; Drescher, Audrey Korsgaard, Welpe, Picot, & Wigand, 2014). When such variance exists, a simple aggregation of the individual levels of engagement to an overall team-level variable is inappropriate (van Knippenberg & Mell, 2016). Given the importance of such variance for team dynamics, scholars have called for a formal conceptualization of variance in team members' engagement or behaviors (Crawford & Lepine, 2013; Klein & Kozlowski, 2000; van Knippenberg

& Mell, 2016). In response to this call, we examine *team leadership asymmetry* and explore its role in linking expertise diversity and team performance. Specifically, team leadership asymmetry describes the within-team *separation* (i.e., differences in degree; Harrison & Klein, 2007) of engagement in Hiller and colleagues' (2006) four leadership functions (i.e., planning and organizing; problem solving; support and consideration; development and mentoring).

We argue that expertise diversity gives rise to team leadership asymmetry for two reasons. First, experts from different knowledge domains perceive team needs differently. Because different experts tend to substantially diverge in the way they represent the problems, specify critical elements, and identify steps toward solving those problems (Majchrzak et al., 2012), they are likely to hold different beliefs about what team needs should be a priority. Second, in teams with high expertise diversity, even when experts' perceptions of team needs are similar, their capabilities to act will differ (e.g., Gruber, Harhoff, & Hoisl, 2013). For example, some members are better at planning the overall workflow, whereas others are better at coming up with new ideas and solving concrete problems as they arise (e.g., Scott & Bruce, 1994; West & Anderson, 1996)

Next, we argue that, contingent on the level of task uncertainty, team leadership asymmetry has drastically different influences on team performance, thereby explaining the changing relationship between expertise diversity and team performance. Under low levels of task uncertainty, team leadership asymmetry brings coordination advantages. For example, members heavily engaged in planning and organizing the overall workflow will develop a more holistic mental representation of the team's task environment. When these members take charge of the planning and organizing functions, they can allocate tasks and address interdependencies according to the overview they have developed (Crawford & Lepine, 2013). Conversely, were every member to participate with equal intensity in planning and organizing the team's workflow, individual efforts might prove redundant. Similarly, were every team member to participate with equal intensity in problem-solving, one member's efforts could clash with—or even nullify—the problem-solving effort of others or create new problems and obstacles. In short, team leadership asymmetry creates a clear division of labor in leadership functions, thereby preventing the cannibalization of other team members' efforts (Jackson, 1996).

Under low levels of task uncertainty, team members' asymmetric engagement in leadership functions could be an efficient way of employing the team's human capital. Individual team members possess both explicit and tacit knowledge. Explicit knowledge is articulated and can be transmitted, whereas tacit knowledge is personal and is deeply rooted in action and context (Nonaka, 1994). In teams with high expertise diversity, a natural variance occurs in both the explicit and tacit knowledge of individual members. First, discipline-specific education and training provide highly specialized explicit knowledge (Hitt, Bierman, Shimizu, & Kochhar, 2001). Second, members accumulate significantly different tacit knowledge in their job roles through "learning by doing" (Hitt et al., 2001). Most organizations have divisions of labor that expose members to different tasks (Hagstrom, 1964). Over time, as members accumulate tacit knowledge specific to their practice and specialization (Crawford & Lepine, 2013), they become more effective at carrying out those tasks. Team leadership asymmetry captures how members self-select into those leadership functions at which they are more proficient, thereby better utilizing the team's human capital.

However, team leadership asymmetry has an important limitation—the lack of adaptability in the team. When certain team members always engage consistently more than others in specific leadership function(s), the team may become dependent upon them for fulfilling certain team need(s). Moreover, asymmetric engagement also alienates those members who engage comparatively little in leadership functions, over time making them less motivated or less capable of stepping up to meet the team needs.

Under high levels of task uncertainty, the coordination and human capital advantages associated with team leadership asymmetry decrease significantly. Unclear cause-and-effect relationships make it more challenging for teams to establish whose knowledge is potentially valuable for a task (Grant, 1996; Schulz, 2001), in turn lowering the possibility of making a clear division of labor from the start. Moreover, when coupled with information deficits about the task at hand, existing knowledge differences and task dependencies among members require more frequent reconsideration and updates (Carlile, 2002; Davison, Hollenbeck, Barnes, Sleesman, & Ilgen, 2012; Gittell, 2002; Weingart, 1992). These increased coordination demands then require additional time and effort for establishing shared languages, methods, or artifacts that help facilitate team functioning (Stasser & Titus, 1985). For example, Hofmann and colleagues (2009) show that making sense out of ambiguous, novel, and uncertain situations imposes additional demands on the interpersonal processes within a team. At the same time, high task uncertainty further increases the workload of those members already heavily involved in leadership functions, thereby potentially hampering their performance.

In addition, high task uncertainty exacerbates the "rigidity disadvantage" associated with team leadership asymmetry (Hollenbeck, Ellis, Humphrey, Garza, & Ilgen, 2011). High task uncertainty requires team members to discover both what and whose expertise is relevant for each knowledge-creation step (Carlile & Rebentisch, 2003; Hofmann et al., 2009) and to determine how to integrate diverse expertise (Majchrzak et al., 2012). After the team has discovered the optimal match between expertise and task, it must collectively respond to any change by adapting the distribution of leadership engagement among team members. While a lack of adaptability may not be as harmful under low task uncertainty, under high task uncertainty it prevents the team from effectively responding to changing situational demands or (re)organizing activities to fit the task demand (e.g., Ben-Menahem et al., 2016).

In sum, members in knowledge teams with high expertise diversity tend to engage themselves differently in leadership functions. While such team leadership asymmetry may be largely beneficial for team performance under low levels of task uncertainty, it becomes harmful under high levels of task uncertainty, due to reduced advantages and exacerbated disadvantages. Therefore, we hypothesize:

Hypothesis 2: The negative moderating effect of task uncertainty in the relationship between expertise diversity and team performance is due to the positive effect of expertise diversity on team leadership asymmetry and the increasingly negative relationship between team leadership asymmetry and team performance as task uncertainty rises.

8.2.3. Team Identification

Given that individuals' behavioral tendencies are a function of both their capacity and their motivation (Chan & Drasgow, 2001; Chen & Kanfer, 2006), a thorough understanding of the relationship between expertise diversity in the team and team members' subsequent behaviors must account for their motivation. An important source of motivation in teams is members' identification with the team (Milliken et al., 2003; Van Der Vegt & Bunderson, 2005). While functional leadership theory provides much insight into individuals' evaluations of various team needs and their ability to fulfill them, it does not include their motivation. Therefore, to better explain individuals' leadership behaviors, we combine social identity theory (Ashforth & Mael, 1989; Turner, 1985) with functional leadership theory.

Although members of a team with high expertise diversity likely engage asymmetrically in leadership functions, this tendency can be mitigated when they identify strongly with the team. To work toward satisfying team needs, individuals must first either internalize the collective team needs as their own or perceive those needs as related to their personal wellbeing (Turner, 1985). Thus, the degree of engagement asymmetry does not *solely* depend on team members' different perception of team needs or different capabilities for meeting those needs. As Van Der Vegt and Bunderson (2005) aptly point out, team members' motivations to act for the benefit of the team may indeed determine the effect of expertise diversity on team dynamics. As such, we examine the moderating role of team identification, defined as the degree to which team members feel psychologically intertwined with the group's fate (Mael & Ashforth, 1995; Pearsall & Venkataramani, 2015).

Social identity theory posits that individuals tend to classify themselves according to social categories and that such classification enables individuals to define themselves in the social environment (Tajfel & Turner, 1985). The social identification process is essentially the development of "oneness with or belongingness" to some social group (Ashforth & Mael, 1989, p. 21). For individuals working in teams, identification with the team gives them that "belongingness" to one of the most important social categories in their work life.

We expect team identification to reduce the strength of the positive association between expertise diversity and team leadership asymmetry for two reasons. First, team identification motivates individual members to communicate and interact with one another, thereby reducing the differences in their perception of team needs. Given that individuals are more inclined to interact with those whose attitudes and beliefs are similar to theirs (McPherson et al., 2001; van Knippenberg et al., 2004; Williams & O'Reilly, 1998), members of a highly diverse knowledge team need an extra impetus for overcoming the differences that prevent interaction. Team identification provides the necessary motivation for members to exchange information, take different perspectives, and learn across specialization boundaries (Van Der Vegt & Bunderson, 2005). With enhanced communication and interaction, experts from different knowledge domains can establish a shared understanding of what constitutes an important imminent team need and of what course of action to pursue (Burke, Stagl, Salas, Pierce, & Kendall, 2006). As a result of such shared understanding, variance in members' leadership behaviors will likely decrease.

Second, team identification generally elevates individual members' tendency to engage in leadership functions. To identify with a team implies that individuals consider the fate of the team as closely related to their own (Tajfel & Turner, 1985). Put differently, team identification leads team members to assign the needs of the team a personal significance. With such alignment between personal and team needs, members are more likely to contribute their skills, knowledge, and ideas to satisfy team needs (Milliken et al., 2003; Shin & Zhou, 2007). Consequently, in the presence of high team identification, the strong motivation will likely reduce the variance in team members' engagement in leadership functions as they become more engaged.

Hypothesis 5: Team identification moderates the relationship between expertise diversity and team leadership asymmetry, making the relationship less positive as team identification increases.

8.3. Method

8.3.1. Sample

The sample comprises 99 drug discovery project teams from the three international research sites of *InterPharma* (a pseudonym for a leading pharmaceutical company). In the United States the development of a new drug takes from 10 to 15 years and encompasses the following three distinct phases before the drug enters large-scale manufacturing (Ding, 2014): (1) drug discovery (3–6 years), (2) clinical trials (6–7 years), and (3) FDA (Food and Drug Administration) review (0.5–2 years). Projects in the drug discovery phase feature various degrees of uncertainty (Ben-Menahem et al., 2016): For each compound that reaches the market as an approved drug, researchers test between 5,000 and 10,000 compounds (Ding, 2014). Given the high cost and complexity of drug discovery research, pharmaceutical firms often collaborate with research institutes, universities, and hospitals (Perkmann, Neely, & Walsh, 2011). A typical drug discovery project team comprises members from multiple scientific disciplines, including molecular biology, medicine, chemistry, computer modeling, and toxicology (Cardinal, 2001; Rodriguez-Esteban & Loging, 2013). Thus, drug discovery teams constitute an ideal context for exploring the link between expertise diversity and the performance of knowledge teams under different levels of task uncertainty.

8.3.2. Procedure

Using an internet-based survey with anonymous and confidential data treatment assured, we collected data from two sources at three different times. In September 2015 (T1), we sent all project team members (including team leaders and members) an email with a link to our survey, asking them to report all control variables, their field of expertise, and their identification with their project teams. After three email reminders, 669 members from 187 project teams (an 85% response rate) responded to the first survey. Six months later (T2), we asked all T1 respondents, except the 35 individuals who had left their projects, to report their engagement in various leadership behaviors. After three email reminders and one telephone call reminder, 511 members from 168 project teams (an 81% response rate) responded. For each survey

they completed, respondents received a $10 gift voucher from different online or retail stores, depending on the country.

Approximately two months later (T3), we asked senior managers at *InterPharma* to evaluate the performance and task uncertainty of all 187 projects with more than one response at T1 in a separate survey. These senior managers had extensive experience in drug discovery and were overseeing a number of projects at *InterPharma*. We received responses from 79 senior managers, evaluating 144 project teams (a 77% response rate). We then paired all data sources, using a unique identifier for each project team.

The minimum number of responding team members necessary for inclusion in the study was three per project team. This criterion reduced the sample size to 128 teams. After list-wise deletion of incomplete responses, our final sample size was 99. The average project in our final sample had been running for 1.42 years (SD = 1.01) and had 4.74 (SD = 1.83) team members. The average response rate within the teams in our final sample was 88%. The final sample comprises 469 individuals participated in the study, including 282 drug discovery scientists from *InterPharma* and 187 from partnering research institutes. On average, participants were 44 years of age and had spent seven years in their current role within their organization. Participants in our sample are highly educated, with 86% of them holding as their highest degree a PhD or MD; 10%, a Master degree; and 4%, a Bachelor degree. The majority (74%) of the participants were male. A series of t-test comparisons showed no substantial differences among the project teams from the three different sites.

8.3.3. Measures

Team performance. The performance of a knowledge team corresponds to the degree to which the team creates new knowledge (Eisenbeiss, van Knippenberg, & Boerner, 2008; Huang et al., 2014). Because no existing scale precisely measures the scientific knowledge created by drug discovery project teams, we developed a new scale. We first identified 12 items capturing relevant knowledge outcomes in previous studies (Choo, Linderman, & Schroeder, 2007; Lewis, Welsh, Dehler, & Green, 2002) and modified their wording to fit our context. An expert panel of six senior managers from *InterPharma* then discussed the relevance of these 12 items and selected the eight most suitable for drug discovery project teams.

We then validated this scale in a pilot survey (N = 30) with researchers at a large public university. We ran an exploratory factor analysis with data from the pilot survey and removed three items with a factor loading of less than 0.4 (Field, 2009). Further factor analysis of the remaining five items supported a single-factor structure, explaining 49.92% of the variance. Additionally, using the final sample, we ran a confirmatory factor analysis (CFA) of these items. The results confirmed the validity of this 5-item scale ($\chi^2 = 11.75$; $df = 4$; $p < 0.02$; comparative fit index (CFI) = 0.95; root mean square error of approximation (RMSEA) = 0.13 and standardized root mean square residual (SRMR) = 0.04). The final items measure the extent to which "solutions found in this project will be unique and innovative," "insights from this project will lead to follow-up projects," "results of this project will be published in a peer-review journal," "this project will yield knowledge helpful to other ongoing projects," and "this project will lead to important scientific results." The Cronbach alpha for this scale is 0.78.

In line with other studies on R&D teams (e.g., Eisenbeiss et al., 2008), we asked senior managers from *InterPharma* to evaluate the performance of project teams. These managers rated the team's knowledge creation on a five-point scale (1 = "very unlikely" to 5 = "very likely"). On average, each manager evaluated 1.51 projects. We used a one-way analysis of variance (ANOVA) to test for potential nesting effects in the managers' ratings. The intra-class correlation coefficient ICC(1) for this measure was 0.08. Given this low ICC(1) value, the level of non-independence in our data is unlikely to affect the scale reliabilities or lead to incorrect rejection of the null hypotheses (Kenny, Kashy, & Bolger, 1998).

Expertise diversity. We operationalized expertise diversity as the diversity in the team members' disciplinary background (see Bunderson & Sutcliffe, 2002, for a similar approach). In response to our request, "Please select the scientific field that best describes your background and area of expertise," team members indicated their dominant discipline using the widely adopted categorization from the Nature Publishing Group (2015).

With the detailed information from the team members, we computed the expertise diversity for each team using the Teachman entropy index,[11] calculated as $-\sum_k [p_k \cdot \ln(p_k)]$ (Harrison & Klein, 2007). A higher value of this index indicates more variety. For example, a team of six analytical chemists has an expertise diversity value of zero; a team of five analytical chemists and one cell biologist has an expertise diversity value of 0.65; and a team of three analytical chemists, two cell biologists, and one oncologist has an expertise diversity value of 1.46. In our sample, the highest expertise diversity value is 2.81.

Team leadership asymmetry. Using the 25-item scale developed by Hiller and colleagues (2006), we measured each team members' engagement in various leadership functions. Two sample items read as follows: "I help organizing tasks so that work flows more smoothly" and "I provide support to team members who need help." Team members rated their leadership behaviors on a five-point scale (1 = "never" to 5 = "always"). The Cronbach alpha for the aggregate scale is 0.96.

We calculated the team leadership asymmetry using the mean Euclidean distance,[12] calculated as $\sum_i \sqrt{[\sum_j (S_i - S_j)^2 / n]}/n$ (Harrison & Klein, 2007). Specifically, we initially computed the leadership behavior score for each member separately (using the average of all 25 items) and then calculated the mean Euclidian distance score for the team. The resulting asymmetry scores ranged from 0.00 (symmetric) to 1.87 (highly asymmetric), with a mean of 0.71 (SD = 0.40).

Task uncertainty. Given that the teams in our sample work on scientific research, we focused on the scientific aspect of uncertainty in knowledge creation. We adapted the five items used by Song and Montoya-Weiss (2001), rewording them to fit our research context. Sample items include "the scientific knowledge involved in this project is mature, i.e., the cause-and-effect relationships are well known"

[11] Expertise diversity corresponds to *variety,* as categorized in Harrison and Klein's (2007) nomenclature of diversity types.

[12] Team leadership asymmetry corresponds to *separation,* as categorized in Harrison and Klein's (2007) nomenclature of diversity types.

(reverse coded) and "the changes in the scientific knowledge basis for this project are very unpredictable." Senior managers with a broad exposure to various drug discovery projects rated the uncertainty level on a five-point scale (1 = "strongly disagree" to 5 = "strongly agree"). The Cronbach alpha for this scale is 0.82.

Team identification. We measured individual members' team identification using the four-item scale by Van Der Vegt and Bunderson (2005) and adapted the items to the individual-level. Two sample items include "I feel a strong sense of belonging to this project team" and "I feel as if the problems in this project team are my own." Team members rated their identification with the team on a five-point scale (1 = "strongly disagree" to 5 = "strongly agree"). Since our unit of analysis was the team, we averaged individual members' responses to a mean score for each team, using an additive model (Chan, 1998). This aggregation approach allows for variance in individual members' identification with the team and does *not* assume convergence in their responses. The Cronbach alpha for this scale is 0.84.

Control variables. In addition to the explanatory variables that we have identified, other factors could potentially influence team performance. First, because team performance might depend on the number of members and the time they have been working together (e.g., Chiu et al., 2016), we controlled for team size and team tenure. Second, given that more frequent interaction facilitates knowledge creation (e.g., Nonaka 1994), we controlled for the interaction frequency among team members.[13] Third, because divergent goals can obstruct team accomplishment (e.g., Edmondson & Nembhard, 2009), we controlled for goal diversity.[14] Fourth, as previous research has revealed the important roles of team innovation and transformational leadership (e.g., Eisenbeiss et al., 2008; Kearney & Gebert, 2009) as facilitators of knowledge creation, we added these variables as controls[15]. Fifth, to test whether the theorized effect of the team leadership asymmetry is above and beyond that of the team leadership mean, we controlled for the mean level of team leadership behaviors.

8.4. Results

8.4.1. Assessing Method/Source Bias

Table 1 shows the descriptive statistics and correlations among the study's variables. Given the possibility that the observed relationships could be inflated due to the common method/source bias (Podsakoff,

[13] We measured the interaction frequency using four multiple choice questions to all team members regarding their physical and virtual interaction with the other team members.

[14] To understand the typical goals in a drug discovery collaboration project, from September 2014 to May 2015 we conducted 31 exploratory interviews with experienced researchers. These interviews led us to develop a list of nine goals, including, for example, publishing in peer-reviewed journals and learning new technologies. We asked each member to rank these nine goals according to his or her priorities. We operationalized the degree of goal diversity in a team as the average of the separation diversity for each of the nine goals. To measure the separation diversity, we used the Euclidian distance measure recommended by Harrison and Klein (2007).

