Does Familiarity Foster Innovation?  
The Impact of Alliance Partner Repeatedness  
on Breakthrough Innovations  

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ABSTRACT  Does familiarity with alliance partners promote breakthrough innovations? This study draws on the literature of interorganizational routines to examine the impact of repeated R&D collaborations within a firm’s alliance portfolio on its breakthrough innovations. Specifically, we contend that the benefits and liabilities of interorganizational routines, arising from alliance partner repeatedness at a firm’s alliance portfolio level, lead to an inverted U-shaped relationship between alliance partner repeatedness and breakthrough innovations. Further, we build on the recent theoretical development of interorganizational routines to propose that technological dynamism will make the inverted U-shaped relationship steeper. Analyses of approximately 230 firms in the US biopharmaceutical industry from 1983 to 2002 support our hypotheses. Our findings provide important implications for research on alliance portfolio and management of firm innovation.  

Keywords: alliance partner repeatedness, alliance portfolio, breakthrough innovations, technological dynamism  

INTRODUCTION  
Innovation is becoming increasingly critical for high-tech firms to gain competitive advantages. As the locus of innovation shifts from individual firms to firm networks, firms often form alliance portfolios to manage innovation activities (Powell et al., 1996). Prior research has suggested that the characteristics of a firm’s alliance portfolio affect the quantity and quality of resources that it is able to access (Lavie, 2007; Wassmer and Dussauge, 2012). How to configure an alliance portfolio to achieve superior innovation performance therefore becomes a critical strategic issue (Faems et al., 2005; Hoffmann, 2007). Indeed, technology firms often ally repeatedly with prior partners to develop novel technologies (Phelps, 2010; Sampson, 2005). While researchers have explored repeated collaborations at multiple levels of analysis (Cowan and Jonard, 2009; Goerzen, 2007;  

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Vanneste and Puranam, 2010), it remains unclear whether repeated R&D collaborations with partners in a firm’s alliance portfolio lead to desirable innovation outcomes, particularly high-impact innovations. In this study, we specifically ask: To what extent will repeated collaborations within a firm’s alliance portfolio affect breakthrough innovations?

We argue that there exist at least two important gaps in this area. First, prior research has provided only a partial account of how working with repeat partners impacts innovation. While some researchers have investigated how repeated partnerships may facilitate innovation though reduced transaction costs and improved coordination (Vanneste and Puranam, 2010; Wuyts et al., 2004), others have shown that repeated ties inhibit innovation by fostering inert mental models and locking firms into prior trajectories (Goerzen, 2007; Laursen and Salter, 2006; Uzzi and Lancaster, 2003). We contend that it is imperative to develop a perspective that captures the tension between the benefits and liabilities associated with repeated partnering.

Second, prior studies have seldom examined the boundary conditions of the impact of repeat collaborations on breakthrough innovations. For example, Sampson (2005) found that a firm’s repeated interactions with specific partners improve innovation outcomes, while Phelps (2010) showed that a firm’s repeated partnerships have no impact on exploratory innovations. Indeed, some of the inconsistencies surrounding the impact of repeated collaborations on innovation may arise from different contextual factors. Without a thorough understanding of the contingent effects involved, it may be difficult to precisely assess the consequences of repeated partnering and effectively manage alliance portfolio configurations.

We draw on the literature of interorganizational routines to investigate whether a firm’s familiarity with its R&D alliance partners facilitates or inhibits breakthrough innovations. On the one hand, the complexity, coordination, and uncertainty involved in producing breakthrough innovations suggest that a certain degree of familiarity with partners should facilitate the development of interorganizational routines, efficient coordination, and effective monitoring of the collaboration process (Zollo et al., 2002). On the other hand, too much partner familiarity may backfire if the partnership’s interorganizational routines are hamstrung by inertia and rigidity (Baum and Wally, 2003). These opposing tendencies would suggest that there is an inverted U-shaped relationship between alliance portfolio repeatedness and breakthrough innovations.

We further investigate the contingent effect of technological dynamism in the aforementioned curvilinear relationship. Although prior research has suggested that a dynamic environment may induce inferior learning among repeated partnerships (Goerzen, 2007), we follow the recent theoretical development in the organizational routine literature and argue that routines are inherently generative in nature and adaptive in changing environments (Howard-Grenville, 2005). The importance of interorganizational routines will be more salient in a dynamic environment because routines help reduce uncertainty and free cognitive resources for solving new problems (Feldman and Pentland, 2003; Lewin et al., 2011). Interorganizational routines not only provide simple rules for firms to cope with uncertainty in a high-velocity environment (Davis et al., 2009; Eisenhardt, 1989), but they also facilitate concerted effort to reach out for new knowledge in dynamic environments (Zollo et al., 2002). We thus contend that
technological dynamism will increase the value of partner repeatedness for breakthrough innovations before interorganizational routines become rigid.

