

DETERMINANTS OF FIRM'S INNOVATION-RELATED EXTERNAL KNOWLEDGE SEARCH STRATEGY: THE ROLE OF POTENTIAL ABSORPTIVE CAPACITY AND APPROPRIABILITY REGIME

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Firms, especially those in the knowledge-based economy, make increasing use of external knowledge in their innovation processes. To tap into external knowledge sources, the firm follows a search strategy, which is known to be affected by both endogenous and exogenous factors. This study examines the influence of potential absorptive capacity on firms' external knowledge search strategy. We also propose and test a moderation effect of the appropriability regime on this relationship. Based on a panel dataset of 170 international

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firms from various industries, we find a curvilinear relationship between the level of a firm's potential absorptive capacity and the external knowledge search breadth. We also confirm the moderating role of the appropriability regime on this relationship. Our results highlight the role of the endogenous and exogenous factors determining the firm's use of external knowledge in the innovation process.

Keywords: Innovation; potential absorptive capacity; external knowledge search strategy; appropriability regime.

Introduction

In the knowledge-based economy (Grant, 1996; Dean and Kretschmer, 2007), knowledge, rather than traditional production factors such as land, labour, and capital, is critical for the firm's sustainable success and survival in high- or medium-high technology industrial domains (Grimpe and Sofka, 2009; Martín-de-Castro *et al.*, 2011). Valuable knowledge is the most important asset of firms for creating and achieving competitive advantage (Liebeskind, 1996). In addition, valuable knowledge allows the firm to deploy internal resources to efficiently cope with technological and environmental change, and to create platforms on which the firm can develop new product and process (Ndofor and Levitas, 2004). Specifically, the recent trend towards open innovation (Chesbrough, 2003) has emphasised the importance of valuable external knowledge in enabling firms to achieve sustainable competitive advantage and improve innovative performance (Chesbrough, 2006). According to the knowledge-based view (Grant, 1996), firms tend to find valuable external knowledge and integrate it with their internally developed knowledge to reduce the time and cost of new product development (Chesbrough, 2003). Thus, it is important for firms to have an appropriate search strategy for obtaining valuable knowledge from external actors such as a university, institutes, supplier, or customers.

According to the external knowledge search perspective, firms decide on an appropriate search strategy to create new products and processes internally through identifying and acquiring external valuable knowledge (Chen and Lin, 2004; Laursen, 2012). Generally speaking, external knowledge search strategies encompass both knowledge search breadth, i.e., how widely firms acquire external knowledge from knowledge sources or search channels, and knowledge search depth, i.e., how deeply firms draw from the different knowledge sources or search channels (Katila and Ahuja, 2002; Laursen and Salter, 2006; Chen *et al.*, 2011). In other words, in terms of external knowledge search strategies, prior studies largely focus on knowledge sources (Katila and Ahuja, 2002) and search channels (Laursen and Salter, 2006). Besides, a number of prior studies treated firm's search strategy as the independent variable and examined its impact on the firm's innovative performance (Laursen and Salter, 2006; Huizingh, 2011; Ferreras-Méndez

et al., 2015). However, although external knowledge search strategies are important for a firm's innovative performance, little is known about the endogenous and exogenous factors influencing external knowledge search strategies.

Recently, some studies from the field of knowledge management have suggested, theoretically or empirically, factors related to external knowledge search strategies: absorptive capacity (Grimpe and Sofka, 2009), the availability of technology opportunities (Cohen and Levinthal, 1990), the type of innovation output that the firm seeks to achieve (Köhler *et al.*, 2012), the diversity of knowledge provided by external sources (Olsen *et al.*, 2017), the communication and coordination process (Knudsen and Srikanth, 2014), and the appropriability strategy of the firm (Laursen and Salter, 2014). From the knowledge-based view of the firm (Grant, 1996), a firm's internal ability to identify and acquire valuable knowledge relates to its external knowledge search strategies (Zahra and George, 2002). This view implies that the firms' internal ability, based on its own knowledge stock might directly affect its external knowledge search strategies. Moreover, according to contingency theory (Hambrick, 1983), firms tend to determine external knowledge search strategies based on the external knowledge environment. In other words, external environments related to knowledge flows may indirectly affect the decision on the firm's external knowledge search strategies. Recently, studies have investigated endogenous and exogenous factors of firms' external knowledge search strategies (Drechsler and Natter, 2012; Laursen and Salter, 2014). However, there is a lack of research simultaneously addressing the direct or indirect effects of both endogenous and exogenous factors on the firm's external knowledge search strategies.

In search activities related to the innovation process, firms require absorptive capacity (Cohen and Levinthal, 1990) in terms of their internal capabilities to identify and acquire the knowledge from external sources (Grimpe and Sofka, 2009). Absorptive capacity refers to the ability to learn from valuable knowledge, assimilate it, and exploit it to commercial ends (Cohen and Levinthal, 1990). Absorptive capacity can be divided into two dimensions: potential absorptive capacity (PACAP) and realised absorptive capacity (RACAP) (Zahra and George, 2002). Whereas PACAP relates to knowledge acquisition and assimilation, RACAP relates to knowledge transformation and exploitation (Zahra and George, 2002). Accordingly, we suggest that PACAP is one of the factors in firms' search decisions by enabling firms to identify and recognise valuable knowledge (Todorova and Durisin, 2007).

In terms of exogenous factors, in order to protect the firm's sustainable competitive advantage (Arora *et al.*, 2001) and appropriate the returns from new innovation, industry-level institutional systematic mechanisms are critical. In this paper, we refer to these institutional systematic mechanisms as the appropriability regime (Teece, 1986). Cohen and Levinthal (1990) define appropriability conditions as the extent to which firms capture the financial benefits of their innovation

process. In general, the appropriability regime is the ability of different stakeholders to retain for themselves the financial benefits that arise through the willingness to use various knowledge sources (Willman, 1992; Atkins, 1998; Laursen and Salter, 2014). Specifically, Teece (1986) and Teece *et al.* (1997) suggest that the appropriability regime not only has three levels (strong, intermediate, and weak) but is also the environmental factor that governs a firm's ability to capture the financial benefits from innovative products and processes. Accordingly, we propose that the appropriability regime is one of the factors that affect the firm's search process during the creation of innovation.

Based on the above literature, it is important that firms should consider the nature of the external knowledge and environment, such as institutional systemic mechanisms, related to knowledge appropriation before knowledge searching. First, firms identify the nature of the external knowledge based on their internal knowledge stock and then acquire it. Second, the environment related to knowledge appropriation allows firms to transfer knowledge and to gain financial returns within their industry domain. Thus, we explore two factors related to knowledge search strategies: potential absorptive capacity as an endogenous factor and appropriability regime as an exogenous factor related to the external knowledge search process.

To extend and complement prior literature, this research investigates how PACAP affects the choice of the firm with respect to the use of knowledge in its innovation process. First, we investigate the relationship between the firm's external knowledge search strategy and PACAP. We propose that the level of the firm's PACAP affects its external knowledge search strategy. We argue that PACAP and the firm's external knowledge search strategy theoretically go hand-in-hand, but that high levels of PACAP are associated with a decreasing use of new knowledge in the innovation process. Second, we analyse whether the appropriability regime moderates the relationship between PACAP and the firm's external knowledge search strategy. We propose that the appropriability regime, as an important external factor, moderates the relationship between PACAP and the firm's external knowledge search strategy.

