JOURNAL OF MANAGEMENT STUDIES

Journal of Management Studies 55:8 December 2018
doi: 10.1111/joms.12396

Alliance Portfolio Diversity and Innovation: The Interplay of Portfolio Coordination Capability and Proactive Partner Selection Capability

Philip Degener, Indre Maurer and Suleika Bort

University of Göttingen; Chemnitz University of Technology

ABSTRACT This study seeks to explain how the innovation potential entailed in the structural characteristics of a diverse alliance portfolio can be leveraged by two different alliance management capabilities of a focal firm: portfolio coordination and proactive partner selection. An analysis of German biotechnology firms, based on database and survey data, indicates that each alliance management capability positively interacts with portfolio diversity to foster innovation. In addition, regarding their joint influence as capability bundle on the portfolio diversity–innovation link, portfolio coordination and proactive partner selection seem to substitute rather than complement each other. These results suggest that firms realize innovation benefits from a diverse set of external alliance partners only when they focus on and apply internal coordination or partner selection routines to manage these alliances, thus acting as either portfolio coordinators or portfolio configurators.

Keywords: alliance portfolio diversity, alliance management capabilities, proactive partner selection, portfolio coordination, innovation performance

INTRODUCTION

Firms often maintain a portfolio of diverse inter-organizational alliances to enhance their competitive position (Lee et al., 2017). Accordingly, prior research has examined the various performance outcomes related to a focal firm's alliance portfolio diversity (APD), commonly defined as the degree of variance in alliance partners' resources, capabilities, and knowledge (Jiang et al., 2010). In addition to financial advantages (Baum et al., 2000), market value (Caner et al.,

Address for reprints: Philip Degener, Chair of Organization and Corporate Development, University of Göttingen, Platz der Göttinger Sieben 3, 37073, Göttingen, Germany (philip.degener@wiwi.uni-goettingen.de).

2018), and organizational growth (De Leeuw et al., 2014; Powell et al., 1996), APD fosters innovation performance (Hagedoorn et al., 2017; Wuyts et al., 2004). The impact of APD on innovation seems especially relevant for high-technology firms, such as those in the semiconductor (Stuart, 2000), automotive (Jiang et al., 2010), and biotechnology industries (George et al., 2001), in which a set of diverse partners allows firms to compensate for their own lack of resources and to keep pace with technological development. In this context, alliance portfolios consisting of diverse partner firms provide simultaneous access to heterogeneous and non-redundant resources, capabilities, and knowledge, which can be combined to stimulate innovation (Wassmer, 2010).

While a great number of previous studies have emphasized APD benefits and empirically corroborated that increases in the diversity of a firm's alliance portfolio are related to increases in a firm's innovation performance (Baum et al., 2000; Phelps, 2010; Wuyts et al., 2004), some studies question the simple logic that more always leads to more. Instead, they point to potential challenges arising from increases in portfolio diversity: The management of diverse alliance portfolios is complex. This circumstance may lead to high coordination costs (Goerzen and Beamish, 2005) as well as difficulties in assimilating and making use of the heterogeneous resources and knowledge provided (Sampson, 2007), a combination that reduces the benefits of APD from a certain point. Instead of a linear relationship between APD and innovation performance, these studies hypothesized and found an inverse U-shaped relationship (Duysters and Lokshin, 2011; Hagedoorn et al., 2017; Sampson, 2007). Still other studies did not find a significant impact of APD on innovation outcome (Cui and O'Connor, 2012; Eisingerich et al., 2009; Faems et al., 2010).

Recent research has begun to explore potential contingencies in order to explain such inconclusive findings. Based on an emerging capability perspective on alliance portfolios, research started to accentuate internal firm capabilities as decisive factors (Wuyts and Dutta, 2014). However, one hitherto largely neglected explanation might be that some firms are endowed with a specific bundle of alliance management capabilities (AMCs) and are thus better able to cope with the challenges of diverse alliance portfolios as well as to take advantage of the benefits of these portfolios and turn them into innovative outcomes. Research on AMCs is rooted in the logic of a resource-based view, which emphasizes variance in alliance capabilities across firms. These capabilities represent a firm's accumulated alliance-related knowledge and therefore a shared belief about how alliance-related activities should be performed (Heimeriks and Duysters, 2007). They manifest in firm specific internal routines putting the firm in a superior position to realize the potential embedded in the structural aspects of its alliance portfolio by facilitating cooperation, supporting knowledge transfer and easing conflicts (Schilke, 2014). Overall, AMCs are accountable for the performance differences that firms are able to derive from their alliances and present a source of competitive advantage (Ireland et al., 2002). This stream of research thus offers a firm-internal managerial perspective on alliance portfolios as opposed to a firm-external perspective on the characteristics of these portfolios (Faems et al., 2012). Even though the concept of AMCs seems to complement the structural perspective on alliance portfolios, and a wide range of prior studies have shown that AMCs impact alliance success on the dyadic level (e.g., Kale and Singh, 2007; Kale et al., 2002), research is only beginning to understand how AMCs can impact the success of alliance portfolios. For example, Sarkar et al. (2009) found that the usefulness of AMCs for generating value from alliance portfolios depends on the structural characteristics of these portfolios. Similarly, Duysters et al. (2012) showed that firms are able to improve the performance of their diverse alliance portfolios by employing deliberate learning mechanisms that reflect their alliance capability.

This study builds on these valuable insights and develops them further. Drawing from resource-based view, we focus on two distinct AMCs – portfolio coordination and proactive partner selection – and theorize the reinforcing or impeding interplay of these two capabilities for managing diverse alliance portfolios. These two AMCs are considered to be particularly relevant for managing the complexity of alliance portfolios because they ensure a constructive cooperation between different partners (Sarkar et al., 2009; Schilke and Goerzen, 2010). At the same time, they present two different approaches firms can take for managing alliance partnerships (Dekker, 2008). Whereas portfolio coordination capability (as reflected by organizational routines to coordinate activities across alliance partners) allows firms to govern the entire alliance portfolio in the post-formation stage, proactive partner selection capability (as reflected by organizational routines to proactively pursue alliance formation opportunities) allows firms to identify and enter into compatible partnerships in the pre-formation stage. This study seeks to provide a more fine-grained picture of the usefulness of these different approaches and to shed more light on whether it is worthwhile for firms to invest simultaneously in different AMCs or whether it is more efficient to focus exclusively on one capability.

Accordingly, this study analyses the respective moderating effects of portfolio coordination capability and proactive partner selection capability on the relationship between APD and innovation outcome. In addition, this study goes one step further and investigates whether the two different AMCs substitute or complement one another by examining the three-way interaction between APD and the bundle of both capabilities. Figure 1 illustrates the theoretical model. Findings are based on a combination of database and survey data from a large sample of firms in the German biotechnology industry. These findings show that a firm's innovation performance depends not only on the set of resources and competencies held by external partners and embedded in a diverse alliance portfolio, but also on the focal firm's organizational capabilities and routines for managing portfolio diversity. More specifically, results regarding the interplay of portfolio coordination capability and proactive partner selection capability indicate that a capability bundle characterized by high levels of both AMCs diminishes

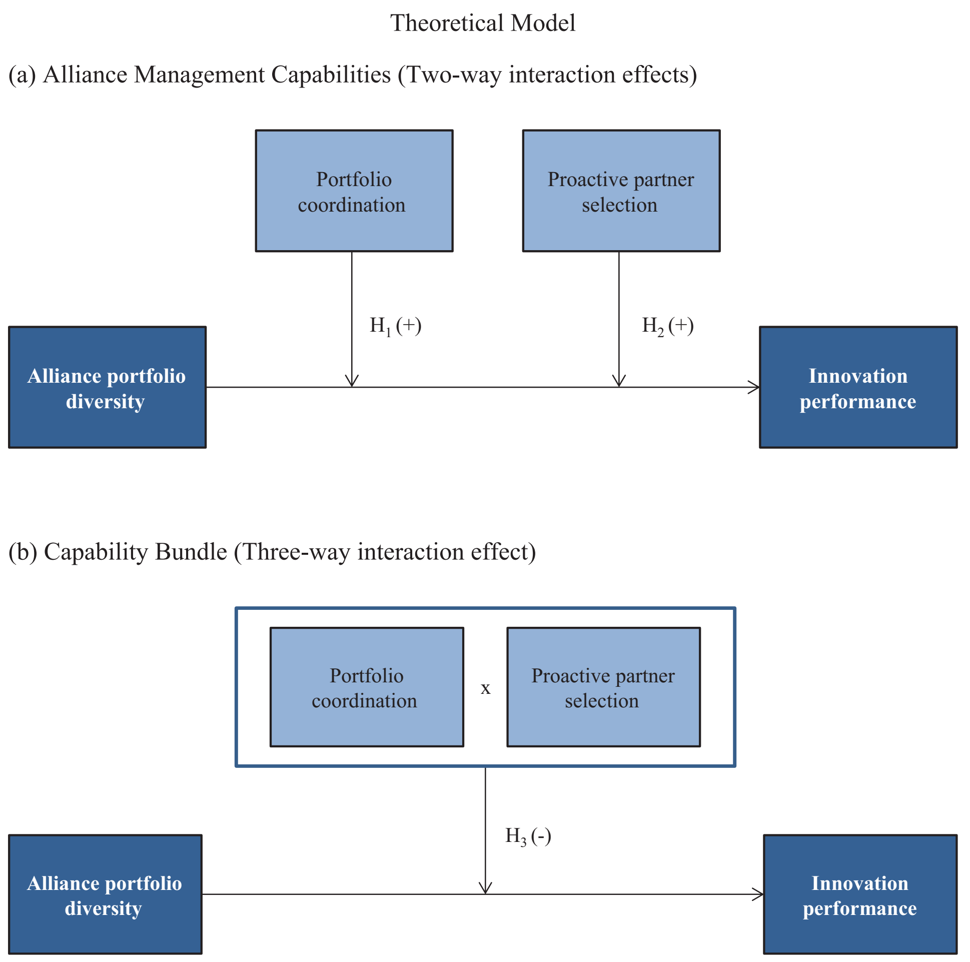

Figure 1. Theoretical Model. (a) Alliance Management Capabilities (Two-way interaction effects). (b) Capability Bundle (Three-way interaction effect) [Colour figure can be viewed at wileyonlinelibrary.com]

innovation performance, and thus firms should focus on one AMC rather than invest in a combination of both.

By addressing recent calls in the literature for further research to study not only the performance implications of alliance portfolios from a structural perspective, but also examine in more detail firms' capabilities to actually manage their alliance portfolio (Demirkan and Demirkan, 2012; Faems et al., 2012; Wang and Rajagopalan, 2015), this study makes two key contributions: First, it contributes to the alliance portfolio literature by focusing on the interplay of two distinct AMCs as a bundle of firm-internal management capabilities that explains focal firms' innovation performance differences resulting from their diverse alliance portfolios. Hence, it helps clarify under which conditions focal firms can capture the benefits of alliance portfolios and advances research on performance implications of alliance portfolios (e.g., Lahiri and Narayanan, 2013; Lavie, 2007; Lee et al., 2017; Wassmer, 2010; Wuyts and Dutta, 2014). Second, it contributes to the literature on firm capabilities in general and on AMCs in particular by separately investigating both the respective moderating effect of portfolio coordination capability and proactive partner selection capability, as well as the interplay of the two AMCs in combination. As a result, this study provides more detailed insights into the interdependencies of different AMCs and emphasizes potential costs of organizational routines that can significantly diminish organizational benefits. Thus, we extend the originating research stream on firm capabilities and their respective as well as joint value in various alliance contexts (e.g., Ethiraj et al., 2005; Fainshmidt et al., 2016; Kale and Singh, 2009; Lioukas et al., 2016; Schilke, 2014; Schreiner et al., 2009; Wang and Rajagopalan, 2015).

THEORY AND HYPOTHESES

Alliance Portfolio Diversity and How It Fosters Innovation

Since the pace of innovation continues to accelerate and innovative developments are complex, time-consuming, and costly, firms often maintain a portfolio of inter-organizational alliances to stimulate innovation (Lahiri and Narayanan, 2013; Zheng and Yang, 2015). This is especially true for the biotechnology industry – the setting of this study – where it has been claimed that the locus of innovation is not the single firm but rather the network of different partner firms (Baum et al., 2000; Oliver, 2009; Powell et al., 1996). Resource-constrained biotechnology firms need to ally with a portfolio of diverse outside partner organizations, including pharmaceutical firms, biotechnology firms, universities, and research institutes in order to access a broader pool of resources, capabilities, and knowledge that provide the foundation for firm innovation (George et al., 2001; Maurer and Ebers, 2006; Oliver, 2001). Accordingly, in this study we define a focal firm's alliance portfolio as the collection of all direct and active alliances on the corporate level (Lavie, 2007; Wassmer, 2010), and its diversity by the variety of organizational types in the alliance portfolio (Baum et al., 2000; Powell et al., 1996).