Our study makes two major contributions. First, it goes beyond the extant research that focuses primarily on repeated ties at a dyadic level, and develops an interorganizational routine perspective to capture the mechanisms of repeated interactions at a portfolio level. We show that a certain degree of repeatedness at the alliance portfolio level is beneficial for firms to develop breakthrough innovations. Second, our study also contributes to the interorganizational routine literature by empirically demonstrating the adaptive nature of routines in a dynamic environment, which highlights the value of repeated interactions for joint problem-solving in the context of innovation development. However, a dynamic environment will also punish firms for their over-embeddness in repeated interactions.

THEORY AND HYPOTHESES

Firms are motivated to collaborate in order to develop breakthrough innovations, which are defined as high-impact innovations with the potential to introduce new technological trajectories or paradigm shifts (Ahuja and Lampert, 2001; Dunlap-Hinkler et al., 2010; Phene et al., 2006). Interfirm collaborations enable firms to combine their existing resources into novel configurations, share the costs and risks of uncertain R&D activities, and expedite the introduction of new technologies. However, setting up alliances involves expending significant time and effort to locate suitable partners and understand and assimilate their knowledge before the partnerships can be productive. This process is full of complexity and uncertainty, which demands smooth and continuous coordination between the firms. Knowledge recombination will be less effective if the participating firms do not develop interorganizational routines that facilitate coordination during this complex process (Zollo et al., 2002). The uncertainty associated with innovation also requires that the partner firms cooperate in formulating collaboration routines and keeping them up to date. The nature of these challenges suggests how repeated collaboration might promote more efficient innovation. Evidence indicates that breakthrough innovations in particular are less likely to emerge from first-time alliances. A certain degree of repeatedness within a firm’s alliance portfolio helps establish the interorganizational routines that facilitate the management of the ambiguities involved in developing breakthrough innovations.

Interorganizational routines are repetitive patterns of interdependent actions that have become embedded and reinforced through repeated interactions (Dionysiou and Tsoukas, 2013; Feldman and Pentland, 2003). A firm that forms repeat collaborations with prior partners often develops structural arrangements such as an alliance office or assigns specific liaison personnel. Such arrangements have been proved to be effective and efficient in managing the pervasive alliances among technology firms (Kale et al., 2002). Familiar partners are likely to develop a ‘who knows what’ directory of each other’s knowledge stock (Gino et al., 2010). Repeated interactions make it possible for partner firms to better understand their own behaviour and also the best practices for joint activities and contexts (Dionysiou and Tsoukas, 2013; Faems et al., 2012). Through
selection, replication, abstraction, and generalization of those best practices, firms develop repetitive patterns to guide their subsequent interfirm collaborations.

Interorganizational routines take various forms ranging from simple rules such as repetitive patterns for day-to-day operating procedures, to higher level routines or meta-routines that guide the smooth adaptation of lower-level routines to changing circumstances (Lewin et al., 2011). The meta-routines reflect the general and abstract nature of routines, while the practised routines are observable and context-specific. Feldman and Pentland (2003) proposed that routines have what they termed ostensive and performative aspects. The ostensive aspect of a routine describes it in principle and in schematic form. Shared ostensive schemata enable a common understanding and reciprocal expectations of joint activities in interfirm relationships (Dionysiou and Tsoukas, 2013). In contrast, the performative aspect of a routine is how it works in practice. Feldman and Pentland (2003, p. 107) observe, ‘... the performative aspect creates, maintains, and modifies the ostensive aspect in practice, in much the same way that speaking creates, maintains, and alters a language’.

The interorganizational routines, generated from repeated interactions among alliance partners, promote breakthrough innovations in at least two ways. First, these routines enhance the interfirm coordination for the management of complex innovative activities. In performative terms, these routines are based on the partners’ experience with what works and what does not work, and why and how the best practices can be applied in the current context (Kale and Singh, 2007). This knowledge codification process helps firms better understand the factors behind their past successes and failures, and helps them develop more convenient and less formal routines to facilitate day-to-day operations (Zollo et al., 2002). Such knowledge replication and transfer through routines reduces ambiguity abundant in the knowledge discovery process, and shifts the focus of those involved to more critical issues.

Second, these interorganizational routines enable firms to learn and adapt to new challenges in the innovation process. Routines are also a source of organizational learning in themselves (Feldman, 2000; Levitt and March, 1988). Departing from the traditional view that routines are a source of stability and inertia, recent development in this area has emphasized the adaptive nature of routines (Dionysiou and Tsoukas, 2013; Feldman and Pentland, 2003; Lewin et al., 2011). Routines are enacted by agents, who will choose from a repertoire of possible routines for the particular context or problem at hand. The performative aspect of routines also emphasizes subjectivity and improvisation in the construction of new routines. In other words, routines are not mindless, but effortful accomplishments building on prior best practices (Pentland and Rueter, 1994). As noted earlier, engaging in repeated interaction helps firms to develop structural arrangements which can revisit the goals, values, and assumptions of existing routines and adapt them to new situations in the innovation process; this is analogous to the ‘double loop learning’ described by Argyris and Schön (1978; cf. Feldman, 2000).