This study makes a number of contributions to the literature on the impact of major knowledge-related factors on firms' external knowledge search strategy. First, we extend the investigation of the role played by absorptive capacity in external knowledge search strategy. While previous research has focused on the moderating or mediating effects of absorptive capacity on the relationship between external knowledge flows and innovative performance (Fosfuri and Tribó, 2008; Hurmelinna-Laukkanen *et al.*, 2012; Yu, 2013; Leal-Rodríguez *et al.*, 2014; Ferreras-Méndez *et al.*, 2015), we link PACAP, the factor which is most related to identifying and assimilating knowledge (Zahra and George, 2002), to the firm's external knowledge search strategy in terms of organisational learning. Second, we

explore the effects of the appropriability regime on external knowledge search strategy and the use of knowledge in innovation. While some researchers have suggested the role of the appropriability regime as an activation trigger (Cohen and Levinthal, 1990; Todorova and Durisin, 2007), others have suggested that the appropriability regime moderates the relationship between RACAP and innovation performance (Zahra and George, 2002). We highlight that the strength of the appropriability regime affects the relationship between PACAP and the firm's external knowledge search strategy. Accordingly, our results show that external knowledge search strategy and the level of the firm's PACAP are very closely connected (Laursen and Salter, 2014). Also, our results lead to the suggestion for managers to select an appropriate external knowledge search strategy based on the level of the appropriability regime affecting the external knowledge environment of the firm.

This paper is structured as follows. Section "Conceptual background and literature review" provides the theoretical background on external knowledge search strategy, PACAP, and appropriability regime. Section "Hypotheses" provides the set of hypotheses driving our analysis. Section "Data and method" provides information on the design of the empirical study and describes the data used for the analysis as well as the definitions of the variables. Section "Results" describes the results of the econometric analysis. Based on these results, we discuss our findings in Section "Discussion" and end with conclusions and limitations in Section "Conclusion and limitations".

Conceptual Background and Literature Review (Theoretical Background)

External knowledge search strategy

Especially in times where open innovation becomes more important, firms need to develop search strategies for gaining access to new and innovative ideas and technologies (Laursen and Salter, 2006). Firms' search strategies strengthen their knowledge pool, enhance recombinatory search, and help add complementary assets (Cohen *et al.*, 2002). Specifically, the search strategy for external knowledge provides an umbrella that integrates a broad range of already existing innovative activities and redefines the organisational boundary between firms and the innovative environment (Cruz-González *et al.*, 2015). Thus, firms need an external knowledge search strategy that provides direction and priorities of valuable knowledge and information inside and outside the organisational boundaries (Laursen and Salter, 2006; Grimpe and Sofka, 2009).

With respect to external knowledge search strategies, Laursen and Salter (2006) built on the concepts of external search breadth and depth as the components of a

firm's external knowledge search strategy. The external search breadth is defined as the number of external sources or search channels that firms rely on in their innovative activities. The external search depth, on the other hand, is defined as the extent to which firms draw from the different external sources or search channels (Laursen and Salter, 2006). Especially, they focus on diversity and intensity of not the external knowledge itself but of the external actors or search channels.

Based on the organisational learning perspective, March (1991) suggest that explorativeness includes search activities captured by distal search, variation, risk taking, experimentation, flexibility, and discovery, whereas exploitativeness signifies search activities related to refinement, trade-off choice, production, efficiency, selection, and implementation (Lee *et al.*, 2014). Accordingly, in the pursuit of explorative knowledge search (explorativeness), firms make an effort to find valuable knowledge and create new technology. However, exploitative knowledge search (exploitativeness) demands more efforts in refining or extending the firm's prior knowledge base (March, 1991).

Katila and Ahuja (2002) have developed a similar approach to examine how firms search or solve problems by adopting the internal learning perspective through extending the ambidexterity concepts of March (1991). They argue that firms can vary in their degree of exploration of external knowledge and reuse of their internal knowledge, just as they can vary in their exploration of new knowledge (Katila and Ahuja, 2002). The former is search depth, which is defined as "how deeply a firm reuses its existing knowledge". The latter is search scope, which is defined as "how widely a firm explores new knowledge" (Katila and Ahuja, 2002: 1183). Thus, based on a learning perspective, search scope fits with the idea of explorative knowledge search and search depth is closer related to exploitative knowledge search (Cruz-González *et al.*, 2015).

Recently, based on heterogeneity, complexity, and distinct uses of knowledge, Santiago and Alcorta (2012) developed explorative and exploitative knowledge search concepts (March, 1991). They suggest that exploration refers to the search for new knowledge and the use of unfamiliar technologies, whereas exploitation refers to the use and refinement of existing knowledge, technologies, and products (Santiago and Alcorta, 2012). Thus, knowledge exploration refers to the distant search for new and unfamiliar knowledge. By contrast, knowledge exploitation refers to the local search for familiar, mature, current or proximate knowledge (Santiago and Alcorta, 2012). More recently, Tippmann *et al.* (2014) find that explorative search is related to a wider search for knowledge in distant domains to generate new combinations, whereas exploitative search is related to a narrow search for knowledge in similar domains to draw on familiar and accumulated knowledge. Accordingly, we focus on the application dimensions of external knowledge sources on the firm's search activities. In other words, the external knowledge search strategy

of the firm should not only encompass the exploratory search perspective but also the exploitative search perspective.

Potential absorptive capacity (PACAP)

Absorptive capacity is the firm's capability to learn from external knowledge sources through the processes of knowledge identification, assimilation, and exploitation (Cohen and Levinthal, 1989). Cohen and Levinthal (1990) reconceptualised the concept of absorptive capacity as the firm's ability to recognise the value of new information, assimilate it, and apply it to commercial ends. Absorptive capacity is not only related to R&D activities, but also to the diversity or breadth of the organisation's knowledge base, its prior learning experience, a shared language, the existence of cross-functional interfaces, and the mental models and problem-solving capacity of the organisation's members. Kim (1998) suggests that absorptive capacity is the learning capability and problem-solving ability that enables a firm to assimilate knowledge and create new knowledge through integrating external knowledge and the internal knowledge base. Christensen *et al.* (2005) understand absorptive capacity as the firm's competence to access, absorb and integrate external ideas, science and other kinds of knowledge inputs for innovation. Focusing on the process of external knowledge inputs, Lane *et al.* (2006) suggest absorptive capacity as the firm's ability to utilise external knowledge through the sequential processes of exploratory, transformative, and exploitative learning.

