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The relationship between partner diversity and innovation performance in multi-partner alliances: the moderating effect of power asymmetry

Abstract

Research examining the inter-organizational differences conceptualized and operationalized variety in multi-partner alliances is usually based on the assumption of equal power. However, power differences exist in almost all alliances, especially in multi-partner alliances. As a result, little is known about the impact of power asymmetry as moderator variable on the relationship between variety and innovation in R&D alliances with multiple partners. Therefore, we investigate the moderation effect of power asymmetry on the relationship between variety and the innovation performance in multi-partner R&D alliances. To address this question, we use a database of 409 R&D alliances with multiple partners granted funding from the Netherlands Technology Foundation STW between 2000 and 2004. We found a mutual reinforcing effect of power asymmetry on the relationship between variety and innovation performance in multi-partner alliances. The innovation-related benefits associated with organizational and industry variety can encourage use of power to facilitate coordination in high power asymmetric relationships, and begin positive reinforcement loops. The coordination challenges associated with functional variety can encourage the opportunistic use of power in high power asymmetric, and initiate a negative spiraling effect. This implies that researchers should always consider power asymmetry to fully understand the effects of variety in multi-partner alliances.

INTRODUCTION

The alliance literature has a rich tradition of examining the *"comparative interorganizational differences on certain attributes or dimensions"* (Parkhe, 1991, p. 582) on the innovation performance of alliances. The great majority of this literature has focused its attention and analysis on dyadic alliances and alliance portfolios. Although this attention on dyads and portfolios is partly justified, this *"does not fully reflect reality, as an increasing number of alliances involving multiple partners are begin formed"* (Albers, Schweiger, & Gibb, 2015, p. 25). Recognizing this gap has led researchers to take a special interest in the effects of interorganizational differences between partners – here conceptualized as variety – on the innovation performance of multi-partner alliances (e.g. Raesfeld, Geurts, & Jansen, 2012; Raesfeld, Geurts, Jansen, Boshuizen, & Luttge, 2012; Spanos & Vonortas, 2012). The authors found that the role of variety in multi-partner alliances to enhance innovation is based on the exchange of resources that can be combined to develop new products. Although some resource sharing may occur spontaneously, the realization of innovation-related benefits from partner variety requires coordination (Cui & O'Connor, 2012). Partners should develop an understanding of the possible interdependencies among them and actively manage the resource flows across them (Ranjay Gulati, Wohlgezogen, & Zhelyazkov, 2012; Hoffmann, 2005). Especially, alliances characterized by both multiple and highly divers partners require more extensive and higher quality coordination efforts between partners. In such a situation, *"partners may find it difficult to efficiently combine the resources they bring to the table, to synchronize their actions and to realize the planned payoffs"* (Ranjay Gulati et al., 2012, p. 537), despite their best intentions. When the partners are not able to effectively coordinate the resource-sharing across the alliance, the innovation-related benefits of variety may not be realized (Cui & O'Connor, 2012).

These insights have provided invaluable understanding of innovation-related benefits and the coordination challenges of variety in alliances with multiple partners. However, the dominant approach to conceptualizing and operationalizing variety in multi-partner alliances based on an implicit assumption of equal power. Insights from literature into intra-organizational variety (e.g. Bunderson, 2003; Bunderson & Reagans, 2011; Harrison & Klein, 2007) and suggestions in the multi-partner alliance literature (e.g. Albers et al., 2015; Heidl, Steensma, & Phelps, 2014) advocate that researchers should take the power asymmetry between the partners into account to create a better understanding gen bij aanof the role of variety in multi-partner alliances. In power-asymmetric alliances, a powerful partner can coordinate the complexities associated with resource-sharing in diverse multi-party relationships. It can use its superior strength combined with its capacity to smooth conflicts, enforce norms and promote fairness (Bunderson & Reagans, 2011; Heidl et al., 2014) among diverse partners. As this creates a safe environment for risk-taking and facilitates resources sharing (Bunderson & Reagans, 2011), power asymmetry can enhance the innovation-related benefits and alleviate the coordination challenges associated with variety in multi-partner alliances. In conclusion, the research into the innovation-related consequences of variety in multi-partner alliances will always be underspecified, if one does not consider variety and power asymmetry simultaneously (Bunderson & Reagans, 2011; Harrison & Klein, 2007). Therefore, we address the following research question in this paper:

Research question: *What is the moderation effect of power asymmetry on the relationship between partner diversity and the innovation performance of multi-partner alliances?*