At the same time, it must be acknowledged that there is a risk of embeddedness in repeated relationships. With a very familiar partner, the structured routines that facilitate communication and coordination can become so rigid that they filter out novel ideas, leading to a familiarity trap. Repeated collaborations run the risk of locking the firms into prior mental models if the familiar partners unthinkingly adopt prior patterns of
interaction (Skilton and Dooley, 2010). The alliance can drift into exploitation at the expense of exploration (Koza and Lewin, 1998). The established routines may filter out brilliant ideas along with wasteful ones. Academic work on firm aging and innovation has shown that older firms tend to develop rigid structures that impede the generation of impactful innovations (Sorensen and Stuart, 2000). Indeed, work by Goerzen (2007) found that repeated alliance experience predicted inferior financial performance in a sample of Japanese multinational firms.

In addition, over-embeddedness in repeated relationships may make it difficult to significantly improve existing routines. Familiar partners also have a tendency to focus more on common knowledge (Stewart and Stasser, 1995), and their adaptation can become quite incremental and local (Rosenkopf and Nerkar, 2001). Their collective knowledge may become ossified with less than optimal recombination of existing knowledge and capabilities (Mayer and Bercovitz, 2008), leading to underutilization of the alliance’s absorptive capacity (Vasudeva and Anand, 2011). Laursen and Salter (2006) found that drawing deeply from certain external sources or channels for innovation activities initially improves innovative performance, but dampens it in the end. Micro-level studies have also suggested that repeated partners must deal with creative abrasion, or the wearing off of creative capacity (Skilton and Dooley, 2010). A higher degree of repeatedness in a firm’s alliance portfolio would therefore inhibit the development of breakthrough innovations, causing a downward slope between alliance partner repeatedness and breakthrough innovations.

Taken together, these influences suggest that the routine benefits of allying with familiar partners may increase with the degree of familiarity up to a point, but beyond that the benefits can be outweighed by the inertia and constrained adaptation of these routines at a higher degree of partner repeatedness, leading to an inverted U-shaped relationship. We thus propose the following hypothesis:

**Hypothesis 1**: A firm’s alliance partner repeatedness will exhibit an inverted U-shaped relationship with its development of breakthrough innovations.

**The Moderating Effect of Technological Dynamism**

We further delineate one contingency that highlights the tension between the benefits and liabilities associated with alliance partner repeatedness. Firms operating in high-technology industries must often deal with technological dynamism – rapid and unpredictable changes in the technologies involved. This resembles the state uncertainty or velocity dimension of uncertainty (Davis et al., 2009; Milliken, 1987). Technological dynamism demands frequent, indeed continuous updates of a firm’s knowledge base, which in turn will make existing routines between the focal firm and its repeated partners quickly obsolete (Glasmeier, 1991).

We argue that technological dynamism would be expected to amplify not only the benefits of repeated partnering but also the negative effects of too much familiarity. When partner repeatedness increases from a low to moderate degree (i.e., the upward curve), interorganizational routines will become more beneficial at a high level of environmental dynamism as compared to a low level for two reasons. First, when the alliance
repeatedness increases from a low to moderate degree, the routines and simple rules
developed from repeated collaborations will be more effective for a firm to navigate
through a high-velocity environment (Davis et al., 2009). Given the flood of information
typical of such environments, simple rules help a firm quickly identify the resources
needed for knowledge recombination, to make rapid decisions, and to capture fleeting
opportunities (Eisenhardt, 1989). In addition, mutual understanding helps each partner
accurately identify useful items in its partners’ knowledge pool and integrate them
effectively. The knowledge codified through prior experience of successes and failures
helps firms ‘see through the fog’ of ambiguities in knowledge discovery (Heimeriks et al.,
2012), which should promote innovation. Indeed, prior research found that scientists in
repeat partnerships could accurately identify the skills and expertise that their partners
possessed, allowing them to quickly respond to emerging opportunities by organizing
new research teams or initiating new research projects (Zollo et al., 2002).

With a moderate degree of familiarity, the interorganizational routines generated in
past collaborations may be flexible enough that the dynamic environment will trigger
higher-order routines (Bresman, 2013) or motivate firms to initiate explicit cognitive
efforts to continuously update previous routines for the new environment (Zollo et al.,
2002). Repeat partners may be able to develop concerted learning efforts (Sampson,
2005). Internal information flow between repeat partners may be limited, but familiar
partners are more likely to be able to collectively assimilate and process rapidly-
changing external knowledge. For example, Vertex Pharmaceuticals had repeatedly
collaborated with Kissei Pharmaceutical and Burroughs Wellcome. The repetition
has allowed Vertex to quickly adjust its alliances to address the rapid technological
changes in HIV research. Repeated ties that capture new knowledge may thus be more
effective than relying on a firm’s existing knowledge in a rapidly-changing technological
environment.

