



Journal of Knowledge Management

Reconfiguring the firm's core technological portfolio through open innovation: focusing on technological M&A

Seungryul Ryan Shin, John Han, Klaus Marhold, Jina Kang,

Article information:

To cite this document:

Seungryul Ryan Shin, John Han, Klaus Marhold, Jina Kang, (2017) "Reconfiguring the firm's core technological portfolio through open innovation: focusing on technological M&A", Journal of Knowledge Management, Vol. 21 Issue: 3, pp.571-591, doi: 10.1108/JKM-07-2016-0295

Permanent link to this document:

<http://dx.doi.org/10.1108/JKM-07-2016-0295>

Downloaded on: 01 June 2017, At: 21:28 (PT)

References: this document contains references to 84 other documents.

To copy this document: permissions@emeraldinsight.com

The fulltext of this document has been downloaded 113 times since 2017*

Users who downloaded this article also downloaded:

(2017), "On the path towards open innovation: assessing the role of knowledge management capability and environmental dynamism in SMEs", Journal of Knowledge Management, Vol. 21 Iss 3 pp. 553-570 <http://dx.doi.org/10.1108/JKM-09-2016-0403>

(2017), "How MNC's subsidiaries may improve their innovative performance? The role of external sources and knowledge management capabilities", Journal of Knowledge Management, Vol. 21 Iss 3 pp. 540-552 <http://dx.doi.org/10.1108/JKM-09-2016-0411>

Access to this document was granted through an Emerald subscription provided by emerald-srm:438659 []

For Authors

If you would like to write for this, or any other Emerald publication, then please use our Emerald for Authors service information about how to choose which publication to write for and submission guidelines are available for all. Please visit www.emeraldinsight.com/authors for more information.

About Emerald www.emeraldinsight.com

Emerald is a global publisher linking research and practice to the benefit of society. The company manages a portfolio of more than 290 journals and over 2,350 books and book series volumes, as well as providing an extensive range of online products and additional customer resources and services.

Emerald is both COUNTER 4 and TRANSFER compliant. The organization is a partner of the Committee on Publication Ethics (COPE) and also works with Portico and the LOCKSS initiative for digital archive preservation.

*Related content and download information correct at time of download.

Reconfiguring the firm's core technological portfolio through open innovation: focusing on technological M&A

Seungryul Ryan Shin, John Han, Klaus Marhold and Jina Kang

Abstract

Purpose – The purpose of this study is to investigate the effects of open innovation, especially focusing on technological M&A, on subsequent innovation and changes to the firm's core technological portfolio.

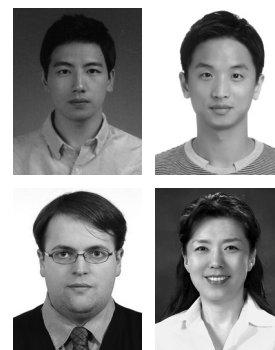
Design/methodology/approach – The study suggests three types of core technological areas, based on prior focus and experience in technological categories. These are 1) the existing core area, in which the acquirer firm retains its knowledge and expertise, 2) the enhanced core area, where knowledge and expertise in the acquirer firm's insufficient areas are strengthened, and 3) the new core area, i.e. new knowledge fields in which the acquirer firm ventures into. The study then analyzes the effects of two key knowledge characteristics of the target firm, similarity and complementarity, on post-M&A innovation outcomes in each of the three core technological areas.

Findings – The results confirm that while none of the investigated knowledge characteristics of the target firm is advantageous for post-M&A innovation outcomes in existing core areas, similarity of the target firm does facilitate post-M&A innovation outcomes in enhanced core areas. Moreover, the results confirm that complementarity of the target firm is beneficial for post-M&A innovation outcomes in new core areas.

Originality/value – The study explains the reconfiguration mechanism of a firm's core technological portfolio. It also suggests an extended framework to analyze innovation outcomes in more detail. Moreover, the study helps to explain why most M&As result in failure.

Keywords Knowledge characteristics, Knowledge management, Open innovation, Core competences, Core technological portfolio, Technological M&A

Paper type Research paper



Seungryul Ryan Shin, John Han, Klaus Marhold and Jina Kang are based at Technology Management, Economics, and Policy Program, Seoul National University, Seoul, South Korea.

1. Introduction

A firm's core technological competence determines its competitiveness in technology-intensive industries (Granstrand *et al.*, 1997; Prahalad and Hamel, 1990; Duysters and Hagedoorn, 2000). Accordingly, firms are required to wisely manage their own core technological portfolio to sustain a competitive advantage. However, firms developing core technological areas solely relying on their own internal development may cause their own "core competencies" to turn into "core rigidities", which prevent the pursuit of new and promising ideas and technologies (Leonard-Barton, 1992; Kraatz and Zajac, 2001). Thus, firms increasingly utilize open innovation and obtain the knowledge and expertise required to develop and adapt their core technological portfolio from external sources (Chesbrough, 2003, 2006a, 2006b; Vanhaverbeke *et al.*, 2002).

Among the various open innovation modes, this research focuses on technological M&A. As technological M&A allows to absorb not only technological knowledge but also technological expertise and capabilities of the target firm (Ahuja and Katila, 2001; Jo *et al.*, 2016), it has significant impacts on the acquirer firm's post-M&A internal changes and subsequent innovation activities (Cassiman *et al.*, 2005; Colombo and Rabbiosi, 2014; Kapoor and Lim,

Received 22 July 2016
Revised 24 November 2016
Accepted 2 January 2017

The authors are grateful to Antonio Messeni Petruzzelli, Lorenzo Ardito and Elias G. Carayannis for their insightful editorship. The authors would also like to thank two anonymous reviewers for their helpful comments and suggestions. This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2016S1A5A2A01026718).

2007). Therefore, technological M&As provide a suitable setting to examine how utilizing open innovation affects the reconfiguration of the firm's core technological portfolio.

Much of the existing literature emphasizes that relational knowledge characteristics between the acquirer firm and the target firm's knowledge bases are an important dyadic factor to be considered in studies of technological M&As (Ahuja and Katila, 2001; Makri *et al.*, 2010; Sears and Hoetker, 2014; Han *et al.*, 2016). Foundational research on technological M&As examined how the similarity of the target firm's and the acquirer firm's knowledge affects post-M&A innovation outcomes (Ahuja and Katila, 2001; Cloudt *et al.*, 2006). More recent research classified the relational knowledge characteristics of the target firm into similarity and complementarity, and examined the effect of each target firm knowledge characteristic on post-M&A innovation outcomes (Makri *et al.*, 2010; Ganzaroli *et al.*, 2016). However, the effects of the target firm's knowledge characteristics on the acquirer firm's core technological portfolio have not been closely examined. This contrasts with the streams of literature which find that firms' competitiveness is determined by their core technological areas rather than the overall technology areas of the entire firm (Granstrand *et al.*, 1997; Phene *et al.*, 2012; Chiesa, 2001).

To remedy the shortcomings of prior research, this study examines the effects of technological M&As, especially focusing on knowledge characteristics of the target firm, on the acquirer firm's core technological portfolio reconfiguration. This research suggests that a firm's open innovation activities, i.e. external knowledge sourcing, involves the reconfiguration of the firm's core technological portfolio through three different mechanisms. Accordingly, the study distinguishes the firm's core technological portfolio into three distinct areas: *Existing core area*, *Enhanced core area* and *New core area*. The study investigates how two key knowledge characteristics of the target firm, i.e. similarity and complementarity, affect post-M&A innovation outcomes in each of the three core technological areas, thereby showing the reconfiguration of the firm's core technological portfolio.

This study makes several contributions to the research on M&As and technology management. First, it explains how firms reconfigure their core technological portfolio by suggesting three types of core technological area formation mechanisms. Second, it provides a new framework that builds up on the existing dichotomy of innovation, i.e. exploitation versus exploration, and allows to analyze innovation outcomes in detail. Third, the findings of the study might help to explain the high rate of "failed M&A deals" reported in the literature. The study also provides managerial implications by listing guidelines for acquirer firms selecting a proper target firm with matching knowledge characteristics according to the purpose of the technological M&A deal.

The remainder of this paper is structured as follows: Section 2 introduces the concepts of core technological areas and knowledge characteristics of the target firm. Section 3 suggests hypotheses linking the knowledge characteristics and subsequent core technology innovation. Section 4 describes the data sample, variable constructs and statistical methods used to test the hypotheses. Section 5 presents the results of the empirical tests, while Section 6 provides a discussion of the results, as well as the study's contributions and implications.

2. Theory and concepts

2.1 Core technological areas

Literature suggests that developing core technological areas of competences and expertise is vital for firms to sustain a competitive advantage (Prahalad and Hamel, 1990; Leonard-Barton, 1992; Chiesa, 2001). This is especially important for firms operating in technology-intensive industries (Duysters and Hagedoorn, 2000). According to Granstrand *et al.* (1997), most firms have distributed core technological areas, rather than

concentrating on a small number of core technological areas, and they create a significant portion of their innovation within these core technological areas. To sustain a competitive advantage, firms are required to keep reconfiguring their core technological portfolio in line with market or technological changes and to furnish expertise in the core technological areas accordingly (Prahalad and Hamel, 1990; Grant, 1996; Chiesa, 2001; Jain, 2015).

