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Does a cluster promote innovation and productivity in its firms?[1]

Um *cluster* promove inovação e produtividade em suas empresas?

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Abstract

Objective: The fierce competition in a globalized market forces firms to adopt innovative strategies to obtain a competitive advantage over their competitors. However, innovating is a difficult task to accomplish in isolation. One way to mitigate this isolation is to separate organizations into sectoral clusters, facilitating the search for innovation and productivity. From this perspective, this research aims to compare the relationship between innovation performance (IP) and the productivity of Brazilian firms, considering whether they are inserted into clusters or not, and analyze their implemented internal and external research and development (R&D) strategies.

Originality/value: This article expands the literature's understanding of open innovation, testing the complementary role of internal and external R&D for the implementation of innovation in firms using a relevant contextual condition: their presence or absence in a cluster. The study helps to enhance the understanding of several mechanisms by which the cluster helps to promote innovation and productivity.

Design/methodology/approach: To test the hypotheses, the study used multigroup structural equation modeling in a sample of 5,581 companies, with 1,878 cluster participants and 3,703 non-participants.

Findings: The results support a positive impact of both external and internal R&D on IP and support the notion that IP, regardless of whether or not the firm is part of a cluster, positively impacts its productivity. The external and internal R&D, in turn, proved to be complementary only for companies inside a cluster.

Keywords: cluster, innovation performance, productivity, R&D, absorptive capacity

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Resumo

Objetivo: A acirrada competição em um mercado globalizado obriga as empresas a adotarem estratégias inovadoras para obter vantagem competitiva sobre seus concorrentes. No entanto, inovar é uma tarefa difícil de realizar isoladamente. Uma forma de amenizar esse isolamento é separar as organizações em *clusters* setoriais, facilitando a busca por inovação e produtividade. Nessa perspectiva, esta pesquisa tem como objetivo comparar a relação entre o desempenho de inovação e a produtividade das empresas brasileiras e, especificamente, se elas estão inseridas em *clusters*, considerando suas estratégias de pesquisa e desenvolvimento (P&D) interno e externo implementadas.

Originalidade/valor: Este artigo expande a compreensão da literatura sobre inovação aberta, testando o papel complementar do P&D interno e externo para a implementação de inovação em empresas usando uma condição contextual relevante: sua presença ou não em um *cluster*. Assim, o estudo ajuda a aumentar a compreensão de uma série de mecanismos pelos quais o *cluster* ajuda a promover a inovação e a produtividade.

Design/metodologia/abordagem: Para testar as hipóteses, o estudo utilizou modelagem de equações estruturais multigrupo em uma amostra de 5.581 empresas, com 1.878 participantes de um *cluster* e 3.703 não participantes.

Resultados: Os resultados suportam um impacto positivo de P&D externo e interno no desempenho da inovação e sustentam a noção de que o desempenho da inovação, independentemente de a empresa fazer ou não parte de um *cluster*, impacta positivamente na sua produtividade. Por outro lado, P&D externo e interno mostraram-se complementares apenas para empresas dentro de um cluster.

Palavras-chave: *cluster*, desempenho de inovação, produtividade, P&D, capacidade absortiva

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INTRODUCTION

The effectiveness of industrial clusters as promoters of innovation and performance for firms has recently been questioned because the digital transformation has made the diffusion of knowledge much more accessible over long distances. Porter (1998) highlighted how easy it had become for firms to obtain resources, such as capital, technology, and inputs, among others, with just one mouse click. Besides, globalization implies that most firms can compete for consumers worldwide, regardless of the physical distance (Levitt, 1993). However, successful clusters do not let the literature neglect the strategic importance of location and proximity for some industries. Some of these examples are the leather industry in Italy; the wine cluster in California (Porter, 1998) and textile companies in North and South Carolina, in the United States; and automotive companies in south Germany (Levitt, 1993). What do these success stories have in common? Are location and proximity factors that influence the achievement of a competitive advantage by these firms in a globalized market?

According to Porter (1998), a cluster is the geographic concentration of companies from the same industry, related industries, and other support institutions (for example, research centers, universities, and government support agencies). Aside from being physically close to one another, these organizations have similar goals and participate in a system that allows competition and simultaneous cooperation (Nalebluff et al., 1996) in search of the development of productive, innovative, and commercial capacities to stand out in national and global markets.

Many successful and well-known clusters exist. Silicon Valley is known worldwide for the generation of new technologies and counts on the presence of major companies, such as Google and Apple (Souza, 2019). Among its most striking features, the Boston biotechnology cluster has more than 80 academic centers to support research and provide the necessary human resources for the firms installed in that location (Cluster Mapping, 2019). Beyond the borders of the United States, we will mention three additional technology clusters: London, Israel, and, more recently, Paris, the latter of which started in 2013 (Ragalado, 2013).

Firms in clusters can achieve competitive advantage by participating in an innovative environment, fostering their innovativeness (Mascena et al., 2013). Developing innovation activities is an arduous task for organizations. It usually requires high investments, high-risk activities, and increased management costs to monitor activities and measure their results. Collabo-

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ration strategies are alternatives to face these challenges (Schilling, 2017). They are boosted by being situated in a cluster environment that facilitates proximity to research institutes, universities, competitors, suppliers, specialized labor, and other relevant knowledge sources for innovation (Porter, 2000). This proximity increases specialization and quality (Porter, 2000), formal and informal exchanges (Ozer & Zhang, 2015) that expedite knowledge transfer (Eisingerich et al., 2010; Guo et al., 2020), and trust among participants (Ozer & Zhang, 2015).