When there is excessive familiarity, however, environment dynamism will tend to
intensify the handicap imposed by rigid interorganizational routines such that the focal
firm will be less likely to assimilate fresh knowledge from external partners. The
interorganizational routines with familiar partners may then turn out to be even more
detrimental for developing breakthrough innovations than in a stable environment for
two reasons. First, the rigidity of interorganizational routines will stifle the creativity in a
dynamic environment because it will filter out more novel ideas arising from the
interfirm interactions. Research on creative destruction has shown how technological
discontinuities can make existing capabilities and routines obsolete (Tushman and
Anderson, 1986). The sunk cost invested in mature interorganizational routines can thus
discourage firms from exploring novel interfirm opportunities associated with increased
level of environmental dynamism. Second, excessive familiarity can induce inertia such
that the partnership will narrow down its knowledge search. This is of course particularly
dangerous when technological dynamism is high and there is a heightened demand for
incorporating novel knowledge into breakthrough innovations. Firms’ inertia in relying
on existing routines will therefore aggravate this adaptation demand, resulting in a
decreasing rate of breakthrough innovations. A dynamic technology environment should
thus exacerbate any inverted U-shaped relationship between partner repeatedness and
innovation performance on both sides of its maximum.
Hypothesis 2: Technological dynamism moderates any inverted U-shaped relationship as specified in Hypothesis 1 such that both the upward and downward slopes of the inverted U-shaped relationship will become steeper at a high level of technological dynamism.

METHODS

Sample

We collected longitudinal data on public firms in the US biopharmaceutical industry. Following the lead of prior studies, the sample was restricted to firms operating in the human diagnostics and therapeutics sectors (Stuart et al., 1999). This treatment is appropriate because the US biopharmaceutical industry relies heavily on alliances and is very research intensive. Prior studies have shown that firms in that industry form alliances in response to rapid technological changes. In addition, breakthrough innovations are crucial for the success of biopharmaceutical firms. They form numerous R&D alliances hoping to co-develop novel, high-impact products.

We obtained a list of companies from Recombinant Capital (RECAP), a leading provider of information on the biopharmaceutical industry. We then tracked these publicly traded firms from 1983 to 2002. This procedure yielded a sample of 351 firms. We collected patent information for those firms from the US Patent and Trademark Office (USPTO), and removed firms that filed fewer than two patents during the observation period. Since our unit of analysis is at the alliance portfolio level, we included only those observations where firms developed two or more R&D alliances. For the remaining firms we collected demographic information using Bioscan, Compustat, initial public offering (IPO) disclosure filings, and firm websites. After triangulating data from these various sources we constructed an unbalanced panel of 1430 firm–year observations.

Dependent Variable

Breakthrough innovations. Since breakthrough innovations are often subjectively defined and the product development process in the biopharmaceutical industry is extremely long, we opted to use the count of patents filed and eventually granted to a focal firm each year that were above the 97th percentile in the number of forward citations. Our operationalization of breakthrough innovations is compatible with those used in prior research on innovation (Ahuja and Lampert, 2001; Srivastava and Gnyawali, 2011). Specifically, we first determined the technical classes in which our sample firms filed patents. We then collected all US utility patents (over 330,000) within these classes, and scaled a patent’s forward citations by the mean value of forward citations for all patents within the same technical class and granted in that year (Hall et al., 2001). We then counted the number of patents that fell above the 97th percentile of weighted forwarded citations within their cohort as defined by the granted year and technical class (Srivastava and Gnyawali, 2011).
Independent Variables

_Altied alliance partner repeatedness_ was measured as the geometric mean of the repeat R&D alliances within a firm’s alliance portfolio. Since many alliances do not have termination dates, we used a five-year moving window to construct a firm’s yearly alliance portfolio (Yang et al., 2011). This was expressed mathematically as \((\prod R_i)^{1/N}\), where \(R_i\) is the number of R&D alliances the focal firm had with its \(i^{th}\) R&D partner and \(N\) is the total number of R&D partners. For example, if firm A has three R&D partners – firms B, C, and D – in year \(t\) and among them B and C are repeat partners (say, the fourth alliance with firm B and the second alliance with firm C), the value of the _alliance partner repeatedness_ variable for firm A would be \((4 \times 2 \times 1)^{1/3} = 2\) in that year. This measure is superior to an arithmetic mean because the geometric mean gives greater weight to even distributions (Fink and Jodeit, 1976). The higher the value, the more a firm engaged in repeated R&D collaborations.

_Technological dynamism_ was measured using a multi-step approach. We began with the entire population of biopharmaceutical patents from the USPTO. We regressed the number of patents filed in the most recent five years for each three-digit patent class on the calendar year. We then divided the standard error of that regression coefficient by the average number of patents filed within the class during the same period. Similar measures have been constructed in prior work on technological dynamism (Keats and Hitt, 1988; Wang and Chen, 2010). The value of the _technological dynamism_ variable for a given firm in year \(t\) is measured with the weighted average of its technological dynamism scores in the three-digit patent classes in which the firm filed patents. For example, if firm A filed one patent in class 424 in a given year and three in class 435, and if the technological dynamism scores for classes 424 and 435 were 0.16 and 0.12 in that year, then value of _technological dynamism_ for firm A in that year would be \(0.16 \times (1/4) + 0.12 \times (3/4) = 0.13\).