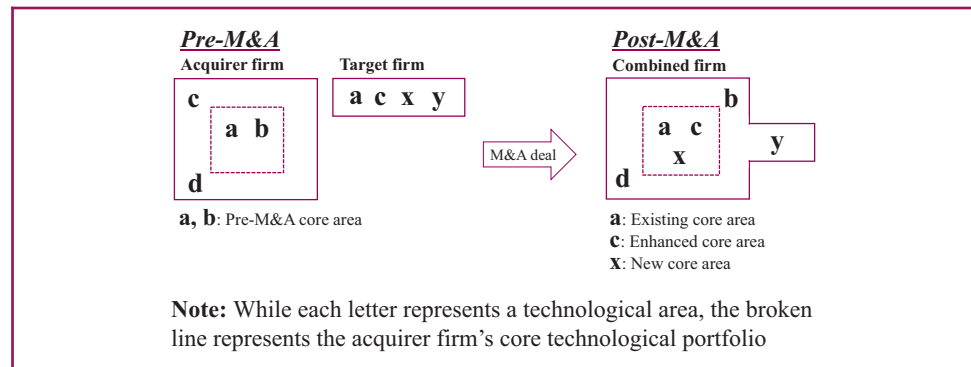
When a firm sources knowledge from outside the firm, the reconfiguration of the firm's core technological portfolio is realized through three distinct change mechanisms. To investigate each change mechanism, this study classifies the core technological areas based on whether the acquirer firm had its strategic focus on the technological area before the external sourcing and on whether the acquirer firm possessed knowledge in the technological area before the external sourcing. First, technological areas, which have been a part of the firm's core technological portfolio before the external sourcing and still reside within the firm's core technological portfolio after the external sourcing, are defined as "existing core area". The firm has retained its strategic focus on the existing core areas. It possessed sufficient technological expertise and capabilities in existing core areas (Granstrand *et al.*, 1997; Prahalad and Hamel, 1990), which allowed it to focus innovation in the technological areas before the external sourcing. Moreover, vigorous innovation activity in the existing core areas established technological trajectories and routines in these technological areas (Dosi, 1982; Nelson and Winter, 1982).

Second, technological areas, which have been a part of the firm's non-core technological areas before the external sourcing and become a part of the core technological areas of the firm after the external sourcing, are defined as "enhanced core area". Enhanced core areas have been peripheral to the firm's strategic focus before the external sourcing. Contrary to the existing core areas, the firm possessed insufficient technological expertise and capabilities in these enhanced core areas (Granstrand *et al.*, 1997). In addition, the technological trajectory and routine are inadequately established in the enhanced core areas due to inactive innovation activities and insufficient experiences (Dosi, 1982; Nelson and Winter, 1982). Changes in the firm's strategic direction to improve the expertise in the enhanced core areas and to secure competences in these technological areas require technological expertise and capabilities that may complement the acquirer firm's existing knowledge and expertise to make up for the existing deficiencies (Kraatz and Zajac, 2001; Phene *et al.*, 2012; Makri *et al.*, 2010).

Third, technological areas, which the firm did not possess before the external sourcing but which become a part of the firm's core technological areas after the external sourcing, are defined as "new core area". The firm had no technological expertise and capabilities in these new core areas, which implies the absence of technological trajectories and routines (Dosi, 1982; Nelson and Winter, 1982). Changes in the firm's strategic direction to find a new technological niche require various opportunities for idea cross-fertilization with other existing knowledge or expertise (Björkdahl, 2009; Makri *et al.*, 2010) and technological expertise and capabilities of technological areas with a high degree of novelty from outside the firm (Phene *et al.*, 2012; Kraatz and Zajac, 2001; Kapoor and Lim, 2007).

This study analyzes how technological M&As affect the reconfiguration of the acquirer firm's core technological portfolio. Consequently, it focuses on the above-mentioned three distinct mechanisms of change, i.e. it investigates the acquirer firm's post-M&A innovation outcomes in each of the core technological areas suggested: *Existing core innovation*, *Enhanced core innovation* and *New core innovation*. Figure 1 illustrates the reconfiguration of the acquirer firm's core technological portfolio through an M&A deal and highlights the definitions for each of the core technological areas suggested by this study.

Figure 1 Reconfiguration of the acquirer firm's core technological portfolio through a technological M&A deal



2.2 Knowledge characteristics

This study examines the effects of two distinct knowledge characteristics of the target firm: *Similarity* and *Complementarity*. Makri *et al.* (2010) suggests a framework for knowledge characteristics based on these measures which has found widespread adoption in recent studies (Orsi *et al.*, 2015; Miozzo *et al.*, 2015; Ganzaroli *et al.*, 2016). Extending this framework and definitions provided by Makri *et al.* (2010), this study defines the similarity and the complementarity of the target firm's knowledge base. *Similarity* is the degree to which the target firm has technological knowledge and expertise that are similar to that of the acquirer firm. Higher similarity of the target firm indicates that the target firm has a knowledge base and expertise more similar to the acquirer firm (Makri *et al.*, 2010; Kapoor and Lim, 2007; Larsson and Finkelstein, 1999). This concept also relates to the concept of technological familiarity, i.e. the extent to which the acquirer firm is familiar with and has prior knowledge of the acquiring technological areas (Arts and Veugelers, 2014; Fleming, 2001; Roberts and Berry, 1984). *Complementarity* of the target firm is the degree to which the target firm possesses technological knowledge and expertise that are new to the acquirer firm but complementary to the acquirer firm's existing knowledge and expertise. A high complementarity of the target firm implies that the target firm possesses more knowledge that has a high recombinative potential with the acquirer firm's existing knowledge base (Ahuja and Katila, 2001; Makri *et al.*, 2010) and expertise that complements the acquirer firm's existing expertise (Kapoor and Lim, 2007; Larsson and Finkelstein, 1999).

3. Hypotheses

In the following section, each of the previously discussed knowledge characteristics of the target firm is linked with the post-M&A innovation outcomes in each type of core technological area. This allows to investigate the reconfiguration of the acquirer firm's core technological portfolio as a result of the technological M&A.

3.1 Existing core innovation

Existing core areas are where the acquirer firm already possesses technological capabilities and expertise (Granstrand *et al.*, 1997; Prahalad and Hamel, 1990). Moreover, concentrated innovation activities before the M&A allowed the acquirer firm to establish technological trajectories and routines in the existing core areas (Nelson and Winter, 1982; Dosi, 1982). Under these circumstances, similarity of the target firm impedes the innovation in the acquirer firm's post-M&A existing core areas. The acquirer firm's knowledge workers in these areas already have sufficient technological expertise and follow established technological trajectories to create innovation in the technological areas on their own

(Dosi, 1982; Benner and Tushman, 2002, 2003; Burgelman, 2002). Thus, a high level of similarity of the target firm's knowledge resources results in redundancy of expertise and knowledge in the existing core areas (Ahuja and Katila, 2001; Sears and Hoetker, 2014). Moreover, firms usually eliminate duplicative technological capabilities and expertise after M&As to increase efficiency and maximize the benefits of the M&As (Cassiman *et al.*, 2005). The threat of being eliminated increases the propensity of the acquirer firm's knowledge workers to refuse accepting the similar expertise of the target firm (Sears and Hoetker, 2014; Larsson and Finkelstein, 1999). Furthermore, integrating two knowledge worker groups with similar expertise but different technological routines (Nelson and Winter, 1982) may cause disruptions in both firms' technological routines for the technological areas (Ranft and Lord, 2002), thereby reducing innovation productivity in the existing core areas (Kapoor and Lim, 2007; Paruchuri *et al.*, 2006).

Complementarity of the target firm is also detrimental for innovation in the existing core areas. The acquirer firm's existing core areas are characterized by a strong path dependence in innovation activities as a result of the acquirer firm focusing on innovation in the existing core areas before the M&A (Nelson and Winter, 1982; Dosi, 1982). The acquirer firm's knowledge workers in the existing core areas tend to follow established technological trajectories (Levinthal and March, 1993; Dosi, 1982). They also tend to resort to local search rather than technological boundary spanning to find new solutions (Rosenkopf and Nerkar, 2001). This has been described as the propinquity trap by Ahuja and Lampert (2001). The propinquity trap leads to the acquirer firm's knowledge workers in the existing core areas being more likely to find solutions around familiar knowledge areas. It reduces opportunities to have cross-fertilization and recombination with the acquired complementary knowledge and expertise. Moreover, as the acquirer firm has established expertise and competency in the existing core areas, the Not-Invented-Here (NIH) syndrome may come into play (Katz and Allen, 1982). The acquirer firm's knowledge workers in the existing core areas may degrade and reject externally developed knowledge (Hussinger and Wastyn, 2015). This leads to complementary knowledge and expertise of the target firm not being adopted and utilized. Therefore, despite the complementarity of the target firm having potential to create synergy from cross-fertilization and novel recombination with the existing knowledge base, the acquired complementary knowledge and expertise are less likely to be adopted and utilized during the acquirer firm's innovation activities in the existing knowledge areas and rather turn into redundancies. Thus, complementarity of the target firm hinders the creation of innovation in these areas.