Zahra and George (2002) redefined absorptive capacity as a set of organisational routines and processes, by which firms acquire, assimilate, transform, and exploit knowledge to produce a dynamic organisational capability. They categorised absorptive capacity into four dimensions in terms of knowledge flow: acquisition, assimilation, transformation, and exploitation (Zahra and George, 2002). Especially, they suggest two distinct constructs of absorptive capacity: potential absorptive capacity (PACAP) and realised absorptive capacity (RACAP). PACAP captures knowledge acquisition and assimilation, i.e., the firm's capacity to identify and acquire externally generated knowledge (Gebauer *et al.*, 2012; Leal-Rodríguez *et al.*, 2014). RACAP reflects knowledge transformation and exploitation, i.e., the firm's ability to leverage absorbed external knowledge and transform it into innovation performance (Fosfuri and Tribó, 2008). Whereas RACAP enhances the combination of relevant knowledge sources and increases the firm's responsiveness to internal changes, PACAP helps firms to align between external knowledge sources and the internal knowledge base and enhances the firm's responsiveness to external changes (Ben-Menahem *et al.*, 2013). According to the process-based notion of Lane *et al.* (2006), PACAP and RACAP are not substitutes but form a complementary relationship. Both of them are needed to

actually benefit from external knowledge. For establishing innovation performance, external knowledge is linked to the firm's internal systems and prior knowledge base through the ability to identify and acquire it (Zahra and George, 2002). Especially, PACAP becomes increasingly important in the era of the knowledge-based economy (Grant, 1996; Dean and Kretschmer, 2007) to help reconfigure the external knowledge base and deploy competitive capabilities for the development of new products and processes (Zahra and George, 2002; Todorova and Durisin, 2007). In addition, PACAP can be constituted by firm's prior complementary knowledge and information assets through M&As and alliances (Zahra and George, 2002; Makri *et al.*, 2010).

In particular, Lichtenthaler and Lichtenthaler (2009) suggest knowledge management capacity as a firm's capability of reconfiguring and realigning internal and external knowledge in the open innovation process. They also argue that external knowledge exploration refers to acquiring knowledge from external sources (Lane *et al.*, 2006), and define PACAP as a firm's ability to explore external knowledge (Lichtenthaler and Lichtenthaler, 2009). Therefore, PACAP is one of the drivers of a firm's external knowledge search strategy to acquire and assimilate external knowledge during the innovation process.

Appropriability regime

Appropriability regime refers to the extent to which firms protect the benefits of their new knowledge and innovative products/processes from external actors by institutional and industry dynamics (Teece, 1986; Cohen and Levinthal, 1990; Willman, 1992; Zahra and George, 2002; Hurmelinna-Laukkanen and Puumalainen, 2007). In general, the appropriability regime can be divided into the legal appropriability regime of the industry (e.g., patents, trademarks, and copyright protection) and the strategic appropriability regime of the firm (e.g., secrecy, lead-time, complexity, first mover advantage, and lock-in) (Amara *et al.*, 2008; Hurmelinna-Laukkanen *et al.*, 2008).

A strong legal appropriability regime increases the firm's reputation for new product development, its negotiation capabilities with external actors, and the firm's accessibility to external knowledge (Cohen *et al.*, 2002; Blind *et al.*, 2006). A strong strategic appropriability regime enhances internal new product development through the learning effect (Hirshmann, 1964). Thus, a legal appropriability regime can protect valuable knowledge sources from external actors, whereas a strategic appropriability regime can protect internally developed knowledge through innovative products and processes (Xu *et al.*, 2012). Based on the contingency theory (Hambrick, 1983), firms' external knowledge search strategy will change under different external appropriation environments. To

explore external environment (as an institutional systematic mechanism) related knowledge flows, we focus on the legal appropriability regime, i.e., the knowledge appropriation mechanism of the industry, as an exogenous factor which affects the relationship between the external knowledge search strategy and PACAP (Teece, 1986). Thus, the appropriability regime in the context of our research is the legal appropriability regime.

With respect to the characters of the appropriability regime, Teece (1986) suggests two dimensions: the nature of the technology and the efficacy of the legal mechanisms of protection. The nature of the technology can be either explicit or tacit (Teece, 1986). Explicit knowledge can be codified and thus transferred easily to the external environment (Liebeskind, 1996), whereas tacit knowledge is often embedded in routines and is difficult to imitate (Hurmelinna-Laukkanen and Puumalainen, 2007). With respect to the efficacy of the legal mechanisms of protection, when knowledge is difficult to imitate and can be legally protected, the appropriability regime can be defined as strong. However, if knowledge can easily be imitated and is difficult to protect, the appropriability regime is defined as weak (Teece, 1986; Hurmelinna-Laukkanen and Puumalainen, 2007). Teece *et al.* (1997) suggest that also intermediate appropriability regimes exist. Specifically, under a strong appropriability regime, firms tend to convert new developed products and processes into patents and increase the claims of their patents to extend the protection areas (Escribano *et al.*, 2009). Theoretically, these patents are useful tools for protecting the financial returns arising from innovation (Teece, 1986) and constitute a firm's sustainable competitive advantage (Escribano *et al.*, 2009). Also, firm's patents send positive signals to potential collaborators, increase bargaining power, prevent unwanted knowledge transfer, and enhance first-mover advantage (Hurmelinna-Laukkanen and Puumalainen, 2007). However, under a weak appropriability regime, firms select secrecy as the preferred strategy for protecting their products and processes innovations (Cohen *et al.*, 2000). Because of registration costs and the paradox of disclosure (Arrow, 1962), it is difficult to extend the knowledge flows between innovating firms and external actors. Thus, firms are likely to sustain competitive advantage differences by hampering knowledge spillovers (Zahra and George, 2002).

Hypotheses

PACAP and external knowledge search strategy

Internal and external knowledge is important for firms to achieve innovative performance in the open innovation system (Chesbrough, 2003). In particular, external knowledge has become more significant in the shift towards an open

innovation system and has become more readily available as information and communication technologies improved (Grimpe and Sofka, 2009). Accordingly, firms should develop internal capabilities to assimilate external knowledge into their internal knowledge bases through acquiring valuable external knowledge from external actors. Zahra and George (2002) define these core capabilities of the firm as potential absorptive capacity (PACAP).

Based on the above literature review, PACAP, as one of the two faces of absorptive capacity in terms of a byproduct of R&D, is thought to be used for the pursuit of two distinctive external knowledge strategies: external knowledge search breadth and external knowledge search depth. The former aims at advancing basic science and finding new technology while the latter is directed toward realising and refining the commercial application of the firm's prior knowledge base (Garcia *et al.*, 2003). Specifically, engaging in knowledge search strategies for external knowledge breadth not only allows firms to obtain financial returns and innovative performances but also affects organisational structure, development routines, and resource endowments (Laursen and Salter, 2006).

