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# Exploration and firms' innovative performance – How does this relationship work?

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## Abstract

**Purpose** – The main purpose of this paper is to analyze (1) the relationship between a firm's exploration strategy and its innovative performance, and (2) whether its absorptive capacity (AC) moderates this relationship.

**Design/methodology/approach** – We adopted an econometric approach, using secondary data. We synchronized two databases – Compustat and USPTO –, from which we extracted common data concerning 275 biopharmaceutical firms for the period between 1990 and 2003. We used negative binomial regression to analyze data.

**Findings** – The exploration strategy positively influences firms' innovative performance. However, excessive emphasis on this strategy can diminish its benefits. Moreover, a firm's AC will not positively moderate the curvilinear relationship between exploration and the firm's innovative performance in all contexts, contradicting our theoretical predictions. This is due to the existence of trade-offs between AC characteristics and other organizational factors.

**Originality/value** – This paper extends the understanding of Open Innovation and AC theories. Our results suggest that AC cannot be understood as a one-dimensional and autonomous capacity located exclusively in R&D departments. Aspects such as financial power, the business model and the different dimensions of AC and their respective locations in the firm's value chain should be considered whenever the influence of AC on exploration strategies is analyzed.

**Keywords** – Exploration; Innovative performance; Patents; Absorptive capacity.

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# 1 Introduction

This article investigates the relationship between a firm's strategy or activity to acquire new knowledge – exploration – and its innovative performance, while analyzing whether the firm's absorptive capacity moderates this relationship. Therefore, this study is expected to contribute to an open innovation approach, and to the firm's perspectives as to knowledge and learning.

The innovation process requires searching for new combinations of knowledge or technologies that harbor commercial potential (Laursen & Salter, 2014; Laursen, 2012; Nelson & Winter, 1982). Literature on innovation has shown the importance of searching for these new combinations beyond the organization's technological boundaries, a strategy that reflects the open innovation model (Chesbrough, 2003; 2006; Berchicci, 2013; Leeuw, Lokshin & Duysters, 2014; Laursen & Salter, 2014).

With regard to how knowledge and organizational learning is viewed, this article emphasizes that new combinations of knowledge and technology involve synchronicity between a firm's current knowledge and new knowledge. Both types of knowledge can be developed within or beyond the organization's physical boundary (Rosenkopf & Nerkar, 2001; Hoang & Rothaermel, 2010). Here, the focus will be on the exploration strategy, a term coined by March (1991), which refers to the following terms: variation, risk, flexibility, discovery and innovation. This strategy expresses the activity adopted by the firm that explores new knowledge, subject to risks and taking advantage of the benefits this strategy can provide (March, 1991).

Implementing the exploration strategy, when aligned with the business model, enables the firm to gain competitive advantage (Chebrough, 2003). In other words, the exploration strategy is an important activity through which the open innovation model materializes. The accumulation of and interaction with new knowledge positively influences the firm's technological development or innovative performance (Rosenkopf & Nerkar, 2001; Katila & Ahuja, 2002; Hoang & Rothaermel, 2010). Consequently, new opportunities may arise in new but uncertain markets (Kogut & Zander, 1992). High levels of search and sharing of knowledge can positively affect exploration activities, which in turn affect innovation performance (Aloini & Martini, 2013), by increasing the firm's positive R&D effect (Ritala, Olander, Michailova & Husted, 2015; Ren, Eisingerich & Tsai, 2015).

However, literature on innovation also acknowledges complexity in the knowledge search strategy. Aspects related to a firm's knowledge protection (Laursen & Salter, 2014; Ritala et al., 2015), to processes and organizational structures (Benner & Tushman, 2001) to integrating new knowledge (Grant, 1996; Katila & Ahuja, 2002) are associated with rising costs that may cause the firm to "suffer the costs of experimentation without gaining many of its benefits" (March, 1991, p. 71). Accordingly, excessive accessing of new knowledge from outside sources must be carefully managed. Otherwise, it may not yield the expected positive returns after a certain point (Laursen & Salter, 2006).

Our study intends to broaden knowledge on how firms can deal with this paradox. Therefore, this paper suggests that the absorptive capacity (AC) of a firm can moderate the relationship between its exploration strategy and its innovative performance. This argument, based on the seminal concept of AC, was coined by Cohen & Levinthal (1990) as the firm's capacity to recognize the value of new, external information, assimilate it and apply it to commercial ends. The review of the concept proposed by Zahra & George (2002) reinforces the argument built herein, by proposing that AC has two different dimensions. Thus, the dimension that adds the capacity to transform and explore new knowledge would not be effective without the previous dimension, by which the firm acquires and assimilates new knowledge.

The connection between AC, the exploration strategy and the subsequent innovative performance is emphasized in that a firm can exploit the new knowledge in various technology fields. It is expected that this (AC) competence positively affects its capability to appropriate – or absorb – the technological innovation value, thereby stimulating subsequent innovations (Meyer & Subramaniam, 2014). Therefore, if the firm has a high capacity of absorbing knowledge or technologies (AC), it can identify and exploit them more efficiently (Zhou & Wu, 2010; Nambisan, 2013). In other words, with increasing levels of AC, the firm can explore a greater or more diverse level of new knowledge before experiencing less rewarding returns.

Here, the innovative performance will be measured based on the annual number of patents granted to a firm over a given period. Patents identify the inventions of products, processes or designs useful for the industry and unprecedented in the technological field to which they belong (Stuart & Podolny, 1996). They are recognized as rich data sources for the study of innovation and technological change (Hall, Jaffe & Trajtenberg, 2001), and represent the firm's history of technological knowledge (Stuart & Podolny, 1996; Lewin, Massini, & Peeters, 2011). Therefore, if this article studies the relationships between the search and absorption of new knowledge with innovative performance, it seems appropriate using patents as an indicator of performance. Furthermore, literature of innovation has added several studies that use patents as proxies for the innovative capacity of a firm (Owen-Smith & Powell, 2004; Rothaermel & Hess, 2007; Rothaermel & Thursby, 2007; Rothaermel & Alexandre, 2009).

Similarly, it also seems appropriate that the American and Canadian biopharmaceutical sectors choose to empirically test the arguments presented above. This segment is "characterized as oriented to technology-intensive R&D and technological knowledge is critical for development and sustainable competitive advantage" (Laursen, Moreira & Markus, 2015:15). Strong competition for patents in this sector encourages organizations by adding knowledge derived from various external sources. Moreover, the regime governing the protection of knowledge created in these countries is strong and therefore encouraging (Tzabbar, Aharonson & Amburgey, 2013).

## 2 Theory and hypotheses

According to literature on open innovation, there are several factors that have contributed for this model to become a new paradigm. Information technology, globalization, increased mobility of skills and capabilities, the extensive availability of types of financing, among other factors, help to reduce uncertainty and costs involved with activities to explore fields that are beyond the firm's knowledge base (Chesbrough, 2003, 2006).

