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ALLIANCE PORTFOLIO AND INNOVATIVE PERFORMANCE OF BRAZILIAN INDUSTRY

Portfólio de alianças e desempenho inovador da indústria brasileira

Portafolio de alianzas y el desempeño innovador de la industria brasileña

ABSTRACT

The main objective of this study is to analyze the relationship between Alliance Portfolio Diversity (APD) and the firm's innovative performance, especially when R&D capacity (RDCAP) and Specialized Complementary Assets (SCA) moderate this relationship at different points in the firm's value chain; the study also identifies the nature of the relationship between such moderators. It applies econometric methods to a database comprised of 13,020 companies from Brazilian industry. The results reveal an inverted U-shaped curvilinear relationship between APD and innovative performance, as well as the effective positive moderation of this relationship by the RDCAP and the SCA. This research contributes to the literature on firm knowledge, especially theories of open innovation and absorptive capacity (AC). The former is progressing to emerging economic contexts and the second, contributing a new way of understanding AC by investigating its spatial dimensions, in addition to the skills and competencies dimensions.

KEYWORDS | Alliance portfolio diversity, innovative performance, R&D capacity, specialized complementary assets, firm's value chain.

RESUMO

O principal objetivo deste artigo é analisar o relacionamento entre a Diversidade do Portfólio de Alianças (APD) e o desempenho inovador da firma, especialmente quando esse relacionamento é moderado pela capacidade de P&D (RDCA) e pelos Ativos Complementares Especializados (SCA) em pontos distintos de sua cadeia de valor, bem como identificar a natureza da relação existente entre tais moderadores. Métodos econométricos foram aplicados a uma base de dados composta por 13.020 empresas da indústria brasileira. Os resultados mostraram relação curvilinear em forma de U-invertido entre a APD e o desempenho inovador, bem como a efetiva moderação positiva desse relacionamento, por parte da RDCA e dos SCA. Esta pesquisa contribui para a literatura que aborda o conhecimento da firma, especialmente para as teorias da inovação aberta e da capacidade de absorção (AC),a primeira avançando em direção aos contextos econômicos emergentes e a segunda adicionando uma nova forma de compreender a AC, que pode ser investigada também a partir de suas dimensões espaciais, além das dimensões de habilidades e competências.

PALAVRAS-CHAVE */ Diversidade de portfólio de alianças, desempenho inovador, capacidade de P&D, ativos complementares especializados, cadeia de valor da firma.*

RESUMEN

El objetivo principal de este documento es analizar la relación entre la diversidad de portafolio de alianzas (APD) y el desempeño innovador de la empresa, especialmente cuando esa relación está moderada por la capacidad de I&D (CAPID) y los activos complementarios especializados (SCA), en puntos distintos de su cadena de valor, así como identificar la naturaleza de la relación entre dichos moderadores. Los métodos econométricos se aplicaron a una base de datos compuesta por 13.020 empresas de la industria brasileña. Los resultados mostraron una relación curvilínea en forma de U invertida entre la APD y el desempeño innovador, así como la moderación positiva efectiva de esta relación por parte de la CAPID y los SCA. Esta investigación contribuye a la literatura que aborda el conocimiento de la empresa, especialmente para las teorías de innovación abierta y capacidad de absorción (AC). Para la primera, al avanzar hacia contextos económicos emergentes y para la segunda, al agregar una nueva forma de entender la AC, que también puede investigarse desde sus dimensiones espaciales, además de las dimensiones de habilidades y competencias.

PALABRAS CLAVE */ Diversidad de portafolio de alianzas, desempeño innovador, capacidad de I&D, activos complementarios especializados, cadena de valor de la firma*

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INTRODUCTION

The knowledge-based literature on firms is rich in analyses of organizational environments and mechanisms related to firms' strategies of accessing various types of knowledge (Benner & Tushman, 2003; Cohen & Levinthal, 1990; March, 1991). These analyses consolidate the importance of accessing knowledge and technologies in a firm's external sources (Chesbrough, 2003, 2006). The greater the range of knowledge or technologies accessed, the greater are the chances that the firm develops new combinations of knowledge and ideas. However, this implies that the firm's absorptive capacity (AC) also has to increase (Cohen & Levinthal, 1990; Zahra & George, 2002).

