MULTI-PARTNER R&D ALLIANCE DIVERSITY AND INNOVATION PERFORMANCE: THE DILEMMA OF VALUE CREATION AND VALUE APPROPRIATION

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Abstract

We systematically examine multi-partner alliance diversity and its innovation performance consequences at both a multi-partner alliance level as well as at the partner firm level in the context of technological knowledge sourcing. Based on resources within-firm, between-firm, and across the entire network, we identify three dimensions of multi-partner diversity, namely partner variety, relational separation, and structural disparity. We argue that each of these dimensions has distinct innovation performance consequence at alliance and partner firm levels. We tested our theory on a sample of R&D collaborations in technology-driven industries from 1990 to 2008. Our findings reveal diverging mechanisms between value creation at the multi-partner alliance level and value appropriation at the partner firm level regarding each dimension of multi-partner R&D alliance diversity. Our results suggest that managers should be cautious about the complexity of the multipartner alliance configuration and the critical trade-offs between value creation and value appropriation when they are deciding to join, stay, or leave multi-lateral partnerships.
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ABSTRACT

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Keywords: multi-partner R&D alliance; multi-partner diversity; value creation; value appropriation.
INTRODUCTION

Multi-partner alliances (MPAs) have gained popularity in technology-driven industries due to the increasing speed of technological advancements, the fierce competitive pressure to set the next technological standards, and the increasing complexity of problems to solve. Firms voluntarily engage in MPAs in multilateral value chain activities to take advantage of their complementary resources and capabilities, to access valuable information, to share the costs and risks of undertaking exploratory and uncertain activities, to shorten the product lifecycle, and to improve their collective competitive advantage (Lazzarini, 2007; Das & Teng, 2002; Lavie, Lechner, & Singh, 2007; Gomes-Casseres, 2003). The MPA appear in different forms such as R&D consortia, multiparty production bundling, supplier networks, joint bidding, and industry constellations (Das & Teng, 2002; Li, Eden, Hitt, Ireland, & Garrett, 2012; Ekeh, 1974; Lavie et al., 2007). MPAs setting is a unique phenomenon to study, as it cannot be considered as a simple collection of dyadic alliances among a group of firms, in which each dyadic relation is independently managed by its corresponding partner firms, or as an ego network (alliance portfolio), in which a focal partner firm manages each of its direct relation with its counterparts independently (Lavie et al., 2007). In addition, the dynamics of multi-lateral interaction within MPAs is substantially different from the dynamics of the dyadic interaction in bilateral alliances, as the received wisdom from sociology suggests that the dynamics of interactions in a group substantially changes when it turns from a dyadic relation to triadic or multilateral relations (Simmel, 1950).

To our knowledge, prior research has not systematically addressed the performance consequence of multi-partner alliance diversity (MPD). At first, while different types of resources utilized in MPAs may have different performance consequences, the current literature does not
take into account the different types of resources that partner firms share, or seek, in MPAs. To this extent, the prior research’s arguments and findings for or against diversity in MPAs are inconclusive. On the one hand, some literature suggests that a highly-diversified partnership provides an opportunity for partner firms to access various sources of information and knowledge, and enriched resource pools to create synergy and hedge the risks of undertaking uncertain activities (Ozcan & Overby, 2008; Sakakibara, 1997a, 2001; Xu, Fenik, & Shaner, 2014). On the other hand, such an opportunity comes at a cost, because a diversified partnership can impede communication, constrain knowledge transfer, and develop potential for conflict and opportunistic behaviours of partners, all of which increase coordination costs and destroy value creation (García-Canal, Valdés-Llaneza, & Ariño, 2003; Gulati, Wohlgezogen, & Zhelyazkov, 2012; Li et al., 2012). Therefore, it seems that the relevant arguments for and against the diversity of MPAs could be equally compelling, and so are its performance consequences.

Another important reason for such ambiguity is that prior research does not distinguish between performance consequences of multi-partner diversity at the MPA level and the partner firm level. The performance consequences of MPD at alliance and partner firm levels are not necessarily aligned, as the mechanisms and dynamics of value creation at the MPA-level, is not necessarily compatible with the mechanisms of value appropriation at the partner firm level. This issue is not limited to the study of MPAs; for instance, Lee, Kirkpatrick-Husk, and Madhavan (2014) show in their meta-analysis that the performance consequences of alliance portfolio diversity are neither theoretically clear nor empirically consistent, as existing studies tend to overlook the fundamental difference of diversity and performance at different levels of analysis.

This study attempts to systematically examine the relation between MPD and performance. We argue that MPAs as a multifaceted phenomenon cannot be simply explained in a single
dimension, as participating firms join MPAs with different attributes in terms of their internal resources and capabilities, their relational resources with their counterparts in MPA, and their status in the global alliance network. To this end, we dimensionalize the MPD construct with respect to partner firms’ attributes and resources within-firm, between-firm, and across the entire network, and we separately examine the performance consequence of each dimension at the MPA level as well as the partner firm level. Following Harrison and Klein’s (2007) conceptualization of diversity, we identify three dimensions of MPD: ‘partner variety’ to address the differences of partner firms’ resources, ‘relational separation’ to address the differences of relational resources (i.e., prior tie strength) between partner firms within the MPA, and ‘status disparity’ to address the differences of network resources (i.e., status) across partner firms.¹

We argue that diversity in each of these dimensions has a quadratic inverted U-shaped relation with MPA performance. Partner variety provides the MPA with more opportunities and resources to achieve its intended goal, but as the MPA’s diversity in this dimension exceeds a certain point, MPAs’ ability to exploit these opportunities sharply decreases. Likewise, moderate relational separation among partner firms may benefit MPA, as partner firms may learn from novel procedures and ideas from the partner firms that they had less interaction before, but excessive relational separation may lead to dividedness in the MPA and may hurt the alliance performance. Finally, while status disparity may ease coordination via higher status firms to a certain level and benefit MPAs to a certain level, the inequality across MPA with high disparity can disturb the

¹ We follow the Harrison & Klein’s (2007) choice of label for the sake of consistency in the literature; we will discuss it in more detail in the next section.
required transparent multilateral interaction for efficient collaboration among the alliance partners, exerting a negative effect on MPA performance.