PACAP plays several important roles related to firms' search breadth for external knowledge: PACAP acts as a technological gatekeeper of external knowledge acquired through alliances and M&As (Allen, 1977). We assume that PACAP allows firms to recognise the nature of their own knowledge assets. Through an assessment of their own knowledge assets, firms can identify the lacking knowledge that would be required to cope with emerging technologies and will be able to take advantage of the pool of technological opportunities (Nieto and Quevedo, 2005). To sustain a competitive advantage, firms are more likely to acquire complementary knowledge of external actors as well as to invest in their internal R&D (Laursen and Salter, 2006). According to the resource-based perspective (Wernerfelt, 1984), firms with a high-level of PACAP may identify and acquire broader knowledge resources to gain economies of scope in external knowledge assets (MacDonald, 1985; Rodríguez-Duarte *et al.*, 2007). Based on the notion of Zahra and George (2002), Enkel and Heil (2014: 245) argue that "potential absorptive capacity precludes firms from becoming locked into a specific area of expertise and running the risk of failing to seek out alternative technologies by providing them with the strategic flexibility to adapt to various industry contexts". Furthermore, prior literature indicates that the attention of innovative firms related to new business and market opportunities play important roles in external knowledge searching (Volberda *et al.*, 2010; Salter *et al.*, 2014). To inspire new business concepts and products/processes, firms are likely to alert to new technological opportunities (Salter *et al.*, 2014). Driven by curiosity and various interests, firms extend their search strategy to a broad range of external knowledge sources to break the conventional logic of their industry and

organisation (Kaish and Gilad, 1991). Thus, the higher the PACAP, the greater the ability to identify which external actors are specialised in the technological areas required to solve the organisational problems. Therefore, if PACAP is high, it is possible to expand into various technological fields, and firms will actively accept the knowledge of broader technical fields.

Although an emphasis on PACAP can be linked to the firm's effective external knowledge searching, we posit that the positive effect of PACAP on external knowledge search strategy may decline after it reaches a certain point for two key reasons: First, firms that have a high level of PACAP are more likely to get stuck in the "trade-off to be made between the opportunity of novelty value and the risk of misunderstanding" (Nootboom *et al.*, 2007: 1030). Theoretically, PACAP enables firms to identify and acquire external knowledge sources through collaborations such as M&A and alliances (Zahra and George, 2002). Meanwhile, as a firm's PACAP increases, the firm might expand its cognitive distance further afield to find novel knowledge (Wales *et al.*, 2013). In other words, for firms with high levels of PACAP, cognitive distance allows finding external technological opportunities for combination and recombination of complementary resources using novel knowledge (Nootboom *et al.*, 2007). However, beyond a certain point, the cognitive distance becomes large enough to preclude a sufficient search strategy for external knowledge sources. For example, Nootboom *et al.* (2007) find that while absorptive capacity increases the level of novel value, excessive absorptive capacity reduces the effect of cognitive distance on novelty. They suggest that moderate levels of distance allow firms to search efficiently for external knowledge sources which have novel value, but are not so distant as to preclude mutual understanding (Nootboom *et al.*, 2007). Accordingly, high levels of PACAP are likely to restrict the efficiency of the firm's external knowledge search strategy.

Second, bounded rationality (Simon, 1947) related to knowledge overload is likely to hamper the efficiency of the external knowledge search strategy. Based on the law of diminishing marginal returns (Karr-Wisniewski and Lu, 2010), we suggest that knowledge overload is a condition that occurs at the level at which a marginal addition of new or complementary technological knowledge reaches the level of diminishing marginal returns. According to the notion of Zahra and George (2002), the firm's level of PACAP is determined by the level of its exposure to complementary knowledge from external actors. Thus, a high level of firm's PACAP is characterised by a knowledge overload within the firm. Simon (2008: 893) defines bounded rationality as "designate rational choice that takes into account the cognitive limitations of the decision-maker limitations of both knowledge and computational capacity". In an internal knowledge overload situations, bounded rationality is likely to prevail. In other words, firms with a high level of PACAP tend to search external knowledge at a satisfying level rather than

at the optimal level (Simon, 1947). Thus, this knowledge overload situation results in firms decreasing the decision-making for external knowledge searching (O'Reilly, 1980; Karr-Wisniewski and Lu, 2010). Recently, based on a meta-analysis of information overload like knowledge overload, Eppler and Mengis (2004) find a potential negative effect of information overload on the firm's external search strategy. Accordingly, a high level of PACAP is likely to decline the efficiency of the firm's external knowledge search strategy.

In summary, prior research has provided reasons to expect that the firm's PACAP, one of the firm's endogenous factor, is linked closely to the firm's external knowledge search strategy. The positive role of PACAP in strengthening the firm's ability to identify and recognise external valuable knowledge widely increases the level of knowledge transfer among industries or sectors. This allows the firm to incorporate knowledge from a broad range of fields in its innovation process. However, increasing the level of PACAP beyond a certain point will weaken the relationship between PACAP and the search breadth for external knowledge. Thus, we propose the following hypothesis:

Hypothesis 1: *A firm's potential absorptive capacity will show a curvilinear relationship with its external knowledge search breadth.*

External knowledge search strategies, PACAP, and appropriability regime

Before identifying and assimilating external knowledge through the innovation process, firms must carefully evaluate the efficacy and efficiency of the appropriability regime in their industry (Teece, 1986; Drechsler and Natter, 2012). The efficacy of the appropriability regime depends on the strength of institutional protection mechanisms such as legal protection for patents (Teece, 1986). In addition, the efficiency of the appropriability regime depends on the nature of firms' knowledge (e.g., explicit and tacit) (Frishammar *et al.*, 2015). In particular, prior research suggests that a high perceived degree of effectiveness (efficacy and efficiency) of the appropriability regime actively influences the relationship between PACAP and external knowledge search strategies (Drechsler and Natter, 2012). Acquiring knowledge from external firms usually involves explicit contracts and patents, which give stronger opportunities for technology exploration (West and Bogers, 2014). Performing an analysis on a sample of start-up ventures, Dushnitsky and Shaver (2009) find that the effectiveness of external knowledge acquisition through contracts and patents is associated with the strength of the appropriability regime. They also suggest that the strength of the appropriability regime as an environmental factor (Teece, 1986) is related to the nature of absorptive capacity such as knowledge-relatedness.

Appropriability regime as an environmental factor plays several roles in the relationship between PACAP and external knowledge search strategy. First,

appropriability regime is related to the flows and pools of external knowledge that can be efficiently used by focal firms. Under strong appropriability regime, firms tend to not only patent their valuable knowledge and information actively (Escribano *et al.*, 2009) but also increase their patent's claims to protect potential revenue streams arising out of their product and process innovation (Xu *et al.*, 2012). These patents contribute to generating comprehensive and accessible external knowledge sources of valuable scientific and technologic information (Granstrand, 1999). Accordingly, in strong appropriability regime, the amount and quality of external knowledge sources flows that focal firms can be used is greater in knowledge market environments. Thus, firm's patenting aims at extending the pool of explicit knowledge transfer through knowledge licensing within the industry (Granstrand, 1999). Additionally, a firm's increasing propensity to patent its innovations results in an increased diversity of explicit knowledge and technology opportunities.