THEORETICAL FRAMEWORK

Variety in multi-partner alliances

Comparative interorganizational differences between partners in dyadic alliances have been usually conceptualized as either heterogeneity, i.e. the differences between a focal company's characteristics and each one of their partners. Studies into alliance portfolios often conceptualize these differences as diversity, i.e. the differences between the characteristics partners in a focal company's alliance portfolio without taking the focal firm into account (Cobeña, Gallego, & Casanueva, 2017). Although each of these terms have also been used in multi-partner alliance literature, we conceptualize interorganizational differences between partners in multi-partner alliances as 'variety'. In this way, we emphasize that differences between characteristics of all involved partners are considered, thereby clearly distinguishing it from partner differences at the dyadic and portfolio levels of analysis. Jiang, Tao, and Santoro (2010) argue that alliances can vary in variety along three dimensions. The first dimension relates to partner characteristics: which partners are selected to join the alliance and which are not. The second dimension relates to the function purpose of an alliance: what are the value chain activities the organizations in the alliance perform. The third dimension relates to the governance structure: how the partners organize and manage the alliance using different organizing structures. Multi-partner alliances are often funded and sponsored by the governments of their countries (Sakakibara, 1997). These supports may be important as they facilitate the realization of large-scale cooperative R&D projects, which would be difficult to realize without subsidies. This public support, however, means that the government usually influences and controls the governance structure of the alliances (Sakakibara, 2002). Therefore, we focus on the effect of variety in partner characteristics (industry and organizational type) and functional purpose on the innovation performance of multi-partner alliances in this paper.

Functional variety and innovation performance in multi-partner alliances

Functional variety refers to the degree to which partners do not share common activities in a multi-partner alliance (Cui & O'Connor, 2012). Partners may be engaged different functional activities, such as research and development (R&D), manufacturing and marketing (Cui & O'Connor, 2012; Jiang et al., 2010). For example, three partners may be involved in the research and development of a new product, two partners may be working on manufacturing it and one partner is engaged in marketing activities for the product. To realize the innovation-related benefits from the potential synergies of such functional variety, resources and capabilities must be shared across functions (Sethi, Smith, & Whan Park, 2001). Especially across organizational boundaries (Goerzen & Beamish, 2005), cross-functional exchange is difficult due to a lack of overlap in prior knowledge and common ground (Sethi et al., 2001). It is more difficult to share resources and capabilities among partners if one partner is involved in R&D and the others carry out marketing activities than if all partners engage in the same type of activity. However, Jiang et al. (2010) found that diversity of alliance functions in the alliance portfolios enhances firm performance. They argued that a balance between R&D, manufacturing and marketing supports a firm in maintaining its current and ensuring its future viability. Yet they focus on financial firm performance instead of innovation. In contrast, Cui and O'Connor (2012) showed that diversity in functional activities in alliance portfolios negatively influence firm innovation performance because it increases the difficulty of resource exchange. The complexity of coordinating functional variety among multiple partners rather than two partners further lowers the contribution of functional variety to innovation. Due to the addition of partners, there is a growing number of resources and capabilities that must be shared to realize innovation-related benefits from potential synergies. This increases the range of options and effort necessary to *"coordinate tasks, manage conflicts and ensure reciprocity"* (Albers et al., 2015, p. 62). In other words, moving from two to three or more partners in an alliance increases the complexity of coordinating the functional variety of partners. Therefore, we argue that an alliance of partners engaged in various functional activities faces more difficulty in realizing innovation from their potential synergies than does an alliance that concentrates on the same functional activities. Following this reasoning, we hypothesize:

Hypothesis 1: Functional variety has a negative effect on the innovation performance of multi-partner R&D alliances.

Organizational variety and innovation performance in multi-partner alliances

Organizational variety refers to the degree to which partners consist of large number of organizational types in a multi-partner alliance. Alliances can be formed between multinational firms, start-ups, research institutes, hospitals, governmental institutes, non-profit organizations, and the like. Each type of organization offers a different pool of resources that can be created, exchanged, and combined (Albers et al., 2015; Jiang et al., 2010). Through the creation of new resources combination, collaborations between various types of organizations enhance the innovative process (M. J. Nieto & Santamaria, 2007). For example, universities and governmental institutes can provide basic research that complements and supplements an industrial firms more applied R&D efforts. However, diverse types of organizations tend to have *"different goals, decision-making processes, and systems that cause communication and coordinating difficulties*" (Jiang et al., 2010, p. 1139). In turn, this increases the likelihood of coordination failures. These coordination failures can have substantial adverse consequences for the innovation potential of the alliance, such as project delays, suboptimal product development and lack of commitment (Ranjay Gulati et al., 2012). Yet multi-partner alliances usually include at least partner without a commercial orientation, such as a non-profit organization, governmental institute, or university. Organizations without a commercial agenda are more interested in the pursuing long-term, collective goals. Consequently, they are willing to manage the contradicting goals, interests, and perspectives among partners, thereby reducing the chances of coordination failure (Wu & Pangarkar, 2015). Accordingly, Schwartz, Peglow, Fritsch, and Günther (2012) found that university involvement in subsidized R&D collaborations positively effects project innovation output, in terms of the number of publications. Also, Raesfeld, Geurts, and Jansen (2012) and Raesfeld, Geurts, Jansen, et al. (2012) show that value chain complementarity, as they call it, has a positive effect on the innovation performance of public nanotechnology R&D projects with multiple partners. Therefore, we argue that a multi-partner alliances with variety of organizational partner types favors innovation more than does an alliance with only one type of partner.

Hypothesis 2: Organizational variety has a positive effect on the innovation performance of multi-partner R&D alliances.