A diverse alliance portfolio prevents firms from being locked into their internal resource base by providing access to new and different kinds of resources from external sources, which in turn supports innovation (Marhold et al., 2017; Wuyts et al., 2004). Such argumentation is in line with one basic rationale of social network theory, which postulates a causal link between the network structure of a focal firm and its performance (Borgatti and Foster, 2003). APD may foster innovation because the variety of recombination possibilities of internal and external resources, capabilities, and knowledge stimulates the potential for creative thinking and experimentation (Fleming, 2001; Lucena and Roper, 2016). Furthermore, increasing APD allows firms to benefit from synergies resulting from alliances because they can exploit interdependencies among different partners (Vassolo et al., 2004). Resources and information can be transferred between alliances, which enhance the efficiency and effectiveness of the alliance portfolio (Hoffmann, 2005). For example, firms can apply solutions from one alliance to problems emerging in another, leading to a diverse set of problem-solving heuristics and better decision-making quality (Beckman and Haunschild, 2002). Additionally, as APD increases, the portfolio serves as a 'radar function' to identify different market and product trends at an early stage, leading to an information advantage over competitors, and in turn stimulating innovative ideas (Ahuja, 2000).

On the opposite side, APD has potential drawbacks that may diminish innovative returns. Every firm has a cognitive limit for coordinating and monitoring its alliance portfolio (Goerzen and Beamish, 2005; Martinez et al., 2017b). At a certain point APD leads to managerial challenges – such as conflicts and competing objectives – that exceed this cognitive limit and hinder optimal decision-making and exploitation of synergies between alliance partners (Duysters and Lokshin, 2011). Moreover, as APD increases, various patterns of communication can lead to misunderstandings between partners and the transfer of resources, capabilities, and knowledge can be hampered (Rothaermel and Deeds, 2006). For instance, in cases of tacit and complex knowledge, the capacity of a firm to acquire and use knowledge from different alliances is limited, and recombination of internal and external knowledge becomes excessively difficult as APD increases (Lane and Lubatkin, 1998; Simonin, 1999).

Considering the benefits and drawbacks of APD, recent research regarding the influence of APD on innovation has generated inconclusive empirical results. Some studies provide results showing an inverse U-shaped relationship (De Leeuw et al., 2014; Duysters and Lokshin, 2011; Sampson, 2007). According to these studies, APD increases innovation only up to a certain point and afterwards the drawbacks of APD outweigh its benefits and innovative outcome decreases. Other studies describe a non-significant impact (Cui and O'Connor, 2012; Eisingerich et al., 2009; Faems et al., 2010). Hence, APD does not strengthen or weaken innovation outcome significantly. These different findings challenge the most frequently empirically confirmed linear relationship between APD and innovation (Baum et al., 2000; Faems et al., 2005; Phelps, 2010; Wuyts et al., 2004). They imply that the drawbacks of APD do not lead to a negative slope of innovative outcome, but instead might lower the gradient of the straight line.

Recent research has begun to elucidate why some firms benefit from diversity more than others do by introducing different contingencies that influence the relationship between APD and innovation. On the one hand, such contingencies may be located at the level of the focal firm's alliance portfolio. Phelps (2010), for example, shows that focal firms are better able to benefit from a diverse composition of alliance partners when these alliance partners are closely connected. Network closure creates trust and common norms among network partners (Coleman, 1988), mitigating the risks associated with increased APD and thus facilitating coordination and resource sharing. On the other hand, such contingencies may be contained within the focal firm itself. Cui and O'Connor (2012), for example, highlight the role of formal organizational mechanisms. Majority control over alliances as well as specific organizational functions for managing alliances endows focal firms with the rights and resources to monitor and coordinate their portfolio of alliances which, in turn, helps to effectively leverage the diversity of alliance partner resources. In contrast to formal structure, Wuyts and Dutta (2014) emphasize a focal firm's past internal knowledge creation strategy for leveraging external knowledge. They find that firms profit differentially from APD depending on how they manage internal knowledge creation. Our study expands on these latter findings and thus answers recent calls in the literature (Demirkan and Demirkan, 2012; Faems et al., 2012; Wang and Rajagopalan, 2015) to consider the contingent effect of a focal firm's capabilities in managing a diverse alliance portfolio. This approach takes into account one argument of social network theory, according to which portfolios of external partnerships present an opportunity to access resources and thus an asset that contains potential value (that can or cannot be realized) (Maurer et al., 2011; Wu, 2008). In theorizing when such potential value can be realized this study follows the most general idea that capabilities enable firms to extract benefits from diversity and thereby to transform diversity into firm performance (Roberson et al., 2017). More specifically, our study focuses on two distinct management capabilities and explores their interplay as a capability bundle for managing a diverse alliance portfolio. Drawing from resource-based view, we argue that portfolio coordination capability and proactive partner selection capability trigger cooperation, knowledge transfer, and conflict resolution (Schilke, 2014) thus putting firms in a superior position to cope with the drawbacks and extract the benefits of a growing diversity in their alliance portfolio. By offering a firm-internal managerial perspective on alliance portfolios as opposed to a firm-external perspective on the characteristics of these portfolios (Faems et al., 2012) we enrich alliance portfolio research and reasoning with a capability perspective theoretically grounded in the logic of the resource-based view.

Organizational Capabilities Supporting the Management of Diverse Alliance Portfolios

Prior research has argued that capabilities for managing alliance portfolios are heterogeneously distributed across firms (Kale and Singh, 2007), and that firms possessing high capabilities levels are more successful than are firms with lower ones (Ireland et al., 2002; Niesten and Jolink, 2015). AMCs have been generally described as distinct capabilities that have the potential to enhance organizational performance by helping firms manage the challenges of alliance relations (Helfat et al., 2009; Schilke, 2014). Research on AMCs builds on the resource-based view. It argues that focal firms employing specific management capabilities are in a superior position to create and capture value from their alliance partners compared to firms without such scarce capabilities (Schilke and Goerzen, 2010; Schreiner et al., 2009; Wang and Rajagopalan, 2015). Due to differences in capability endowments, regarding e.g. organizational capabilities for portfolio coordination or proactive partner selection, AMCs might be accountable for the performance differences firms are able to derive from their alliance portfolio (Sarkar et al., 2009). Consequently, AMCs become a potential source of competitive advantage (Heimeriks and Duysters, 2007). While this line of argument – rooted in the logic of a resource-based view – has significantly stimulated scholarly thinking on why some firms benefit more from their alliance portfolio than others, it must also consider criticism that the resource-based view is vague and tautological and thus not amenable to empirical testing (e.g., Priem and Butler, 2001; Williamson, 1999). Therefore, recent conceptualizations have advocated a process-based approach, which conceptualizes and operationalizes AMCs by means of the underlying organizational routines that constitute the capability (Sarkar et al., 2009; Schilke and Goerzen, 2010; Schreiner et al., 2009). Such an approach both avoids near tautology by separating the notion of capability from its effects, and allows us to identify an observable set of organizational routines that can be tested empirically (Zollo and Winter, 2002). It thus advances a systematic, theoretical, and empirical understanding of AMCs and their underlying organizational routines. In this study, we follow a process-based approach and define AMCs on the portfolio level as a broad set of organizational routines designed to initiate and manage an alliance portfolio (Wang and Rajagopalan, 2015). Because the multiple partner relationships within a firm's alliance portfolio add a level of complexity managing the whole portfolio of alliances imposes – at least in part – different requirements for firms compared to managing alliances on a dyadic level (Hoffmann, 2007).

This study builds on the work of Schilke and Goerzen (2010) as well as Sarkar et al. (2009), who suggest and empirically corroborate different capability dimensions associated with alliance management that are reflected in organizational routines. It picks out those AMCs that are considered particularly relevant for handling the complexity of multiple partner relationships on a portfolio level: (1) portfolio coordination capability, represented by organizational routines for coordinating activities across the portfolio; and (2) proactive partner selection capability, reflected by organizational routines for proactively pursuing alliance formation opportunities.

The next sections start with descriptions of the two capabilities as well as their respective moderating influence on the relationship between APD and innovation, followed by the illustration of the joint interplay of both AMCs.

The Moderating Role of Portfolio Coordination Capability

Portfolio coordination capability is defined as the comprehensive governance of a firm's entire alliance portfolio (Schilke and Goerzen, 2010). It manifests in organizational routines for coordinating the strategies, activities, and knowledge flows across different partners in the portfolio (Sarkar et al., 2009). Such routines encompass regular activities directed towards identifying interdependencies between alliance partners, determining areas of synergy, and synchronizing activities across alliance partners (Goerzen, 2005; Hoffmann, 2005).

As APD increases, it becomes more difficult to identify and act on interdependencies and potential synergy effects between different partners. Firms that have a strong portfolio coordination capability and thus regularly scan their alliance portfolio for areas of overlap are likely to detect in a timely manner the opportunities and risks associated with the increased complexity of a diverse alliance portfolio. Moreover, regularly synchronizing activities and disseminating time-sensitive information across alliance partners allows firms to leverage partner synergies as well as avoid duplication of efforts. As a consequence, these firms are able to cope with the increased complexity of a diverse alliance portfolio and thereby exploit its innovation potential (Kandemir et al., 2006; Leischnig et al., 2014). Furthermore, portfolio coordination can help firms manage differing objectives and reduce conflicts (Hoffmann, 2007; Ireland et al., 2002). This is especially important because in diverse alliance portfolios competing alliance objectives and destructive conflicts are likely, thus potentially dampening innovation (Goerzen and Beamish, 2005; Parise and Casher, 2003). To counteract these tendencies and their effects, firms that search and synchronize their alliance portfolios on a regular basis are able to identify potential conflicts in advance and immediately and constructively handle them. This, in turn, helps to enhance creativity and experimentation, which promotes innovation (Dreu, 2006; Song et al., 2006).

Thus, a high portfolio coordination capability supports the flow of relevant resources, capabilities, and knowledge between different partners, and as a result even a highly diverse alliance portfolio can be more than the sum of its parts and foster innovation. Therefore, we hypothesize:

Hypothesis 1: The portfolio coordination capability of a focal firm positively interacts with alliance portfolio diversity in influencing firm innovation performance.

The Moderating Role of Proactive Partner Selection Capability

Proactive partner selection capability is defined as a firm's engagement in discovering and acting on new alliance opportunities ahead of its competitors (Sarkar et al., 2009). It is reflected by organizational routines to frequently scan the environment for partnership opportunities and to take action when such opportunities arise (Kandemir et al., 2006; Schilke and Goerzen, 2010). Proactive firms regularly search for alliance partners who are reliable and fit culturally to the focal firm as well as to the other alliance partners in its portfolio (Kauppila, 2015).

As APD increases, differences between alliance partners (e.g., in terms of pursued objectives or organizational cultures) increase the potential for disagreements (Parkhe, 1993; Zajac and Olsen, 1993). When conflicts arise, alliance partners tend to protect their resources, capabilities, and knowledge (Kale et al., 2000). Hence, successfully utilizing the innovation potential of a diverse portfolio requires sophisticated skill. To ensure mutual understanding between partners and prevent conflicts, an important task for firms is selecting partners that are compatible with the other alliances in the portfolio (Lavie et al., 2012). Firms endowed with a high proactive partner selection capability actively monitor their environment with regularity and thus have more timely and reliable information about partnering opportunities than do their competitors (Sarkar et al., 2009). When proactively approaching new partners, these firms can pick their alliances from a wider range of potential partners, take into consideration the potential risk of working together with different alliance partners, and thus adequately match new alliance partners with their existing ones (Sarkar et al., 2001). A good fit between focal firms and their alliance partners, as well as between the various partners in their portfolio, facilitates smooth interaction and good cooperation among all the partner firms (Wassmer and Dussauge, 2011). As a results, this supports the exploitation of the innovation potential entailed in a highly diverse set of alliance partners by opening access to their respective resources, capabilities and knowledge. Thus, we hypothesize:

> *Hypothesis 2:* The proactive partner selection capability of a focal firm positively interacts with alliance portfolio diversity in influencing firm innovation performance.