[15] We measured transformational leadership using the 20-item version of the MLQ questionnaire (Bass & Avolio, 1995). Team members evaluated the transformational leadership behaviors of the responsible project leaders.

MacKenzie, Lee, & Podsakoff, 2003), we employed several remedies (Podsakoff, MacKenzie, & Podsakoff, 2012) to mitigate this concern. First, the variables reported by team members followed ***different methodological approaches***. We operationalized expertise diversity, using the Teachman Entropy value of team members' scientific disciplines; team leadership asymmetry, using a Mean Euclidean distance of team members' engagement in leadership functions; and team identification, using aggregation of individual members' responses.

Second, we created ***temporal separation*** to mitigate the potential of common source bias. We gathered team members' reports of their engagement in leadership functions at a different time (T2) from those of their expertise area and identification with the team (T1). Moreover, we collected the ratings of team performance at yet a different time (T3).

Third, we collected the evaluation of team performance and task uncertainty from a ***different source***—senior managers. Additionally, to check whether these two variables, as reported by senior managers, captured distinct constructs versus common source effects, we conducted two CFAs. The two-factor model ($\chi^2 = 46.93$; $df = 31$; $p < 0.05$; CFI = 0.96; RMSEA = 0.07; SRMR = 0.07) provided significant better fit (a χ^2-difference test showed a χ^2 difference significant at $p < 0.001$) than the one-factor model ($\chi^2 = 115.10$; $df = 32$; $p < 0.001$; CFI = 0.77; RMSEA = 0.15; SRMR = 0.15), confirming the discriminant validity between task uncertainty and team performance. These results suggest that common method/source effects are not a significant concern in our study.

INSERT TABLE 1 HERE

8.4.2. Hypothesis Testing

To test our hypotheses, we used a series of ordinary least squares (OLS) regression analyses in a hierarchical setup (Aiken & West 1991). Because data transformation such as mean-centering does not actually improve the statistical fit of regression models or the statistical inference of interaction effects (Dalal & Zickar, 2012; Hayes, 2013), we did not apply any data transformation before conducting the analyses. Tables 2-8 report the results, with unstandardized coefficients and standard errors in parentheses.

We proposed in Hypothesis 1 that task uncertainty moderates the relationship between expertise diversity and performance, making this relationship more negative as task uncertainty increases. To test this moderating effect, we first entered the control variables in Model 1; second, we entered the main predictors of independent variables in Model 2; and, third, we entered the interaction term in Model 3 (displayed in Table 2). Model 3 explained the most variance (R^2=0.14). The interaction term was negative (B=-0.22, *n.s.*) but not significant (p>0.05). However, a plot of this interaction (Figure 2) show that for those teams facing a high task uncertainty, the relationship between expertise diversity and team performance was more negative than that of the teams facing a low task uncertainty. Nevertheless, we cannot claim full support for Hypothesis 1.

To test whether team leadership asymmetry mediated the moderating effect of task uncertainty as Hypothesis 2 predicted, we took three steps. First, we examined the relationship between the independent variable (i.e., expertise diversity) and the mediator (i.e., team leadership asymmetry). We entered the control variables in Model 4 and the main effect in Model 5. The results (Model 5 in Table 3) indicate that expertise diversity relates positively to team leadership asymmetry (B=0.17, p<0.01). Second, we examined the relationship between the mediator and the dependent variable (i.e., team performance). We entered the control variables in Model 6, the main effects in Model 7, and the interacting effects in Model 8. The results (Model 8 in Table 4) show a negative and significant interaction between team leadership asymmetry and task uncertainty (B=-0.44, p<0.05).

Third, using Hayes' (2013) PROCESS macro, a macro for calculating the estimates for conditional indirect effects, we examined the indirect effect of expertise diversity on team performance via team leadership asymmetry, conditional on task uncertainty. In addition, following Hayes' (2013) advice, we used the bootstrapping resampling technique (10,000 samples) to produce more precise standard errors and confidence intervals for the indirect effects at different levels of the moderator. We consider an effect significant if the bootstrapped 95%-confidence interval (CI) of the effect does not include zero (Hayes, 2013). The results in Table 5 show that for low (i.e., one standard deviation below the mean value) and very low (i.e., lowest value of the scale) levels of task uncertainty, the indirect effect of expertise diversity on team performance was positive and significant (c=0.10, p<0.05; and c=1.18, p<0.05; respectively). For high (i.e., one standard deviation above the mean value) and very high (i.e., the highest value of the scale) levels of task uncertainty, the indirect effect decreased and became negative (c=-0.01, *n.s.*; and c=-0.59, *n.s.*; respectively), albeit non-significant. The plots in Figure 3 illustrate the conditional indirect effects under low and high levels of task uncertainty. Taken together, these results fully support Hypothesis 2.

We proposed in Hypothesis 3 that team identification would negatively moderate the relationship between expertise diversity and team leadership asymmetry, making the relationship weaker as team identification increased. To test this hypothesis, we first entered the main effects in Model 9 and then the interaction effect in Model 10. The results (Model 10 in Table 6) show a significant, negative inaction term between team identification and expertise diversity (B=-0.32, p<0.05). As Table 7 and Figure 4 show, the simple slope was positive when team identification was low (c=0.32, p<0.01) and very low (c=1.08, p<0.05) levels. The slope became non-significant at high (c=0.06, *n.s.*) and very high (c=-0.21, *n.s.*) levels of team identification. These results fully support Hypothesis 3.

INSERT TABLES 2-7 AND FIGURES 2-4 HERE

8.4.3. Additional analysis

To examine the indirect effect of expertise diversity via team leadership asymmetry, contingent on the levels of two moderators (i.e., team identification and task uncertainty), we ran a post-hoc analysis. Using Hayes' (2013) PROCESS macro, we calculated the indirect effect of expertise diversity on team performance at low and high levels of team identification and task uncertainty. As Table 8 shows, the indirect effect was positive and significant for teams having low team identification and facing low task

uncertainty (c=0.18, p<0.05). With high levels of team identification or task uncertainty, or both, the indirect effect approached zero and became non-significant.

INSERT TABLE 8 HERE

8.5. Discussion

This study investigated the relationship between expertise diversity and team performance under different levels of task uncertainty. Contrary to our expectation, task uncertainty did not directly moderate the relationship between expertise diversity and team performance. Instead, this moderation effect occurred via the mechanism of team leadership asymmetry. Our data showed that, in knowledge teams with high expertise diversity, members tended to engage asymmetrically in leadership functions. Team leadership asymmetry in turn had a positive or negative impact on team performance according to the level of task uncertainty. Furthermore, we found that high team identification reduced the strength of the positive relationship between expertise diversity and team leadership asymmetry.

8.5.1. Theoretical Implications

Our findings have important implications for the literature on work group diversity (e.g., van Knippenberg & Mell, 2016) and knowledge teams (Faraj & Yan, 2009; Van Der Vegt & Bunderson, 2005). A core debate in this literature is whether and, if so, how task-relevant diversities (such as team members' functional and educational backgrounds) benefit the performance of knowledge teams (Faraj & Sproull, 2000; Van Der Vegt & Bunderson, 2005; van Knippenberg & Schippers, 2007). While previous research has developed an advanced understanding of the behaviors that help team members translate expertise diversity—a key task-related type of diversity—into performance advantages, scholarly understanding of the task-related boundary conditions that render various behaviors more or less beneficial is limited. Our findings expand this research by showing that the effect of expertise diversity in a team hinges on the levels of task uncertainty facing the team and by further explaining such differentiated effects with the dynamics in team members' leadership behaviors.

Our focus on team leadership asymmetry as the mediation mechanism offers novel insights into the ways that members in knowledge teams engage in team processes and fulfil various team needs. Previously identified mediation mechanisms linking expertise diversity and team performance typically relate directly to the knowledge task of the team (e.g., information elaboration or knowledge sharing; Hoever et al., 2012; Huang et al., 2014). What remains less understood are the mechanisms that indirectly facilitate the knowledge tasks of the team. Moreover, although scholars have long argued that team members' engagement in leadership could be an important facilitator of teamwork in teams tackling knowledge-intensive tasks (Drescher et al., 2014; Pearce & Conger, 2003), they have focused on the leadership of formal leaders (e.g., transformational leadership; Kearney & Gebert, 2009) as a factor relevant to the relationship between expertise diversity and team performance. In contrast, to better explain individuals' leadership behavior, we adopt a functional approach (Hiller et al., 2006; Morgeson et al., 2010) that considers every team members' engagement in the team process.

Our examination of the link between expertise diversity and behavioral asymmetry within the team constitutes a response to recent calls in the workgroup diversity literature for moving beyond compositional diversity (van Knippenberg & Mell, 2016, p. 136). By focusing on team leadership asymmetry, we investigate how compositional diversity influences team outcomes via *emergent diversity*—the variance in team processes and psychological states within a team. By showing that team leadership asymmetry links expertise diversity and knowledge team performance, we offer a representative example of the important consequences that emergent diversity has on knowledge team performance. Moreover, we provide first empirical support for Crawford and Lepine's (2013) theoretical conjecture that variance in team processes among team members (i.e., member's asymmetric engagement in leadership behaviors) can prove beneficial under certain conditions (i.e., low levels of task uncertainty). While research on teams largely assumes that uniform increases in teamwork and leadership behaviors are beneficial for team outcomes (e.g., LePine, Piccolo, Jackson, Mathieu, & Saul, 2008), our findings provide a more nuanced view of precisely when variance in team members' behaviors will prove beneficial.

Our research also contributes to the functional leadership literature. Research on functional and shared leadership suggests that members of teams and work groups can take on leadership functions to fulfill the team's needs (Morgeson et al., 2010). More importantly, the extent to which individual members do so has significant implications for team performance (Drescher et al., 2014; Morgeson et al., 2010; Wang, Waldman, & Zhang, 2014). While we are not the first to recognize that knowledge team members share responsibilities or engage in leadership to different degrees, we expand this literature in two important ways. First, we show that a specific team characteristic—expertise diversity—tends to be associated with team members' asymmetric engagement in leadership functions. Second, we reveal a critical mechanism—team identification—for curbing this tendency. Specifically, our results suggest that the engagement of individual members in leadership behaviors is a function of both their capacity and their motivation for doing so. Indeed, while expertise diversity relates to team leadership asymmetry by causing those team members with the most relevant skills to step up, a high team identification increases the motivation of all members to do so, thereby evening out their asymmetric engagement. This enhanced understanding of the motivation underlying members' engagement in leadership functions expands functional leadership research, which has largely focused on cognitive factors.

8.5.2. Practical Implications

Our research offers some valuable recommendations for organizations that use knowledge teams to solve complex and uncertain tasks. First, our findings underline the relevance of expertise diversity as a key team design element. As we find that high task uncertainty reduces the performance advantages of expertise diversity within a team, we recommend designing teams according to the nature of the task with which those teams are charged. When teams face highly uncertain tasks, such as explorative research in uncharted domains, organizations should limit the degree of within-team expertise diversity. For example, team leaders could break down large, complex project teams into sub-teams with a critical mass of certain expertise (e.g., Ben-Menahem et al., 2016).

Second, in light of the significant role of leadership behaviors, organizations should design and use training programs to help team members enact leadership behaviors whenever their expertise allows. Furthermore, organizational leaders need to be aware that the benefits arising from the variance in team members' leadership behaviors differ across team tasks. When knowledge teams face relatively low task uncertainty, keeping leadership engagement flexible may better utilize the human capital in the team. In this case, teams will find it beneficial to allocate leadership responsibilities according to the distribution of expertise or encourage team members with the most relevant expertise to step up as the situation demands (Faraj & Sambamurthy, 2007; Pearce, 2004).

Finally, given the importance of team identification, managers should implement measures for enhancing the team identification of members. As our results suggest, team identification is especially critical when the task at hand requires a highly diverse team despite high uncertainty (e.g., teams working on new product development projects). In such cases managers should pay special attention to motivate every member to assume leadership responsibilities and to fulfil the team's needs. Strong motivation will not be likely without effective measures for facilitating social interactions that foster understanding across members from various domains of expertise. Example of such measures include team-building events, "friendly competition" between teams, or experience-sharing opportunities whereby individual members can develop a sense of belonging to their team (Farmer, Frank Barton, Van Dyne, & Kamdar, 2015).

8.5.3. Limitations and Directions for Future Research

This study has several limitations, all of which offer possibilities for future research. First, the current research design offers limited causal inference. Although our theoretical model builds upon strong theoretical foundations, we cannot draw causal conclusions from our data. However, because we measured the study variables in different survey waves (the independent variable expertise diversity at time 1, the mediating variable team leadership asymmetry at time 2 and the dependent variable team performance at time 3), reverse causality is unlikely (MacKinnon, Fairchild, & Fritz, 2007; Podsakoff et al., 2012). Nonetheless, to further disentangle the causal relationships, future research could employ lab or field experiments to compose teams of various degrees of expertise diversity.

Second, given the lengthy process of pharmaceutical research (Ding, 2014), capturing the performance in drug discovery teams requires a long time window. Bringing a new drug to the market can take up to 15 years, and evaluating the return on the R&D-related investment can take even longer. While having managers evaluate team performance is common in applied research (e.g., Eisenbeiss et al., 2008), such evaluation relies on perceptual data. Future research can corroborate the managers' ratings of team performance with objective records (e.g., the number of peer-reviewed articles published, patents filed, or new drugs developed) as such data become available.

Third, although our unprecedented access to *InterPharma*'s drug discovery teams gives us an ideal context for studying knowledge teams with expertise diversity, it also imposes limitations on our findings. Despite substantial variance in the levels of task uncertainty among the teams in our sample, most of these teams were working on exploratory research projects. On average, these teams may face higher levels of

uncertainty than those of the general population. Future research can validate our findings in different types of teams that are working on a larger spectrum of tasks.

Fourth, asymmetry in different leadership functions may have drastically different implications for performance. For example, a variance in mentoring activities might prove beneficial because team members could have quite different skills and abilities to manage interpersonal dynamics (e.g., Pescosolido, 2002). In contrast, a variance in problem-solving efforts could prove detrimental if the task at hand requires a universally high input from all team members (Klein, Ziegert, Knight, & Xiao, 2006; Morgeson et al., 2010). Future research that further explores these nuanced differences will be able to provide even better guidance for designing and leading knowledge teams.

8.5.4. Conclusion

This study offers new theoretical insights into when and, if so, how knowledge teams with different levels of expertise diversity can effectively tackle complex and uncertain tasks—a situation commonly found in contemporary organizations. We have identified task uncertainty as a critical factor moderating the nature of relationship between expertise diversity and knowledge team performance. This moderating effect, however, is not direct; instead, it takes place indirectly via team leadership asymmetry. In addition, we have shown that team identification can attenuate team members' tendencies to engage asymmetrically in leadership functions. Our findings have important implications for future research and practice on designing and managing knowledge teams.

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Table 1

Descriptive Statistics and Correlations among Study Variables

Variables	Mean	SD	1	2	3	4	5	6	7	8	9	10	11
1. Team size	4.74	1.83	—										
2. Project runtime	1.42	1.01	0.11	—									
3. Interaction frequency	3.29	0.50	0.02	0.03	—								
4. Goal diversity	0.25	0.13	0.78***	0.09	-0.11	—							
5. Team innovation	3.49	0.55	0.12	0.08	0.53***	0.07	—						
6. Transformational leadership	3.88	0.51	-0.02	-0.13	0.32***	-0.01	0.46***	—					
7. Team leadership mean	3.86	0.49	-0.09	-0.08	0.39***	-0.03	0.66***	0.39***	—				
8. Expertise diversity	1.53	0.60	0.59***	0.01	-0.07	0.50***	0.09	-0.05	-0.11	—			
9. Team identification	3.77	0.39	0.02	0.01	0.38***	0.01	0.44***	0.33***	0.55***	0.06	—		
10. Team leadership asymmetry	0.71	0.40	0.24*	-0.04	-0.21*	0.17	-0.23*	-0.18	-0.32**	0.24*	-0.22*	—	
11. Task uncertainty	3.16	0.72	0.04	-0.12	0.03	-0.07	-0.02	0.04	-0.05	0.10	-0.01	0.15	—
12. Team performance	3.85	0.71	0.24*	0.09	0.09	0.20*	0.19	0.01	0.12	0.04	0.05	0.13	0.10

Note. N = 99.

*p<0.05. **p<0.01. ***p<0.001.

Table 2

Regression Analysis of Team Performance on Expertise Diversity and Task Uncertainty

	Team performance		
Predictors	Model 1	Model 2	Model 3
Controls			
Team size	0.07 (0.06)	0.09 (0.07)	0.10 (0.07)
Project runtime	0.03 (0.07)	0.04 (0.07)	0.04 (0.07)
Interaction frequency	0.01 (0.17)	-0.02 (0.17)	-0.01 (0.17)
Goal diversity	0.23 (0.89)	0.51 (0.90)	0.48 (0.89)
Team innovation	0.19 (0.20)	0.24 (0.20)	0.23 (0.20)
Transformational leadership	-0.11 (0.16)	-0.14 (0.16)	-0.12 (0.16)
Team leadership mean level	0.11 (0.20)	0.09 (0.21)	0.08 (0.20)
Main effects			
Expertise diversity		-0.21 (0.15)	0.44 (0.50)
Task uncertainty		0.13 (0.10)	0.48† (0.28)
Interaction effects			
Expertise diversity × task uncertainty			-0.22 (0.16)
R^2	0.10	0.13	0.14
Model F	1.36	1.42	1.47
Adjusted R^2	0.03	0.04	0.05
Change in R^2		0.03	0.02
F for change in R^2		1.55	1.83

Note. N=99. The table reports unstandardized regression coefficients (*B*) with standard errors in parentheses.

$^{\dagger}p<0.10$.

Table 3

Regression Analysis of Team Leadership Asymmetry on Expertise Diversity

	Team leadership asymmetry	
Predictors	Model 4	Model 5
Controls		
Team identification	-0.23* (0.10)	-0.24* (0.10)
Main effects		
Expertise diversity		0.17** (0.07)
R^2	0.05	0.11
Adjusted R^2	0.04	0.09
Model F	4.80*	6.08**
Change in R^2		0.06
F for change in R^2		7.06**

Note. N=99. The table reports unstandardized regression coefficients (*B*) with standard errors in parentheses. *p<0.05. **p<0.01.