We also experimented with an alternative measure. Following Goerzen (2007), a big change in the number of patents was taken as indicating technological dynamism. We therefore measured technological dynamism using the percentage change in patents granted in each technology domain in the biopharmaceutical industry. Although differently constructed, both measures of technological dynamism yielded qualitatively similar results. We opted to report the results from the first measure only.

Control Variables

We controlled for certain key firm-level factors that may influence the occurrence of breakthrough innovations. First, the innovation literature has documented an important curvilinear relationship between firm age and innovation (Sorensen and Stuart, 2000). We therefore included both _firm age_ and _firm age squared_ to allow for the impact of firm aging on innovative output. We also included _firm size_, measured as the logarithm of the number of employees. _Exploration intensity_ was measured as the portion of drug discovery alliances out of the total R&D alliances (Rothaermel and Deeds, 2004). _Current active R&D alliances_ was another control measured as the total number of a firm’s ongoing R&D alliances. A technology firm’s innovative output may be correlated with the resources it allocates to R&D. We therefore included _R&D Intensity_, which was operationalized as the
firm’s annual R&D spending as a percentage of its total sales. Finally, we also included two alliance portfolio variables: portfolio knowledge stock and portfolio knowledge diversity. The former was measured as the total number of patents granted to a firm and its alliance partners in a given year. To construct the portfolio knowledge diversity variable, we first pooled the patents filed by all R&D partners together. We then measured the knowledge diversity at the alliance portfolio level by taking the conventional diversity formula of $1 - \sum (n_i/N)^2$, where $n_i$ is the number of patents within each patent class, and $N$ is the total number of patents filed by all of the R&D partners prior to year $t$.

Analyses

Since breakthrough innovations was a count variable, we adopted a negative binomial regression to estimate the parameters. A negative binomial regression is more appropriate than a Poisson model because the former can better deal with over-dispersion issue commonly found in the latter (Wooldridge, 2002). A potential selection bias might exist in our analyses because we included only firms that formed two or more R&D alliances. We therefore took a Heckman two-stage approach to deal with the potential selection bias. In the first stage we regressed the possibility of being selected to our sample on firm age, geographic density of biopharmaceutical firms within the same region, stock market uncertainty, and a dummy variable representing the passage of the National Cooperative Research and Production Act (NCRPA) in the USA (Beckman et al., 2004; Podolny, 1994; Sorenson and Audia, 2000). Geographic density was considered a good instrument as it is less likely to affect innovation quality directly but is more likely to affect the possibility of partnering with other firms. The passage of the NCRPA in 1993 presumably also affected alliance formation, but not the innovation outcomes. The first stage regression and an additional test suggested that both instruments were significantly correlated with the possibility of being included in the sample but neither significantly predicted breakthrough innovations. The Stock–Yogo test yielded a Cragg–Donald Wald F-statistic of 13.87 ($p < 0.05$), suggesting that the group of instruments was sufficiently strong (Stock et al., 2002). We generated the inverse Mills ratio from the first-stage estimation and included it in the second stage. We then used the xtnbreg command in Stata 12 to estimate the parameters. In order to allow for any unobserved heterogeneities such as organizational culture, we adopted a fixed-effect specification in our analyses, treating each firm as a subject.

RESULTS

Table I presents descriptive statistics of this study. Following Aiken and West (1991), we mean-centred the predictor variables before creating the interaction terms to facilitate interpretation. A variance inflation factors (VIF) test showed an average of 1.53 and a maximum of 2.78, well below the suggested threshold of 10. We also used the coldiag procedure in STATA to conduct an alternative multicollinearity test that showed a condition number of 12.45 for the complete model, also well below the threshold of 30 (Belsley et al., 1980).
Table I. Descriptive statistics and correlations

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<th>Mean</th>
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<td>2. Firm age</td>
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<td>3. Firm age squared/100</td>
<td>12.51</td>
<td>39.3</td>
<td>0.30</td>
<td>0.98</td>
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<td>4. Firm size</td>
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<td>2.17</td>
<td>0.37</td>
<td>0.71</td>
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<td>5. Exploration intensity</td>
<td>0.51</td>
<td>0.29</td>
<td>−0.07</td>
<td>−0.1</td>
<td>−0.08</td>
<td>−0.12</td>
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<td>6. Current active R&amp;D alliances</td>
<td>1.38</td>
<td>2.16</td>
<td>0.22</td>
<td>0.25</td>
<td>0.25</td>
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<td>7. R&amp;D intensity</td>
<td>15.13</td>
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<td>8. Portfolio knowledge stock</td>
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<td>9. Portfolio knowledge diversity</td>
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<td>10. Inverse Mills ratio</td>
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<td>0.11</td>
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<td>11. Alliance partner repeatedness</td>
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<td>0.01</td>
<td>0.04</td>
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<td>12. Alliance partner repeatedness squared</td>
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<td>0.04</td>
<td>0.03</td>
<td>0.02</td>
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<td>−0.01</td>
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<td>0.03</td>
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<td>0.99</td>
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<td>13. Technological dynamism</td>
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<td>−0.10</td>
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Note: N = 1430. Correlations above |0.06| are significant at the 0.05 level.
Table II displays the negative binomial estimations. Model 1 simply included the control variables such as firm age and R&D intensity, and in Model 2 we added our independent variables. As predicted, alliance partner repeatedness squared exhibited a negative and significant relationship with breakthrough innovations ($b = -2.57$, $p < 0.01$). A log likelihood ratio test yielded a score of 13.78, showing significant improvement in terms of model fit over the baseline model. In terms of effect size, a one standard deviation increase in alliance partner repeatedness from 1 predicts a 0.71 unit increase in breakthrough innovations. But the same increase in alliance partner repeatedness when it is 1.54 predicts an almost 0.78 unit decrease in breakthrough innovations. The expected inverted U-shaped curve reaches its maximum at the value of 1.36 for alliance partner repeatedness. Hypothesis 1 was thus considered as supported.