The assumptions used in this text are that the original closed model is no longer entirely satisfactory, given current market characteristics and demands (Chesbrough, 2003): the open model is more effective, particularly in sectors in which technological change comes about quickly (Katila & Ahuja, 2002; Hoang & Rothaermel, 2010). To produce successful innovations that result in competitive advantages, access to an array of knowledge is vital, even if the firm's current knowledge is fundamental in this process (Cohen & Levinthal, 1990; Laursen, 2012).

In this context, if technological change emerges more frequently and significantly in knowledge intensive environments (R&D) (Laursen et al., 2015); and if the exploration activity emphasizes utilizing new knowledge (March, 1991), then the exploration activity refers to the open innovation model, since the possibility of accessing new knowledge is significantly greater when the firm looks for it beyond its organizational boundaries (Cohen & Levinthal, 1990; Chesbrough, 2003; Rothaermel & Alexandre, 2009). In this line of reasoning, the exploration activity will also have important relationships with technological change, suggesting that this activity will likely have an effect on innovation performance.

A part of innovation literature attributes great importance to the number of new products launched as innovative performance indicators. The same applies to financial indicators, when they are associated to selling these products. However, in intensive research/knowledge sectors, without market exclusivity offered by a patent, the development of these products and their commercial viability may be substantially affected (Bawa, 2007; Funk, 2014). Therefore, although less visible to the market, the patenting stage can be a reliable way to measure innovative performance, specially in environments in which open innovation is a reality – for example, a patent not used by a firm can be exploited by another firm (Chesbrough, 2003; 2006). This practice is called "outbound open innovation" by Huizingh (2011), when internal knowledge is externally exploited.

Particularly in this article, three factors indicate that patents can effectively measure a firm's innovative performance. Firstly, to the extent that they represent an effective knowledge recombination (Laursen et al., 2015), a central element of the main theoretical line addressed here. Secondly, the internalization of external knowledge through patents is a source of competitive advantage, especially in dynamic industries (Laursen et al., 2015; Tzabbar et al., 2013), a strong characteristic of the industry studied here. Third, the scope of this study is limited by the phase in which new knowledge is generated internally or accessed through partnerships (recombination). In this phase, the firm identifies the potential and registers the new knowledge to protect it. Therefore, the product launch phase and the intermediate phases that precede it are excluded from analysis in this paper.

Innovation is in essence an uncertain process that involves learning, providing new combinations of knowledge and technology (Pavitt, 2005). The exploration of new knowledge plays a key role in this context by enabling the firm to acquire a wide array of experiences (Mom, Van Den Bosch & Volberda, 2007). This array of experiences leads to "discoveries and new opportunities, while enabling a greater potential for developing the firm's current knowledge" (exploitation) (Rothaermel & Deeds, 2004, p. 203).

Previous studies have made advances in terms of relating exploration to a firm's innovative performance, admitting its disposition to experimentation. Intrinsic to the exploration strategy, failures are important in R&D results, for although they can lower the performance of this field in terms of volume, they increase it in terms of quality (Khanna, Guler & Nerkar, 2016). When compared to the activity that explores the firm's current knowledge – exploitation – the exploration activity is more likely to generate disruptive inventions (Ahuja & Lampert, 2001; Henderson & Clark, 1990). This occurs by increasing inventive performance variance (Jung & Lee, 2014). The exploration of unfamiliar knowledge generates recombination with knowledge, experience and previous technologies, and it is this recombination that enable the firm to develop radical innovations (Li, Maggitti, Smith, Tesluk & Katila, 2013; Jung & Lee, 2014).

The literature that supports the configuration and the importance of the exploration strategy does so by highlighting the exchange of formal and informal knowledge by means of interorganizational networks and strategic alliances (Powell & Grodal, 2005; Lavie & Rosenkopf, 2006; Phelps, 2010), through the firm's point of view that licenses a new technology (Laursen, Leone & Torrisi, 2010), and also through relationships between firm and consumers and other institutions or sources of information (Laursen, 2011, 2012).

In the literature that relates the exploration strategy to innovative performance, we emphasize that firms which are able to modify their technological positions relative to their competitors are those that shift to better technological prospects than the ones previously held (Noteboom et al., 2007). These firms do not perform this search alone, but as part of a dynamic in which a group of organizations implement search strategies beyond its borders (Stuart & Podolny, 1996), while benefiting from the external flow of new knowledge (Escribano, Fosfuri & Tribó, 2009).

For some previous studies, a "local search" (exploitation) can be restrictive. A "non-local search" (exploration), although more expensive and more risky, can be more effective because as it is not substantially different from the knowledge already consolidated in the firm, it offers more possibilities for experimentation and recombination of ideas and technologies, positively affecting the unprecedented nature of innovation (Ahuja & Lampert, 2001; Laursen, 2012). Similarly, the "width" and "depth" of the search strategy by new knowledge can enhance the introduction of new products (Katila & Ahuja, 2002), as well as the firm's innovative performance (Laursen & Salter, 2006).

Nevertheless, although positive, what should be the intensity of this search for new knowledge? To March (1991), organizations that adhere to a concentrated exploration over time at the expense of exploitation are more likely to receive less gains proportional to their efforts with new experiments or knowledge (March, 1991).

In addition to the inherent vulnerability of the exploration strategy, related to temporal and financial (March, 1991), knowledge protection (Laursen & Salter, 2014; Ritala et al., 2015), environmental (Neil & York, 2012), structural, and cultural aspects (Benner & Tushman, 2001; Jansen, Tempelaar, Van Den Bosch & Volberda, 2009), an excessive variety of ideas – an extreme example – can render difficult the most basic form of communication. This would be the spoken and written language, characterizing a trade-off between the firm's wide range of knowledge and its communication structure (Cohen & Levinthal, 1990).

Specifically in environments in which change occurs very quickly, firms undergo time-related pressures. This can prompt them to develop very narrow or very wide search processes (Levinthal & March, 1993; Laursen, 2012). For example, a firm advances externally in the search for new knowledge, while remaining internally focused on the exploitation activity (Hoang & Rothaermel, 2010). In other words, the firm develops a new combination from a new technology, but decides to maintain its investments in its current technology.

Thus, the scope of the search for new knowledge can go from an important factor that enhances alternatives or recombination, to a source of rising costs with the addition of new knowledge. Moreover, it may be held accountable for the loss of trustworthiness by taking advantage of these opportunities (Katila & Ahuja, 2002). Consequently, an excessive search for new knowledge may call for costs that are related to adding and assimilating activities, which may be higher than the benefits provided. Then, over time, there may be a change from a positive to a negative effect in the relationship between the exploration activity and innovative performance, characterizing the curvilinear relationship between these variables.