Industry variety and innovation performance in multi-partner alliances

Industry variety refers to the degree to which partners in a multi-partner alliance are distributed across many industries. Alliances with organizations from different industries can enjoy potential innovation benefits, but they also create coordination difficulties. Consequently, Marhold, Jinhwan Kim, and Kang (2017) show that the effect of industry portfolio diversity on firm innovation performance is only positive up to a certain point, thereafter the coordination difficulties outweigh the innovation-related benefits. At low levels of industry variety, the alliance partner's common industrial background facilitates the assimilation and combination of knowledge (Cui & O'Connor, 2012; Jiang et al., 2010). Moreover, similar backgrounds increase agreement among partners about coordination requirements (Ranjay Gulati et al., 2012). At the same time, however, it also increases the risk of redundancies of resources and limiting access to complementary resources and capabilities. Thereby, it decreases the possibility of developing new useful combinations of resources necessary for successful innovation (Marhold et al., 2017; Oerlemans, Knoben, & Pretorius, 2013). At moderate levels of industry variety, alliance partners gain access to different resources and capabilities that it can employ in their innovation processes (Marhold et al., 2017). In addition, they can recognize and efficiently manage the coordination-related issues that flow from the various resources of the involved partners (Ranjay Gulati et al., 2012; Oerlemans et al., 2013). At high levels of industry variety, alliance partners face many different routines, structures and processes, political and economic systems, and government policies. Too much of such contextual differences are likely to limit the overlap in backgrounds, experiences, and technological bases necessary to combine the resources and capabilities of partners (Cui & O'Connor, 2012; Jiang et al., 2010). Moreover, alliances partners are likely to experience more conflicting views about key inter-organizational coordination decisions. These disagreements can cause incompatibility between partners intended to be complementary (Ranjay Gulati et al., 2012).In the context of multi-partner alliances, Raesfeld, Geurts, and Jansen (2012) found a weak positive effect of industry heterogeneity, as they call it, on the innovation performance of nanotechnology R&D projects. However, they did not test for a curvilinear effect as often suggested, explained, and found in the alliance portfolio literature (e.g. Cobeña et al., 2017; Marhold et al., 2017). Following this reasoning, we hypothesize:

Hypothesis 3: Industry variety has an inverted U-shaped effect on the innovation performance of multi-partner R&D alliances.

The effect of power asymmetry on the relationship between variety and innovation performance

Power asymmetry refers to the composition of differences in proportion of power held among partners in the multi-partner alliances, that is inequality of relative concentration. Low power asymmetry occurs when all partners of the multi-partner alliance have the same proportion of power, while high power asymmetry arises when only one partner is superior compared to all others in terms of power (Harrison & Klein, 2007). In line a *"socialized"* perspective of power grounded in functionalism theory, it can be argued that a powerful partner in high power-asymmetric alliance can coordinate the complexities associated with diverse multi-party relationships. In general, multi-partner R&D alliances have a greater need for coordination than dyadic alliances (Heidl et al., 2014; Li, Eden, Hitt, Ireland, & Garrett, 2012; Zeng & Chen, 2003). O'Sullivan (2005, p. 127) argued that *"it seems a heroic assumption that such exchanges would not need to be deliberately orchestrated by some central and powerful agency"*. Accordingly, previous research has shown that powerful partners can promote trust, act as conflict solvers, play a strategic role in coordinating collective action and monitor partner behavior in multi-partner alliances (Chesbrough, Vanhaverbeke, & West, 2006; R. Gulati, 1998; Heidl et al., 2014; O'Sullivan, 2005; Vanhaverbeke, Duysters, & Noorderhaven, 2002). Especially in multi-partner alliance characterized by high variety, powerful partners may leverage resource exchange among partners (Li et al., 2012). They can help lower-ranked others to feel safe contributing to the innovation process, and help them feel they must be engaged in that process. Moreover, powerful partners can identify, draw out, and legitimize resource contributions from lower-ranked partners (Bunderson & Reagans, 2011). Consequently, resources will flow more freely between partners, enabling alliance partners to realize their combined potential for innovation (Heidl et al., 2014; O'Sullivan, 2005). From this perspective, it can be concluded that higher levels of power asymmetry would tend to increase the innovation-related benefits and decrease coordination challenges from the presence of variety in multi-partner alliances.

In line with a *"personalized"* perspective on power grounded in conflict theory, however, it can be argued that high power asymmetry diminishes the innovation-related benefits of resources synergies between partners in a multi-partner alliance. In general, powerful partners are more likely to initiate competitive actions (Gnyawali & Madhavan, 2001), such as freeriding, opportunistic behavior and premature withdrawal, in high power-asymmetric alliances. In such situation, lower-ranked organizations are often not able to change the situation because they lack the necessary resources to coordinate a response and provoke a powerful partner (Chen, 1996). Particularly in multi-partner alliance characterized by high variety, the different resources and capabilities of lower-ranked alliance partner are therefore not equally represented in the alliance's deliberations. Instead the characteristics of the powerful partner will tend to dominate decision-making. As a result, the partners with resources that are most valuable to realizing synergies may not be involved in making coordination decisions. In turn, this will reduce the variety of knowledge, perspectives and insights that will be included in the alliance's innovation process (Bunderson, 2003; Bunderson & Reagans, 2011; Colurcio, Wolf, Kocher, & Spena, 2012; Harrison & Klein, 2007). From this perspective, it can be concluded that lower levels of power asymmetry would tend to increase the innovation-related benefits and diminish coordination challenges from the presence of variety in multi-partner alliances.