The Interplay of Portfolio Coordination Capability and Proactive Partner Selection Capability

Building on the previous explanations, we now investigate the interplay of portfolio coordination capability and proactive partner selection capability in influencing the innovation impact of diverse alliance portfolios. We argue that the two AMCs act as substitutes for each other because they support firms in managing the complexities of diverse portfolios and thereby put them in a position to attain the benefits of APD in distinctive, yet equifinal ways: On one side, once a specific alliance portfolio constellation is formed, firms with a high portfolio coordination capability are able to overcome the challenges of APD by handling ensuing conflicts and monitoring tasks (Parise and Casher, 2003). Firms regularly synchronize activities among partners and create synergies (Schilke and Goerzen, 2010). Hence, firms with a high portfolio coordination capability possess adequate organizational routines that they can use to derive innovation benefits even when the complexity of the alliance portfolio is high.

On the other side, proactive firms use the complexity of diverse alliance portfolios to their advantage by selecting compatible and reliable partners and matching these new partners with their existing alliance portfolio (Sarkar et al., 2009). By applying proactive partner selection they avoid conflicts and ensure mutual understanding (Lavie et al., 2012; Spekman et al., 1998) and therefore help realize the synergistic potential among the many different alliance partners in their portfolios (Sarkar et al., 2001; Wassmer and Dussauge, 2012).

The two ways of approaching the complexity of APD are distinct, as they rely on substantially different competencies, yet at the same time are equifinal, as they result in similar innovation benefits. Therefore, portfolio coordination capability and proactive partner selection capability act as substitutes (Milgrom et al., 1991).

This means that a lack of portfolio coordination capability can be compensated by a strong proactive partner selection capability and vice versa. Similarly, a strong portfolio coordination capability does not increase but rather decreases the value of a proactive partner selection capability and vice versa. More concretely, proactive firms do not rely on a particularly high portfolio coordination capability to realize synergies among alliances because they can easily identify potential interdependencies among their partners; and firms endowed with a high portfolio coordination capability do not need to be specifically proactive because they have the capacity to coordinate even highly complex portfolios. Since one set of organizational routines – coordination routines or proactive partner selection routines – is sufficient to achieve the innovation effect that results from exploiting a diverse alliance portfolio, it is more efficient for firms to focus on the development and maintenance of one AMC rather than both capabilities at the same time. Moreover, possessing both capabilities at the same time may be even detrimental for the innovation performance of a focal firm because creating and maintaining AMCs usually requires substantial investments (Schilke, 2014), as repetitive portfolio coordination and partner selection activities cost money, time, and human resources (Heimeriks and Duysters, 2007). For example, portfolio coordination requires firms to organize frequent alliance-management workshops and maintain an alliance function or coordination manager, which increases their costs (Heimeriks et al., 2009). Likewise, a proactive approach to alliance partner selection requires due diligence to identify and assess potential partners (e.g., visiting industry conventions and trade shows) and to negotiate alliance contracts, which can be complex and resource intensive (Mellewigt and Decker, 2014).

Summing up, enacting both AMCs simultaneously and employing unnecessary alliance-management routines can be inefficient, and requires extensive resources that firms could instead use to innovate. Therefore, by either being highly proactive or possessing a strong portfolio coordination capability, firms efficiently utilize their resources and derive the highest degree of innovation outcome from APD. Thus, we propose:

> *Hypothesis 3:* There is a three-way interaction between alliance portfolio diversity, portfolio coordination capability, and proactive partner selection capability: the level of firm innovation performance is highest when alliance portfolio diversity is high, portfolio coordination capability is high, and proactive partner selection capability is low; or when alliance portfolio diversity is high, portfolio coordination capability is low, and proactive partner selection capability is high.

METHODS

Sample and Data

Our empirical research setting is the German biotechnology industry. The industry seems suitable for studying the relationship between alliances and innovation for two main reasons: First, the German biotechnology industry is characterized by small- and medium-sized enterprises that enter into many inter-organizational alliances to overcome internal lack of resources (Ernst and Young, 2013; Maurer and Ebers, 2006). Second, firms in this high-technology industry need to innovate their processes and develop new technologies to be competitive in the long term. Thus, innovation outcome is an appropriate performance measure (Casper, 2000; Kaiser and Prange, 2004) and a firm's alliance portfolio is an important source of innovation.

We tested our hypotheses by using several sources and a combination of primary and secondary data from 132 biotechnology firms. In this way, our study follows recent requests in the literature to combine secondary data and survey data when studying the interactions between structural aspects of the alliance portfolio and capabilities to manage them (Faems et al., 2012). First, we identified the complete population of German biotechnology firms using the 'Yearbooks of the German Biotechnology Industry', an annual directory of all active biotechnology firms in Germany published by BIOCOM AG. Second, we used the daily registration and deregistration records of the German Commercial Register, as well as yearly reports from the internet platform biotechnologie.de, which is hosted by BIOCOM AG and supported by the Federal Ministry of Education and Research, in order to precisely define the respective firms' founding dates, exit dates and circumstances, legal forms and structures, and headquarter locations. Third, the latter internet platform was used to gather information about the grants firms received from government agencies. Next, we used archival data coded from the monthly *Transcript* newsmagazine and the internet news platform bionity.com[1] – both of which report on the German biotechnology industry – as well as the individual daily press releases published by the respective firms, in order to collect and code events such as the formation and termination of alliances, licensing agreements, and the initiation or termination of international activities. Using *Transcript,* bionity.com, and the daily press releases of the firms allowed us to precisely record the date of individual firm events.

Finally, we used a survey in 2014 to collect data on the AMCs of firms. We constructed a questionnaire based on established scales from previous literature. The questionnaire was thoroughly pre-tested with 15 respondents from industry and academia to ensure use of adequate terminology and to avoid ambiguity in our statements (Podsakoff et al., 2003). Similar to former research in the area of inter-organizational alliances and firm capabilities (e.g., Schilke and Goerzen, 2010; Schreiner et al., 2009; Zollo et al., 2002), we used the key-informant approach to collect the data. All of our respondents are experienced executives. Over 90 per cent are chief executive officers, managing directors, heads of business development, or heads of research and development. On average they have worked 8.09 years for their firms. The respondents of our survey are especially suitable as key informants: Since our sample consists of small firms, these executives are closely involved and familiar with the organizational processes and alliance activities and are thus qualified as well as appropriately positioned to give information about the firms' AMCs. This approach is in line with former research (e.g., Yli-Renko et al., 2001) examining inter-organizational alliances of small firms. In addition, our pre-test clearly confirmed the suitability of our respondents.

Our data is based on a larger research project. Therefore, we contacted all 465 German biotechnology firms identified by the biotechnology.de industry platform and in existence by telephone and our response rate (based on 163 returned questionnaires) was 35 per cent. For the purpose of this study, we excluded 31 firms because of missing data or because these firms are subsidiary companies and thus do not file patents by themselves. Therefore, our final sample includes 132 firms that, on average, are 13 years old and have 20 employees.

Because we rely on secondary data for our independent and dependent variables and solely rely on single source self-reported data for our moderator variables we do not need to further consider possibility of common method bias (Podsakoff et al., 2003). In order to reduce social desirability bias, we assured respondents that we would keep collected data anonymous and guaranteed that identification of individual firms would not be possible and the results of our study would be limited to aggregate statistics.

Variables and Measures

Dependent Variable. In line with prior researchers, we measure the *innovation performance* of the firms in our sample as the number of their successful patent applications (Demirkan and Demirkan, 2012; Owen-Smith and Powell, 2004; Schilling and Phelps, 2007; Sytch and Tatarynowicz, 2014; Zheng and Yang, 2015). We also followed earlier research and considered a three window (2014 until 2016) for our innovation performance (Sampson, 2007).[2] This takes into account that alliances are not immediately consequential for innovation performance (Lahiri and Narayanan, 2013; Rosenkopf and Padula, 2008). Thus, it is important to consider a time lag between APD and innovation performance. Again, following methods used in prior research, we assigned a patent to a biotechnology firm on the date of application rather than the date of granting, since the application date is a more accurate representation of the date of innovation (Ahuja, 2000). Considering the date of application as the point an invention was made, this measure accounts for potentially different patent review time horizons (Sytch and Tatarynowicz, 2014). Patent counts are considered valid and robust indicators of the innovation performance of firms (Griliches, 1998; Schilling and Phelps, 2007; Trajtenberg, 1987). Because obtaining patent protection is costly, a patent application indicates an inventor's positive expectation about the economic significance of the newly created knowledge. In a study of fifty-seven pharmaceutical firms, Comanor and Scherer (1969) provide evidence that the number of patent applications is more closely related to subsequent innovation in the form of new products than is the number of patents granted.

Despite this measure's frequent use to study innovation, there are some potential limitations to using patent counts. Patenting itself is a strategic choice, hence not all firms choose to patent innovations (Spender and Grant, 1996). That said, in highly dynamic environments, a firm's temporary advantage can be easily eroded by imitative or innovative competition (Grant, 1996). This outcome suggests that firms operating in such competitive environments are encouraged to patent innovations, since patents provide firms with fairly strong protection for their proprietary knowledge (Ahuja, 2000). Against this background, patent protection and the subsequent management of intellectual-property rights is particularly important in the biotechnology industry (Demirkan and Demirkan, 2012; George et al., 2008; Shan et al., 1994), which is characterized by significant R&D spending and high risks associated with new-drug development (Gassmann et al., 2008).

Keeping the potential limitations using patents as a measure of innovation performance in mind, we further validated our measure by investigating the relationship between firms' patent applications and the innovation performance reported by our firms in the survey. Thus, we compare the objective measure of patent applications and the subjective estimation of firm innovation of the respondents. To assess *innovation performance*, we asked respondents about the development and successful market introduction of new products and technologies. We measured the construct by two items on a five-point Likert scale. The scale obtained good reliability (Cronbach's alpha = .830). For patent applications we considered a three year window prior to the survey data and find a significant positive relationship ($r = .27$, $p < .05$) between the number of a firm's patent applications and the reported innovation performance in the survey. As a result of this positive correlation, we conclude that that patents are one important component that makes up a firm's innovation performance. However, we want to add that this correlation also shows that there may be additional factors that determine a firm's own perception of the level of new products and technologies development that is not captured when assessing innovation performance via patent applications.

Independent Variables. Alliance portfolio diversity is obtained by constructing a Blau (inverse Herfindahl) index (Blau, 1977). We used organizational type diversity as an APD measure and coded all alliance partners into five categories (biotechnology firms, pharmaceutical firms, universities and research institutes, suppliers, and service providers). Prior literature has identified these alliance partner types as critical resource providers for generating innovation in the biotechnology industry. For example, pharmaceutical firms often provide access to information about market trends, financial resources, expertise in managing clinical trials as well as marketing and distribution infrastructure (Ahuja, 2000; Oliver, 2009; Rothaermel and Deeds, 2004). Universities and research institutes provide timely access to new ideas and concepts, which mainly entail basic knowledge (Baum et al., 2000; George et al., 2001). Alliances with other biotechnological firms open access to primarily applied research skills as well as specific knowledge about processes and demands in the biotechnology industry (Powell et al., 1996; Rothaermel and Deeds, 2006). We consider the firms' alliance portfolio from 2013. In line with prior research that uses a five year window as an appropriate alliance timeframe in the biotechnology industry (e.g., Ahuja et al., 2009; Phene and Tallman, 2012) the alliance portfolio from 2013 include all alliances entered by a firm from 2009–13. Overall, we found that the alliance portfolios of the firms in our sample contained 530 alliance partners (104 biotechnology firms, 78 pharmaceutical firms, 61 suppliers, 199 universities and research institutes, and 88 service firms). Thus, we calculated the Blau index (Blau, 1977) according to the formula:

$$H = 1 - \sum_{i=1}^{n} \left(s_i^2\right).$$

In this formula s_i indicates the proportion of firms in the portfolio of organizational type i, and n is the number of different organizational types in the alliance portfolio. The index ranges from 0 to 1, where large values indicate a heterogeneous, and accordingly diverse, portfolio and small values indicate dominant types of alliance partners in terms of their organizational type. Thus, the Blau index describes the diversity of alliance types in the portfolio. This index is frequently used to measure APD (Jiang et al., 2010; Powell et al., 1996).