Several empirical studies have tested the curvilinear relationship between the exploration activity and the innovative performance of a firm. Laursen and Salter (2006) addressed and empirically tested that the concepts of "width of external search" – a variety of knowledge sources used – and the concept of "depth of external search" – the intensive application of knowledge sources used – have a U-inverted curvilinear relationship with the innovative performance of a firm. Laursen (2011) found that high levels of concentration of the knowledge innovation processes of its customers and consumers, Danish business units, had experienced negative returns, attributing this relationship to the conservative and inept characteristics of these individuals.

Sytch & Tatarynowicz (2014) attributed the turnover rate of network community members who exchange knowledge in the computer industry as the cause for this curvilinear relationship. When these communities experience turnover among its members, they increase the creative results of their firms (patents) by upgrading and leveling the knowledge base of these communities. However, to the extent that this turnover rate becomes excessive, the inventive productivity (patents) of its members is restricted, due to increased risks, collaborative costs, integration and adaptation to new environments (Sytch & Tatarynowicz, 2014).

Considering that local search and non-local search activities can be complementary (Katila & Ahuja, 2002; Leeuw et al., 2014), this paper suggests that the curvilinear relationship will not occur due to the shortage of resources searched – knowledge – not because accessing this can be limitless but because of the resources these two activities compete for (March, 1991). Thus, following a significant part of the literature, we assume that the exploration strategy is beneficial for firms, but after a certain intensity it has a negative relationship with performance. Therefore, our first hypothesis:

> **H1:** *The exploration activity has a positive impact on a firm's innovation performance to a certain point. From that point on, the risks and costs involved in this strategy will neutralize the benefits provided, characterizing a U-inverted curvilinear relationship between these two variables.*

## 2.1 Organizational absorptive capacity as a moderating variable

The open innovation paradigm and the firm's knowledge based view (KBV) incorporate into the competitive environment the characteristic of a learning space via knowledge exchange between organizations. The R&D department takes on the role as the most important interface between the firm and that environment (Chesbrough, 2003; Cohen & Levinthal, 1990). Therefore, the organizational skills related to research and development are very important in the alignment and development of this learning process. High levels of these skills allow the firm to identify the opportunities of lesser or greater potentials that may arise in this environment of inter-organizational interactions (March, 1991; Hoang & Rothaermel, 2010).

The capability to identify the best knowledge potential is revealed by the concept coined in the text by Cohen and Levinthal (1990), which supports the arguments presented in this article. Following these authors, the "absorptive capacity" (AC) of the organization, supported by cognitive and behavioral structures at the individual level, is the cumulative capacity to recognize value, assimilate and commercially exploit new and external knowledge.

Although the organizational AC is developed from investments in individual absorptive capacities, the organizational AC "is not, however, simply the sum of the absorptive capacities of its employees" (Cohen & Levinthal, 1990, p. 131). Therefore, as important as identifying and assimilating the new opportunity, the capacity to exploit it puts the micro-foundations of AC at the center of this context – the communication structure and the distribution of expertise within the organization (Cohen & Levinthal, 1990).

Within this reasoning, organizational AC can also be seen as a procedural skill, in which internal and external events of the firm can stimulate its experience with complementary knowledge sources (Zahra & George, 2002). According to Zahra and George (2002), AC can be dismembered in potential AC (knowledge acquisition and assimilation) and the realized AC (transformation and exploitation of knowledge). In this conceptual review of Zahra and George, the transition from potential AC to realized AC is moderated by factors that the authors call "mechanisms of social integration". Within the perspective developed in this text, the two theoretical approaches are connected by the importance of communication structure and distribution of expertise proposed by Cohen and Levinthal (1990), which can be precisely the mechanisms of social integration, as proposed by Zahra and George (2002).

Interpreting these theoretical models, in this article we understand that, in order to identify, assimilate and exploit unprecedented and external knowledge, the organization should invest primarily in R&D (Cohen & Levinthal, 1990). It should also invest in various mechanisms related to the organizational background and to the external environment (Cockburn & Henderson, 1998; Zahra & George, 2002). Therefore, its current knowledge base is sustained so that it can identify, among the new knowledge accessed, those that can be absorbed or combined with its current knowledge, hence technological opportunities.

The theory of organizational AC, particularly in the context of innovation, has included a wide and consistent number of publications in the field that Volberda, Foss and Lyles (2010) called "tangible results of AC". Among these results, the number of patents remains incipient and not fully developed in the domain "technological innovation and firm performance", even though this field has received more attention since the beginning of 2000 (Volberda et al., 2010). Accordingly, the objective of this article is to contribute to the KBV by implementing AC construct as a moderating variable, a format not often used in the theoretical discussion of the field.

This article suggests that organizational AC acts as a moderating element between the strategy to access a firm's new knowledge – exploration – and its innovative performance. Important and recent empirical studies have investigated this relationship. Enkel & Heil (2014) highlight this kind of moderated relationship by identifying that the highly developed potential absorptive capacity allows the firm to look for innovation processes in industries alongside its partners who detain knowledge which is very different from their own knowledge base (...) "constituting a new means to leverage exploratory innovation" (Enkel & Heil, 2014:254).

Similarly, Chang, Gong & Peng (2012) studied the transfer of new knowledge in 162 Taiwanese multinational firms for each of its British subsidiaries, via expatriates sent from the "parent firm". These authors highlighted the moderating role of absorptive capacity of the subsidiary firm as a major factor that determined the performance differences between them. Despite the skills, motivation and the expatriate's sense of opportunity, the subsidiaries with low absorptive capacity had their performance affected by the low rate of assimilation and application of the new knowledge transferred (Chang et al., 2012).

Escribano et al. (2009) also identified the firm's AC as an important element of moderation in the process of assimilation of external knowledge flows and its impact on innovative performance. In a sample containing 2265 Spanish firms, these authors found empirical evidence that the greater the absorptive capacity, the better equipped the firms will be to identify the presence of external knowledge flows and to efficiently exploit them. AC would then be a source of competitive advantage, also assuming a more significant role in dynamic sectors in terms of knowledge, as well as wherever intellectual property rights are strategic (Escribano et al., 2009). Following literature, hypothesis 2 of this article is presented as follows:

> **H2:** *AC moderates the existing U-inverted curvilinear relationship between the firm's exploration activity and its innovative performance, so that high AC levels render the firm greater efficiency to identify, assimilate and exploit new knowledge, delaying the point when the risks and costs neutralize the benefits.*

## 3 Methods

This hypothetical-deductive research uses a quantitative approach based on the positivist tradition. To test the hypotheses proposed here, the negative binomial regression technique was applied. Data from two different databases were used.

## 3.1 Databases and sample

This study used two databases. The first was the US Compustat, which lists the financial and market data from more than 24,000 publicly traded firms in the United States and Canada, each with its own unique identification code and the SIC code – Standard Industrial Classification – of four digits that identifies each of the sectors that comprise it. The control variables of the study were extracted from this database. The second is the patent database of the NBER (National Bureau of Economic Research) Patent Project, developed from the USPTO – The United States Patent and Trademark Office. The USPTO registers and protects millions of granted US patents, with detailed information about the technological field, the assignee firm, inventors, citations and other details (Hall et al., 2001). The dependent and independent variables and the moderating variable are extracted from this second database. The two databases were connected using as reference the identification code of the firm, per year.

