How geographic diversity and collaborative breadth prevent knowledge leakage during open innovation processes

Chunhsien Wang, Tachia Chin, Yuan Yin Chiew and Cinzia Capalbo

Abstract

Purpose – *Drawing upon insights from knowledge-based theory and the learning perspective, this study aims to explore safeguarding strategies in open innovation. Geographic diversity and collaborative breadth can effectively protect proprietary innovations that limit knowledge leakage concerns.*

Design/methodology/approach – *Using a cross-industry sample from the Taiwanese Technological Innovation Survey III, which covered 1,519 firms, the authors investigate the conditions under which partnership portfolios affect radical innovation.*

Findings – *The findings suggest that the partnership portfolio has an inverted U-shaped influence on radical innovation and that this relationship is moderated by geographic diversity and collaborative breadth. This work identifies a balance in the tension between diverse partnership portfolios and knowledge leakage with regard to open innovation activities.*

Practical implications – *This study provides senior managers with an indication of the relationships between partnership portfolios and innovative knowledge protection, identifying the geographic diversity and collaborative breadth that serve as safeguards to prevent leakages of a firm's innovative knowledge.*

Originality/value – *This study makes an original contribution to the empirical exploration of innovation knowledge protection and provides new insights into the field of open innovation. The authors, thus, balance the tension between partnership portfolios and knowledge leakage.*

Keywords *Partnership portfolios, Safeguard mechanism, Geographic diversity, Collaborative breadth, Radical innovation, Taiwan*

Paper type *Research paper*

Chunhsien Wang is based at the College of Management, National Chiayi University – Sinmin Campus, Chiayi, Taiwan. Tachia Chin is based at the School of Management, Zhejiang University of Technology, Hangzhou, China. Yuan Yin Chiew is based at the Policy Research Division, National Applied Research Laboratories Science and Technology Policy Research and Information Center, Taipei, Taiwan. Cinzia Capalbo is based at the Department of History Anthropology Religions Art History, Media and Performing Arts, University of Rome La Sapienza, Rome, Italy.

Introduction

Firms are increasingly forming partnership portfolios with extramural partners in open innovation processes (Chesbrough, 2003), which facilitate their innovation capacity (Love *et al.*, 2014; Hwang *et al.*, 2022) and innovative results (Laursen and Salter, 2006). Partnership portfolios matter because multilateral ties within a portfolio can connect heterogeneous partners (Sampson, 2007; Bianchi *et al.*, 2016; Magni *et al.*, 2022; Wang *et al.*, 2020) and span distant and unfamiliar geographic settings (Ardito *et al.*, 2019; Kim, 2016; Lahiri, 2010) for patent-holder- and location-specific knowledge acquisition. Empirical evidence has shown the positive impact of partnership portfolios on firms' innovation and performance (Ardito *et al.*, 2019; Garcia Martinez *et al.*, 2017; Caputo *et al.*, 2021; Oerlemans *et al.*, 2013). While previous studies have suggested that firms' engagement in partnership portfolios helps achieve innovation outcomes (Ardito and Petruzzelli, 2017; Hohberger and Wilden, 2022; Wang *et al.*, 2020; Oerlemans *et al.*, 2013), two different but related multilateral ties regarding knowledge sourcing are variety in partner types (breadth of collaboration) and variety in the geographic origins of partners (geographic diversity).

First, relying on the open innovation perspective (Chesbrough, 2003; Laursen and Salter, 2006), some firms collaborate with numerous different types of partners to gain extramural

Received 21 April 2022
Revised 12 September 2022
31 March 2023
Accepted 1 June 2023

This paper is supported by the Ministry of Science and Technology (MOST) of the Republic of China, Taiwan (MOST 106–2410-H-415-038-MY2) and the National Natural Science Foundation of China (No. 72272136).

knowledge, and such firms are expected to exhibit good innovation performance (Leiponen and Helfat, 2010; Wang *et al.*, 2020). Firms that are connected to multiple partners across different domains enable they to learn valuable external knowledge (Laursen and Salter, 2006; Magni *et al.*, 2022; Love *et al.*, 2014) and thus drive radical innovation (Zobel *et al.*, 2016). Connections with multiple partners across different domains enable firms to learn valuable external knowledge (Laursen and Salter, 2006; Magni *et al.*, 2022; Love *et al.*, 2014) and thus drive radical innovation (Zobel *et al.*, 2016). Notably, collaborative breadth can connect firms to different partners (suppliers, universities, R&D institutions, etc.), to help them generate cutting-edge ideas and novel combinations of knowledge components (Ardito *et al.*, 2019; Taylor and Greve, 2006; Garcia Martinez *et al.*, 2019).

Geographic diversity, on the other hand, involves extramural knowledge acquisition with a wide range of external partners scattered across different geographic regions (Katila and Ahuja, 2002; Laursen, 2012; Lahiri, 2010). A wide geographic search range enables firms to "search [for], learn [about], and create" value widely and to acquire diverse market knowledge, which allows them to identify diverse solutions to existing problems (Ardito *et al.*, 2019; Garcia Martinez *et al.*, 2017; Hohberger and Wilden, 2022). Furthermore, collaborating with geographically diverse partners enables firms to access different types of knowledge and technological opportunities, which can increase the probability that these firms will successfully commercialize innovative products (Ahuja and Katila, 2001; Laursen and Salter, 2006; Van Beers and Zand, 2014), especially abroad (Patel *et al.*, 2014). Collaborating with overseas partners enables firms to glimpse global knowledge sourcing and then identify key institutional and business knowledge elements that best fit their innovation. However, outside of a recent study by Ardito *et al.* (2019), how the geographic diversity of partners' origins facilitates radical innovation is still poorly understood, particularly in relation to extramural knowledge sources being widely distributed across a variety of regions or countries.

Although the above two types of multilateral ties are likely to be a benefit to innovation outcomes, the fact that the process of collaborating with external partners may produce core knowledge leakages is usually neglected (Grimpe and Kaiser, 2010; Wadhwa *et al.*, 2017). Specifically, one prior study emphasized that firms engaging with multilateral partners may not only leak their proprietary innovative knowledge to external partners (Wadhwa *et al.*, 2017) but also potentially induce multilateral competition among partners (Bogers, 2011; Lavie, 2007). Therefore, partnership portfolios may also require building safeguards to protect their core knowledge and resources.

Consequently, firms' use of collaboration breadth as a safeguard is expected to protect their innovation resources to avoid the danger of being controlled or imitated by particular partners (Anokhin *et al.*, 2011). Thus, collaborative breadth with heterogeneous partner connections can explain the different levels of relational embeddedness among firms in terms of their ability to dilute competitor threats to protect the valuable knowledge that they appropriate. Similarly, the role of geographic diversity may also highlight the importance of exploring why firms with different levels of geographic diversity in terms of partner origins have heterogeneous safeguard framing mechanisms to appropriate innovation returns. Clearly, both geographic diversity and collaborative breadth have received considerable attention as safeguards to prevent unintended leakages of innovative knowledge to external rivals and to reduce the likelihood of innovative knowledge spillovers that benefit potential entrants.

To explore these ideas, we develop a theory to explain how geographic diversity and collaborative breadth can serve as safeguard mechanisms (Lippman and Rumelt, 1982; Rumekt, 1984) that help firms protect against leakages of core knowledge when opening innovation boundaries to acquire extramural knowledge. Thus, the purpose of this study is to provide a strong theoretical basis for assessing these two safeguard mechanisms and to examine how they impact the relationship between the portfolio of collaboration with

external partners and radical innovation. We test our theoretical model with a unique data set from the Taiwanese Technological Innovation Survey III (TTIS III), which extracted 1,519 available firm-level innovation activities across different industries from 2010 to 2012.

Our results show that there is an inverted U-shaped relationship between partnership portfolios and radical innovation performance. Our results further suggest that when a firm's geographic diversity is highly involved with its knowledge sourcing, it may be possible to reverse this decline. Specifically, we found that strong collaborative breadth with knowledge sourcing has a positive effect on the inverted U-shaped relationship between partnership portfolios and radical innovation performance.

This study is structured as follows. The next section focuses on key theoretical developments along with the theoretical framework used to develop the research hypotheses. The following section explains the methodology used to conduct the present empirical research. The next section analyzes the findings of the empirical results. The final section presents a discussion and the implications and limitations of this research.