Second, appropriability regime is related to firm's decision on conducting collaboration with external actors for identification and acquisition of external knowledge sources. For instance, the transaction cost theory suggests that appropriability problem can hamper the efficient market for technology (Arrow, 1962; Williamson, 1985; Kim, 2009). Following Arrow's description (1962), appropriability problem refers to the possibility to use the external knowledge without paying for it. Because of this appropriability concerns, a firm will be reluctant to grant access their own core technology. Thus, in weak appropriability regime, the collaboration for accessing external knowledge is curtailed. By contrast, strong appropriability regime can be considered as the remedy for the appropriability problem in the market for technology (Cohen *et al.*, 2002; Kim, 2009). According to transaction cost theory (Williamson, 1985), strong appropriability regime reduce the risk of unintended knowledge spillover, uncertainties about the future value creation and capture, and transaction costs involved in knowledge transfer through collaboration (Baughn *et al.*, 1997; Ritala and Hurmelinna-Laukkanen, 2013; Kim, 2009). Accordingly, the strength of appropriability regime would affect the firm's decision related to external knowledge identification and acquisition.

At each level of PACAP, firms operating under a stronger appropriability regime will search for external knowledge with a broader scope, taking advantage of the increasingly diverse knowledge and opportunities offered by their increased patenting activities. In other words, an increasing strength of the appropriability regime shifts the curve depicting the relationship between PACAP and external knowledge search breadth upwards. This leads to the following hypothesis:

Hypothesis 2: *The strength of the appropriability regime positively moderates the curvilinear relationship between a firm's potential absorptive capacity and its external knowledge search breadth.*

Data and Method

Data

For the empirical analysis, a panel dataset containing patent and financial information of 170 international firms from various industries and covering the time period from 2005 to 2009 was compiled. Such a panel dataset is suitable to address the dynamic effects of the searching strategic changes. To prevent a potential bias problem, sample firms were chosen from 78 different industries based on the Standard Industrial Classification (SIC) 4-digit code. This research defines the innovation-related search activities of the sample firms using data on granted US patents. As a mean of protecting intellectual properties, patents are widely used in studies analysing the innovative performances of firms. Additionally, US patents provide detailed information in the form of patent classes that allow researchers to identify links between patents and technological fields (Trajtenberg *et al.*, 1997). Considering the time lag between the R&D activities and the time a patent is actually granted, we based the analysis on the application year of the patent. We collected information on the 61,888 patents which were applied for from 2005 to 2009 and which were ultimately granted to the firms in our sample. We also retrieved information on the 280,031 patents which were granted to 3,744 external partners of the sample firms. The data was obtained from the patent databases provided by the United States Patent and Trademark Office (USPTO). For measuring financial indices such as the firms' R&D intensity and total sales, we used the Compustat database provided by Standard & Poors and the Datastream database provided by Thomson Reuters. Furthermore, we gathered information on the M&A and alliance deals of the sample firms during the past seven years from the Securities Data Company (SDC) Platinum database provided by Thomson Reuters. A total of 4,010 M&A deals and 509 alliance deals were used to calculate the sample firms' external knowledge sourcing activities.

Variables

Dependent variables

External search is inherently linked with the search for and use of new technological knowledge as well as technological fields from outside the organisation. Accessing ideas and knowledge of new technological fields from the external partners could be considered as an exploring activity to enlarge the firm's technological boundaries. In other words, the firm's intentions of its external knowledge search strategies through external partners could be reflected in how many

external partners have similar knowledge compared to the focal firm. If the external partners have little common knowledge with the focal firm, it could be argued that the focal firm's external knowledge search strategies are designed to source knowledge to broaden its technological boundaries. Therefore, to identify the breadth of external knowledge search, we compared the patents of the focal firms and their external knowledge sources such as alliance partners and organisations acquired by the focal firms. At first, we retrieved the USPC main class of the external partners' granted patents before the alliance or M&A deal event occurred. We then identified the number of the external partner's patents that were not classified into the USPC main classes where patents were also granted to the focal firms. Finally, we calculated the external knowledge search breadth through the total number of patents classified into new technological fields to the focal firms and granted to external partners until one year prior to the deal event year. We only considered the deal events occurring in the two years after the specific year ($t \sim t + 2$) to measure the firm's strategic response to the PACAP and the appropriability regime. We used the log scale to normalise dependent variables.

Independent variables

Potential Absorptive Capacity (PACAP): According to Zahra and George (2002), firm's exposure to knowledge from external sources, including acquisitions and inter-organisational relationships such as alliances and joint ventures, would influence strategic decision making as well as the development of future capabilities. Identifying and acquiring knowledge from different external sources significantly influences the constitution of the subsequent acquisition and assimilation capabilities (Zahra and George, 2002). In this sense, Zahra and George (2002) concluded that the firm's level of PACAP is determined by the level of its exposure to complementary knowledge from external sources. By adopting the concepts of Zahra and George (2002), we measured the firm's PACAP through the level of exposure to complementary knowledge. First, we identified the patents granted to the sample firms' and their external sources which have entered contracts with sample firms or were acquired by the sample firms in the time period of year $t-3$ to year $t-1$. Specifically, we considered patents that were applied for until year $t-1$ and were ultimately granted to the firms. We then classified the patent classes into 36 technological subcategories (Hall *et al.*, 2001) to compare the knowledge overlap between the sample firms and their external sources. Last, we calculated each firm's PACAP using the following formula, which was suggested by Makri *et al.* (2010) and is used to measure technological complementarity between

organisations.

Potential Absorptive Capacity (PACAP)

$$= \frac{\text{Number of Patent with Overlapping Subcategories}}{\text{Total Number of Patents (Focal Firms and their External Sources)}} \times \frac{\text{Number of Patent with Overlapping All Patent Classes}}{\text{Total Number of Patents (Focal Firms and their External Sources)}} \times \frac{\text{Total Number of Focal Firm's Patents in Common Subcategories}}{\text{Total Number of Patents (Focal Firm)}}$$

Appropriability regime: Firms in an industry are facing the same environment to protect their innovation outcomes. The different tendency for protecting R&D outcomes in each industry leads to firms engaging in the legal protection of their innovations to different degrees. Therefore, firms within an industry which more heavily focuses on the protection of intellectual property rights will have more patent claims in their patents. This research uses the efforts of firms to protect their innovation through patent claims as an indicator of the strength of the appropriability regime they operate in. To identify the appropriability regime of each industry, we identified the patent activity information of the top companies in each industry (SIC 4-digit level) because we considered the top companies to reflect the standard level of competitiveness in the particular industries. We then calculated the appropriability regime as the average number of patent claims, i.e., the average number of claims of the patents which were applied in year t and granted to the top 20 companies in each industry in the year t . Those top 20 companies were selected by the volume of their sales in year $t-1$.

Control variables

Firm size: The size of a firm can affect the level of its innovation activities such as the level of sourcing external knowledge. For example, small ventures in high-tech industries usually aim at explorative innovation while incumbent large firm focuses on their core activities for exploitative R&D projects. Therefore, we controlled for different firm sizes using the total sales of the sample firms in the year t . The variable was log-transformed.

R&D intensity: As external knowledge is considered to be a key factor of open innovation, R&D investments facilitate not only learning by doing but also allow to hire external specialists for internalising and understanding external knowledge which results in enhancing the firm's internal knowledge bases (Cohen and Levinthal, 1990; George *et al.*, 2001). Additionally, the expenditures related to R&D activities reflect reproducing existing knowledge as well as acquiring new

knowledge to deal with changes in the external environment. Therefore, we controlled for the firm's R&D activities through the *R&D intensity* variable, which is defined as R&D expenses over sales in year t .