Despite this *"personalized"* perspective on power, we argue that powerful partners often resist the impulse to initiate competitive actions to enhance their status or to promote self-serving interests in the context of multi-partner alliances. This behavior could not only damage their relationship with the lower-ranked partners, but also their relations with the other partners.

Subsequently, this would harm their reputation as a trustworthy partner in their network (Bae & Gargiulo, 2004; Bunderson & Reagans, 2011). Moreover, organizations who develop a reputation as 'team player' will find it easier to form and increase it changes of being selected to join new inter-organizational relationships (Bunderson & Reagans, 2011). Therefore, they tend to use their power to enhance the innovation potential of diverse multi-partner alliance, especially in alliances in which they have a considerable stake (Casciaro & Piskorski, 2005; Heidl et al., 2014). In addition, lower ranked partners in high power-asymmetry alliances may voluntarily give up their power. Especially, if they expect innovation-related benefits from resource synergies they cannot achieve without a powerful partner's coordination efforts. In this situation, the lower-ranked partners legitimate the powerful position of the established organization and transfer decision rights and authority to this organization to allow for effective coordination in the innovation process (Albers et al., 2015; Bunderson & Reagans, 2011). In conclusion, powerful organizations in a multi-partner R&D alliances are able, motivated and legitimized to use their power to coordinate the diverse multi-party relationships within the collaboration. Therefore, we hypothesize that:

Hypothesis 4: Power asymmetry has a positive moderating effect on the relationship between functional (a), organizational (b), industry variety and the innovation performance of multi-partner R&D alliances.

METHODS

Sample and data sources

The hypotheses were tested in a set of multi-partner R&D alliances funded by the Dutch Technology Foundation STW. The foundation funds application-oriented research projects in which research institutes and users, such as large, medium-sized, and small businesses, non-profit organizations, and healthcare institutes, of the generated knowledge collaborate. We used the publicly available data of the 409 R&D alliances with multiple partners initiated between 2000 and 2004. Besides basic information, such as project title, project budget and starting date, the data includes information about: a) the research institute that filed for the project; b) the users involved in the project; and c) the project results five years after the project finished. To enrich the dataset, for each user the year of establishment and the number of employees between 2000 and 2009 were extracted from REACH (Bureau van Dijk, Amsterdam, The Netherlands). This database provides comprehensive information, such as financial details, number of employees and company history, on organizations in the Netherlands. If this information was unavailable, especially in the case of non-Dutch users, the required data were retrieved from ORBIS (Bureau van Dijk, Amsterdam, The Netherlands). This database is like REACH, but provides information about over 200 million private and listed firms around the world. The information in the two databases is standardized and, therefore, can be used in parallel. In addition, the dataset was enriched with the centrality of each user in the STW network. The centrality was calculated with the support of UCINET (version 6.623; Analytic Technologies, Harvard, MA, USA).

Measurement

We used the product generation scale from STW to measure *innovation performance*. The product generation scale evaluates *"the degree to which the project leads to a tangible product such as software, patent, prototype or process description"* (Raesfeld, Geurts, & Jansen, 2012, p. 754), five years after project completion. The STW product generation scale consists of three categories. In projects classified in category (A) there is no concrete product. More research is necessary to obtain a useful product. Although preliminary conclusions were drawn, several things still must be verified: the project is still in the phase of basic technology. In projects classified in category (B) a partial product was developed. A useful preliminary model, principle or conceptual method has been created. Yet verification and refinement are still required before one can speak of a final product because the users cannot completely independently use the investigational product. In projects classified in category (C) a full product, for example in the form of software, a working prototype, a process description, a patent, was developed. The product is a finalized concept that users can independently use.

To measure multi-partner alliance variety, we classified each partner into different categories. For *functional diversity*, we coded the project partners' roles into three categories: (1) researcher and/or developer; (2) producer; or (3) user. For *organizational variety*, we coded the project partners' organizational types into six categories: (1) companies; (2) governmental parties; (3) research institutes; (4) hospitals and medical institutes; (5) universities and schools; and (6) special interest groups. For industry variety, we classified the project partner's industry using the Dutch version of the SIC coding, i.e. SBI codes, which consists of 21 industry classes. For each, the variety at the multi-partner alliance level was calculated with the Blau index. Since the number of categories in each measure of variety was different, we normalized the index for the number of categories.

We operationalized *power asymmetry* as the degree of concentration in the centrality across the multi-partner R&D alliance partners. To determine the centrality of the users, we used Bonacich's (1987) measure of power centrality which reflects the centrality of the users in the network it is connected with. Here, the network consists of the user relations involved in all the projects initiated between 2000 and 2004 together. The Bonacich (1987) power centrality of a user was calculated in UCINET (version 6.623; Analytic Technologies, Harvard, MA, USA). Then, the coefficient of variation was used to measure power asymmetry at the multi-partner alliance level.

We included three *control variables* in our analysis: project budget, number of project partners and technology field. Project budget was measured as the amount of funding (in Euros) the project received from STW. The number of partners was calculated as the absolute number of partners involved in the project. the possible influence of technology by creating a dummy variable for whether the project is directed at nanotechnology (1) or not (0). An expert in the field of nanotechnology assessed whether the project aimed to the develop nanotechnology applying the National Nanotechnology Initiative's definition.