Theoretical development

Partnership portfolios and radical innovation

Multilateral collaborative partners enable firms to identify and implement cutting-edge ideas and novel knowledge sources for the purpose of developing breakthrough innovations (Ahuja and Katila, 2001; Chesbrough, 2003; Laursen and Salter, 2006). In line with the knowledge-based view of the firm (Grant and Baden-Fuller, 2004; Nickerson and Zenger, 2004), firms may exploit a variety of knowledge sources to combine complementary knowledge and explore the likelihood of breakthrough innovations. The existing innovative literature offers support for novel recombination functions that can create potential novel innovations (Fleming, 2001; Leiponen and Helfat, 2010; Teece, 1986). Interdependent partnership portfolios influence firms' radical innovation; however, this process may bring both benefits and challenges.

First, collaboration with major external partners gives firms a chance to probe and access novel knowledge beyond their boundaries to improve their innovativeness (Ardito *et al.*, 2019; Abdulkader *et al.*, 2020; Wang *et al.*, 2020) and to use cutting-edge knowledge that can lead to new product introductions (Brown and Eisenhardt, 1997), such as valuable extramural knowledge beyond firm boundaries (Chesbrough, 2003) and breakthrough innovations (Phene *et al.*, 2006). Collaboration with multiple partners increases the variety of knowledge sources in potentially novel combinations (Ardito *et al.*, 2019; Fleming, 2001; Scuotto *et al.*, 2017), which are likely to go beyond the limitations of local learning (Rosenkopf and Nerkar, 2001) and consequently contribute to breakthrough innovations (Utterback, 1994).

Second, collaboration with multiple partners increases the pool of exploratory research available to firms and facilitates expansion beyond from current organizational routines and knowledge bases (Miner *et al.*, 2001). A broader exploratory search for a larger pool of collaborative partners allows firms to replace their current knowledge bases with new knowledge bases (Katila and Ahuja, 2002) and refine and create new knowledge bases (Abernathy and Clark, 1985; Benner and Tushman, 2003). This makes it possible for firms to benefit from new concepts and fresh ideas and to realize breakthroughs to extend or defend their core businesses, minimizing the risks from investing in technology; this, in turn, is likely to affect their ability to innovate (Chesbrough and Crowther, 2006).

However, having too many partnership portfolios could increase the potential constraints on radical innovation. First, firms' collaboration with major heterogeneous partners may incur managerial and transaction costs (Duysters and Lokshin, 2011; Garcia Martinez *et al.*, 2017). These costs stem from opportunistic behavior such as cheating, shirking, distorting information,

misleading partners, providing substandard products/services and appropriating partners' critical knowledge resources (Das and Teng, 1998). Transaction risks may also require an increase in contractual negotiation costs and the implementation of costly monitoring mechanisms (Dyer, 1997). Thus, such marginal costs are likely to exceed their contribution to the value of knowledge creation (McFadyen and Cannella, 2004). Obviously, the costs associated with coordination and integration may escalate, sometimes quite rapidly (Katila and Ahuja, 2002; Leiponen and Helfat, 2010), because of the complexity and challenges involved (Grant, 1996a), thus eroding profit margins. This phenomenon suggests that partnership portfolios may be subject to diminishing innovation returns.

Second, firms collaborating with different heterogeneous partners may also face the risk of losing their original innovative knowledge to external collaborators (Hwang *et al.*, 2022). Specifically, knowledge sources from multiple partners are likely to induce competition among partners in partnership portfolios, which may lead to the risk of undesirable knowledge leakage (Lavie, 2007). That is, partnership portfolio negotiations about unintended knowledge and know-how include the risk of disclosing relevant knowledge to potential competitors, who may often acquire valuable and critical knowledge at a marginal cost close to zero. Thus, firms simultaneously collaborating with a wide variety of partners may not only incur additional costs but also lead to a negative influence on innovation outcomes. Third, given the limitations of their capacity and managerial attention, as the knowledge and know-how of different collaborative partners are inherently heterogeneous, firms may look beyond their knowledge and organizational boundaries for emerging and new knowledge. Under these circumstances, firms may face conflicts that arise from an increase in relevant information for problem-solving. Diverse partnership portfolios may strain a firm's ability to coordinate among partners and handle emerging conflicts among collaborators, resulting in less fruitful knowledge combinations for innovation. An excess of partnership portfolios may reduce a firm's ability to combine and use different knowledge integration practices for innovation demands. The above reasoning leads to the following hypothesis:

H1. There is a curvilinear (inverted U-shaped) relationship between partnership portfolios and the radical innovation of firms.

Role of geographic diversity

Prior research has shown that the geographic diversity of partner origins notably influences a firm's novel innovations (Phene *et al.*, 2006). For example, Frost *et al.* (2002) and Nelson (1993) found that the geographic dispersion of partners enables firms to easily access novel and diverse knowledge and resources dispersed across countries while gaining the benefits of cross-fertilization. This enables firms to pool their resources in the process of sourcing external knowledge and developing strategic links with organizations in open innovation deployment. To the extent that such benefits are anticipated, firms may face the risk of knowledge leakage to external actors, which might lead to innovation failures. Firms with geographically diverse partners may also require protective mechanisms to prevent leakages of their innovative knowledge. Based on this background, we propose that geographically diverse partners offer valuable and unique external knowledge, thereby contributing to firms' innovation, and it may have a contingent effect on the partnership portfolio–radical innovation relationship.

The extent to which a firm acquires knowledge from multiple partners dispersed across different regions can be a source of value appropriation (Kim, 2016), which creates a safeguard mechanism. This safeguard mechanism works by being novel, unique and heterogeneous, which, in turn, protects innovative knowledge and forms barriers to imitation. First, a geographically diverse range of knowledge is a source of novelty (Bahlmann, 2015) that is relatively likely to keep competitors from accessing or using newly created innovative knowledge (Lippman and Rumelt, 1982). Thus, a higher degree of

novelty can create mobility barriers that may limit technical knowledge and know-how leakages, impeding the ability of rivals to imitate the firm (Attewell, 1992). Second, obtaining unique local-specific knowledge may provide an advantage over competing firms that are unable to make such acquisitions (Boschma, 2005; Dyer and Singh, 1998). By facilitating greater acquisitions and control over unique local knowledge, firms can isolate themselves or establish buffers from insufficient substitutes. In turn, these firms may be able to appropriate greater returns by preventing scarce resource leakages (Lieberman and Montgomery, 1988), by obtaining unique knowledge and by creating scarce resources that are unavailable to competitors.

Third, having collaborative partners with location-specific knowledge from a variety of geographic areas will make it easier for firms to combine nonredundant knowledge and to situate it in their innovation (Fabrizio and Thomas, 2012; Kogut and Zander, 1992), thus preventing imitation by rivals. Therefore, the heterogeneity of geographically dispersed knowledge sources can create a safeguard mechanism (Kim, 2016), not only making imitation by competitors difficult but also impeding replication or transfer across competitors (Maritan and Brush, 2003). Based on the above three mechanisms, through which firms can lend causal ambiguity and uniqueness to their innovative knowledge sourcing, firms can enjoy additional benefits by exclusively capturing and appropriating created value.

Essentially, while geographic diversity may prevent innovative knowledge leakages, it may also impose significant transaction costs and managerial information-processing demands (Hitt *et al.*, 1997) that might hamper the integration of externally sourced knowledge with a firm's in-house innovation base. Integrating geographically dispersed knowledge into in-house innovation processes requires firms to understand how various government regulations, trade laws, forms of cultural diversity and skills must interact with existing systems. Such an understanding requires transaction information processing related to coordination and managerial costs across multiple geographic regions (Hitt *et al.*, 1997) and the creation of coordination and integration mechanisms to handle diverse knowledge from multiple partners (Grant, 1996a). Thus, higher transaction costs and managerial information-processing demands arise when dealing with escalating geographic diversity and integrating diverse knowledge with a firm's existing technologies, potentially increasing the failure rates of innovativeness. Accordingly, we propose the following:

H2. The more geographically diverse a firms' partners are in terms of their origins, the less positive (and more negative) the impact of partnership portfolios on radical innovation becomes.