Table 4

Regression Analysis of Team Performance on Team Leadership Asymmetry and Task Uncertainty

	Team performance		
Predictors	Model 6	Model 7	Model 8
Controls			
Team size	0.07 (0.06)	0.08 (0.07)	0.08 (0.07)
Project runtime	0.03 (0.07)	0.04 (0.07)	0.04 (0.07)
Interaction frequency	0.01 (0.17)	0.00 (0.17)	0.03 (0.17)
Goal diversity	0.23 (0.89)	0.53 (0.89)	0.60 (0.88)
Team innovation	0.19 (0.20)	0.24 (0.20)	0.29 (0.20)
Transformational leadership	-0.11 (0.16)	-0.12 (0.16)	-0.15 (0.16)
Team leadership mean level	0.11 (0.20)	0.13 (0.21)	0.08 (0.21)
Main effects			
Expertise diversity		-0.22 (0.15)	-0.23 (0.15)
Team leadership asymmetry		0.26 (0.20)	1.62* (0.71)
Task uncertainty		0.11 (0.10)	0.42* (0.19)
Interaction effects			
Team leadership asymmetry × task uncertainty			-0.44* (0.22)
R^2	0.10	0.14	0.18
Adjusted R^2	0.03	0.05	0.08
Model F	1.36	1.46	1.74†
Change in R^2		0.05	0.04
F for change in R^2		1.62	4.04*

Note. N=99. The table reports unstandardized regression coefficients (*B*) with standard errors in parentheses. †p<0.10. *p<0.05.

Table 5
Conditional Indirect Effects of Expertise Diversity on Team Performance, Moderated by Task Uncertainty

Task uncertainty	Conditional indirect effect (SE) Expertise diversity → Team leadership asymmetry → Team performance	95% CI
Very low	1.18* (0.50)	[0.19, 2.17]
Low	0.10* (0.06)	[0.01, 0.23]
High	-0.01 (0.05)	[-0.13, 0.08]
Very high	-0.59 (0.46)	[-1.51, 0.33]

Note. N = 99. Unstandardized coefficients (*c*) with standard errors (SE) in brackets. Low and high levels of task uncertainty correspond to the mean level plus/minus one standard deviation. Very low and very high levels of task uncertainty correspond to the lowest and highest value of the measurement scale. Standard errors (SE) for the conditional indirect effect and the corresponding 95% confidence intervals (CI) have been bias-corrected using with 10,000 bootstrap samples (Hayes 2013).
*p<0.05.

Table 6
Regression Analysis of Team Leadership Asymmetry on Team Identification and Expertise Diversity

	Team leadership asymmetry	
Predictors	Model 9	Model 10
Main effects		
Team identification	-0.24* (0.10)	0.18 (0.24)
Expertise diversity	0.17** (0.07)	1.40* (0.62)
Interaction effects		
Expertise diversity × Team identification		-0.32* (0.16)
R^2	0.11	0.15
Adjusted R^2	0.09	0.12
Model F	6.08**	5.51**
Change in R^2		0.04
F for change in R^2		3.99*

Note. N=99. The table reports unstandardized regression coefficients (B) with standard errors in parentheses.
*p<0.05nmn ; **p<0.01 (two-tailed significance).

Table 7
Conditional Effect of Expertise Diversity on Team Leadership Asymmetry, Moderated by Team Identification

Team identification	Conditional effect (SE) Expertise diversity → Team leadership asymmetry	95% CI
Very low	1.08* (0.46)	[0.17, 1.99]
Low	0.32** (0.09)	[0.13, 0.51]
High	0.06 (0.08)	[-0.10, 0.23]
Very high	-0.21 (0.20)	[-0.61, 0.19]

Note. N = 99. Unstandardized coefficients (*c*) with standard errors (SE) in brackets. Low and high levels of task uncertainty correspond to the mean level plus/minus one standard deviation. Very low and very high levels of task uncertainty correspond to the lowest/highest value of the measurement scale. Standard errors (SE) for the conditional indirect effect and the corresponding 95% confidence intervals (CI) have been bias-corrected using with 10,000 bootstrap samples (Hayes 2013).
*p<0.05. **p<0.01.

Table 8
Conditional Indirect Effects of Expertise Diversity on Team Performance, Moderated by Team Identification

Task uncertainty	Team identification	Conditional indirect effect (SE) Expertise diversity → Team leadership asymmetry → Team performance	95% CI
Low	Low	0.18* (0.10)	[0.01, 0.39]
	High	0.04 (0.05)	[-0.04,0.15]
High	Low	-0.02 (0.09)	[-0.22, 0.15]
	High	-0.01 (0.03)	[-0.07, 0.03]

Note. N = 99. Unstandardized coefficients (*c*) with standard errors (SE) in brackets. Low and high levels of both moderators correspond to the mean level plus/minus one standard deviation. Standard errors (SE) for the conditional indirect effect and the corresponding 95% confidence intervals (CI) have been bias-corrected using with 10,000 bootstrap samples (Hayes 2013).
*p<0.05.

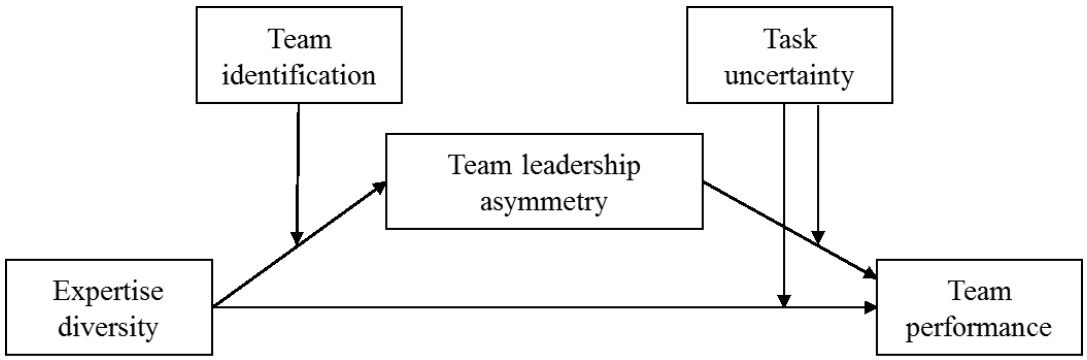

Figure 1. Conceptual model.

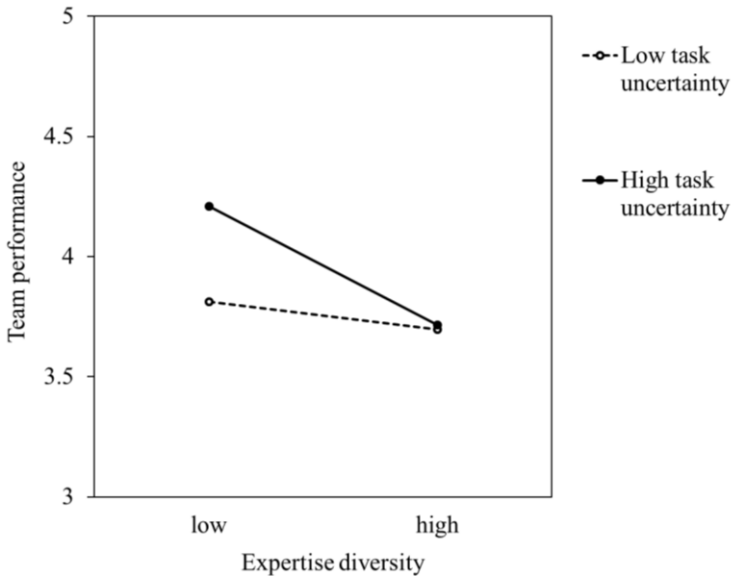

Figure 2. Task uncertainty as a moderator in the relationship between expertise diversity and team performance.

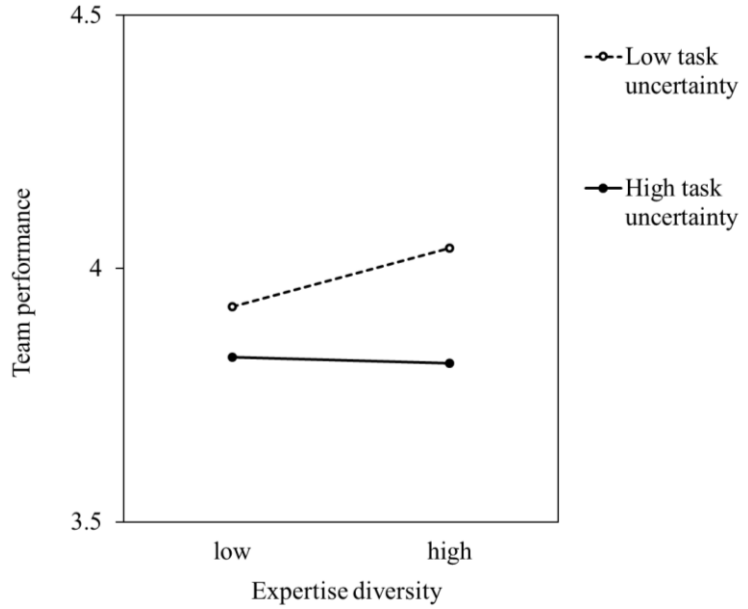

Figure 3. Task uncertainty as a moderator in the relationship between expertise diversity and team performance mediated by team leadership asymmetry.

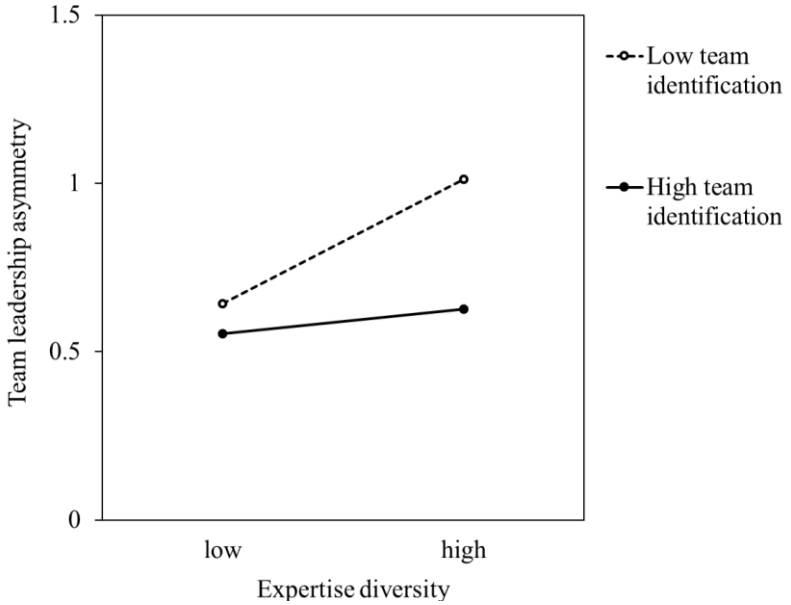

Figure 4. Team identity as a moderator in the relationship between expertise diversity and team leadership asymmetry.

9. Essay 2 - The impact of orientation-based dissimilarities in university–industry collaboration on project outcomes: Investigating the critical roles of conflict and transformational leadership

Revise & Resubmit (1st round) **at Research Policy**

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Vivianna Fang He, ETH Zurich

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Abstract

Prior research considers *orientation-based dissimilarities*—fundamental differences in the goals and expectations of partnering organisations in a collaborative project—as critical impediments to successful university–industry collaboration. Despite the common belief that orientation-based dissimilarities constitute major barriers to effective collaboration, empirical evidence on how they impact university–industry collaboration is rare. In this study, we draw on literature on collaborative teams and conflict management to develop a theoretical model stipulating that conflict in collaboration project teams mediates the impact of orientation-based dissimilarities on team outcomes. While orientation-based dissimilarities relate positively to the level of conflict in such teams, project leaders' transformational leadership decreases the strength of this relationship. In turn, conflict likely affects two types of collaboration outcomes. First, conflict relates positively to project performance up to a certain level but has an increasingly negative impact on project performance beyond the inflection point. Second, conflict decreases project team members' intention to collaborate again. Analysing multisource data from 118 university–industry collaborations comprising 531 project team members, we find empirical support for the theoretical model. Our study sheds light on the team dynamics of university–industry collaboration and, more generally, on the functioning of collaboration project teams. We discuss implications for researchers, policymakers, and managers of university–industry collaboration.

***Keywords**:* university–industry collaboration, orientation-related dissimilarities, conflict, leadership, project performance.

9.1. Introduction

Research collaboration between universities and firms plays a pivotal role in their ability to create and disseminate scientific knowledge, and to transform scientific results into useful applications for the economy and society (Bishop et al., 2011; Cohen et al., 2002; Mansfield, 1995). While universities and firms collaborate to benefit from complementary knowledge (Du et al., 2014; Meyer-Krahmer and Schmoch, 1998; Perkmann et al., 2013), it is not uncommon that their collaboration fails to realise its intended outcomes (Bruneel et al., 2010; Estrada et al., 2016; Perkmann and Salter, 2012). Additionally, while university–industry collaboration promises economic and social benefits, it also has potential risks and costs for both universities and firms (e.g., opportunity costs—De Fuentes and Dutrénit, 2012; Perkmann and Salter, 2012; knowledge protection costs—Laursen and Salter, 2014). Therefore, understanding the mechanisms underlying the performance of university–industry collaboration is important for managers, principal investigators, and policymakers.

Prior research proposes *orientation-based dissimilarities*[16]—the differences in goals and expectations between collaborating organisations—as an important mechanism that shapes university–industry collaboration (e.g., Bruneel et al., 2010; Estrada et al., 2016; Tartari et al., 2012). However, with rare exceptions (e.g., Estrada et al., 2016), most existing studies assume that orientation-based dissimilarities hinder effective knowledge exchange without supportive evidence on how such dissimilarities shape current or future collaborations (Bruneel et al., 2010). Previous studies have tended to focus on challenges *perceived* by project members in university–industry collaboration (Bruneel et al., 2010), or factors (e.g., repeated collaborations) that mitigate certain challenges (Bruneel et al., 2010; Tartari et al., 2012). Recently, Estrada and colleagues (2016) began exploring how different types of dissimilarities interact to influence the processes within university–industry collaborations. Their analysis revealed that coordination efforts mitigate routine-based dissimilarities when orientation-based dissimilarities are absent or latent. Yet, Estrada and colleagues' study (2016) did not demonstrate how orientation-based dissimilarities may affect collaboration outcomes or what coordination efforts could mitigate these dissimilarities.

Building on Estrada and colleagues' (2016) seminal work, the goal of the current study is to shed light on how, and under what conditions, orientation-based dissimilarities may affect different outcomes of university–industry collaboration projects. In particular, the outcomes considered include performance of the current project, and intentions for future collaboration (Jap, 2001; Jap and Anderson, 2003). This intention, defined as the willingness to collaborate again (Jap, 2001), is a measure of the relationship quality with the collaboration partner. Because of the many advantages associated with repeated collaboration, this intention constitutes a particularly important outcome of university–industry collaboration (Bruneel et al., 2010; Hemmert et al., 2014; Mora-Valentin et al., 2004).

[16] Orientation-based dissimilarities are different from routine-based dissimilarities, which relate to differences in how organisations operate and interact with collaboration partners (Estrada et al., 2016). The alliances literature (e.g., Lavie et al., 2012; Zollo et al., 2002) hosts an extended discussion on routine-related dissimilarities, which are beyond the focus of the present study.

Accumulated research shows that conflict is a salient factor explaining collaboration performance (e.g., Bstieler et al., 2015; Kale et al., 2000; Mora-Valentin et al., 2004), and studies underscore that university–industry collaboration is especially prone to conflicts stemming from a weak alignment of interests between partners (Bruneel et al., 2010; see also Kale et al., 2000; Mora-Valentin et al., 2004; Welsh et al., 2008). Prior work on leadership in teams has demonstrated that transformational leadership, a type of leadership influence that offers a purpose and moves followers beyond short-term goals to focus on higher order intrinsic needs (Bass, 1985; Judge and Piccolo, 2004), could be an effective mechanism aligning team members' diverse individual interests toward a joint team goal (e.g., Atwater and Bass, 1994; Zhang et al., 2011). Hence, we integrate the literature on conflicts and the literature on team leadership, to develop a theoretical model in which team conflict is a key mechanism linking orientation-based dissimilarities and project outcomes (Figure 1). We examine this model using data from 118 university–industry collaborations, comprised of 531 project team members.

This study strengthens understanding of orientation-based dissimilarities' role in university–industry collaboration. It is—to the best of our knowledge—the first study to examine the impact of these dissimilarities on the outcomes of university–industry collaborations. We theorise and find empirical support that orientation-related dissimilarities increase team conflict, which in turn impacts project outcomes. Moreover, our results confirm that project team leaders' transformational leadership mitigates the impact of orientation-related dissimilarities on team conflict. Indeed, while orientation-related dissimilarities exert a negative indirect effect on project outcomes via project team conflict, project leaders' transformational leadership may reduce this negative effect. These findings suggest that projects involving partners with major differences in goals and objectives are not necessarily futile. Instead these projects may be as successful as their counterparts with minor goal differences, given strong transformational leadership. These findings pave the way for future research on the leadership mechanisms mitigating the orientation-based dissimilarities that are omnipresent in university–industry collaboration.

Further, our study expands the literature on university–industry collaboration by differentiating two important collaboration outcomes—project performance and project team members' intention to repeat the collaboration. Because many university–industry collaborations are contracted and organised as a stream of projects with specific goals and milestones that must be met in order to continue the joint efforts (Mora-Valentin et al., 2004; Perkmann et al., 2011), collaborative projects may need to be managed according to the priority of current performance relative to the possibility of future collaboration (e.g., Perkmann et al., 2011). However, previous research has largely overlooked the possibility that a certain collaboration setup might have different implications for different collaboration outcomes. Our study shows that whereas orientation-based dissimilarities increase the level of conflict in project teams, the impact of conflict differs vis-à-vis current project performance and for members' willingness to engage in future collaboration. While conflict has an inverted U-shaped relationship with project performance, project team conflict resulting from orientation-based dissimilarities produces a linear negative effect on the intention to repeat collaboration. These findings suggest that if current project performance is a top priority, a moderate number of orientation-based dissimilarities is desirable. Conversely, if opportunities for future

collaboration outweigh current performance, minimizing these dissimilarities is warranted. As such, this study addresses an important puzzle of theoretical and practical interest.

Our study also contributes to the literature on interorganisational collaboration in general. Prior studies emphasise the relevance of conflict in interorganisational collaboration, arising from differences between partnering organisations (e.g., Doz, 1996; Huxham and Vangen, 2000). Scholars have long sought to identify mechanisms that attenuate such conflict (Das and Teng, 1998; Kale et al., 2000). Our theorising and empirical evidence points to the importance of transformational leadership, which thus far has received the most attention in the leadership literature (e.g., Osborn and Marion, 2009). By drawing on the leadership literature and examining transformational leadership in the context of university–industry collaboration project teams, we advance the debate about how interorganisational collaboration can be effectively managed.

Finally, our research design offers an unprecedented empirical perspective on university–industry collaboration. Prior studies have mostly relied on data from universities (e.g., D'Este and Perkmann, 2011; De Fuentes and Dutrénit, 2012), firms (e.g., Bruneel et al., 2010; Bstieler et al., 2015), or archival public records such as patent or publication databases (e.g., Banal-Estañol etBoo al., 2015; Cassiman et al., 2008). Since most university–industry collaborations are implemented by project teams comprising members from both types of organisations (Cyert and Goodman, 1997), scholars have called for work based on data from both firms and universities to complement existing theory and research (e.g., Perkmann et al., 2013). Our study responds to this call by collecting and analysing first-hand data from ongoing projects with team members from both universities and firms.