Silicon Valley, for instance, promotes a strong relationship network between participants (Saxenian, 1994). It encourages the necessary opening to discuss the problems common to all stakeholders and seeks joint solutions, allowing the community's interest to surpass the individual interests of each firm (Saxenian, 1994). In China, technological learning and participants' knowledge spillovers boost the emergence of successful clusters (Guo & Guo, 2011; Guo et al., 2020). These arguments indicate that participation in clusters is still a condition that improves firms' innovativeness and competitive advantage.

The literature has explored the relationship between firms' participation in clusters and innovation. Several authors state that clusters incentive the development of internal R&D capabilities (Eisingerich et al., 2010; Porter, 1998) and, consequently, provide more innovative firms (Bittencourt et al., 2019; Lai et al., 2014), which, usually, achieve higher productivity and performance (Greco et al., 2021; Griffith et al., 2006; Paula & Silva, 2019). Some of the reasons are related to resource and knowledge trades between competitors stimulated by the proximity (Castro, 2015; Ozer & Zhang, 2015), evidencing how such arrangements promote open innovation (Chesbrough, 2003). However, other studies focus on some problems caused by clusters – such as excessive resource redundancy (Boschma, 2005; Presutti et al., 2019) and misappropriation of innovation by firms other than the innovator, caused by unintended knowledge spillovers (Cassiman & Veugelers, 2006) – to justify that they can be detrimental to innovative efforts. Despite this divergence in academia, there is a lack of empirical studies comparing the relationship between open innovation activities, innovativeness, and performance of firms participants and non-participants of clusters. This study intends to fill this gap by answering the following research question: to what degree does participation in an industrial cluster influence the relationship between a firm's innovation activities (especially R&D), innovation performance (IP), and productivity?

The article's contribution is twofold. Regarding the innovation management theory, it extends the understanding of open innovation by testing

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some of its mainstream theories using a new contextual condition: the firm's presence in a cluster. These theories are based on the strategic alliances' literature (Gulati, 1998; Powell et al., 1996; Zaheer et al., 2010), which discusses the positive influence of external knowledge sources for collaborating with different partners on the innovation outputs (Hagedoorn, 1993; Hagedoorn & Wang, 2012; Oerlemans et al., 2013) and on the absorptive capacity literature (Cohen & Levinthal, 1990; Zahra & George, 2002), which reinforces the existence of complementarity between external knowledge (from strategic alliances) and internal knowledge (mainly from R&D) (Cassiman & Veugelers, 2006; Paula & Silva, 2018a). For the cluster literature, in turn, the contribution is that, beyond the already recognized influence of the presence in clusters to improve innovation (Eisingerich et al., 2010; Ozer & Zhang, 2015; Mascena et al., 2013) and financial performance (Nalebluff et al., 1996; Newlands, 2003; Porter, 1998, 2000; Saxenian, 1994), this study helps to understand specific mechanisms through which the cluster helps to promote innovation and productivity.

The structure of the article is as follows: it starts with a literature review, presenting the concepts and theories concerning open innovation activities, IP, productivity, and the influence of the cluster, proposing the theoretical model and hypotheses to answer the research question. Next, the method section describes the data source and the constructs' rationale and explains the statistical methods used. Then, we present the results, followed by the discussion section, and, finally, the conclusions, including the study's contributions, limitations, and suggestions for future research.

LITERATURE REVIEW

Internal and external R&D and innovation performance

A firm's R&D can be carried out within walls (also called internal R&D) or outside its boundaries by its partners, technology suppliers, or absorbed from knowledge spillovers from other organizations (all of which are called external R&D). The contemporary open innovation approach (Chesbrough, 2003) presupposes that integrating both internal and external R&D is fundamental to succeed (Cassiman & Veugelers, 2006; Paula & Silva, 2018a). According to Berchicci (2013), external R&D refers to an organization's exposure to external partners, allowing the outsourcing of R&D projects and technologies. It can take different forms, including contracts, strategic

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alliances with other firms, partnerships with universities, among others (Fey & Birkinshaw, 2005).

External R&D has a substantial impact on IP. In accordance with Chesbrough (2003), a firm would not innovate, whatever the intended type is, without using external knowledge. Currently, the technologies are complex and demand multiple partnerships with different types of partners that have the complementary resources needed to succeed in the innovation process (Cobeña et al., 2017, 2019). Among the main benefits expected by firms that perform external R&D activities, there is diluting the risks and costs of R&D activities, facilitating the transfer of tacit or codified knowledge from partners, and having access to complementary assets and capacities that are hard to develop internally (Faems et al., 2005).

Internal R&D, in turn, is a set of learning-oriented activities conducted within walls (i.e., the development of scientific knowledge, learn-by-doing, R&D training) that accumulate knowledge and technological capabilities (Bell & Figueiredo, 2012; Malerba, 1992), which are the basis of innovation. Furthermore, it can also produce the necessary expertise to better take advantage of the innovation opportunities outside the organization's boundaries (Hagedoorn & Wang, 2012). This capability is referred to in the literature as absorptive capacity (AC) (Cohen & Levinthal, 1990; Zahra & George, 2002). Bell and Figueiredo (2012) discussed the rationale for developing AC, stating that a complementary relationship between internal and external learning activities is based on two steps: in an *ex-ante* moment, internal learning efforts are necessary to form the knowledge base required to acquire external knowledge. Subsequently, similar efforts are needed to ensure effectiveness in absorbing the knowledge gained outside the walls. According to this rationale, internal R&D investments are necessary to improve the firm's AC.