Table II. Negative binomial model estimating the impact of alliance partner repeatedness on breakthrough innovations

<table>
<thead>
<tr>
<th>Variables</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
<th>Model 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firm age</td>
<td>-0.02*</td>
<td>-0.02</td>
<td>-0.02</td>
<td>-0.02</td>
<td>-0.02</td>
</tr>
<tr>
<td></td>
<td>(-1.98)</td>
<td>(-1.45)</td>
<td>(-1.46)</td>
<td>(-1.42)</td>
<td>(-1.64)</td>
</tr>
<tr>
<td>Firm age squared/100</td>
<td>0.02**</td>
<td>0.02**</td>
<td>0.02**</td>
<td>0.02**</td>
<td>0.02**</td>
</tr>
<tr>
<td></td>
<td>(3.03)</td>
<td>(2.64)</td>
<td>(2.68)</td>
<td>(2.66)</td>
<td>(2.81)</td>
</tr>
<tr>
<td>Firm size</td>
<td>0.09†</td>
<td>0.10*</td>
<td>0.11*</td>
<td>0.11*</td>
<td>0.11*</td>
</tr>
<tr>
<td></td>
<td>(1.89)</td>
<td>(2.12)</td>
<td>(2.29)</td>
<td>(2.24)</td>
<td>(2.38)</td>
</tr>
<tr>
<td>Exploration intensity</td>
<td>0.51*</td>
<td>0.48*</td>
<td>0.45*</td>
<td>0.45*</td>
<td>0.49*</td>
</tr>
<tr>
<td></td>
<td>(2.37)</td>
<td>(2.31)</td>
<td>(2.20)</td>
<td>(2.24)</td>
<td>(2.38)</td>
</tr>
<tr>
<td>Current active R&amp;D alliances</td>
<td>0.02†</td>
<td>0.03*</td>
<td>0.03*</td>
<td>0.03*</td>
<td>0.02†</td>
</tr>
<tr>
<td></td>
<td>(1.72)</td>
<td>(2.20)</td>
<td>(2.34)</td>
<td>(2.16)</td>
<td>(1.93)</td>
</tr>
<tr>
<td>R&amp;D intensity</td>
<td>0.00</td>
<td>-0.01</td>
<td>0.02</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>(-0.04)</td>
<td>(-0.13)</td>
<td>(0.30)</td>
<td>(0.31)</td>
<td>(0.19)</td>
</tr>
<tr>
<td>Portfolio knowledge stock</td>
<td>0.03**</td>
<td>0.04***</td>
<td>0.04***</td>
<td>0.03**</td>
<td>0.03**</td>
</tr>
<tr>
<td></td>
<td>(2.65)</td>
<td>(2.93)</td>
<td>(2.84)</td>
<td>(2.79)</td>
<td>(2.70)</td>
</tr>
<tr>
<td>Portfolio knowledge diversity</td>
<td>0.25</td>
<td>0.28</td>
<td>0.23</td>
<td>0.24</td>
<td>0.23</td>
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<tr>
<td></td>
<td>(0.90)</td>
<td>(1.00)</td>
<td>(0.86)</td>
<td>(0.88)</td>
<td>(0.88)</td>
</tr>
<tr>
<td>Inverse Mills ratio</td>
<td>1.15***</td>
<td>1.15***</td>
<td>1.01***</td>
<td>0.99***</td>
<td>1.01***</td>
</tr>
<tr>
<td></td>
<td>(4.98)</td>
<td>(5.00)</td>
<td>(4.26)</td>
<td>(4.17)</td>
<td>(4.26)</td>
</tr>
<tr>
<td>Alliance partner repeatedness</td>
<td>7.00***</td>
<td>7.19***</td>
<td>7.36***</td>
<td>7.68***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3.22)</td>
<td>(3.39)</td>
<td>(3.18)</td>
<td>(3.80)</td>
<td></td>
</tr>
<tr>
<td>Alliance partner repeatedness squared</td>
<td>-2.57**</td>
<td>-2.64**</td>
<td>-2.73**</td>
<td>-2.87***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-3.10)</td>
<td>(-3.24)</td>
<td>(-3.01)</td>
<td>(-3.75)</td>
<td></td>
</tr>
<tr>
<td>Technological dynamism</td>
<td>1.39*</td>
<td>1.38*</td>
<td>1.22*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.57)</td>
<td>(2.55)</td>
<td>(2.22)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technological dynamism × alliance partner repeatedness</td>
<td>3.12</td>
<td>79.51*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technological dynamism × alliance partner repeatedness squared</td>
<td>(0.65)</td>
<td>(2.13)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>1430</td>
<td>1430</td>
<td>1430</td>
<td>1430</td>
<td>1430</td>
</tr>
<tr>
<td>Wald $\chi^2$</td>
<td>108.86</td>
<td>127.97</td>
<td>136.60</td>
<td>136.21</td>
<td>145.03</td>
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<tr>
<td>Log likelihood</td>
<td>-1338</td>
<td>-1331</td>
<td>-1328</td>
<td>-1327</td>
<td>-1324</td>
</tr>
</tbody>
</table>