Role of collaborative breadth

Although multiple partners boost the acquisition of knowledge for innovation deployment (Chesbrough, 2003; Laursen and Salter, 2006), they introduce the need to use safeguards for core knowledge protection. For firms that use varied multiple partners, the costs of leakages to directly linked collaborators will be high, especially when they engage in broad collaboration with a variety of partners. Under these circumstances, firms are likely to adopt some defense responses to limit their core innovation knowledge losses. These defenses stem primarily from constructions of lock-in effects, causal ambiguity and path dependence (Gulati, 1999; Lee, 2007). Such mechanisms can impede the flow of knowledge and enable firms to prevent potential competitors from accessing their core innovative knowledge.

While collaborative breadth may be a defense mechanism, we posit that it will also enhance the positive effect of partnership portfolios on radical innovation for three reasons. First, firms that connect with a variety of partners are likely to access nonredundant and unique knowledge across distinct knowledge domains (Goerzen and Beamish, 2005; Wuyts and Dutta, 2014). Collaboration with different partners increases the opportunity to access the

partner-specific knowledge and ideas of particular partners. Collaboration with particular partners may form specific, closed-loop and exclusive knowledge that can lead to lock-in effects (Li *et al.*, 2013). Accordingly, these characteristics make it difficult for core knowledge to flow freely (Teece, 1986). Thus, a lock-in effect may significantly limit innovative knowledge leakage in partnership portfolios.

Second, having strong connections to particular external partners in different regions makes firms more likely to have informed market control power (Kim, 2016), thus exposing such firms to a range of innovation trajectories and market development paths (Bahlmann, 2015). Such linkages with various partners are intended to tap into the business opportunities of external markets. These practices make firms capture multilateral market intelligence and their rivals' market deployment through a process in which diverse partners' connections are spread across various regions. Hence, collaborative breadth is a key approach through which firms attempt to create tacit and cospecialized knowledge, as they can impede their rivals' ability to access specific resources. The effects of collaborative breadth in firm-specific knowledge resources are subject to time compression diseconomies (Dierickx and Cool, 1989). The extent of the gains from causal ambiguity (Lippman and Rumelt, 1982), in terms of explaining innovative knowledge and know-how, can be captured through tacit and specialized knowledge. Once the collaborative breadth starts to compress over time, diseconomies may also be more engaging, which is an unambiguous explanation of how firms engage in co-innovative work. Such causally ambiguous connections might prevent innovative knowledge from being duplicated and extended (Lippman and Rumelt, 1982) and contribute to firm innovativeness (Reed and DeFilippi, 1990).

Third, collaboration with multilateral partners requires knowledge sourcing (Chesbrough, 2003; Powell *et al.*, 1996; von Hippel, 1988), which reflects firms' knowledge transfer, and exchanges are rooted in path dependence between multiple parties. Thus, a firm can detect changes occurring outside the existing technological development of its collaborators through path dependence, which enables firms to keep pace with significant changes. Firms can thus use the complex knowledge embeddedness that arises through the path-dependent interactions among various partners in local markets and complex knowledge routines designed to reduce imitation by rivals, thus preventing losses of valuable innovative knowledge combinations (Brusoni *et al.*, 2001). This requires the ability to engage with the knowledge complexity associated with tacit firm-specific knowledge and the operational routines of partner firms, which may be regarded as a barrier to knowledge imitation by competitors (Nelson and Winter, 1982). The complexity, embeddedness and path-dependent interactions of partner connections are thus likely to cause much of firms' innovative knowledge to be formulated as knowledge stickiness. Such defensive mechanisms involve behavioral regularities that result from cumulative experience and that constitute the building blocks of multiple collaborative capabilities. We expect that these informal defensive mechanisms are well equipped to bring benefits from collaborative breadth for protecting cospecialized knowledge that contributes to novel innovation:

H3. The stronger a firm's collaborative breadth is, the more positive (and less negative) the impact of the partnership portfolio on radical innovation.

Data and methods

Research setting and sample

Our study uses data from the TTIS III, which is an official survey on firm-level innovation activities conducted by the Ministry of Science and Technology (MOST) and the Institute of Technology, Innovation & Intellectual Property Management at National Chengchi University. The TTIS III was designed following the guiding principles of the OECD's Oslo Innovation Manual (OECD, 2005). The TTIS III was a large-scale government-led survey designed to collect data on firm-level innovation activities from various industries from 2007 to 2010, as well

as information from the EU Community Innovation Survey (CIS) on innovation activities. A major strength of the TTIS III is that its data set is established, and it includes all manufacturing and service firms across all Taiwanese regions. The original survey questionnaire required senior managers to answer questions related to firm-level innovation processes and activities. The pretest and pilot studies confirmed the suitability of the survey across a comprehensive set of industries, helping determine and assess the effectiveness of the survey. Thus, the TTIS III is a reliable and valid data set on firm-level innovation activities and is thus suitable for innovation research (Cassiman and Veugelers, 2006; Laursen and Salter, 2006).

The TTIS III is 11 pages long and includes a page of definitions. The core questionnaire of the TTIS III covers firm-level innovation activities, including the acquisition of external knowledge and technologies, process skills, product design, personnel training, market analysis and innovation output. Using a stratified proportional random sampling procedure, the TTIS III was sent to 42,000 business units with 10 or more employees in Taiwan in October 2010. Typical response samples were received from 13,841 firms, representing a response rate of 32.9% (SRDA, 2013). After eliminating missing values and limiting our sample to innovating firms in the original TTIS III data set, we extracted useful, available data from the TTIS III panel. The subsample used in our empirical analysis included 1,519 firms engaged in external collaborative partnerships and innovative activities that provided information for all the variables used in this study.

We chose Taiwanese firms from TTIS III as our research context for three reasons. First, as Taiwan is an island country in East Asia, firms operating in the country need to collaborate on innovation with partners around the world to acquire necessary knowledge and resources (Hagedoorn, 1993; Wang *et al.*, 2020). Second, Taiwanese firms have collaborated extensively with global partners, such as suppliers, universities, research institutions and customers, as well as rivals from advanced countries, to improve their innovation outcomes (Hwang *et al.*, 2022). Third, the above evidence is based on a variety of data sources that provide a realistic, rich interfirm collaboration context in which to examine open innovation behavior. In line with CIS data, the data offer us a direct measure of success in commercializing innovations within a wide range of industries (Laursen and Salter, 2006). Such real data are intimately connected with empirical reality and are thus conducive to the development of a testable, relevant and valid theory (Eisenhardt, 1989).

In addition, in contrast to previous TTIS waves, the TTIS III takes a step forward by including various partners across different geographic locations in the survey. We developed specialized software algorithms that assessed each firm's innovation engagement in co-innovation activities with a variety of partners from different geographic regions from 2007 to 2010, and a 9×8 matrix in the original TTIS III questionnaire was also designed to represent nine different regions (see the variable on the geographic diversity of partner origins) and eight collaborative partners (see the variable on breadth of collaboration). Accordingly, we extracted all available information about geographic diversity and collaborative breadth. The matrix provides a detailed description of the geographic diversity and multilateral ties present in the data collected and a number of consistency checks. The matrix data are particularly instrumental because of our interest in studying how firms engage in co-innovation activities in relation to protective mechanisms depending on the characteristics of their multilateral collaboration.

Measurement

Radical innovation. The new-to-market products that a firm can produce are used to measure radical innovation because they indicate the level of a firm's breakthrough innovation ability (Laursen and Salter, 2006). Consistent with previous studies (Dahlin and Behrens, 2005), we defined radical innovations as novel and unique products and services launched in the market. To reflect the novel context, we measured radical innovation as the

fraction of a firm's turnover corresponding to new-to-market product output. Although the use of a single-item variable may make it less possible to assess measure reliability (Hair *et al.*, 2006), this approach was adopted because innovation outcome variables are typically challenging to measure, and there are no universally accepted measures (Tomlinson, 2010) for the evaluation of radical innovation. The single-item radical innovation measure used in this study was relatively straightforward and unambiguous. Thus, a single item was used as an indicator of radical innovation performance, as this item effectively reflects firms' ability to generate new-to-market products for successful innovation.

Because the dependent variable of radical innovation is a fraction variable, ordinary least squares (OLS) regression is not appropriate. Instead, the dependent variable for the radical innovation measure is the fraction of new-to-market products a firm holds; therefore, by definition, it ranges between 0 and 100. As Kennedy (2003) suggested, when the range of values for the dependent variable is limited, OLS estimates are biased, and maximum likelihood estimation is preferred. To reduce estimation bias, Tobit regression should be used in such analyses, as it is more appropriate (Greene, 2000). The Tobit regression estimator constitutes a more direct measure of a firm's radical innovation output.