The measurement *of alliance management capabilities* is associated with major challenges arising from *the* intangible nature *of* capabilities per se but also from *the* potential risk *of* vaguely defining *and* tautologically conceptualizing *the*m. As a remedy, recent literature conceptualizes and operationalizes AMCs by means of their manifestations, this is the organizational processes and routines related to the management of alliances (Sarkar et al., 2009; Schilke and Goerzen, 2010; Schreiner et al., 2009). In line with our definition and conceptualization of AMCs we follow this approach. Specifically, to operationalize the AMCs *portfolio coordination* and *proactive partner selection capability*,[3] we adapted scales previously validated by Schilke and Goerzen (2010) and measure them on the basis of the organizational routines to coordinate activities across the alliance portfolio and to proactively pursue alliance formation opportunities, respectively. We measured the constructs on a five-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). We conducted principal-component factor analysis to test for convergent validity of the multi-item constructs. Standardized factor loadings for all items are clearly above the recommended minimum of 0.40 (Ford et al., 1986). Further, the average variances extracted by the factors are above the recommended minimum of .50 (Fornell and Larcker, 1981) and the Cronbach's alphas of all constructs are clearly above the recommended minimum of 0.70. Table 1 shows individual items and their standardized loadings on different constructs, as well as the Cronbach's alphas and the average variance extracted by the factors.

Table I. Measurement, validity and reliability of constructs

Factors and items	*Standardized loadings*	*Cronbach's alpha*	*Average variance extracted*
Portfolio coordination capability (*Source:* Schilke and Goerzen, 2010)		0.91	0.85
We determine areas of synergy in our alliance portfolio	0.89		
We ensure that interdependencies between our alliances are identified.	0.91		
We determine if there are overlaps between our different alliances.	0.89		
Proactive partner selection capability (*Source:* Schilke and Goerzen, 2010)		0.84	0.77
We often take the initiative in approaching firms with alliance proposals.	0.87		
Compared to our competitors, we are far more proactive and responsive in finding and 'going after' partnerships.	0.85		
We actively monitor our environment to identify partnership opportunities.	0.79		

Additionally, we tested the discriminant validity of our constructs, and the variance extracted from each construct is higher than the squared correlation between the constructs (Fornell and Larcker, 1981). Overall, our measures illustrate very good validity and reliability. We also tested that we have sufficient variation in the capability measures. The Pearson Chi^2-test indicated a significant difference between the groups. 48 (36.36 per cent) out of the 132 firms have a score above the mean on both capability measures, 42 (31.8 per cent) firms have a score below the mean on both capabilities and 42 (31.8 per cent) firms in our sample are in the group in which one capability measure is below and the other is above the mean.

We also controlled for *nonresponse bias*. In line with Armstrong and Overton, 1977, we applied an independent group t-test and compared the mean number of employees, alliances and prior patents, score between the group of firms that participated in our study and the firms that did not respond to our survey. We did not find a statistically significant difference.

Additionally, we test for *early and late respondent bias*. We conducted t-tests on the responses from two subsamples separating respondents who answered early and respondents who answered late. Results showed no significant differences between these two groups for the variables measured with our survey.

All in all, the time structure of our dataset can be summarized as follows: We measured the variable APD based on the alliance portfolios of the firms cumulated from 2009 until 2013. The AMCs measures are based on the survey done over the course of the year 2014. Even though we collected the AMCs data in

2014 – and after we gathered the alliance portfolio data – we are confident that the manifestation of AMCs in the surveyed firms is applicable to the period of the alliance portfolios, since we, like (Cohen, 2007), assume that organizational routines are stable and rigid over time. Finally, the dependent variable firm innovation is based on a three-year window from 2014 to 2016. In doing so, we made sure that we control the fact that the innovation performance of a firm can also serve as a signal for the attractiveness of the firm as potential alliance partner which increases the chance to find and form new partnerships (e.g., Stuart, 1998; Caner et al., 2018; Stuart et al., 1999).

Control Variables. Number of prior patent applications. In accordance with previous research, we controlled for the number of prior patent applications per firm (Rost, 2011; Tzabbar et al., 2008). Prior patents represent a firm's overall knowledge stock (Tzabbar et al., 2008), and indicate its experience with the patent-filing process (Whittington et al., 2009). Thus, number of prior patents can have a positive impact on innovation. We computed this variable as the cumulative number of prior patent application of a firm to the year 2013. Using patent counts for the previous year instead of cumulative counts does not change our results.

Firm size. The size of a firm is commonly included as a control variable in research studies concerned with knowledge creation and innovation in networks (e.g., Gulati and Gargiulo, 1999). Firm size can be advantageous and disadvantageous for innovation creation: On the one hand, large organizations employ more skilled workers and possess more R&D as well as financial resources than do small firms. On the other hand, small firms are more flexible and creative than large ones, and can thus better adapt to a changing environment (Damanpour, 1992). We measured firm size by the number of employees (i.e., number of employees in the year 2013). Since most biotech firms in our sample are relatively young, they usually do not have a positive revenue stream. Measuring firm size in terms of the number of employees circumvents the problems arising when trying to use financial measures such as revenues or market share (Stuart et al., 2007). We used a natural log to normalize the distribution of the variable.

Firm age. In addition to firm size, the age of the firm can have an impact on its innovative outcome. Consistent with prior research studies, we used firm age as a control variable (e.g., Owen-Smith and Powell, 2004). Since older, established firms often encounter difficulties in keeping up with external technological advances, they tend to exploit existing technologies rather than exploring new opportunities (Sørensen and Stuart, 2000).

R&D intensity. We include the percentage of employees operating in R&D as a measure for R&D intensity as firms strongly focus on internal R&D may possess the technological skill set to generate innovation by themselves (Laursen and Salter, 2006).

Biotech type dummy. Regarding the type of biotech firm, we differentiated the firms in our sample based on their focused application of biotechnology. We used a dummy variable with 1 indicating that a biotechnology firm is mainly active in medical applications, and 0 if otherwise. Thus, we control for differences in firm specialization that may impact the propensity to innovate. In addition, in controlling for the type of firm specialization, we account for the fact that research and development in the biotechnology industry is driven by a different agenda and operates within a distinctive regulatory regime (Powell et al., 1996).

Number of prior alliances. To account for firms' prior alliance experience, we included a measure indicating the cumulative number of alliances of the respective firm prior to the observed patent application observation window. In doing so, we controlled for the total alliances in the observed alliance window. We thus controlled for the possibility that portfolio size rather than the diversity attributes explains our innovation measure (Wassmer, 2010). To check the robustness of our findings, we also computed an alternative measure of the number of prior alliances that only includes alliance until the observed five year alliance portfolio window, and tested the hypotheses. Both measures provided identical results.

Grant. To account for differences in firms' resource endowments, as well as potential reputational differences, we added the amount of *financial grants received from* the BMBF in the year 2013. We used a natural log to normalize the distribution of the variable.

Model Specification. Since the dependent variable *firm innovation performance* – measured by the number of patent applications – is a count variable, a count-model analysis represents an appropriate approach for testing our hypotheses (Hilbe, 2011). Researchers often use Poisson regression as the preferred approach to analyse count data (Ahuja, 2000). We follow such an approach and apply a Poisson regression. All calculations are based on STATA 13 SE using the *poisson* command. We standardized all independent and control variables to make the interpretation and graphical illustration of our models easier.

Since multiplicative interaction terms can cause multicollinearity, we tested for it using variance inflation factors (VIFs). As evident from Table II, the VIFs for all variables in our study were well below the often-cited critical threshold of 10 (Neter et al., 1996). Additionally, the condition numbers of all our models remained well below the widely recognized threshold of 30 (see Table III) that indicates substantial multicollinearity (Belsley et al., 2005, . ; Cohen et al., 2013). Thus, the examination of VIFs and condition indices alleviate multicollinearity concerns.

RESULTS

Table 2 provides the descriptive statistics and the correlation table.

Table 3 shows the results of our models. Model 1 gives parameter estimates only for the control variables. The other models add parameter estimates for the two-way as well as the three-way interactions. In Hypothesis 1 we proposed a positive

Table II. Correlations and Descriptive Statistics

	Variable	*Mean*	*Std. Dev.*	*VIF*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
1	**DV: Patent applications**	1.83	3.50	1.32										
2	Number of prior patent applications	3.37	7.49	1.43	.43*									
3	Firm size (ln)	2.36	1.06	1.16	.14	.19*								
4	Firm age	10.10	7.15	1.35	–.01	.27*	.27*							
5	Biotech-type dummy (red=1)	0.77	0.42	1.09	.02	–.08	.05	.06						
6	Number of prior alliances	4.39	6.28	1.26	.15	.16	.14	.11	.08					
7	Grant (ln)	1.74	4.26	1.13	.17	.14	.22*	.06	.12	.06				
8	R&D intensity	52.88	30.50	1.19	–.01	–.01	–.08	–.28*	–.09	.16	–.02			
9	Portfolio coordination capability	3.77	1.06	1.42	–.02	.06	–.02	.13	–.11	–.15	.09	.09		
10	Proactive partner selection capability	3.63	0.84	1.36	.07	.09	.07	.02	–.09	.15	.14	.11	.45*	
11	Alliance portfolio diversity	0.43	0.31	1.15	.02	–.14	–.06	–.06	.18*	.17*	–.11	–.07	.02	.02
	Mean VIF			1.26										

* p<.05

Table III. Results of Poisson Regression for Innovation Performance

Variable	*Model 1*	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*	*Model 7*
Number of prior patent applications	0.32***	0.32***	0.33***	0.33***	0.34***	0.33***	0.35***
	(0.03)	(0.03)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
Firm size (ln)	0.21**	0.20**	0.21**	0.20**	0.20**	0.20**	0.18*
	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)
Firm age (in years)	–0.31***	–0.30***	–0.29***	–0.31***	–0.30***	–0.31***	–0.24**
	(0.08)	(0.09)	(0.09)	(0.09)	(0.09)	(0.09)	(0.09)
Biotech-type dummy (red=1)	0.06	0.07	0.05	0.06	0.04	0.06	0.08
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.08)
Number of prior alliances	0.14*	0.13*	0.10	0.11	0.06	0.08	–0.01
	(0.06)	(0.06)	(0.07)	(0.07)	(0.07)	(0.07)	(0.09)
Grant (ln)	0.10†	0.09	0.11†	0.14*	0.12*	0.14*	0.10
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.07)
R&D intensity	–0.08	–0.08	–0.06	–0.07	–0.04	–0.05	0.01
	(0.07)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)
Portfolio coordination capability		–0.04	–0.06	–0.02	–0.12	–0.06	0.15
		(0.08)	(0.08)	(0.08)	(0.08)	(0.09)	(0.11)
Proactive partner selection capability		0.10	0.01	0.01	0.06	0.02	0.17†
		(0.08)	(0.08)	(0.08)	(0.08)	(0.09)	(0.10)
Alliance portfolio diversity (APD)			0.14†	0.18*	0.16†	0.17*	0.22*
			(0.08)	(0.08)	(0.08)	(0.08)	(0.09)
APD x Portfolio coordination				0.23***		0.15†	0.36***
				(0.06)		(0.08)	(0.08)
APD x Proactive partner selection					0.24***	0.15†	0.38***
					(0.07)	(0.08)	(0.10)

Table III. *Continued.*

Variable	*Model 1*	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*	*Model 7*
Portfolio coordination x Proactive partner selection							–0.81***
							(0.10)
APD x Portfolio coordination x Proactive partner selection							–0.56***
							(0.09)
Constant	0.44***	0.44***	0.43***	0.39***	0.39***	0.38***	0.37***
	(0.07)	(0.07)	(0.07)	(0.08)	(0.08)	(0.08)	(0.09)
Chi^2	115.00	116.49	119.64	132.43	132.40	136.18	247.50
N	132	132	132	132	132	132	132
Likelihood-ratio test		116.49	119.64	132.43	132.40	136.18	247.50
AIC	650.51	653.02	651.87	641.08	641.11	639.33	532.01

† $p < .1$
* $p < .05$
** $p < .01$
*** $p < .001$

interaction between portfolio coordination capability and APD in influencing a firm's innovation performance. Model 4 in Table 3 shows that the coefficient for the interaction between APD and portfolio coordination capability is positive and statistically significant ($b = .228$, $p < .001$), providing strong support for Hypothesis 1. In Hypothesis 2 we proposed a positive interaction between proactive partner selection capability and APD on innovation outcome. Model 5 in Table 3 shows that the coefficient for the interaction between APD and proactive partner selection capability is positive and highly significant ($b = .241$, $p < .001$). Thus, our data support Hypothesis 2. Finally, in Hypothesis 3 we assumed a three-way interaction between APD, portfolio coordination capability, and proactive partner selection capability. Specifically, we assumed that the level of firm innovation performance is highest when APD is high, portfolio coordination capability is high, and proactive partner selection capability is low; or when APD is high, portfolio coordination capability is low, and proactive partner selection capability is high. Model 7[4] in Table 3 shows that the coefficient for this three-way interaction is negative and statistically significant ($b -.558$, $p < .001$). Thus, we find strong support for Hypothesis 3.

