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Summary

Patent strategy has become an essential part of technology development in R&D intensive industries. A patent portfolio can be built through an internal technology development as well as an external technology sourcing. We consider the context where acquisition and strategic alliance are used as mechanisms to obtain new technology sources beyond a firm's borders. We empirically explore how a firm's internal knowledge basis impacts its preferences in external technology sourcing. We consider proximity to science, degree of novelty and quality of patent portfolio as core aspects of internal technological knowledge. Our regression analyses provide evidence on the fact that a high degree of proximity to science of patent portfolio increases the likelihood to prefer acquisition over strategic alliance, but in a decreasing rate. However, a low degree of novelty patent portfolio has a partial impact on the likelihood to prefer acquisition over strategic alliance. Finally, we conclude that quality of patent portfolio increases the likelihood to prefer strategic alliance over acquisition, but in a decreasing rate. We tested our hypotheses on a panel dataset of European firms operating in the biopharmaceutical industry.

Keywords : Patent portfolio, internal technology sourcing, acquisition, strategic alliance, external technology sourcing

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INTERNAL TECHNOLOGICAL KNOWLEDGE AND THE CHOICE BETWEEN ACQUISITION AND ALLIANCE

Abstract.

Patent strategy has become an essential part of technology development in R&D intensive industries. A patent portfolio can be built through an internal technology development as well as an external technology sourcing. We consider the context where acquisition and strategic alliance are used as mechanisms to obtain new technology sources beyond a firm's borders. We empirically explore how a firm's internal knowledge basis impacts its preferences in external technology sourcing. We consider proximity to science, degree of novelty and quality of patent portfolio as core aspects of internal technological knowledge. Our regression analyses provide evidence on the fact that a high degree of proximity to science of patent portfolio increases the likelihood to prefer acquisition over strategic alliance, but in a decreasing rate. However, a low degree of novelty patent portfolio has a partial impact on the likelihood to prefer acquisition over strategic alliance. Finally, we conclude that quality of patent portfolio increases the likelihood to prefer strategic alliance over acquisition, but in a decreasing rate. We tested our hypotheses on a panel dataset of European firms operating in the biopharmaceutical industry.

Keywords: Patent portfolio, internal technology sourcing, acquisition, strategic alliance, external technology sourcing

INTRODUCTION

The mechanism behind the combination of internal technology development and the choice between different sources of external technology is still an open and interesting topic in the strategy literature. In this paper we focus on acquisition and strategic alliance as these mechanisms are traditionally used as modes of external technology sourcing by several scholars (Capron and Mitchell, 2013; van de Vrande et al., 2009; Vanhaverbeke, Duysters and Noorderhaven, 2002). However, we must note that other mechanisms, such as corporate venture capital or crowdsourcing, may also be used by firms.

Prior research suggested that firms can efficiently use their internal technological resources to develop, deploy and accumulate knowledge that might help them to produce new products and/or services (Katila and Ahuja, 2002; Eisenhardt and Martin, 2000). As development and the exploitation of technological resources are costly and risky due the uncertainty of technological environment, many scholars have investigated the need for firms to leverage these risks through an exposure to external sources of technology (Stuart and Podolny, 1996; Chesbrough, 2003; Laursen and Salter, 2006; Arora and Ceccagnoli, 2006). As such, they can get access to new technological ideas and maintain continuous search and selection processes to upgrade their existing technological knowledge (Rosenkopf and Nerkar, 2001; Capron and Mitchell, 2009). However, the lack of internal capacity to exploit or to integrate these new technological ideas represents an important issue when firms look for external technology outside their organizational boundaries (Cohen and Levinthal, 1990; Ranft and Lord, 2002). Indeed, this lack may lead to additional costs of integration and considerably reduce the potential net benefits of this access to external knowledge (Puranam and Srikanth, 2007).

In that context, attention has been put on the complementarity between internal technology development and external technology sourcing (Arora and Gambardella, 1990; Cassiman and Veugelers, 2006; Hagedoorn and Wang, 2012). However, prior research investigating this link largely focused on one source of external technology at a time, whether it is acquisition (Cassiman and Veugelers, 2006; Higgins and Rodriguez, 2006; Makri, Hitt and Lane, 2010), strategic alliance (Veugelers, 1997; Colombo, Grilli and Piva, 2006; Hoang and Rothaermel, 2010), or Corporate venture capital (Dushnitsky and Lenox, 2005; van de Vrande, Vanhaverbeke and Duysters, 2009; Benson and Ziedonis, 2009). Indeed, these mechanisms are often studied in the literature as compensating failures of each other (Yin and Shanley, 2008). Recent literature called for more comparative studies between these mechanisms (Wang and Zajac, 2007). Moreover, these studies mainly focused on R&D expenditures as an internal source of technology, rather than the inventions that these R&D expenditures are supposed to lead to and the associated intellectual property rights (i.e. patents). Yet, Hall and Ziedonis (2001) found that the propensity of patenting has risen dramatically since the mid-1980s. Developing strong patent portfolio strategies is a crucial challenge on which practitioners and also academics are giving more attention (Blind, Cremers and Mueller, 2009; Somaya, 2012; Reitzig and Puranam, 2009; Ziedonis, 2004). For instance, Scott Frank, president and CEO of AT&T Intellectual Property stated recently that “Technology is evolving faster than ever and there is more invention and patenting than ever before. Companies are becoming increasingly sophisticated in their IP[1] strategies. IP management is going to become more and more important in our society.”[2] Despite the important contributions highlighted by prior scholars, little has been done on the effect of patent portfolio strategy on the choice between different sources of external technology.

In this study, our research question is: how do firms choose between acquisition *versus* strategic alliance depending on the characteristics of their internal patent portfolio? Answering this question is important because the focal firms will have to reassess and recombine their technological knowledge base with regard to the technology obtained from outside (Kaul, 2012; Karim and Mitchell, 2004; Lavie, 2006). Because the issue we attempt to tackle here involves dynamic processes in an uncertain environment, we draw upon a dynamic capabilities perspective. In addition, this perspective has largely been used, since the seminal work of Teece, Pisano and Shuen (1997), to support influencing research on whether firms can respond to the context of technological environment changes that they have to cope with (Agarwal and Helfat, 2009; Anand, Oriani and Vassolo, 2010).

Here, we suggest that the characteristics of the patent portfolio will strongly influence the choice between acquisition versus strategic alliance as external sources of technology. We refer to the characteristics of the patent portfolio as its proximity to scientific research, its novelty and its quality, following prior research on patents (Blind et al., 2009; Reitzig, 2004; Blind, Edler, Frietsch and Schmoch, 2006). Particularly, we argue that the decision to choose acquisition over strategic alliance as external sources of technology is strongly influenced by the proximity to science and the novelty of the patent portfolio, but not in the same proportion. In contrast, we argue that the quality of the patent portfolio will be more likely to lead to the choice of strategic alliance over acquisition.

1 Here IP refers to intellectual property
2 http://deloitte.wsj.com/riskandcompliance/2014/09/19/patent-reform-and-the-new-era-of-ip-weekend-reading/

We based our empirical analysis on a unique panel database of 304 European firms (2293 year-observations) operating in the biopharmaceutical industry between 2000 and 2011. This database includes 500 transactions made by 188 European firms. To avoid selection bias we have also included firms that have not made any transactions during the given period but that have strong R&D expenditures and patent portfolio.