Data analysis

The statistical analysis was performed using SPSS (version 22; IBM Corp., Armonk, NY, USA). Mean, standard deviation (S.D.) and correlations were run for the dependent, independent and control variables. A multinomial logistic regression was performed to test the effect of functional, organizational and industry variety on innovation performance and the moderating effect of power asymmetry on these relationships, after controlling for project budget, number of project partners and technology field. To meaningfully interpret the inverted U-shaped effect and interaction effects, the variables were standardized before the regression analysis. The suitability of multi-nominal logistic regression was assessed prior to analysis. One-tailed values of $p < .05$ were considered statistically significant.

RESULTS

Table 1 presents the mean and standard diaviations as well as the correlations for all variables. A multinominal logistic regression was run to test our hypotheses, after controlling for the technology field, project budget and number of partners. First, Table 2 shows that technology field did not significantly predict whether no product or a partial product was developed. In contrast, project budget and number of partners significantly predict wheter no product or a partial product was developed. The odds ratio shows that as the project budget and the number of partners increases, the change in the odds of developing a partial product are 1.43 and 2.47 respecitvely. Second, Table 2 shows that technology field and project partners did not significantly predict whether no product or a full product was developed. However, project budget significantly predicted whether no product or a full product was developed. The odds ratio shows that as the budget increases, the change in the odds of developing a full product is 1.43.

Hypothesis 1 proposed that functional variety has a negative effect on the innovation performance of multi-partner alliances. Table 2 shows that the functional variety significantly predicted whether no product or a partial product as well as whether no product or a full product was developed. The odds ratio shows that as functional variety increases, the change in odds of developing a partial product 0.46 and a full product is 0.48 Thus, a multi-partner alliance is signifcantly less likely to develop a partial product or a full product if functional variety is high. Therefore, Hypothesis 1 is supported.

Hypothesis 2 proposed that organizational variety has a positive effect on the innovation performance of multi-partner alliances. Table 2 shows that organizational variety significantly predicted whether no product or a partial product as well was whether no product or a full product was developed. The odds ratio shows that as organizational variety increases, the change in odds of developing a partial product is 1.82 and a full product is 1.52. Thus, a multi-partner alliance is significantly more likely to develop a partial product or full product if organizational variety is high. Therefore, Hypothesis 2 is supported.

Hypothesis 3 proposed that industry variety has an inverted U-shaped effect on the innovation performance of multi-partner alliances. Table 2 shows that direct and squared effects industry variety have a positive and significant effect on odds of whether no product or a partial product was developed as well as the odds of whether no product or a full product was developed. Futher analysis shows that there is a U-shaped relationship between the odds of developing no product versus a partial product, and a J-shaped relationship between the odds of developing no product versus a full product. Therefore, Hypothesis 3 is rejected.

Hypothesis 4a proposed that there is a positive moderation effect of power asymmetry on the negative relationship between functional variety and innovation performance. The results show a significant negative interaction effect on the odds of whether no product or a partial product was developed. The plot of this interaction in Figure 1 demonstrates that the effect of functional variety on the odds of developing a partial product compared to no product was subtaintially decreased when power asymmetry was high. In addition, the results show a negative, but insignificant interaction effect on the odds of whether no product or a full product was developed. Therefore, Hypothesis 4a is rejected.

Hypothesis 4b proposed that there is a positive moderation effect of power asymmetry on the positive relationship between functional variety and innovation performance. The results show a significant positive interaction effect on the odds of whether no product or a partial product was developed. The plot of this interaction in Figure 3 demonstrates that the effect of organizational variety on the odds of whether a partial or no product was developed was substaintially increased under high power assymmetry. Furthermore, the results show positive, but insignificant interaction effect on the odds of whether no product or a full product was developed. Therefore, Hypothesis 4b is partially supported.

Hypothesis 4c proposed that there is positive moderation effect of power asymmetry on the inverted U-shaped relationship between indust ry variety and the innovation performance of multi-partner alliances. The results show a significant positive interaction effect on the odds of whether no product or a partial product as well as whether no product or a full product was developed. Further analysis shows that the effect of industry variety on the odds of whether a partial or no product was developed was substaintially increased under high power assymmetry. Therefore, Hypothesis 4c is supported.

		Mean	S.D.	1	2	3	4	5	6	7	8	9	10
1	No proudct vs partial product	0,47	0,50	1,00									
2	No proudct vs full product	0,30	0,46	-0,62	1,00								
3	Field of nanotechnology	0,49	0,50	-0,04	-0,02	1,00							
4	Project budget	458880,74	252445,73	0,06	0,04	0,09	1,00						
5	Number of project partners	5,54	2,53	0,07	0,05	-0,10	0,20	1,00					
6	Power asymmetry	0,97	0,41	0,08	0,11	-0,14	-0,03	0,16	1,00				
7	Functional variety	3,45	3,01	-0,02	0,00	-0,11	0,10	0,68	-0,02	1,00			
8	Organizational variety	0,83	0,59	0,04	-0,06	-0,08	-0,17	-0,41	-0,19	-0,15	1,00		
9	Industry variety	1,10	0,04	0,03	0,07	-0,07	0,17	0,86	0,03	0,66	-0,26	1,00	
10	Industry variety (squared)	1,22	0,09	0,03	0,06	-0,07	0,17	0,84	0,02	0,66	-0,23	1,00	1,00

Table 1. Means, standard divation (S.D.) and correlations of the variables, N = 409.