Partnership portfolios. Following the TTIS III, we measured the partnership portfolio of the firms' collaboration with different types of external parties based on the number of "important" or "very important" sources of innovation: internal efforts, suppliers, customers, competitors, universities, consultants, public research organizations, conferences, scientific and trade publications, professional and industry associations and technological and service specification documents (0–11). In this case, each of the 11 external collaborative sources was coded as 1 when the firm in question reported that it used that form of external collaboration to a high or intermediate degree and 0 in the case of no or low usage. The 11 linkages were subsequently summed so that each firm would receive a score of 0 if no external collaborative sources were used to a high degree and receive a score of 11 if all external collaborative sources were used to a high degree. Thus, it was assumed that firms with more external collaboration partners had greater "portfolios" with respect to broad sourcing than firms that did not. To test the curvilinear relationship hypothesized in *H1*, we used the squared term of the portfolio of partnership.

Geographic diversity of partner origins. We used the geographic diversity of partner origins to capture geographic dispersion, which refers to the distribution of a firm's external collaborative partners across different countries. Focusing on the geographic diversity of a firm allowed us to identify its actual acquisition of unique knowledge or experimentation with new competencies, as these events actually occurred across multiple regions and countries. Hence, to a great extent, our measure of firm geographic diversity captured the geographic scope of a firm in terms of its collaboration partners' origins, and it was thus consistent with the level at which we measured the knowledge leakages facing the managers of the firm. In the TTIS III, geographic diversity was measured using nine different nations or continents:

1. Taiwan;
2. Mainland China;
3. The USA;
4. Japan;
5. South Korea;
6. India;
7. Europe;
8. Other; and
9. Not applicable.

Accordingly, we identified each firm's external sources of innovative knowledge in a variety of geographic locations to determine the degree to which the firms were concentrated in one or a few regions. We included the geographic diversity of each firm's partners and calculated a Herfindahl index (Berry, 2015; Cannella *et al.*, 2008) that denoted the extent to which a firm's firm collaborative partners were dispersed around the world:

$$\textit{Geographic diversity} = 1 - \sum_{j=1}^{n} (s_j)^2$$

where (s_j) is the proportion of the focal firm's collaborative partners that were dispersed across different overseas countries j between 2007 and 2010. Higher scores indicate greater geographic diversity in terms of partner origins, which provides access to overseas knowledge sources.

Breadth of collaboration. To measure the collaborative breadth a firm has, we defined a measure related to the number of types of external collaborative partners with which each firm was connected. Firms search for novel knowledge by engaging and collaborating with different types of partners (Powell *et al.*, 1996), which constitutes a measure of collaborative breadth in the context of firms' search for innovation resources. Our sample firms had a wide range of partnership types:

- subsidiary companies owned by the same parent company;
- equipment, material or software suppliers;
- customers or consumers;
- competitors;
- consultants, private labs or R&D institutions;
- cross-industry labs or R&D institutions;
- universities or other colleges; and
- governmental or nonprofit R&D institutions.

Accordingly, the Herfindahl index was used to capture the breadth of collaboration by estimating the extent to which a firm's collaborative partnerships had included a variety of category types over the past three years:

$$\textit{Breadth of collaboration} = 1 - \sum_{i=1}^{n} (p_i)^2$$

where (p_i) is the proportion of the firms' collaborative partnerships in category i from 2007 to 2010. Higher scores indicate a greater number of diverse partner ties.

Control variables

We controlled for several firm-level characteristics that could be related to firms' open innovation activities, as well as the likelihood of their impact on innovation outcomes. We controlled for *industry type* because different industries may have different approaches to innovation. The industry type variable was dichotomous and took the value of 1 if the firm was a manufacturing firm and 0 if the firm was a service firm. We controlled for *firm size* by using the natural logarithm of the number of employees. Larger firms tend to have greater financial resources and the capacity to engage in R&D efforts; thus, they may exhibit more innovative outcomes. In addition, we controlled for *R&D intensity*, which was measured as the firm's R&D expenditure divided by its sales, to control for the effect of R&D on innovation

performance (Laursen and Salter, 2006). *Revenues* reflect the firm's sales volume from product sales, as the degree to which a firm's product shares are accepted by the market or by customers can affect innovation performance. To capture this possibility, we used annual sales revenue as a proxy of each firm's prior performance, and this variable was measured as the log of the annual sales revenue of each firm as captured by the TTIS III. Griliches (1995) suggested that governmental support for R&D and innovation can have positive effects on the innovation activities of firms. Thus, we also controlled for government-supported innovation activities. The government-sponsored R&D variable took the value of 1 if the R&D and innovation activities of the firm were partly supported by government subsidies (Griliches, 1995). In addition, a firm that possesses abundant prior product innovation experience can quickly develop the necessary skills and resources to conduct innovation development, which can influence its innovation performance. We thus use *prior product innovation experiences* to control for the influence of each firm's previous product innovation experience (Eisenhardt and Tabrizi, 1995). We include a dummy for prior product innovation experience that equals 1 if the firm engaged in product innovation activities from 2010 to 2012 and 0 otherwise.

Results

Table 1 lists the descriptive statistics and correlations of all the variables of interest. The mean of partnership portfolio is 4.08, with a standard deviation of 2.06. The mean value of geographic diversity is 0.49. The mean value of collaborative breadth is 0.63. Partnership portfolio is positively and significantly correlated with radical innovation performance, but both geographic diversity and collaborative breadth have negative and significant correlations with radical innovation performance. Based on the correlation matrix, it appears that no severe problem of multicollinearity is present. To examine potential multicollinearity concerns, we used variance inflation factors (VIFs) to test whether multicollinearity impacted our regression analysis. All the VIF values were less than 10 (the highest was 3.56).

The results of the Tobit regression analysis can be found in Table 2. All the regression models include six control variables. Model 1 is the baseline model and includes only the control variables. *H1* predicts an inverted U-shaped relationship between partnership portfolios and radical innovation performance. The results in Model 2 indicate that the linear term, the partnership portfolio, is positive and significant (β = 0.027, $p < 0.01$) and that partnership portfolios squared is negative and significant (β = −0.002, $p < 0.05$), thus supporting *H1*.

Table 1 Descriptive statistics and correlation coefficients (N = 1,519)

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
1. Industry type	1									
2. Prior firm performance	−0.13**	1								
3. Firm size	0.020	0.35***	1							
4. R&D intensity	−0.23**	−0.07**	−0.09**	1						
5. Government-sponsored R&D	−0.12**	−0.07**	0.06*	0.18***	1					
6. Prior product innovative experience	−0.04	0.04	0.14***	−0.01	0.09***	1				
7. Collaborative breadth	0.09***	−0.01	−0.05*	0.02	−0.16**	0.14***	1			
8. Geographic diversity	−0.01**	−0.01	−0.12**	0.24***	−0.18**	0.01	0.66**	1		
9. Partnership portfolios	−0.12***	−0.03	−0.12**	0.08**	0.03	−0.13**	−0.05	0.03	1	
10. Radical innovation performance	0.07**	−0.07**	0.01	0.02	−0.06*	0.09***	−0.08**	−0.19**	0.05*	1
Mean	0.45	13.67	4.59	0.61	0.14	0.71	0.63	0.49	4.08	0.25
SD	0.50	2.37	1.68	0.26	0.35	0.46	0.39	0.44	2.06	0.23
Minimum	0	6.80	0.69	0	0	0	0	0	0	0
Maximum	1	20.06	10.45	1	1	1	1	1	11	1