These considerations lead to the specific context of the Alliance Portfolio Diversity (APD) (Faems, Visser, Andries, & Looy, 2010) as a driver of the firm's innovative performance. This study defines APD considering portfolio as a set of formal active alliances of the focal firm (Baum et al., 2000; Leeuw, Lokshin, & Duysters, 2014) and diversity as the distribution of differences among these alliances, in relation to an attribute "X" (Leeuw et al., 2014). Regarding this topic, the literature has investigated the characteristics and relationships with partners (Lavie & Miller, 2008; Leeuw et al., 2014) and the characteristics of the resources and knowledge involved (Asgari, Singh, & Mitchell, 2017; Srivastava & Gnyawali, 2011; Vasudeva & Anand, 2011). Further, the literature has examined the management of tasks and tools (Oerlemans, Knoben, & Pretorius, 2013) and the frequency of new strategic and tactical competitive actions (Andrevsky, Brass, & Ferrier, 2016). The functions, relationships, and routines of alliance portfolio management have also been studied in relation to public institutions (Milagres, Rezende, & Silva, 2017).

However, correlating partner diversification with the existence of resources along a firm's value chain has been little explored, especially in emerging economic scenarios where companies exhibit low adherence to open innovation practices (Bogers, Burcharth, & Chesbrough, 2019). Idiosyncrasies related to the protection of intellectual property, immature industrial standards, as well as a weakening of social capital, help explain such contexts, including the Brazilian one (Bogers et al., 2019). To address this academic gap, this study postulates that successful innovation requires capabilities existing upstream of the value chain—in terms of R&D activities—and capabilities downstream of the value chain, where market-related activities occur (Bruyaka & Durand, 2012; Rothaermel & Hill, 2005).

Bruyaka and Durand (2012) showed the simultaneous existence of exploration and exploitation activities at different stages of a firm's value chain, which involves the development of different organizational units and also contradictory organizational processes (Benner & Tushman, 2003). These activities aim to invent a novelty, as well as to create the structure and strategy for launching it into the market (Rothaermel & Deeds, 2004). Therefore, in the context of an alliance portfolio, different partners provide different types of knowledge and skills (Leeuw et al., 2014) at different points of a firm's value chain (Bruyaka & Durand, 2012). Thus, firms face trade-offs between the interactions and distribution of costs and the benefits generated by these activities (March, 1991). With high levels of variability, the rising costs related to integrating new knowledge can outweigh the benefits (Faems et al., 2010).

Thus, the main objective of this study is to understand the relationship between APD and a firm's innovative performance, incorporating investments in R&D capacity (RDCA) and Specialized Complementary Assets (SCA) as moderating organizational factors. RDCA occurs predominantly at the beginning of the firm's value chain and the SCA along the chain and at the end of it. It is assumed that such organizational factors will positively moderate the relationship between costs and benefits generated by APD, as well as clarify the relationship between these organizational factors. Based on data from the Innovation Research database (Pintec) of the Brazilian Institute of Geography and Statistics (IBGE), this study incorporated a sample of 13,020 Brazilian companies belonging to 5 sectors of the extractive industry and 24 sectors of the manufacturing industry. The results show substantial support for the hypothesis of an inverted U-shaped relationship between APD and innovative performance, as well as for the hypotheses regarding the moderating effects. The hypothesis that predicted a positive relationship between the moderating factors was refuted.

THEORY AND HYPOTHESES

According to the concept of open innovation, a firm can exploit knowledge developed by a partner or can license its own knowledge to other partners so they can exploit it (Chesbrough, 2003; Huizingh, 2011). Through these channels, the firm creates and disseminates new knowledge throughout the organization, embedding it in products, services, and systems (Caloghirou, Kastelli, & Tsakanikas, 2004). Contact with and absorption of knowledge originating from many agents that are external to the organization are important (Katila, 2002; Laursen & Salter, 2006, 2014), since only a few can generate viable combinations (Nelson & Winter, 1982).

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Leeuw et al. (2014) highlight studies that address the importance of diversity of competencies and skills accessed externally. Examples of this are suppliers improving production processes, process innovations, and cost reductions (Sobrero & Roberts, 2002), or customers and consumers feedback reducing the uncertainty associated with new product introductions, market expansions, and adaptations to existing products and services (Tether, 2002). Other examples include competitors allowing access to industry-specific knowledge and sharing costs/research facilities (Kim & Higgins, 2007), and universities and public research institutes generating new scientific and technological knowledge (Leeuw et al., 2014).

Therefore, developing a portfolio of alliances can be an important strategy for an innovative firm; such a portfolio is the set of all types of strategic alliances that a firm currently maintains, as well as those it developed in the past.