	Model 1			Model 2			Model 3		
	B	s.e.	Sig.	B	s.e.	Sig.	B	s.e.	Sig.
Partial product vs. no product									
Intercept	0.63	0.18	.00	0.58	0.21	.00	0.66	0.22	.00
Field of nanotechnology	0.33	0.26	.10	0.32	0.27	.12	0.24	0.28	.20
Project budget	0.33	0.15	.02	0.34	0.16	.02	0.36	0.16	.01
Number of project partners	0.30	0.15	.02	1.03	0.33	.00	0.90	0.37	.01
Functional variety				-0.83	0.25	.00	-0.78	0.29	.00
Organizational variety				0.34	0.19	.04	0.60	0.22	.00
Industry variety				-0.14	0.33	.34	0.01	0.37	.49
Industry variety^2				0.17	0.15	.13	0.41	0.21	.02
Power asymmetry							0.33	0.19	.04
Power asymmetry x Functional variety							-0.57	0.25	.01
Power asymmetry x Organizational variety							0.36	0.20	.04
Power asymmetry x Industry variety							0.58	0.28	.02
Power asymmetry x Industry variety^2							0.41	0.19	.01
Full poduct vs. no product									
Intercept	0.19	0.20	.17	0.14	0.22	.27	0.22	0.24	.18
Field of nanotechnology	0.31	0.28	.13	0.35	0.29	.11	0.20	0.30	.25
Project budget	0.33	0.16	.02	0.33	0.17	.03	0.36	0.17	.02
Number of project partners	0.31	0.16	.03	0.61	0.36	.04	0.42	0.39	.14
Functional variety				-0.72	0.25	.00	-0.74	0.30	.01
Organizational variety				0.15	0.20	.22	0.42	0.23	.03
Industry variety				0.24	0.36	.25	0.50	0.39	.10
Industry variety^2				0.15	0.15	.16	0.40	0.21	.03
Power asymmetry							0.38	0.20	.03
Power asymmetry x Functional variety							-0.32	0.27	.12
Power asymmetry x Organizational variety							0.31	0.22	.08
Power asymmetry x Industry variety							-0.04	0.32	.45
Power asymmetry x Industry variety^2							0.50	0.19	.01

Table 2. Results of multi-nominal logistic regression. Note: Model 1: $R^2 = .04$ (Nagelkerke); χ^2 (6) = 14.63, p = .020. Model 2: $R^2 = .09$ (Nagelkerke); χ^2 (14) = 33.51, p = .002. Model 3: $R^2 = .17$ (Nagelkerke); χ^2 (24) = 67.43, p < .001