At the partner firm level, however, we argue that the performance consequence of each aforementioned diversity dimension is not consistent with the MPA level. Partner firms with lower internal knowledge variety, or in the other words with narrower knowledge breadth, do not benefit from partner variety as much as their counterparts with broader knowledge in an MPA. With respect to relational separation and status disparity, likewise, partner firms with a brokerage role in divided partnerships, as well as those with high status in the global alliance network can extract a higher share of value created by the MPA.

We examine our theory in the context of technological collaboration, focusing on R&D consortia in high-tech sectors including electronic and computer components producers, telecommunication equipment and system providers, medical equipment producers, and firms from the pharmaceutical industry. The rationale behind this choice is that these industries regularly practice multi-lateral partnership for their technology-based activities. We compiled a sample of multi-partner R&D collaborations from the SDC platinum data set, enhanced by FACTIVA, and combined with the patent data extracting from PATSTAT by matching assignee names of granted patents to firm names of the MPA sample. Then, to have more precision for the patent-based dependent variables, we established the technological scope of each alliance by carrying out an elaborate content analysis on the alliance’s technological description to code their technological domain based on the patent classification index. We test our hypotheses at two distinct levels of MPA and partner firms. Overall, our findings are consistent with our main arguments that the performance consequence of multi-partner alliances are different with respect to the distinct
dimensions of MPD. Specifically, our results underline the distinction between underlying mechanisms of value creation at MPA-level and value appropriation at firm-level.

To our knowledge, this study is the first to distinguish systematically the different dimensions of MPAs and examine the performance consequences of each dimension at both the alliance and partner firm levels. It offers a novel insight into the conceptual meaning of MPD and its performance consequences. We believe that this approach may contribute to our understanding of performance consequences of diversity in the general strategy literature as diversity is such an important construct in a wide range of contexts. The findings contribute to our understanding about the complex configuration of MPAs. They particularly underline the distinct dynamics of alliance and partner firm performance in MPAs. There are critical trade-offs to be considered by partner firms in their decision to join, stay, or leave multi-partner alliances. Finally, our findings also contribute to the resource-based view, as our approach examines the performance consequence of different types of resources at partner firm, between-firm, and global alliance network levels.

MULTIPLE-PARTNER ALLIANCE DIVERSITY: THE DIMENSIONS

Multi-partner alliances benefit from the diversity of their partner firms’ resources to fulfil their intended goals. The partner firms join an alliance with their internal resources within their organizational boundaries, with their relational resources based on prior relations with their counterparts in the MPA, and with their social capital based on the status that they have acquired in the global alliance network. Given the different nature and functions of these types of resources in MPAs, and consistent with Harrison and Klein’s (2007) systematic approach to the diversity construct, we identify three dimensions for MPA diversity based on resources within-firm, between-firm, and across the entire network.
Harrison and Klein’s (2007) theoretical paper identifies three "within-unit" diversity types: variety, separation, and disparity. Variety refers to differences in kind, source, or category of background and associated experience among actors (e.g., different functional domains or industrial experience) that implies uniqueness or distinctiveness of information. Separation refers to differences in lateral position or opinion among actors (e.g., different values, beliefs, or attitudes of partners), implying disagreement or opposition. Finally, disparity refers to differences between actors’ social capital or resources held among members (e.g., different network status, size, and revenue) and implies inequality or relative concentration (Harrison & Klein, 2007). In the following, we explain each dimension of diversity in the context of MPAs with respect to Harrison and Klein’s (2007) typology ('HK typology' hereafter). We also describe the nature of minimum and maximum diversity in each dimension in this context. Table 1 summarizes the key attributes of each dimension and its manifestation in MPAs.

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Insert Table 1 about here
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In the context of technological-based MPAs and at firm level, partner variety can be attributed to the differences of knowledge, information, and resources across partner firms; partner firms with unique and distinct attributes provide their partnerships with the maximum partner variety. These attributes are consistent with the HK specification regarding to the variety types of diversity that refers to the qualitative difference of members on a categorical attribute such as functional backgrounds, knowledge, source of information and resources. A high level of variety usually suggests a broad level of availability of the target attribute.
As pertain to relational resources between each pair of partner firms within an MPA, it is argued that different partner firms develop varying levels of trust, kinship, and understanding toward each other based on their prior relations. Therefore, the difference in the strength of relations can potentially lead to faultlines between cohesive subgroups of partner firms, because of mistrust, animosity, and conflict in their approaches to their collaboration (Heidl, Steensma, & Phelps, 2014). In this respect, the highest degree of separation occurs when partner firms are divided into two subgroups, each taking a stance as far from the other as possible; in contrast, the minimum relational separation occurs when all partner firms practice similar approach in their partnership and form a single cohesive group. These attributes suit the HK separation type of diversity that refers to the difference in opinions, beliefs, goals, and cognitive processes among the members. That is, the members’ differences in terms of a single continuous attribute such as commitment, trust, or belief in the goal of collaboration affects the cohesion between them and leads to a set of systematic consequences; a high degree of polarization in such attributes often represents a high level of conflict and separation among the members.