First, unlike prior research studying the impact of internal technology development on external technology sourcing, we extend prior research by making a comparative study of the most used sources (i.e. acquisition *versus* strategic alliance) as suggested by recent scholars (Villalonga and McGahan, 2005; Stettner and Lavie, 2014). Second, we provide empirical evidence that internal technological resources might not be taken as a whole or as adjustment variables in a firm's corporate strategy. Rather, their heterogeneity and their dynamic role should be taken into account in firms' corporate decision making (Wang and Zajac, 2007). Finally, this study highlights that internal technology capabilities can also play a signalling role in direction of other stakeholders, and strengthen a firm's credibility.

BACKGROUND AND HYPOTHESES DEVELOPMENT

The benefits of relying on external sources of technology are becoming well recognized and accepted by practitioners, especially in the biopharmaceutical industry. For instance, Sean E. Harper, M.D., executive vice president of Research and Development at Amgen, reacting to the announcement of a new partnership in the biopharmaceutical industry between Merck and Amgen[3], said, "We are pleased to enter these collaborations with Merck that build upon our growing cancer immunotherapy portfolio." He also said, "We look forward to learning more about potential new combination treatment options for BLINCYTO and AMG 820 in disease areas where there remains a high unmet need." Adopting this behavior, companies recognize that they need to continue to upgrade their own technology (Nelson and Winter, 1982; Chang, 1996).

Recent studies have shown that companies should rely on both modes of technology sourcing to build new technological capabilities or reconfigure existing ones, and hence boost their innovation performance (Cockburn and Henderson, 1998; Karim and Mitchell, 2004; Anand et al, 2010). Doing this should help them to maintain their competitive advantage over time (Agarwal and Helfat, 2009). Indeed, companies relying on both internal technology development as well as external technology sourcing may experience potential synergies between different knowledge sources (Piscitello, 2004). Addressing the benefits in the case of technology acquisition, Capron and Mitchell (2009) have shown that companies could acquire technology from outside to fill gaps in their existing internal technological resources. Companies can benefit from the information on the technology of their targets in the due-diligence process pre-acquisition and also increase their own portfolio of technological knowledge post-acquisition (Higgins and Rodriguez, 2006; Ahuja and Katila, 2001; Capron and Shen, 2007). As shown by Cassiman and Veugelers (2006), firms may complement their internal R&D with external knowledge acquisition, but this complementarity is sensitive to contextual variables such as information from universities. In the case of strategic alliance, technology similarity and complementarity in the knowledge base of potential partners may increase their ability to learn from each other and increase their innovation output (Lane and Lubatkin, 1998, Simonin, 1999; Rothaermel and Alexandre, 2009; Rothaermel and Hess, 2007). In addition, internal know-how helps to screen possible projects outside

[3] http://investors.amgen.com/phoenix.zhtml?c=61656&p=irol-newsArticle_Print&ID=2120224

(Arora and Gambardella, 1994) whereas strategic alliance stimulates R&D expenditures within the firms (Veugelers, 1997).

Overall, looking outside their boundaries, firms can cope with their fast changing environment, but also anticipate future technological changes, which is a challenge addressed in the dynamic capabilities perspective (Teece et al., 1997; Teece, 2007; Helfat, Finkelstein, Mitchell, Peteraf, Singh, Teece and Winter, 2009). It implicitly means that firms can be able to screen their environment (i.e. competitors or other stakeholders), and constantly assess the trajectory of their innovative activities (Zhou and Wu, 2010; Hall and Ziedonis, 2001). As such, they can also overcome the potential organizational and cognitive inertia which is inherent to internal technology development in the context of disruptive technology (Kapoor and Klueter, 2015). However, the mechanism behind the interaction between internal development of technology and external technology sourcing is still an open and interesting topic in the strategy and innovation field. Particularly, we know less about the choice between the different modes of external technology sourcing. In addition, literature has long focused on R&D to measure internal technology development. Yet, the inventions stemming from R&D should be protected by intellectual property rights (i.e. patents). These intellectual property rights (IPR) provide a temporary technological lead which provides a certain competitive advantage (Arora, Fosfuri and Gambardella, 2001; Somaya, 2012). Firms can also obtain royalties from the licensing of their patents to other firms (Arora and Ceccagnoli, 2006; Blind et al., 2006; Arora and Gambardella, 2010). Rivette and Kline (2000) highlighted that the annual patent-licensing royalties received by IBM have increased from $30 million in 1990 to nearly $1 billion in 2000 because of their aggressive patent effort. Patents may also help firms prevent the risk of infringement suits (Somaya, 2003). A valuable patent portfolio may also provide to the owner with a bargaining power during negotiations for partnership or merger with other companies (Hall and Ziedonis, 2001; Agarwal, Ganco and Ziedonis, 2009). The strategic use of patents becomes more and more important for firms and they start to take into account IPR strategies in their search for external technology.

Proximity to science of patent portfolio and choice of governance mode

Companies operate in an uncertain environment and face numerous and rapid changes. These changes can be significant challenges that firms will have to manage and require good adaptability (Kapoor and Lee, 2013). Although the ability to adapt to changes is clearly an advantage for any firms (Teece and Pisano, 1994; Hill and Rothaermel, 2003) a proactive behavior of firms may help them to anticipate future changes including technological changes. Dynamic capability perspective suggests that firms should develop capabilities to sense future promising technological knowledge (Teece, 2007, Helfat et al., 2007).

The literature in innovation considers the proximity to science as an important way to sense promising technological evolution (Fleming and Sorenson 2004; Tijssen, 2001; Cassiman, Veugelers and Zuniga, 2008), as well as a way of detecting potential technological knowledge recombination. We refer here to proximity to science as closeness of patents' claims to scientific, engineering or technical publications (Tijssen, 2004; Reitzig, 2004). In the European Patent Office (EPO) patent examination process, scientific publications (i.e. Non-Patent literature) are categorized depending on their relevance. The "X-type"[4] documents are the more relevant ones (Harhoff and wagner, 2009; Haeusseler, Harhoff and Mueller,

[4] (see EPO Guidelines for Examination, Part B, Chapter X, Section 9.2.1, available at http://www.epo.org/law-practice/legaltexts/html/guidelines/e/b_x_9_2_1.htm, latest access on 30th of December 2013).

2014). The more references to this type of publication there are in the patent examination process, the higher the proximity to science (Meyer, 2000; Reitzig, 2004).
Proximity to science is also considered as an important source of information on technology (Agrawal and Henderson, 2002). Fleming and Sorenson (2004) showed that proximity to science helps to optimize the search process for optimal combinations of components, which in turn increases the opportunity to find out new potential inventions (Laursen, 2012; Maggitti, Smith and Katila, 2013). They describe it as a 'map' for future technology, which should improve firms' abilities to learn from this technology path (Narin et al., 1997). As Such, proximity to science may help firms to avoid wasting time on less promising technologies while focusing on more valuable ones (Fleming and Sorenson, 2004; Cassiman et al., 2008). Hence, firms are able to get first-mover advantage and develop pioneered inventions (Nagoaka, 2007). These pioneered inventions constitute core assets that Teece (1986) refers to as technological knowledge or skills fundamentally required for product or service creation (Anand et al., 2010).