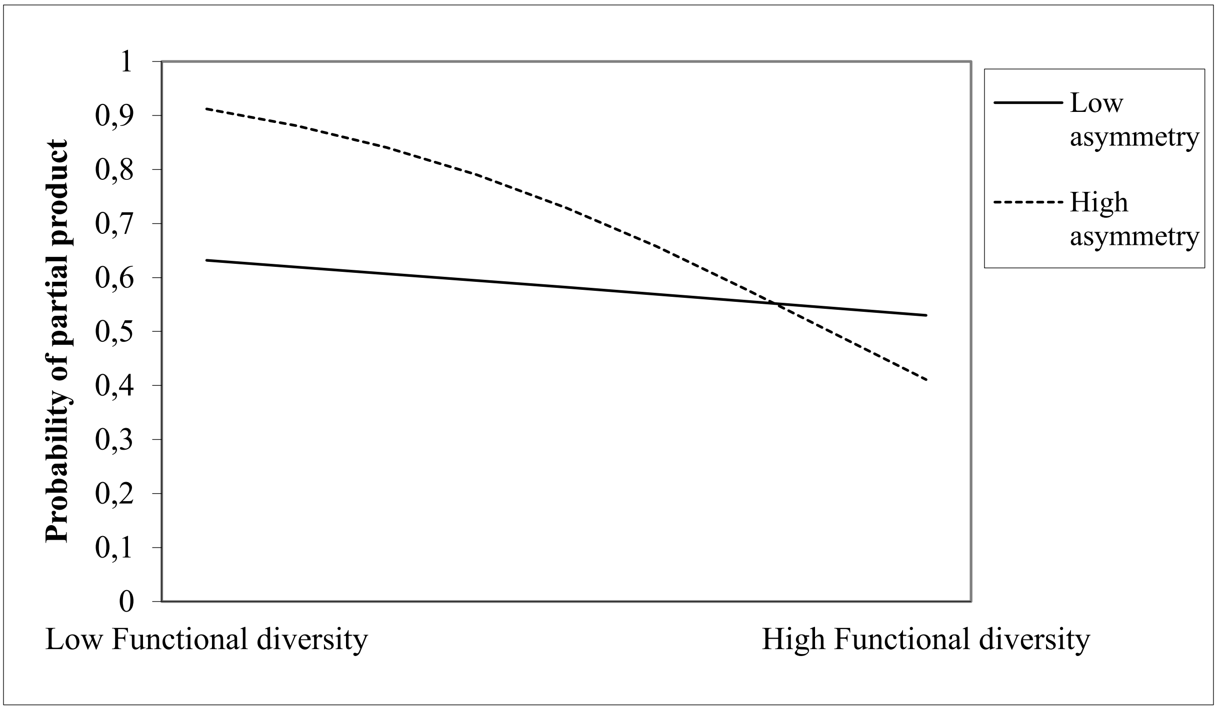

Figure 1. The interaction effect of power asymmetry on the relationship between functional diversity and the odds of whether a no product or a partial product is developed.

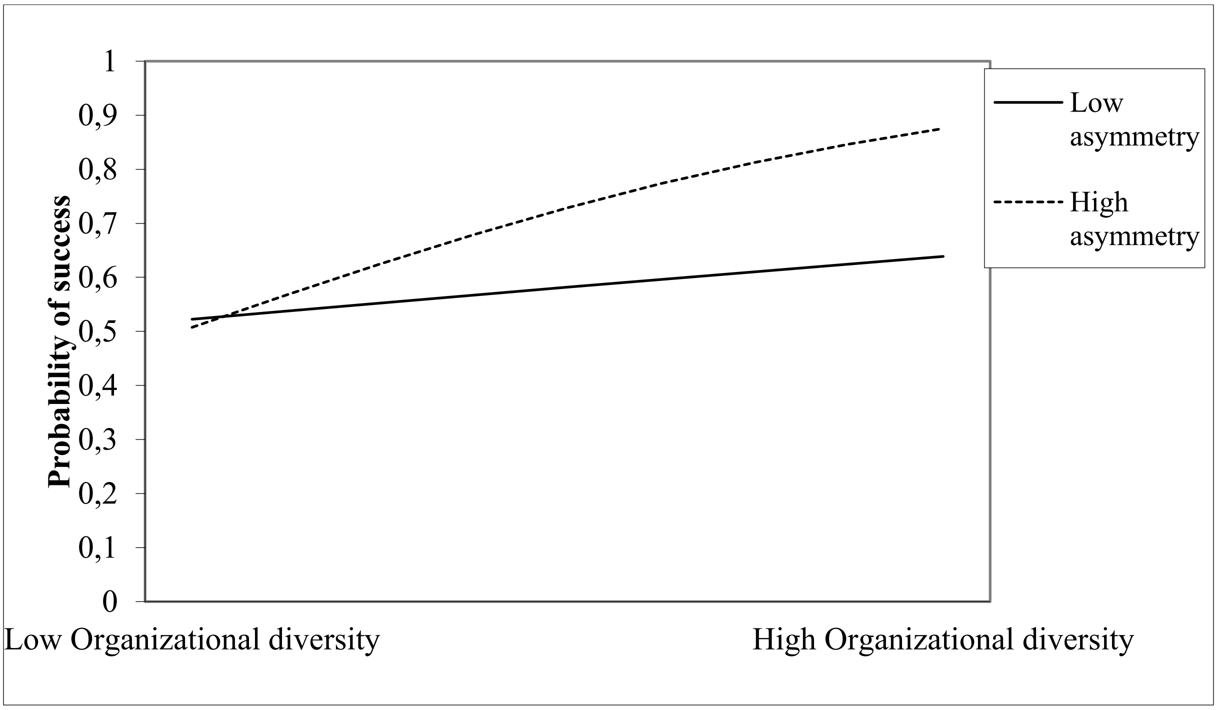

Figure 2. The interaction effect of power asymmetry on the relationship between organizational diversity and the odds of whether a no product or a partial product is developed.

DISCUSSION

The results of our study suggest that the effect of organizational variety on innovation performance is positively moderated by power asymmetry. Also, they imply that the effect of industry variety on innovation performance is positively moderated by power asymmetry, but only for the odds of developing a partial product. In contrast, the results indicate that the relationship between industry variety and innovation performance is negatively moderated by power asymmetry. These results confirm our expectations that power asymmetry plays an important role in the relationship between variety and innovation performance. In contrast to our expectations, however, power asymmetry did not always facilitate the coordination within a highly diverse multi-partner alliance. Instead, the findings suggest that there is a mutual reinforcing effect of power asymmetry on the relationship between variety and innovation performance. The innovation-related benefits associated with organizational and industry diversity encourage the *"socialized"* use power in high-asymmetric multi-partner alliances, possibly leading to a positive spiraling effect (Bunderson & Reagans, 2011; Ranjay Gulati et al., 2012). When powerful partners expect benefits from the combination of the large diverse multi-layered pool of resources created in a multi-partner alliances, they may perceive it as worthwhile to help the alliance to reach its collective goal (Bunderson & Reagans, 2011). In such a situation, they are more likely to use its capabilities to coordinate the complexities that arise from increased variety. They can encourage others to contributing resources to the innovation process to ensure they will flow more freely between partners. Eventually, this will enable alliance partners to realize their combined potential for innovation (Heidl et al., 2014; O'Sullivan, 2005).