Reinforcing these arguments, Kim (1997) stated that AC consists of two dimensions: the accumulated internal knowledge and the continuous learning effort (Kim, 1997). Developing these two items increases the firm's capacity to identify, assimilate, and apply external knowledge (Cohen & Levinthal, 1990). Several studies have used investments in internal R&D as a proxy for AC, mainly reflecting the continuous learning effort dimension (Belussi et al., 2010; Berchicci, 2013; Cohen & Levinthal 1990). Regarding the dimension of accumulated internal knowledge, some proxies are employees' level of education (Berchicci, 2013; Paula & Silva, 2018a) and patent stock (Dushnitsky & Lenox, 2005a, 2005b; Vanhaverbeke et al., 2015).

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Innovation performance and productivity

According to Rattner (1967), productivity is the relationship between inputs and outputs and relates from the firm level to the level of the global economy. Increasing productivity means increasing the value added to a firm's production resources, which is closely associated with the growth of the monetary production of a worker (King et al., 2014).

Several studies have investigated the relationship between R&D efforts, IP, and productivity at the firm level (Griffith et al., 2006; Paula & Silva, 2019). Innovation, especially open innovation, is crucial for improving organizational performance due to a direct and measurable increase in productivity (Greco et al., 2021). Process innovation is the first innovation type commonly related to improvements in productivity (Paula & Silva, 2019). In many cases, it lowers the product or service costs by improving the productive process (Moutinho et al., 2015). According to Findik and Beyhan (2017), process innovation improves production reliability and quality, adding value to customers. Additionally, it increases production flexibility and capacity, reduces labor costs and improves work health and safety conditions. Similarly, product innovation generates the need to adapt the production process to new product lines (Utterback & Abernathy, 1975). Corroborating these ideas, Dabla-Norris et al. (2012) identified that firms that innovated by changing their product line or by adopting a new technology managed to increase their productivity by 8% when compared to firms that did not innovate. Moreover, Aldieri et al. (2021) found evidence that all types of innovation (product, process, organizational, and marketing), individually and conjointly, improved productivity in Italian manufacturing firms.

The influence of the cluster on a firm's open innovation activities

The innovation management literature recognizes that clusters are influential factors in firms' innovative capacity. Inhan et al. (2013) described several types of innovation that entrepreneurs stated they developed due to their insertion in a cluster. Among the most important ones, it was the launch of new products and innovations in their production processes. This innovativeness happened because firms that are part of clusters tend to have better conditions to develop their internal R&D capabilities, as they usually have access to more specialized and productive employees (Porter, 1998), which leads to the opportunity to attend the best universities and work in

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the best companies in a competitive environment and having the chance to be more productive. Local customers tend to be more sophisticated and demanding (Porter, 2000), naturally selecting more innovative firms to survive in this environment. Besides more advanced internal innovative capabilities, these firms benefit from more fluent knowledge flows inside clusters (Eisingerich et al., 2010), both intentional and non-intentional. The latter of these is called knowledge spillovers (Cardamone, 2018; Cassiman & Veugelers, 2002). Deliberate knowledge exchange between firms is facilitated by their proximity, according to Ozer and Zhang (2015). The authors stated that firms in a cluster tend to develop a common identity and a sense of belonging that encourages participation in industry events and the development and sharing of common tools, language, and business standards. The cluster also generates trust and reciprocity that facilitates information sharing and improves innovation.

Furthermore, Castro (2015) highlighted that combining complementary knowledge of different actors is a stimulus to innovation in clusters. According to this study, innovation in clusters is also the result of the dynamics of peer interaction, which enables collaboration even in diverse and ambiguous environments. Per this argument, Bittencourt et al. (2019) stated that clusters generate more innovative companies. According to Lai et al. (2014), clusters influence IP in daily activities by bringing together similar sectors, attracting talents, and promoting information sharing that improves operational performance. These organizational formats also foster interaction between schools, the government, and upstream and downstream companies, generating knowledge and promoting innovation. Proximity, shared goals, and a sense of belonging encourage more competition in the network of institutions inside a cluster (Nalebluff et al., 1996; Ozer & Zhang, 2015; Saxenian, 1994).

Regarding non-intentional knowledge spillovers, firms in clusters can watch rivals more closely and learn about new product features, designs, and marketing efforts (Ozer & Zhang, 2015). The proximity this arrangement promotes allows knowledge spillovers as a result of the increase in information circulation (Acs et al., 2017), employees' job mobility (Fernandes & Ferreira, 2013), and leaked knowledge, due to collaboration with cluster partners (Cassiman & Veugelers, 2002). The effect of these knowledge spillovers in clusters is associated with firms' positive IP (Cardamone, 2018). In addition to knowledge exchanges, geographical proximity can facilitate the development of joint projects to share costs and risks, especially for small and medium-sized enterprises (SMEs), which usually lack resources (Kapetaniou & Lee, 2019).

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However, some studies present a different point of view. Although there are clear advantages of the geographical proximity promoted by the clusters, there are some negative aspects. Too much geographical proximity may provoke an excessive redundancy of resources from too similar firms, causing lock-in problems (Boschma, 2005; Presutti et al., 2019). On the contrary, partnerships with firms from other places, especially other countries, can add value by allowing access to new markets, with the local partner helping to adapt products and services to local demands (Beers & Zand 2014; Garcia Martinez et al., 2017, 2019; Zhang et al., 2020). Geographically distant partners also bring more diverse knowledge that is possibly unavailable in the firm's location (Ardito et al., 2019).