Past innovation experiences: The experience of successfully conducting R&D projects allows firms to understand the most efficient way of pursuing R&D and aids the knowledge searching process. Consequently, such experiences enhance firm's development capabilities and increase the possibility of discovering the necessary knowledge from the firm's external partners. Therefore, this research included the firm's innovation experience, defined as the total number of granted patents for each firm until the $t-1$ year, as a control variable.

Current R&D capacity: Not only the past successful innovation experiences but also the current abilities of the firm's R&D could affect the external knowledge search strategies. To control for the effects of the firms' most recent R&D activities on the level of external knowledge searching activities via external partners, we included this control variable defined as the number of each firm's patent applications in the year $t-1$.

Technological diversity: Some firms narrowly focus on particular technological fields while other firms are involved in a broad range of technologies. From the view of organisational inertia, a firm's tendency of either focusing on few particular technologies or breaking into various technological fields would influence the firm's further external knowledge search strategies. To control for each firm's technological diversity, we identified the firm's patents which were granted until year $t-1$ and calculated the diversity index based on the following equation:

$$\text{Technological diversity} = \sum_i^k f_i * \ln(1/f_i),$$

where f_i represents the proportion of patent in the i th patent class and k represents the entire number of patent classes.

M&A, Alliance experiences: As technology becomes more complex, firms tend to adopt open innovation strategies, i.e., sourcing external knowledge rather than conducting the entire R&D internally, to increase the efficiency of their R&D processes (Chesbrough, 2003). Especially alliances and M&A deals are considered as effective means of sourcing codified as well as tacit knowledge. Because alliance and M&A deal frequently occur when firms are entering new technologic fields, we controlled for these activities that influence the firms' external knowledge search strategies. We defined the two experience variables as the number of alliance and M&A deals of each firm during the five years before the year t .

Industrial dummy: To control for any differences between the various industries comprising our data sample, this research included industry dummy variables in

Table 1. Results of the Variance Inflation Factor (VIF) test.

Variable	VIF	1/VIF
PACAP	1.76	0.5679
PACAP ²	2.01	0.4968
Appropriability regime (AR)	2.17	0.4602
PACAP × AR	1.5	0.6671
PACAP ² × AR	2.81	0.3556
Firm size	3.26	0.3066
R&D intensity	1.41	0.7102
Current R&D capacity	2.66	0.3758
Past innovation experience	4.24	0.2358
Technological diversity	2.16	0.4626
M&A experience	1.43	0.6991
Alliance experience	1.3	0.7710
Mean	2.23	0.5091

our regression model. Seven dummy variables were coded based on the first digit of the SIC codes of the sample firms.

Model

For the tests of our suggested hypotheses, we used panel regression analysis. To begin with, we conducted a Hausman test to determine whether the fixed-effect or the random-effect model is more suitable for our analysis. The results of the Hausman test suggest that the random-effect model is appropriate. Therefore, we employed a random-effect generalised least square (GLS) regression analysis for the analysis of our dependent variables, external knowledge search breadth. Additionally, we conducted a Variance Inflation Factor (VIF) test to address possibilities of multicollinearity between the variables, including independent and control variables as well as interaction terms. The results of VIF test are shown in Table 1. The mean value of the VIFs is 2.23 and the maximum value is 4.24, indicating that no problems with multicollinearity exist in our dataset.

Results

Before testing our hypotheses, we prepared the descriptive statistics and analysed the correlations between the variables in Table 2. We found a strong correlation between firm size and firm's current R&D capacity, past innovation experience and technological diversity. This can be explained by the ability of larger firms to invest more resources into their R&D processes.

Table 2. Descriptive statistics and correlations.

	Mean	S.D.	Min	Max	1	2	3	4	5	6	7	8	9	10
(1) External knowledge search breadth ¹	2.22	2.69	0	10.04	1									
(2) PACAP	0	1	-1.02	3.83	0.136**	1								
(3) Appropriability regime	0	1	-4.79	5.34	-0.009	0.011	1							
(4) Firm size ¹	7.62	1.97	0.91	12.45	0.096**	0.093**	-0.294*	1						
(5) R&D intensity	0.16	0.34	0.001	4.72	0.029	-0.025	-0.021	-0.397	1					
(6) Current R&D capacity	3.23	1.46	0	6.91	0.027	0.026	-0.081**	0.522*	-0.081	1				
(7) Past innovation experience	5.91	1.48	2.20	9.48	-0.038	-0.081**	-0.254**	0.657*	-0.168	0.742**	1			
(8) Technological diversity	2.53	0.86	0.46	4.66	0.023	0.070**	-0.202	0.579**	-0.282	0.322*	0.627	1		
(9) M&A experience	8.60	9.01	0	60	0.119	0.124*	-0.078*	0.525	-0.166*	0.257	0.308*	0.303**	1	
(10) Alliance experience	1.19	2.67	0	21	0.078**	0.030**	-0.188**	0.280*	0.174*	0.235	0.219	0.005	0.098**	1

Note: $n = 170$. ¹Transposed to log scale. Sectoral dummy variables were excluded. ** $p < 0.01$; * $p < 0.05$.

Table 3. Results for the Random-Effect of GLS Regression model.

Dependent variable (external knowledge search breadth)	Model 1	Model 2	Model 3	Model 4	Model 5
<i>Control Variables</i>					
Firm size	0.130 (0.130)	0.111 (0.130)	0.103 (0.130)	0.135 (0.131)	0.112 (0.131)
R&D intensity	0.271 (0.353)	0.251 (0.352)	0.215 (0.352)	0.280 (0.353)	0.226 (0.352)
Current R&D capacity	0.275** (0.116)	0.269** (0.116)	0.258** (0.116)	0.269** (0.117)	0.262** (0.117)
Past innovation experience	-0.600*** (0.168)	-0.550*** (0.169)	-0.549*** (0.170)	-0.592*** (0.169)	-0.555*** (0.171)
Technological diversity	0.318 (0.256)	0.289 (0.255)	0.287 (0.256)	0.318 (0.257)	0.309 (0.258)
M&A experience	0.0153 (0.0167)	0.0131 (0.0167)	0.00984 (0.0168)	0.0148 (0.0167)	0.00992 (0.0168)
Alliance experience	0.00964 (0.0556)	0.00409 (0.0555)	-0.00257 (0.0556)	0.0103 (0.0557)	0.00505 (0.0558)
Sectoral dummy			<i>Included</i>		
_Cons	1.183 (1.716)	1.101 (1.707)	1.472 (1.721)	1.121 (1.723)	1.499 (1.734)
<i>Independent Variables</i>					
PACAP		0.183* (0.0940)	0.371*** (0.127)		0.382*** (0.127)
PACAP ²			-0.161** (0.0726)		-0.224*** (0.0789)
Appropriability regime (AR)				0.0485 (0.0978)	0.0806 (0.124)
PACAP × AR					-0.00692 (0.108)
PACAP ² × AR					0.132* (0.0780)
Observations	850	850	850	850	850
Adjusted R-square	0.080	0.087	0.087	0.079	0.087
Number of firms	170	170	170	170	170