Notes: *$p < 0.05$; **$p < 0.01$ and ***$p < 0.001$
Source: Authors' own work

Table 2 Results of Tobit regression analysis of radical innovation performance

Variables	*Radical innovation performance*				
	Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 5*
Partnership portfolios		0.027** (0.010)	0.064** (0.021)	−0.015 (0.021)	−0.014 (0.022)
Partnership portfolios squared		−0.002* (0.001)	−0.007** (0.002)	0.002 (0.002)	0.002 (0.002)
Geographic diversity			−0.054 (0.052)		0.367*** (0.104)
Collaborative breadth				−0.235*** (0.057)	−0.560*** (0.116)
Partnership portfolios × geographic diversity			−0.066* (0.026)		−0.301*** (0.055)
Partnership portfolios squared × geographic diversity			0.009** (0.003)		0.034*** (0.006)
Partnership portfolios × Collaborative breadth				0.069** (0.027)	0.323*** (0.059)
Partnership portfolios squared × Collaborative breadth				−0.006* (0.003)	−0.035*** (0.006)
R&D intensity	0.039 (0.030)	0.036 (0.030)	0.099** (0.031)	0.042 (0.029)	0.085* (0.036)
Prior firm performance	−0.008** (0.003)	−0.008** (0.003)	−0.008** (0.003)	−0.008** (0.003)	−0.009** (0.003)
Firm size	0.006 (0.004)	0.008+ (0.004)	0.005 (0.004)	0.007+ (0.004)	0.005 (0.004)
Government-sponsored R&D	−0.059** (0.019)	−0.064** (0.020)	−0.109*** (0.021)	−0.084*** (0.020)	−0.111*** (0.021)
Industry dummy	0.038** (0.014)	0.040** (0.014)	0.019 (0.013)	0.048** (0.014)	0.008 (0.013)
Prior product innovation experience	0.057*** (0.014)	0.063*** (0.014)	0.067*** (0.015)	0.076*** (0.014)	0.061*** (0.014)
Constant	0.253*** (0.049)	0.180** (0.053)	0.191** (0.059)	0.317*** (0.063)	0.335*** (0.065)
p-value	0.00	0.00	0.00	0.00	0.00
Log pseudolikelihood	−356.65	−351.61	−306.86	−337.97	−283.36

Notes: $N = 1{,}519$. Robust standard errors are shown in parentheses; $^{+}p < 0.1$; $^{*}p < 0.05$; $^{**}p < 0.01$ and $^{***}p < 0.001$
Source: Authors' own work

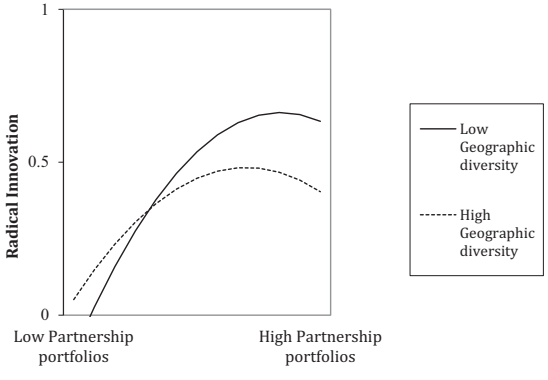
To test *H2*, we introduce geographic diversity as a moderator of the association between partnership portfolios and radical innovation (Model 3). Consistent with our prediction, geographic diversity negatively moderates the positive association between partnership portfolios and radical innovation ($\beta = -0.066$, $p < 0.05$) while positively moderating its quadratic term ($\beta = 0.009$, $p < 0.05$). Hence, geographic diversity attenuates the inverted U-shaped association between partnership portfolios and radical innovation. *H2* is supported.

To test *H3*, we introduce collaborative breadth as a moderator of the association between partnership portfolios and radical innovation (Model 4). Consistent with our prediction, the interaction terms of collaborative breadth with the partnership portfolios are positive and significant (Model 4, $\beta = 0.69$, $p < 0.05$; Model 5, $\beta = 0.323$, $p < 0.001$), while the interaction terms of collaborative breadth with the quadratic term of the partnership portfolios are negative and significant (Model 4, $\beta = -0.006$, $p < 0.05$; Model 5, $\beta = -0.035$, $p < 0.001$). Thus, *H3* is supported.

To test interaction effects, we used the approach of Haans *et al.* (2016) to examine the moderating effect of geographic diversity on the curvilinear relationship between partnership portfolios and radical innovation performance. The results are graphically shown in Figure 1. At a high level of geographic diversity, the curve moves to the right, and the downward effect on the partnership portfolios is larger than that at a low level of geographic diversity; thus, a high level of geographic diversity decreases the positive effect of the partnership portfolios and mitigates the positive effect of the partnership portfolios on radical innovation performance. Accordingly, *H2* is supported, as these results suggest that a high level of geographic diversity flattens the inverted U-shaped relationship between partnership portfolios and radical innovation performance.

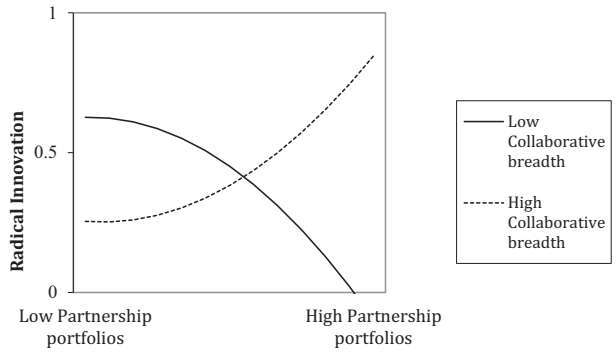
Similarly, to further confirm the hypothesized moderating effects of collaborative breadth on inverted U-shaped relationship between partnership portfolios and radical innovation performance, we adopted the approach suggested by Haans *et al.* (2016). The results are graphically shown in Figure 2. At a greater breadth of collaboration, the inverted U-shaped curve of the partnership portfolios and radical innovation performance moves to the right and steepens; thus, a greater breadth of collaboration increases the positive effect of the partnership portfolios on radical innovation performance. It indicates the magnitude of the impact of a marginal increase in reliance on collaborative breadth on the relationships between partnership portfolios and radical innovation performance. Accordingly, *H3* is further supported.

Figure 1 Moderating effect of geographic diversity between the partnership portfolio and radical innovation performance



Source: Author's own work

Figure 2 Moderating effects of collaborative breadth between the partnership portfolio and radical innovation performance



Source: Author's own work

Discussion

Established firms connect with globally dispersed collaborative partners, aiming to access external knowledge sources to facilitate their radical innovation. However, as the number of their external collaborative partners continues to increase, challenges and risks become dominant. An inverse U-shaped relationship between partnership portfolios and radical innovation performance emerges. We propose that the effects of geographic diversity and collaborative breadth are important boundary conditions, especially in the context of simultaneous engagement across a wide range of external collaborative partners.

These results empirically contribute to the research on open innovation in three distinct ways. First, most previous research focuses on partnership portfolios for knowledge sourcing; however, these studies largely ignore how to prevent core innovation knowledge leakages. To date, only a few studies have discussed the employment of informal protective mechanisms (James *et al.*, 2013; Spithoven and Teirlinck, 2015; Miric *et al.*, 2019) to prevent core knowledge leakages. In line with the extant literature, our findings underscore the need to develop informal defense mechanisms, such as geographic diversity and collaborative breadth, as these can serve as important safeguards preventing core knowledge leakages in the context of open innovation.

Second, we extend the research on collaboration with external partners for knowledge sourcing (Chesbrough, 2003; Garcia Martinez *et al.*, 2017; Garcia Martinez *et al.*, 2019; Oerlemans *et al.*, 2013) and add to a recent stream of studies that has suggested a need for research examining core innovative knowledge defenses in the context of partnership portfolios (Hwang *et al.*, 2022). While past studies have focused on how collaborating with external partners in accessing knowledge sources can spur innovation outcomes (Laursen, 2012; Laursen and Salter, 2006; Wang *et al.*, 2020), this study goes beyond this topic by examining how safeguards are developed among firms and their partners during open innovation processes. This study adds new insight to the relevant theory, as it considers acting to be not only a knowledge brokerage initiative but also a knowledge protection mechanism for open innovation activity.

Third, building on and contributing to the knowledge base (Grant, 1996; Grant and Baden-Fuller, 2004) of firms, we found that the integration of geographic diversity and collaborative breadth improves the understanding of the nuances of partnership portfolios and thus leads to well-developed safeguard approaches and mechanisms. Moreover, our evidence fills the gap between open innovation and knowledge protection (Grimpe and Kaiser, 2010;

Wadhwa *et al.*, 2017). We thus contribute to the literature by examining the effects of balancing the tension in the relationship between the partnership portfolios and the knowledge leakages of firms as they open their boundaries to collaborate with a wide range of external partners.