Note: z-values in parentheses; two-tailed test. *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; † $p < 0.10$. 

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Hypothesis 2 states that technological dynamism moderates the impact of partner repeatedness on breakthrough innovations such that the slopes of the inverted-U relationship become steeper. The quadratic interaction term between technological dynamism and alliance partner repeatedness squared did indeed have a negative and statistically significant coefficient ($b = -29.25$, $p < 0.05$) in Model 5, the full model. Besides, when we entered only the first order interaction term, it was not significant ($b = 3.12$, $p > 0.10$) at all in model 4. Moreover, a log likelihood ratio test also confirmed that model fit improved significantly from Model 2 to Model 5, which included the interaction terms (log likelihood statistic $= 7.93$, $p < 0.05$, $df = 2$).

Nonetheless, it is still premature to claim support for the moderation hypothesis. As prior studies have shown (Hoetker, 2007; Wiersema and Bowen, 2009), interpreting the interaction terms in non-linear regressions requires careful examination at specific values of certain variables because the actual interaction effect, expressed as the partial derivative, often includes variables instead of constants as in linear regressions. We therefore checked the significance of the interaction term at three different levels of alliance partner repeatedness and technological dynamism (3 by 3, or 9 scenarios in total) in the negative binomial regression (Hilbe, 2011). The interaction effect did indeed show non-linearity by changing its sign, but all interaction effects were still significant at the 0.05 level. Figure 1 visually demonstrates the impact of alliance partner repeatedness on breakthrough innovations. As the three curves reveal, that impact hinges on the level of technological dynamism and the curvilinear relationship becomes steeper at high levels of technological dynamism.

We further substantiated our empirical results by conducting additional tests. First, we experimented with a few alternative measures of breakthrough innovations. These included adopting the international patent classifications instead of the US ones, excluding
self-citations, and using different threshold percentiles (99%, 98%, 95%, and 90%). The results remained qualitatively the same. For example, using the 99th percentile rather than the 97th, the coefficient relating alliance partner repeatedness squared with breakthrough innovations was still negative and significant \((b = -2.34, p < 0.01)\). The moderating effect of technological dynamism on the curvilinear relationship between alliance partner repeatedness and breakthrough innovations \((b = -25.93, p < 0.05)\) remained similar to the previous estimate.

Second, we conducted a formal test to investigate whether our theoretical framework applies to incremental innovations. The measure of incremental innovations was similar to that used for breakthrough innovations, but it counted patents below the 50th percentile in forward citations. We also experimented with 40th and 60th percentiles as cut-off points. Our results demonstrate that alliance partner repeatedness no longer exhibits an inverted U-shaped relationship with the number of incremental innovations. The estimate of alliance partner repeatedness squared was negative and not significant \((b = -0.20, p > 0.10)\). Interestingly, we found that R&D intensity seemed to be positively and significantly correlated with incremental innovations \((b = 0.07, p < 0.05)\), but did not exhibit the same pattern with regard to breakthrough innovations.

To rule out other alternatives such as the impact of network cohesiveness, we also included a new control – ego network density (Phelps, 2010). As predicted, it exhibited a positive and significant relationship with breakthrough innovations but the main findings remained qualitatively unchanged. Together, these results show that alliance partner repeatedness does predict the incidence of breakthrough innovations.

**DISCUSSION**

How does the repeatedness of a firm’s alliance portfolio affect breakthrough innovations? Our study suggests that a certain degree of alliance partner repeatedness does promote high-impact innovations. The interorganizational routines arising from familiarity with partners are likely to facilitate knowledge integration for new knowledge discovery in addition to the efficiency arguments proposed by prior studies. These routines may become rigid and undermine breakthrough innovations when a firm is embedded in a high degree of partner repeatedness in its alliance portfolio. Moreover, technological dynamism amplifies both the benefits and drawbacks stemming from repeated partnerships at the alliance portfolio level such that the overall effect of alliance partner repeatedness should be viewed in the light of a firm’s technological environment.