Yet, despite this first-mover advantage, firms need to continuously update their inventions by an openness to external sources of technology, especially in their rapid changing environment, in order to maintain a sustainable competitive advantage (Rosenkopf and Nerkar, 2001). However, achieving this objective comes with the threat of being imitated. In the context of high-technology industry and particularly in the biopharmaceutical industry where intangible assets lie at the heart of the firm core values, obtaining external technology while limiting risks of being copied by competitors remains an important challenge (Laursen and Salter, 2014; Ceccagnoli, 2009). Therefore, the choice of the right external technology source to best fit the objectives previously mentioned is crucial as asset ownership is an advantage that firms need to maintain and control, especially intangible assets (Kogut and Zander 1992). Acquisition fit best with the requirement to keep control of assets. Moreover, it is often argued that reluctance to share control is a key motivation for preference for acquisition over strategic alliance (Capron and Mitchell, 2013). In the opposite situation strategic alliance requires that partners share at least part of their valuable internal technology and part of their control (Laursen and Salter, 2006; Stuart, 2000). This situation may be detrimental, especially when core assets are involved.

We, thus, suggest that a higher proximity to science of a firm's patent portfolio will positively impact their attractiveness for acquisition, whereas it will negatively impact their attractiveness for strategic alliance. Moreover, we suggest that firm will prefer acquisition over strategic alliance as external sources of technology.

Yet, we must note that the issue of integration post-acquisition, which has largely been discussed in the literature of strategic management (Birkinshaw, Bresman and Håkanson, 2000; King, Dalton, Daily and Covin, 2004; Puranam, Singh and Chaudhuri, 2009), remains a major concern. The target acquired becomes part of the focal company and its technological knowledge will be redeployed into a new organizational settings owned by this focal firm (Capron, Dussauge and Mitchell, 1998; Capron and Pistre, 2002). In addition, the acquiring firm will also have to reconfigure its own technological knowledge. For instance, when Novartis completed the acquisition of GSK's oncology portfolio, the objective was not only to strengthen its substantial oncology portfolio, but also to combine some of GSK's targeted-drugs with their own existing targeted disease. One example of drugs acquired and implying a recombination is GSK's Ofatumumab[5]. This drug works as a cancer drug, it has already passed Phase II trial as a potential treatment for people with relapsing remitting multiple sclerosis, a disease

[5] https://www.novartis.com/news/media-releases/novartis-acquires-all-remaining-rights-gsks-ofatumumab-develop-treatments-ms-and

affecting more than 2.3 million people worldwide. But reconfiguring the technology obtained with the existing knowledge base is costly (Karim and Kaul, 2014; Capron and Mitchell, 2009).
Hence, we suggest that the benefits gained through acquisition will diminish beyond a certain point. At the same time, the potential opportunistic behavior that can stem from partners in strategic alliance is also costly because it involves a monitoring and a coordination of the partnership (Lumineau and Oxley, 2012), especially when it concerns intangible assets. Therefore, we suggest that the negative attractiveness for strategic alliance will continue in an increasing rate. Based on the following arguments, we hypothesize:

> *Hypothesis 1a. Focal firms' attractiveness for acquisition opportunities will be positively related to the proximity to science of their patent portfolio, but in a decreasing rate.*
>
> *Hypothesis 1b. Focal firms' attractiveness for alliance opportunities will be negatively related to the proximity to science of their patent portfolio, and in an increasing rate.*
>
> *Hypothesis 1c. Focal firms' preference for acquisition over alliance will be positively related to the proximity to science of their patent portfolio, but in a decreasing rate.*

Degree of novelty of patent portfolio and choice of governance mode

Once a technology opportunity has been assessed and an invention developed around this opportunity, one appropriability strategy consists of protecting this invention with a patent (Cohen, Nelson and Walsh, 2000; Somaya, 2003).

An invention cannot be legally examined in the patent search process if it does not make any references to prior patents, namely backward citations (Reitzig, 2004). The terms "novelty" or "non-obviousness" have often been used in the literature on innovation to describe technological distance between an invention to be patented and the prior art in its technology field (Reitzig, 2003; Greene and Scotchmer, 1995). From this point of view, the value of backward citations is rooted in the fact that their primary role is to give legal access to the patent examination process.

However, even if a direct link of backward citations on the value of the patent itself is not completely clear, one can argue that these citations could impact how competitors or external investors perceive the value of the technological knowledge possessed by the focal firm in its technology field (Reitzig, 2004). In the European patent search process, prior patents to be cited as prior art are classified depending on their relevance in their technology field. The most relevant ones are prior patents classified as "X-type" category (Harhoff and wagner, 2009; Haeusseler et al., 2014). Citing "X-type" patents in the search process means that the claims referring to these patents cannot be considered as novel (Criscuolo and Verspagen, 2008).

Therefore, a firm owning a patent with a high number of "X-type" backward citations during the patent search process have a low degree of novelty (Reitzig, 2004). This firm is more likely to be perceived as a firm with less valuable and highly uncertain technological knowledge (Haeusseler et al., 2014). Because these firms lack valuable technological knowledge, they will need to obtain this lacking knowledge from external sources (Capron and Mitchell, 2009).

Obtaining valuable technology through strategic alliance may be hard, because the primary goal of strategic alliance is to give opportunity to partners to share complementary and value-added knowledge (Gulati, 1999; Ahuja, 2000, Phelps, 2010). On the contrary, obtaining valuable technology through acquisition gives a higher chance to the focal firm to obtain the lacked technology. The key objective of technology acquisition is the access to unavailable internal technological knowledge (Capron and Mitchell, 2013), even if they have to take into account the issue of the efficient integration post-acquisition (Puranam et al., 2009). For instance, they can make sure to keep the inventors of the previously mentioned valuable knowledge in the new organizational settings (Ganco, Ziedonis and Agarwal, 2015). Thus, we suggest the following hypotheses:

Hypothesis 2a. Focal firms' attractiveness for acquisition opportunities will be positively related to the low degree of novelty of their patent portfolio, and in an increasing rate.

Hypothesis 2b. Focal firms' attractiveness for alliance opportunities will be negatively related to the low degree of novelty of their patent portfolio, and in an increasing rate.

Hypothesis 2c. Focal firms' preference for acquisition over alliance will be positively related to the low degree of novelty of their patent portfolio, and in an increasing rate.

Quality of patent portfolio and choice of governance mode

Innovation is a process going from the invention of a product or service to its diffusion on the market (Hagedoorn and Cloodt, 2003). Although the proximity to science and the degree of novelty of an invention contribute to an assessment of the opportunities for future technologies, innovation is the step that enables firms to gain real benefits from their invention (Nadiri, 1993). Literature on innovation has often used the quality of a patent as an indicator of innovation performance (Hall, Jaffe and Trajtenberg, 2001, 2005; Gomes-Casseres, Hagedoorn, and Jaffe, 2006). Many research articles measure the quality of a focal patent by the number of citations, namely forward citations that it receives from other patents in the same technology field during their examination process (Ahuja and Katila, 2001; Trajtenberg 1990; Hall et al.2001). Even if the relevance of forward citations as an indicator of the economic value of a focal patent has long been debated in this literature producing mixed conclusion (Alcacer and Gittelman, 2006; Criscuolo and Verspagen, 2008), these citations may be considered at least as a signal of the presence of valuable technological knowledge (Haeusseler et al., 2014). In addition, theses citations may also represent a signal of less uncertainty about the value of the knowledge developed within the focal firm (Stuart, 2000). When a firm possesses valuable technological knowledge, there may be two ways to manage it.