In this study, the sample encompasses 2382 observations and consists of 275 firms from the pharmaceutical (SIC 2834) and biological diagnostics (SIC 2835 and 2836) sectors, collected in the US Compustat database. Sectors 2835 and 2836 hold firms that develop biotechnology and are involved in the production of *in vitro* (test tube) and *in vivo* (in the body) vaccines – antibacterial and virus vaccines, as well as allergen extracts and analogous products for human or veterinary use.

This article uses nomenclature proposed by Xia and Roper (2010) – "biopharmaceutical firms" – which, as in this article, have been linked to the literature of open innovation through product development processes in which alliances between this sector of firms and the pharmaceutical sector combine internal and external knowledge. These practices are characterized by using the exploration strategy. Similarly, Rothaermel and Deeds (2004), on the one hand, segmented the exploration alliances, biotech firms that have developed alliances focused on basic research and drug discovery; and on the other hand, the exploitation alliances – marketing, distribution, regulatory processes, among others.

Therefore, these sectors are chosen in line with the study objectives stated herein, as they hold high-tech industries (Rothaermel & Alexandre, 2009). They are research/knowledge intensive firms and regularly develop technology search strategies in external sources (exploration).

Furthermore, they have consistently developed a significant number of patents (Laursen et al., 2015). The data is longitudinal, covering the period ranging between 1990 and 2003.

Two reasons led to determining this period: first, although the NBER makes available the data up to 2006, according to previous studies the data can lose quality when it approaches this time limit. This study then takes on a conservative approach by determining 2003 as the upper limit. Secondly, the lower limit (1990) was employed in order to reduce heterogeneity, which over the years can become excessive, since the Compustat database refers to the 1950s. The fact that the data is relatively old does not generate a bias that could invalidate the analysis built here. This bias would probability be considered if the objective of this article were to create a relationship with an anomalous behavior of the firms studied here in relation to the theoretical framework used here. However, ex-ante, there is no reason to expect that the behavior of these firms – in relation to the theoretical reference – has changed over the period considered herein. The 275 firms in the sample totaled 44,420 patents during the study period.

Another key aspect explained in this article also concerns the time period covered – that is, 14 years. How must one capture the innovative performance only via patents, given that a product development period in the biopharmaceutical industry is relatively long and is often over a decade long? The answer to that question involves certain assumptions and arguments.

First, the central issue studied here is firm's knowledge – access (exploration), absorption (AC) and patenting (performance). Therefore, the new knowledge, after it has been accessed and absorbed, affects the innovative performance when it is transformed into a patent granted to the firm, which is the scope of this research.

Secondly, the innovation literature recognizes patents as repositories of technological knowledge (Stuart & Podolny, 1996; Lewin et al., 2011), which yields them the condition of innovative process results. Additionally, through the perspective of open innovation, a firm can be considered innovative by licensing its patents to another organization, other technology fields than its own field (Chesbrough, 2003; 2006). Thus, the scope of this article does not address the other phases in which knowledge is transformed into a final product. That is a longer process, which is based on the complexity of the final product and especially because of the strict oversight and monitoring by the FDA – Food and Drug Administration. In this longer process – which often goes beyond a decade – the product will be tested throughout various stages at the end of the firm's value chain before it is launched.

Therefore, the period emphasized in this research, in which knowledge is accessed, absorbed and patented, occurs at the beginning of the firm's value chain. At that stage, it is the potential skills of AC that should be favored: acquisition and assimilation skills (Zahra and George, 2002). This phase – consisting of the incoming request to grant the patent – lasts on average 2.5 years in the USPTO (Hall et al., 2001; Funk, 2014). Therefore, based on the premises and arguments exposed in preceding paragraphs, the 14-year period covered by the empirical approach of this research is sufficient and appropriate to the average cycle of the application and concession of patents in the USPTO.

### 3.2 Measuring variables

**Dependent variable** – how a firm's innovative performance was measured followed previous studies by estimating the number of patents awarded to a firm in a given period (Nooteboom, Vanhaverbeke, Duysters, Gilsing, & van den Oord, 2007; Rothaermel & Alexandre, 2009). This study, then, is not a forerunner in this type of measurement. Accordingly, the first step was to eliminate from the sample the organizations that did not file any patent application in the period analyzed. Next, the databases were connected between the firms in the US Compustat and in the NBER (USPTO) with patents in this period through their unique identification codes in each of the databases. Therefore, innovative performance is better when a firm holds the largest possible number of patents issued annually between 1990 and 2003.

Although using the number of patents is widely accepted as an innovative performance indicator, it is not free of critiques regarding their consistent regularity. In this study, using this indicator is justified not only because it reduces ambiguity when compared with more subjective answers regarding what is or not considered innovation. Another reason is the reduction of heterogeneity, since the database used here is made up of firms that are part of sectors that – especially the countries they belong to – traditionally produce innovations using the intellectual property protection resource involved in this process. Moreover, they are all public firms and are therefore aligned with the kind of organizational culture that favors this type of activity. This aspect also reflects a certain financial power that can afford the costs generated by these practices.

**Independent variable** – the basis used here to measure the independent variable is that a firm demonstrates its technological domain by the patents it applies. When applying a patent the firm cites the technologies or previous knowledge that contributed to developing its patent (Hall et al., 2001). Therefore, the more diverse the citations in a patent related to its field, the more the strategy that exploits the firm's new knowledge (exploration) is characterized, because it translates access to unfamiliar knowledge.

Following this concept, the independent variable – exploration – was measured in this study using the concept of technological search scope (Katila & Ahuja, 2002) or also the number of different channels through which the firm develops its technological search (search breath) in its innovative activities (Laursen & Salter, 2006). Thus, the search activity for new knowledge corresponds to the percentage of unprecedented citations in the list of all citations of a particular firm in a given year (Katila & Ahuja, 2002; Funk, 2014), assuming possible results in the range between 0 and 1.

$$Exploration = \frac{\text{new citations}}{\text{total citations}}$$

A four-year "moving window" was admitted here, that is, the percentage of new citations and the total citations of a particular firm in a given year were considered, provided that these citations had not been mentioned in other patents in the four years immediately prior to the focal year. The use of the four-year moving window is justified by previous studies that defined this period as the most appropriate for the knowledge depreciation rate created and developed in the industries, the subject of this study.

**Moderating variable** – the measurement of the moderating variable assumes AC viewpoint, which Mowery, Oxley and Silverman (1996) defined as more in line with the level of disaggregation and specificity, characteristic of patents. Therefore, here we used the idea that the greater the size or scope of knowledge a firm holds, the more it can venture beyond its knowledge and the more successful the absorption of this technological search will be (Lane, Koka & Pathak, 2006). Another way to explain this logic includes the concept of dispersion of the firm's technology patent portfolio, that is, the greater the assimilation capacity of external technologies, the dispersion index of the firm's technology experiences will be greater, represented by classes of patents the firm has applied (Mowery et al., 1996; Laursen et al., 2010).