Our study makes two major contributions. First, it contributes to the well-established research on repeated interactions among firms. Our findings go beyond the traditional focus on repeated ties at the dyadic level to demonstrate the importance of examining repeat interactions at the portfolio level. Repeated dyadic interactions have been shown to promote trust (Gulati, 1995), facilitate contract re-negotiation (Argyres et al., 2007; Vanneste and Puranam, 2010), and develop firm-specific capabilities (Ethiraj et al., 2005), but they have also been shown to introduce inertia (Uzzi and Lancaster, 2003). However, it has remained unclear what mechanisms are at work at the portfolio level (Faems et al., 2005). Our study develops an interorganizational routines perspective and demonstrates how repeated interactions work in a portfolio to promote breakthrough innovations.
In addition, our study complements the work of Goerzen (2007) in that we find that a certain degree of repeatedness in a firm’s alliance portfolio does indeed promote breakthrough innovations. Although his work suggests that repeated relations with prior partners may dampen a firm’s economic performance, our study reveals that repeated interactions may be beneficial in terms of promoting breakthrough innovations. A certain degree of partner repeatedness is necessary for firms to understand each other’s knowledge structure and develop routines for knowledge discovery. It also has demonstrated the utility of the interorganizational routines perspective for examining the pros and cons of repeated interactions.

Second, our study contributes to the research on interorganizational routines. Although prior research has emphasized the positive role of routines in reducing costs and facilitating coordination, routines are often perceived as an unnecessary constraint in a dynamic environment (Goerzen, 2007). However, our results show that a dynamic environment highlights the importance of interorganizational routines. Such contexts may in fact trigger the formation of high-order routines for capturing new knowledge. These results thus provide empirical evidence of the adaptive nature of interorganizational routines (Dionysiou and Tsoukas, 2013; Feldman and Pentland, 2003; Lewin et al., 2011).

Our study also provides additional insights into the research on exploitation and exploration. Prior work has considered network consolidation (i.e., forming alliances with existing partners in the alliance network) as a form of structure exploitation (Beckman et al., 2004; Lin et al., 2007), implicitly hypothesizing it as detrimental to developing breakthrough innovations. However, the results of this study suggest that a certain level of familiarity between a firm and its partners is critical for the focal firm to develop breakthrough innovations. Well-managed repeated alliances apparently tend to promote breakthrough innovations, particularly when a certain level of structure or routine facilitates knowledge assimilation and integration. These results, therefore, contribute to a deeper understanding of how structure exploitation can affect innovation and how firms can best manage the trade-offs involved.

Further, our study has implications for alliance portfolio management. Prior research has found the value-creation effect of alliance portfolios in terms of resource complementarity, competition among the partners (Lavie, 2007), portfolio diversity (Cui and O’Connor, 2012), internationalization (Lavie and Miller, 2008), exploration or exploitation choices (Lin et al., 2007), as well as knowledge distance among the partners (Vasudeva and Anand, 2011). This study adds an important dimension – alliance partner repeatedness to the research on alliance portfolio, and reveals its rich implications for high-impact innovations. Our study suggests that practitioners ought to take this dimension into account, particularly when the strategic goal is to develop breakthrough innovations.

Limitations and Future Research

Despite its merits, our study has a few limitations that also hold promise for future research. First, it must be acknowledged that this research relied on data from an industry well known for innovation and frequent alliances. Future studies may examine
whether or not our proposed theory holds true in other contexts such as low tech industries, and for other performance indicators. In addition, the sample firms were all publicly-traded firms. An extension to privately-held firms is clearly in order. Third, this study relied heavily on patent data. Although a reasonable proxy, many firms innovate continuously but rarely file patents. Breakthrough innovations are presumably more likely to be patented than more mundane advances, but the mundane are by definition much more numerous and may, in total, be at least as important as the possibility of a breakthrough to the firms concerned. Extending this work to such developments would be challenging, but perhaps worthwhile.

Future work might usefully explore different mechanisms leading to incremental and breakthrough innovations. We focused on breakthrough innovations in this study because the tension between benefits and liabilities is presumed to be more intense when developing breakthrough innovations. However, our post hoc analyses reveal that developing breakthrough innovations might follow different paths compared to developing incremental innovations. Research that further explores the intricate relationship between different types of innovation is therefore warranted.

CONCLUSION

Does familiarity with alliance partners lead to breakthrough innovations? Our study unravels this puzzle from the perspective of interorganizational routines, and suggests that the trade-off between the benefits and liabilities of interorganizational routines, arising from repeated interactions within a firm’s alliance portfolio, significantly influences the innovation outcome, particularly breakthrough innovations. A moderate level of alliance partner repeatedness appears to be optimal. The results also reveal the importance of technological dynamism in shaping the relationship between alliance partner repeatedness and breakthrough innovations. Allying with familiar partners can apparently be a double-edged sword for a firm seeking to develop breakthrough innovations. It must configure its research alliance portfolio with a reasonable level of repeatedness and consider the dynamism of the environment to develop breakthrough innovations.

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