In summary, the similarity of the target firm gives rise to knowledge workers' resistance and technological routine disruptions in the existing core areas. Hence, it negatively affects innovation in the existing core areas. Also, the complementarity of the target firm would not be utilized due to the effects of the propinquity trap and NIH syndrome in the existing core areas. Thus, it negatively affects innovation in the existing core areas:

- H1a.* Similarity of the target firm negatively affects post-M&A innovation in existing core areas.
- H1b.* Complementarity of the target firm negatively affects post-M&A innovation in existing core areas.

3.2 Enhanced core innovation

Contrary to the existing core areas, enhanced core areas are where the acquirer firm only possessed limited technological expertise and capabilities (Granstrand *et al.*, 1997). Moreover, being peripheral to the acquirer firm's strategic focus before the M&A implies that technological trajectories or routines in the enhanced core areas are not fully developed (Nelson and Winter, 1982; Dosi, 1982). Under these circumstances, similarity of the target firm facilitates innovation in these areas. Owing to the insufficient expertise and technological routines in the enhanced core areas, the acquirer firm's knowledge workers

in the technological areas are less likely to resist acquiring the target firm which possesses similar expertise (Larsson and Finkelstein, 1999), and rather welcome and cooperate with the target firm's knowledge workers (Sears and Hoetker, 2014). Thus, the target firm's technological routines are less likely to be disrupted (Ranft and Lord, 2002) and the innovation productivity of the target firm's knowledge workers is more likely to be preserved (Kapoor and Lim, 2007; Paruchuri *et al.*, 2006). Moreover, the combined firm's knowledge workers can achieve a higher invention productivity and synergies through economies of scale and scope (Makri *et al.*, 2010; Hagedoorn and Duysters, 2002; Larsson and Finkelstein, 1999), which promote innovation outcomes in enhanced core areas.

Complementarity of the target firm is also beneficial for the innovation within the enhanced core areas. As technological trajectories or routines are insufficient in the enhanced core areas, the acquirer firm's knowledge workers in the technological areas may avoid the "myopia of learning" (Levinthal and March, 1993). Consequently, they are more likely to search for solutions, which may complement the existing knowledge, from outside the acquirer firm's knowledge base (Rosenkopf and Nerkar, 2001). Complementary knowledge is knowledge with a high potential of combination with the acquirer firm's existing knowledge (Makri *et al.*, 2010) and is relatively easier for the acquirer firm to learn due to higher absorptive capacity for related technological areas (Cohen and Levinthal, 1990; Ahuja and Katila, 2001). Moreover, as the complementary expertise of the target firm is not duplicated with the expertise of the acquirer firm, the acquirer firm's knowledge workers in underdeveloped knowledge areas are more likely to cooperate with the target firm's complementary expertise (Sears and Hoetker, 2014), which provides opportunities for the cross-fertilization of ideas (Greve, 2003; Kang, 2007; Petruzzelli and Savino, 2014). This allows the acquirer firm to achieve a higher productivity within the enhanced core areas (Kapoor and Lim, 2007), thereby increasing the enhanced core innovation output.

In summary, the similarity of the target firm supplements the insufficient expertise and innovation productivity in enhanced core areas, thus positively affecting enhanced core innovation. The complementarity of the target firm allows combinations with the existing expertise or knowledge in enhanced core areas, thus positively affecting enhanced core innovation:

H2a. Similarity of the target firm positively affects post-M&A innovation in enhanced core areas.

H2b. Complementarity of the target firm positively affects post-M&A innovation in enhanced core areas.

3.3 New core innovation

New core areas are where the acquirer firm had no prior technological expertise and capabilities as well as innovation experiences before the M&A. Under these circumstances, similarity of the target firm deters innovation in new core areas. In order for the acquirer firm to create innovation and secure expertise in new technological areas, acquiring knowledge and expertise that are familiar in new technological areas and learning from the acquired knowledge and expertise are essential (Roberts and Berry, 1984; Ahuja and Lampert, 2001). However, similarity of the target firm is more likely to provide knowledge and expertise in knowledge areas that are already familiar to the acquirer firm rather than knowledge and expertise in new technological areas (Makri *et al.*, 2010). Moreover, prior experience in the familiar knowledge areas forms technological trajectories and routines which allow the firm to obtain immediate returns from the knowledge. This causes the acquirer firm to fall into a familiarity trap (Levinthal and March, 1993; Ahuja and Lampert, 2001). Despite the need for the acquired familiar knowledge to be recombined in unprecedented ways to create novel innovation (Arts and Veugelers, 2014), the familiarity trap increases the likelihood of the acquirer firm to follow existing technological trajectories and routines in utilizing the acquired familiar knowledge (Ahuja and Lampert, 2001). Finally,

as the similar expertise and knowledge of the target firm are more likely to supplement the acquirer firm's existing technological areas, the acquirer firm is less likely to reallocate its resources and attention to new technological areas (Kraatz and Zajac, 2001; Koput, 1997). Hence, similarity of the target firm hinders new core innovation.

Complementarity of the target firm, on the other hand, facilitates innovation in new core areas. First, complementarity of the target firm broadens the combined firm's knowledge and areas of expertise, which increases the potential for combinations with the acquirer firm's existing technological areas (Ahuja and Katila, 2001; Makri *et al.*, 2010; Larsson and Finkelstein, 1999). The broadened knowledge base becomes a source of solutions for the acquirer firm's search activities (Prabhu *et al.*, 2005). It provides the acquirer firm with various opportunities for idea cross-fertilization (Björkdahl, 2009; Makri *et al.*, 2010; Greve, 2003), which may facilitate novel invention in new technological areas. Second, combining the target firm's complementary knowledge and expertise with the acquirer firm's existing expertise may create knowledge and expertise in new technological areas, which the acquirer firm did not have before (Cassiman *et al.*, 2005). Thus, complementarity of the target firm provides opportunities to create novel invention and expertise in new technological areas. In addition, as the acquirer firm did not possess any knowledge or technological routine in the new technological areas, disruption in the target firm's technological trajectories or routines in the new technological areas may be minimized (Ranft and Lord, 2002). The acquired expertise and in-house development of the target firm can thus maintain its invention productivity in the new core areas (Song *et al.*, 2003; Demsetz, 1988) and facilitate innovation.

In summary, similarity of the target firm, which provides knowledge of low novelty and impedes resource and attention reallocation to new technological areas, negatively affects new core innovation. Complementarity of the target firm, on the other hand, enlarges the combined firm's search scope to provide various opportunities for idea cross-fertilization and helps in maintaining the target firm's invention productivity in the new core areas, thus positively affecting new core innovation (Table I):

H3a. Similarity of the target firm negatively affects post-M&A innovation in new core areas.

H3b. Complementarity of the target firm positively affects post-M&A innovation in new core areas.

4. Data and methods

4.1 Data specification

The data sample in this study was collected from the biopharmaceutical industry. The biopharmaceutical industry provides an ideal setting for this research for the following reasons: First, as the biopharmaceutical industry is a technology-intensive industry, each firm's technological learning, especially innovation in its focus areas, determines the firm's competitiveness (Bierly and Chakrabarti, 1996). Firms in this industry fiercely develop knowledge and expertise in their own core technological areas to sustain a competitive advantage, thus it allows for an in-depth analysis of the dynamic change and development of a firm's core technological areas. Second, the industry's characteristics of a weak appropriability regime and secrecy dearth encourage firms' patenting activity (De Carolis, 2003; Bierly and Chakrabarti, 1996), allowing to capture a firm's knowledge base operations through analyzing the firm's patenting activity. Third, the industry consists of

Table I Overall research model

| <i>Data and methods</i> | <i>Existing core innovation</i> | <i>Enhanced core innovation</i> | <i>New core innovation</i> |
|-------------------------|---------------------------------|---------------------------------|----------------------------|
| Similarity | (-) | (+) | (-) |
| Complementarity | (-) | (+) | (+) |

several sub-industries spanning diverse knowledge areas, allowing for a multifaceted analysis on the distinct knowledge characteristics within a single industry (Carayannopoulos and Auster, 2010). In addition, firms in this industry actively utilize M&As to keep up with changes in both market and technology (Higgins and Rodriguez, 2006), or to acquire the expertise and knowledge required for research breakthroughs (De Carolis, 2003; Carayannopoulos and Auster, 2010).

The data set was collected based on technological M&A deals made by biopharmaceutical firms from 2001 to 2008. Information on M&A deals conducted between 2001 and 2008 by the firms in the biopharmaceutical industry, which comprises biotech firms, pharmaceutical firms and other chemical and bio-related firms, was drawn from the Thomson Reuters SDC Platinum database. In the next step, self-acquisition M&A deals, which firms usually conduct to acquire remaining assets or interests, were excluded. Patenting information of each firm from 1996 to 2014 was obtained from the US Patent and Trademark Office (USPTO) database. It was ensured that all the considered patents had indeed been granted to the firms. To take only technological M&A deals into consideration, M&A deals involving target firms with no patent granted during the five years prior to the M&A deal were excluded (Ahuja and Katila, 2001; Phene *et al.*, 2012). Each firm's financial information was obtained from the Datastream database. Removing entries with missing values, the final data set includes 412 technological M&A deals involving 187 acquirer firms.