Following this literature, this study proposes measurement of AC using the Herfindahl index. As in Laursen et al. (2010), this index reflects the degree of dispersion of the technology fields of patents that the firm produced in the years prior to the focal year.

$$1 - \sum_{i=1}^{n} \alpha_i^2,$$

where $\alpha$ is the percentage of patents in a given class of patents *i*, in the firm's stock of patents, applied in a four-year moving window. The class assigned to a particular patent can be interpreted as an indicator of the technology field this patent belongs to.

A given firm will have a given variety of classes of patents in its portfolio. Each of these classes will have a particular role in this portfolio, defined within the four years immediately prior to the focal year. The sum of squares of each participation will be the element of subtraction of number 1, which will determine the degree of dispersion that will vary between 0 and 1. The higher this index, the greater the firm's technological knowledge scale and it will be better able to absorb new technologies and new knowledge.

With the same assumptions and arguments presented in item 3.1, the definition of the four-year moving window is aligned with the approach performed on the constructs of this study, delimited to the exploration strategy, the potential AC and the patent concession, at the beginning of the firm's value chain. In other words, the process of access, absorption and registration of knowledge via patents, at the beginning of the chain, is the analysis period of this article. Therefore, two points are reiterated here: a) the exclusion of the phase that includes the product development monitoring by the FDA; and b) the contributions of Hall et al. (2001) and of Funk (2014), in defining the four year period, which is based on the average cycle of 2.5 years between the patent application and the granting of this patent. Figure 1 graphically shows the research variables, their relationships and hypotheses.

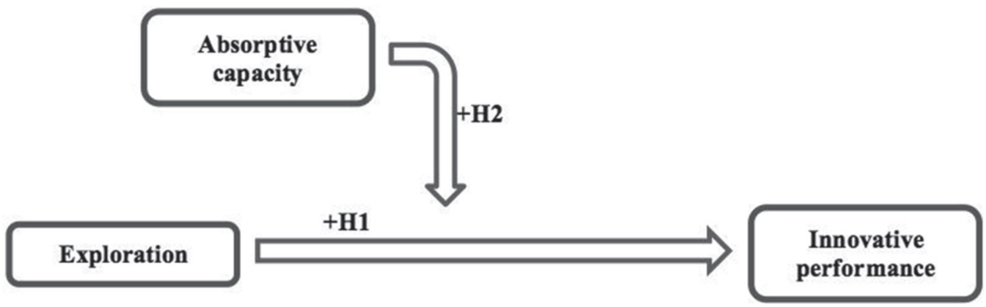


**Figure 1.** Graphic representation of the research model

**Control variables** – Cohen and Levinthal (1990) included the idea of intensity in terms of time and efforts by firms to develop their own knowledge to enable them to assimilate and use innovation. This ability was also associated with their absorptive capacity, which will be more effective the more consistent their R&D investments are. Therefore, this study considers the intensity of R&D investments as one of the control variables in the interaction environment between the firm's exploration activities and its innovative performance. This variable was measured as the ratio between R&D spending and firm sales.

As in Laursen et al., (2010), this study employs two other important variables to control its statistical results. If prior knowledge is decisive to innovative capacity, especially its capacity to combine diverse knowledge, then the firm's stock of patents and experience in this technological context (timeline during the study period, between the focal year of a particular patent and the year of the organization's first patent) can influence the relationship between the firm's exploration and innovative performance.

The exploration activity assumes open innovation practices that allow access to institutions and firms that provide new knowledge, characterizing cooperation between these organizations. Thus, the co-patent variable – which is the number of patents developed by firm I, in year t, in partnership with one or more firms within the seven-year "moving window", in the period studied here – is also a control variable. The seven-year moving window was used because, in the innovation scenario, the activity of patenting in partnerships is an uncommon phenomenon. The robustness of this alternative was tested after analyzing the results, adding or subtracting a year.

Firm size also affects its innovative performance (Rothaermel & Deeds, 2004). Specifically in the pharmaceutical and biotechnology sectors, the smaller ones are usually more specialized and therefore more agile in their innovative processes, while the larger ones are likely to have greater market power and skills related to the activities of marketing, distribution, logistics and other activities (Hoang & Rothaermel, 2010). This study monitors the statistical results found here using the variable firm size, measuring the same way as Phelps (2010): the natural logarithm of sales for firm I, in the focal year t. Table 1 summarizes the operational description of all the variables of the study.

**Table 1**
**Operational description of research variables**

| Variable | Description |
|---|---|
| **Dependent Variable** | |
| Innovative performance | Number of patents attributed to the firm within a given year. |
| **Independent Variable** | |
| Exploration | Ratio between new annual citations and total citations of the firm, ranging between 0 and 1. |
| **Moderating Variable** | |
| Absorptive Capacity | Herfindahl Index – degree of dispersion of technology fields of the patents produced by the firm, ranging between 0 and 1. |
| **Control Variables** | |
| R&D Intensity | Ratio between R&D spending and firm sales, ranging between 0 and 1. |
| Patent Stock | Firm's cumulative total number of patents |
| Firm Experience | Timeline between the focal year of a patent and the year of the firm's first patent |
| Co-patent | Number of patents developed by the firm in partnership with one or more firms. |
| Firm Size | Natural logarithm of annual firm sales. |

## 3.3 Statistical model

Given the nature of the dependent variable, to estimate the coefficients applied here, this study used the Negative Binomial regression model. Previous studies addressing the same dependent variable (patents) have also used this model as a way to accommodate the specificities referring to the use of patents as a dependent variable. Additionally, this study also used fixed effects to treat the non-observable characteristics between the sample firms. The fixed effects model was used because it allows dealing with possible correlations between non-observable invariant factors and independent variables (Wooldridge, 2009).

The negative binomial model relates to the application of the variable "patents" because it can accommodate count and integer values. Another reason is in regard to previous studies on counting the patents that incorporate the regression technique that includes many "zeros", that is, many firms might respond they had not developed any patent over that period. The alternative use of the Poisson model, although it can consistently specify coefficients, could underestimate the standard error, possibly leading to spurious significance levels, since its premises could be violated because the variance would be proportional to the average. This study used the negative binomial model, which is a generalization of the most indicated Poisson model under conditions of over-dispersion. That is, it allows the variance of the dependent variable to exceed its average (Moreira, 2014). Another advantage of the negative binomial model when applied to longitudinal data is that it allows implementing the fixed effects model as well as the random or random effects model (Moreira, 2014). The reason for using fixed effects was made clear in the preceding paragraph.

## 3.4 Research design matrix

Table 2 summarizes the design of this research, demonstrating its objective, hypotheses, variables and data analysis techniques.