Considering the contradictory arguments in favor and against proximity, some authors advocate that the relationship between partners' geographical proximity has an inverted-U shape (Boschma, 2005; Leeuw et al., 2014). In the lower levels, the lock-in effect happens; in the higher levels, the firms are so distant that the costs of management and coordination of this relationship are too high. Alternatively, an average level of proximity would be ideal.

Consequently, innovativeness is no guarantee of improvement for firms in a cluster. It is contingent on several variables, one of the most important being the firm's AC (Beers & Zand, 2014; Kapetaniou & Lee, 2019; Leeuw et al., 2014; Presutti et al., 2019). As it corresponds to the ability of the firm to identify, absorb, use, and exploit external knowledge (Cohen & Levinthal, 1990; Zahra & George, 2002), it defines how effectively the knowledge flows from external sources to the firm both in the case of intentional cooperation and knowledge spillovers (Aldieri et al., 2018). Giuliani and Bell (2005), studying the knowledge flows inside a Chilean wine cluster, found that firms with a higher AC level can develop more links to exchange knowledge with other firms from the cluster. According to several authors, AC is strongly related to the firm's intensity of efforts and accumulated knowledge in R&D (Cohen & Levinthal, 1990; Kim, 1997). This correlation between internal R&D and AC indicates a complementarity of internal and external sources of knowledge (Cassiman & Veugelers, 2006; Paula & Silva, 2018a).

Some of these arguments reveal that firms in clusters have better conditions to develop internal R&D, which would increase their AC. In parallel, they would be more exposed to external knowledge than firms that are not part of clusters, indicating a stronger positive relationship between external R&D, internal R&D, and IP. Other arguments, however, contradict these affirmatives by considering that geographical proximity is detrimental to

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innovation. Nevertheless, one consensus is that the AC helps to improve IP in this context. Considering the arguments just mentioned, this study defends the positive influence of clusters in the relationship between R&D and IP. Thus, we propose the following hypotheses:

- H1: The positive influence of a firm's external R&D on its IP is more intense for clustered firms than for the non-clustered ones.
- H2: The positive influence of a firm's internal R&D on its IP is more intense for clustered firms than for the non-clustered ones.
- H3: A firm's internal R&D positively moderates the impact of external R&D on IP more intensely in clustered firms than in non-clustered ones.

Similarly, clustered firms should feel the effect of innovation on productivity more strongly. Gaining competitive advantages usually increases productivity as it means an increase in revenues most of the time. Many authors suggested that clusters are sources of competitive advantage (Perry, 2005; Porter, 1990, 1998; Powell, 1987; Schmitz & Nadvi, 1999). There are several possible explanations for this relationship. Firms inside clusters tend to cooperate more, providing complementary resources and capabilities that bring competitive advantages. Additionally, the proximity increases the interfirm trust, which lowers transaction costs (Newlands, 2003). Considering these arguments, we formulate the following hypothesis.

- H4: The positive influence of a firm's IP on its productivity is more intense for clustered firms than for the non-clustered ones.

Figure 1 presents the conceptual model proposed in this paper, which contains all the hypotheses.

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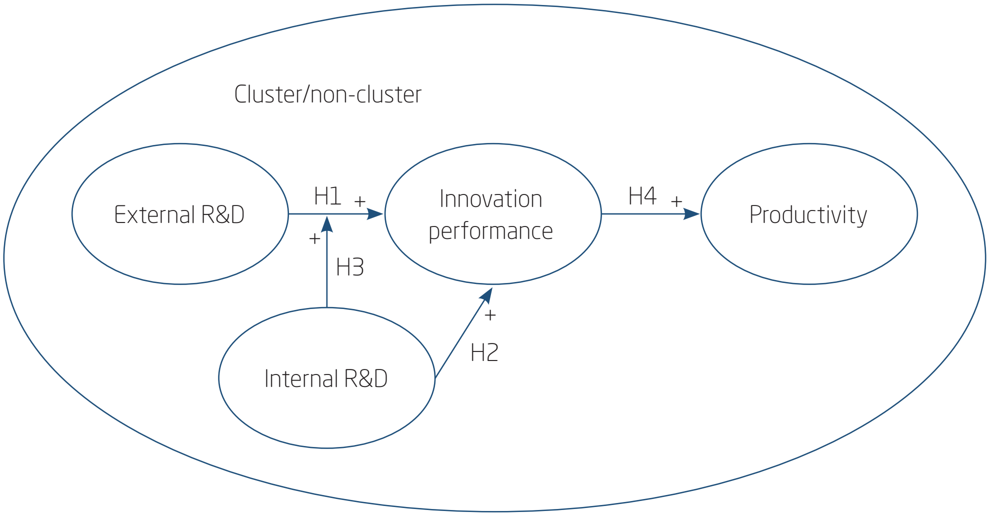
Figure 1
Conceptual model



Source: Elaborated by the authors.