Finally, the network resources, or the social capital of partner firm can be a source of diversity. While relational resources refer to prior ties between partner firms within an MPA, network resources brought by a partner firm is accumulated from the entirety of its past relations, not just those relations with partner firms of the focal MPA. Social capital can provide firms with credit, privileged access to information, opportunities, and reputation or status (Nahapiet & Ghoshal, 1998; Granovetter, 1985). According to social network theory the centrality position of an entity, as a particular node in the global network, can reflect its social status (Bonacich, 1987). Likewise, the centrality position of a partner firm in its global networks can provide access to information through direct and indirect ties, and being in the different possible paths of information
provides firms with this chance to influence the information flow between the other firms in the network. Likewise, disparity attributes in HK typology are income, prestige, status, and social power of members. It is assumed in this dimension that members can be different in the degree of possession of specific attributes or situation that also implies their prestige, quality and income (Gnyawali & Madhavan, 2001). In this respect, multi-partner alliances in which the status of one firm outranks the others has the maximum disparity, because the high-status firm can dominate the MPA; in contrast, minimum diversity occurs when all firms are in the same status, either low or high. It should be considered that disparity dimension is asymmetric by nature; that is, if all partner firms have high status except one, the disparity would be low, because in this case just one firm is disadvantaged relative to the majority.

It is worthy to note that the overall size of MPA (i.e., the number of partner firms) does not address "within-unit" types of diversity; in addition, prior research has shown that the advantage of a multi-partner alliance is in fact not so much determined by its size, but by certain characteristics and quality of the partner firms and their interrelations (e.g., Stuart, 2000).

THE ALLAINECE & PARTNER FIRM PERFORMANCE IN MULTIPARTNER ALLIANCES

"A multi-partner alliance is a collective, voluntary organizational association that interactively engages its multiple members in multilateral value chain activities, such as collaborative research, development, sourcing, production, or marketing of technologies, products, or services" (Lavie et al., 2007, p. 578). Strategic alliance research suggests that MPAs may provide some benefits such as cost sharing, risk reduction, knowledge and resource access, and flexibility to the partner firms (Sakakibara, 1997b; Das & Teng, 2002; Hagedoorn, 1993), existing
studies provide only limited support to these expectations. In the context of alliance portfolios, studies show that value creation at the alliance level does not guarantee the value appropriation at firm level, and partner firms may not reap the benefit as they expected or as they were supposed to do (Lavie, 2007; Lee et al., 2014). In other words, a partner may not be able to fully appropriate the produced collaborative rent from shared resources. In addition, the competitive nature of relationships between the partner firms, may affect the value appropriation process of the partner firm (Lavie, 2007). Likewise, to have a true understanding of the performance consequences of multi-partner alliances, it would be insightful to distinguish between the value creation mechanism, leading the alliance performance, and the value appropriation mechanism, leading to the partner firm performance. In the following, we separately examine the performance at MPA level and at partner firm level with respect to each dimension of diversity.

**Value Creation at MPA level**

**Partner Variety**

The most explored dimension of diversity in the alliances is partner variety. Extant studies show that variety in terms of partners’ differences in their resources, knowledge, information, or experience is a prevalent rationale for creating multiple alliances (Baum, Calabrese, & Silverman, 2000; Das & Teng, 2002; Ozcan & Overby, 2008; Sakakibara, 1997b).

A diversified MPA in this dimension can benefit from the critical and complementary resources and capabilities to achieve fuller utilization of partner firms’ resources and create more synergy and added value (Das & Teng, 2000; Lazzarini, 2007). The variety of knowledge and problem-solving capabilities, as well as the spread of non-redundant knowledge across partner
firms enable the partnership to explore novel opportunities and find more creative solutions for their common problems (Olk & Young, 1997).

However, when the difference between partner firms’ shared resources increases, the exploitation of these resources and opportunities within MPAs is not guaranteed. Indeed, studies in dyadic alliances show that as the difference between partner firms’ resources increases, the required mutual understanding and relational absorptive capacity to assimilate and recombine their shared resources decreases (Sampson, 2007; Lane & Lubatkin, 1998; Mowery, Oxley, & Silverman, 1996). In the context of MPAs, this undesired effect can be even stronger as the resources are embedded in idiosyncratic routines of multiple partner firms, so more difficult to be extracted and exploited in their collective effort.

Therefore, while partner variety increases the chance of accessing complementary resources and non-redundant knowledge, it also comes with difficulties in absorption and exploitation of these resources in MPAs, so we expect that partner variety bears a nonlinear relationship with innovative performance of MPAs.

**Hypothesis 1a:** Multi-partner R&D alliances with moderate partner variety has higher innovation performance (create more value) than alliances with very low or very high levels of partner variety.

**Relational Separation**

As discussed earlier the separation type of diversity refers to the difference in opinions, beliefs, and cognitive processes among the members. Extant studies suggest that partner firms who are strongly tied to each other are more likely to develop a shared understanding and closer opinions and beliefs to reinforce their existing relationships and facilitate the exploitation of shared
knowledge bases (Beckman, Haunschild, & Phillips, 2004; Verspagen & Duysters, 2004). That is, engaging in recurrent alliances with a select group of partner firms can influence their cooperative behaviour (Gulati, 1998), diminish exchange hazards and promote trust (Gulati & Nickerson, 2008), and improve the chance of effective coordination across partner firms to facilitate the flow of knowledge and information and complete their joint and individual tasks (Gulati et al., 2012).

Hence, as the variation of tie strength between a group of partner firms based on their prior interactions increases, fragmented subgroups, which are cohesive within but cannot effectively interact between, emerges (Heidl et al., 2014; Gibson & Vermeulen, 2003). Such polarization leads to more conflicts, reduces the cooperative motivation of partner firms, and damages the embedded relation between these subgroups, so the expected synergy, coordination, cooperative culture, and the performance of working with a group of partners diminishes (Das & Teng, 2002).

Nevertheless, having new partners with no prior ties, implying the difference in opinions and cognitive processes in this context, can lead to productive conflict specifically in research collaborations. In addition, new partners can provide MPAs with new channels with different perspectives and new knowledge that was not available through existing immediate network (Lavie & Rosenkopf, 2006), so increase the chance of finding novel ideas, or new configuration of knowledge resources.

Therefore, while relational separation to a certain level can provide partner firms with new channels of information and knowledge resources, excessive relational separation can severely reduce the required cooperative culture in MPAs, so we expect that relational separation bears a nonlinear relationship with innovative performance of MPAs.
Hypothesis 2a: Multi-partner R&D alliances with moderate relational separation has higher innovation performance (create more value) than alliances with very low or very high levels of relational separation.