**Table 2**
**Research Design**

| | |
|---|---|
| **Objective** | To analyze (1) the relationship between the firm's exploration strategy and its innovative performance and (2) whether the firm's absorptive capacity moderates this relationship. |
| **Hypotheses** | **H1**: the exploration activity has a positive impact on a firm's innovation performance to a certain point. From that point on, the risks and costs involved in this strategy will neutralize the benefits provided, characterizing a U-inverted curvilinear relationship between these two variables.<br>**H2**: AC moderates the existing U-inverted curvilinear relationship between the firm's exploration activity and its innovative performance, so that high AC levels render the firm greater efficiency to identify, assimilate and exploit new knowledge, delaying the point when the risks and costs neutralize the benefits. |
| **Variables** | Firm's innovative performance<br>Exploration<br>Absorptive capacity<br>R&D Intensity<br>Patent Stock<br>Firm Experience<br>Co-patents<br>Firm Size |
| **Analysis techniques** | Quantitative approach using multivariate data analysis technique. More specifically, it uses the Negative Binomial regression model. This model accommodates the count and integer values, and also fits well when there are many "zeros" in the dependent variable. The unobserved heterogeneity between the sample firms is treated by the fixed effects estimation method. |

## 4 Empirical results

Table 3 summarizes the descriptive statistics and correlations between all variables of the study. The average number of patents annually attributed per firm, considering the entire sample is of about 19 patents per year. However, there is a large variance in this item since 431 patents were granted to at least one firm in one year. When the sample firms have their patents granted annually, they declare on average that 60% of the citations for these patents are related to new knowledge, thus the strategy exploration represents a very significant proportion of the knowledge search activities.

Regarding the firm's absorptive capacity the table shows an average dispersion degree of 0.51. This degree may vary between 0 and 1, i.e., zero may represent that the firm has no technological knowledge and no AC, and 1 if the firm has high AC and therefore dominates all possible technology fields within the biopharmaceutical industry, which are both very unlikely scenarios. However, considering all firms in the sample, the index of 0.51 indicates a moderate average AC.

The correlation coefficient between the variables AC and firm size (0.21) is important, but only moderate. This condition does not state that firm size is crucial in developing AC. A similar condition is also found in the coefficient that relates AC to the number of patents (0.18). Thus, while AC contributes positively, it does not have such a decisive role in the innovation performance of the firms in the sample. However firm size does in fact indicate that it influences the capacity to create patents (0.57), although it is not a very strong relationship. With regard to the strategy exploration, although the coefficient is also moderate when compared to innovation performance, the average of 60% declared by the sample firms can be considered high.

In summary, considering the entire sample, the results in Table 3 bring some doubt regarding the disproportion between the exploration strategy and AC. Therefore, a preliminary analysis seems to suggest that on average the biopharmaceutical firms in the sample explore new knowledge in a proportion that may not be monitored as it should. This is due to the fact that the firm's average AC is only moderate. In other words, exploration strategies may be generating patents in technology fields that are not dominated by the firms, which corroborates the theory of March (1991) which emphasizes a higher index of failure in terms of the exploration strategy related to the exploitation strategy.

**Table 3**
**Descriptive statistics and correlation matrix**

| | Mean | S.D. | Min. | Max. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of Patents | 18.65 | 48.91 | 0.00 | 431.00 | 1.00 | | | | | | | |
| Exploration | 0.60 | 0.37 | 0.00 | 1.00 | -0.16 | 1.00 | | | | | | |
| Absorptive Capacity | 0.51 | 0.32 | 0.00 | 1.00 | 0.18 | -0.43 | 1.00 | | | | | |
| R&D Intensity | 11.82 | 104.38 | 0.00 | 4.146.75 | -0.04 | 0.01 | 0.01 | 1.00 | | | | |
| Patent Stock | 4.81 | 18.62 | 0.03 | 661.22 | -0.06 | -0.01 | -0.03 | 0.01 | 1.00 | | | |
| Firm Experience | 6.84 | 5.06 | 0.00 | 23.00 | -0.07 | 0.13 | -0.02 | -0.02 | -0.05 | 1.00 | | |
| Co-patents | 1.58 | 4.31 | 0.00 | 57.00 | 0.02 | -0.05 | 0.10 | -0.00 | -0.01 | 0.17 | 1.00 | |
| Firm Size | 3.26 | 3.01 | -6.21 | 10.85 | 0.57 | -0.14 | 0.21 | -0.23 | -0.16 | 0.04 | 0.04 | 1.00 |

Table 4 presents estimated regression models, from number 1 to number 4, in which the dependent variable is the firm's innovative performance. The Chi-square test value (Wald chi$^2$) is higher as it advances from the first to the fourth model, indicating that the inclusion of the linear term and the quadratic term of the variable exploration increases the explanatory power of the models. Model 1 shows the relationships between the control variables and innovation performance. The firm size and intensity of R&D investments positively affect its innovation performance, while the firm's patent stock and experience in developing patents were not significant.

As for the variable firm size, as it is defined in a logarithmic form it allows interpreting it as the elasticity between firm size and the capacity to develop patents. Although positive, the coefficient is marginally significant and much smaller than 1 (0.05), thereby indicating that the number of patents increases if the firm is bigger, but in a less proportional manner. This result is very similar to that found by Gilsing, Nooteboom, Vanhaverbeke, Duysters and van den Oord (2008) which state that smaller firms are more likely to develop exploratory patents. The positive and significant relationship of the variable R&D intensity corroborates the theoretical importance of the firm's current knowledge base in the identification and assimilation processes of technological opportunities.

**Table 4**
**Binomial regressions explaining innovative performance**

| | Dependent Variable: Number of Patents | | | |
|---|---|---|---|---|
| | **Model 1** | **Model 2** | **Model 3** | **Model 4** |
| R&D Intensity | 0.002***(0.001) | | | |
| Patent stock | -0.003(0.002) | | | |
| Firm Experience | -0.020 (0.015) | | | |
| Co-patents | 0.002 (0.008) | | | |
| Firm sales volume | 0.051* (0.022) | | | |
| Exploration | | 0.426*** (0.092) | 0.348*** (0.100) | 0.365*** (0.102) |
| Exploration squared | | | -0.756* (0.331) | -0.717* (0.333) |
| Absorptive Capacity (Herfindahl index _firm) | | 0.275** (0.100) | 0.290** (0.101) | 0.299* (0.123) |
| Exploration X Absorptive Capacity | | | | 0.245 (0.315) |
| Exploration squared X Absorptive Capacity | | | | 0.214 (1.050) |
| Years (*dummies*) | SIM | SIM | SIM | SIM |
| Constant | 0.392* (0.187) | 0.211 (0.193) | 0.483* (0.227) | 0.495* (0.228) |
| N | 1.725 | 1.725 | 1.725 | 1.725 |
| II | -2932.757 | -2921.965 | -2919.336 | -2918.953 |
| Wald chi$^2$ | 333.386*** | 364.901*** | 369.367*** | 370.099*** |

+ p<0.10, * p<0.05, **p<0.01, ***p<0.001

Hypothesis 1 states that the exploration activity has a positive effect on the firm's innovative performance – but it also suggests that this effect is negatively affected after the point when the risks and costs involved in this activity outweigh the benefits it provides, characterizing a curvilinear relationship. Plotting results shows this relationship in the graph of Figure 2.