The final data sample consists of M&A deals conducted by firms from several technological sectors within the biopharmaceutical industry, including major firms such as Boston Scientific Corp, Medtronic Inc, Novartis AG, Du Pont, Abbott Laboratories, Invitrogen Corp and Pfizer Inc. Measuring, medical, photo equipment sector; Drugs sector; and Chemicals and the other bio-related subindustries account for 48.1 per cent, 38.8 per cent, and 13.1 per cent of the M&A deals, respectively. Firms in the data sample have their main base of operation in 20 different countries. Firms based in the USA account for the majority (64.1 per cent) of the M&A deals, followed by firms based in Japan with 14.1 per cent. Firms based in Switzerland, the UK, Denmark and Germany accounted for 6.6 per cent, 3.2 per cent, 2.2 per cent, and 2.2 per cent of the M&A deals, respectively.

4.2 Variables

4.2.1 Dependent variables. The study analyzed firms' pre- and post-M&A patenting activities, which have been considered as a suitable indicator of a firm's technological knowledge base operations and innovation output (Patel and Pavitt, 1991; Duysters and Hagedoorn, 2000). The dependent variables were constructed by investigating the acquirer firm's pre- and post-M&A patenting activities and the change in the acquirer firm's core technological areas. Following prior research, for pre-M&A activities, the study observed patents granted during the five years prior to M&A deals (Ahuja and Katila, 2001; Cloudt *et al.*, 2006). The study uses a two-year time lag between the M&A deal and the post-M&A acquirer patenting activity observation. A prior research by Popp *et al.* (2004) examining determinants of the time lag between patent application and patent grant suggests that patent applications require an average of 28 months to be granted. Consequently, much of the prior literature uses a two-year time lag between the M&A deal and the post-M&A acquirer patenting activity observation (Phene *et al.*, 2012; Makri *et al.*, 2010). Subsequently, the acquirer firm's patents granted within a five-year window after the two-year time lag were included in the observation for the post-M&A period (Phene *et al.*, 2012). This five-year window also allows to capture patents that require more than two years to be granted.

To distinguish the pre- and post-M&A acquirer firm's core technological areas, the study used a 3 per cent cutoff, as suggested by Granstrand *et al.* (1997) and used in Phene *et al.* (2012). For each pre- and post-M&A timeframe, particular technological areas (defined as patent main-classes) whose granted patents make up more than 3 per cent of the total

number of the acquirer firm's patents granted during each period were considered as the acquirer firm's core technological areas. Then, the lists of pre- and post-M&A core technological areas were compared to distinguish the three distinctive core technological areas, i.e. existing core areas, enhanced core areas and new core areas:

Existing core technological areas are the technological areas that are found on both the pre- and post-M&A core technological areas lists. Enhanced core technological areas and new core technological areas are the technological areas that are only included in the list of post-M&A core technological areas but not in the list of pre-M&A core technological areas. They are distinguished by prior patenting activities. Enhanced core areas are areas in which the acquirer firm was granted patents during the five years prior to the M&A, while new core areas are the remaining areas in which the acquirer firm had no patent granted during the five-year period prior to the M&A.

Similar to prior research utilizing patent count to measure innovation output (Ahuja and Katila, 2001; Puranam and Srikanth, 2007; Ernst and Vitt, 2000), this study counted the number of the acquirer firm's patents granted within each of the core technological areas during the above-mentioned post-M&A period to define the dependent variables *Existing core innovation*, *Enhanced core innovation* and *New core innovation*.

4.2.2 Independent variables. Similar to prior research (Ahuja and Katila, 2001; Cloudt *et al.*, 2006; Miozzo *et al.*, 2015), the patents granted to the acquirer firm and the target firm during the five years prior to M&A deals were compared to distinguish the target firm's knowledge base characteristics. The study constructed variables for each knowledge characteristic of the target firm, *Similarity* and *Complementarity*. The study used patent main-class and subcategory classification to distinguish the knowledge characteristics, following the framework suggested by Makri *et al.* (2010), as many other recent research did (Ganzaroli *et al.*, 2016; Miozzo *et al.*, 2015). The study adopted the US classification system provided by USPTO (2012), which categorizes patent main-classes into 50 relevant subject groups. (Throughout the study, this classification system is referred to as "subcategory" to prevent any confusion with the subclasses defined as subsets of the individual USPTO main-classes.) Utilizing patent main-class and subcategory classification, the study constructed the independent variables through the below-mentioned methods.

Similarity measures the extent to which the pre-M&A target firm's knowledge base is similar to the pre-M&A acquirer firm's knowledge base. Following prior research (Ahuja and Katila, 2001; Makri *et al.*, 2010; Petruzzelli, 2011), this study considered the overlapped patent main-classes, in which both the acquirer firm and the target firm have patents granted during the five years prior to the M&A, as the target firm's similar technological areas. The study calculated the independent variable *Similarity* using the following equation:

$$\text{Similarity} = \frac{\text{Total target patents in common mainclasses}}{\text{Total granted patents of acquirer and target}}$$

Complementarity measures the extent to which the pre-M&A target firm's knowledge base has combinational potential with the pre-M&A acquirer firm's knowledge base. Following prior studies (Makri *et al.*, 2010; Ganzaroli *et al.*, 2016), the study considered the non-overlapped target firm's patent main-classes, in which only the target firm has patents granted during the five years prior to the M&A but resides in the subcategories of the pre-M&A acquirer firm's knowledge base, as the target firm's complementary technological areas. The study calculated the independent variable *Complementarity* using the following equation:

$$\text{Complementarity} = \frac{\text{Total target patents in common subcategories} - \text{Total target patents in common mainclasses}}{\text{Total granted patents of acquirer and target}}$$

4.2.3 Control variables. Several control variables, which may affect the firm's subsequent innovation activity, were included. First, the acquirer firm's *R&D intensity* was included to control the influence stemming from the acquirer firm's efforts and investments in R&D activities. R&D intensity was computed as the acquirer firm's R&D expense divided by total

sales measured in the year before the M&A deal (Hall *et al.*, 1986; Phene and Almeida, 2008; Phene *et al.*, 2012). Second, the acquirer firm's *Firm size* was included, as prior studies have demonstrated the significant direct effect of firm size on the subsequent innovation performance (Acs and Audretsch, 1988; Cohen and Klepper, 1996). Following prior research (Rosenkopf and Almeida, 2003; Phene and Almeida, 2008; Ahuja and Katila, 2001), the study measured firm size of the acquirer firm by taking the log of the number of employees. Third, to control the influences of the acquirer firm's innovation ability and knowledge stock accumulated before the M&A (Desyllas and Hughes, 2010; Oettl and Agrawal, 2008; Phene *et al.*, 2012), the study included the absolute size of the acquirer firm's knowledge base (*Acquirer knowledge base*). Following Phene *et al.* (2012), *Acquirer knowledge base* was measured using the number of the acquirer firm's patent granted during the five years prior to the M&A. Fourth, the relative size of knowledge base (*Relative size knowledge base*) was included to control influences that may be caused by the size difference between the knowledge base of the acquirer firm and the target firm (Ahuja and Katila, 2001; Larsson and Finkelstein, 1999). *Relative size knowledge base* was calculated by dividing the total number of patent granted to the target firm during five years prior to the M&A by *Acquirer knowledge base*. Fifth, *Acquirer diversification* was included to control the degree to which the acquirer firm diversified its technological portfolio (Miller, 2004; Garcia-Vega, 2006). The study calculated *Acquirer diversification* using the formula of the Shannon entropy index: $\sum P_i \times \ln(1/P_i)$, where P_i is the percentage of the patents granted within the i th main-class (Ganzaroli *et al.*, 2016). Sixth, *Number of M&A deals* for the acquirer firm in the same year was included to control the effects of the number of M&A deals the acquirer firm conducted in the same year. The variable is constructed by counting the number of M&A deals that the acquirer firm carries out in the same year. Finally, the study introduced four dummy variables, *Year dummy*, *Technological sector dummy*, *Foreign acquisition dummy* and *Acquirer firm nationality dummy*, which control for the influence from the M&A deal year, the acquirer firm's specific technological sector, cross-border M&A deal and the acquirer firm's nationality, respectively.

4.3 Method

As all three of the dependent variables consist of non-negative discrete integer values, Poisson regression or negative binomial regression may be used (Hausman *et al.*, 1984). However, Poisson regression requires that the mean and the variation of the dependent variable should be nearly the same. The dependent variables are over-dispersed, which does not satisfy the requirement to use Poisson regression. Thus, negative binomial regression was used.