In order to assess the two-way as well as the three-way interactions accurately, we rely on graphical illustrations for all models with significant interaction terms (Aguinis et al., 2011; Greene, 2010). Figures 2 and 3 below represent graphical illustrations of the two-way interaction effects based on Models 4 and 5, including APD as predictor, and portfolio coordination capability and proactive partner selection capability as respective moderators. Figure 4 visualizes the supported three-way interaction effect based on Model 7 and shows that firms endowed with a high portfolio coordination capability and a low proactive partner selection capability; or a low portfolio coordination capability and a high proactive partner selection capability are more successful in exploiting APD than are firms that simultaneously possess both capabilities at high levels.

In line with Dawson and Richter, 2006 we conducted a slope difference test for the results of the three-way interaction effect in order to analyse whether the differences between the respective pairs of slopes are significant. We centred the respective moderating variables one standard deviation above and/or below the mean and re-ran the regression. The interaction between APD and portfolio coordination capability (one SD above the mean) and proactive partner selection capability (one SD below the mean) (Line 2 in Figure 4) is statistically different from the slope of line 1 (both moderators are 1 SD above mean) ($p < .001$). The interaction between APD and portfolio coordination capability (one SD below the mean) and proactive partner selection capability (one SD above the mean) (Line 3 in Figure 4) is also statistically different from the slope of line 1 ($p < .001$). In addition, the simple slope of line 1 is positive and statistically significant ($p < .001$).

Additional Analyses

We tested our results for several possible problems. First, in contrast to portfolio coordination capability, proactive partner selection capability is a pre-formation capability and therefore we consider the possibility of its more direct effect in building diverse alliance portfolios rather than its moderating effect on the relationship between APD and innovation outcome. Thus, in addition to our theoretical argumentation in the theory section, we further addressed this possibility by using a statistical approach that tested the main effect of proactive partner selection capability on APD. Our results show no statistically significant effect $p = .979$). Furthermore, the correlation between the two variables is low ($r = .023$) and not statistically significant. Consequently, there are reasons to believe that proactive partner selection capability – as hypothesized and statistically supported – indeed acts as a moderator variable between APD and innovation.

Second, we build on recent team diversity research and use an alternative bias-corrected diversity measure that corrects for variations in group size (Biemann and Kearney, 2010):

$$H_N = 1 - \sum \frac{N_i \left(N_i - 1\right)}{N\left(N - 1\right)},$$

where N_i is the number of alliance partners in the ithcategory (for example, a pharmaceutical firm or university) and N is the size of the alliance portfolio. The results from this alternative measure are consistent with our other results.

Third, a possible problem with using a Poisson regression is overdispersion. We found evidence of overdispersion in our data. In order to deal with overdispersion, the negative binominal regression has been proposed as an alternative (Hilbe,

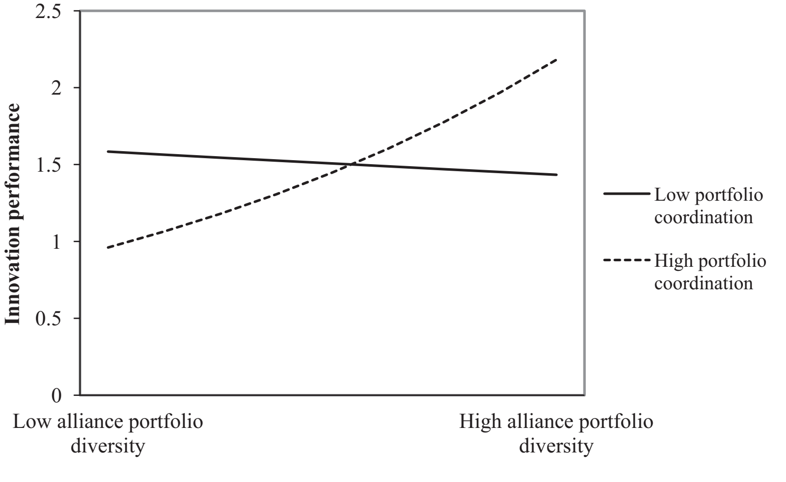

Figure 2. Graphical illustration of the two-way interaction effect between alliance portfolio diversity and portfolio coordination capability on innovation performance

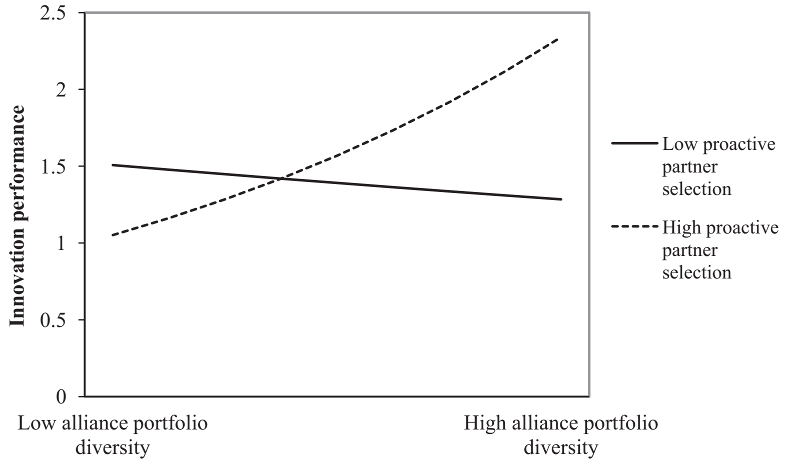

Figure 3. Graphical illustration of the two-way interaction effect between alliance portfolio diversity and proactive partner selection capability on innovation performance

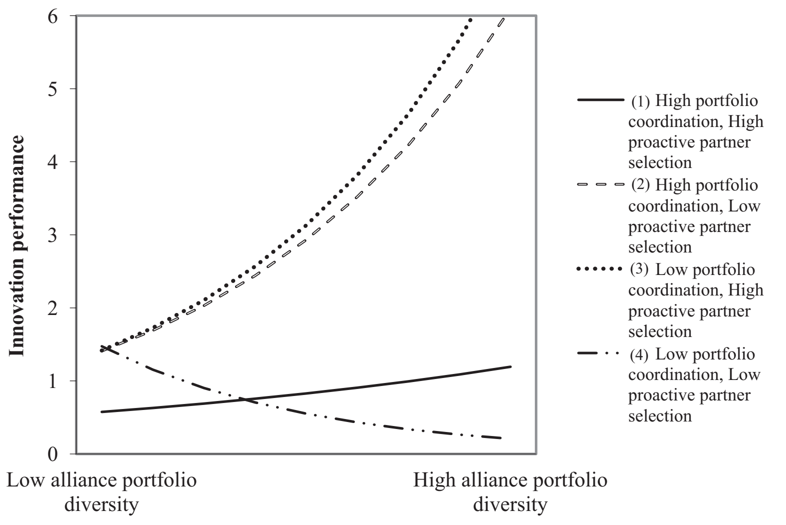

Figure 4. Graphical illustration of the three-way interaction effect between alliance portfolio diversity, portfolio coordination capability and partner selection capability on innovation performance

2011). Yet, it is important to know the source of the overdispersion. In our case it is driven by a larger number of zeros (i.e., firms without patents). In such a situation, a two-part modelling approach whereby the first part is a binary outcome model and the second part is a truncated count model might be more appropriate (Cameron and Trivedi 1998). In particular, recent innovation research suggests that innovations are generated by two separate processes and that these processes should be modeled independently (e.g., Berger et al., 2017). The first process determines what is necessary in order for a firm to innovate, and the second process analyses the factors that allow an already innovating firm to continue innovating (Berger, et al., 2017). In line with these arguments, we ran an additional model that takes into account a case in which the first innovation is more difficult to achieve than succeeding innovations are, and that also considers that different factors might impact both processes. We find that the factors that impact innovation in the first stage (i.e., having a patent or not) are indeed different from the factors that drive subsequent innovation outcome. However, the results in this two-stage approach (i.e., impact on further innovation outcome) are consistent with our findings, which further underscore the robustness of our results.

Forth, in an analysis comparing the results of the negative binomial models, the Poisson and the zero-inflated Poisson models, we had consistent results. We therefore report and interpret our results based on the Poisson regression because this is frequently used and the econometric standard for measuring count data (Gardner et al., 1995).

Fifth, we observed that the mean levels of both of our capabilities are relatively high (see Table 2). Thus, we checked to see whether we had a sufficient number of observations and variations. Out of the 132 firms in our sample, 66 firms (50 per cent) have a score above the mean in the proactive partner selection variable and 72 firms (55 per cent) have a score above the mean in the portfolio coordination variable. The Pearson Chi^2-test indicates a significant difference between the two capability groups (above and below the mean) (Chi^2 [1] = 17.6; Pr = 0.000). Thus, we are confident that we have a sufficient number of observations and variations across the two capability variables.

Next, as recent research point to the possibility of a curvilinear relationship between APD and innovation outcome (e.g., Duysters and Lokshin, 2011), we also consider this possibility and tested for it. We did not find a significant curvilinear relationship.

Finally, we also address potential endogeneity concerns that might bias our results and that are common in alliance and network research: Reverse causality and omitted variable bias (Martinez et al., 2017a).

A frequent problem in cross-sectional data is reverse causation. For example, in our case, it might be possible that as soon as firms have more patents, they are more attractive as alliance partners. Prior research suggests that in technology-intensive industries, such as biotechnology, a new patent is not only a revenue-generating invention but also a signal of the firm's underlying technological capabilities, important for potential future alliance partners (Caner et al., 2018; Stuart et al., 1999). To address this issues, we used the information from our secondary longitudinal dataset on the complete population of German biotech firms from 1996 until 2012 (see Oehme and Bort (2015) for details). In particular, we updated the dataset from Oehme and Bort (2015) until 2015 and regressed the APD on subsequent innovation relationship while controlling for age, size, biotech-type, received grants and the number of prior patent applications. Our results show a significant positive impact of APD on innovation. These results underscore that APD has a positive impact on innovation. To account for a reverse association between prior innovation and APD, we regressed firms' prior innovation on APD. Our results did not support a reverse association, as the number of prior patent applications did not significantly predict future APD. To further assess whether innovation indirectly influences APD, we follow recent innovation and diversity research (e.g., Bogers et al., 2018) and included the interaction between prior innovation (i.e., patent applications from 2009–13) and prior APD on future APD. The idea behind this interaction is that innovation may not directly impact APD but may strengthen the link between prior (2009–13) and future levels (2014–16) of APD. We find that this interaction is not significant. Thus, we assume that innovation does not indirectly influences APD.

We also addressed potential omitted variable bias concerns. For example, there might be chance that a variable is omitted which affects innovation performance and which is also correlated with APD. One approach to address potential omitted variable bias is to apply the Heckman two-step procedure (Heckman, 1979). This procedure has already been used to account for omitted variable bias in the context of alliance partner diversity and innovation performance (e.g., Sampson, 2007). In general, it is challenging to find good instruments for a two-stage instrumental variables approach. It is particularly challenging, from a theoretical as well as econometrically point of view, as soon as the model implies instrumenting interaction terms (Yang et al., 2015). We selected the number of prior APD (2009–13) as well as the diversity of organizational types in the cluster in which a firm is located (according to the two digits) as instrument variables. A common test to analyse the strength of the instruments is the first-stage F-statistics from Stock and colleagues (e.g., Stock and Yogo, 2002; Bascle, 2008, p. 296). With a first-stage F-statistic of 16.92 we are above the recommended value of approximately 10 (e.g., Stock and Yogo, 2002). Thus, we are confident that the two variables are relevant instruments for predicting APD. The Sargan statistic has a p-value of 0.918. Thus, the exogeneity of the instrument can also be confirmed. We further follow Hilbes' (2011) two-stage approach to account for endogeneity in count models. The first-stage equation includes the two instrument variables and the controls and regressed it on APD. We find that in particular prior APD is a significant positive predictor of subsequent APD. In the second stage we run a poisson model with the predictor and the two instruments. As recommended by Hilbe (2011, p. 419) we based the standard errors on a robust sandwich variance estimator. We find that the residual term is significant but negatively related to APD. Thus, the underlying latent factor that impacts prior APD has a negative relationship on innovation.