METHOD

Data source and sample

This study used data from the Brazilian Technological Innovation Survey (Pesquisa de Inovação Tecnológica – Pintec) of 2014 (Instituto Brasileiro de Geografia e Estatística – IBGE, 2019a) and the Annual Industrial Survey (Pesquisa Industrial Annual – PIA) of 2014, 2015, and 2016 (IBGE, 2019b). Pintec 2014 investigated R&D, innovation activities and outcomes of Brazilian firms in the period between 2012 and 2014. Productivity was calculated using variable indicators from PIA 2014, 2015, and 2016. It enabled us to have data from productivity with a two-year lag compared to innovation and R&D data. We used this lag because previous studies indicated that some time is needed for R&D and innovation activities to influence IP, as inventions created by combinations of internal and external knowledge achieved by R&D activities need to mature to become new products and services ready to reach the market with success (Paula & Silva, 2018b). To identify if the firm participated in a cluster or not, we used the employee numbers data from firms and cities from the Annual List of Social Information

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(Relação Anual de Informações Sociais – Rais) of 2019 (Ministério do Trabalho, 2020) to calculate a dummy variable described in the next section.

The sample consisted of 5,581 Brazilian manufacturing firms that introduced product or process innovation from 2012 to 2014, had abandoned or suspended projects during this period or had an ongoing innovation project by the end of 2014. The sample was split into two groups: cluster, which aggregated 1,878 firms that participated in an industrial cluster, according to a method shown in the next section, adapted from Britto and Albuquerque (2000); and non-cluster, which aggregated 3,703 firms that were not part of a cluster.

Description of the variables

The model tested in the study was composed of external R&D, internal R&D, IP, productivity, and a moderation variable cluster, which will split the sample into two groups to train a multigroup structural equation modeling (SEM). Table 1 illustrates the variable definitions, calculations, and sources.

Table 1

Variables list

Construct	Proxy	Format	Year	Source
Moderation variable	Cluster	0 – no; 1 – yes.	2014	Rais 2019 (Ministério do Trabalho, 2020)
Internal R&D	PercSpenndR&D	R&D expenses/total revenues.	2014	Pintec 2014 (IBGE, 2019a)
	PercSpendTrain	Training expenses/total revenues.	2014	Pintec 2014 (IBGE, 2019a)
	PercEmpR&D	Employees in R&D/total employees.	2014	Pintec 2014 (IBGE, 2019a)
	EducR&D	(No. PhD * 3 + No. Msc * 2 + No. graduated) /total employees.	2014	Pintec 2014 (IBGE, 2019a)
Innovation performance (IP)	IProd	0 – no; 1 – yes.	2014	Pintec 2014 (IBGE, 2019a)

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Table 1 (conclusion)

Variables list

Construct	Proxy	Format	Year	Source
Innovation performance (IP)	InnovExt	0 – it did not introduce innovation; 1 – innovation to the firm; 2 – innovation to the country; 3 – innovation to the world.	2014	Pintec 2014 (IBGE, 2019a)
	InnovRad	0 – it did not introduce innovation; 1 – incremental innovation; 2 – radical innovaton.	2014	Pintec 2014 (IBGE, 2019a)
	PercRevInnov	Sales of new products/total sales.	2014	Pintec 2014 (IBGE, 2019a)
External R&D	Cli (importance)	0 – not used; 1 – low; 2 – medium; 3 – high.	2014	Pintec 2014 (IBGE, 2019a)
	Supp (importance)	0 – not used; 1 – low; 2 – medium; 3 – high.	2014	Pintec 2014 (IBGE, 2019a)
	Comp (importance)	0 – not used; 1 – low; 2 – medium; 3 – high.	2014	Pintec 2014 (IBGE, 2019a)
	Consult (importance)	0 – not used; 1 – low; 2 – medium; 3 – high.	2014	Pintec 2014 (IBGE, 2019a)
	Univ (importance)	0 – not used; 1 – low; 2 – medium; 3 – high.	2014	Pintec 2014 (IBGE, 2019a)
Productivity	Productivity	Average of 2014, 2015, and 2016's total revenues/total employees.	2014, 2015, and 2016	PIA 2014, 2015, and 2016 (IBGE, 2019b)

Source: Elaborated by the authors.

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External R&D and IP are reflective constructs. The model represents them as latent variables reflected by their proxies. Internal R&D, which also represents AC, was considered formative. According to Kim (1997), two conditions are necessary to AC, forming and not reflecting this concept: learning efforts and accumulated knowledge. Variables such as PercSpenndR&D and PercSpendTrain represent the learning efforts, while employees' accumulated knowledge, EducR&D and PercEmpR&D, represent the accumulated knowledge. As SEM is not appropriate to deal with formative constructs, we proposed the identification of perpendicular factors in the space of the proxies of AC and calculated their resulting vector, which is the variable of AC: internal R&D. We conducted an exploratory factor analysis (EFA) with varimax rotation (Hair et al., 2006) that resulted in four factors, each weighted by one of the four proxies, supporting the notion that the four variables are approximately orthogonal. Therefore, we calculated the indicator of Internal R&D as the square root of the sum of the four squared variables.