5. Results

The descriptive statistics and correlations of the variables used in the analysis are shown in Table II. Most of the correlation values between the variables have acceptable values of discriminant validity, which are lower than the 0.70 threshold (Cohen *et al.*, 2003). Only the correlation between the dependent variable *Enhanced core innovation* and the control variable *Acquirer knowledge base* exceeds the 0.70 threshold, which may cause multi-collinearity problems. However, as the control variable *Acquirer knowledge base* captures the acquirer firm's knowledge stock (Phene *et al.*, 2012) or invention productivity (Kapoor and Lim, 2007) before the M&A, it should be included to control the influences that could be attributed to the acquirer firm's existing innovation ability (Oettl and Agrawal, 2008). Thus, the study measured variance inflation factors (VIFs) for each regression model to check whether the multi-collinearity problem exists in each regression model. The mean and the maximum values of VIF for each regression model are indicated in Table III. The mean VIF and maximum VIF values for each regression model fall below 3, which implies that no multi-collinearity problems exist between the variables used in each regression model (Myers, 1990).

Table II Descriptive statistics

| Variables | Mean | SD | Min | Max | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---------------------------------|--------|----------|------|-----------|----------|---------|----------|----------|----------|-------|---------|-------|---------|---------|----|
| 1. Existing core innovation | 119.47 | 234.00 | 0.00 | 1,811.00 | 1 | | | | | | | | | | |
| 2. Enhanced core innovation | 13.71 | 41.42 | 0.00 | 529.00 | 0.33*** | 1 | | | | | | | | | |
| 3. New core innovation | 6.25 | 9.35 | 0.00 | 64.00 | -0.20*** | -0.13** | 1 | | | | | | | | |
| 4. Similarity | 0.12 | 0.17 | 0.00 | 0.83 | -0.15*** | -0.07 | 0.11** | 1 | | | | | | | |
| 5. Complementarity | 0.05 | 0.12 | 0.00 | 0.93 | -0.18*** | -0.12** | 0.26*** | 0.10** | 1 | | | | | | |
| 6. R&D intensity | 64.61 | 1,265.75 | 0.00 | 25,684.40 | -0.02 | -0.02 | 0.14*** | 0.03 | 0.02 | 1 | | | | | |
| 7. Firm size (Log employee) | 3.62 | 0.90 | 0.30 | 5.21 | 0.41*** | 0.33*** | 0.00 | -0.19*** | -0.30*** | -0.05 | 1 | | | | |
| 8. Relative size knowledge base | 4.70 | 45.06 | 0.00 | 685.00 | -0.05 | -0.03 | 0.12** | 0.13*** | 0.13*** | -0.00 | 0.05 | 1 | | | |
| 9. Acquirer knowledge base | 204.00 | 418.50 | 1.00 | 2,617.00 | 0.59*** | 0.74*** | -0.24*** | -0.18*** | -0.18*** | -0.02 | 0.45*** | -0.05 | 1 | | |
| 10. Acquirer diversification | 2.66 | 3.63 | 0.00 | 27.17 | 0.30*** | 0.24*** | -0.15*** | -0.11** | -0.16*** | -0.02 | 0.38*** | -0.07 | 0.39*** | 1 | |
| 11. Number of M&A deals | 2.40 | 1.57 | 1.00 | 7.00 | 0.18*** | 0.27*** | -0.01 | -0.23*** | -0.15*** | -0.04 | 0.44*** | -0.03 | 0.45*** | 0.15*** | 1 |

Notes: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Table III Negative binomial regression results for core technology innovation

| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 | Model 8 | Model 9 |
|------------------------------|-------------------|-------------------|-------------------|------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| <i>Control variables</i> | | | | | | | | | |
| R&D intensity | -0.000 (0.000) | -0.000 (0.000) | -0.000 (0.000) | -0.002 (0.010) | -0.002 (0.010) | -0.002 (0.010) | 0.000 (0.000) | 0.000 (0.000) | 0.000 (0.000) |
| Firm size (Logemployee) | 0.981*** (0.087) | 0.955*** (0.087) | 0.881*** (0.087) | 1.769*** (0.219) | 1.739*** (0.219) | 1.776*** (0.219) | 0.541*** (0.113) | 0.541*** (0.113) | 0.611*** (0.113) |
| Relative size knowledge base | -0.008*** (0.002) | -0.008*** (0.002) | -0.008*** (0.002) | -0.418** (0.163) | -0.793*** (0.264) | -0.471*** (0.208) | 0.000 (0.002) | 0.000 (0.002) | -0.001(0.002) |
| Acquirer knowledge base | 0.001*** (0.000) | 0.001*** (0.000) | 0.001*** (0.000) | 0.001*** (0.000) | 0.001*** (0.000) | 0.001*** (0.000) | -0.005*** (0.001) | -0.005*** (0.001) | -0.005*** (0.001) |
| Acquirer diversification | 0.044** (0.021) | 0.045** (0.021) | 0.049** (0.020) | 0.183*** (0.048) | 0.183*** (0.048) | 0.183*** (0.048) | -0.057 (0.035) | -0.057* (0.035) | -0.056* (0.034) |
| Number of M&A deals | -0.147*** (0.043) | -0.148*** (0.043) | -0.140*** (0.042) | -0.046 (0.087) | -0.031 (0.087) | -0.047 (0.087) | 0.090 (0.059) | 0.089 (0.059) | 0.062 (0.058) |
| <i>Independent variables</i> | | | | | | | | | |
| Similarity | | -0.715** (0.352) | | | 2.498** (1.221) | | | 0.155 (0.459) | 1.682*** (0.583) |
| Complementarity | | | -2.825*** (0.500) | | | 0.875 (1.994) | | | |
| Observations | 412 | 412 | 412 | 412 | 412 | 412 | 412 | 412 | 412 |
| Control dummy variables | Included | Included | Included | Included | Included | Included | Included | Included | Included |
| Log likelihood | -2,095.00 | -2,093.04 | -2,082.34 | -852.34 | -850.01 | -852.24 | -1,062.74 | -1,062.68 | -1,057.82 |
| Prob > χ^2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| LR χ^2 | 361.03 | 364.95 | 386.35 | 210.16 | 214.82 | 210.36 | 120.51 | 120.63 | 190.35 |
| Mean VIF | 1.29 | 1.30 | 1.29 | 1.29 | 1.30 | 1.29 | 1.29 | 1.30 | 1.29 |
| Max VIF | 1.67 | 1.67 | 1.67 | 1.67 | 1.67 | 1.67 | 1.67 | 1.67 | 1.67 |

Notes: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

The results from the negative binomial regression are shown in Table III. Three different dependent variables, *Existing core innovation*, *Enhanced core innovation* and *New core innovation*, were tested. Models 1 to 3 examine the effects of each control variable and the target firm's knowledge base characteristics on *Existing core innovation*. As Model 1 indicates, the control variables *Firm size*, *Relative size knowledge base*, *Acquirer knowledge base*, *Acquirer diversification* and *Number of M&A deals* have a significant effect on *Existing core innovation*. Especially, the significant negative effect of *Number of M&A deals* on *Existing core innovation* could imply that frequent M&A impedes innovation in the existing core areas. Model 2 confirms that the target firm's knowledge base *Similarity* has a negative and significant ($p < 0.05$) effect on the post-M&A *Existing core innovation*, which supports *H1a*. Model 3 examines the effect of the target firm's knowledge base *Complementarity* on the post-M&A *Existing core innovation*, and confirms its negative and significant ($p < 0.01$) effect. Thus, *H1b* is also supported.

Models 4 to 6 examine how each control variable and the target firm's knowledge base characteristics affect *Enhanced core innovation*. Model 4 confirms that the control variables *Firm size*, *Relative size knowledge base*, *Acquirer knowledge base* and *Acquirer diversification* significantly influence *Enhanced core innovation*. Model 5 examines *H2a*, which suggests a positive relationship between the target firm's knowledge base *Similarity* and the post-M&A *Enhanced core innovation*, and indicates a positive and significant ($p < 0.05$) relationship between the two variables. Thus, *H2a* is supported. *H2b* argues that the target firm's *Complementarity* positively affects the post-M&A *Enhanced core innovation*. However, Model 6 finds no significant effect of *Complementarity* on the post-M&A *Enhanced core innovation*. Consequently, *H2b* is not supported.

Models 7 to 9 examine the effects of each control variable and the target firm's knowledge base characteristics on *New core innovation*. Model 7 demonstrates that the control variables *Firm size*, *Acquirer knowledge base*, and *Acquirer diversification* have a significant impact on *New core innovation*. Model 8 examines *H3a*, which proposed a negative relationship between the target firm's knowledge base *Similarity* and the post-M&A *New core innovation*, but shows no significant relationship between the two variables. Thus, *H3a* is not supported. Model 9 confirms a positive and significant ($p < 0.01$) effect of the target firm's knowledge base *Complementarity* on the post-M&A *New core innovation*, which supports *H3b*.

To increase the robustness of the results, an additional robustness test has been performed using dependent variables with a three-year time lag and a four-year window to capture the innovation performance in each of the three distinct core areas. The results of this robustness test, reported in Table AI, validate the robustness of our findings.

6. Discussion and conclusion

This study analyzed a data set of 412 technological M&A deals in the biopharmaceutical industry to examine the impacts of various knowledge characteristics of the target firm on the acquirer firm's post-M&A innovation outcomes in core technological areas. The empirical results support the main arguments of the study. They confirm that, in technological M&As, 1) none of the investigated knowledge characteristics of the target firm, similarity and complementarity, is advantageous for innovation in the existing core areas where the acquirer firm already has established technological expertise and technological routine before the M&A, 2) similarity of the target firm facilitates innovation in the enhanced core areas where the acquirer firm had only insufficient expertise and inadequate technological routines before the M&A, and 3) complementarity of the target firm is beneficial for innovation in the new core areas where the acquirer firm did not have any expertise or knowledge before the M&A.