DISCUSSION AND CONCLUSION

Most literature examining innovation effects of inter-organizational alliance portfolios has so far focused either on an external structural perspective, considering portfolio characteristics (e.g., alliance portfolio diversity), or on a firm-internal management perspective, including capabilities of the focal firm (e.g., alliance management capabilities). Our study expands on initial research that brings together these two perspectives (e.g., Duysters et al., 2012; Faems et al., 2012; Sarkar et al., 2009). We examine whether the innovation potential entailed in the structural aspects of a diverse alliance portfolio can be leveraged by two different capabilities of a focal firm in managing these alliances: portfolio coordination capability and proactive partner selection capability. Going one step further, we particularly investigate whether the two capabilities reinforce or impede each other by analysing their joint value as a capability bundle.

We test the respective two-way interaction effects of these AMCs, as well as the three-way interaction combining the two AMCs as a capability bundle with APD, on the innovation performance of German biotechnology firms. Our results provide strong support for our hypotheses. Portfolio coordination capability and proactive partner selection capability separately reinforce the innovation outcome resulting from APD, but the analysis of their joint interplay reveals a substitutive rather than a complementary effect of both AMCs. In sum, our findings illustrate that firms endowed with either high capability levels of portfolio coordination or proactive partner selection are in a superior position to benefit from the simultaneous access to heterogeneous and non-redundant resources, capabilities, and knowledge of their diverse alliance partners, all of which they can combine to stimulate innovation. However, simultaneously employing both AMCs increases the outlays required for the underlying organizational routines to such a degree that innovation performance suffers.

Our findings contribute to current research in the following ways. First, the results extend alliance portfolio literature by introducing two equifinal approaches firms can take to manage alliance portfolio diversity. These approaches rely on the distinct AMCs of portfolio coordination and proactive partner selection respectively. In doing so, we elucidate under which conditions the benefits of alliance portfolios can be captured by the focal firm and transferred into performance outcome. A recent meta-analysis by Lee et al. (2017) reveals that previous research has shown inconclusive results regarding the impact of APD on innovation outcome. Empirical studies have therefore started to examine contingencies that may explain why some firms can benefit from APD more than others do (e.g., Cui and O'Connor, 2012; Phelps, 2010; Wuyts and Dutta, 2014). As literature highlights potential managerial challenges of APD that may dampen organizational performance (Goerzen and Beamish, 2005; Sampson, 2007), some of these studies focus on the importance of a focal firm's AMCs as potential contingency factors (e.g. Duysters et al., 2012; Faems et al., 2012; Sarkar et al., 2009). We extend this line of research by revealing the strong relevance of two AMCs and their specific interplay as contingency factors necessary to successfully derive innovation from APD – namely, portfolio coordination capability and proactive partner selection capability. Findings show that focal firms possessing a high portfolio coordination capability maintain organizational routines directed at identifying interdependencies, synchronizing activities, and handling conflicts (Hoffmann, 2005; Parise and Casher, 2003). In turn, this allows them to manage the complexities of APD and thus realize the benefits entailed in highly diverse portfolios. Similarly, proactive firms – because they are engaged in discovering and acting on new alliance opportunities ahead of competitors (Kauppila, 2015; Sarkar et al., 2001) – can respond to potential constraints of diverse portfolios by ensuring compatibility between partners, thus avoiding misunderstandings and conflicts. Furthermore, regarding the contingency of the capability bundle of both capabilities, firms endowed with either high portfolio coordination capability or high proactive partner selection capability are more successful in terms of innovation than are firms possessing high levels of both AMCs. This result indicates that firms can take two equifinal approaches (Fiss, 2011) to managing the complexities and leveraging the benefits of diverse alliance portfolios: On the one hand, proactive firms set up an alliance portfolio with high compatibility between alliance partners but not invest effort in coordinating the diverse portfolio, thus acting as 'portfolio configurators'. On the other hand, another group of firms focus on coordination between diverse partners (e.g., handling conflicts and managing differing interests) but neglect the selection of partners that fit together, thus acting as 'portfolio coordinators'. Altogether, we show that portfolio coordination and proactive partner selection are relevant contingency factors in order to manage the complexity of diverse portfolios, but that these two approaches act as substitutes rather than as complements. Thus, we help to further clarify the portfolio diversity–performance link and reveal that under conditions of either high portfolio coordination capability or high proactive partner selection capability, firms are well equipped to benefit from their alliance portfolios. These implications underscore the prolificacy of bringing in firm internal capabilities as rooted in the logic of the resource-based view in the study of firm external alliances to better understand the distinction between the potential and realized benefits embedded in firms' alliance networks.

Second, our results extend the literature on firm capabilities by showing the impeding rather than reinforcing combination of portfolio coordination capability and proactive partner selection capability for achieving innovation outcome. Past research argues that significant firm-specific investments are necessary in order to establish and develop firm capabilities (Fainshmidt et al., 2016; Helfat et al., 2009; Zollo and Winter, 2002) and therefore spending resources to develop a full range of firm capabilities without the need to actually use them is not justified, because these capabilities do not generate sufficient value for their investment (Ethiraj et al., 2005; Helfat and Winter, 2011; Winter, 2003). We further advance this research on potential outlay, and thereby the possible value, of organizational routines and indicate that various firm capabilities may substitute for one another and solely and discretely evoke desired outcomes. Our results show that high levels of portfolio coordination capability and proactive partner selection capability separately (and almost equally) foster innovation performance from diverse alliance portfolios, but that firms endowed with the capability bundle of both at high levels suffer considerably compared to firms relying on only one capability. These findings suggest that the two respective AMCs represent equivalent and substituting approaches for firms to manage the complexities and realize the value of diverse alliance portfolios. Consequently, the value of portfolio coordination capability is comparatively low when proactive partner selection is high and vice versa. Our study further illustrates that establishing and maintaining AMCs does not come without costs (Heimeriks and Duysters, 2007; Kale et al., 2002; Schilke, 2014; Wang and Rajagopalan, 2015) and that in order to successfully derive innovation benefits from their diverse set of alliance partners, firms face a trade-off between proactive partner selection capability and portfolio coordination capability. To avoid being overinvested and inefficient, firms are confronted with the strategic 'nature versus nurture'[5] decision regarding their alliance portfolio: They can either invest in configuring the nature of their portfolio by picking the most compatible partners or they can nurture active relationships among partners by employing alliance-management routines for portfolio coordination on a frequent basis. Overall, we show that employing firm capabilities may indeed cost firms, and thus firm capabilities that separately increase organizational performance may cause negative performance implications as a capability bundle. This is because entertaining a bundle of both capabilities leads to inefficiencies and implies unnecessary investment of resources that firms could instead use for value creation.

Linked with the above, we need to acknowledge that our data is biased towards small high-technology firms. These firms generally face great innovation pressure and resource scarcity at the same time which forces them to ally with various alliance partners (Oliver, 2001; Rothaermel and Deeds, 2004). Paradoxically, due to their limited resource base the inefficient management of their alliance portfolio might immediately endanger the desired innovation performance outcomes. In contrast, larger firms have slack organizational resources (Damanpour, 1992). In addition, the objectives larger firms pursue with their alliance portfolios are much broader than those of small high-technology firms (Hoffmann, 2005; Jenssen and Nybakk, 2009). They thus have greater freedom to exploit different emerging opportunities. As a consequence, the need to focus on either portfolio coordination or proactive partner selection might not be as pressing for larger firms as it is for smaller ones. Still we assume that also larger firms derive performance benefits from the efficient management of their alliance portfolios.

This points to the limitations of this study that invite future research: First, while we assume that our findings apply to larger firms we cannot substantiate this assumption. This study focuses on firms in the German biotechnology industry and our results are not generalizable beyond this specific context, as different empirical settings vary in their underlying characteristics. While we expect that our results apply to other small high-technology firms, future research should examine to what extent our results hold true for larger firms beyond these settings. Second, for the AMCs as our moderator variables we used the key informant method, which relies exclusively on a single respondent rather than validating data via multiple informants. While similar to other research on inter-organizational alliances and organizational capabilities (e.g., Schreiner et al., 2009; Yli-Renko et al., 2001), we consider the key informant as adequate to give valid and reliable information about the AMCs. We leave it to future research to cross validate this measurement by also considering archival data documenting alliance management routines, as well as by asking other informants inside the focal firm and the partner firms. Third, as in most empirical studies in social sciences, we cannot completely rule out the problem of endogeneity. We used several approaches to address potential endogeneity issues, but we do not want to underestimate the complex relationship between APD and innovation. Thus, we encourage further research to investigate this relationship in greater detail; for example, by using experimental designs or longitudinal settings with larger sample sizes. Forth, we concentrate on portfolio coordination capability and proactive partner selection capability separately as well as jointly in the context of diverse alliance portfolios. By doing so, we respond to the specific management challenges a diverse set of alliance partners poses for focal firms seeking to realize potential benefits. Nevertheless, investigating the interplay of other AMCs (see e.g., Schilke and Goerzen, 2010) in the context of various alliance settings could be a fruitful research direction. Future studies could identify the performance effects of other capability bundles and thereby contribute to the debate on whether capabilities operate in a substitutive, additive or synergistic manner (Ebers and Maurer, 2014; Song et al., 2005). Furthermore, future research might explore whether firms are free in their strategic choice for a specific capability bundle or whether this choice is limited by path dependency. Addressing these open questions will hopefully further advance our understanding of the interplay between different AMCs, their origins and performance implications.

NOTES

[1] The bionity.com internet news platform is designed to inform about news in the fields of biotechnology, life sciences and medicine with regard to products, company profiles and technical information.

[2] Given our time frame, we used only a three-year window rather than a four-year window.

[3] Schilke and Goerzen (2010) use the term *alliance proactiveness* instead of *proactive partner selection*.

[4] According to Dawson (2014), it is necessary to include the main effects of the independent variable (i.e., APD) and the moderators (i.e., the two capabilities) as well as the two-way interaction terms between each pair of variables and the three-way interaction term to interpret the results meaningfully.

[5] We would like to thank an anonymous reviewer for pointing out this appropriate metaphor.

REFERENCES

Aguinis, H., Gottfredson, R. K. and Wright, T. A. (2011). 'Best-practice recommendations for estimating interaction effects using meta-analysis'. *Journal of Organizational Behavior,* **32**, 1033–43.

Ahuja, G. (2000). 'Collaboration networks, structural holes, and innovation: A longitudinal study'. *Administrative Science Quarterly,* **45**, 425–55.

Ahuja, G. (2000). 'The duality of collaboration: Inducements and opportunities in the formation of interfirm linkages'. *Strategic Management Journal,* **21**, 317–43.

Ahuja, G., Polidoro, F. and Mitchell, W. (2009). 'Structural homophily or social asymmetry? The formation of alliances by poorly embedded firms'. *Strategic Management Journal,* **30**, 941–58.

Armstrong, J. S. and Overton, T. S. (1977). 'Estimating nonresponse bias in mail surveys'. *Journal of Marketing Research,* **14**, 396–402.

Bascle, G. (2008). 'Controlling for endogeneity with instrumental variables in strategic management research'. *Strategic Organization,* **6**, 285–327.

Baum, J. A. C., Calabrese, T. and Silverman, B. S. (2000). 'Don't go it alone: Alliance network composition and startups' performance in Canadian biotechnology'. *Strategic Management Journal,* **21**, 267–94.

Beckman, C. M. and Haunschild, P. R. (2002). 'Network learning: The effects of partners' heterogeneity of experience on corporate acquisitions'. *Administrative Science Quarterly,* **47**, 92–124.

Belsley, D. A., Kuh, E. and Welsch, R. E. (2005). *Regression Diagnostics: Identifying Influential Data and Sources of Collinearity.* New York: John Wiley & Sons.