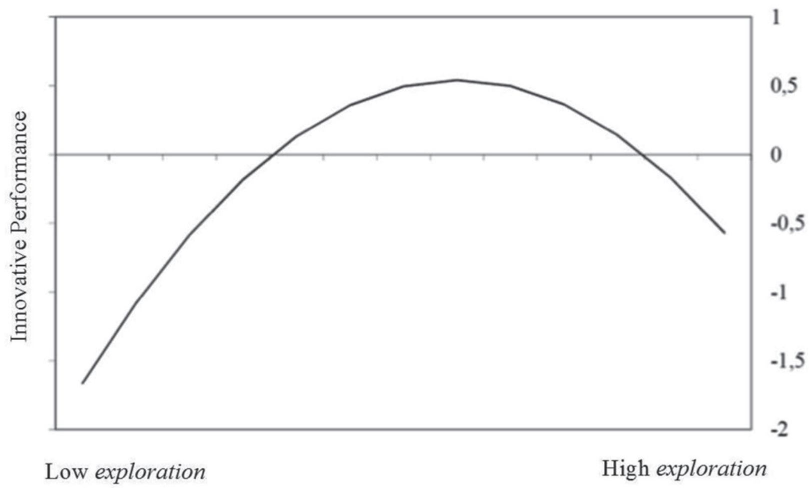


**Figure 2.** Relationship between exploration and innovative performance

The positive part of the curve was strongly supported by the positive and significant coefficients found in model 2 (0.426, $p<0.001$), in model 3 (0.348, p<0,001) and in model 4 (0.365, $p<0.001$). The negative part of the curve was also confirmed by the negative and significant coefficients representing the quadratic term of the exploration strategy, in model 3 (-0.756, $p<0.10$) and in model 4 (-0.717, $p<0.10$). The full curve shown in Figure 2 captures the relationship between the exploration strategy and number of patents developed by the firm. As the strategy intensifies, the number of patents will undergo a decreasing marginal effect. Therefore, hypothesis 1 cannot be rejected.

Although AC was only analyzed based on its moderating effect on the second hypothesis, it should be noted that AC, as a linear term, is also seen as a variable that positively affects innovative performance. The coefficients representing this relationship are positive and significant, as shown in model 2 (0.275, $p<0.01$), in model 3 (0.290, $p<0.01$) and in model 4 (0.299, $p<0.05$). The directions and significance of the coefficients of variables in this study are stable in the models presented, indicating the robustness of the results.

Hypothesis 2 postulates that the organizational absorptive capacity exerts a moderating effect on the relationship between the firm's exploration activity and innovative performance. The estimate in this specific context suggests that the more consistent the firm's capacity is to identify and assimilate the potential of new knowledge, the longer the positive segment of the curvilinear relationship will be, as mentioned in hypothesis 1. Hypothesis 2 was rejected as its result – in model 4 – did not exhibit statistical significance, in terms of the interaction between the independent variable (linear and quadratic) and the moderating variable. This finding will be analyzed in detail in the discussion of results.

## 5 Discussion and implications

This study investigates the role of strategy exploration in the firm's innovative performance considering not only its implementation, but also its application level. In this context, it also investigates the consequence of this knowledge absorptive capacity. In this approach, some important empirical results associate the theory of open innovation and the firm's knowledge based view, especially the absorptive capacity (AC) theory.

First, open innovation, recognized as a process that can access new knowledge within and beyond the organizational boundaries of the firm, provides advantages and disadvantages. The exploration strategy exemplifies the open model and allows the firm to access new knowledge. Combinations and recombination of knowledge can emerge from this access, which can lead to increased innovation performance. However, high levels of exploration involve search and coordination costs – and these costs can undermine returns provided by this strategy, making it disadvantageous. This scenario reflects the initial findings of this research and describes the first hypothesis. When hypothesis 1 is not rejected, it indicates the complexity of the firm's innovation activities and establishes considerable challenges in its management.

The exploration strategy in the context of open innovation assumes collaborative relationships with several organizations. Therefore, the challenges faced by the organization involve the manager's capability to know how to establish the optimal range of partnerships. The critical indicator here is that the exploration strategy should not be a tool to "find and copy" research models of other organizations. There are two important work lines for the manager: a) to align the activities that explore new knowledge and those that exploit the firm's current knowledge; b) to construct a portfolio of alliances aligned with the firm's business model and its technology expansion plans.

Secondly, it confirms the importance of the firm's knowledge based view, especially the absorptive capacity (AC) theory. This theoretical approach attributes critical importance to the firm's current knowledge base. It is this stock of knowledge that allows new knowledge to be identified, assimilated and combined. Although it was not proposed as a hypothesis, all regression models incorporated and confirmed the positive effect of AC on innovative performance. In practical terms, the firm's AC is usually an attribution of the organization's R&D. This perception is completely aligned with the seminal theory of AC (Cohen & Levinthal, 1990). As a result, the firm's R&D field is not only able to develop the organization's knowledge base, but can also identify technological opportunities that can arise within and outside the firm. This condition can only be achieved if that field receives systematic investments from the organization's senior management.

The discussions mentioned in the above two paragraphs, although they bring important contributions, have already been widely discussed in literature. Nevertheless, they are fundamental to introduce and expand the discussion that addresses the effectiveness of AC in the search process for new knowledge. Therefore, the focus is not on discussing the overall positive impact of AC on the firm's innovation strategy. We discuss here the second hypothesis of this article, which predicted more specifically that the AC automatically enhances the innovative performance by optimizing the exploitation of new knowledge. In other words, AC assists the organization's management to define the diversity of partnerships.

Hypothesis 2 proposed that high AC levels could not definitely prevent, but could delay the negative effects caused by the research and coordination costs required by high exploration levels. This delay would give the firm the conditions to be more effective to explore new knowledge, while neutralizing part of these costs. This neutralization could occur either by the capacity to quickly understand a greater volume of new knowledge, or by the capacity to choose and understand only the volume of strictly necessary new knowledge. However, in this article this theoretical condition was not empirically confirmed. Then, with the rejection of hypothesis 2, we discuss here the organizational factors and dimensions of AC that may have influenced this result, which were unexpected.

Although not expected, this result already appeared when the correlation matrix showed only a moderate coefficient between AC and the size of the firm. The correlation coefficient between firm size and performance in the regression model 1 – although positive – was also quite modest. The moderate size of this coefficient contradicts the theoretical notion that a firm's AC is higher when the systematic investments in qualified personnel, facilities and research equipment in the R&D field are higher. Therefore, it was expected that firm size was highly correlated to AC, since all 275 sample firms are publicly traded firms. This attribute usually indicates they are large and financially powerful firms. Such firms can usually afford these R&D investments.