On one hand, the company may want to continue improving its knowledge and then search for complementary knowledge from external sources (Eisenhardt and Schoonhoven, 1996). As suggested by Chang (1996), continuous search and selection processes to upgrade knowledge are critical for the survival of the firm. In this situation, the company will be more likely to assess a strategic alliance opportunity to obtain this complementary knowledge. As previously mentioned, engaging in strategic alliance implies sharing valuable knowledge and reducing costs (Gulati, 1999; Stuart, 2000). However, the company cannot be completely sure that the potential partner will share valuable complementary knowledge or reduce costs because strategic alliance also requires coordination and monitoring (Lumineau and Malhotra, 2011; Gulati et al., 2012). In addition, sharing technological knowledge through strategic alliance could be an opportunity to diffuse this knowledge to other firms operating in the same technology field, whether they are competitors or not, with the objective to benefit from what other companies have learned from this knowledge. For instance, Yang, Phelps and Steensman (2010) have shown that the originating company also benefits from the spillovers generated by the diffusion of its knowledge. Indeed, based on a study of firms operating in the telecommunications sector, they have shown that the adoption and recombination made by the recipient firms generate new spillovers that the originating company can capture because this company better knows the originating knowledge. Yet, knowledge spillovers are difficult to evaluate (Henderson and Cockburn, 1996). This difficulty can induce an uncertainty on the assessment of the net benefit of the originating diffusion. We suggest a positive impact of a patent portfolio with a high level of quality on the assessment of strategic alliance opportunities, but in a decreasing rate due to the aforementioned uncertainty.

On the other hand, the company can consider that internal knowledge is sufficiently valuable and may try to obtain other promising technology that is different and not available internally (Leiponen and Helfat, 2010). In this situation, the company will be more likely to make an acquisition. Acquiring this technological knowledge from external sources should induce an increase of the company's technological knowledge base (Ahuja and Katila, 2001), but raises two issues. The first issue is the efficient evaluation of the new technology to be reached, given the potential asymmetry of information (Ranft and Lord, 2002). Even if the firm already possesses a valuable knowledge base and capabilities to manage its internal technology, it is not necessarily able to master this unknown technology. Therefore, this evaluation should be hard to make. The second issue is about the integration of the new unrelated technology in the company's existing knowledge base. This integration may take a long time since the firm does not have the required knowledge and is not sure to be able to hire the needed human resources (Puranam and Srikanth, 2007). Moreover, several research articles have investigated unrelated acquisition and have shown that it is more likely to lead to failure post-acquisition (Datta and Grant, 1990; Vanhaverbeke and Duysters, 2002). In both cases, assessing external technology opportunities is clearly a great challenge. However, because the company already possesses a valuable technological knowledge base, we suggest that the risk related to assessment of strategic alliance opportunity in order to obtain complementary knowledge is lower than the risk related to the acquisition of unrelated technological knowledge. Thus we posit:

Hypothesis 3a. Focal firms' attractiveness for acquisition opportunities will be negatively related to the quality of their patent portfolio, and in an increasing rate.

Hypothesis 3b. Focal firms' attractiveness for alliance opportunities will be positively related to the quality of their patent portfolio, but in a decreasing rate.

Hypothesis 3c. Focal firms' preference for alliance over acquisition will be positively related to the quality of their patent portfolio, but in a decreasing rate.

METHODS

Data and Sample

We based our empirical analysis on a unique panel database of 304 European firms (2293 year-observations) operating in the biopharmaceutical industry between 2000 and 2011. This database includes 500 transactions made by 188 European firms. To avoid selection bias we have also included firms that have not made any transactions during the given period but that have strong R&D expenditures and patent portfolio. Among these transactions, 70% were acquisitions. The descriptive statistics are presented in the Results section.

The research setting for this study was the biopharmaceutical industry. This study used the USSIC code USSIC283 to identify the firms in this industry. We selected this industry for three reasons. First, the industry is ranked as number one in terms of R&D expenditures according to the European scoreboard[6], with a one-year growth rate of 14.4 % between the top 15 sectors, which account for 92.1% of the total R&D investment. Second, this industry is traditionally highly involved in intensive research and development and is strongly dependent on production innovation (Nicholls-Nixon and Woo, 2003), but is also characterized by technological discontinuities, resulting in a growing and systematic use of patents to protect inventions (Cockburn and MacGarvie, 2011). These technological discontinuities increase the risk of in-house technology development leading firms to source part of their technological knowledge outside their boundaries (Laursen and Salter, 2006). Third, the industry also faces a high failure rate of drug development and blockbuster patent expiration (Yu, Umashankar and Rao, 2015) as well as generics firms' competition. Finally, the aforementioned reasons added to the need for European governments to reduce healthcare subsidies have lead the biopharmaceutical industry to review its technology development in light of these changes.

The sample is based on a unique dataset drawn upon four sources of data, the OECD patent citation database[7] for the patents, SDC platinum database and Bureau Van Dijk's Zephyr database for acquisition and strategic alliance, and Compustat for financial statements. We selected this sample using the following process.

First, we used patent data from the citation database of OECD that derives from the patent database of the European Patent Office (EPO). Because firms often file patents in their country of origin, we focused on European pharmaceutical firms. Numerous studies have compared patent systems in Europe and in the US and have highlighted several differences (Graham and Harhoff, 2014; Graham et al., 2002; Van Pottelsberghe de la Potterie, 2011). Among these differences, Haeussler, Harhoff and Mueller (2014) reported that the cost of the patent protection search process is higher *via* EPO than USPTO. Moreover, this process involves a strong *ex-ante* commitment due to the limited possibility of filing continuations. There is also limited possibility to easily amend the patent once the process is started. Another important aspect is that the authority conferred to the examiners is greater in the EPO than in the USPTO, which makes EPO search process seem more rigorous (Useche, 2014). Furthermore, patents that can be cited during the search process are classified depending on their relevance as explained in the section Degree of novelty of patent portfolio.

Second, we limited the sample to the period 2000 to 2011.

Third, we limited the sample to public companies in order to ensure availability and reliability of financial data. We obtained these financial data from Compustat.

Fourth, we focused on strategic alliance and acquisition as alternative governance modes to source technological knowledge externally. Therefore, we selected in our sample of European firms in the biopharmaceutical industry those that have made at least one deal of technological acquisition or

[6] The 2015 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG Research & Innovation).
[7] OECD Citations database, September 2013

strategic alliance. An acquisition or a strategic alliance was included in the sample if the deal rationale explicitly mentions that the objective was technological knowledge sourcing. Moreover, all the sampled acquisitions involve the acquirer taking a controlling interest in the target (i.e., greater than 50%), and 90% of these transactions are full acquisitions (Reuer and Ragozzino, 2012; Bena and Li, 2014). We also manually searched on different additional databases such as Lexis-Nexis and Factiva to be sure that we did not omit deals that were not included in the two previous databases. Moreover we rely on the website of "Businessweek" maintained by Bloomberg to find additional information.
Finally, in order to avoid sample bias, we included in the global sample firms that did not make any deals. However, these firms should have done in-house R&D at least one-year as the biopharmaceutical industry is generally considered as an R&D intensive industry.

Dependent variables

Acquisition attractiveness. This dependent variable is the cumulative number of acquisitions made by a given firm *j* in a year *t*. We use this variable to measure the attractiveness of acquisition opportunities. The variable used in the empirical regressions is transformed as $\ln(1+NBRACQ_{i,t})$

Alliance attractiveness. This dependent variable is the cumulative number of strategic alliances made by a given firm *j* in a year *t*. We use this variable to measure the assessment of alliance opportunities. The variable used in the empirical regressions is transformed as $\ln(1+NBRALL_{i,t})$. To measure the preference for acquisition over strategic alliance and vice versa we tested these hypotheses Hypothesis 1c, Hypothesis 2c and Hypothesis 3c using differences in the variables coefficients across the acquisition and alliance equations at the same time.