9.2. Theoretical background

9.2.1. University–industry collaboration

Collaboration between universities and firms is known to benefit academic research at universities (e.g., Agrawal and Henderson, 2002; D'Este and Perkmann, 2011; Lee, 2000; Perkmann and Walsh, 2009; Siegel et al., 2003) and innovation at firms (e.g., Bishop et al., 2011; Mansfield, 1995; Motohashi, 2005; Murray, 2002). However, despite a common desire for such collaboration to succeed, participants of university–industry collaboration often face fundamental differences. Universities and firms often pursue different organisational goals (Cyert and Goodman, 1997; De Fuentes and Dutrénit, 2012; Hagedoorn et al., 2000; Perkmann et al., 2013). While firms seek to profit from marketable products and services, universities seek to create scientific knowledge in the form of new concepts, models, empirical findings, and measurement techniques (Cyert and Goodman, 1997; Elmuti et al., 2005; Merton, 1973). The (predominantly short-term) performance orientation of industrial research conflicts with the (long-term) exploratory and learning orientation of academic research (Lee, 1996; Meyer-Krahmer and Schmoch, 1998; Tartari et al., 2012).

Furthermore, universities and firms differ in their collaborative orientations and expectations (Bjerregaard, 2010; Dasgupta and David, 1994; Davenport et al., 1998; Foray and Lissoni, 2010). Two institutional logics—the "academic logic" and the "commercial logic" (Sauermann and Stephan, 2013, p. 889)—shape

the material practices, assumptions, values, beliefs, and rules by which participants from these organisations provide meaning to their collaboration activity (Thornton and Ocasio, 2008, p. 101). The differences in logics, particularly in relation to rewards (peer recognition vs. appropriation of financial returns) and the disclosure of results from knowledge creation (open disclosure of research results vs. protection of intellectual property), may shape the collaboration. In contrast to corporate employees, academics work for universities largely based on their personal preferences and values (Agarwal and Ohyama, 2013; Roach and Sauermann, 2010; Sauermann and Stephan, 2013) and they likely extend such preferences to their research collaboration. Academics also prioritize and value journal publications more than scientists working in a for-profit firm, and they thus generally expect collaboration to materialise in publications (Perkmann et al., 2011).

The literature on university–industry collaboration conceptualises these fundamental differences in organisational goals, collaborative orientation, and expectations as "orientation-based dissimilarities" (Bruneel et al., 2010; Dasgupta and David, 1994; Estrada et al., 2016, p. 2009; Tartari et al., 2012). While orientation-based dissimilarities are prominent in most university–industry collaborations (De Fuentes and Dutrénit, 2012; Estrada et al., 2016; Perkmann and Walsh, 2007), the literature is inconclusive regarding their implications for collaboration outcomes.

On the one hand, scholars argue that orientation-based dissimilarities impede collaboration (Bruneel et al., 2010; Tartari et al., 2012) because they give rise to conflicting attitudes among project members toward several aspects of the collaboration project, such as the focus of the research domain and the timing or form of the results disclosure (Bruneel et al., 2010). Moreover, scholars argue that a "cultural divide" between academic and corporate research and development (Dasgupta and David, 1994) hinders the emergence and maintenance of trust in university–industry collaboration (Davenport et al., 1998; Hemmert et al., 2014). Insofar as trust is imperative for members of partnering organisations to exchange knowledge, jointly resolve problems, and understand the needs of the other organisation (Bruneel et al., 2010), the presence of orientation-based dissimilarities is expected to impede successful collaboration between firms and universities.

On the other hand, some scholars do not consider orientation-based dissimilarities as a problem per se in industry–university collaboration. For example, Bjerregaard (2010) argues that the differences in the two parties' institutional logics are not likely to cause negative consequences for team functioning. When institutional logics are different but complementary, they may converge over time (Bjerregaard, 2010; Sauermann and Stephan, 2013; York et al., 2016). During a collaboration, researchers from industry may adapt to academic norms—a phenomenon visible in the co-authoring of scientific publications. Academics adapt to the "entrepreneurial logic," which is visible in the founding of spin-offs or the licensing of their intellectual property. The mobility of personnel between industry and academia reinforces the convergence of logics and thereby facilitates a "shared cultural micro-cosmos for collaboration" (Bjerregaard, 2010, p. 106). Taken together, the current contrasting findings indicate that our understanding of orientation-based dissimilarities and their impact on project outcomes remains incomplete.

A closer examination of the process within university–industry collaboration projects and the context around this process could help shed light on the impact of orientation-based dissimilarities on project outcomes. For example, much team research suggests that the dynamics in a project team, such as the level of trust (e.g., Bstieler et al., 2015) or leadership (e.g., Hemmert et al., 2014), are able to influence outcomes of collaborative projects. However, although previous studies have uncovered the impact of several project characteristics (e.g., whether a project conducts applied or basic research—Hemmert et al., 2014; Perkmann and Walsh, 2009; the tie strength between and the reputation of collaborating organisations, the presence of contractual safeguards and project champions—Hemmert et al., 2014) and team composition (e.g., Iseke et al., 2015), little is known about how the process within a university–industry collaboration project team may shape collaboration outcomes. It seems prudent for scholarship on university–industry collaboration to consider the possibility that orientation-based dissimilarities may shape the dynamics among participants, and in particular the conflicts in a collaboration project team.

9.2.2. Conflict in collaboration project teams

Conflict, defined as "the process arising from perceived or real incompatibilities among group members," has long been considered a primary mediator that can explain the effects of various dimensions of team diversity on a team's performance (Jehn and Greer, 2012, p. 180). Disagreements among team members may arise around the content and outcomes of the task being performed (task conflict); disagreements about non–work-related issues, norms, and values (relationship conflict); and disagreements about the logistics of task accomplishment, such as the delegation of tasks and responsibilities (process conflict). Since conflicts arising from these sources strongly correlate (Bendersky et al., 2014; Korsgaard et al., 2008; Simons and Peterson, 2000) and mutually reinforce each other (Jehn et al., 2008; Jehn and Greer, 2012), scholars have elected to conceptualise "team conflict" as the overall level of conflict within a team (e.g., Jehn et al., 2010; Jehn and Greer, 2012; Klein et al., 2011). Team diversity factors, including those in demographic attributes, functional or educational background, knowledge bases, interests, goals, and values, generally increase the level of conflict within a team (Jehn and Greer, 2012; Korsgaard et al., 2008; Pelled et al., 1999).

The level of conflict exerts a strong impact on team functioning and outcomes (De Dreu and Weingart, 2003; De Wit et al., 2012; Jehn, 1995). Scholars further distinguish "distal outcomes" (e.g., goal-attainment performance—De Wit et al., 2012) from "proximal outcomes" (e.g., satisfaction, commitment, trust, cohesion, and group viability). Regarding distal outcomes, prior research suggests a largely negative impact of conflict on team performance, unless the team has a supportive atmosphere or is facing high task complexity (Bradley et al., 2015; De Wit et al., 2012; Jehn, 1997; Thiel et al., 2017). In contrast, conflict has a consistently negative effect on proximal group outcomes, including satisfaction, commitment, and group viability (De Wit et al., 2012). Therefore, the literature on conflict in teams within organisations suggests that team conflict is the predominant mechanism by which the diversity of a team affects its outcomes.

While previous studies have independently shed light on the impact of project team conflict on proximal and distal outcomes, they have failed to address the trade-off between different outcomes, a typical

dilemma facing participants of university–industry collaborations (e.g., Mora-Valentin et al., 2004). For university–industry collaborations, it is likely that both types of outcomes are important because collaborators value relationship/goodwill as much as they do performance (Lee, 2000; Mora-Valentin et al., 2004). Correspondingly, this study seeks to capture the effects of conflict on both outcomes.

9.3. Hypothesis development

9.3.1. Orientation-based dissimilarities and team conflict

In the context of university–industry collaboration, scholars refer to conflict as a "lack of harmony and agreement between the cooperating organisations" (Alter, 1990; Mora-Valentin et al., 2004). Orientation-based dissimilarities are a relevant source of conflict in collaborative projects (Bruneel et al., 2010; Estrada et al., 2016; Mora-Valentin et al., 2004). Unless the collaboration is purely transactional (e.g., the company pays academic scientists a fee for carrying out a specific analysis), university–industry relationships are typically "team-based partnerships" (Cyert and Goodman, 1997, p. 53; Perkmann et al., 2013). The abundance of team-based partnerships accentuates the need to examine orientation-based dissimilarities and conflict at the project team level.

Orientation-based dissimilarities likely elevate collaboration project team conflict in three ways. First, when the goals of the project team members from involved organisations differ significantly, they give rise to task-related conflicts. First, team members with different agendas might struggle to settle task priorities (Bjerregaard, 2009; Cyert and Goodman, 1997; Tartari et al., 2012). Next, they may diverge on how to accomplish these tasks (De Wit et al., 2012). Such disagreements create conflicting directions as team members interact. Furthermore, orientation-based dissimilarities may engender conflict over the distribution of project outcomes. Past studies have underscored the prominence of "allocation battles" in university–industry collaboration, including the distribution of intellectual property rights and financial rewards (Ankrah et al., 2013; Bruneel et al., 2010; Bstieler et al., 2015; Welsh et al., 2008).

Second, orientation-based dissimilarities can spark interpersonal conflicts. One team member may disagree with another team member's goal of or approach to collaboration and consequently withhold knowledge or fail to respond to that team member's queries. For example, one party may accuse the other of opportunism and refuse to disclose certain results for publication (Estrada et al., 2016; Fey and Beamish, 2001). Indeed, previous research shows that dissimilarities in goals or approaches not only inhibit the flow of knowledge but also deteriorate trust between the collaborating organisations (Ankrah et al., 2013; Bjerregaard, 2010; Tartari et al., 2012).

Third, orientation-based dissimilarities may give rise to process conflict. Orientation-based dissimilarities are usually associated with different work styles, time frames for deadlines, and management approaches (Bjerregaard, 2010; Bstieler et al., 2017; Cyert and Goodman, 1997; Mora-Valentin et al., 2004; Ruuska and Teigland, 2009). Team members with different objectives and interests also tend to attach different meanings to events, which complicates communications within a project (Estrada et al., 2016; Muscio and

Pozzali, 2013). These communication difficulties may further hamper interaction and coordination within the team. For example, when project team members discover new scientific findings that raise doubts about the current approach, they may disagree about how the project should proceed due to different interpretations of such findings (Estrada et al., 2016; Weber and Mayer, 2014). Therefore, we hypothesize the following:

H1. Orientation-based dissimilarities increase the level of conflict in collaboration project teams.

9.3.2. The moderating role of transformational leadership

Research on interorganisational collaboration has examined different mechanisms that reduce conflict in collaborative projects (Poppo and Zenger, 2002; Ryall and Sampson, 2009). While contracts are effective for mitigating moral hazard in collaborations that are transactional in nature (e.g., undesired disclosure of information—Kale and Singh, 2009), managerial mechanisms are imperative for reducing conflict during the course of a collaborative project (Gulati et al., 2012). Managerial mechanisms include steering committees (e.g., Reuer and Devarakonda, 2016), relational governance (e.g., Kale et al., 2000; Poppo and Zenger, 2002), and leadership (e.g., Borys and Jemison, 1989; Davis and Eisenhardt, 2011; Judge and Ryman, 2001; Selznick, 1957). In particular, project leaders play an important role in preventing coordination and cooperation failures during a collaboration (Gulati et al., 2012; Kale et al., 2000; Kale and Singh, 2009).

While the literature has examined different types of leadership in teams and collaborations, scholars have argued that transformational leadership may play a particularly important role in project teams consisting of members with differences in goals or interests (Bass, 1985; Podsakoff et al., 1990; van Knippenberg and Sitkin, 2013). Transformational leadership is associated with identifying and articulating a vision for the team, providing an appropriate role model, fostering the acceptance of team goals, demanding high performance, providing individualised support, and providing intellectual stimulation (Podsakoff et al., 1990). In identifying and articulating a team vision, transformational leadership establishes collective values and norms among team members (Zhang et al., 2011) and promotes cooperation among project team members to work toward the common goal (Mackenzie et al., 2001; Podsakoff et al., 1990). Concurrently, transformational leadership fosters trust and an open climate within a team, which enhances communication among project members (Atwater and Bass, 1994). In providing intellectual stimulation, transformational leadership encourages team members to challenge existing assumptions, reframe problems, and approach the task in new ways (Eisenbeiss et al., 2008; Podsakoff et al., 1990). As a consequence, project team members may overcome interpretation and communication difficulties more easily (Zhang et al., 2011), as well as focus their attention on discovering solutions collectively (Bass, 1985; Eisenbeiss et al., 2008; Howell and Avolio, 1993). In emphasising and fostering acceptance of the team's collective goals, transformational leadership makes team members think beyond their individual objectives and interests (Bass, 1985; Podsakoff et al., 1990). Further, this type of leadership prioritises intrinsic motivation over extrinsic incentives; it thus reduces discrepancies in expected personal gains from project outcomes (Shamir et al., 1993) and consequently reduces intra-team competition (Shin and Zhou, 2007).

Indeed, studies on research and development project teams show that the project leaders'[17] transformational leadership facilitates team functioning. Transformational leadership provides project team members with a sense of importance about the project's overall mission, stimulates members to think about emergent problems in new ways, and emphasises project goals over personal self-interests (Keller, 1995; van der Weijden et al., 2008). When research projects span different organisations or different sectors, scholars have found transformational leadership to be effective in bringing members from these organisations together, preventing the emergence of conflict, and facilitating collaborative research (Bstieler et al., 2015; Ranga and Etzkowitz, 2013). Building on the theoretical arguments and empirical evidence above, we hypothesise:

H2. Project leaders' transformational leadership moderates the impact of orientation-based dissimilarities on conflict in collaboration project teams.

9.3.3. The mediating role of team conflict

In line with previous research on university–industry collaboration (De Wit et al., 2012; Jehn and Greer, 2012; Perkmann et al., 2011), we argue that the outcome of a collaborative project has at least two distinct dimensions. First, whether the current project is progressing according to plan or is realising the desired objectives is an important outcome (Perkmann et al., 2011). Such project performance as a collaboration outcome has attracted the most scholarly attention (e.g., Grimaldi and Tunzelmann, 2002; Peterson, 1993). Second, because repeated collaboration projects have advantages such as trusted relationships among partners and accumulated learning from past experience (Bruneel et al., 2010; Bstieler et al., 2015), the likelihood of repeating current collaboration is worthy of consideration when evaluating project outcomes. Furthermore, many university–industry collaborations may be organised as a sequence of projects with separate goals and milestones, where agreement on a new project depends on the success of a past project. Therefore, another important outcome of university–industry collaboration projects concerns participants' intention to repeat their collaboration in the future (Jap, 2001; Jap and Anderson, 2003; Mora-Valentin et al., 2004).

Regarding project performance, different levels of team conflict have drastically different impacts, either unleashing the power of within-group interaction or destroying the dynamics between team members (Bradley et al., 2015; De Wit et al., 2012; Jehn, 1995). At low levels, team conflict can have a positive impact on team performance (e.g., Bradley et al., 2015; Jehn, 1997; Thiel et al., 2017). A small amount of conflict around the tasks at hand, or cooperative negotiation (De Dreu and Weingart, 2003, p. 742), may stimulate reflection, facilitate the consideration of alternative courses of action, and help generate different approaches to problem solving, all of which enhance team performance (Jehn, 1997; Jehn and Greer, 2012;

[17] In university–industry collaboration, the responsible project leaders from the partnering organisations play an important role in exercising leadership within a project (Bstieler et al., 2015; Hemmert et al., 2014; Santoro and Betts, 2002). There are typically two officially responsible project leaders—the principal investigator from the university and the project leader from the firm (Santoro and Chakrabarti, 2002; Van Dierdonck et al., 1990).

Pelled et al., 1999). These positive effects are particularly pronounced when the task is sufficiently complex and the team has adequate means to process information (Bradley et al., 2015). Similarly, small disagreements on how tasks should be carried out help team members spot inefficiencies and improve problem-solving approaches (Jehn, 1997). Furthermore, although conflict arising from relationship issues between team members is often viewed as a strong impediment to team performance, teams with coping strategies can still rebound from emerging relationship tension and eventually benefit from it by cognitively reappraising past affective events (Thiel et al., 2017).

When team conflict escalates, however, its beneficial effects on team performance likely decrease and the negative effects likely strengthen. When a team faces a high level of conflict, such as a situation of "hostile negotiation" (De Dreu and Weingart, 2003, p. 742), the process of reflection by which project team members obtain different perspectives weakens, and interpersonal tensions and dissatisfaction among project team members may increase substantially (De Wit et al., 2012; Dreu, 2006; Jehn, 1997). Consequently, information processing, joint planning and coordination within a project team deteriorate, and team norms including mutual care, respect, and responsiveness among team members likely diminish in strength (Bstieler and Hemmert, 2010; Iseke et al., 2015). Therefore, high levels of project team conflict tend to create mistrust and negative emotions that hinder cooperation between team members and distract them from conducting their tasks. As a result, increasing levels of conflict hinder both cooperation and coordination among project team members (Dreu, 2006; Jehn and Greer, 2012), thereby inducing an increasingly negative effect on team performance (Bstieler and Hemmert, 2010; Greer et al., 2008).

H3a. Conflict in collaboration project teams has an inverse U-shaped relationship with project performance. The relationship is positive for low levels of conflict, but beyond a threshold, it becomes increasingly negative as the level of conflict increases.

Team conflict is likely to exert a negative impact on the project team members' intention to repeat the collaboration for two reasons. First, conflict in collaboration project teams leads to dissatisfaction among team members. Relationship-related conflict, for example, is generally regarded as a negative experience that triggers dissatisfaction among team members (De Wit et al., 2012). Although task-related conflict may have performance benefits as argued above, team members may still perceive such conflict as a sign of trouble, which may lower their satisfaction with the ongoing teamwork (Amason, 1996). Meta-analyses have confirmed a consistently negative effect of conflict on the project team members' satisfaction (De Dreu and Weingart, 2003; De Wit et al., 2012). Dissatisfaction about the work or their relationships with partners in the collaboration, in turn, decreases individual team members' motivation to further invest their time and personal resources in future collaborations (Jehn and Bendersky, 2003; Jehn and Greer, 2012).

Second, conflict deteriorates trust in the collaboration partner. In the context of university–industry collaboration, trust refers to the "capacity of firms and universities to work together to resolve problems and demonstrate a willingness to understand and adjust behaviours to align with the needs of the partners" (Bruneel et al., 2010, p. 861; McEvily et al., 2003). Trust fosters project members' confidence that their partner will act in a reliable way in future collaboration (Jap, 2001), and reduces fears that the partner

will act opportunistically (Bruneel et al., 2010). With trust, individuals are more likely to extend the collaboration project or to engage in a new project with the same partner (Mora-Valentin et al., 2004). Given that conflict within a project team reduces trust (Bstieler et al., 2015; Hemmert et al., 2014), it is likely to harm project members' intention to collaborate again. Therefore, we hypothesise the following:

H3b. Conflict in collaboration project teams has a negative relationship with project team members' intention to collaborate again.