This study advances the fields of technology management and M&A research through the following contributions: First, the study explains the reconfiguration processes in the acquirer firm's core technological portfolio by suggesting three distinct types of core technological areas in the core technological portfolio. Prior research highlights the importance of firms nurturing core competences and expertise because the core competence determines a firm's competitiveness (Prahalad and Hamel, 1990; Leonard-Barton, 1992). Firms are required to secure core technological components and technological expertise to cope with the rapidly changing market and technology (Chiesa, 2001). Despite the fact that wisely managing core technological portfolio is essential for firms to survive in technology-intensive industries (Prahalad and Hamel, 1990; Duysters and Hagedoorn, 2000), previous literature only discussed why the firm's core technological portfolio should be wisely managed but did not provide insights into how the reconfiguration of the firm's core technological portfolio is performed. Extending the literature on the firm's core technological portfolio, this study empirically analyzes the reconfiguration processes in the firm's core technological portfolio. The three types of the core technological areas suggested in this research, existing core area, enhanced core area and new core area, allow to explicate the firm's core technological portfolio reconfiguration occurring through external knowledge sourcing. This research specifically examines the reconfiguration processes of a firm's core technological portfolio in the context of technological M&As. It enables to observe the reconfiguration processes by analyzing post-M&A innovation outcomes in each of the core technological areas.

Second, the study contributes to the literature on organizational learning by suggesting an extended framework to analyze the firm's innovation outcomes or learning activities. Since March (1991), the dichotomy of innovation, i.e. exploitation versus exploration, has been extensively adopted in the literature of organizational learning (Levinthal and March, 1993; Tushman and O'Reilly, 1996; He and Wong, 2004; Raisch and Birkinshaw, 2008; Voss *et al.*, 2008). Especially, much of prior research used the concepts of exploitation and exploration in examining how various external sourcing modes affect the firm's learning and innovation (Stettner and Lavie, 2014; Lavie and Rosenkopf, 2006; Phene *et al.*, 2012; Wagner, 2011; Ganzaroli *et al.*, 2016). However, as not all of the firm's existing knowledge areas have received an equal amount of prior experience and attention and established the same degree of technological trajectories and expertise, a firm's exploitation activity should be investigated considering the circumstances and characteristics of each knowledge area. Considering the difference in the extent to which expertise and technological routines have been established in each technological area allows the study to divide exploitative innovation, which builds on existing technological areas (March, 1991; Levinthal and March, 1993), into existing core innovation and enhanced core innovation. This classification is suitable to investigate the firm's exploitation activities in more detail and to differentiate how acquired knowledge and expertise are applied in each technological area after the M&A. Moreover, advancing prior studies, which merely considered learning or innovation outcomes in new knowledge areas as explorative innovation (March, 1991; Levinthal and March, 1993), this study specifies the explorative innovation that is created in the acquirer firm's core areas as new core innovation. This allows to examine the firm's explorative innovation in new knowledge areas that the firm actually focuses on and creates vigorous innovation, which helps improving the firm's competitiveness.

Third, the findings of the study help to explain the common notion of "most M&As are failing". Despite firms actively utilizing technological M&As as a means to obtain external knowledge, many reports on M&As reveal a high failure rate of M&As (Deutsch and West, 2010). This study explains this failure of M&As by stressing the importance of a cautious approach in combining the acquirer firm's and the target firm's technological expertise and capabilities after the M&A. In the existing core areas, where the acquirer firm's knowledge workers possess proven strength and ability to create innovation, the knowledge workers are less likely to cooperate with the target firm's knowledge workers and might even refuse to utilize

the knowledge provided by the acquisition of the target firm. Thus, M&As are more likely to result in failure if a firm utilizes the M&A for the purpose of further strengthening its existing core areas. On the other hand, for the enhanced core areas and the new core areas, where the acquirer firm's knowledge workers do not possess sufficient technological expertise and capabilities to create innovation, the acquirer firm's knowledge workers are more likely to embrace target firms with proper knowledge characteristics, thereby creating synergies with the target firm and increasing innovation outcomes. Thus, acquiring a suitable target firm is crucial for M&A success in the enhanced core areas and new core areas.

The findings of this study allow us to provide managerial implications for firms planning to conduct open innovation activities through technological M&A. Firms conduct technological M&A with various objectives of 1) developing existing core technological areas, 2) changing the strategic focus toward their insufficient technological areas and 3) expanding expertise and knowledge into new technological areas. This study provides firms a guideline that allows them to better select a proper target firm with best-suited knowledge characteristic according to their objectives. Specifically, the research suggests firms to look for other knowledge acquisition methods for their existing core technological areas, such as internal development or technological alliances, and to refrain from technological M&As for the purpose of existing core area development. It also suggests firms to select a target firm with similar expertise and knowledge to enhance their insufficient technological areas. Moreover, a target firm with complementarity is suggested as the most promising choice to successfully expand the existing knowledge base into new areas.

Although this study provides a number of important contributions and implications, it has a number of limitations. First, this study focused on technological M&A as a prominent mode of open innovation knowledge sourcing. Open innovation activities are not limited to M&A, however, but can encompass a wide range of modes, which differ, e.g. in scope or the employed mode of governance. Future research should thus try to uncover the effects of other open innovation modes on the firm's core technological portfolio. Second, the hypotheses of this study were tested on a data set of technological M&As conducted by firms in the biopharmaceutical industry. As industrial effects may differ under other research settings, future studies should test the hypotheses using data from other industries, to generalize the results. Third, the evaluation was based on patent analysis. While this is an accepted and objective approach, patent analysis is known to have limitations, e.g. the inability to capture innovation which is not patented (Kleinknecht *et al.*, 2002; Lane *et al.*, 2006). Thus, future research could address the shortcoming of the patent-based measures and corroborate the findings by using other data sets, such as survey results or new product development statistics.

References

- Acs, Z.J. and Audretsch, D.B. (1988), "Innovation and firm size in manufacturing", *Technovation*, Vol. 7 No. 3, pp. 197-210.
- 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.
- Ahuja, G. and Lampert, C.M. (2001), "Entrepreneurship in the large corporation: a longitudinal study of how established firms create breakthrough inventions", *Strategic Management Journal*, Vol. 22 Nos 6/7, pp. 521-543.
- Arts, S. and Veugelers, R. (2014), "Technology familiarity, recombinant novelty, and breakthrough invention", *Industrial and Corporate Change*, Vol. 24 No. 6, pp. 1215-1246.
- Benner, M.J. and Tushman, M. (2002), "Process management and technological innovation: a longitudinal study of the photography and paint industries", *Administrative Science Quarterly*, Vol. 47 No. 4, pp. 676-707.

- Benner, M.J. and Tushman, M.L. (2003), "Exploitation, exploration, and process management: the productivity dilemma revisited", *Academy of Management Review*, Vol. 28 No. 2, pp. 238-256.
- Bierly, P. and Chakrabarti, A. (1996), "Generic knowledge strategies in the US pharmaceutical industry", *Strategic Management Journal*, Vol. 17 No. 2, pp. 123-135.
- Björkdahl, J. (2009), "Technology cross-fertilization and the business model: the case of integrating ICTs in mechanical engineering products", *Research Policy*, Vol. 38 No. 9, pp. 1468-1477.
- Burgelman, R.A. (2002), "Strategy as vector and the inertia of coevolutionary lock-in", *Administrative Science Quarterly*, Vol. 47 No. 2, pp. 325-357.
- Carayannopoulos, S. and Auster, E.R. (2010), "External knowledge sourcing in biotechnology through acquisition versus alliance: a KBV approach", *Research Policy*, Vol. 39 No. 2, pp. 254-267.
- Cassiman, B., Colombo, M.G., Garrone, P. and Veugelers, R. (2005), "The impact of M&A on the R&D process: an empirical analysis of the role of technological-and market-relatedness", *Research Policy*, Vol. 34 No. 2, pp. 195-220.
- Chesbrough, H.W. (2003), "The logic of open innovation: managing intellectual property", *California Management Review*, Vol. 45 No. 3, pp. 33-58.
- Chesbrough, H.W. (2006a), "The era of open innovation", *Managing Innovation and Change*, Vol. 127 No. 3, pp. 34-41.
- Chesbrough, H.W. (2006b), *Open Innovation: The New Imperative for Creating and Profiting from Technology*, Harvard Business Press, Boston, MA.
- Chiesa, V. (2001), *R&D Strategy and Organisation: Managing Technical Change in Dynamic Contexts*, Imperial College Press, London.
- Cloodt, M., Hagedoorn, J. and Van Kranenburg, H. (2006), "Mergers and acquisitions: their effect on the innovative performance of companies in high-tech industries", *Research Policy*, Vol. 35 No. 5, pp. 642-654.
- Cohen, P., Cohen, J., West, S.G. and Aiken, L.S. (2003), *Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences*, Lawrence Erlbaum Associates, Hillsdale, NJ.
- Cohen, W.M. and Klepper, S. (1996), "A reprise of size and R & D", *The Economic Journal*, Vol. 106 No. 437, pp. 925-951.
- Cohen, W.M. and Levinthal, D.A. (1990), "Absorptive capacity: a new perspective on learning and innovation", *Administrative Science Quarterly*, Vol. 35 No. 1, pp. 128-152.
- Colombo, M.G. and Rabbiosi, L. (2014), "Technological similarity, post-acquisition R&D reorganization, and innovation performance in horizontal acquisitions", *Research Policy*, Vol. 43 No. 6, pp. 1039-1054.
- De Carolis, D.M. (2003), "Competencies and imitability in the pharmaceutical industry: an analysis of their relationship with firm performance", *Journal of Management*, Vol. 29 No. 1, pp. 27-50.
- Demsetz, H. (1988), "The theory of the firm revisited", *Journal of Law, Economics, & Organization*, Vol. 4 No. 1, pp. 141-161.
- Desyllas, P. and Hughes, A. (2010), "Do high technology acquirers become more innovative?", *Research Policy*, Vol. 39 No. 8, pp. 1105-1121.
- Deutsch, C. and West, A. (2010), *Perspectives on Merger Integration*, McKinsey Company, Mumbai.
- Dosi, G. (1982), "Technological paradigms and technological trajectories: a suggested interpretation of the determinants and directions of technical change", *Research Policy*, Vol. 11 No. 3, pp. 147-162.
- Duysters, G. and Hagedoorn, J. (2000), "Core competences and company performance in the world-wide computer industry", *The Journal of High Technology Management Research*, Vol. 11 No. 1, pp. 75-91.
- Ernst, H. and Vitt, J. (2000), "The influence of corporate acquisitions on the behaviour of key inventors", *R&D Management*, Vol. 30 No. 2, pp. 105-120.
- Fleming, L. (2001), "Recombinant uncertainty in technological search", *Management Science*, Vol. 47 No. 1, pp. 117-132.