Independent variables

Proximity to science. Several studies have used citations of non-patent literature to measure the proximity of a given patent with science (Fleming and Sorenson, 2004; Cassiman et al., 2008; Arundel and Geuna, 2004). We followed these studies and used the same indicator. Firms usually protect inventions through the patent authority of their country of origin as this country generally represents their primary market. A patent is valid only in the country or the region in which it has been granted (Harhoff and Reitzig, 2004). We measured the proximity to science *(PROXISCI)* as the number of citations of non-patent literature from the "X-type" category that is made by a focal firm *j* at the EPO for a focal patent *i* in a year *t-1*.
Degree of patent novelty. We used backward citations to measure the degree of patent novelty *(DEGNOV)*. Backward citations have long been used in prior literature to measure the technological distance between an invention to be patented and the prior art (Reitzig 2004, Meyer, 2000). We focus here on prior patent classified in the "X-type" category, as we did for non-patent backward citations. A high number of citations of prior patents during the patent examination process should reveal a lower degree of patent novelty since the technical distance with prior patents becomes lower (Reitzig, 2003). We measured *DEGNOV* as the number of backward citations of patents from the "X-type" category, made by a focal firm *j* at the EPO for a focal patent *i* in a year *t-1.*

Patent Quality. In order to capture the quality of the patent (*PATQUAL*) we used the number of citations received by a focal patent *i* owned by a focal firm *j* since this patent filing, namely forward citations. We tested Hypothesis 3a, Hypothesis 3b and Hypothesis 3c using these forward citations following several prior studies (Trajtenberg, 1990; Harhoff, Scherer and Vopel, 2003). Prior patent literature debated the relevance of this proxy as an indicator of the economic value of patent quality (Alcacer and Gittelman,

2006; Czarnitzki et al. 2006).To the best of our knowledge, forward citations as signalling the presence of high technological value has not been contested. We suggest here that the patent quality can be considered at least as a signal showing other firms that the focal firm possesses good technological knowledge (Useche, 2014).
We must note that we have transformed here our explanatory variables using the natural logarithm. In addition, these variables are lagged one year.

Control variables

We incorporated a set of control variables.

Firm-level control variables. We used the financial performance of the firm. This performance confers to the focal firm a status and power of attracting potential partners for strategic alliance or targets to be acquired (Capron and Mitchell, 2009; Hagedoorn and Wang, 2012). Firms with a high level of performance may also possess idiosyncratic processes that enable them to better evaluate external technological knowledge (Steensma and Corley, 2000). We measured the financial performance using the return on asset (i.e. *ROA*) equal to net sales scaled by total assets. We also used the size of the firm, namely *SIZE*. Indeed, acquisition, as well as strategic alliance, requires that focal firms possess recombinant capabilities facilitating the absorption of external technological knowledge (Cohen and Levinthal, 1990). The size of the firm influences these capabilities (Carnabuci and Operti, 2013). The size also facilitates their ability to take advantage of external strategic options. For instance, larger firms are more likely to combine various technological knowledge sources than smaller ones (Beneito, 2006). We measured *SIZE* using the log-value of the total number of employees of a firm *j* in year *t-1* (Bertrand and Capron, 2014; Rothaermel and Hess, 2007). Finally, we followed Bena and Li (2014) and used the financial leverage of the firm that we refer to as the degree of financial flexibility of a given firm, and reflective of its relative power when needed to make transactions such as acquisition. We measured financial leverage*, namely RDEBT,* as the long-term debts in year *t-1* divided by shareholders equity in year *t-1.* We also used *RCASH* as a control variable. *RCASH* is measured here by cash and cash equivalents in year *t-1* divided by total assets in year *t-1*. Cash and cash equivalents is an item on the balance sheet referring to the firm's assets that can be converted into cash immediately.

Transaction-level control variables. For this purpose we used the experience of acquisition deals *(ACQEXP)* and the experience of strategic alliance deals *(ALLEXP)*. Focal firms that have significant experience in acquisition deals are more likely to develop capabilities facilitating the management of future acquisition deals (Reuer and Ragozzino, 2012; Villalonga and McGahan, 2005). Drawing data from our acquisition database and following several studies, we measured acquisition experience as the lagged-value of the cumulative number of acquisitions made prior to the focal year (Zollo and Reuer, 2010; Wang and Zajac, 2007). For similar reasons we incorporated *ALLEXP* as a control variable, because it can provide capabilities for managing future alliance collaborations and facilitate interfirm knowledge transfer (Phelps, 2010; Arikan and McGahan, 2010; Kale and Singh, 2007). This control variable is calculated counting the cumulative number of strategic alliances made prior to the focal year (i.e. year *t*).

Patent-level control variables. In order to count for impact of variables impacting patent value, we used the intensity of R&D (*RDINT*). We used *RDINT* to control the potential variance that can stem from the heterogeneity between the most R&D intensive firms and the lesser ones. Several studies considered that R&D intensity impacts the stock of patents granted by a firm (Wang and Hagedoorn, 2014). We measured *RDINT* as the total R&D expenditures of the focal firm *j* in the year *t-1* scaled by the total sales year *t-1*, and we took the log-value. We also used a dummy variable (*DPCT),* which is coded as "1" if the focal patent, has also been filed in the international patent examination process and "0" if it has not. We included this control variable because firms operating in the biopharmaceutical industry are by nature exposed to the global market, resulting in a need to protect inventions internationally as well as locally. *DPCT* equal "1" means that focal firms consider the need of property rights for their invention sufficiently important to accept paying additional costs to file patent internationally (Harhoff and Reitzig, 2004; Harhoff and Wagner, 2009). For the same reason we used another proxy for patents filed in the international search process (*PCT_XNPL).* This variable is measured by the number of citations of non-patent literature made by the focal firm when it files a patent in the international search process. There is not a specific authority dedicated to manage the international search process. Each firm expecting to protect inventions internationally has to choose one of the national authorities for their international search process (Webb, Dernis, Harhoff and Hoisl, 2005). Patent literature has shown that the EPO receives most of the applications for this international search process (Haeussler et al., 2014; Useche, 2014).

Fixed effect. We included year fixed effect. First, we used dummies for each year of the panel database with 2000 being the omitted year. Because we investigated an 11-year time period, we needed to control time varying factors that may influence the choice of governance modes (Rothaermel and Hess, 2007). For the same reason we included sub-sector fixed effect.

A table presenting a description of each variable used in our regression is in appendix.

Statistical approach

We tested our hypotheses using a seemingly unrelated regression model (SUR)[8] with robust standard errors. This model appears often in the literature, particularly when treating two dependent variables that have potential correlated error terms (Reuer, Tong, Tyler and Ariño, 2013; Duplat and Lumineau, 2015). We used this model for our analysis because we suspected a correlation between acquisition activities and those of strategic alliance. Several studies have shown that when companies engage in a strategic alliance, for example, they are more likely to acquire one of their former partners (Vanhaverbeke et al., 2002; Reuer and Ragozzino, 2012). Our SUR analyses revealed a significant correlation in the error terms across the acquisition and alliance equations (i.e., $r=0.1218$, $p<0.001$), and a Breusch-Pagan test rejected the null hypothesis that the two equations are independent (i.e., $\chi2=12.902$, $p<0.001$), suggesting SUR as the most interesting statistical model. The primary objective of this paper is to study the impact of internal technological capabilities on the choice between acquisition and strategic alliance. Therefore, analyzing this choice in this model required testing differences in the coefficents of independent variables across the acquisition and the alliance equation at the same time (Arceneaux and Nickerson, 2009).