Note: Standard errors in parentheses. *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$;

Table 3 shows the results of the empirical testing of the suggested hypotheses. The dependent variables in Model 1 to Model 5 are external knowledge search breadth in Table 3. Among these models, Model 1 is the base model and contains only the control variables, and Model 5 is the full model that contains the entire variables including the interaction terms. Table 3 shows that the current R&D

capacity has a significant positive relationship and past innovation experience a significant negative relationship with the firm’s external knowledge search breadth. These results indicate that an enhanced current R&D capacity encourages the firm to search more broadly for external knowledge, i.e., the larger the current R&D capacity, the better it is to understand external knowledge from various fields. Meanwhile, a firm’s past innovation experience has a negative impact on external knowledge search breadth. In other words, the scope of the external knowledge search by a firm could be negatively affected by past innovation experiences while being positively affected by current capacity.

To test the curvilinear relationship between PACAP and external knowledge search breadth, we included only the first order term of PACAP in Model 2 and included both the first order and the second order (square) term of PACAP in Model 3. Model 2, Model 3 and Model 5 show that the first order term of PACAP is positively significant. Moreover, the results of Model 3 and Model 5 indicate that the square term of PACAP was negatively significant (−0.161 and −0.224, respectively) with the firm’s external knowledge search breadth. Additionally, Fig. 1 displays the curvilinear relationship between PACAP and external knowledge search breadth. The empirical results provide support for our Hypothesis 1. Increasing the level of PACAP in firms causes facilitation of external knowledge search breadth. Beyond a certain level of PACAP, however, an excessive level of PACAP hampers the increase of external knowledge search breadth.

Next, we included the interaction terms of both first order and square term of PACAP and appropriability regime in our models. The quadratic main effect (X) and the linear moderation effect (Z) can be expressed using the following formula:

$$Y = \beta_0 + \beta_1X + \beta_2X^2 + \beta_3Z + \beta_4XZ + \beta_5X^2Z + \epsilon.$$

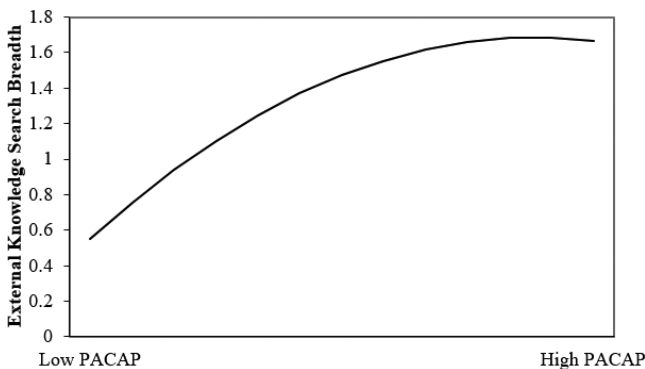


Fig. 1. The relationship between PACAP and external knowledge search breadth. Low and high are one standard deviation below/above the mean value.

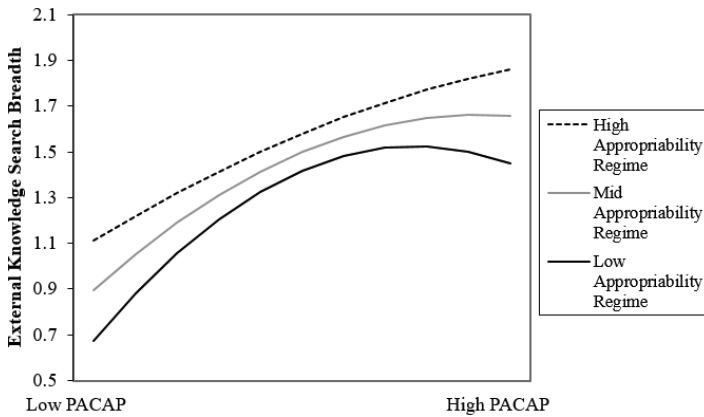


Fig. 2. The moderation effect of the appropriability regime on the relationship between PACAP and external knowledge search breadth. Low and high are one standard deviation below/above the mean value (mid).

Prior to testing the moderating effect of the appropriability regime proposed in Hypothesis 2, we conducted F -test between the complete model and a model without the XZ and X^2Z terms to test whether the appropriability regime moderates the relationship between PACAP and external knowledge search breadth (Dawson, 2014). Based on the tests of coefficients β_4 and β_5 , we confirmed that the moderation effect of the appropriability regime on the relationship between PACAP and external knowledge search breadth is statistically significant (p -value < 0.001).

Model 5 in Table 3 indicates that the coefficient of the square term of PACAP is negatively significant (-0.224) while the moderating coefficient affecting the square term of PACAP is positively significant (0.132). This shows that the curvilinear relationship between PACAP and external knowledge search breadth is flattened with an increase in the strength of the appropriability regime (Aiken and West, 1991; Haans *et al.*, 2016). Figure 2 shows that in accordance with the level of the appropriability regime, the relationship between PACAP and external knowledge search breadth exhibits an inverted U-shape. As the level of appropriability regime increases, the relationship curve is pushed upwards and flattened through the moderation effect. This shows that the relationship between PACAP and external knowledge search breadth is positively moderated (flattened) through a moderation effect of the appropriability regime. This supports our Hypothesis 2.

Discussion

The purpose of this study is to uncover the relationship between a firm's PACAP and its search strategy for external knowledge during the innovation process. In

addition, we confirmed the moderating effects of the appropriability regime, one of the major factors in planning and executing search activities for external knowledge sourcing, on the relationship between PACAP and external knowledge search strategy.

The results of this study advance the prior theoretical literature, especially literature on the endogenous and exogenous factors related to external knowledge search strategy, in several ways. First, our results show that PACAP has a curvilinear relationship with external knowledge search breadth. This implies that there are positive returns to PACAP, but beyond a certain level, it becomes detrimental to external knowledge search breadth. These findings support the theoretical propositions from prior literature that high level of PACAP in external knowledge searching activities may be associated with the trade-off to be made between cognitive distance and bounded rationality (Nooteboom *et al.*, 2007; Simon, 2008) for identifying and acquiring external knowledge, thereby diminishing external knowledge search breadth. On the one hand, PACAP allows firms to have the cognitive capability to assess the firm's own knowledge assets, and the incentive to search broader knowledge resources in terms of economies of scope (Rodríguez-Duarte *et al.*, 2007). On the other hand, high levels of PACAP increase the cognitive distance for external knowledge search breadth. This might increase the novelty of broader knowledge resources, but it also reduces the benefits of mutual understanding (Nooteboom *et al.*, 2007; Wales *et al.*, 2013). In addition, for firms with limited time and attention, bounded rationality allows arriving at restricted satisfactory searching rather than one that is wider to all others in every dimension (March and Simon, 1958; Haas, 2006). In other words, based on the bounded rationality perspective (Simon, 1997), high levels of PACAP are more likely to decrease the efficiency of decision-making for the external knowledge breadth. Accordingly, our results show that PACAP is directly linked to a firm's external knowledge search breadth, and accelerates the firm's absorption of external knowledge through the innovation process. Our results further show that a high level of PACAP reduces this acceleration of firms' absorption in terms of external knowledge search breadth. In conclusion, the results confirm PACAP as one of the major factors that heavily influence firm's search activities for external knowledge sources.