Berger, S., Stocker, H. and Zeileis, A. (2017). 'Innovation and institutional ownership revisited: An empirical investigation with count data models'. *Empirical Economics*, **52**, 1675–88.

Biemann, T. and Kearney, E. (2010). 'Size does matter: How varying group sizes in a sample affect the most common measures of group diversity'. *Organizational Research Methods*, **13**, 582–99.

Blau, P. M. (1977). *Inequality and Heterogeneity: A Primitive Theory of Social Structure.* New York: Free Press.

Bogers, M., Foss, N. J. and Lyngsie, J. (2018). 'The "human side" of open innovation: The role of employee diversity in firm-level openness'. *Research Policy,* **47**, 218–31.

Borgatti, S. P. and Foster, P. C. (2003). 'The network paradigm in organizational research: A review and typology'. *Journal of Management,* **29**, 991–1013.

Cameron, C. and Trivedi, P. (1998). *Models for count data.* Cambridge: Cambridge University Press.

Caner, T., Bruyaka, O. and Prescott, J. E. (2018). 'Flow signals: Evidence from patent and alliance portfolios in the US biopharmaceutical industry'. *Journal of Management Studies,* **55**, 232–64.

Casper, S. (2000). 'Institutional adaptiveness, technology policy, and the diffusion of new business models: The case of German biotechnology'. *Organization Studies,* **21**, 887–914.

Cohen, J., Cohen, P., West, S. G. and Aiken, L. S. (2013). *Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences.* New York: Routledge.

Cohen, M. D. (2007). 'Reading dewey: Reflections on the study of routine'. *Organization Studies,* **28**, 773–86.

Coleman, J. S. (1988). 'Social capital in the creation of human capital'. *American Journal of Sociology,* **94**, S95–S120.

Comanor, W. S. and Scherer, F. M. (1969). 'Patent statistics as a measure of technical change'. *The Journal of Political Economy,* **77**, 392–98.

Cui, A. and O'Connor, G. (2012). 'Alliance portfolio resource diversity and firm innovation'. *Journal of Marketing,* **76**, 24–43.

Damanpour, F. (1992). 'Organizational size and innovation'. *Organization Studies,* **13**, 375–402.

Dawson, J. F. and Richter, A. W. (2006). 'Probing three-way interactions in moderated multiple regression: Development and application of a slope difference test'. *Journal of Applied Psychology,* **91**, 917–26.

Dawson, J. F. (2014). 'Moderation in management research: What, why, when, and how'. *Journal of Business and Psychology,* **29**, 1–19.

De Dreu, C. K. W. (2006). 'When too little or too much hurts: Evidence for a curvilinear relationship between task conflict and innovation in teams'. *Journal of Management,* **32**, 83–107.

De Leeuw, T., Lokshin, B. and Duysters, G. (2014). 'Returns to alliance portfolio diversity: The relative effects of partner diversity on firm's innovative performance and productivity'. *Journal of Business Research,* **67**, 1839–49.

Dekker, H. C. (2008). 'Partner selection and governance design in interfirm relationships'. *Accounting, Organizations and Society,* **33**, 915–41.

Demirkan, I. and Demirkan, S. (2012). 'Network characteristics and patenting in biotechnology, 1990–2006'. *Journal of Management,* **38**, 1892–927.

Duysters, G., Heimeriks, K. H., Lokshin, B., Meijer, E. and Sabidussi, A. (2012). 'Do firms learn to manage alliance portfolio diversity? The diversity-performance relationship and the moderating effects of experience and capability'. *European Management Review,* **9**, 139–52.

Duysters, G. and Lokshin, B. (2011). 'Determinants of alliance portfolio complexity and its effect on innovative performance of companies'. *Journal of Product Innovation Management,* **28**, 570–85.

Ebers, M. and Maurer, I. (2014). 'Connections count: How relational embeddedness and relational empowerment foster absorptive capacity'. *Research Policy,* **43**, 318–32.

Eisingerich, A. B., Rubera, G. and Seifert, M. (2009). 'Managing service innovation and interorganizational relationships for firm performance to commit or diversify?'. *Journal of Service Research,* **11**, 344–56.

Ernst and Young. (2013). *Rethinking: German Biotechnology Report 2013*. Stuttgart: Ernst and Young.

Ethiraj, S. K., Kale, P., Krishnan, M. S. and Singh, J. V. (2005). 'Where do capabilities come from and how do they matter? A study in the software services industry'. *Strategic Management Journal,* **26**, 25–45.

Faems, D., Janssens, M. and Neyens, I. (2012). 'Alliance portfolios and innovation performance connecting structural and managerial perspectives'. *Group & Organization Management,* **37**, 241–68.

Faems, D., van Looy, B. and Debackere, K. (2005). 'Interorganizational collaboration and innovation: Toward a portfolio approach'. *Journal of Product Innovation Management,* **22**, 238–50.

Faems, D., de Visser, M., Andries, P. and van Looy, B. (2010). 'Technology alliance portfolios and financial performance: Value-enhancing and cost-increasing effects of open innovation'. *Journal of Product Innovation Management,* **27**, 785–96.

Fainshmidt, S., Pezeshkan, A., Lance Frazier, M., Nair, A. and Markowski, E. (2016). 'Dynamic capabilities and organizational performance: A meta-analytic evaluation and extension'. *Journal of Management Studies,* **53**, 1348–80.

Fiss, P. C. (2011). 'Building better causal theories: A fuzzy set approach to typologies in organization research'. *Academy of Management Journal,* **54**, 393–420.

Fleming, L. (2001). 'Recombinant uncertainty in technological search'. *Management Science,* **47**, 117–32.

Ford, J. K., MacCallum, R. C. and Tait, M. (1986). 'The application of exploratory factor analysis in applied psychology: A critical review and analysis'. *Personnel Psychology,* **39**, 291–314.

Fornell, C. and Larcker, D. F. (1981). 'Evaluating structural equation models with unobservable variables and measurement error'. *Journal of Marketing Research,* **18**, 39–50.

Gardner, W., Mulvey, E. P. and Shaw, E. C. (1995). 'Regression analyses of counts and rates: Poisson, overdispersed Poisson, and negative binomial models'. *Psychological Bulletin,* **118**, 392–404.

Gassmann, O., Reepmeyer, G. and von Zedtwitz, M. (2008). *Leading Pharmaceutical Innovation: Trends and Drivers for Growth in the Pharmaceutical Industry*. Heidelberg: Springer Science & Business Media.

George, G., Kotha, R. and Zheng, Y. (2008). 'Entry into insular domains: A longitudinal study of knowledge structuration and innovation in biotechnology firms'. *Journal of Management Studies,* **45**, 1448–74.

George, G., Zahra, S. A., Wheatley, K. K. and Khan, R. (2001). 'The effects of alliance portfolio characteristics and absorptive capacity on performance: A study of biotechnology firms'. *The Journal of High Technology Management Research,* **12**, 205–26.

Goerzen, A. (2005). 'Managing alliance networks: Emerging practices of multinational corporations'. *The Academy of Management Executive,* **19**, 94–107.

Goerzen, A. and Beamish, P. W. (2005). 'The effect of alliance network diversity on multinational enterprise performance'. *Strategic Management Journal,* **26**, 333–54.

Grant, R. M. (1996). 'Toward a knowledge-based theory of the firm'. *Strategic Management Journal,* **17**, 109–22.

Greene, W. (2010). 'Testing hypotheses about interaction terms in nonlinear models'. *Economics Letters,* **107**, 291–96.

Griliches, Z. (1998). 'Introduction to R&D and productivity: the econometric evidence'. In Griliches, Z. (Ed.), *R&D and Productivity: The Econometric Evidence*. Chicago, IL: University of Chicago Press, 1–14.

Gulati, R. and Gargiulo, M. (1999). 'Where do interorganizational networks come from?'. *American Journal of Sociology,* **104**, 1439–93.

Hagedoorn, J., Lokshin, B. and Zobel, A. K. (2017). 'Partner type diversity in alliance portfolios: Multiple dimensions, boundary conditions and firm innovation performance'. *Journal of Management Studies,* **55**, 809–36.

Heckman, J. J. (1979). 'Sample selection bias as a specification error'. *Econometrica,* **47**, 153–61.

Heimeriks, K. H. and Duysters, G. (2007). 'Alliance capability as a mediator between experience and alliance performance: An empirical investigation into the alliance capability development process'. *Journal of Management Studies,* **44**, 25–49.

Heimeriks, K. H., Klijn, E. and Reuer, J. J. (2009). 'Building capabilities for alliance portfolios'. *Long Range Planning,* **42**, 96–114.

Helfat, C. E., Finkelstein, S., Mitchell, W., Peteraf, M., Singh, H., Teece, D. and Winter, S. G. (2009). *Dynamic Capabilities: Understanding Strategic Change in Organizations*. New York: John Wiley & Sons.

Helfat, C. E. and Winter, S. G. (2011). 'Untangling dynamic and operational capabilities: Strategy for the (N) ever-changing world'. *Strategic Management Journal,* **32**, 1243–50.

Hilbe, J. M. (2011). *Negative Binomial Regression*. Cambridge: Cambridge University Press.

Hoffmann, W. H. (2005). 'How to manage a portfolio of alliances'. *Long Range Planning,* **38**, 121–43.

Hoffmann, W. H. (2007). 'Strategies for managing a portfolio of alliances'. *Strategic Management Journal,* **28**, 827–56.

Ireland, R. D., Hitt, M. A. and Vaidyanath, D. (2002). 'Alliance management as a source of competitive advantage'. *Journal of Management,* **28**, 413–46.

Jenssen, J. I. and Nybakk, E. (2009). 'Inter-organizational innovation promoters in small, knowledge-intensive firms'. *International Journal of Innovation Management,* **13**, 441–66.

Jiang, R. J., Tao, Q. T. and Santoro, M. D. (2010). 'Alliance portfolio diversity and firm performance'. *Strategic Management Journal,* **31**, 1136–44.

Kaiser, R. and Prange, H. (2004). 'The reconfiguration of national innovation systems—the example of German biotechnology'. *Research Policy,* **33**, 395–408.

Kale, P., Dyer, J. H. and Singh, H. (2002). 'Alliance capability, stock market response, and long-term alliance success: the role of the alliance function'. *Strategic Management Journal,* **23**, 747–67.

Kale, P. and Singh, H. (2007). 'Building firm capabilities through learning: The role of the alliance learning process in alliance capability and firm-level alliance success'. *Strategic Management Journal* **28**, 981–1000.

Kale, P. and Singh, H. (2009). 'Managing strategic alliances: What do we know now, and where do we go from here'. *Academy of Management Perspectives,* **23**, 45–62.

Kale, P., Singh, H. and Perlmutter, H. (2000). 'Learning and protection of proprietary assets in strategic alliances: Building relational capital'. *Strategic Management Journal,* **21**, 217–37.

Kandemir, D., Yaprak, A. and Cavusgil, S. T. (2006). 'Alliance orientation: Conceptualization, measurement, and impact on market performance'. *Journal of the Academy of Marketing Science,* **34**, 324–40.

Kauppila, O.-P. (2015). 'Alliance management capability and firm performance: Using resource-based theory to look inside the process black box'. *Long Range Planning,* **48**, 151–67.

Lahiri, N. and Narayanan, S. (2013). 'Vertical integration, innovation, and alliance portfolio size: Implications for firm performance'. *Strategic Management Journal,* **34**, 1042–64.

Lane, P. J. and Lubatkin, M. (1998). 'Relative absorptive capacity and interorganizational learning'. *Strategic Management Journal,* **19**, 461–77.

Laursen, K. and Salter, A. (2006). 'Open for innovation: The role of openness in explaining innovation performance among UK manufacturing firms'. *Strategic Management Journal,* **27**, 131–50.

Lavie, D. (2007). 'Alliance portfolios and firm performance: A study of value creation and appropriation in the US software industry'. *Strategic Management Journal,* **28**, 1187–212.

Lavie, D., Haunschild, P. R. and Khanna, P. (2012). 'Organizational differences, relational mechanisms, and alliance performance'. *Strategic Management Journal,* **33**, 1453–79.

Lee, D., Kirkpatrick-Husk, K. and Madhavan, R. (2017). 'Diversity in alliance portfolios and performance outcomes: A meta-analysis'. *Journal of Management,* **43**, 1472–97.