Status disparity

Network research shows that the firm’s structural position, centrality, comes with status and social power (Bonacich, 1987; Gulati, Nohria, & Zaheer, 2000; Nahapiet & Ghoshal, 1998; Stuart & Sorenson, 2007). As firms develop more central network positions, they accrue resource and information benefits that enhance their ability, social power, and so their performance (Powell, Koput, & Smith-Doerr, 1996; Shipilov & Li, 2008). In addition, firms with central positions in the global network are particularly able to achieve the benefits of ties to prominent partners because centrality provides superior information, legitimacy, and prestige thus lessens power asymmetry and improve their negotiation power (Bae & Garguilo, 2004).

Status disparity addresses the difference of partner firms’ status in the global alliance network. Status disparity implies that at least one partner firm has higher status than its counterparts do. Such disparity may benefit MPAs in twofold. First, it provides valuable information, legitimacy, and prestige to MPA that can benefit all. In addition, powerful, high status partner firms can facilitate coordination across partner firms to align and adjust partners’ actions to achieve jointly determined goals (Gulati et al., 2012, p. 537).

However, high level of status disparity comes with the inequality of the status and asymmetry of social power among partner firms that leads to conflict of interest and disturbs the required transparency for efficient cooperation. This disparity induces high-status firms to their unilateral outcome at the cost of their partners, so the chance of their opportunistic behaviour
increases (Lavie, 2006, 2007). Low-status firms, in anticipation of such opportunistic behaviour by high-status counterparts, will exert less effort towards the MPA. Therefore, even if partner firms have strong intention for collaboration, status disparity induces them to be less transparent and institute protective mechanisms to limit their outbound spillover, which will dampen the MPA performance.

Therefore, while status disparity provides partner firms with accessing superior information, prestigious, and legitimacy as well as easing the coordination within MPA, it can harms the cooperation in MPAs, so we expect that status disparity bears a nonlinear relationship with innovative performance of MPAs.

**Hypothesis 3a:** Multi-partner R&D alliances with moderate structural disparity has higher innovation performance (create more value) than alliances with very low or very high levels of structural disparity.

**Value Appropriation at Partner-firm Level**

Diversity in different types of resources has performance consequences at both MPA and partner firm levels, but their effects on the partner firms’ performance are conditioned by partner firm’s resources. We argue that the mechanism of value creation at MPA-level is not necessarily applicable to value appropriation mechanisms at partner-firm level, so we do not focus on the main effect of diversity dimensions at MPA-level on the firm-level performance. We focus on the interaction of MPA diversity in each dimension with its corresponding partner firm resources on the proportional value that partner firms appropriate in compare to all MPA.
Partner variety at MPA-level and internal Knowledge variation at partner-firm level

At firm level, received research shows that getting access to a variety of knowledge provide more recombination and reconfiguration opportunities between new knowledge and existing knowledge to come up with more creative solutions (Sampson, 2007; Caner, Cohen, & Pil, 2017). However, the firms’ ability to learn and utilize novel knowledge from different types of knowledge sources is a function of their absorptive capacity with respect to each of these new sources of knowledge (Cohen & Levinthal, 1990; Lane & Lubatkin, 1998). The prior related knowledge allows firms to absorb and recombine the created knowledge and resources in their partnerships with their own existing ones (Grant & Baden-Fuller, 1995; Lavie, 2006; Dyer, Singh, & Kale, 2008; Kogut & Zander, 1992) and offers them the opportunity to access complementary knowledge and skills to exploit their existing capabilities or to explore novel opportunities (Lavie et al., 2007; Lavie & Rosenkopf, 2006).

In the MPAs with a higher variety of knowledge and resources due to the partner variety, partner firms with broader internal knowledge have more chance to appreciate new knowledge and can appropriate more value than their counterparts with limited internal knowledge variety. In the other words, partner firms with limited variety of knowledge can proportionally appropriate less value that their counterparts who enjoy a broader variety of knowledge in a diversified MPA in this dimension.

Therefore, regardless of the relation between partner variety and value creation at MPA which was indeed a function of partners’ resource variety, partner firms’ value appropriation from their collective effort diverges to the extent of their differential internal knowledge variety.
Hypothesis 1b: The interaction between MPA partner variety and partner firm's internal knowledge variety has a positive effect on partner firm’s value appropriation.

Relational separation at MPA-level and brokerage role of partner firm

At the firm level in a multilateral partnership setting, partner firms who have stronger relations with their counterparts, especially with those who are weakly connected with each other, can enjoy their brokerage role (Ahuja, 2000; Zaheer & Bell, 2005). Brokerage role can provide firms with more diverse and timelier information to take advantage of weak ties between counterparts as well as power and control to play off one counterpart against another (Burt, 2009; Zaheer, Gözübüyük, & Milanov, 2010).

With this respect, a partner firm with close relations with its counterparts in an MPA with high relational separation has the chance to take advantage of both different novel ideas and perspectives as well as the fault lines between them. Having relation with separated subgroups improve the bargaining power of the focal firm in terms of the possibility of working with both subgroups and of the unique information from both subgroups, giving it the upper hand to appropriate a larger share of created value (Dyer et al., 2008; Lavie, 2006). With this respect, partner firms with more brokerage opportunities take even more advantage of their unique positions in MPAs with deep divisive fault lines (Heidl et al., 2014).

Therefore, it follows that regardless of the relation between relational separation and value creation at MPA, particular partner firm(s) can take advantage of their brokerage role to appropriate more value than other partners.
**Hypothesis 2b:** The interaction between MPA relational separation and partner firm’s brokerage role has a positive effect on partner firm’s value appropriation.