As we argued earlier in this section, orientation-based dissimilarities affect the level of conflict within a team (i.e., internal team processes), moderated by the level of transformational leadership. In turn, project team conflict affects the outcomes of the collaborative project, that is, project performance and the project team's intention to collaborate again, where the effect on project performance is non-linear. Compounding these arguments, we hypothesise that orientation-based dissimilarities affect project outcomes via the level of project team conflict.

H4a. Project leaders' transformational leadership moderates the indirect effect of orientation-based dissimilarities on project performance.

H4b. Project leaders' transformational leadership moderates the indirect effect of orientation-based dissimilarities on project team members' intention to collaborate again.

9.4. Research design

9.4.1. Empirical setting

We collected data from research collaboration projects between the research and development unit of "DrugCo"—a pseudonym for a global top-five pharma company by sales revenue—and its academic partner institutions (universities and university-associated teaching hospitals). The pharmaceutical industry is research intensive (Rotolo and Camerani, 2017) and collaboration between firms and academic institutions in early-stage pharmaceutical research is common (Ali and Gittelman, 2016; Rafols et al., 2014). The projects in our sample all fall within the first two phases of the research and development process of new drugs: pre-discovery and drug discovery research (Ding et al., 2014). The projects had formal contractual agreements regulating the creation and exploitation of intellectual property rights and, in some cases, procedural details of the project (e.g., resource commitment of collaborating organisations and confidentiality). The minimal configuration of a project team was a designated project leader at DrugCo and a principal investigator (typically a professor, assistant professor, or post-doctoral researcher) at the partnering academic institution, both of whom were formally responsible for the project. There were typically additional team members from both organisations; the average project team had 4.50 (SD = 1.78) members. All project team members had roles and responsibilities within their respective organisations in addition to those associated with the collaboration. Across organisational roles, project members spent on average 25% of their time on the collaboration project.

9.4.2. Sampling

We obtained from the internal database of DrugCo's legal department a list of contractual agreements pertaining to 209 collaborations with an academic partner. Our sampling criteria required that the contractual agreements belonged to projects that (a) had started before we started our data collection in September 2015, (b) had a scheduled end date after we completed our data collection in September 2016, and (c) entailed knowledge-creation or intellectual exchange (i.e., more than the mere transfer of intellectual property rights). Our final sample included 118 projects at the three major research sites of DrugCo, located on three continents.

9.4.3. Procedure

We sent all project team members (783 individuals from both DrugCo and their collaboration partners in 209 projects) an online survey at time 1 (T1). The survey asked respondents to report their goal priorities with respect to the collaborative project, whether they had been involved in collaboration with the same partner before, the level of conflict in the project team, and the level of the project leader's transformational leadership. The division heads of DrugCo's research and development department sent out a supporting email introducing our study and encouraging employees at DrugCo to participate. We sent out a similar introduction email to employees from the academic institutions. At weeks four, six, and eight, we sent email reminders to non-respondents. Overall, 669 project members (an 85% response rate) in 187 teams (an 89% response rate) responded, 416 from *DrugCo* and 253 from academic partners.

At time 2 (T2), approximately six months after T1, we sent a second survey to all respondents of the first survey to ask about their intention to collaborate again with the same partner. We received 511 responses (a 76% response rate) from members in 168 project teams (a 90% response rate). Since our study concerns university–industry collaboration project teams, we selected projects with three or more members for our analysis; at least one member belongs to *DrugCo* and one to the external partner. This selection criterion yielded 120 projects. During the analysis, we deleted two projects with incomplete responses on key variables, yielding a final sample size of N = 118.

At time 3 (T3), approximately two months after T2, we invited senior managers at DrugCo to review the project performance of the sample projects. We received evaluations for 101 projects (an 84% response rate).

9.4.4. Measures

Project performance. We measured project performance using a seven-item scale that we developed in a pilot study. First, we selected eight items from previous studies (Bryde, 2008; Lewis et al., 2002) to assess the degree to which a project will reach its objectives. Next, we conducted a pilot study at a large public university to validate these items. A total of 30 researchers who had experiences in collaborating with industry partners participated in this pilot study. Using this data, we ran exploratory and confirmatory factor analyses and removed one item with a negative, non-significant loading. Further factor

analysis using the remaining items confirmed a single-factor structure (one eigenvalue above 1), explaining 86% of the total variance. A confirmatory factor analysis (CFA) using the final sample supported the validity of this seven-item scale ($\chi^2 = 38.11$; df = 21; $p < 0.001$; comparative fit index (CFI) = 0.94; root mean square error of approximation (RMSEA) = 0.13 and standardised root mean square residual (SRMR) = 0.05). The Cronbach's alpha for the final scale is 0.89. Scale items are listed in Table 1. Participants rated these listed items on a scale from 1 = "Very unlikely" to 5 = "Very likely."

To reduce potential bias from common source variance (Podsakoff et al., 2012), we asked senior managers at DrugCo to rate project performance using the seven-item measure. These managers were not directly involved with the particular collaboration but they oversaw a large number of research projects at DrugCo and all had extensive experience in drug discovery. Since each manager evaluated 1.51 projects on average, we analysed the potential bias from the non-interdependence of ratings. An analysis of the intra-class correlation coefficient (e.g., Bliese, 2000) yielded an ICC(1) well below zero (–0.24), which suggested a low agreement in the evaluation ratings of a single manager and confirmed that such bias is unlikely.

Intention to repeat collaboration. We measured the project team's intention to repeat collaboration by asking each team member, "Would you collaborate with the [external partner/DrugCo] again?" Respondents gave their answers on a scale from 1 = "Very unlikely" to 5 = "Very likely" and individual responses were aggregated to a team average. An analysis of the ICC coefficients showed that project team members indicated similar levels of intention to repeat collaboration with the same partner (ICC(1) = 0.24 and ICC(2) = 0.53).

Orientation-based dissimilarities. Inspired by the literature on organizational goal congruence[18] (Colbert et al., 2008; Vancouver and Schmitt, 1991), we operationalise orientation-based dissimilarities as the difference in goal priorities between members of DrugCo and the academic partner. To identify the most relevant goals in university-industry collaboration projects within the drug discovery context, we conducted 31 exploratory interviews with experienced researchers working on drug discovery projects. Building on the interview data, we developed a list of nine goals.[19] We asked each project team member to rank these nine goals in terms of priority (1 = most important; 9 = least important).

The level of orientation-based dissimilarities (OBD) within a team corresponds to the sum of all differences in the average priority of each goal for DrugCo employees and scientists employed at an academic institute. Similar to Colbert and colleagues' (2008) measures of goal importance and dyadic goal congruence, we then calculated the level of orientation-based dissimilarities using the formula $\mathrm{OBD} = \sum_{i=1}^{9} \left| \overline{p_i^D} - \overline{p_i^A} \right|$,

[18] This literature conceptualizes the degree of goal congruence as the extent to which members of a team or an organization have similar perceptions about the importance of specific goals to the organization (Colbert et al., 2008).

[19] The nine goals follow: help develop new medicines for patients; establish a good relationship; publication; learning from the partner and internalizing knowledge; applying results from collaborations in our group/organization; access to novel scientific knowledge from the partner, funding, and/or monetary rewards; access to technology; infrastructure, material, or data from the partner; and exploration of novel science.

where $\overline{p_i^D}$ and $\overline{p_i^A}$ are the average priorities of goal i of all DrugCo and academic organisation members, respectively. The smallest value possible for OBD is 0, which indicates complete agreement between the two parties in terms of goal priorities. The OBD values in our sample range from 0.72 (very similar goal priorities) to 4.00 (very different goal priorities).

Project team conflict. We measure project team conflict via the commonly-used nine-item scale from Jehn and Mannix (2001). Project team members rate the items (see Table 1) on a scale from 1 = "Not at all" to 5 = "Very much." To operationalise project team conflict as a project-level measure, we aggregated individual responses. An analysis of the ICC coefficients (ICC(1) = 0.23 and ICC(2) = 0.55) confirmed aggregation to the project level (Bliese, 2000).

In line with previous studies on team conflict (e.g., Klein et al., 2011), we conceptualised project team conflict as a one-dimensional construct capturing the "general level of conflict" in the team, arising from task, relationship, or process issues (Jehn and Greer, 2012, p. 180). An explorative factor analysis using the final sample suggested a one-factor structure of this measure (first eigenvalue = 4.99; second eigenvalue = 0.49). The Cronbach's alpha for the scale is 0.92.

Transformational leadership. Previous research has suggested that both the project champion at a firm and the principal investigator at an academic institution are instrumental in leading university–industry collaborations (e.g., Santoro and Chakrabarti, 2002). We therefore consider both the project champion at DrugCo and the principal investigator for its academic partner as project leaders. We asked other project team members to rate the transformational leadership exhibited by these two leaders using the 20-item version of the widely used Multifactor Leadership Questionnaire (Bass and Avolio, 1995). We then aggregated these two leadership evaluations to form a score of transformational leadership in a collaboration project team.

Control variables. We controlled for project characteristics that could also explain variance in our dependent variables and the mediator. Because larger and longer-running projects could potentially exhibit different levels of performance and project team satisfaction (Bstieler et al., 2017; Perkmann et al., 2011), we controlled for the size of the project and the project runtime. Additionally, because a previous collaboration experience can potentially increase the level of trust between the two organisations and lead to higher performance (Bruneel et al., 2010), we controlled for the number of project team members who had collaborated with the same partnering organisations before.

9.4.5. Analytical strategy

Our theorising suggests a moderated mediation model with a non-linear effect between the mediator and the dependent variable. We tested our model using structural equation modelling (SEM) in Mplus (Muthén and Muthén, 2017); this allows computation of interaction effects between latent variables, which is necessary to compute the moderation and non-linear effects. After confirming the validity of the measures

in a measurement model,[20] we compared two SEM models: Model 1 examines all direct effects except the moderation (Hypothesis 2), and Model 2 examines all direct effects including the moderation effect.

To estimate the indirect effects predicted in Hypotheses 3 and 4, we employed the Mplus MODEL CONSTRAINT command, which allows the computation of indirect effect estimates, including their (bootstrapped) confidence intervals. Since the calculation of the indirect effect of orientation-based dissimilarities on project performance involves a non-linear effect that depends on the value of the mediator (project team conflict), we followed the procedures outlined by Hayes and Preacher (2010) to calculate the "instantaneous indirect effect." We computed the indirect effect of *orientation-based dissimilarities* on *project performance* via *project team conflict* moderated by *transformational leadership* as the product of the moderated effect for the first leg ($a = a_1 + a_3W$; Hayes, 2013) and the non-linear effect for the second leg ($b = b_1 + 2b_2M$; Hayes and Preacher, 2010), yielding $c_P = ab = (a_1 + a_3W)(b_1 + 2b_2M)$. This effect depends on the value of the mediator M, which can be expressed in terms of dependent variables $M = a_0 + a_1X + a_2W + a_3WX + \text{covariates}$ (Hayes, 2013). The indirect effect of *orientation-based dissimilarities* on the *intention to repeat collaboration* via *project team conflict* only involves a linear effect (b_1) for the second leg, yielding $c_I = ab = (a_1 + a_3W)(b_1)$.

Because the computation of indirect effects using product terms can be biased when study variables are not normally distributed, we used a bootstrapping approach with 200 samples to calculate bias-corrected estimates and confidence intervals for the indirect effects (Hayes, 2013; Hayes and Preacher, 2010).

9.5. Results

Table 2 reports the descriptive statistics and correlations among all study variables.

9.5.1. Measurement model

We first tested the discriminant and convergent validity of our measures. Our dependent variables (i.e., project performance and the intention to collaborate again) measure two aspects of the project outcome. To test if they each capture a unique latent construct, we ran a series of CFAs. We compared a one-factor model (all items of these two variables load on one factor) with a two-factor model (items of project performance and those of the intention to collaborate again load on two factors, respectively). The two-factor model ($\chi^2 = 38.11$; df = 21, $p < 0.001$; CFI = 0.94; RMSEA = 0.13; SRMR = 0.05) showed a significantly better fit (Sartorra-Bentler difference test TRd = 17.68; $p < 0.001$) than the one-factor model ($\chi^2 = 55.79$; df = 24, $p < 0.001$; CFI = 0.92; RMSEA = 0.12; SRMR = 0.06). Moreover, the correlation

[20] Since much previous research measures transformational leadership in five dimensions based on the Multifactor Leadership Questionnaire (Bass and Avolio, 1995), we organized these items into five parcels reflecting such dimensions. Parcelling is an established technique that helps to reduce the statistical complexity of an analysis, and is particularly justified when the grouping dimensions are known (Little et al., 2002).

between the two variables is low ($\rho = 0.18$) and not significant. These results confirm the discriminant validity of our measures for project performance and the intention to collaborate again.

To test the discriminant and convergent validity of the latent measures, we calculated the average variance extracted (AVE) for all three latent constructs (project performance, project team conflict, and transformational leadership), shown in Table 1. The AVE exceeds 0.5 for all measures and is higher than all squared correlations, and the final measurement with the latent measures shows a good model fit ($\chi^2 = 292.34$; df =78, $p < 0.001$; CFI = 0.93; RMSEA = 0.08; SRMR = 0.27); therefore, these measures exhibit good discriminant and convergent validity (Fornell and Larcker, 1981).

9.5.2. Hypothesis testing

First, we compared Model 1 (main effects without the moderation effect, Hypothesis 2) and Model 2 (all effects including the moderation effect). Because both models include the computation of products between latent variables, the computation of model fit indices is not supported by the Mplus integration algorithm (Muthén and Muthén, 2017). To assess model fit, we computed the model fit of Model 0 without any product terms of the latent variables (i.e., no moderation effect or non-linear effect) and assessed whether Models 1 and 2 represent a significant improvement from Model 0. Model 0 exhibited a good model fit ($\chi^2 = 420.32$; df =270, $p < 0.001$; CFI = 0.92; RMSEA = 0.07; SRMR = 0.23). Following Muthén and Muthén's (2016) suggestions, we computed a chi-square difference score using the log-likelihood values and scale-correction factors (Muthén and Muthén, 2016; Satorra and Bentler, 2010) and found that Models 1 and 2 indeed significantly differ from Model 0 ($p < 0.03$ and $p < 0.001$, respectively). A direct comparison of Models 1 and 2, using both a chi-square difference test (Sartorra-Bentler TRd = 18.68; $p < 0.001$) and an AIC (Akaike information criterion)–difference test (ΔAIC = 3.964; Burnham and Anderson, 2004), indicates that Model 2 fits the data best. Table 3 shows the unstandardised estimates, standard errors, and significance levels for Model 2.

The estimates for the coefficients in Model 2 provide support for our theoretical model. Hypothesis 1 suggested a positive effect of orientation-based dissimilarities on project team conflict and was supported ($\beta = 0.15$, $p < 0.01$). Hypothesis 2 suggested that this positive effect weakens as project leaders engage increasingly in transformational leadership. The interaction term is negative and significant ($\beta = -0.28$, $p < 0.05$), and therefore confirms the hypothesised moderation effect.

Hypothesis 3a predicted an inverse-U–shaped effect of project team conflict on project performance. The coefficient corresponding to the quadratic effect is negative, as expected, and significant ($\beta = -0.46$, $p < 0.05$). The slope of the curve changes from a positive value ($s_L = 1.50$) for very lower values of project team conflict (mean value minus two standard deviations) to a negative value ($s_U = -0.32$) for very high values of project team conflict (mean value minus two standard deviations); the difference between these two slopes was significant ($s_U - s_L = 1.83$, $p < 0.05$). We computed the turning point to $\hat{x} = -\frac{a_1}{2\,a_2} = 1.18$ (a_1 is the estimate for the linear term, and a_2 for the quadratic term), which is well within the data range. Figure 2 plots the curvilinear effect. Therefore, Hypothesis 3a was supported.

Hypothesis 3b, predicting a negative effect of project team conflict on the project member's intention to collaborate again, was only partially supported ($\beta = –0.32$, $p = 0.06$). The correlation between the project team members' intention to collaborate again and project performance is low ($\rho = 0.14$, $p < 0.05$).

Hypotheses 4a and 4b predicted that orientation-based dissimilarities impact project performance and the intention to collaborate again, respectively, via the mediator project team conflict, moderated by transformational leadership. Table 4 shows the estimates for the conditional indirect effect, computed for different levels of orientation-based barriers and transformational leadership. Hypothesis 4 was partially supported because the conditional indirect effect is significant for low but not for high levels of transformational leadership. Figures 3 and 4 plot the effects suggested in Hypotheses 4a and 4b.

9.5.3. Additional Analysis and Robustness Check

Although we did not hypothesize a curvilinear relationship between project team conflict and the intention to collaborate again, we conducted an additional analysis to check the possibility of a non-linear relationship between these variables. This analysis yielded non-significant estimates for both the linear ($\beta = 0.06$, $p = 0.91$) and quadratic coefficient ($\beta = -0.25$, $p = 0.50$). Therefore, we deduce that the relationship between project team conflict and the intention to collaborate again is best explained as a linear relationship.

As a robustness check, we tested a Model 2b with all TFL dimensions aggregated into one dimension. The estimates in Model 2b were qualitatively[21] similar to those in Model 2, which was the basis of our main hypothesis testing. The estimates also indicated the positive effect of orientation-related dissimilarities on project team conflict ($\beta = 0.75$, $p = 0.09$) as suggested by Hypothesis 1, and the moderating effect of transformational leadership (interaction term $\beta = -0.16$, $p = 0.13$), as suggested by Hypothesis 2. The estimates also indicated an inverse-U shaped effect on project performance, as predicted in Hypothesis 3a (linear term $\beta = 2.13$, $p = 0.08$; quadratic term $\beta = -0.53$, $p = 0.06$) and a negative effect on the project team members intention to collaborate again, as predicted in Hypothesis 3b ($\beta = -0.39$, $p = 0.05$). Although none of these estimates was significant at the $p < 0.05$ level, they indicated similar results as in our main hypothesis testing.

9.6. Discussion

This study's goal was to analyse how orientation-based dissimilarities relate to different outcomes of university–industry collaboration and to identify mechanisms that influence this effect. We found that orientation-based dissimilarities influenced both project performance and project members' intention to collaborate in the future, via project team conflict. Furthermore, we found these effects to be contingent

[21] Note that the quantitative estimates are not directly comparable, as latent variables differ from continuous variables in both their characteristics (e.g., latent variables have a mean of 0) and give rise to differences in the implementation of the estimation algorithms (Muthén and Muthén, 2017).

on the level of project leaders' transformational leadership. Under weak transformational leadership, orientation-based dissimilarities had a negative indirect effect on project performance. Under strong transformational leadership, this negative effect on project performance was largely mitigated. The indirect effect of orientation-based dissimilarities on the intention to collaborate again, mediated by project team conflict, was negative under weak transformational leadership, and became less negative as the level of transformational leadership increased.