The moderation variable *cluster* calculates according to a method adapted from Britto and Albuquerque (2000), which consists of the following formulas (all data to calculate the formula is from RAIS 2019):

$$Q = \frac{\text{participation of sector i in city j}}{\text{participation of sector i in Brazil}} \tag{1}$$

If Q > 1 and number of firms > 10, cluster = 1; otherwise, cluster = 0.

$$\text{Participation of sector i in region j} = \frac{\text{total employees of sector i in city j}}{\text{total employees in section j}} \tag{02}$$

$$\text{Participation of sector i in region Brazil} = \frac{\text{total employees of sector i in Brazil}}{\text{total employees in Brazil}} \tag{03}$$

Statistical method

As the database came from different surveys, common-method bias was not an issue. In the first step, we conducted a multigroup confirmatory factor analysis (CFA) with both the latent variables (external R&D and IP), forcing all regression weights to be the same in both groups (cluster and non-cluster) to validate the measurement model. Then, we conducted a

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multigroup SEM to test the hypotheses. Minimum acceptable fit measures for both were a comparative fit index (CFI) higher than 0.95 and a root mean square error of approximation (RMSEA) lower than 0.07 (Hair et al., 2006). We used the mean-centering technique (Little et al., 2006) to represent the moderation of AC (internal R&D) on the relationship between external R&D and IP. This technique suggests creating a new construct representing the interaction between the indicator of internal R&D and the construct external R&D, which loaded the IP construct. The proxies of this construct are the products of internal R&D and all the factors of external R&D after applying the Z-score. The residuals of all proxies correlate in the SEM.

RESULTS

The descriptive statistics of the variables used in the model and others for both groups are presented in Table 2. Analysis of variance (Anova) was used to test average differences between groups and did not identify any significant difference for all variables. IP from clustered firms is higher than for the non-clustered counterparts. Considering the sample, 58% of the firms outside clusters and 68% in clusters introduced product innovation between 2012 and 2014. Besides this, clustered firms produce more radical innovation (1.01 *versus* 0.87) and more innovation to the market or to the world (1.02 *versus* 0.80). These data reinforce the assumption that firms that participate in clusters have better conditions to innovate.

Another interesting fact concerns internal R&D activities. With 1.49% and 1.78% of employees in R&D, respectively, non-cluster and cluster firms have the following investments: in R&D, it varies from 0.79% (non-cluster) to 1.09% (cluster); in R&D training expenses, this value is around 0.1% in both groups. The level of education of employees in clustered firms is also higher (0.34 *versus* 0.23). Therefore, considering the variables of internal R&D, clustered firms score higher in all except for R&D training expenses, which is similar for both groups.

Analyzing the importance of different partner types for innovation, which reflects external R&D activities, clustered firms also score higher than the non-clustered ones considering all types of partners: clients, with 0.61 *versus* 0.43; suppliers with 0.67 *versus* 0.50; competitors, with 0.22 *versus* 0.16; consultants, with 0.33 *versus* 0.23; and universities, with 0.35 *versus* 0.23. We can verify the importance of vertical alliances, with suppliers

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being considered the most important, followed by clients for both groups. Horizontal alliances (those with competitors) are considered less important and surpassed by the ones with consulting firms, universities, and research institutes. Lastly, productivity is also higher for clustered firms (0.443 *versus* 0.321). If R&D activities and IP are higher for this group, and IP, as this paper advocates, positively influences productivity, this study predicted that clustered firms have superior productivity than the non-clustered ones.

Table 2

Descriptive statistics

		Non-cluster (n = 3,703)		Cluster (n = 1,878)	
Variable	Description	Average	Standard deviation (SD)	Average	SD
IProd	The firm introduced product innovation.	0.58	0.49	0.68	0.47
InnovExt	Innovation to the firm, to the market, or to the world.	0.80	0.81	1.02	0.89
InnovRad	Innovation is incremental or radical.	0.87	0.83	1.01	0.81
SpendR&D (BRL x 1,000)	Total R&D expenses.	1,213.52	9,269.98	5,968.24	66,238.18
SpendTrain (BRL x 1,000)	Total training expenses.	53.90	869.16	105.31	1,321.02
TotalEmpR&D	Total R&D employees.	5.35	25.53	19.51	136.02
PercEmpR&D	Percentage of employees working in R&D activities.	1.49%	4.77%	1.78%	4.45%
PercSpendR&D	Percentage of revenue invested in R&D.	0.79%	6.93%	1.09%	8.31%
PercSpendTrain	Percentage of revenue invested in training.	0.11%	0.66%	0.10%	1.03%
EducR&D	Level of education of employees in R&D.	0.23	0.41	0.34	0.48
PercRevInnov	Percentage of sales revenue generated by innovations.	17.29	27.77	21.50	30.62
Cli	How important the clients are for innovation activities.	0.43	1.00	0.61	1.15

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Table 2 (conclusion)

Descriptive statistics

		Non-cluster (n = 3,703)		Cluster (n = 1,878)	
Variable	Description	Average	Standard deviation (SD)	Average	SD
Supp	How important the suppliers are for innovation activities.	0.50	1.06	0.67	1.17
Comp	How important the competitors are for innovation activities.	0.16	0.58	0.22	0.68
Consult	How important the consulting firms are for innovation activities.	0.23	0.70	0.33	0.81
Univ	How important the universities are for innovation activities.	0.23	0.72	0.35	0.87
SalesRev2014 (BRL x 1,000,000)	Sales revenue in 2014.	224	1,440.00	588.00	5,870.00
NumEmp2014	Number of employees at the end of 2014.	490.55	2,439.30	795.49	2,191.64
Productivity (BRL x 1,000,000)	2014 sales revenue/number of employees in 2014.	0.321	0.593	0.443	0.626

Source: Elaborated by the authors.

The results of the multigroup CFA are presented in Table 3. Convergent validity was acceptable for both the latent variables, as all average variance extracted (AVE) was higher than 0.5 (Fornell & Larcker, 1981), and the standardized regression weights mainly were higher than 0.7 (Nunally & Bernstein, 1978). Discriminant validity was also achieved, with the construct AVE being higher than the squared correlation between the constructs, in addition to nomological validity, with this correlation being significant but low (Hair et al., 2006).