**Status disparity at MPA-level and status of partner firm**

At the firm level, a partner firm that has higher status enjoys its superior situation to access critical information, to get the upper hand in the ex-ante negotiations, and to take actions in cooperation that cannot be easily responded by their counterparts (Gnyawali & Madhavan, 2001). In addition, high status partner firm(s) usually take the lead to coordinate the collaboration, so they can influence it in a way to be more consistent with their routines and appropriate more value than their counterparts.

Therefore, it follows that regardless of the relation between status disparity and value creation at MPA, particular partner firm(s) can take advantage of their higher status to appropriate more value than other partners.

**Hypothesis 3b:** The interaction between MPA status disparity and partner firm’s status has a positive effect on partner firm’s value appropriation.

**METHODS**

**Empirical Design and Data**

**Empirical Design.** We tested our theory in the context of research collaboration in a group of high-tech industries. We selected a group of high-tech industries that regularly involve in practice of patenting innovations, and their heterogeneous population provides ample variation to test the hypotheses (Stuart, 2000). In addition, these industries regularly engage in multiple and simultaneous alliances to address different technological requirements and the risks of developing
and launching new products. With this respect, we focus on high-tech industries such as pharmaceutical, medical equipment, laboratory, computer, and electronics and communication industries with the following three-digit SIC codes: Drugs (SIC: 283), Computer and office equipment (SIC: 357), communication equipment (SIC: 366), Electronic Components and Accessories (SIC: 367), Laboratory, Optic, Measure, Control Instruments (SIC: 382), Surgical, Medical, Dental Instruments (SIC: 384), Telephone Communications (SIC: 481), Communication Services (SIC: 489), Computer Programming, Data Processing, etc. (SIC: 737), and Research, Development, Testing Services (SIC: 873).

Data. We collected the alliance data from the JV & Alliance section of SDC Platinum database. We selected the multi-partner R&D alliances that formed between 1990 and 2008 in the aforementioned high-tech industries, considering the SIC-Primary (i.e., SICP) flag of alliances. We identified 137 multilateral R&D alliances after re-checking the alliance status (i.e., completion), removing MPAs with undisclosed partners, and comparing the SDC information with the ones in FACTIVA dataset. Finally, we tracked historical alliances (all types of alliances, including dyadic alliances) all the way back to the year 1985 in order to ensure sufficient coverage of active alliances for the required analysis in this study.

The patents included in this study are obtained from the PATSTAT. Collected patents were granted between 1985 and 2013 to the partner firms of our sample. To determine the technological scope of each alliance, we did a content analysis on the technological description of each alliance in the SDC platinum database and FACTIVA, and followed the patent office examiners’ procedure.
to find the most relevant CPC\textsuperscript{2} sub-classes from the European Patent Office (EPO) search engine (Hunt, Nguyen, & Rodgers, 2012; White, 2010)\textsuperscript{3}. To evaluate our process and results, we checked our search process as well as a random sample of our findings with a patent examiner at the EPO office in the Hague in the Netherlands.

**Measures at MPA-level**

*Dependent Variable.* The measurement of *alliance innovative performance* in this study context is the aggregated number of granted patents to partner firms within the technological scope of alliances in a 5-year window after the alliance formation, namely *MPA partners’ post alliance in-scope patents*. The rationale behind this choice is that in successful R&D partnership, firms tend to legally protect their collective created knowledge in their partnership. We originally preferred to use patents registered by all partners as joint-assignees; however, the prior studies showed that this practice is not common in high-tech industries due to the legal issues (Hagedoorn, 2003), so we counted the post-alliance registered patents by partner firms as a proxy of their collective created knowledge.

*Independent Variables at MPA level.* MPD is a multidimensional construct that includes the variety, the separation, and the disparity dimensions. To this extent, we followed Harrison and Klein (2007) guidelines and measured each dimension with respect to their distinct attributes.

For the partner variety, we measured the variation of partner firms’ prior-alliance knowledge with respect to different knowledge categories. We used the Blau Index (Blau, 1977)

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\text{Blau Index} = \frac{\sum_{i=1}^{n} \sum_{j=1}^{m} (x_{ij} - \bar{x_i})(y_{ij} - \bar{y_j})}{\sum_{i=1}^{n} \sum_{j=1}^{m} (x_{ij} - \bar{x_i})^2 (y_{ij} - \bar{y_j})^2}
\]

\text{where } x_{ij} \text{ is the number of patents in category } i \text{ for partner } j, \bar{x_i} \text{ is the average number of patents in category } i, y_{ij} \text{ is the number of patents in category } j \text{ for partner } i, \text{ and } \bar{y_j} \text{ is the average number of patents in category } j.

\text{2 Cooperative Patent Classification}

to measure partner variety: $D = 1 - \sum p_i^2$, where ‘D’ represents degree of diversity, $p$ represents the proportion belonging to a given category ‘i’ which was coded based on. The variables range from 0 (a perfectly homogeneous group) to 1 (a perfectly heterogeneous group, with members spread evenly among all categories).

For the relational separation, we followed Heidl et al. (2014) suggestion to compute tie strength dispersion. Therefore, to assess tie strength dispersion within each multi-partner alliance $k$ in year $t-1$, we counted the number of prior ties formed by each dyad in the multi-partner alliance in a five-year moving window (i.e., $t-5$ to $t-1$). The strength of each prior tie was weighted based on the scope of activities that occurred in the prior alliance: 2 if technology co-development is involved and 1 for other activities. We then computed tie strength variance across multiple dyads within each sample multi-partner alliance for each year. Variance is essentially a measure of polarization that suits measuring of this variable (Harrison & Klein, 2007). A value of 0 indicates that tie strength is equal across all partner pairs. Higher values of variance indicates that tie strength within a multi-partner alliance is concentrated among a subset of partner pairs.