The findings of this study have a number of theoretical implications. First, we contribute to the literature on university–industry collaboration by shedding light on the processes within a collaborative project *after* the involved parties have agreed to engage in the project. Existing research on university–industry collaboration has tended to focus on the decisions and underlying motives to initiate different types of such collaboration (e.g., D'Este and Perkmann, 2011; De Fuentes and Dutrénit, 2012; Perkmann et al., 2013). Our study shows that the outcomes of university–industry collaboration depend not only on the configuration of collaborations (e.g., the selection of collaboration partners—Perkmann et al., 2013, 2011) but also on the process of collaboration. Further, the internal project team dynamics around the level of conflict significantly shape the outcomes of an academia–industry collaboration project. We encourage future research to examine other aspects of such collaboration processes such as patterns of communication (Broström, 2010), cognitive distance between members from universities and firms (Muscio and Pozzali, 2013), and transaction-related barriers (Bruneel et al., 2010). Research in this direction should help to resolve the issue aptly identified by Bruneel and colleagues (2010): "[a]lthough it has been widely understood that there are substantial barriers to successful collaboration and knowledge exchange between universities and firms, few studies have attempted to measure and map these perceived barriers or *investigate what may attenuate them*" (emphasis added).

Second, and more generally, we contribute to the literature on inter-organisational collaboration by identifying a managerial mechanism that helps unite individuals with very different goals within an inter-organisational collaboration project. Our findings highlight the role of project leaders' transformational leadership in "holding together" collaboration project teams when members pursue divergent goals. Instead of perceiving collaboration between organisations as something inherently difficult, our findings suggest that such collaboration can succeed with almost any level of orientation-based dissimilarities as long as the level of transformational leadership is sufficiently high. In line with previous research emphasising the role of transformational leadership in promoting a group vision and engaging group members in scientific and technical research projects (e.g., Keller, 1995), we show that leadership is critical to driving collaborative projects to success, especially when project teams have a highly diverse membership.

Next, our study offers methodological insights for future research on academia–industry collaborations. With few exceptions (e.g., De Fuentes and Dutrénit, 2012), prior work has typically analysed only one party in such collaborations. Some scholars examine the perspective of academics (e.g., D'Este and Perkmann, 2011; Tartari et al., 2012), while others examine the perspective of firms (e.g., Bruneel et al., 2010; Bstieler et al., 2015). This study takes into account the perspectives of both university and industry partners and is thus able to reveal the interactions *between* the project team members from both collaborating organisations. Integrating the responses from individual project members to the project team

level, we also respond to calls for a more in-depth investigation of representative *project-level* data sets (e.g., Perkmann et al., 2013).

9.6.1. Policy implications

Our findings call for policymakers to consider factors that not only incentivise university–industry collaborations but also improve the process of collaboration. Given the high opportunity costs for both academic and industrial scientists to collaborate (e.g., De Fuentes and Dutrénit, 2012; Hagedoorn et al., 2000; Perkmann and Salter, 2012), ensuring that university–industry collaborations realise their potential value must be a concern for policymakers. Our study shows that orientation-based dissimilarities between universities and firms may not be detrimental when these dissimilarities are properly addressed throughout the collaboration process. Thus, policymakers should put the leadership skills of project managers in university–industry collaboration on the agenda. On the training end, policymakers are encouraged to implement policies that improve project management skills of scientists at universities. One example would be to set up programmes within universities to train principal investigators and scientists in areas including conflict management and leadership. Policymakers could also launch a country-wide leadership development and certification programme and encourage potential scientists from both universities and firms to attend the training and obtain the certificate.

When making funding decisions, funding agencies and research commissions should pay attention to the project management skills of lead applicants, by examining either their previous track records of leading collaboration or their relevant certificates. Additionally, publicly funded university–industry collaboration could require grant applications to detail the managerial responsibilities within the project team (e.g., by specifying the establishment of a steering committees or assigning scientists with extensive collaboration experience formal roles for coordination) and evaluate the clarity and feasibility of these details as part of the selection criteria. Particular attention must be given to how principal investigators monitor and handle conflicts as they arise in the collaboration process.

9.6.2. Managerial implications

Our findings have implications for the management of university–industry collaboration. Successful collaboration that delivers the expected benefits demands attention from both partnering organisations. Most importantly, our study reveals that transformational leadership is a critical managerial lever for facilitating collaboration when the partnering organisations differ substantially in their goals and expectations with respect to the collaborative project (i.e., the orientation-based dissimilarities are high). At times, scientists from universities might, for example, aim at fundamentally understanding a new technology, whereas their counterparts from firms in the same collaborative project aim at a rapid commercialisation of that technology. In projects where orientation-based dissimilarities are pronounced, a high level of transformational leadership in the group is necessary to unite project members and keep the level of conflict at a "healthy" level. Managers who supervise collaboration projects (e.g., academic liaison officers in firms, principal investigators, and department heads in universities) must be aware of

such situations and adjust their leadership practice accordingly. Additionally, universities and firms should invest in the selection (e.g., determining who has the required skill set to bridge expectations and goals) and development of their employees' leadership capacity. Because leadership is a largely malleable quality (e.g., Yukl, 2010), tailored trainings will improve project performance and the likelihood of future collaboration.

Conflict in university–industry collaboration is a delicate issue. A moderate level of conflict is beneficial for solving emergent problems or finding the ideal approach to a task, thereby leading to superior performance of the current project. However, even low levels of conflict may cause dissatisfaction and destroy trust among the project team members, thereby diminishing their intention for future collaboration. Given the many benefits of repeated collaborations mentioned in the literature (e.g., Bruneel et al., 2010; Mora-Valentin et al., 2004), managers of collaboration projects must weigh the value of the current project relative to the value of a future one and carefully consider the trade-off between allowing a "healthy" level of conflict within the team and suppressing emerging conflicts. This trade-off is particularly critical in newly established collaborations, where conflicts and misunderstandings can cause the "initially granted trust" to break down and thereby severely hamper collaborative relationships (Hemmert et al., 2014). In newly established collaboration projects, project leaders should closely monitor the level of conflict in their projects and allow only a very small amount of conflict (e.g., allow an open debate on how the project should proceed, but intervene as soon as this debate escalates) to safeguard future collaboration with the collaboration partner. For these reasons, training and development programmes to improve collaboration project leaders' conflict awareness and conflict management skills will prove to be highly valuable.

9.6.3. Limitations and implications for further research

This study has limitations that open up future research opportunities. First, while our hypotheses are built on strong theoretical foundations and our lagged research design aims to reduce the likelihood of reverse causation, we draw only limited causal inferences. Future research could consider experimental designs (e.g., manipulating the goals of a project team or the level of conflict) to further disentangle the causal relationships between orientation-based dissimilarities, team conflict, and project outcomes.

Second, our measure of project performance relies on the judgement of senior managers. While such an approach can mitigate potential *common source bias* (Podsakoff et al., 2012), this measure is not free from the subjective bias of managers. When the number of scientific publications or patents resulting from a project becomes available, future research should triangulate subjective measures with such objective performance measures.

Third, although our sample of 118 collaborative research projects between DrugCo and its academic partners covers more than 18 different countries and a broad range of therapeutic areas, our results might be susceptible to the characteristics of DrugCo. Thus, future research should validate our findings across organisational and industrial settings.

9.6.4. Conclusions

We show that orientation-based dissimilarities have different implications for the two important outcomes of university–industry collaboration—project performance and the intention to collaborate again. Orientation-based dissimilarities relate positively to the level of conflict, which in turn affects the two types of collaboration outcomes in distinct ways: First, conflict relates positively to project performance up to a certain level, but it has an increasingly negative impact on project performance beyond the inflection point. Second, conflict decreases project team members' intention to repeat collaboration. However, strong transformational leadership mitigates the impact of orientation-based dissimilarities on team conflict, thereby reducing the negative indirect effect of these dissimilarities via conflict on current project performance and team members' intention to collaborate again. We identify transformational leadership as key to the success of collaborations with high orientation-based dissimilarities and encourage policymakers and managers of university–industry collaboration to consider leadership capacity in the selection and training of collaboration participants. We also highlight the trade-off around the level of conflict for current project performance and future collaboration likelihood and recommend practitioners to monitor and manage conflict collaboration projects accordingly.

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Figure 1: Theoretical Model.

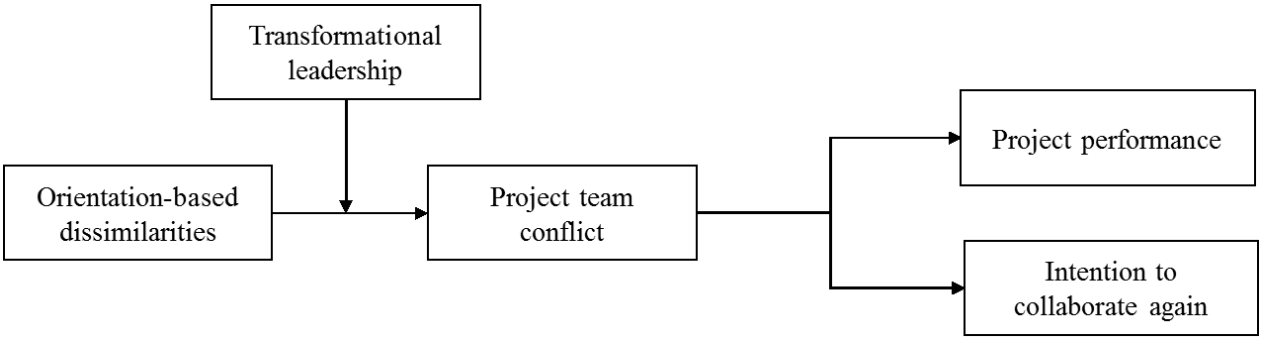

Figure 2: Curvilinear Effect between Project Team Conflict and Project Performance.

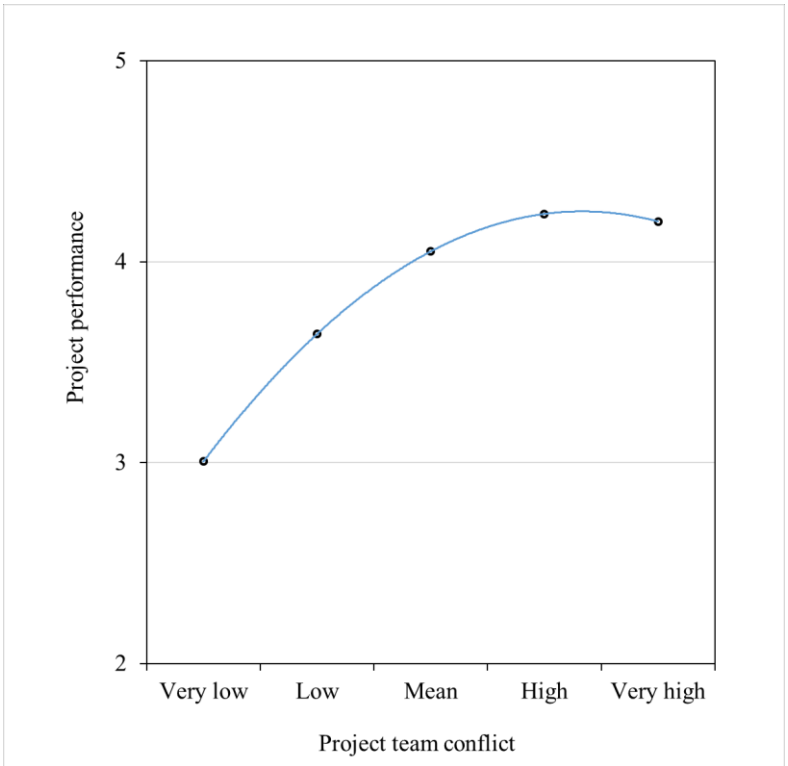

Figure 3: Total Indirect Effect of Orientation-Based Dissimilarities (OBD) on Project Performance via Project Team Conflict.

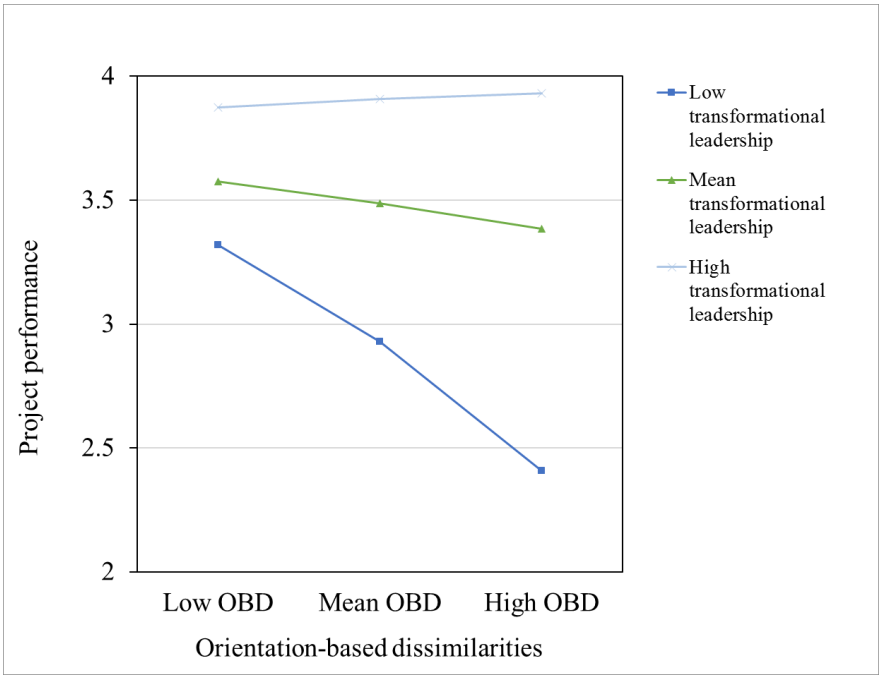

Figure 4: Total Indirect Effect of Orientation-Based Dissimilarities (OBD) on Intention to Repeat Collaboration via Project Team Conflict.

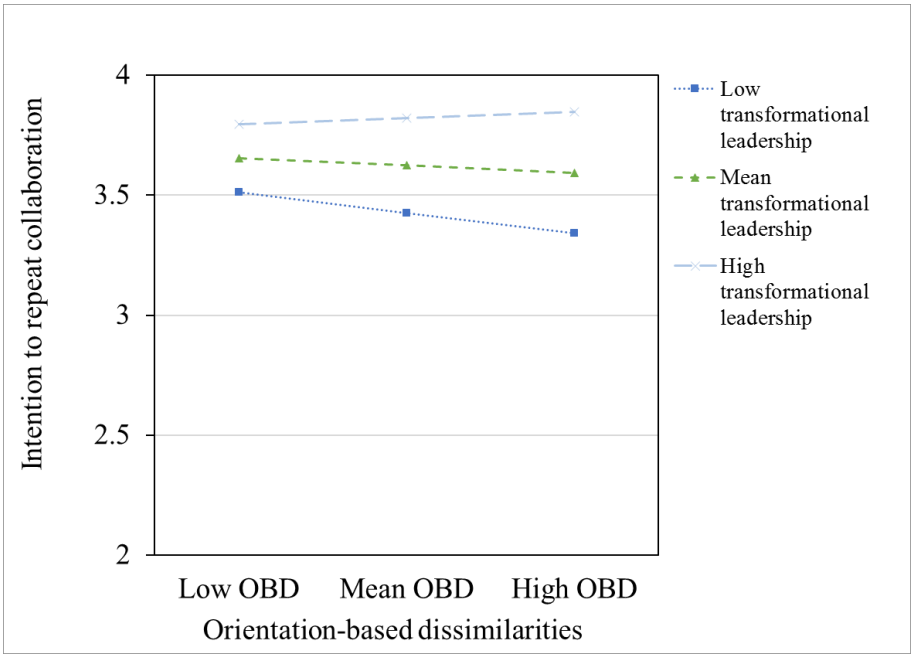

Table 1: Latent Variables and Measures.

Construct and items	Factor loadings	AVE	Cronbach's alpha
Project performance		0.53	0.89
Please indicate how likely or unlikely you find the following:			
1. This project will meet the time objectives.	0.80		
2. This project will yield tangible benefits for our organization.	0.54		
3. This project will yield intangible benefits (such as learning) for our organization.	0.51		
4. The project goals will be met by the end of the project.	0.82		
5. The members of the project team are happy working on this project.	0.58		
6. The project will progress toward achieving the goals.	0.83		
7. This project will be successful.	0.91		
Project team conflict		0.60	0.91
Please answer the following questions about working in this specific collaborative project as a whole (including the partnering organization):			
1. How much relationship tension is there in this project team?	0.73		
2. How often do people get angry while working in this project team?	0.74		
3. How much emotional conflict is there in this project team?	0.81		
4. How much conflict of ideas is there in this project team?	0.80		
5. How frequently do you have disagreements within this project team about the tasks within this project?	0.83		
6. How often do people in this project team have conflicting opinions about this project?	0.72		
7. How often are there disagreements about who should do what in this project team?	0.81		
8. How much conflict is there in this project team about task responsibilities?	0.83		
9. How often do you disagree about resource allocation in this project team?	0.68		
Transformational leadership parcels, items from Avolio and Bass (2004)		0.69	0.91
1. Inspirational motivation (4 items)	0.78		
2. Idealized influence, attributed (4 items)	0.92		
3. Idealized influence, behaviour (4 items)	0.84		
4. Intellectual stimulation (4 items)	0.73		
5. Individualized consideration (4 items)	0.85		

Notes: N = 99 projects (list-wise deletion). Standardized factor loadings. AVE = average variance extracted (Fornell and Larcker, 1981). Model fit: $\chi 2 = 253.15$, df = 172, $\chi 2/\text{df} = 1.47$; $p < 0.001$; comparative fit index (CFI) = 0.95; root mean square error of approximation (RMSEA) = 0.07; standardised root mean square residual (SRMR) = 0.07.

Table 2: Correlations and Descriptive Statistics.

		Mean	St. Dev.	1	2	3	4	5	6	7
1	Project performance	0.11[22]	0.78	1.00						
2	Intention to collaborate again	4.29	0.67	0.18	1.00					
3	Project team conflict	0.53[7]	0.49	0.23*	-0.22	1.00				
4	Transformational leadership	0.00[7]	1.00	–0.05	0.05	-0.20	1.00			
5	Orientation-based dissimilarities	2.20	0.62	–0.05	–0.08	0.13	0.00	1.00		
6	Previous collaboration experience	1.64	0.69	–0.09	0.15	0.03	0.00	–0.15	1.00	
7	Project runtime	2.57	1.18	0.06	0.05	0.05	0.00	–0.07	0.17	1.00
8	Project size	4.50	1.78	0.13	0.13	0.09	0.00	–0.22*	0.09	0.03

Note: N = 118.

*$p < 0.05$ (two-tailed significance).

[22] The mean of an independent latent variable is zero, the mean of dependent latent variables is typically nonzero. In both cases, the mean of a latent variable is not directly related to the mean of the items representing the latent variable (Muthén and Muthén, 2017).

Table 3: Results of Structural Equation Modelling (SEM) Analysis.