Implications

This study has several key implications. First, firms need to invest in appropriate safeguards to develop partnership portfolio diversity. However, established, well-developed, informal protective practices are important (Foege *et al.*, 2019) in helping firms prevent core innovative knowledge leakages. Firms characterized by well-developed informal defense mechanisms are better able to protect their core knowledge and develop partnership portfolios across their organizational and technological boundaries. We reveal how and when firms implement informal safeguards to address the tensions between multilateral collaborative innovation and knowledge protection. In this way, we encourage firms to design informal safeguards that might reduce the risks of knowledge theft by external innovative collaborators.

Second, our findings show that partnership portfolios go beyond the simplistic linear association between partnership portfolios and radical innovation, but we advance that understanding by exposing the partnership portfolio–knowledge protection relationship in a more explanatory contingency framework. The moderation of safeguard mechanisms highlights the importance of core knowledge protection in open innovation partnership portfolio processes. This implies that firms must choose different knowledge protection mechanisms for different innovation collaborative activities. That is, when firms collaborate with many external actors, they should be careful and discreet when monitoring their partners' behaviors in light of the risks and problems related to leakage. They should continue investing in informal defense mechanisms to prevent undesired knowledge leakages.

Finally, our study has significant implications that can help firms better design and protect their core knowledge and implement safeguarding practices in their partnership portfolio activities; indeed, the importance of these issues is expected to increase in the wake of open innovation activities. Firms should devote more attention not only to the safeguarding properties of partnership portfolios for core knowledge but also to the potential they have to strengthen an optimal mix of distinct protective mechanisms for innovative collaboration.

Limitations and future research

The findings and limitations of our study offer several avenues for future research. First, we assessed the partnership portfolios using an aggregated measure based on 11 sources. Cheng and Huizingh (2014) proposed well-developed measurement items, which may also be relevant in terms of openness, but we omitted those additional dimensions from our partnership portfolio construct because we lacked the appropriate data. Moreover, our analysis can be extended to other measurement constructs in future research. Second, we focused on two complementary safeguard mechanisms across different partners and countries: geographic diversity and collaborative breadth. Other potential limitations, such as cross-cultural differences, may moderate the relationship between partnership portfolios and radical innovation performance. Future studies should test cross-cultural practices and other moderating variables between partnership portfolios and radical innovation to further test the theoretical predictions for robustness. Third, in devising appropriate measures to estimate different sources of geographic diversity and the collaborative breadth embedded in cross-boundary innovation activities, we resorted to borrowing constructs such as the Herfindahl index from other fields of study and to deriving measures such as interactions with the partnership portfolio. Further refining these measures would be a worthwhile

endeavor. Nevertheless, the measures used in this study can be used to complement other subjective measures in future research.

Conclusion

In conclusion, our study shows that partnership portfolios can play a determining role in facilitating radical innovation outcomes, but this is only one perspective among several. As such, it complements existing research and contributes to open innovation theory on partnership portfolios by enhancing our understanding of how simultaneity can be used in open co-innovation and knowledge protection (Grimpe and Kaiser, 2010; Wadhwa *et al.*, 2017). Additionally, this study identifies geographic diversity and collaborative breadth as moderators of the relationship between firms' partnership portfolios and radical innovation performance. This finding may indicate that firms' geographic diversity and collaborative breadth can prevent unintended knowledge from being disclosed to external partners. We call this a "safeguard mechanism." From this perspective, our findings provide a foundation for reconciling the tension between partnership portfolios and knowledge protection and proposing informal appropriability strategies (Miric *et al.*, 2019).

References

Abdulkader, B., Magni, D., Cillo, V., Papa, A. and Micera, R. (2020), "Aligning firm's value system and open innovation: a new framework of business process management beyond the business model innovation", *Business Process Management Journal*, Vol. 26 No. 5, pp. 999-1020.

Abernathy, W. and Clark, K.B. (1985), "Innovation: mapping the winds of creative destruction", *Research Policy*, Vol. 14 No. 1, pp. 3-22.

Ahuja, G. and Katila, R. (2001), "Technological acquisitions and the innovation performance of acquiring firms: a longitudinal study", *Strategic Management Journal*, Vol. 22 No. 3, pp. 197-220.

Anokhin, S., Örtqvist, D., Thorgren, S. and Wincent, J. (2011), "Corporate venturing deal syndication and innovation: the information exchange paradox", *Long Range Planning*, Vol. 44 No. 2, pp. 134-151.

Ardito, L. and Petruzzelli, A.M. (2017), "Breadth of external knowledge sourcing and product innovation: the moderating role of strategic human resource practices", *European Management Journal*, Vol. 35 No. 2, pp. 261-272.

Ardito, L., Peruffo, E. and Natalicchio, A. (2019), "The relationships between the internationalization of alliance portfolio diversity, individual incentives, and innovation ambidexterity: a micro foundational approach", *Technological Forecasting and Social Change*, Vol. 148, p. 119714.

Attewell, P. (1992), "Technology diffusion and organizational learning: the case of business computing", *Organization Science*, Vol. 3 No. 1, pp. 1-19.

Bahlmann, M.D. (2015), "Finding value in geographic diversity through prior experience and knowledge integration: a study of ventures' innovative performance", *Industrial and Corporate Change*, Vol. 25 No. 4, pp. 576-589.

Benner, M.J. and Tushman, M.L. (2003), "Exploitation, exploration, and process management: the productivity dilemma revisited", *The Academy of Management Review*, Vol. 28 No. 2, pp. 238-256.

Berry, H. (2015), "Knowledge inheritance in global industries: the impact of parent firm knowledge on the performance of foreign subsidiaries", *Academy of Management Journal*, Vol. 58 No. 5, pp. 1438-1458.

Bianchi, M., Croce, A., Dell'Era, C., Di Benedetto, C.A. and Frattini, F. (2016), "Organizing for inbound open innovation: how external consultants and a dedicated R&D unit influence product innovation performance", *Journal of Product Innovation Management*, Vol. 33 No. 4, pp. 492-510.

Bogers, M. (2011), "The open innovation paradox: knowledge sharing and protection in R&D collaborations", *European Journal of Innovation Management*, Vol. 14 No. 1, pp. 93-117.

Boschma, R.A. (2005), "Proximity and innovation: a critical assessment", *Regional Studies*, Vol. 39 No. 1, pp. 61-74.

Brown, S.L. and Eisenhardt, K.M. (1997), "The art of continuous change: linking complexity theory and time-paced evolution in relentlessly shifting organizations", *Administrative Science Quarterly*, Vol. 42 No. 1, pp. 1-34.

Brusoni, S., Prencipe, A. and Pavitt, K. (2001), "Knowledge specialization, organizational coupling, and the boundaries of the firm: why do firms know more than they make?", *Administrative Science Quarterly*, Vol. 46 No. 4, pp. 597-621.

Cannella, A.A., Park, J.H. and Lee, H.U. (2008), "Top management team functional background diversity and firm performance: examining the roles of team member colocation and environmental uncertainty", *Academy of Management Journal*, Vol. 51 No. 4, pp. 768-784.

Caputo, F., Magni, D., Papa, A. and Corsi, C. (2021), "Knowledge hiding in socioeconomic settings: matching organizational and environmental antecedents", *Journal of Business Research*, Vol. 135, pp. 19-27.

Cassiman, B. and Veugelers, R. (2006), "In search of complementarity in innovation strategy: internal R&D and external knowledge acquisition", *Management Science*, Vol. 52 No. 1, pp. 68-82.

Cheng, C.C.J. and Huizingh, E.K.R.E. (2014), "When is open innovation beneficial? The role of strategic orientation", *Journal of Product Innovation Management*, Vol. 31 No. 6, pp. 1235-1253.

Chesbrough, H.W. (2003), *Open Innovation, the New Imperative for Creating and Profiting from Technology*, Harvard Business School Press, Boston, MA.

Chesbrough, H. and Crowther, A.K. (2006), "Beyond high tech: early adopters of open innovation in other industries", *R&D Management*, Vol. 36 No. 3, pp. 229-236.

Dahlin, K.B. and Behrens, D.M. (2005), "When is an invention really radical?: Defining and measuring technological radicalness", *Research Policy*, Vol. 34 No. 5, pp. 717-737.

Das, T.K. and Teng, B.S. (1998), "Between trust and control: developing confidence in partner cooperation in alliances", *The Academy of Management Review*, Vol. 23 No. 3, pp. 491-512.

Dierickx, I. and Cool, K. (1989), "Asset stock accumulation and sustainability of competitive advantage", *Management Science*, Vol. 35 No. 12, pp. 1504-1511.