Second, our results on the moderating effect of the appropriability regime have been supported. The strength of the appropriability regime positively moderates the relationship between PACAP and external knowledge search breadth. This finding supports the theoretical proposition of prior literature that the strength of the appropriability regime enhances not only the external knowledge flows of firms by increasing patenting and patent's claims (Escribano *et al.*, 2009; Xu *et al.*, 2012) but also the collaboration for searching external knowledge sources (Ritala

and Hurmelinna-Laukkanen, 2013; Kim, 2009). In other words, this seems to indicate that the search for various knowledge sources increases as the environment in which a firm operates can better secure an appropriation of the innovation outcomes. This is because a strong appropriability regime not only decreases fear about the imitative behaviours of external competitors (Teece, 2002) but also creates confidence in the possibility of building an external environment where firms can be assured to be rewarded for their innovative activities (Chesbrough, 2006). Accordingly, the tendency of search activities for external knowledge breadth increases with an increase in the firm's PACAP and is further increased by a strengthened appropriability regime. This result confirms the appropriability regime as one of the major factors that affect search activities for external knowledge sources depending on the level of a firm's PACAP.

Conclusions and Limitations

Extending the contextual theory related to PACAP and the contingency theory related to the appropriability regime during the external knowledge search activities, this study examines PACAP as a central determining factor of external knowledge search strategy (Zahra and George, 2002). Also, this study investigates the appropriability regime as an activation trigger during external knowledge search activities (Todorova and Durisin, 2007).

This study provides a number of theoretical and empirical implications for the research on external knowledge search strategy. First, prior studies have considered the role of PACAP in moderating innovative performance as a complementary factor (Cohen and Levinthal, 1990; Katila and Ahuja, 2002; Chesbrough *et al.*, 2006; Laursen and Salter, 2006; Escribano *et al.*, 2009) and in enhancing competitive advantage as a transformation factor (Zahra and George, 2002; Todorova and Durisin, 2007; Laursen and Salter, 2014). This study proposes that PACAP play an important role in external knowledge identification and acquisition from external actors for extending Zahra and George (2002) concept. Consistent with the above proposition, our results call for a contextual perspective of external knowledge search strategy in which the efficacy of PACAP should be considered with a careful reflection of not only on its potential gains but also of its pains.

Second, this study also extends the few empirical studies that investigated the moderation effect of the appropriability regime on the relationship between PACAP and external knowledge search strategy. Theoretically, Todorova and Durisin (2007) suggested that the appropriability regime acts as an activation trigger for external knowledge absorption. Recently, Laursen and Salter (2014)

empirically investigated the contextual model of the effect of firms' appropriability strategy on openness. However, they have not considered the appropriability regime of the industry, but the appropriability strategy of the firm as an endogenous factor (Laursen and Salter, 2014). To date, no previous empirical study has investigated how the strength of the appropriability regime moderates the relationship between PACAP and external knowledge search strategy at the firm level. This study demonstrates that as the strength of the appropriability regime increases, it acts as a contingency factor that leads to firms pursuing external knowledge search breadth.

The results of this study suggest the following managerial implications: First, contrary to prior literature about the moderation effects of absorptive capacity for innovative performance (Cohen and Levinthal, 1990; Katila and Ahuja, 2002; Chesbrough *et al.*, 2006; Laursen and Salter, 2006; Escribano *et al.*, 2009), our findings suggest that PACAP has a curvilinear effect on external knowledge search breadth. In this vein, managers should be cognisant of the potential disadvantages of PACAP, in particular, the costs of excessive levels of PACAP such as the trade-off to be made between cognitive distance and bounded rationality (Nooteboom *et al.*, 2007; Simon, 2008). Thus, for a successful external knowledge search strategy, managers should make a conscious choice to keep a rational level of PACAP without the associated potential problems.

Second, our findings suggest that when firms try to explore external knowledge sources, the appropriability regime is an important contingency factor that managers have to consider. Specifically, when engaging external knowledge search breadth, managers should carefully monitor the strength of the appropriability regime as an institutional systematic mechanism in terms of their industry context in order to make informed decisions concerning the levels of the firm's PACAP. Accordingly, when the strength of the appropriability regime increases from weak to strong, to facilitate external knowledge search breadth, managers need to be concerned with ensuring appropriate process-based reward systems and greater stimulation of risky and innovative behavior in new product and process development (Li *et al.*, 2010).

While providing insights into the effects of PACAP and the appropriability regime on firms' external knowledge search strategy, our study has several limitations. First, we use patent data to calculate the dependent and independent variables. While patents are generally regarded as a very objective measure, some knowledge of the firm may not be easily codified and not explicitly revealed in the form of patents. In other words, patents also only represent successfully "found" knowledge, which might hide some search activities of the firm which was either prematurely terminated or did not result in patentable innovations (Olsen *et al.*, 2017). Although the findings of this study make it clear that the characteristics of

the endogenous and exogenous factors related to the external knowledge search strategy do matter, we suggest that the data set of this study would be enriched if it could include nonpatented knowledge such as tacit knowledge. Several innovation outcomes might not be patented due to strategical considerations (Rosenberg, 1990) or because they were considered to have failed. Accordingly, we believe that future research can address this limitation by collecting data on R&D activities (external knowledge search strategy, PACAP, and appropriability regime) from other data sources such as surveys or in-depth interviews and use it to supplement the patent data. Second, we focus on the external knowledge search breadth, one of the external knowledge search strategies. However, in terms of exploitative knowledge search, external knowledge search depth also plays an important role in the organisational learning process (March, 1991). Specifically, PACAP serves as a knowledge platform using similar cognitive structure, common skills, and shared languages (Kim and Kogut, 1996; Lazaric *et al.*, 2008; Ferreras-Méndez *et al.*, 2015). This knowledge platform is useful for developing deep connections between external actors to transfer information and knowledge and increase external knowledge search depth (Laursen and Salter, 2006). Especially, when the knowledge of the donor firm is tacit, firms need to establish a deep connection with external actors to facilitate the knowledge transfer and the combination with the firm's prior knowledge base through an external knowledge search depth process (Chen *et al.*, 2011). Thus, future research should investigate the effects of endogenous and exogenous factors on the external knowledge search depth. Third, we examine the strength of the appropriability regime of the industry using patent claims in firms' patents. Specifically, we calculate the strength of appropriability regime as the average number of patent claims. However, the appropriability regime, in general, is composed of patent, trademark, and copyright protection (Amara *et al.*, 2008; Hurmelinna-Laukkanen *et al.*, 2008). Thus, future research should develop more inclusive measurements with respect to the appropriability regime.

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