For the status disparity, Bonacich centrality, to measure a firm’s positional embeddedness. That is, we measured the Bonacich centrality for all sample firms based on their collaborative activities in the global alliance network. Then, we followed Harrison and Klein (2007) to calculate the coefficient of variance (i.e., variance/mean) of positional embeddedness among the multi-partner alliance members. Aligned with our definition for this dimension, the coefficient of variance captures the relative dominance in the MPA of partner firms with high levels of global network centrality.
Control Variables. This study controls several variables at MPA level. We controlled for the total registered patents by alliance partners before the alliance formation, the number of partners, international flag, SIC variety, governance type dummies, and the year indicator for the study time interval (we divided the time-interval of our sample to three 6-year period). We also followed Harrison and Klien’s (2007) guideline and considered the average of the weighted prior alliance number in our model to distinct between the relational separation in an MPA with high number of prior alliances and an MPA with lower number of prior alliances.

Measures at firm-level

Dependent Variable. To measure value appropriation, we measure the firm’s proportional innovative performance. That is the number of post-alliance patents, granted within the technological scope of alliance, by the firm to all post-alliance patents, granted within the technological scope of alliance, by all partner firms, namely Firm’s proportional post alliance in-scope patents. The rationale behind this choice is that we assumed that this measure reflects their appropriated value, or more precisely the acquired knowledge, from their partnership in compared to their counterparts at the same alliance.

Moderating variables at partner firm level. For measuring the Firm Internal knowledge variety, we measured the variation of partner firms’ prior-alliance knowledge with respect to different knowledge categories. We used the Blau Index (Blau, 1977) to measure partner variety:

\[ D = 1 - \sum p_i^2 \]

where ‘D’ represents degree of diversity, p represents the proportion belonging to a given category ‘i’ which was coded based on. The variables range from 0 (a perfectly homogeneous group) to 1 (a perfectly heterogeneous group, with members spread evenly among all categories).
For measuring the broker status of partner firms within MPA, we used the ratio of the mean to the standard deviation of the number of prior alliances of each partner firm. With this approach, partner firms with high and uniform numbers of prior alliances with their counterparts get the higher values, consistent with the situation of brokerage role in MPAs.

Finally, for measuring the status of partner firms we used the Bonacich centrality of each partner firm, as the common measure for the status of the firms (e.g., Shipilov & Li, 2008).

**Control Variables.** At firm level analysis, we incorporate relevant MPA-level control variables as well as the firm-level control variables. We control total registered patents by each partner firm before the alliance formation as a proxy of size (following Sampson (2007)), proportional innovative performance of each partner firm before the alliance formation (also as a proxy of proportional R&D expenditure of a partner firm), SIC code, and finally governance type dummy.

**Statistical methods**

As each partner firm nested in a multi-partner alliance, and we take into account both group level (i.e., MPA) and individual level (i.e., partner firms) in our analysis, multilevel analysis could be a recommended choice to test the hypotheses. However, as we used different variables at MPA level, we tried aggregation mode for MPA level and disaggregated model for individual firm level. It means that we only considered MPA variables at the group level, and we take partner firms variable into account at the partner firm level, as well as the MPA variables with which the partner firm-level variables interact. The results had more explanatory power (less log likelihood) than multilevel analysis so we report these results.
The dependent variables of our model are the sum of post-alliance in-scope granted patents to the partner firms at MPA level, so we run a negative binomial regression model to test our hypothesis at MPA level. At the partner firm level, the dependent variable of our model is the proportion of the count of partner firms’ in-scope granted patents to the total patents of partner firms in MPA, so OLS regression was the proper choice.

RESULTS

Results at MPA level

Table 2 presents the descriptive statistics at MPA level. Correlation table does not show any evidence for multicollinearity and multicollinearity test also show no VIF higher than 2 which is significantly lower that the suggested threshold in literature.

-----------------------------
Insert Table 2 about here
-----------------------------

In Table 3, we report the results of hypothesis tests at MPA level. Model 1 includes only the control variables. The control variables reports can be subject to inaccuracy due to other possible explanations (Cinelli & Hazlett, 2018), so our following report on the control variables should be considered with caution. The results show that the sum of prior in-scope patents of partner firms is positively associated with innovative performance of MPA, but the not the sum of total prior patents of partner firms. It underlines the importance of focusing on the technological scope of alliances, rather than the count of all patents of partner firms. The results also show that the variety of partner government mode (such as state-owned companies, universities, and private firms) in an MPA negatively associated with MPA performance. These results are consistent with the findings of alliance portfolio studies (Jiang, Tao, & Santoro, 2010) and suggests that MPAs
with different types of partners’ government mode and industry are less innovative than uniform
MPAs with those respects, due to lower levels of mutual understanding and incentive across
partner firms.

--------------------------------
Insert Table 3 about here
--------------------------------

In Model 2, the variable *Partner Variety* is introduced to test H1a. The results suggest a
curvilinear association between partner variety and innovative performance of the MPA. Partner
variety is positive, partner variety squared is negative, and our slope tests at the higher and lower
ranges of variety were significant (Haans, Pieters, & He, 2016), providing support for Hypothesis
1a. In model 3, we included the variable *Relational Separation* to tests Hypothesis 2a. The results
suggest a curvilinear association between relational separation and innovative performance of the
MPA. Relational separation is positive, relational separation squared is negative, and again our
slope tests at the higher and lower ranges of knowledge variety were significant. The Model 4
includes variable *Status Disparity* to test the H3a. The coefficient of status disparity and status
disparity squared are both positive and insignificant despite our prediction in this hypothesis. In
Model 4.1, we test the linear effect of status disparity. The results suggest a positive, but marginally
significant linear association between status disparity and innovative performance of MPA. These
results, which is in contrary to our prediction suggest that at least in the context of research
collaboration, status disparity might be a source of new ideas and coordination rather than lack of
cooperative culture.
We incorporate all the independent variables corresponding to the Hypotheses H1a, H2a, and H3a into Model 5. The results were unchanged. In sum, while the results provide support for Hypothesis 1a and 2a, the Hypothesis H3a is not supported in our sample.

**Results at partner firm level**

Table 4 presents the descriptive statistics at partner-firm level. Correlation table does not show any evidence for multicollinearity and multicollinearity test also shows no VIF higher than 2.