Accordingly, the first fact mentioned in this discussion that may explain the rejection of hypothesis 2 is that, in many cases, sample firms develop exploration because of their financial power. The high rate of exploration identified in the correlation matrix – and confirmed by the coefficients in the regressions models 2, 3 and 4 – monitors the competitive environment. At the first promising sign of a technological opportunity, the large firms in the sample license the new knowledge developed by the smaller innovative firms. This licensing occurs through alliances or because the large firms end up fully acquiring the smaller ones. In this context, therefore, although AC continues to act as a "tracking system" of potential opportunities, it may become less important than the financial capacity. This conclusion is supported in the empirical study of Hoang & Rothaermel (2010). This study emphasizes the fact that small biotechnology firms are more agile in developing innovations, however, many of them license their discoveries to large pharmaceutical firms.

Another important fact and also complementary to the first one can be identified if the concepts of upstream capabilities and downstream capabilities in the firm's chain are understood. Accordingly, two theoretical views are connected here: reviewing the AC concept itself – highlighting its two dimensions: potential and realized (Zahra & George, 2002) – and the concept of different skills and competences throughout the firm's value chain (Bruyaka & Durand, 2012). The connection of the two theoretical views can identify the potential AC at the beginning of the chain and the realized AC at the end of the chain. The skills of the first one include the acquisition and assimilation of knowledge. These skills account for the firm's capacity to absorb technological opportunities. These opportunities are raised by the exploration strategy. The skills of the second one include the transformation and exploitation of knowledge, making it applicable for distribution and marketing.

As already mentioned, in this article, focus is on potential AC skills at the beginning of the value chain. However, the effects of realized AC on the potential AC cannot be removed from analysis. Although located in different points, they are absolutely complementary, or should be. In other words, especially in sectors such as the goal of this study, the flow of new knowledge would be effective from the beginning to the end of the chain, aligning the activities in order to identify, select and develop the accessed knowledge. However, the relationship between the two dimensions of AC is not linear. In the various development stages of a biopharmaceutical product, there are those that include testing and retesting activities. These routines often determine the product should return to the previous stages to go through revisions and adaptations. Thus, it is reasonable that there are misalignments between the two AC dimensions. For example, potential AC can acquire and assimilate a technology at the beginning of the chain, which prompts a rupture process of the competencies and skills of transformation and exploration, established by the realized AC at the end of the chain. The consequence of this type of scenario were well explained by Chesbrough & Crowther (2006) and exemplified by Chesbrough (2003; 2006) which cited the case of Dow Chemical in which 25% of its patents in 1993 did not reach the marketing stage.

Thus, considering the 275 firms in the sample, we emphasize that, in the industry studied, large firms are characterized by having well-established and mature distribution and marketing structures (downstream capabilities). Therefore, the perception developed here is that potential AC – emphasized in this article – must undergo internal pressures imposed by the firm's business model. This is the second fact that helps understand the rejection of hypothesis 2. These pressures eventually diminish the effect that the potential AC could have on the relationship between the firm's exploration and its innovative performance. This type of phenomenon has been tested and is empirically supported in the study of Kapoor & Klueter (2015). According to these authors, the pressures are called "inertial pressures", imposed, among other factors, by the fact that the individual who performs the research is not the same one who decides whether it will continue.

The set of arguments in the preceding paragraphs validates the importance of open innovation, especially in dynamic sectors such as the biopharmaceutical sector. The strategy of looking for new knowledge from formal and informal relationships with other organizations and individuals enables the firm to increase the number of patents, but this also generates costs. The two absorptive capacity dimensions acting in alignment can neutralize some of these costs. If the potential AC acquires and assimilates a new technology, the realized AC should carry out its transformation and exploitation. If this technology is disruptive, the gains will be proportionate to the risks and may even be monopolistic.

However, if the business model of the firm is imposed, it is then likely that the potential AC is not strictly fulfilling its role and is therefore not perceived as such. A likely consequence of this situation is the number of patents that remain "on the shelf" of the firm. If the potential AC is operated as a moderator of the exploration strategy, even if a new patent does not suit the firm's business model, it will not remain on the shelf. Even prior to acquiring it, the firm will know the partner it can be licensed to. This is the open innovation concept.

## 6 Final considerations

Particularly in dynamic environments, firms have already recognized the importance of open innovation. They recognize that the R&D field does not necessarily have to be within the firm. Thus, these firms will concentrate their efforts on the exploration strategy. To better understand how this process takes place, this study examined the effect of this strategy on innovation performance, when it reaches high investment levels. It also examined the moderating role of the firm's absorptive capacity (AC) in this relationship.

In general terms, this article advances the understanding of the open innovation strategy and the absorptive capacity theory. Unlike previous studies, this study contributes to understanding that AC will not moderate the relationship between exploration and performance in all contexts. The positive moderating effect depends on some important aspects. Therefore this study suggests that AC cannot be understood as a sole and autonomous capacity, located only in the R&D field. AC comprises two interdependent dimensions, as proposed by Zahra & George (2002). Between these two dimensions there are important trade-offs at the cognitive and spatial level. At the cognitive level, the synchronicity of exploring the new knowledge and the firm's current knowledge requires investment alignments and adjustments. At the spatial level, the synchronicity of different competencies and skills at different points of the firm's value chain requires integration and coordination. In short, at the strategic level, the relationship between the two AC dimensions should be complementary, not a substitute. Otherwise, one sabotages the other, weakening their functions in the firm's innovative processes.

Addressing these issues is the responsibility of the organization's senior management. Consequently, these findings also provide managerial implications. The average results reported by the sample firms show that 60% of the citations that involve the patents developed by the firm are citations from technology fields that are new to the firm. However, the degree of dispersion of technology fields of the patents produced by the firm is 50%. This suggests that management can increase its innovative performance if it achieves higher levels of the degree of dispersion of technology fields dominated by the firm, which means increasing its potential AC. But not without first establishing clear strategic policies that define the firm's technology expansion plan and the role of potential AC to achieve these goals. And finally, although this measured dispersion level is related to the potential AC at the beginning of the firm's value chain, it can and should be encouraged by the realized AC at the end of the firm's value chain, because as stated earlier, both are absolutely interdependent.

This study also has some limitations. Firstly, the sample includes only firms from the biopharmaceutical sector. Incorporating other equally dynamic sectors – for example, nanotechnology and conductors – could yield the statistical model a greater explanation and comparison scope. Secondly, the AC approach considered only potential AC. The conjecture of an ideal setting between the two AC dimensions, as being complementary to each other, indicates the addition of the realized AC. For example, the realized AC could be measured as the degree of dispersion of the markets served by the firm. Finally, the types of partnerships developed by the firm were not taken into consideration. Future studies could examine whether AC has different levels of moderation when the firm cooperates with different partners such as universities and suppliers.

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|---|---|---|---|
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