Duysters, G. and Lokshin, B. (2011), "Determinants of alliance portfolio complexity and its effect on innovative performance of companies", *Journal of Product Innovation Management*, Vol. 28 No. 4, pp. 570-585.

Dyer, J. (1997), "Effective interfirm collaboration: how firms minimize transaction costs and maximize transaction value", *Strategic Management Journal*, Vol. 18 No. 7, pp. 535-556.

Dyer, J.H. and Singh, H. (1998), "The relational view: cooperative strategy and sources of interorganizational competitive advantage", *The Academy of Management Review*, Vol. 23 No. 4, pp. 660-679.

Eisenhardt, K.M. (1989), "Building theories from case study research", *The Academy of Management Review*, Vol. 14 No. 4, pp. 532-550.

Eisenhardt, K.M. and Tabrizi, B.N. (1995), "Accelerating adaptive processes: product innovation in the global computer industry", *Administrative Science Quarterly*, Vol. 40 No. 1, pp. 84-110.

Fabrizio, K.R. and Thomas, L.G. (2012), "The impact of local demand on innovation in a global industry", *Strategic Management Journal*, Vol. 33 No. 1, pp. 42-64.

Fleming, L. (2001), "Recombinant uncertainty in technological search", *Management Science*, Vol. 47 No. 1, pp. 117-132.

Foege, J.N., Lauritzen, G.D., Tietze, F. and Salge, T.O. (2019), "Reconceptualizing the paradox of openness: how solvers navigate sharing-protecting tensions in crowdsourcing", *Research Policy*, Vol. 48 No. 6, pp. 1323-1339.

Frost, T.S., Birkinshaw, J.M. and Ensign, P.C. (2002), "Centers of excellence in multinational corporations", *Strategic Management Journal*, Vol. 23 No. 11, pp. 997-1018.

Garcia Martinez, M., Zouaghi, F. and Sanchez Garcia, M. (2017), "Capturing value from alliance portfolio diversity: the mediating role of R&D human capital in high and low tech industries", *Technovation*, Vol. 59, pp. 55-67.

Garcia Martinez, M., Zouaghi, F. and Sanchez Garcia, M. (2019), "Casting a wide net for innovation: mediating effect of R&D humanand social capital to unlock the value from alliance portfolio diversity", *British Journal of Management*, Vol. 30 No. 4, pp. 769-790.

Goerzen, A. and Beamish, P.W. (2005), "The effect of alliance network diversity on multinational enterprise performance", *Strategic Management Journal*, Vol. 26 No. 4, pp. 333-354.

Grant, R.M. (1996), "Toward a knowledge-based theory of the firm", *Strategic Management Journal*, Vol. 17 No. S2, pp. 109-122.

Grant, R.M. and Baden-Fuller, C. (2004), "A knowledge accessing theory of strategic alliances", *Journal of Management Studies*, Vol. 41 No. 1, pp. 61-84.

Greene, W.H. (2000), *Econometric Analysis*, 4th ed., Prentice-Hall, Upper Saddle River, NJ.

Griliches, Z. (1995), "R&D and productivity: econometric results and measurement issues", in Stoneman, P. (Ed.), *Handbook of the Economics of Innovation and Technological Change*, Blackwell, Oxford.

Grimpe, C. and Kaiser, U. (2010), "Balancing internal and external knowledge acquisition: the gains and pains from R&D outsourcing", *Journal of Management Studies*, Vol. 47 No. 8, pp. 1483-1509.

Gulati, R.N. (1999), "Network location and learning: the influence of network resources and firm capabilities on alliance formation", *Strategic Management Journal*, Vol. 20 No. 5, pp. 397-420.

Haans, R.F., Pieters, C. and He, Z.L. (2016), "Thinking about U: theorizing and testing U-and inverted U-shaped relationships in strategy research", *Strategic Management Journal*, Vol. 37 No. 7, pp. 1177-1195.

Hair, J.F. Jr., Black, W.C., Babin, B.J., Anderson, R.E. and Tatham, R.L. (2006), *Multivariate Data Analysis*, 6th ed., Pearson International Education, Upper Saddle River, NJ.

Hagedoorn, J. (1993), "Understanding the rationale of strategic technology partnering: interorganizational modes of cooperation and sectoral differences", *Strategic Management Journal*, Vol. 14 No. 5, pp. 371-385.

Hitt, M.A., Hoskisson, R.E. and Kim, H. (1997), "International diversification: effects on innovation and firm performance in product-diversified firms", *Academy of Management Journal*, Vol. 40 No. 4, pp. 767-798.

Hohberger, J. and Wilden, R. (2022), "Geographic diversity of knowledge inputs: the importance of aligning locations of knowledge inputs and inventors", *Journal of Business Research*, Vol. 145, pp. 705-719.

Hwang, B.N., Lai, Y.P. and Wang, C. (2022), "Open innovation and organizational ambidexterity", *European Journal of Innovation Management*, doi: 10.1108/EJIM-06-2021-0303.

James, S.D., Leiblein, M.J. and Lu, S. (2013), "How firms capture value from their innovations", *Journal of Management*, Vol. 39 No. 5, pp. 1123-1155.

Katila, R. and Ahuja, G. (2002), "Something old, something new: a longitudinal study of search behavior and new product introduction", *Academy of Management Journal*, Vol. 45 No. 6, pp. 1183-1194.

Kennedy, P. (2003), *A Guide to Econometrics*, 5th ed., MIT Press, Cambridge, MA.

Kim, M. (2016), "Geographic scope, isolating mechanisms, and value appropriation", *Strategic Management Journal*, Vol. 37 No. 4, pp. 695-713.

Kogut, B. and Zander, U. (1992), "Knowledge of the firm, combinative capabilities, and the replication of technology", *Organization Science*, Vol. 3 No. 3, pp. 383-397.

Lahiri, N. (2010), "Geographic distribution of R&D activity: how does it affect innovation quality?", *Academy of Management Journal*, Vol. 53 No. 5, pp. 1194-1209.

Laursen, K. (2012), "Keep searching and you'll find: what do we know about variety creation through firms' search activities for innovation", *Industrial and Corporate Change*, Vol. 21 No. 5, pp. 1181-1220.

Laursen, K. and Salter, A. (2006), "Open for innovation: the role of openness in explaining innovation performance among UK manufacturing firms", *Strategic Management Journal*, Vol. 27 No. 2, pp. 131-150.

Lavie, D. (2007), "Alliance portfolios and firm performance: a study of value creation and appropriation in the U.S software industry", *Strategic Management Journal*, Vol. 28 No. 12, pp. 1187-1212.

Lee, G.K. (2007), "The significance of network resources in the race to enter emerging product markets: the convergence of telephony communications and computer networking, 1989–2001", *Strategic Management Journal*, Vol. 28 No. 1, pp. 17-37.

Leiponen, A. and Helfat, C.E. (2010), "Innovation objectives, knowledge source, and the benefits of breadth", *Strategic Management Journal*, Vol. 31 No. 2, pp. 224-236.

Li, W., Veliyath, R. and Tan, J. (2013), "Network characteristics and firm performance: an examination of the relationships in the context of a cluster", *Journal of Small Business Management*, Vol. 51 No. 1, pp. 1-22.

Lieberman, M.B. and Montgomery, D.B. (1988), "First-mover advantages", *Strategic Management Journal*, Vol. 9 No. S1, pp. 41-58.

Lippman, S.A. and Rumelt, R.P. (1982), "Uncertain imitability: an analysis of interfirm differences in efficiency under competition", *The Bell Journal of Economics*, Vol. 13 No. 2, pp. 418-438.

Love, J.H., Roper, S. and Vahter, P. (2014), "Learning from openness: the dynamics of breadth in external innovation linkages", *Strategic Management Journal*, Vol. 35 No. 11, pp. 1703-1716.

McFadyen, M.A. and Cannella, A.A. Jr. (2004), "Social capital and knowledge creation: diminishing returns of the number and strength of exchange relationships", *Academy of Management Journal*, Vol. 47 No. 5, pp. 735-746.

Magni, D., Chierici, R., Fait, M. and Lefebvre, K. (2022), "A network model approach to enhance knowledge sharing for internationalization readiness of SMEs", *International Marketing Review*, Vol. 39 No. 3, pp. 626-652.