![Insert Table 4 about here](image)

Table 5 shows the results of our OLS estimation. Model 1 includes the control variables. The proportion of partner firms’ prior alliance in-scope patent number to MPA (total patents) has a significant positive effect on the proportion of partner firms’ post alliance in-scope patent number to MPA, as value appropriation (hereafter), and the number of partners has a negative effect; both expectable.

![Insert Table 5 about here](image)

In Model 2, the interaction of internal knowledge variety and partner variety on value appropriation (H1b) is tested. The coefficient is positive and significant. The marginal plot of interaction terms in Figure 1a shows that when Partner firms’ internal knowledge variation increases the marginal effect of partner knowledge variety on partner firm’ innovative performance increases.
Model 3 includes the interaction of brokerage-role of the partner firms with relational separation to address the H2b. The results are not significant; the coefficient is positive, but its magnitude is marginal. The marginal plot of interaction terms in Figure 1b show that as the broker status increases the positive effect of relational separation on innovative performance of partner firm increases. However, the results do not support H2b.

Finally, Model 4 addresses H3b, in which we asserted that partner firms with the higher status can enjoy the disparity in their partnerships. The coefficient of interaction term is positive and significant. The marginal plot of interaction terms in Figure 1c illustrates how with increasing the status disparity of partner firms, firms with stronger network position benefit from status disparity. The full model also supports above findings, and

--------------------------------
Insert Fig. 1 about here
--------------------------------

DISCUSSION

This study investigates the performance consequence of multi-partner alliance diversity (MPD) at both multi-partner alliance (MPA) and partner firm levels in the context of research collaboration. It complements prior research on the heterogeneity of alliance benefit among the partner firms (i.e., firm performance) in MPA (Lavie et al., 2007; Lazzarini, 2007), by considering the performance variation of both MPA and partner firms with respect to the different dimensions of MPD. We make a distinction among the different types of resources, to underline the distinct dynamics of different dimensions of diversity in multi-partner alliances. Our results show while diversity in within-firm resources, namely partner variety, and between-firm resources have an inverted U-shaped effect on MPA performance, diversity in network resources, namely status
disparity has a linear positive effect on performance. Our findings also reveal the diverging mechanisms between value creation at the multi-partner alliance level and value appropriation at the partner firm level regarding each dimension of MPD. We demonstrate that some partners can benefit more than what others do, even if the total partnership worse off, and vice versa. This divergence depends on the advantage or disadvantage of a partner firm to its counterpart in each dimension.

This study joins to the longstanding stream of strategy research on the performance consequence of diversification strategy (Rumelt, 1982; Montgomery, 1985; Markides & Williamson, 1996; Jiang et al., 2010; Richter, Schommer, & Karna, 2017; Ahuja & Novelli, 2017). In the context of multi-partner alliances, as collective, voluntary organizational associations; the diversification is a consequence of the initial decision of partner firms at the time of alliance formation, as well as the decision of partner firms to stay, leave, or invite and accept the new partners to join their alliance. Our findings show that diversity in different types of resource leads to distinct rent variation at both MPA and partner firm levels. This approach addresses the quest of literature for more fine grained theoretical and empirical analysis of the mechanisms through which diversity adds or subtracts value (Ahuja & Novelli, 2017).

Our findings also contribute to the resource-based view literature (Amit & Schoemaker, 1993; Barney, 1991; Wernerfelt, 1984), by examining the effect of variation of different types of resources on the collective rent of partner firms at MPA level as well as the rent of partner firms in their multi-lateral partnership. At MPA level, our results show that the performance consequences of variation in different types of resources across sub-entities within an entity. At firm level, our findings show that how partner firms’ resources conditions their benefit from the available resources and values in their environment.
Our findings also contribute to the understanding of value creation and appropriation mechanisms of MPAs by taking into account both the value creation at MPA from the value appropriation mechanisms at partner firm levels in the same study. On one hand, the value creation mechanism at MPA is a function of partner firms’ contributed resources MPA as well as the dynamics of cooperation and coordination of partner firms in their mutual effort (Gulati et al., 2012; Gulati, 1998). On the other hand, the value appropriation mechanism at partner firm level depends to the value of their contribution, the relevancy of resources, their status and power, and their brokerage position (Adegbesan & Higgins, 2011; Dyer et al., 2008; Lavie, 2006; Lavie et al., 2007). Our findings show the divergent of these two mechanisms at MPA and firm level in such a way that value creation mechanism in MPAs alongside with diversification in each mentioned dimensions in this study may not compatible with the value appropriation mechanism in partner firms. In simple words, we show that what is beneficial for alliance is not necessarily beneficial for all partner firms.

Naturally, this research has important limitations. First, the alliances examined in this study are those pertaining to research collaborations, and although our argumentation is general and can apply to all types of alliances, but there is a cautious in the generalizability of our findings to the other types of alliances (e.g., marketing, manufacturing, and supply chain).

Second, our selected measures for the MPA and partner firm’s performance are not the most precise measure of the performance, given the accuracy of patents in measuring the firm’s (innovative) performance. However, our treatment in specifying the scope of alliance offers a solution to use patent data in a more precise way to measure innovative performance of the firms. Third, the performance is a multifaceted construct and measuring the performance in one aspect may not represent the realized performance of alliances and partner firms. However, we tried to
partially address this issue by narrowing our sample selection strategy to the research collaborations that explicitly specified their research agenda. In addition, the same argument might be applicable to the other aspects of performance such as status accumulation, market share, or financial outcome.

Further studies are needed to understand better the complexity of configuration and dynamics of value creation and appropriation in MPAs. MPAs appear in different forms and we only focus on one form (i.e., R&D collaboration) in this research. Investigating the configuration and dynamics of the other forms of MPAs may improve our general understanding about this phenomenon. Future research might also take into account the other types of performance to improve our theoretical and empirical understanding of dynamic of value creation and creation in MPA. This research tried to address the performance of MPAs in a specific context with elaboration on the alliance scope. However, we believe that it is necessary to have a systematic examination of alliance performance measures at alliance level, rather than common focal firm level. Finally, our approach to systematically examine the diversity in the context of multi-partner alliances can apply to other relevant phenomena such as alliance portfolios and corporate firms.