However, the coordination costs associated with functional diversity encourage the *"personalized"* use of power in high-asymmetric, possibly leading to a negative spiraling effect

(Bunderson & Reagans, 2011; Ranjay Gulati et al., 2012). When the coordination challenges fuel worry about the benefits of a relationship, powerful partners may doubt whether effortful forms of coordination are worthwhile. In turn, they may try to minimize individual efforts and risks, while they may try to maximize individual benefits. The mere potential of such opportunistic behavior may lead other partners to withhold information critical to successful resource exchange and coordination. Ultimately, this causes the coordination issues to worsen and coordination gaps to widen (Ariño & de la Torre, 1998; Ranjay Gulati et al., 2012). The implications of this reinforcement logic support a balanced approach, equally focusing on variety and power asymmetry at the beginning of a multi-partner alliances.

In addition, the results of our study suggest that the innovation performance of multi-partner alliances is negatively influenced by functional variety and positively by organizational variety. Moreover, they indicate that the relationship between industry variety and innovation performance is U-shaped for the odds of developing a partial product and J-shaped for the odds of developing a full product. The results confirm our expectations that the effect of functional diversity in alliance portfolios on firm innovation performance (e.g. Cui & O'Connor, 2012; J. Nieto & Santamaría, 2010) is similar in the context of multi-partner alliances. Moreover, they underscore the findings of researchers who found that organizational variety positively influences the innovation performance of multi-partner alliances (Raesfeld, Geurts, & Jansen, 2012; Raesfeld, Geurts, Jansen, et al., 2012; Schwartz et al., 2012). In contrast, the proposed effect of industry variety on innovation performance was reversed from what we found. Although this is in line with research into the effect of industry diversity in alliance portfolios on firm performance in general (Goerzen & Beamish, 2005; Jiang et al., 2010), it contradicts the findings of most research into the effect of industry diversity in alliance portfolios on the innovation performance of firms (Marhold et al., 2017).

Theoretical and managerial implications

The key contribution of our study is advancing our understanding of the moderating effect of power asymmetry on the relationship between functional, organizational and industry variety and innovation performance in multi-partner alliances. Research examining the comparative inter-organizational differences on certain attributes or dimensions conceptualized and operationalized variety in multi-partner alliances based on the assumption of equal power (Bunderson & Reagans, 2011). However, power differences exists in almost all alliances, especially in multi-partner alliances (Albers et al., 2015). We show that there showing a mutual reinforcing effect of variety and power asymmetry on the innovation performance of alliances with multiple partners. On the one hand, the innovation-related benefits associated with organizational and industry variety can encourage the socialized use of power in high power asymmetric relationships, and can kick off positive reinforcement loops. On the other hand, the coordination challenges associated with functional variety can encourage the personalized use of power in high power asymmetric, and can kick of a negative reinforcement loop.

Our findings also provide an answer to business managers' question: whom to allow to join a multi-partner alliance and whom to invite in? Most importantly, they need to suitably design such an alliance in terms of the variety of the members. We encourage managers to collaborate with various types of organization, such as universities, hospital, governmental organizations, and the like. We caution managers to ally with partners from a moderate amount of different industries: either a few or a lot of different industries is beneficial for the innovation performance of multi-partner alliances. Also, we suggest managers to involve only partners with a single functional focus: either R&D, production, or marketing. Too enhance the innovation-related benefits of high organizational variety and moderate industry variety, the involvement of a single powerful partner may be worthwhile. If there are, however, multiple functional activities within the same alliance, high power asymmetry is best avoided in multi-partner alliances. In this way, the negative effects of functional variety are not further aggravated.

Limitations and future research

Despite the theoretical contributions and managerial implications of our study, it is subject to some limitations that suggest avenues for further research. One limitation arises from the selection of publicly funded multi-partner R&D alliances as sample. Although we did not select only successful projects, Schwartz et al. (2012) suggests that R&D projects with a considerable risk of failure may be excluded in our sample because they are screened to a number of criteria before the allocation of funding. Therefore, future research might compare the effects of power asymmetry in subsidized multi-partner R&D projects to its effect in projects that did not receive public funding.

A further limitation of our study results from our conceptualization and measurement of power asymmetry. We focused the underlying capacity of organizations to influence and control the behaviors of others (Huxham & Vangen, 2013; Olsen, Prenkert, Hoholm, & Harrison, 2014), but an organization will seldom exercise all its potential power in all situations (Provan, 1980). Consequently, further research might create a better understanding of how partners use their potential power in multi-partner alliances. Second, we relied on centrality as approximate measures of its power. Although it has been used as a proxy of power previously, it would be rather important to use more direct measures of power – see for example Nyaga, Lynch, Marshall, and Ambrose (2013) and Wang (2011) who investigated of dyadic power asymmetry through survey, case study or ethnographical research.

Another limitation of our analysis arises from our operationalization of centrality. There exist alternative ways to measure centrality, each of them reflecting another aspect of power, such as closeness and betweenness centrality. Studies in other contexts (see Valente, Coronges, Lakon, & Costenbader, 2008) have shown that the measures are conceptually related, yet distinct. Therefore, future studies should include multiple measures of centrality simultaneously.

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