Leischnig, A., Geigenmueller, A. and Lohmann, S. (2014). 'On the role of alliance management capability, organizational compatibility, and interaction quality in interorganizational technology transfer'. *Journal of Business Research,* **67**, 1049–57.

Lioukas, C. S., Reuer, J. J. and Zollo, M. (2016). 'Effects of information technology capabilities on strategic alliances: Implications for the resource-based view'. *Journal of Management Studies,* **53**, 161–83.

Lucena, A. and Roper, S. (2016). 'Absorptive capacity and ambidexterity in R&D: Linking technology alliance diversity and firm innovation'. *European Management Review,* **13**, 159–78.

Marhold, K., Jinhwan, K. M. and Kang, J. (2017). 'The effects of alliance portfolio diversity on innovation performance: A study of partner and alliance characteristics in the bio-pharmaceutical industry'. *International Journal of Innovation Management,* **21**, 1–24.

Martinez, O. J., Oxley, J. E. and Silverman, B. S. (2017a). 'Addressing endogeneity issues in alliance research in collaborative strategy'. In Mesquita, L. F., Ragozzino, R. and Reuer, J. J. (Eds), *Critical Issues for Alliance and Networks.* Cheltenham: Edward Elgar, 260–68.

Martinez, M. G., Zouaghi, F. and Garcia, M. S. (2017b). 'Capturing value from alliance portfolio diversity: The mediating role of R&D human capital in high and low tech industries'. *Technovation,* **59**, 55–67.

Maurer, I., Bartsch, V. and Ebers, M. (2011). 'The value of intra-organizational social capital: How it fosters knowledge transfer, innovation performance, and growth'. *Organization Studies,* **32**, 157–85.

Maurer, I. and Ebers, M. (2006). 'Dynamics of social capital and their performance implications: Lessons from biotechnology start-ups'. *Administrative Science Quarterly,* **51**, 262–92.

Mellewigt, T. and Decker, C. (2014). 'Costs of partner search and selection in strategic alliances'. *Journal of Business Economics,* **84**, 71–97.

Milgrom, P., Qian, Y. and Roberts, J. (1991). 'Complementarities, momentum, and the evolution of modern manufacturing'. *The American Economic Review,* **81**, 84–88.

Neter, J., Kutner, M. H., Nachtsheim, C. J. and Wasserman, W. (1996). *Applied Linear Statistical Models*. Chicago, IL: Irwin.

Niesten, E. and Jolink, A. (2015). 'The impact of alliance management capabilities on alliance attributes and performance: A literature review'. *International Journal of Management Reviews,* **17**, 69–100.

Oehme, M. and Bort, S. (2015). 'SME internationalization modes in the German biotechnology industry: The influence of imitation, network position, and international experience'. *Journal of International Business Studies,* **46**, 629–55.

Oliver, A. L. (2001). 'Strategic alliances and the learning life-cycle of biotechnology firms'. *Organization Studies,* **22**, 467–89.

Oliver, A. L. (2009). *Networks for Learning and Knowledge Creation in Biotechnology*. Cambridge: Cambridge University Press.

Owen-Smith, J. and Powell, W. W. (2004). 'Knowledge networks as channels and conduits: The effects of spillovers in the Boston biotechnology community'. *Organization Science,* **15**, 5–21.

Parise, S. and Casher, A. (2003). 'Alliance portfolios: Designing and managing your network of business-partner relationships'. *The Academy of Management Executive,* **17**, 25–39.

Parkhe, A. (1993). 'Partner nationality and the structure-performance relationship in strategic alliances'. *Organization Science,* **4**, 301–24.

Phelps, C. C. (2010). 'A longitudinal study of the influence of alliance network structure and composition on firm exploratory innovation'. *Academy of Management Journal,* **53**, 890–913.

Phene, A. and S. Tallman. (2012). 'Complexity, context and governance in biotechnology alliances'. *Journal of International Business Studies,* **43**, 61–83.

Podsakoff, P. M., MacKenzie, S. B., Lee, J.-Y. and Podsakoff, N. P. (2003). "Common method biases in behavioral research: A critical review of the literature and recommended remedies'. *Journal of Applied Psychology,* **88**, 879–903.

Powell, W. W., Koput, K. W. and Smith-Doerr, L. (1996). 'Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology'. *Administrative Science Quarterly,* **41**, 116–45.

Priem, R. L. and Butler, J. E. (2001). 'Is the resource-based "view" a useful perspective for strategic management research?'. *Academy of Management Review,* **26**, 22–40.

Roberson, Q., Holmes IV, O. and Perry, J. L. (2017). 'Transforming research on diversity and firm performance: A dynamic capabilities perspective'. *Academy of Management Annals,* **11**, 189–216.

Rosenkopf, L. and Padula, G. (2008). 'Investigating the microstructure of network evolution: Alliance formation in the mobile communications industry'. *Organization Science,* **19**, 669–87.

Rost, K. (2011). 'The strength of strong ties in the creation of innovation'. *Research Policy,* **40**, 588–604.

Rothaermel, F. T. and Deeds, D. L. (2004). 'Exploration and exploitation alliances in biotechnology: A system of new product development'. *Strategic Management Journal,* **25**, 201–21.

Rothaermel, F. T. and Deeds, D. L. (2006). 'Alliance type, alliance experience and alliance management capability in high-technology ventures'. *Journal of Business Venturing,* **21**, 429–60.

Sampson, R. C. (2007). 'R&D alliances and firm performance: The impact of technological diversity and alliance organization on innovation'. *Academy of Management Journal,* **50**, 364–86.

Sarkar, M. B., Aulakh, P. S. and Madhok, A. (2009). 'Process capabilities and value generation in alliance portfolios'. *Organization Science,* **20**, 583–600.

Sarkar, M. B., Echambadi, R. A. and Harrison, J. S. (2001). 'Alliance entrepreneurship and firm market performance'. *Strategic Management Journal,* **22**, 701–11.

Schilke, O. (2014). 'On the contingent value of dynamic capabilities for competitive advantage: The nonlinear moderating effect of environmental dynamism'. *Strategic Management Journal,* **35**, 179–203.

Schilke, O. and Goerzen, A. (2010). 'Alliance management capability: An investigation of the construct and its measurement'. *Journal of Management,* **36**, 1192–219.

Schilling, M. A. and Phelps, C. C. (2007). 'Interfirm collaboration networks: The impact of large-scale network structure on firm innovation'. *Management Science,* **53**, 1113–26.

Schreiner, M., Kale, P. and Corsten, D. (2009). 'What really is alliance management capability and how does it impact alliance outcomes and success?'. *Strategic Management Journal,* **30**, 1395–419.

Shan, W., Walker, G. and Kogut, B. (1994). 'Interfirm cooperation and startup innovation in the biotechnology industry'. *Strategic Management Journal,* **15**, 387–94.

Simonin, B. L. (1999). 'Ambiguity and the process of knowledge transfer in strategic alliances'. *Strategic Management Journal,* **20**, 595–623.

Song, M., Droge, C., Hanvanich, S. and Calantone, R. (2005). 'Marketing and technology resource complementarity: An analysis of their interaction effect in two environmental contexts'. *Strategic Management Journal,* **26**, 259–76.

Song, M., Dyer, B. and Thieme, R. J. (2006). 'Conflict management and innovation performance: An integrated contingency perspective'. *Journal of the Academy of Marketing Science,* **34**, 341–56.

Sørensen, J. B. and Stuart, T. E. (2000). 'Aging, obsolescence, and organizational innovation'. *Administrative Science Quarterly,* **45**, 81–112.

Spekman, R. E., Forbes, T. M., Isabella, L. A. and MacAvoy, T. C. (1998). 'Alliance management: A view from the past and a look to the future'. *Journal of Management Studies,* **35**, 747–72.

Spender, J. and Grant, R. M. (1996). 'Knowledge and the firm: Overview'. *Strategic Management Journal,* **17**, 5–9.

Stock, J. H. and Yogo, M. (2002). 'Testing for weak instruments in linear IV regression'. NBER Technical Working Paper No. 284, Issued in November 2002. Available at: https://www.nber.org/papers/t0284.

Stuart, T. E. (2000). 'Interorganizational alliances and the performance of firms: A study of growth and innovation rates in a high-technology industry'. *Strategic Management Journal,* **21**, 791–811.

Stuart, T. E. (1998). 'Network positions and propensities to collaborate: An investigation of strategic alliance formation in a high-technology industry'. *Administrative Science Quarterly,* **43**, 668–98.

Stuart, T. E., Hoang, H. and Hybels, R. C. (1999). 'Interorganizational endorsements and the performance of entrepreneurial ventures'. *Administrative Science Quarterly,* **44**, 315–49.

Stuart, T. E., Ozdemir, S. Z. and Ding, W. W. (2007). 'Vertical alliance networks: The case of university–biotechnology–pharmaceutical alliance chains'. *Research Policy,* **36**, 477–98.

Sytch, M. and Tatarynowicz, A. (2014). 'Exploring the locus of invention: The dynamics of network communities and firms' invention productivity'. *Academy of Management Journal,* **57**, 249–79.

Trajtenberg, M. (1987). *Patents, citations and innovations: tracing the links.* NBER Working Paper No. 2457, National Bureau of Economic Research Cambridge, MA.

Tzabbar, D., Aharonson, B. S., Amburgey, T. L. and Al-Laham, A. (2008). 'When is the whole bigger than the sum of its parts? Bundling knowledge stocks for innovative success'. *Strategic Organization,* **6**, 375–406.

Vassolo, R. S., Anand, J. and Folta, T. B. (2004). 'Non-additivity in portfolios of exploration activities: A real options-based analysis of equity alliances in biotechnology'. *Strategic Management Journal,* **25**, 1045–61.

Wang, Y. and Rajagopalan, N. (2015). 'Alliance capabilities review and research agenda'. *Journal of Management* **41**, 236–60.

Wassmer, U. (2010). 'Alliance portfolios: A review and research agenda'. *Journal of Management,* **36**, 141–71.

Wassmer, U. and Dussauge, P. (2011). 'Value creation in alliance portfolios: The benefits and costs of network resource interdependencies'. *European Management Review,* **8**, 47–64.

Wassmer, U. and Dussauge, P. (2012). 'Network resource stocks and flows: How do alliance portfolios affect the value of new alliance formations?'. *Strategic Management Journal,* **33**, 871–83.

Whittington, K. B., Owen-Smith, J. and Powell, W. W. (2009). 'Networks, propinquity, and innovation in knowledge-intensive industries'. *Administrative Science Quarterly,* **54**, 90–122.

Winter, S. G. (2003). 'Understanding dynamic capabilities'. *Strategic Management Journal,* **24**, 991–95.

Williamson, O. E. (1999). 'Strategy research: Governance and competence perspectives'. *Strategic Management Journal,* **20**, 1087–108.

Wu, W. P. (2008). 'Dimensions of social capital and firm competitiveness improvement: The mediating role of information sharing'. *Journal of Management Studies,* **45**, 122–46.

Wuyts, S. and Dutta, S. (2014). 'Benefiting from alliance portfolio diversity the role of past internal knowledge creation strategy'. *Journal of Management,* **40**, 1653–74.

Wuyts, S., Dutta, S. and Stremersch, S. (2004). 'Portfolios of interfirm agreements in technology-intensive markets: Consequences for innovation and profitability. *Journal of Marketing,* **68**, 88–100.

Yang, H., Zheng, Y. and Zaheer, A. (2015). 'Asymmetric learning capabilities and stock market returns'. *Academy of Management Journal,* **58**, 356–74.

Yli-Renko, H., Autio, E. and Sapienza, H. J. (2001). 'Social capital, knowledge acquisition, and knowledge exploitation in young technology-based firms'. *Strategic Management Journal,* **22**, 587–613.

Zajac, E. J. and Olsen, C. P. (1993). 'From transaction cost to transactional value analysis: Implications for the study of interorganizational strategies'. *Journal of Management Studies,* **30**, 131–45.

Zheng, Y. and Yang, H. (2015). 'Does familiarity foster innovation? The impact of alliance partner repeatedness on breakthrough innovations'. *Journal of Management Studies,* **52**, 213–30.

Zollo, M., Reuer, J. J. and Singh, H. (2002). 'Interorganizational routines and performance in strategic alliances'. *Organization Science,* **13**, 701–13.

Zollo, M. and Winter, S. G. (2002). 'Deliberate learning and the evolution of dynamic capabilities'. *Organization Science* **13**, 339–51.