RESULTS

Table 1 depicts the descriptive statistics and bivariate correlation matrix respectively. We note that acquisition represents 70 percent of the transactions of our sample, against 30 percent for strategic alliance. Our database includes five sub-sector of the USSIC code 283 going from 2833 to 2836. We note that the sub-sector "Pharmaceutical Preparations" (SIC2834) represents about 59 percent of the sample; the sub-sector "Biological Products, Except Diagnostic Substances" (SIC2836) represents about 30

[8] We used here the Stata command SUREG

percent of the sample; and the other sub-sector about 11 percent of the sample. These three sub-segments represent about ninety-three percent of the sample. In addition, we note that firms from the "Pharmaceutical Preparations" sub-sector have made the largest number of transactions (about 68% of acquisitions and 74% of strategic alliances). Both SIC2834 and SIC2836 have the highest number of Non-PL citations of "X-type" category (about 37% for SIC2834 and 50% for SIC2836) and forward citation (about 41% for SIC2834 and 48% for SIC2836). Moreover, table 2 shows that the acquirers' prior acquisition and alliance experiences are on average 2.6 and 0.92 years, respectively. The average number of backward citations of X-type patents is about 6.8 for Non-PL and 3.9 for PL, whereas this number is about 23.7 for forward citations. This latest average number of citations is calculated with non-transformed data and the highest standard deviation is relative to forward citations (e.g., 99). This table also showed that a two-by-two correlation coefficient between *PATQUAL* and *PROXISCI* is 0.82. To assess a potential threat of collinearity, we estimated the variance inflation factors (VIF) and found none greater than 5. Furthermore, the mean VIF was 3.03. Hence, these VIF values were below the recommended rule of thumb of 10 (Rothaermel and Alexandre, 2009).

Insert the Table 1

Table 2 presents the multivariate results from the SUR model (column 1 to 5) with the sample. Model 1 presents our baseline model and depicts the estimates for the control variables. Model 2, 3 and 4 augment the baseline model with each of the independent variables, whereas Model 5 depicts the full model. Table 3 reports the t-test depicting the difference in the impact of each of our independent variable on acquisition versus strategic alliance for each of our hypotheses (based on model 5). We will essentially rely on Model 5 to depict the results. Before reporting the results from hypotheses testing, we depict hereby some interesting and insightful results of the control variables. In table 2, Model 5 shows that cumulative experience in technological acquisition has a positive and significant ($p<0.01$) impact on acquisition attractiveness as well as on alliance attractiveness ($p<0.01$). We also found that cumulative experience in strategic alliance has a positive and significant ($p<0.01$) impact on the alliance attractiveness. However, the effect is negative and significant ($p<0.05$) for acquisition attractiveness. These results are consistent prior research, but partially inconsistent with recent articles showing that experiencing the same governance mode over a long time have little impact, and in the worst case will start to produce negative effect at a certain point on the propensity to use this mode in the future. Using another mode will have the opposite effect (Castañer, Mulotte, Garrette and Dussauge, 2014). Another interesting finding is that *SIZE* has a negative and significant ($p<0.1$) effect on either acquisition attractiveness ($p<0.1$) and at an increasing rate. We found the same result for the effect of *SIZE* on alliance attractiveness ($p<0.01$). However, the difference in covariate effect across the two equations is not statistically significant. This result shows that the size of the firm may influence acquisition or alliance attractiveness. However it has no impact on the preference for acquisition over strategic alliance (see table 3).

Depicting the results of the predictions of our hypotheses, we found that the proximity to science of patent portfolio has a positive and significant effect ($p<0.1$) on acquisition attractiveness but at a decreasing rate, which support Hypothesis 1a. On the contrary, the effect is negative for alliance attractiveness ($p<0.05$), meaning that Hypothesis 1b is also supported. Hypothesis 1c predicted a preference for acquisition rather than strategic alliance in the presence of high proximity to science of the patent portfolio, but at a decreasing rate. Results in table 2 shows that the variable *PROXISCI* has a positive and significant (χ^2 with p<0.01) difference in its impact across technological acquisition and strategic alliance equations, indicating that when their patent portfolio is closer to science, firms are more likely to prefer acquisition over strategic alliance as external source of technology. This result supports Hypothesis 1c.

Thus, Hypothesis 2a posits that low level of patent novelty will positively impact acquisition attractiveness at an increasing rate, whereas Hypothesis 2b posits that this impact will be negative for alliance attractiveness, also with an increasing rate. The results in table 2 show a positive though non-significant impact of a low degree of patent novelty on acquisition attractiveness and at an increasing rate. Hence, Hypothesis 2a is not supported. The results in table 2 also show a negative though non-significant impact of a low degree of patent novelty on the alliance attractiveness, which does not support Hypothesis 2b. In addition, Table 3 shows that *DEGNOV* has a positive though non-significant effect difference across acquisition and alliance equations, which does not support Hypothesis 2c. These are surprising, since several studies have shown that the novelty of patents may signal valuable knowledge. One could imagine a positive effect on the decision to acquire or make a strategic alliance to obtain external knowledge since novel patents may represent future promising invention (Reitzig, 2004).

Finally, Hypothesis 3a proposes that the quality of a patent portfolio negatively impacts acquisition attractiveness at increasing rate, whereas Hypothesis 3b posits that this impact will be positive for alliance attractiveness, but at a decreasing rate. The results in table 2 indicate a support for Hypothesis 3a but only partially. Although the covariate for *PATQUAL* is negative and significant (p<0.01), the square value of this variable is not significant, which means that the increasing rate predicted is not supported. In the case of Hypothesis 3b the results in table 2 confirm those predicted. *PATQUAL* has a positive and significant (p<0.001), but at a decreasing rate (p<0.001). Moreover, Hypothesis 3c, which predicted the firm preference for strategic alliance over acquisition in the presence of a high quality patent portfolio, is supported. The results in table 3 show a negative and significant difference in effect (χ^2 with p<0.001) across acquisition and alliance equations.

Insert the Table 2 and 3

DISCUSSION AND CONCLUSION

Innovation literature has long discussed the interplay between internal sources of technology development and external technology sourcing. Are these two ways of technology “grafting” substitute (Hagedoorn and Wang, 2012) or complementary (Cassiman and Veugelers, 2006, Colombo et al., 2006)?

This paper is built on the grounds of the research stream arguing for this complementarity and we addressed the question of how the internal patent portfolio of firms impacts their choice between technological acquisition and strategic alliance as sources of external technology. We hypothesized and found that focal firms having a patent portfolio with high degree of proximity to science are more likely to choose technological acquisition over strategic alliance as external mode of technology sourcing. However, although we hypothesized the same effect for patent portfolios with low degree of novelty, we found only a partial result. The effect on technological alliance attractiveness is confirmed but only for model 3 where we tested this variable alone with the control variables. In contrast, we hypothesized and found that focal firms having a patent portfolio with high degree of quality are more likely to choose strategic alliance over technological acquisition as external mode of technology sourcing.

Until now scholars have largely overlooked the importance of patent portfolios on the choice between different sources of external technology, focusing on one source at a time and on R&D as the main internal technology resource. However, as in our research context, firms may construct a different type of patent portfolio. The specific characteristic of this portfolio should, in turn, affect their choice of external technology sourcing. As such, this study offers rich contributions for strategic management research, especially for research focusing on the interplay between internal technology development and external technology sourcing, as well as practice.