The SEM analysis (see Table 4) determined that all the relationships proposed by the model are significant for both groups (t-test presenting $p < 0.05$ for all relationships). External R&D positively influenced IP for the cluster and non-cluster groups (0.197 and 0.168, respectively). The relationship between internal R&D and IP was positive and significant in all cases (0.046 for non-cluster and 0.023 for cluster). The moderation of internal R&D on the relationship between external R&D and IP, in turn, was different when comparing both groups. For clustered firms, the relationship was 0.012 and significant. In the case of the non-clustered ones, the rela-

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tionship, although significant, was negative (-0.038), indicating a negative moderation of AC in the influence of external R&D on IP for firms in this group. The influence of IP on productivity was also positive for both groups (0.211 for non-cluster and 0.320 for cluster).

Table 3

CFA results

Non-cluster (n = 3,703)						
Construct	Proxy	Std. R.W.	SE	p-value	AVE	CR
Innovation Performance	PercRevInnov	0.526			0.689	0.895
Innovation Performance	InnovRad	0.892	0.049	***		
Innovation Performance	InnovExt	0.834	0.046	***		
Innovation Performance	IProd	0.995	0.054	***		
External R&D – alliances	Cli	0.914	0.039	***	0.570	0.837
External R&D – alliances	Supp	0.833	0.037	***		
External R&D – alliances	Comp	0.619	0.033	***		
External R&D – alliances	Univ	0.608				
Cluster (n = 1,878)						
Construct	Proxy	Std. R.W.	SE	p-value	AVE	CR
Innovation Performance	PercRevInnov	0.485			0.655	0.878
Innovation Performance	InnovRad	0.875	0.074	***		
Innovation Performance	InnovExt	0.806	0.075	***		
Innovation Performance	IProd	0.985	0.079	***		
External R&D – alliances	Cli	0.900	0.050	***	0.567	0.835
External R&D – alliances	Supp	0.847	0.047	***		
External R&D – alliances	Comp	0.604	0.044	***		
External R&D – alliances	Univ	0.614				

Source: Elaborated by the authors.

*** $p < 0.01$.

Considering the hypotheses, which stated that all the previous relationships are more intensely felt in clustered than in non-clustered firms, only

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H3 was supported, and all the others were rejected. An analysis of the confidence intervals of the four regression weights, calculated with p-value = 0.05 according to the t distribution (see Table 5), indicated that among all of them, only external R&D x internal R&D → IP had a statistically significant difference considering both groups, while the others did not (highlighting that a statistically significant difference between groups happens when the confidence intervals do not overlap). Consequently, the only difference the results indicated was that AC, represented by the indicator of internal R&D, positively moderates the relationship between external R&D and IP in clusters. At the same time, this moderation is negative outside clusters.

Table 4

SEM results

	Non-cluster (n = 3,703)		Cluster (n = 1,878)	
Relationship	S. R. W.	p-value*	S. R. W.	p-value*
External R&D → IP	0.168	0.000	0.197	0.000
Internal R&D → IP	0.046	0.000	0.023	0.003
External R&D x internal R&D → IP	-0.038	0.000	0.012	0.024
IP → productivity	0.211	0.000	0.320	0.000

Source: Elaborated by the authors.

* Statistical significance with $p < 0.05$ (t-test).

Table 5

Confidence intervals

Non-cluster (n = 3,703)				
Relationship	Low	High	Sig.	Hypotheses test
External R&D → IP	0.137	0.199	**	H1: rejected
Internal R&D → IP	0.032	0.060	**	H2: rejected
External R&D x internal R&D → IP	-0.050	-0.026	**	H3: supported
IP → productivity	0.142	0.280	**	H4: rejected

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Table 5 (conclusion)

Confidence intervals

Cluster (n = 1,878)			
Relationship	Low	High	Sig.
External R&D → IP	0.150	0.244	**
Internal R&D → IP	0.007	0.039	**
External R&D x internal R&D → IP	0.002	0.022	**
IP → productivity	0.216	0.424	**

Source: Elaborated by the authors.

** p-value = 0.05 (t distribution).

DISCUSSION

The results indicated that the development of internal R&D and external R&D does not directly promote higher IP in Brazilian manufacturing firms participating in a cluster, as Table 4 shows. These results ensure the influence of geographical proximity (as high as possible inside a cluster) on IP remains an open topic of research. The literature diverges from this result, with some studies indicating that the impact is positive (Cardamone, 2018), some suggesting that it is negative (Presutti et al., 2019), and others saying that low and high levels of proximity are harmful while an intermediate level is more favorable (Boschma, 2005; Leeuw et al., 2014). In this study, the direct effects of both R&D sources separately on IP were positive, and their differences were not statistically significant, as demonstrated in Table 5, contradicting all the streams mentioned above.

The influence of IP on productivity was also similar for both groups. These results and the close average of firms' productivity in both groups contrast with the conclusions of Arimoto et al. (2014). The authors compared the productivity of firms in and out of clusters in the silk industry. They concluded that firms in clusters are more productive due to the concentration of the best firms from the industry and related sectors, which would also influence innovation. The results also diverge from Cavalcante et al. (2015), who found a statistically significant positive relationship between R&D, innovation, and productivity in Brazilian firms in clusters.