	Mediator	*Dependent variables*	
	Project team conflict	Project performance	Intention to repeat collaborate
Main effects			
Orientation–based dissimilarities	0.15**	–0.12	0.00
	(0.05)	(0.11)	(0.11)
Conflict		1.10*	–0.32†
		(0.45)	(0.17)
Conflict^2		–0.46*	
		(0.22)	
Transformational leadership	0.49*		
	(0.24)		
Interaction effects			
Transformational leadership × Orientation–based dissimilarities	–0.28*		
	(0.12)		
Control variables			
Collaboration experience	0.01	–0.15	0.14
	(0.07)	(0.10)	(0.08)
Project runtime	0.02	0.04	0.02
	(0.04)	(0.07)	(0.06)
Project size	0.03	0.04	0.05†
	(0.02)	(0.04)	(0.03)
Model log likelihood		–1453.75	
Akaike information criterion (AIC)		3097.50	

Notes: N = 118. Unstandardized coefficients. Standard errors in parentheses.
†$p < 0.1$; *$p < 0.05$; **$p < 0.01$ (two-tailed significance).

Table 4: Conditional Indirect Effect between Orientation-Based Dissimilarities and Project Performance/Intention to Repeat Collaboration.

Path	Orientation-based dissimilarities	Transformational leadership	Effect	St. Error (B.S.)	LLCI (B.S.)	ULCI (B.S.)
Orientation-based dissimilarities → Conflict → Project performance	L	VL	–0.16	0.15	–0.56	0.01
	L	L	–0.11	0.10	–0.41	–0.01
	L	M	–0.06	0.05	–0.23	0.01
	L	H	0.01	0.04	–0.04	0.17
	L	VH	0.09	0.12	–0.03	0.42
	M	VL	–0.30	0.25	–1.06	–0.02
	M	L	–0.17	0.14	–0.57	–0.01
	M	M	–0.07	0.06	–0.27	–0.01
	M	H	0.01	0.04	–0.05	0.15
	M	VH	0.07	0.09	–0.03	0.38
	H	VL	–0.44	0.38	–1.56	–0.03
	H	L	–0.23	0.19	–0.83	–0.02
	H	M	–0.08	0.07	–0.31	0.01
	H	H	0.01	0.04	–0.04	0.13
	H	VH	0.04	0.07	–0.04	0.19
Orientation-based dissimilarities → Conflict → Intention to collaborate again	–	VL	–0.16	0.12	–0.48	0.01
	–	L	–0.10	0.07	–0.31	–0.01
	–	M	–0.05	0.03	–0.15	–0.01
	–	H	0.01	0.03	–0.04	0.07
	–	VH	0.06	0.07	–0.06	0.18

Notes: $N = 118$. Conditional indirect effects evaluated at different levels of leadership (VL = very low/L = low/M = medium/H = high/VH = very high, corresponding, respectively, to 2 SD below the mean, 1 SD below the mean, the mean level, 1 SD above the mean, and 2 SD above the mean) and different levels of project team conflict (low, medium, and high, corresponding to lower end of scale, medium or middle part of scale, and upper end of scale, respectively). LLCI = lower-level 95% confidence interval; ULCI = upper-level 95% confidence interval. Standard errors and confidence intervals have been bias corrected using 200 bootstrap samples (Hayes, 2013).

10. Essay 3 - Demystifying industry-academia collaboration

Published in Nature Reviews Drug Discovery (Forthcoming)

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The past decade has seen intensified research collaboration between pharmaceutical companies and academic institutions. Although such partnerships are recognized as a source of innovation and a key pillar to advance science in drug discovery, they are replete with challenges. Despite much anecdotal evidence and debate, fact-based evidence on the nature of these challenges and how to manage them is scarce. Here, we present results from a systematic analysis of quantitative and qualitative data from the portfolio of academic collaborations at a major pharmaceutical company, Novartis, which illuminate the challenges associated with industry–academia collaborations. We also offer advice on how to make such collaborations more effective.

10.1. Analysis

We surveyed participants in 187 collaborative research projects in the field of drug discovery that Novartis conducted with different academic partners (excluding purely transactional activities such as in-licensing and out-licensing). Our study includes responses from 669 participants (416 from Novartis and 253 from the academic partners) and represents, to our knowledge, the most comprehensive study of its kind.

We employed two analytical approaches. First, a qualitative methodology provided a systematic account of the challenges of industry–academia collaboration as seen by both parties. To probe the challenges in an unbiased way, we asked open-ended questions that respondents could answer in a free text field. Using thematic content analysis, we decomposed the responses into lower- and higher-order categories. We validated the resulting categorization scheme using two independent researchers (see Supplementary Box 1). Figure 1 shows the resulting categories of challenges and the frequency by which they were mentioned. Second, we assessed

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the impact of one salient factor for each category on project success (Figure 2; see Supplementary Box 2 for details).

10.2.Challenges in collaborative projects

10.2.1. Categories of challenges

Our results indicate seven categories of challenges in industry–academia collaborative projects (Figure 1). First, resource constraints, the most frequently mentioned category, refers to the limited availability of human, monetary and organizational resources (for example, tools or instruments) for the project. Second, legal and administrative process complexity includes challenges due to 'paperwork', internal approval processes, ethical reviews, and contract negotiations that take time and often limit the partner's access to relevant knowledge. Third, coordination challenges relate to difficulties in teamwork, the frequency and quality of communication, the coordination of tasks, and the exchange of goods and knowledge. Fourth, scientific challenges arise from negative results, issues with the scientific methodology, and difficulties in interpreting data. These four categories together constitute 79% of all challenges mentioned by participants.

The fifth category, goal alignment challenges, relates to diverging expectations and goals among project members and insufficient priority of the project in the partnering organizations. Sixth, interpersonal challenges include issues related to differences in project members' individual attitudes, behaviors and interests, a lack of trust in the partner, a lack of commitment by single project members and interpersonal conflict. Last, technological challenges arise from scarce knowledge on new technologies and methods, uncertainty in the technical feasibility of methods and unreliable experimental techniques.

10.2.2. Prevalence of challenges

Counter to many anecdotal reports, we found that the most frequently mentioned challenges do not relate to conflicting goals or cultural differences between industry and academia, but rather to resource constraints, legal and administrative process complexity, coordination and scientific challenges. The good news is that, with the exception of scientific and technological challenges, challenges are mainly within the control of the collaboration team and can thus be mitigated through more effective teamwork and project management.

Novartis-based and academic scientists mentioned challenges in most categories with similar frequencies. However, we did find differences in how scientific challenges and goal alignment challenges are perceived: the former is mentioned significantly more often by academic scientists, and the latter more often by Novartis scientists.

10.3.Impact on project success

We analyzed seven factors, each corresponding to one challenge category, and found that they showed different impacts on reported project success (Figure 2). In most cases, a stronger presence of the factor was associated with a significantly lower project success half a year later (confirmed using an ANOVA statistical test; see

Supplementary Box 2). The lack of coordination factor exhibited the strongest negative relationship with project success. Interestingly, projects in our sample on average turned out to be more successful if they involved a higher degree of explorative technology or methods (for example, projects that adopt an advanced technology for a scientific problem for which that technology has not yet been used). We also found that those projects involving more complex legal contracts (for example, collaboration agreements as opposed to material transfer agreements) reported higher levels of project success. Legal matters are often portrayed as a major challenge to industry–academia collaboration. Our data suggest, however, that while complex legal contracting may be a hurdle at the onset, it does not impede a project once it is running.

10.4. Conclusions

Our study suggests that 'conflicting incentives' or 'clashing cultures' are in fact not key roadblocks to industry–academia collaboration. Adequate resource commitments, however, are critical for collaborative project success. As many challenges we identified are under the control of scientists and managers, we conclude with four concrete suggestions for effectively managing industry–academia collaboration.

10.4.1. Evaluate and manage the collaboration portfolio

As collaborations demand ample resources and vigorous efforts to overcome legal and administrative hurdles, decisions are needed on the systematic allocation of resources across a project portfolio. Channeling resources to fewer projects, each with high potential, might be advantageous compared to handling a larger number of projects that diverts scientists' attention and lowers their engagement in any single project.

10.4.2. Ensure high-quality communication and coordination

As effective coordination provides the largest lever for project success, many collaborative projects will probably benefit from an intentional adoption of good practices of teamwork and project management. Adopting simple practices such as regular updates, frequent coordination of tasks, open discussions of disagreements, and training conflict resolution methods are vital to successful collaboration.

10.4.3. Accommodate changing needs

Because early-stage scientific research entails substantial uncertainty, unforeseen results may require adapting the scientific approach and the project direction. Foreshadowing evolving needs for different types of expertise, human resources, and other in-kind resources is important and should include some contingency reserves. When necessary, project leaders need to proactively re-organize a project; for example, by incorporating scientists with different expertise or replacing team members who leave their organization.

10.4.4. Foster commitment and enthusiasm

Successful inter-organizational collaboration requires a particularly good relationship between partners and a high level of intrinsic motivation for the project. To overcome barriers from differences in organizational goals

and scientists' workstyles, attitudes and personal priorities, leaders in both firms and academic institutions should demonstrate a high personal commitment. Informal interactions, for example, spending some joint time outside of work, may increase familiarity with the partnering organization. Finally, leaders should make external collaboration a key priority of their organization and reward project progress and success.

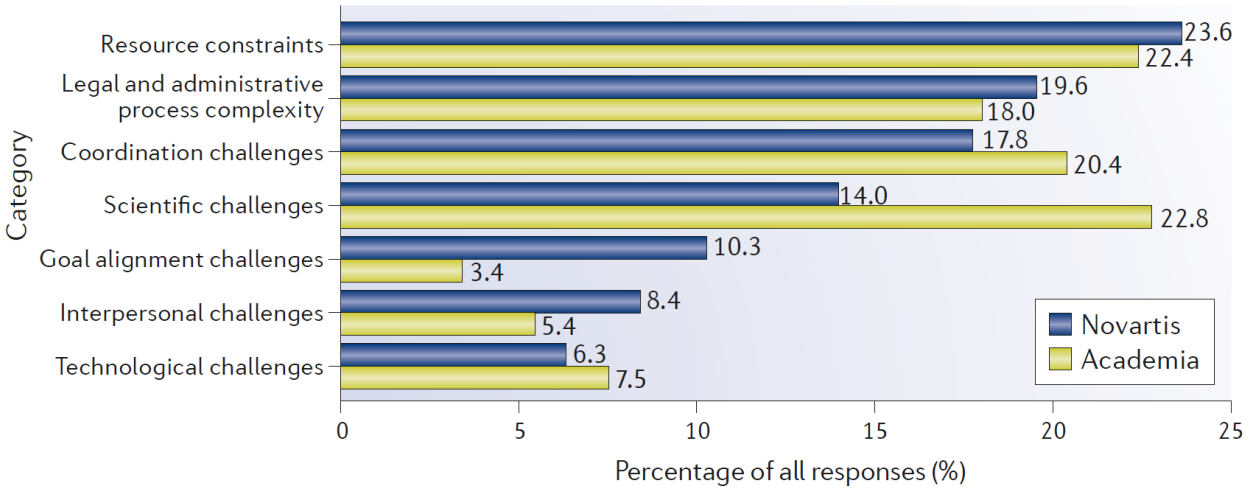

Figure 1 | **Relative importance of different challenges in industry–academia collaborations by organization.** The figure shows the relative frequency at which the challenges within each category were reported by scientists in the 187 collaborations in our sample. The analysis is based on data from 722 responses to the question about the most pressing challenge in the project and was carried out separately for Novartis scientists (428 responses, blue bars) and academic scientists (294 responses, yellow bars). The categories are ordered by the total number of responses (from Novartis and academic scientists combined). See text and Supplementary Box 1 for details.

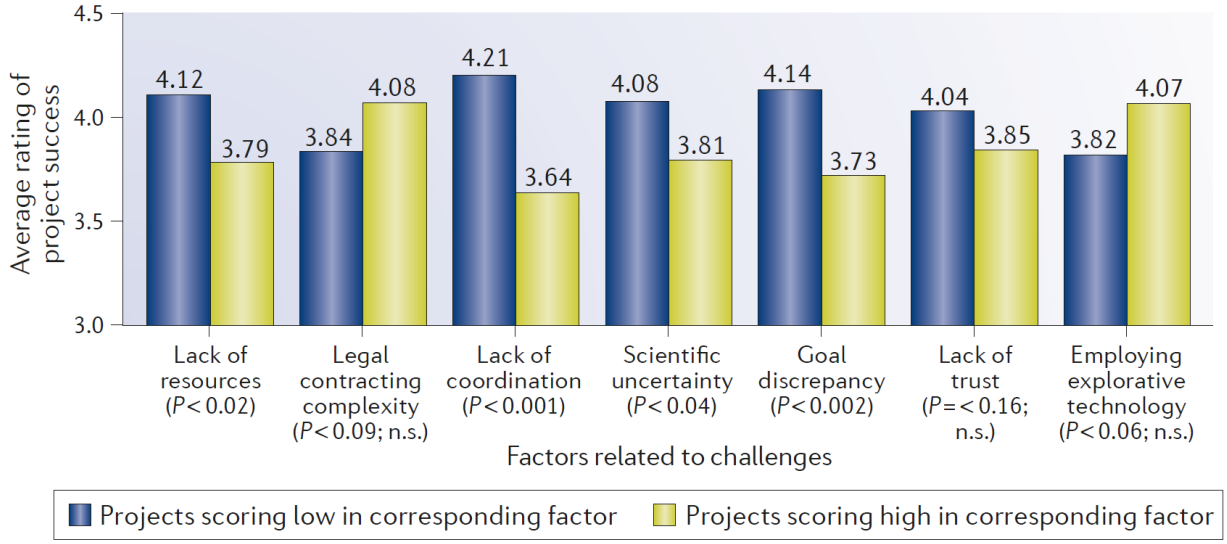

Figure 2 | **The impact of factors related to challenges on project success.** The figure shows the average rating of project success for all the projects that scored low and high in factors related to the seven categories of challenges. The yellow bars represent the projects in which the specified factor was reported to be high (above the mean) and the blue bars represent projects in which the factor was reported to be low (below the mean). Project success corresponds to the evaluation of goal attainment in the collaboration after 6 months, rated by the project leaders from Novartis and the academic partners on a scale from 1 to 5. The *P* values indicate for each factor whether a difference in that factor also corresponds to a significant difference in the rating of project success. See Supplementary Box 2 for details on the methodology. n.s., not significant.

10.5. Supplementary Box 1: Data source and methodology for the qualitative analysis[24]

To systematically analyse the challenges in industry–academia collaborations, we employed a thematic content analysis approach to inductively analyse qualitative data from the projects in our sample. Thematic analysis helps to identify and report patterns—so-called *themes*—within qualitative data to describe phenomena[1]. The open-ended inquiry in this approach is well suited to identify similarities and differences in a data set and point to its key features[1].

10.5.1. Data source

We analysed the challenges reported in a survey by the project members of 187 industry–academia collaborations between the Novartis Institutes for BioMedical Research (NIBR) and academic organisations. Novartis, as the second-largest seller of prescription drugs worldwide in 2016[2], is a good example of a large

[24] Please note that starting in this section, superscript numbers denote references, while superscript letters denote footnotes.

company in the pharmaceutical industry engaging in industry-academia collaboration. NIBR is the research unit of Novartis and comprises approximately 6000 scientists, physicians and business professionals[4]. Novartis spent the second-highest amount on research and development of all companies in the industry in 2016[2], and published the largest number of scientific articles in peer-reviewed journals of all pharmaceutical companies in 2017[5].

The projects in our sample are collaborative research projects that yield a number of different outcomes including new assays, new methods, pre-validated targets, compounds, intangible learning, and knowledge transfer. As these projects target the creation of new knowledge that can be utilized by both partnering organizations, they constitute a form of open innovation that is beneficial to both the firm and the academic institution[3]. The projects involve scientists from Novartis and one or more partnering academic institutions, predominantly universities and hospitals. Overall, our empirical data includes responses from 669 individuals: 416 at NIBR and 253 at the academic institutions.

10.5.2. Data collection

The data collection proceeded in multiple steps (see Figure S1 for an overview). First, we compiled a list of all industry–academia collaborations at NIBR that (i) could potentially include collaborative research or intellectual exchange and (ii) were active in September 2015 (the point of selection), drawn from a list of all contracts with external parties. Second, for all projects, we approached the project leader at NIBR to confirm whether the project indeed included collaborative research or intellectual exchange, and was active. Third, we asked the NIBR project leader to explicitly name all project team members from both NIBR and the partnering academic institution who were actively involved in this project. The NIBR project leader decided if the project team members from the academic partner were to be included (academics for all but 9 projects were included). As a result, we identified 783 scientists involved in 209 collaborations.

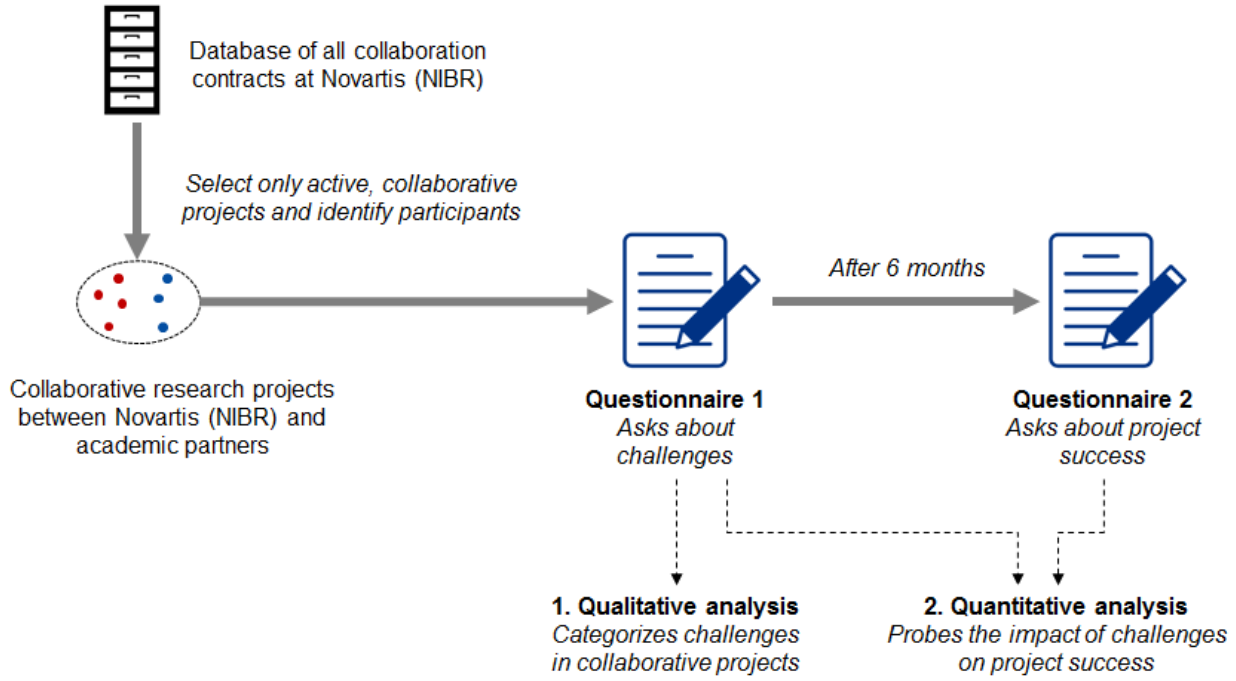

Figure S1 | **Procedure of this study.** After selecting active, collaborative projects from among all legal contracts at NIBR, we identified the members of these projects. We then sent two consecutive questionnaires to the project members from NIBR and the academic partner. The resulting data form the basis for the qualitative data analysis and the quantitative data analysis (see Supplementary Box 2).