- Ganzaroli, A., De Noni, I., Orsi, L. and Belussi, F. (2016), "The combined effect of technological relatedness and knowledge utilization on explorative and exploitative invention performance post-M & A", *European Journal of Innovation Management*, Vol. 19 No. 2, pp. 167-188.
- Garcia-Vega, M. (2006), "Does technological diversification promote innovation? An empirical analysis for European firms", *Research Policy*, Vol. 35 No. 2, pp. 230-246.
- Granstrand, O., Patel, P. and Pavitt, K. (1997), "Multi-technology corporations: why they have 'distributed' rather than 'distinctive core' competencies", *California Management Review*, Vol. 39 No. 4, pp. 8-25.
- Grant, R.M. (1996), "Prospering in dynamically-competitive environments: organizational capability as knowledge integration", *Organization Science*, Vol. 7 No. 4, pp. 375-387.
- Greve, H.R. (2003), *Organizational Learning from Performance Feedback: A Behavioral Perspective on Innovation and Change*, Cambridge University Press, Cambridge, MA.
- Hagedoorn, J. and Duysters, G. (2002), "The effect of mergers and acquisitions on the technological performance of companies in a high-tech environment", *Technology Analysis & Strategic Management*, Vol. 14 No. 1, pp. 67-85.
- Hall, B.H., Griliches, Z. and Hausman, J.A. (1986), "Patents and R and D: is there a lag?", *International Economic Review*, Vol. 27 No. 2, pp. 265-283.
- Han, J., Jo, G.S. and Kang, J. (2016), "Is high-quality knowledge always beneficial? Knowledge overlap and innovation performance in technological mergers and acquisitions", *Journal of Management & Organization*.
- Hausman, J.A., Hall, B.H. and Griliches, Z. (1984), "Econometric models for count data with an application to the patents-R&D relationship", *Econometrica*, Vol. 52 No. 4, pp. 909-938.
- He, Z.-L. and Wong, P.-K. (2004), "Exploration vs exploitation: an empirical test of the ambidexterity hypothesis", *Organization Science*, Vol. 15 No. 4, pp. 481-494.
- Higgins, M.J. and Rodriguez, D. (2006), "The outsourcing of R&D through acquisitions in the pharmaceutical industry", *Journal of Financial Economics*, Vol. 80 No. 2, pp. 351-383.
- Hussinger, K. and Wastyn, A. (2015), "In search for the not-invented-here syndrome: the role of knowledge sources and firm success", *R&D Management*, Vol. 46 No. 3, pp. 945-957.
- Jain, A. (2015), "Learning by hiring and change to organizational knowledge: countering obsolescence as organizations age", *Strategic Management Journal*, Vol. 37 No. 8, pp. 1667-1687.
- Jo, G.S., Park, G. and Kang, J. (2016), "Unravelling the link between technological M&A and innovation performance using the concept of relative absorptive capacity", *Asian Journal of Technology Innovation*, Vol. 24 No. 1, pp. 55-76.
- Kang, J. (2007), "Testing impact of knowledge characteristics and relationship ties on project performance", *Journal of Knowledge Management*, Vol. 11 No. 3, pp. 126-144.
- Kapoor, R. and Lim, K. (2007), "The impact of acquisitions on the productivity of inventors at semiconductor firms: a synthesis of knowledge-based and incentive-based perspectives", *Academy of Management Journal*, Vol. 50 No. 5, pp. 1133-1155.
- Katz, R. and Allen, T.J. (1982), "Investigating the Not Invented Here (NIH) syndrome: a look at the performance, tenure, and communication patterns of 50 R & D project groups", *R&D Management*, Vol. 12 No. 1, pp. 7-20.
- Kleinknecht, A., Van Montfort, K. and Brouwer, E. (2002), "The non-trivial choice between innovation indicators", *Economics of Innovation and New Technology*, Vol. 11 No. 2, pp. 109-121.
- Koput, K.W. (1997), "A chaotic model of innovative search: some answers, many questions", *Organization Science*, Vol. 8 No. 5, pp. 528-542.
- Kraatz, M.S. and Zajac, E.J. (2001), "How organizational resources affect strategic change and performance in turbulent environments: theory and evidence", *Organization Science*, Vol. 12 No. 5, pp. 632-657.
- Lane, P.J., Koka, B.R. and Pathak, S. (2006), "The reification of absorptive capacity: a critical review and rejuvenation of the construct", *Academy of Management Review*, Vol. 31 No. 4, pp. 833-863.

- Larsson, R. and Finkelstein, S. (1999), "Integrating strategic, organizational, and human resource perspectives on mergers and acquisitions: a case survey of synergy realization", *Organization Science*, Vol. 10 No. 1, pp. 1-26.
- Lavie, D. and Rosenkopf, L. (2006), "Balancing exploration and exploitation in alliance formation", *Academy of Management Journal*, Vol. 49 No. 4, pp. 797-818.
- Leonard-Barton, D. (1992), "Core capabilities and core rigidities: a paradox in managing new product development", *Strategic Management Journal*, Vol. 13 No. S1, pp. 111-125.
- Levinthal, D.A. and March, J.G. (1993), "The myopia of learning", *Strategic Management Journal*, Vol. 14 No. S2, pp. 95-112.
- Makri, M., Hitt, M.A. and Lane, P.J. (2010), "Complementary technologies, knowledge relatedness, and invention outcomes in high technology mergers and acquisitions", *Strategic Management Journal*, Vol. 31 No. 6, pp. 602-628.
- March, J.G. (1991), "Exploration and exploitation in organizational learning", *Organization Science*, Vol. 2 No. 1, pp. 71-87.
- Miller, D.J. (2004), "Firms' technological resources and the performance effects of diversification: a longitudinal study", *Strategic Management Journal*, Vol. 25 No. 11, pp. 1097-1119.
- Miozzo, M., DiVito, L. and Desyllas, P. (2015), "When do acquirers invest in the R&D assets of acquired science-based firms in cross-border acquisitions? The role of technology and capabilities similarity and complementarity", *Long Range Planning*, Vol. 49 No. 2, pp. 221-240.
- Myers, R.H. (1990), *Classical and Modern Regression with Applications*, Duxbury Press, Boston, MA.
- Nelson, R.R. and Winter, S.G. (1982), *An Evolutionary Theory of Economic Change*, Harvard University Press, Cambridge, MA.
- Oettl, A. and Agrawal, A. (2008), "International labor mobility and knowledge flow externalities", *Journal of International Business Studies*, Vol. 39 No. 8, pp. 1242-1260.
- Orsi, L., Ganzaroli, A., De Noni, I. and Marelli, F. (2015), "Knowledge utilisation drivers in technological M&As", *Technology Analysis & Strategic Management*, Vol. 27 No. 8, pp. 877-894.
- Paruchuri, S., Nerkar, A. and Hambrick, D.C. (2006), "Acquisition integration and productivity losses in the technical core: disruption of inventors in acquired companies", *Organization Science*, Vol. 17 No. 5, pp. 545-562.
- Patel, P. and Pavitt, K. (1991), "Large firms in the production of the world's technology: an important case of non-globalisation", *Journal of International Business Studies*, Vol. 22 No. 1, pp. 1-21.
- Petruzzelli, A.M. (2011), "The impact of technological relatedness, prior ties, and geographical distance on university-industry collaborations: a joint-patent analysis", *Technovation*, Vol. 31 No. 7, pp. 309-319.
- Petruzzelli, A.M. and Savino, T. (2014), "Search, recombination, and innovation: lessons from haute cuisine", *Long Range Planning*, Vol. 47 No. 4, pp. 224-238.
- Phene, A. and Almeida, P. (2008), "Innovation in multinational subsidiaries: the role of knowledge assimilation and subsidiary capabilities", *Journal of International Business Studies*, Vol. 39 No. 5, pp. 901-919.
- Phene, A., Tallman, S. and Almeida, P. (2012), "When do acquisitions facilitate technological exploration and exploitation?", *Journal of Management*, Vol. 38 No. 3, pp. 753-783.
- Popp, D., Juhl, T. and Johnson, D.K. (2004), "Time in purgatory: examining the grant lag for US patent applications", *Topics in Economic Analysis & Policy*, Vol. 4 No. 1, pp. 1-43.
- Prabhu, J.C., Chandy, R.K. and Ellis, M.E. (2005), "The impact of acquisitions on innovation: poison pill, placebo, or tonic?", *Journal of Marketing*, Vol. 69 No. 1, pp. 114-130.
- Prahalad, C.K. and Hamel, G. (1990), "The core competence of the corporation", *Harvard Business Review*, Vol. 68 No. 3, pp. 79-91.
- Puranam, P. and Srikanth, K. (2007), "What they know vs. what they do: how acquirers leverage technology acquisitions", *Strategic Management Journal*, Vol. 28 No. 8, pp. 805-825.
- Raisch, S. and Birkinshaw, J. (2008), "Organizational ambidexterity: antecedents, outcomes, and moderators", *Journal of Management*, Vol. 34 No. 3, pp. 375-409.