First, we provide empirical evidence that firms should strongly assess the characteristics of their internal knowledge base, reflected here in the characteristics of their patent portfolio, before choosing their source of external technology. Although many scholars found that it is becoming more and more necessary for firms to be exposed to different sources of knowledge outside their boundaries (Chesbrough, 2003; van de Vrande, 2013), these scholars also recognized that the risks related to this openness are not negligible (Laursen and Salter, 2014). Our findings show that this paradox of openness can be overcome through a thorough assessment of the interaction between the internal technological knowledge base and the choice between different sources of external technology comparatively. However, our study is based on the biopharmaceutical industry and focuses exclusively on acquisition and strategic alliance. We choose to focus on one industry to ensure a homogeneous measure of internal technological knowledge. However, this choice is idiosyncratic and poses limits to the generalizability of the results. Future research can address this limit by extending our analysis to other high-tech industries strongly involved in patent filing, such as the software industry. In addition, we do not analyze the implication of our results on the subsequent performance of the focal firm. Recent studies have started to investigate this issue (Sttetner and Lavie, 2014; van de Vrande, 2013). However, the study of van de Vrande (2013), for example, investigated the choice between external technology sources as moderating the U-shaped relationship between technology proximity and innovation performance. Investigating the direct effect of this choice on the innovation performance post-transaction deserves more attention and could be an insightful avenue for future research.

Second, the mixed results regarding the effect of proximity to science and novelty of a patent portfolio on the one side, and the quality of patents on the other, suggest that internal technological resources might not be taken as a whole or as adjustment variables in a firm's corporate strategy. Rather, their heterogeneity and their dynamic role need be taken into account when investigating strategic choices that a firm has to make, and particularly the choices that involve long-term commitment as acquisition and strategic alliance do (Wang and Zajac, 2007). Although the findings highlighted in this study are strong, characteristics of the patent portfolio are not the only factor affecting the choice between acquisition and strategic alliance. Other factors such as resource gap and need for broad and deep relationships with the resource provider (Capron and Mitchell, 2013; Kaul, 2012), environmental uncertainty (van de Vrande et al., 2009), network characteristics (Vanhaverbeke et al., 2002) or being backed by venture capital companies and investment banks (Reuer and Ragozzino, 2012), could explain this choice. Therefore, future research can investigate how the interaction of the aforementioned factors with patent portfolios could alter the direct links that we have investigated in this study.

Third, this study highlights that internal technology capabilities can also play a signalling role in direction of other stakeholders and strengthen a firm's credibility. For example, the quality of patents stimulated interesting debates in the literature on innovation about its role as knowledge spillover indicator (Czarnitzki et al. 2006; Hall et al. 2005; Alcacer and Gittelman, 2006). We show here that beyond this debate, the quality of patents can be strategically used at least as a signal of less uncertainty of firms' knowledge base to potential partners, investors or financial analysts for instance. This may help build trust on an equally profitable knowledge transfer between partners (Stuart, 2000). Quality of patents can also be considered as an additional virtue in the technology path of the firm and an important signal to influence the path of technology within an industry. Future research can investigate other factors used by firms to influence the path of technology in their industry.

Finally, our study has implications for practitioners. Knowledge can involve very complex combinations of technologies (Fleming and Sorenson, 2004). Hence, by a better understanding of their patent portfolios, managers could precisely map the landscape of known technologies available within the company and better sense and assess the most promising ones outside the company. This also means that they will have to decide how to reconfigure their resource allocation to favour combinations with the technology obtained from outside in order to increase innovation performance.

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Table 1: Descriptive statistic and correlation matrix

Variables	Mean	S.D.	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 Ln (1+ NBRACQ)	0.09	0.27	0	1.95	1.00														
2 Ln (1+ NBRALL)	0.04	0.19	0	2.30	0.28	1.00													
3 PROXISCI	0.82	1.24	0	5.58	0.20	0.26	1.00												
4 DEGNOV	0.48	1.02	0	5.72	0.24	0.32	0.73	1.00											
5 PATQUAL	1.28	1.64	0	7.34	0.19	0.21	0.82	0.67	1.00										
6 ACQEXP	2.6	1.87	0	21.00	0.42	0.42	0.28	0.37	0.24	1.00									
7 ALLEXP	0.95	1.26	0	14.00	0.19	0.35	0.38	0.45	0.33	0.53	1.00								
8 RDINT	23.62	243.95	0	6099.00	-0.03	-0.02	-0.02	-0.04	-0.03	-0.04	-0.02	1.00							
9 SIZE	5.55	2.36	0	11.69	0.32	0.32	0.53	0.56	0.55	0.47	0.45	-0.11	1.00						
10 SIZE_SQR	36.33	30.63	0	136.67	0.34	0.38	0.59	0.64	0.60	0.51	0.53	-0.10	0.97	1.00					
11 ROA	0.44	0.51	0	10.51	0.09	0.02	-0.01	0.07	-0.01	0.11	0.03	-0.08	0.38	0.35	1.00				
12 RDEBT	0.42	6.25	-28.17	226.64	-0.01	0.00	0.02	0.03	0.02	0.03	0.03	-0.01	0.02	0.01	0.00	1.00			
13 RCASH	0.49	2.64	-19.56	63.95	0.01	-0.02	0.00	0.00	0.03	0.00	0.03	0.02	-0.02	-0.03	-0.05	0.07	1.00		
14 DPCT	0.46	0.5	0	1.00	0.07	0.12	0.49	0.38	0.56	0.11	0.16	0.04	0.26	0.27	-0.09	0.03	0.05	1.00	
15 PCT_XNPL	5.45	19.46	0	245.00	0.22	0.24	0.66	0.63	0.63	0.30	0.34	-0.02	0.53	0.62	0.09	-0.01	-0.02	0.30	1.00

Table 2: Results of seemingly unrelated regression [a]