REFERENCES


Table 1:

A Summary of the Diversity Dimensions in MPA
(The first two columns are retrieved from Harrison and Klein (2007, T.1)).

<table>
<thead>
<tr>
<th>Diversity Type</th>
<th>Represents the composition of differences in</th>
<th>Manifestation at MPA</th>
<th>The MPA configuration at maximum diversity</th>
<th>MPD Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variety</td>
<td>Kind, source, or category of relevant knowledge or experience among unit members; unique or distinctive</td>
<td>The type of resources and capabilities of the partner firms</td>
<td>Each partner firm has a unique and distinct resource and capability to contribute to their collaboration.</td>
<td>Partner variety</td>
</tr>
<tr>
<td>Separation</td>
<td>Lateral position or opinion among unit members, primarily of value, belief, or attitude; disagreement or opposition</td>
<td>The strength of prior alliance relations across partner firms</td>
<td>Divided in two subgroups with the maximum possible opposition in their approaches to their collaborations.</td>
<td>Relational separation</td>
</tr>
<tr>
<td>Disparity</td>
<td>Proportion of socially valued assets or resources held among unit members; inequality or relative concentration</td>
<td>The status of partner firms in their global network.</td>
<td>One partner firm has the highest possible status, while the other are at the lowest.</td>
<td>Structural disparity</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>S.D.</td>
<td>Min</td>
<td>Max</td>
</tr>
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<td>------------</td>
<td>------------</td>
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<td>-------</td>
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<td>1</td>
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<td>Status Disparity</td>
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<td>1265.3358</td>
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<td>6</td>
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<td>7427.1448</td>
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<td>Partner government mode variety dummy</td>
<td>0.5036</td>
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### TABLE 3: Negative Binomial Estimates for MPD and Value Creation

<table>
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<tr>
<th>VARIABLES</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
<th>Model 4.1</th>
<th>Model 5</th>
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<td>Partner Variety (H1a)</td>
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<td>14.43***</td>
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<td></td>
<td>(1.791)</td>
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<td>Partner Variety Squared (H1a)</td>
<td>-13.93***</td>
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<td>(1.746)</td>
<td>(1.716)</td>
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<td>Relational Separation (H2a)</td>
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<tr>
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<td>(0.00402)</td>
<td>(0.00434)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Relational Separation Squared (H2a)</td>
<td>-7.45e-05***</td>
<td>-6.53e-05***</td>
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<tr>
<td></td>
<td>(1.28e-05)</td>
<td>(1.25e-05)</td>
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<tr>
<td>Structural Disparity (H3a)</td>
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<tr>
<td>Structural Disparity Squared (H3a)</td>
<td>0.272</td>
<td>0.561*</td>
<td>-0.333</td>
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<td></td>
<td>(0.980)</td>
<td>(0.288)</td>
<td>(0.851)</td>
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<td>Prior alliance mean within MPA</td>
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<tr>
<td></td>
<td>(0.00103)</td>
<td>(0.000966)</td>
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<tr>
<td>Mean of Centrality within MPA</td>
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<td></td>
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<tr>
<td>MPA partners' pre alliance in-scope patents</td>
<td></td>
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<td></td>
<td>0.000675***</td>
<td>0.000694***</td>
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<td>(0.000110)</td>
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<td>(2.45e-05)</td>
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<tr>
<td>Partner government mode variety dummy</td>
<td>-0.413*</td>
<td>-0.390**</td>
<td>-0.242</td>
<td>-0.444**</td>
<td>-0.443**</td>
<td>-0.310</td>
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<td></td>
<td>(0.227)</td>
<td>(0.196)</td>
<td>(0.224)</td>
<td>(0.222)</td>
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<td>SIC variety</td>
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<td>(0.760)</td>
<td>(0.678)</td>
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<td>(0.667)</td>
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<td>Joint venture dummy</td>
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<td>(0.301)</td>
<td>(0.275)</td>
<td>(0.277)</td>
<td>(0.292)</td>
<td>(0.291)</td>
<td>(0.256)</td>
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<td></td>
<td>(0.0892)</td>
<td>(0.0771)</td>
<td>(0.0865)</td>
<td>(0.0922)</td>
<td>(0.0911)</td>
<td>(0.0771)</td>
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<td>Constant</td>
<td>5.164***</td>
<td>1.403***</td>
<td>3.968***</td>
<td>4.330***</td>
<td>4.252***</td>
<td>1.087*</td>
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<td></td>
<td>(0.615)</td>
<td>(0.576)</td>
<td>(0.630)</td>
<td>(0.766)</td>
<td>(0.724)</td>
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<td>Observations</td>
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<td>Log Likelihood</td>
<td>-1084</td>
<td>-1060</td>
<td>-1071</td>
<td>-1080</td>
<td>-1080</td>
<td>-1047</td>
</tr>
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</table>

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1
(Year and Industry dummies are included)
<table>
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<th>Min</th>
<th>Max</th>
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<td>1</td>
<td>Proportion of post-alliance patents</td>
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<td>2</td>
<td>Proportion of pre-alliance patents</td>
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<td>Firm Internal knowledge variety</td>
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<td>0.9894</td>
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<td>Broker status</td>
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<td>Bonacich Centrality</td>
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Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1
(Year, Industry, JV, IJV dummies are included)
Figure 1a, b, & c:
The marginal effect plot of interaction terms for partner firm prior alliance patents (internal knowledge variety) and knowledge variety in MPAs (a: the upper one), for broker status of partner firms and the variation of prior-alliance firms in MPAs (b: the middle one), and for the Bonacich centrality of partner firms and structural disparity in MPAs (c: the lowest one).