Maritan, C.A. and Brush, T.H. (2003), "Heterogeneity and transferring practices: implementing flow manufacturing in multiple plants", *Strategic Management Journal*, Vol. 24 No. 10, pp. 945-959.

Miner, A., Bassoff, P. and Moorman, G. (2001), "Organizational improvisation and learning: a field study", *Administrative Science Quarterly*, Vol. 46 No. 2, pp. 304-337.

Miric, M., Boudreau, K.J. and Jeppesen, L.B. (2019), "Protecting their digital assets: the use of formal & informal appropriability strategies by app developers", *Research Policy*, Vol. 48 No. 8, p. 103738.

Nelson, R. (1993), *National Innovation Systems: A Comparative Analysis*, Oxford University Press, Oxford.

Nelson, R.R. and Winter, S.G. (1982), "The Schumpeterian tradeoff revisited", *The American Economic Review*, Vol. 72 No. 1, pp. 114-132.

Nickerson, J.A. and Zenger, T.R. (2004), "A knowledge-based theory of the firm: the problem-solving perspective", *Organization Science*, Vol. 15 No. 6, pp. 617-632.

OECD (2005), *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data*, 3rd ed. OECD, Paris and Eurostat, Luxembourg.

Oerlemans, L.A., Knoben, J. and Pretorius, M.W. (2013), "Alliance portfolio diversity, radical and incremental innovation: themoderating role of technology management", *Technovation*, Vol. 33 Nos 6/7, pp. 234-246.

Patel, P.C., Fernhaber, S.A., McDougall-Covin, P.P. and Van der Have, R.P. (2014), "Beating competitors to international markets: the value of geographically balanced networks for innovation", *Strategic Management Journal*, Vol. 35 No. 5, pp. 691-711.

Phene, A., Fladmoe-Lindquist, K. and Laurence, M. (2006), "Breakthrough innovations in the US biotechnology industry: the effects of technological space and geographic origin", *Strategic Management Journal*, Vol. 27 No. 4, pp. 369-388.

Powell, W.W., Koput, K.W. and Smith-Doerr, L. (1996), "Interorganizational collaboration and the locus of innovation: networks of learning in biotechnology", *Administrative Science Quarterly*, Vol. 41 No. 1, pp. 116-145.

Reed, R. and DeFilippi, R.J. (1990), "Causal ambiguity, barriers to imitation, and sustainable competitive advantage", *The Academy of Management Review*, Vol. 15 No. 1, pp. 88-102.

Rosenkopf, L. and Nerkar, A. (2001), "Beyond local search: boundary-spanning, exploration, and impact in the optical disk industry", *Strategic Management Journal*, Vol. 22 No. 4, pp. 287-306.

Rumelt, R.P. (1984), "Towards a strategic theory of the firm", *Competitive Strategic Management*, Vol. 26 No. 3, pp. 556-570.

Sampson, R.C. (2007), "R&D alliances and firm performance: the impact of technological diversity and alliance organization on innovation", *Academy of Management Journal*, Vol. 50 No. 2, pp. 364-386.

Scuotto, V., Del Giudice, M., Bresciani, S. and Meissner, D. (2017), "Knowledge-driven preferences in informal inbound open innovation modes. An explorative view on small to medium enterprises", *Journal of Knowledge Management*, Vol. 21 No. 3, pp. 640-655.

Spithoven, A. and Teirlinck, P. (2015), "Internal capabilities, network resources and appropriation mechanisms as determinants of R&D outsourcing", *Research Policy*, Vol. 44 No. 3, pp. 711-725.

SRDA (2013), "3rd community innovation survey", Survey Research Data Archive, Academia Sinica, Taiwan.

Taylor, A. and Greve, H.R. (2006), "Superman or the fantastic four? Knowledge combination and experience in innovative teams", *Academy of Management Journal*, Vol. 49 No. 4, pp. 723-740.

Teece, D.J. (1986), "Profiting from technological innovation: implications for integration, collaboration, licensing and public policy", *Research Policy*, Vol. 15 No. 6, pp. 285-305.

Tomlinson, P.R. (2010), "Co-operative ties and innovation: some new evidence for UK manufacturing", *Research Policy*, Vol. 39 No. 6, pp. 762-75.

Utterback, J.M. (1994), "Radical innovation and corporate regeneration", *Research-Technology Management*, Vol. 37 No. 4, p. 10.

Van Beers, C. and Zand, F. (2014), "R&D cooperation, partner diversity, and innovation performance: an empirical analysis", *Journal of Product Innovation Management*, Vol. 31 No. 2, pp. 292-312.

von Hippel, E. (1988), *The Sources of Innovation*, Oxford University Press, New York, NY.

Wadhwa, A., Bodas Freitas, I.M. and Sarkar, M.B. (2017), "The paradox of openness and value protection strategies: effect of extramural R&D on innovative performance", *Organization Science*, Vol. 28 No. 5, pp. 873-893.

Wang, C.H., Chin, T. and Lin, J.H. (2020), "Openness and firm innovation performance: the moderating effect of ambidextrous knowledge search strategy", *Journal of Knowledge Management*, Vol. 24 No. 2, pp. 301-323.

Wuyts, S. and Dutta, S. (2014), "Benefiting from alliance portfolio diversity: the role of past internal knowledge creation strategy", *Journal of Management*, Vol. 40 No. 6, pp. 1653-1674.

Zobel, A.K., Balsmeier, B. and Chesbrough, H. (2016), "Does patenting help or hinder open innovation? Evidence from new entrants in the solar industry", *Industrial and Corporate Change*, Vol. 25 No. 2, pp. 307-331.

Further reading

Arora, A., Athreye, S. and Huang, C. (2016), "The paradox of openness revisited: collaborative innovation and patenting by UK innovators", *Research Policy*, Vol. 45 No. 7, pp. 1352-1361.

Bell, G.G. and Zaheer, A. (2007), "Geography, networks, and knowledge flow", *Organization Science*, Vol. 18 No. 6, pp. 955-972.

Golden, T.D. and Viega, J.F. (2005), "The impact of extent of telecommuting on job satisfaction: resolving inconsistent findings", *Journal of Management*, Vol. 31 No. 2, pp. 1-15.

Laursen, K. and Salter, A. (2014), "The paradox of openness: appropriability, external search and collaboration", *Research Policy*, Vol. 43 No. 5, pp. 867-878.

Nonaka, I., Toyama, R. and Nagata, A. (2000), "A firm as a knowledge-creating entity: a new perspective on the theory of the firm", *Industrial and Corporate Change*, Vol. 9 No. 1, pp. 1-20.

About the authors

Chunhsien Wang is currently a Professor with the College of Management, National Chiayi University, Chiayi, Taiwan. He teaches MBA, EMBA and undergraduate students in the field of technology of management, innovation management, entrepreneurship and strategic management. His current research interests include technological innovation and innovation strategic, open innovation and high-technology management, R&D innovation and interfirm alliances as well as social network and its applications. He has published more than 50 articles in top English and Chinese journals. He was a member of PICMET and IEEE.

Tachia Chin is a Professor at School of Management, Zhejiang University of Technology, Hangzhou, China. She earned her Ph.D. at Jinan University and completed her post-doc study at Sun Yat-sen University. She has more than 10 years of working experience as a

senior HR/CSR executive for foreign-invested manufacturing firms in China. She has published more than 100 articles in top English and Chinese journals such as Technological Forecast and Social Change, International Journal of Production Economics, Journal of International management, International Journal of Human Resource Management, Career Development International and Journal of Knowledge Management, and has served as a leading guest editor for Asia Pacific Business Review, Journal of Knowledge Management and Career Development International. Her research focuses are cross-cultural management, Knowledge Management, leadership and strategic HRM. Tachia Chin is the corresponding author and can be contacted at: tachiachin@zjut.edu.cn

Yuan Yin Chiew is a Research Assistant. Her research focuses on the policy research for the open innovation and energy sustainable development. She is currently working at the National Applied Research Laboratories, Science & Technology Policy Research and Information Center. Her research has been published in international conferences.

Cinzia Capalbo is an Associate professor in Economic History and Teacher in Economic History and History of the Fashion Industry at the Department of History Anthropology Religions Art History, Media and Performing Arts, Sapienza University of Rome. Cinzia Capalbo is also the Director of the Masters in Fashion Management Sapienza University of Rome.