Variables	Model 1				Model 2				Model 3				Model 4				Model 5			
	Acquisition attractiveness		Alliance attractiveness		Acquisition attractiveness		Alliance attractiveness		Acquisition attractiveness		Alliance attractiveness		Acquisition attractiveness		Alliance attractiveness		Acquisition attractiveness		Alliance attractiveness	
PROXISCI					0.013	(0.026)	-0.027	(0.018)									0.055*	(0.032)	-0.045**	(0.021)
PROXISCISQR					-0.003	(0.008)	0.014***	(0.006)									-0.016*	(0.010)	0.019***	(0.007)
DEGNOV									-0.010	(0.025)	0.005	(0.017)					-0.011	(0.027)	0.004	(0.018)
DEGNOVSQR									0.005	(0.007)	0.007	(0.005)					0.005	(0.008)	0.006	(0.005)
PATQUAL													-0.041*	(0.021)	0.027*	(0.015)	-0.061**	(0.025)	0.044***	(0.017)
PATQUALSQR													0.011**	(0.005)	-0.005	(0.003)	0.015***	(0.006)	-0.013***	(0.004)
ACQEXP	0.045***	(0.006)	0.024***	(0.004)	0.045***	(0.006)	0.024***	(0.004)	0.045***	(0.006)	0.025***	(0.004)	0.046***	(0.006)	0.023***	(0.004)	0.047***	(0.006)	0.023***	(0.004)
ALLEXP	-0.036***	(0.010)	0.024***	(0.007)	-0.036***	(0.010)	0.022***	(0.007)	-0.039***	(0.011)	0.017**	(0.007)	-0.036***	(0.010)	0.024***	(0.007)	-0.038***	(0.011)	0.016**	(0.007)
RDINT	0.000	(0.000)	-0.000	(0.000)	0.000	(0.000)	-0.000	(0.000)	0.000	(0.000)	-0.000	(0.000)	0.000	(0.000)	-0.000	(0.000)	0.000	(0.000)	-0.000	(0.000)
SIZE	-0.064***	(0.024)	-0.074***	(0.016)	-0.066***	(0.025)	-0.059***	(0.017)	-0.061**	(0.024)	-0.067***	(0.016)	-0.042	(0.026)	-0.084***	(0.018)	-0.046*	(0.026)	-0.075***	(0.018)
SIZE_SQR	0.007***	(0.002)	0.008***	(0.001)	0.008***	(0.002)	0.006***	(0.001)	0.007***	(0.002)	0.007***	(0.001)	0.005**	(0.002)	0.008***	(0.002)	0.006**	(0.002)	0.008***	(0.002)
ROA	-0.004	(0.020)	-0.017	(0.014)	-0.003	(0.020)	-0.016	(0.014)	-0.004	(0.020)	-0.016	(0.014)	-0.005	(0.020)	-0.015	(0.014)	-0.004	(0.020)	-0.015	(0.014)
RDEBT	-0.001	(0.001)	-0.000	(0.001)	-0.001	(0.001)	-0.000	(0.001)	-0.001	(0.001)	-0.000	(0.001)	-0.001	(0.001)	-0.000	(0.001)	-0.001	(0.001)	-0.000	(0.001)
RCASH	0.002	(0.003)	-0.001	(0.002)	0.002	(0.003)	-0.001	(0.002)	0.002	(0.003)	-0.001	(0.002)	0.002	(0.003)	-0.001	(0.002)	0.002	(0.003)	-0.000	(0.002)
DPCT	0.024	(0.022)	0.038***	(0.015)	0.017	(0.025)	0.032*	(0.017)	0.024	(0.023)	0.028*	(0.016)	0.035	(0.026)	0.023	(0.018)	0.032	(0.027)	0.022	(0.018)
PCT_XNPL	0.000	(0.001)	-0.001***	(0.000)	0.000	(0.001)	-0.002***	(0.001)	-0.000	(0.001)	-0.002***	(0.000)	-0.001	(0.001)	-0.001*	(0.000)	-0.000	(0.001)	-0.002***	(0.001)
Intercept	0.155**	(0.073)	0.242***	(0.050)	0.155**	(0.075)	0.214***	(0.051)	0.149**	(0.074)	0.227***	(0.050)	0.120	(0.075)	0.258***	(0.051)	0.120	(0.075)	0.239***	(0.051)
Year fixed effect	Included				Included				Included				Included				Included			
Sub-sector fixed effect	Included				Included				Included				Included				Included			
Observations	869		869		869		869		869		869		869		869		869		869	
R-squared	0.239		0.345		0.239		0.353		0.239		0.353		0.243		0.348		0.246		0.364	

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

[a] Independent variables are at time t-1 and transformed using the natural logarithm, notation is omitted.

Table 3: Differences in covariate effect across acquisition and alliance equation

Variables	β Acquisition attractiveness	γ Alliance attractiveness	β - γ	Chi2
PROXISCI	0.05*	-0.045**	0.100	7.72***
PROXISCISQR	-0.016*	0.019***	-0.035	10.61**
DEGNOV	-0.011	0.004	-0.015	0.23
DEGNOVSQR	0.005	0.006	-0.001	0.01
PATQUAL	-0.061**	0.044***	-0.105	13.36***
PATQUALSQR	0.015***	-0.013***	0.028	18.32***
ACQEXP	0.047***	0.023***	0.024	11.96***
ALLEXP	-0.038***	0.016**	-0.054	19.34***
RDINT	0.0000347	-0.00000516	0.000	0.11
SIZE	-0.046*	-0.075***	0.029	0.96
SIZE_SQR	0.006**	0.008***	-0.002	0.56
ROA	-0.004	-0.015	0.011	0.21
RDEBT	-0.001	-0.000	-0.001	0.6
RCASH	0.002	-0.000	0.002	0.4
DPCT	0.032	0.022	0.010	0.12
PCT_XNPL	-0.000	-0.002***	0.002	3.1*

Appendix

Table A.1. Description of the variables

Variable name	Variable name in the regression	Description of the variable
Dependent variables		
Acquisition attractiveness	$\ln(1+NBRACQ_{i,t})$	Natural logarithm value of the number of acquisitions made in a year *t* by a firm *j*
Alliance attractiveness	$\ln(1+NBRALL_{i,t})$	Natural logarithm value of the number of alliances made in a year *t* by a firm *j*
Independent variables		
Proximity with science	PROXISCI	Number of "X-type" non-patent literature citations made by the focal firm in the EPO examination process prior to the transaction (acquisition or alliance)
Proximity with science - square value	PROXISCISQR	Square value of the number of "X-type" non-patent literature citations made by the focal firm in the EPO examination process prior to the transaction (acquisition or alliance)
Degree of novelty	DEGNOV	Number of "X-type" Patent citation made by the focal firm in the EPO examination process prior to the transaction (acquisition or alliance)
Degree of novelty - square value	DEGNOVSQR	Square value of the number of "X-type" Patent citation made by the focal firm in the EPO examination process prior to the transaction (acquisition or alliance)
Patent quality	PATQUAL	Number of citations received by a focal patent prior to the transaction (acquisition or alliance)
Patent quality - square value	PATQUALSQR	Square value of the number of citations received by a focal patent prior to the transaction (acquisition or alliance)
Control variables		
Acquisition experience	ACQEXP	Cumulative number of acquisition made prior to year *t*
Alliance experience	ALLEXP	Cumulative number of alliance made prior to year *t*
R&D intensity	RDINT	R&D expenditures year in year *t-1* scaled by total sales in year *t-1*
Firm size	SIZE	Number of employee in year *t-1* (ln value)
Firm size square	SIZE_SQR	Square value of the number of employee in year *t-1* (ln value)
Financial performance	ROA	Net sales in year *t-1* scaled by Total asset in year *t-1*
Financial leverage	RDEBT	Long-term debts in year *t-1* scaled by total assets in year *t-1*
Cash	RCASH	Cash and cash equivalent in year *t-1* scaled by total assets in year *t-2*
Dummy PCT	DPCT	equal "1" if the focal patent has been filled in an international patent examination process and "0" otherwise.
NPL citations in PCT process (X-type)	PCT_XNPL	Number of "X-type" non-patent literature citations made by the focal firm in the international examination process prior to the transaction (acquisition or alliance)
2000	YR2000	Dummy variable for fixed effect on year 2000
2001	YR2001	Dummy variable for fixed effect on year 2001
2002	YR2002	Dummy variable for fixed effect on year 2002
2003	YR2003	Dummy variable for fixed effect on year 2003
2004	YR2004	Dummy variable for fixed effect on year 2004
2005	YR2005	Dummy variable for fixed effect on year 2005
2006	YR2006	Dummy variable for fixed effect on year 2006
2007	YR2007	Dummy variable for fixed effect on year 2007
2008	YR2008	Dummy variable for fixed effect on year 2008
2009	YR2009	Dummy variable for fixed effect on year 2009
2010	YR2010	Dummy variable for fixed effect on year 2010
2011	YR2011	Dummy variable for fixed effect on year 2011
Sub-sector 2833	SIC2833	Dummy variable for fixed effect on the sub-sector USSIC code 2833
Sub-sector 2834	SIC2834	Dummy variable for fixed effect on the sub-sector USSIC code 2834
Sub-sector 2835	SIC2835	Dummy variable for fixed effect on the sub-sector USSIC code 2835
Sub-sector 2836	SIC2836	Dummy variable for fixed effect on the sub-sector USSIC code 2836