- Ranft, A.L. and Lord, M.D. (2002), "Acquiring new technologies and capabilities: a grounded model of acquisition implementation", *Organization Science*, Vol. 13 No. 4, pp. 420-441.
- Roberts, E.B. and Berry, C.A. (1984), "Entering new businesses: selecting strategies for success", Working Paper [1492-3-84], Alfred P. Sloan School of Management, MA Institute of Technology, November.
- Rosenkopf, L. and Almeida, P. (2003), "Overcoming local search through alliances and mobility", *Management Science*, Vol. 49 No. 6, pp. 751-766.
- 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.
- Sears, J. and Hoetker, G. (2014), "Technological overlap, technological capabilities, and resource recombination in technological acquisitions", *Strategic Management Journal*, Vol. 35 No. 1, pp. 48-67.
- Song, J., Almeida, P. and Wu, G. (2003), "Learning-by-hiring: when is mobility more likely to facilitate interfirm knowledge transfer?", *Management Science*, Vol. 49 No. 4, pp. 351-365.
- Stettner, U. and Lavie, D. (2014), "Ambidexterity under scrutiny: exploration and exploitation via internal organization, alliances, and acquisitions", *Strategic Management Journal*, Vol. 35 No. 13, pp. 1903-1929.
- Tushman, M.L. and O'Reilly, C.A. (1996), "The ambidextrous organizations: managing evolutionary and revolutionary change", *California Management Review*, Vol. 38 No. 4, pp. 8-30.
- USPTO (2012), "Classes within the US classification system arranged by related subject matter", United States Patent and Trademark Office (USPTO).
- Vanhaverbeke, W., Duysters, G. and Noorderhaven, N. (2002), "External technology sourcing through alliances or acquisitions: an analysis of the application-specific integrated circuits industry", *Organization Science*, Vol. 13 No. 6, pp. 714-733.
- Voss, G.B., Sirdeshmukh, D. and Voss, Z.G. (2008), "The effects of slack resources and environmental threat on product exploration and exploitation", *Academy of Management Journal*, Vol. 51 No. 1, pp. 147-164.
- Wagner, M. (2011), "To explore or to exploit? An empirical investigation of acquisitions by large incumbents", *Research Policy*, Vol. 40 No. 9, pp. 1217-1225.

Appendix

Table A1 Robustness test results

| | DV: Existing core innovation | | | DV: Enhanced core innovation | | | DV: New core innovation | | |
|------------------------------|------------------------------|-------------------|-------------------|------------------------------|-------------------|------------------|-------------------------|-------------------|-------------------|
| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 | Model 8 | Model 9 |
| <i>Control variables</i> | | | | | | | | | |
| R&D intensity | -0.000 (0.000) | -0.000 (0.000) | -0.000 (0.000) | -0.002 (0.009) | -0.001 (0.009) | -0.002 (0.009) | 0.000 (0.000) | 0.000 (0.000) | 0.000 (0.000) |
| Firm size (Logemployee) | 1.001*** (0.092) | 0.977*** (0.092) | 0.901*** (0.091) | 1.821*** (0.215) | 1.802*** (0.215) | 1.826*** (0.215) | 0.558*** (0.115) | 0.557*** (0.115) | 0.623*** (0.114) |
| Relative size knowledge base | -0.009** (0.002) | -0.008** (0.002) | -0.008** (0.002) | -0.407** (0.158) | -0.716*** (0.250) | -0.444** (0.199) | 0.000 (0.002) | 0.000 (0.002) | -0.001 (0.002) |
| Acquirer knowledge base | 0.001*** (0.000) | 0.001*** (0.000) | 0.001*** (0.000) | 0.001*** (0.000) | 0.001*** (0.000) | 0.001*** (0.000) | -0.004*** (0.001) | -0.004*** (0.001) | -0.004*** (0.001) |
| Acquirer diversification | 0.045** (0.022) | 0.046** (0.022) | 0.048** (0.021) | 0.177*** (0.047) | 0.173*** (0.046) | 0.176*** (0.046) | -0.073** (0.035) | -0.073** (0.035) | -0.072** (0.034) |
| Number of M&A deals | -0.164*** (0.045) | -0.166*** (0.045) | -0.157*** (0.045) | -0.137 (0.088) | -0.127 (0.088) | -0.138 (0.088) | 0.075 (0.059) | 0.075 (0.059) | 0.046 (0.059) |
| <i>Independent variables</i> | | | | | | | | | |
| Similarity | | -0.751** (0.372) | | | 2.133* (1.172) | | | 0.077 (0.455) | 1.591*** (0.575) |
| Complementarity | 412 | 412 | 412 | 412 | 412 | 412 | 412 | 412 | 412 |
| Observations | Included | Included | Included | Included | Included | Included | Included | Included | Included |
| Control dummy variables | -2,003.85 | -2,001.92 | -1,992.51 | -819.97 | -818.14 | -819.92 | -1,010.79 | -1,010.78 | -1,006.32 |
| Log likelihood | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Prob > χ^2 | 335.37 | 339.23 | 358.06 | 220.96 | 224.62 | 221.06 | 112.83 | 112.86 | 121.78 |
| LR χ^2 | 1.29 | 1.30 | 1.29 | 1.29 | 1.30 | 1.29 | 1.29 | 1.30 | 1.29 |
| Mean VIF | 1.67 | 1.67 | 1.67 | 1.67 | 1.67 | 1.67 | 1.67 | 1.67 | 1.67 |
| Max VIF | | | | | | | | | |

Notes: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

About the authors

Seungryul Ryan Shin is a doctoral student of Technology Management, Economics, and Policy Program at Seoul National University. He received his bachelor's degree in Mechanical Engineering from UCLA. His main research interests are knowledge management, innovation strategy and technological mergers and acquisitions.

John Han is a doctoral student of Technology Management, Economics, and Policy Program at Seoul National University. He received his bachelor's degree in Electrical Engineering from the Korea Advanced Institute of Science and Technology. His current research interests include technological mergers and acquisitions and knowledge management.

Klaus Marhold received his PhD from the Technology Management, Economics, and Policy Program at Seoul National University. After majoring in Industrial Engineering, he worked in the European aerospace industry before receiving his BA and MA in Korean Studies as well as an MA in East Asian Economy and Society from the University of Vienna, Austria. His main research interests are innovation strategies of high-tech firms and international R&D cooperations.

Jina Kang is a Professor in the Technology Management, Economics, and Policy Program and the Industrial Engineering Department at Seoul National University. Prof Kang's research centers on strategy and technology and innovation management. Her work has been published in academic journals, including *Journal of Knowledge Management*, *International Business Review*, *Journal of Product Innovation Management*, *Creativity and Innovation Management*, *R&D Management*, *Technology Analysis and Strategic Management* and *Asia Pacific Journal of Management*. Prof Kang received her PhD in strategy and Strategy and Technology Management from the Anderson School of UCLA, MBA from the Wharton School of University of Pennsylvania and undergraduate degree in Management Science from KAIST. Jina Kang is the corresponding author and can be contacted at: profkang@snu.ac.kr

For instructions on how to order reprints of this article, please visit our website:

www.emeraldgroupublishing.com/licensing/reprints.htm

Or contact us for further details: permissions@emeraldinsight.com