The only difference in the comparison between both groups concerns the moderation of internal R&D on the relationship between external R&D and IP. This relationship tests the hypothesis based on the AC theory (Cohen

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& Levinthal, 1990; Zahra & George, 2002), with the internal R&D construct reflecting this capability (Cohen & Levinthal, 1990). The moderation was positive in the group of firms participating in clusters and negative in non-clustered firms. This finding indicates that the relationship between internal and external R&D is complementary (Paula & Silva, 2018a; Cassiman & Veugelers, 2006) in clusters, while these sources of R&D are substitutes (Berchicci, 2013) outside them.

These results are consistent with the nature of the clusters and the geographical proximity brought about by this type of arrangement. Clusters facilitate knowledge transfer (Eisingerich et al., 2010; Guo et al., 2020), to which the firms' AC is central. Furthermore, participation in clusters stimulates the development of relative AC (Lane & Lubatkin, 1998) among the participant firms. This phenomenon occurs because the proximity favors mutual observation and informal exchanges that promote the development of shared concepts, tools, language, and standards of business conduct, increasing trust and reciprocity, which facilitate information sharing and innovation (Ozer & Zhang, 2015). As stated by Bittencourt et al. (2019, p. 657), the "process of assimilation, transformation, and application of knowledge can be linked to absorptive capacity", and clusters stimulate the formation of learning relationships and partnerships that promote innovative potential in institutions through interactions that generate knowledge and innovation (Bittencourt et al., 2019). This argument was reinforced by Ikram et al. (2018), which stated that the relationship between industries, government, and universities (also called Triple Helix, Ikram et al., 2018) within clusters creates a business environment that integrates companies, thus favoring innovation.

Another possible explanation for the positive influence of AC solely in the group of firms in clusters is that the geographical proximity between companies operating in the same segment, which occurs naturally in clusters, can also facilitate knowledge spillovers (Cassiman & Veugelers, 2002). A high AC may allow these firms to take advantage of spillovers with more intensity (Aldieri et al., 2018; Caldas et al., 2019; Cardamone, 2018) than firms that are not in clusters, obtaining superior performance and, consequently, competitive advantage.

CONCLUSIONS

This study could verify that internal and external R&D are complementary in Brazilian manufacturing firms that operate in clusters, while they are

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substitutes in firms outside clusters. These results support the hypothesis that external R&D is available for every firm and helps to promote innovation in both contexts. However, participation in a cluster facilitates interaction and trust between firms from the same or correlated sectors with a level of knowledge redundancy sufficient for their relative AC to be higher on average than in the case of firms outside a cluster. Therefore, clustered firms' AC is more effective in promoting open innovation activities, in which internal and external knowledge should be combined, helping to improve their IP.

The influence of the cluster on the effectiveness of AC to promote open innovation and improve IP of firms implies that other factors – besides the effort they put into learning and their previously accumulated knowledge (Kim, 1997) – are relevant in the development of AC. Geographical proximity could be one crucial factor. Another one could be the sense of belonging that facilitates identification and commitment among firms in clusters (Ozer & Zhang, 2015), which help to build more effective communication channels. These factors might promote gains in the relative AC (Lane & Lubatkin, 1998), thus increasing their ability to interact effectively and conduct innovation activities.

Considering the results, we can extract relevant contributions. The main theoretical contribution is the significant evidence of the contingent nature of open innovation and AC theories. The theory presupposes a complementary relationship between internal and external R&D to improve a firm's IP. However, our results indicate that they are complementary for clustered firms and substitutes for non-clustered firms. As a practical contribution, we can mention that managers from clustered and non-clustered firms should have distinct priorities when deciding on their innovation strategies. Clustered firms should invest conjointly in internal R&D and in their alliances with other firms inside the cluster to improve external R&D, and their combination potentiates IP and productivity. Non-clustered firms, in turn, should choose whether they want to invest in internal R&D (if they have enough monetary resources) or prioritize external R&D, by investing in forming alliances with partners that possess the resources they lack.

We can point out several limitations in the study. The method adopted by Britto and Albuquerque (2000), besides considering the participation (in terms of employees) of a sector, uses the proportion of industries that are suppliers of machinery, equipment, and processes for the focal industry. However, we did not have access to information about these suppliers' industries and only used the sector's participation in the calculation. Another limitation is that we worked with Brazilian manufacturing firms, making the

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results country and industry-specific. Another limitation is that Pintec is a survey based on the impressions and feelings of interviewees, which can cause bias to the results. Also, as not all firms answered Pintec and PIA, and the non-respondents are not identifiable, the sample was not probabilistic. Finally, it is a limitation that the only control variable used in the analysis was firm participation in a cluster, with this comparison being the study's main contribution. We did not consider other control variables commonly used in the innovation management literature, such as firm size, location, age, and sector. It can be a source of model misspecification, and testing the model with additional control variables is an opportunity for future studies.

However, Brazil is a relevant emerging country in Latin America, part of the group composed of Brazil, Russia, India, China and South Africa (Brics), so the results may presumably be generalized for Latin American and other emerging economies. For future studies, we suggest using the complete method of Britto and Albuquerque (2000) to classify clusters more precisely. Also, there is an opportunity to expand the analysis to other Latin America countries, to the countries that compose the Brics, or other developing countries. Lastly, we suggest expanding the study to other industries, such as service and agribusiness, and the control by sector could be more precise, using, for instance, the industrial classification of Pavitt (1984).

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