Fourth, we sent a first questionnaire to the scientists at NIBR and the identified academic partners using an electronic survey software (Qualtrics) and an accompanying email that explained the purpose of the survey. The NIBR project leader also contacted their academic counterparts to explain the study and encourage participation. We reminded project members who did not respond with up to three emails and a telephone call. In total, 669 individuals (416 NIBR project members, 253 academic project members) in 187 projects completed the questionnaire. Fifth, about 6 months after the first questionnaire, we sent all respondents of the first questionnaire a second follow-up questionnaire that probed the progress and the outcomes of the project so far among other variables not used in this analysis. The data from this second questionnaire were used in the quantitative analysis (see Supplementary Information 2).

The projects in our sample covered all research disciplines at NIBR, and lasted on average 2.9 years. We obtained one or more responses from the academic project team members for 77% of all projects in our sample. Respondents indicated that they spent on average 24% (NIBR participants) and 26% (academic participants) of their work time on the collaborative project that the survey asked about.

Table S1 | **Response and analysis statistics** [a]

	Number of data points
Number of text fields from surveys with responses	879
- Number of blank responses	55
Number of responses considered for coding	824
- Number of ambiguous responses, not coded	58
- Number of responses indicating absence of challenges, not coded	44
Number of responses successfully coded (428 responses from Novartis participants, 294 from academic participants)	722

[a] The table shows the number of responses obtained from the first questionnaire in response to the question: "Thinking about this collaborative project as a whole, what were/are three highest hurdles in this specific project?". Details of the stratification of the data are described in the text.

10.5.3. Qualitative data analysis

The qualitative analysis is based only on data from the first questionnaire. In this analysis, the focus is on the responses to the open-ended question "Thinking about this collaborative project as a whole, what were/are three highest hurdles in this specific project?" Respondents were asked to name up to three challenges in three free text boxes in the questionnaire. The text boxes were not mandatory to conclude the questionnaire, and of the 669 returned questionnaires, 293 survey participants answered this question, providing 824 text-based responses (non-empty data from all three free text fields combined together, see table S1 for details). The qualitative data analysis proceeded in four steps. First, we corrected spelling mistakes, cleaned the data, combined the responses from all three text boxes responses and anonymized all 824 responses to ensure an unbiased analysis.

Second, we developed a coding scheme that categorizes the text-based responses. Coding schemes are a key element in the inductive analysis of qualitative data[6]. The development of a coding scheme involves grouping responses that concern the same topic into so-called "themes" and subsequently interpreting these themes to aggregate them into more abstract categories[6].

To develop the coding scheme, an independent research assistant who is not part of the author team was tasked with examining the data and grouped all 824 responses into themes. The development of this coding scheme was guided by the principles (i) maximize the differences between themes and (ii) minimize the difference within themes, such that the responses can be mapped unambiguously to a single theme.

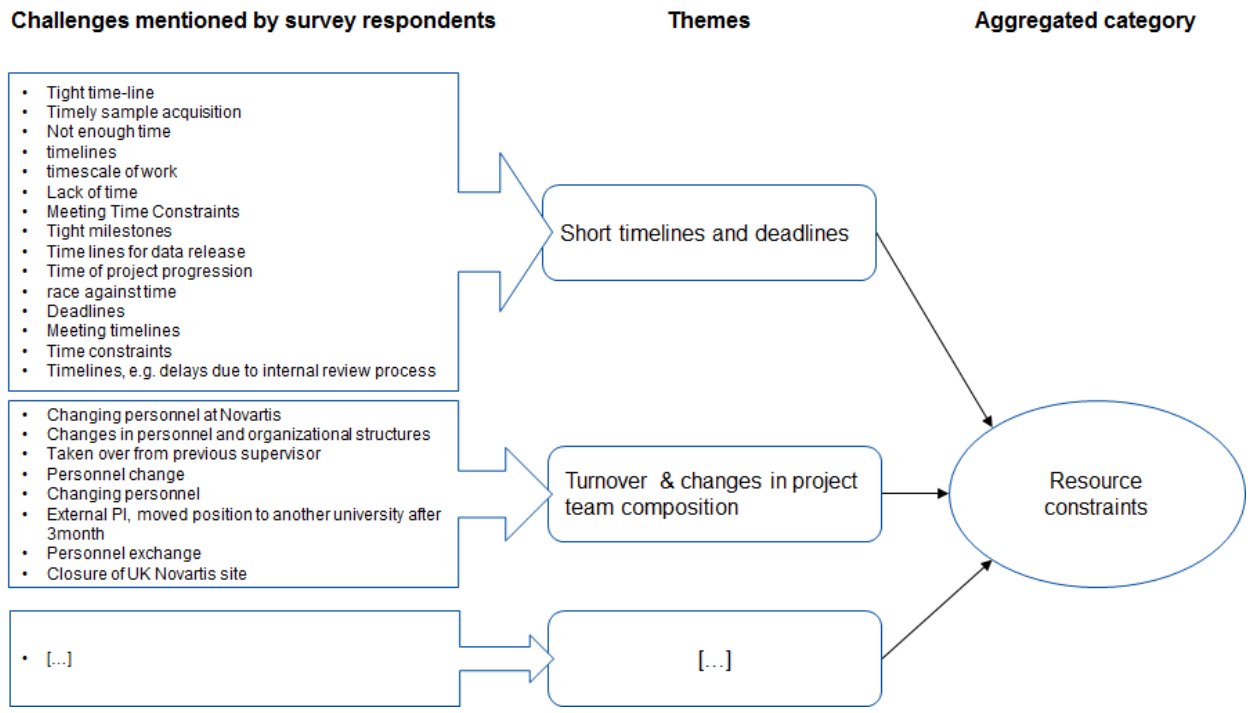

Figure S2 | **Illustration of the coding methodology.** The figure shows a subset of the coding scheme in the category "Resource constraints" to illustrate the approach. The left column contains the raw responses that were coded into themes. The centre column shows 2 out of 9 themes within the category "resource constraints". Afterwards, the themes were aggregated into categories, which constitute the final set of overarching categories in our analysis (right column, showing 1 out of 7 categories).

Three of the authors discussed this provisional coding scheme, analysed similarities and differences between the responses assigned to each theme and refined the coding scheme[6]. The authors also aggregated the themes to more abstract categories by grouping them according to their meaning (see Figure S2 for an illustration of this procedure). The coding scheme was refined and re-applied to the data. Five iterations of this procedure yielded the first version of the coding scheme. As figure S2 shows, our coding scheme involves two hierarchical levels. In the first level, responses that relate to the same topic, typically share a large fraction of the wording, or represent synonyms, are grouped into themes. In the second level, we interpreted these themes to group them into aggregated categories.

Third, we tested the reliability of the first version of the coding scheme with two additional research assistants, who are not part of the author team. Specifically, we tested the degree to which two different people would assign the text-based responses to the same category. We sent both research assistants the data, the list of the themes in the first version of the coding scheme (67 themes in total), a document detailing the coding procedure and a glossary of company-internal abbreviations and industry-specific terms that survey participants used. Both research assistants were tasked to independently assign the original data to the themes in the coding scheme. A comparison of the research assistants' application of the assignment showed a good agreement and

therefore a high inter-coder reliability: both research assistants assigned 61% of the data (502 out 824 responses) to the same theme. Given that there was a large number of themes (67 themes in total in the first version of the coding) and comparing this agreement to the standards and recommendations for qualitative data analysis[11], these numbers suggest a good reliability of our coding scheme[6].

Fourth, we refined the coding scheme by comparing our own assignment of the responses into the different themes with the assignment by both research assistants. This refinement comprised the following steps:

I. Join themes that describe very similar challenges (4 themes joined into 2 themes) and refine the description of some themes (6 themes)

II. Keep all assignments between responses and themes where our initial assignment matches the assignment of **both** research assistants (409 responses, 50%). Drop those responses that were marked as ambiguous by **both** research assistants (7 responses, 1%)

III. Keep assignments where our initial assignment matches the assignment of **one** research assistant (193 responses, 23%), but drop responses where the discrepancies between the research assistants were large and indicated that the response could not be assigned unambiguously (22 responses, 3%)

IV. For all assignments where **none** of the research assistant's assignments matched with our original assignment: Discuss the disagreement with the research assistants and jointly agree on the preferable assignment. Select either the research assistants' assignment (90 responses, 11%) or the original response (74 responses, 9%) as the final assignment. Drop responses where no final agreement was found (29 responses, 4%).

Excluding the dropped responses, the refined coding scheme comprised 766 responses assigned to 65 themes. We dropped 44 responses that were assignment to the theme "No challenges", in which the respondents verbally indicated the absence of any challenges (e.g., by stating "no challenges"). Table S1 shows the compositions of the data set. In the final coding scheme, 722 responses were assigned into 64 themes, which were aggregated to 7 overarching categories.

10.5.4. Results

We computed the number of responses that were coded into each of the seven aggregated categories describing the different types of challenges as shown in Table S2. We ranked the challenges categories by the total number of responses. Furthermore, we computed the relative percentage of responses within each category in relation to the overall number of responses, separately for Novartis and academic respondents. The results are displayed in Figure 1 in the main article.

Table S2 | **Total number of responses categorized in the categories of challenges**[a]

Category	Novartis	Academic	Total	Rank
Resource constraints	101	66	167	1
Legal and administrative process complexity	84	53	137	2
Coordination challenges	76	60	136	3
Scientific challenges	60	67	127	4
Goal alignment challenges	44	10	54	5
Interpersonal challenges	36	16	52	6
Technological challenges	27	22	49	7
Total	428	294	722	

[a] The table lists the number of responses that we coded into the categories of challenges using the final coding scheme, shown separately for Novartis and academic respondents. The challenges are ranked using the total number of responses coded into each category.

10.5.5. References

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10.6. Supplementary Box 2: Data source and methodology for the quantitative analysis

10.6.1. Research design

To test the extent to which the challenges identified in the qualitative analysis (see Supplementary Box 1) impact project success, we carried out a quantitative analysis. Our research design comprises two different questionnaires that were both sent to the project members of the collaborations in our sample. In our first questionnaire (the same used for identifying the challenges), we quantitatively measured a large number of factors that probe different project characteristics and team dynamics. To do so, we selected more than 40 different factors that are established concepts in management science. Our selection is based on the management literature on industry-academia collaboration, and interviews with seasoned experts in industry-academia collaboration in the pharmaceutical industry, technology transfer office professionals, and principal investigators at universities. Each factor was queried with one or more questions in the survey to reduce interpretation bias. Note that these factors were not chosen based on the categories of challenges, allowing the coding of responses into categories without prior bias (see Supplementary Box 1 for information on the establishment of the categories of challenge).

The two questionnaires were spaced by about 6 months in a time-lag setup. This approach allows us to probe the factors related to the categories of challenges and project success separately in order to separate causes and effects. Unlike a cross-sectional research design that relies on only one questionnaire, a time-lag design reduces—albeit does not eliminate completely—the likelihood of a bias from reverse causality[1,2]. The detailed procedure of the data collection is described in the Supplementary Box 1. Overall, we collected responses for questionnaire 1 from 669 project members in 187 projects (416 from NIBR project members, 253 from academic project members; overall response rate 85%) and responses for questionnaire 2 from 511 members in 168 projects (313 from NIBR project members, 198 from academic project members; overall response rate 76%).

Post-hoc, we associated each challenge category identified in the qualitative analysis with a quantitative factor exemplary for that category. The measurement of quantitative factors using a survey is based on research techniques established in management science[1,2]. In this approach, factors that describe both the characteristics and the dynamics of a project are measured using the assessment of all project team members. Querying and aggregating the perspectives of all team members helps to reduce the subjectivity bias. For each factor (e.g., the level of trust among project participants), the questionnaire included a set of questions that probe this factor on standardized Likert-scales (e.g., from 1 = “very low” to 5 = “very high”). The usage of multiple questions yields better reliability because it reduces bias due to different interpretations of the question[1].

To measure the outcome, we created a measure of project success based on similar measures in the management literature. Our conceptualization of project success measures the extent to which the project has achieved, or has made progress in achieving, the project’s goals and is based on established measures[3,4]. As the intermediate outcomes of industry-academia collaborations are hard to measure and quantify[5], we rely on the assessment of project success by the project leaders from *both* organisations. The advantage of this approach is that it

measures the performance of a project relative to the goals of the project that were jointly set by both project partners.

10.6.2. Quantitative data analysis

After the data collection had been concluded, we first carried out the inductive analysis (see Supplementary Box 1) to group the challenges reported by project participants into overarching categories. Afterwards, we associated each category with a factor from our first questionnaire that best represents this category. Table S3 provides an overview of all associations. For example, we relate the category "coordination challenges" from the inductive analysis to the factor "lack of coordination" that we measure with a previously selected measure of the degree of coordination (selected independent of inductive analysis). These factors serve as proxies to describe the extent to which challenges from that category are present in a project. Although these factors can by design not measure all aspects of each category of challenges, they represent factors that were named frequently in the qualitative analysis. The advantage of using pre-defined, concise factors from the previous literature is that established quantitative scales are available, which allow a reliable measurement of these factors.

As Table S3 shows, all but one of the seven factors that we measured are quantitative in nature. That is, participants responded to the questions in the questionnaire on quantitative scale. Since the contract type is a categorical variable, we grouped the available contract options into low (e.g., template-based, such as a material transfer agreement or a confidentiality agreement) and high (e.g., customized, such as a research agreement) complexity contracts depending on the effort required to set up such a contract based on the experience of senior managers at Novartis. In the subsequent analysis, we aggregated all responses within a project that measure the same variable.

To assess project success, we used the responses from the project leaders from both organizations in the second questionnaire (259 responses in total, 144 from Novartis project leaders and 115 from academic project leaders). We further restricted our analysis to projects for which we had received at least three responses and at least one response from each organisation (120 projects total) to reduce the potential subjectivity bias in the responses. To ensure the reliability of the outcome measure *project success*, we examined intra-class correlation coefficients (ICCs). The results showed a good agreement between the two project leaders that assessed the success of a project (the ICC(1) value for the overall project success measure was 0.54, indicating a high agreement between the different ratings for the same project[6]). Therefore, we aggregated the project leaders' rating of the outcome variable *project success* for each project.

Table S3 | **Measures quantifying factors related to the categories of challenges**

Category of challenges	**Related factor: description**	**Measure**
Resource constraints	*Lack of resources:* The home organisation provides little flexibility to pursue creative ideas and to spend time on projects except pipeline projects.	Quantitative factor based on 1 multiple choice question (Likert scale) from an established measure of the organisational innovation climate[7]
Legal & administrative process complexity	*Legal contract complexity:* The underlying legal contract is not based on standardized or template-based contracts, but is customized and typically requires negotiation.	Binary measure: 0=low-complexity contract 1= high-complexity contract
Coordination challenges	*Lack of coordination:* Problems in coordinating tasks and activities with the team at the partnering organisation.	Quantitative factor based on 5 multiple choice questions (Likert scale) from an established measure in the multi-team literature[8]
Scientific challenges	*Scientific uncertainty:* The scientific phenomena are not well understood, there is much trial and error, and cause-and-effect relationships are largely unknown.	Quantitative factor aggregated from 5 multiple choice questions (Likert scale), adapted from an existing measure of uncertainty in product development projects[9]
Goal alignment challenges	*Goal discrepancy:* There is a low overlap between the goals of the two partnering organisations.	Quantitative factor based on 1 question using a graphical measure depicting various configurations of goal alignment, adapted from an established measure[10]
Interpersonal challenges	*Lack of trust:* Participants do not trust participants from the other organisation.	Quantitative factor based on 4 multiple choice questions (Likert scale) from an established measure in the alliances literature[11]
Technological challenges	*Employing explorative technology:* The project involves technology, methods and compounds that are based on fundamentally new concepts or principles.	Quantitative factor based on 2 questions using a continuous quantitative scale 1-100 from an established measure in the R&D teams literature[12]

[a] The table shows the selection of seven factors that relate to the categories of challenges identified from questionnaire 1 and describes the employed measure. Most measures have been adapted from the literature to fit the context of industry-academia collaborations in the pharmaceutical industry.

To infer the relationship between the challenge-related factors and project success, we stratified all projects in our sample into two groups for each factor, sorted into projects scoring (1) high or (2) low in that factor. We considered all projects with a score higher than the mean in that factor as "high", and below the mean as "low". We then calculated the average level of project success separately for (1) the projects that face a high level of challenges and (2) the projects that face a low level of challenges in the corresponding category. Finally, we employed an ANOVA (analysis of variance) statistical test to infer whether the groups scoring high and low in a specific factor also differ significantly in their average rating of project success. Since the outcome measure *project success* was only fully reported by 110 teams, this analysis includes 110 projects in our sample.

Table S4 | **The impact of factors related to challenges on project success**[a]

Factor	**Average rating of project success**		**Differences between projects scoring low and high in factor (ANOVA)**
	Projects scoring low in factor (below average)	**Projects scoring high in factor (above average)**	
Lack of resources	4.12 (N=51)	3.79 (N=49)	Significant at p<0.02
Legal contract complexity	3.84 (N=58)	4.08 (N=47)	Not significant (p<0.09)
Lack of coordination	4.21 (N=57)	3.64 (N=52)	Significant at p<0.001
Scientific uncertainty	4.08 (N=55)	3.81 (N=55)	Significant at p<0.04
Goal discrepancy	4.14 (N=58)	3.73 (N=52)	Significant at p<0.002
Lack of trust	4.04 (N=55)	3.85 (N=55)	Not significant (p<0.16)
Employing explorative technology	3.82 (N=54)	4.07 (N=54)	Not significant (p<0.06)

[a] The table shows the average rating of project success for (i) projects that score low in a specific factor and (ii) projects that score high in that factor. The overall sample of 110 projects is split into these two groups for each factor separately (the numbers do not add up to 110 in four cases due to missing data). The column on the right shows the results from analyses of variances (ANOVAs), indicating whether there is a significant difference in the average rating of project success for projects that score low and for those that score high in the specific factor.

10.6.3. Results

Table S4 presents the results, which are plotted in Figure 2. The results indicate that a higher manifestation of five out of the seven factors examined is associated with a lower average level of project success. For example, projects scoring above average with respect to coordination problems (N=52) exhibited an average rating of project success of 3.64 out of 5. This value is significantly lower than the average rating of projects success of 4.21 for projects that scored below average in coordination problems (an analysis of variance (ANOVA) showed that the difference is significant at $p<0.001$). We found similar results for four other factors (i.e., lack of resources, scientific uncertainty, goal discrepancy, and lack of trust). The strongest impact on project success arises from of a lack of coordination.

10.6.4. References

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