Only some partnerships will be viable; this implies that AC reflects a "firm's ability to recognize the value of new and external information, assimilate it and apply it for commercial purposes" (Cohen & Levinthal, 1990, p. 128). Assimilating and applying information for commercial purposes indicates that AC should not be a construct restricted to creating a new product (R&D), but also to producing and marketing it. The concept of AC reviewed by Zahra and George (2002) emphasizes the skills of acquisition and assimilation of new and external knowledge—potential AC—and the skills of transformation and exploration of this knowledge—realized AC. This approach establishes two conditions implicit in the concepts of potential AC and realized AC: a) they are different from each other, and b) they occur at different times. The theoretical view of the "functional diversity of a firm's partners in their different positions in its value chain" (Bruyaka & Durand, 2012, p. 9) incorporates a third condition: the aforementioned skills are acquired at different stages in the firm's value chain.

Decisions to invest in RDCA, as well as in certain SCA, can be critical to the development of an alliance portfolio. The first type of investment, upstream in the chain, enables the firm to identify the partner that generates more benefits than costs when accessing new knowledge/technology—potential AC (Cohen & Levinthal, 1990; Zahra & George, 2002). The second type of investment, downstream in the chain, enables the firm to identify the partner that generates more benefits than costs when accessing the market—realized AC (Teece, 1986; Zahra &George, 2002). "Innovative firms without manufacturing requirements and related capacities may die, even if they are the best in innovation" (Teece, 1986, p. 285). Thus, ensuring that the appropriate type of external knowledge is absorbed at different points in the firm's value chain presupposes the existence of diversity in the focal firm's partners.

Organizations that try to balance such very different activities have to reconcile very different internal subunits that are not substantially integrated with each other in terms of structure (Benner & Tushman, 2003). This management challenge is highly likely to emerge in APD contexts. As the complexity of its alliance portfolio increases, the organization needs to develop functions and relationships at its corporate level, in an area especially dedicated to alliances (Faems et al., 2010; Milagres et al., 2017). This increases the number of tasks and skills required and, consequently, changes the firm's internal cost structure (Faems et al., 2010; Kale & Singh, 2009).

These costs are related to the creation of relationships and communication networks between the firm and the external environment. The reliability of knowledge can be negatively affected, as the firm's capacity to correctly assimilate new knowledge decreases if the diversity of alliances increases excessively (Lee, 2007). Further, the resulting profit can also be negatively impacted, especially when this increase in diversity is related to speedy and regular portfolio expansion (Hashai, Kafouros, & Buckley, 2018). Faems et al. (2010) concluded that APD positively impacted the innovative performance of 305 Belgian manufactures but the increase in portfolio diversity triggered additional control and monitoring costs that made the net effect negative. Jiang, Tao, and Santoro (2010) found results showing the cancellation of the benefit provided by the last partner added to the alliance portfolio of 138 multinationals in the global automotive industry. Therefore, based on the aforementioned contexts and considering the theoretical and empirical contributions reviewed here, the first hypothesis of the present study is as follows:

> H1: APD has an inverted U-shaped relationship with a firm's innovative performance.

The knowledge-based view of the firm attributes the significance of R&D routines not only as an activity that creates the firm's knowledge but also as an activity that develops its AC (Cohen & Levinthal, 1990; Jong & Freel, 2010). Therefore, R&D initiatives are activities often considered to have a positive relationship with the firm's innovative performance, including the development of competitive advantages (Andrevsky et al., 2016; Cassiman & Veugelers, 2006).

On the other hand, the uncertainty and often irrecoverable costs associated with innovation are also automatically associated with R&D activities. Due to these levels of uncertainty, R&D activities are often conducted on a cooperative basis (Chesbrough,

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2003). Nevertheless, according to Oxley (1997), hierarchical alliances are chosen when ownership risks are high.

If firms whose knowledge or technologies are complementary form an R&D partnership (Cassiman & Veugelers, 2006; Tsai & Wang, 2008), the combination of their technologies will occur in a more straightforward and efficient way, which in most cases can generate incremental innovations. If, on the contrary, the partner firms' technologies are substitutes (Laursen & Salter, 2006), the interactions between the two partners' R&D areas can generate redundant knowledge or technology, generating irrecoverable costs and few possibilities for new combinations. However, substitutability may be preferable when it increases flexibility and provides a firm with a greater possibility to develop more exploratory combinations (Dibiaggio, Nasiriyar, & Nesta, 2014) and, therefore, have more possibilities to arrive at unprecedented knowledge (March, 1991).

Despite the inconclusive results of studies on complementarity and substitutability (Ceccagnoli, Higgins, & Palermo, 2014), this study emphasizes the complementarity between firms' R&D areas for three reasons: a) the "path-dependent" nature of knowledge or innovation (Cohen & Levinthal, 1990; March, 1991); b) the wide predominance of incremental innovations in the Brazilian industry (Pintec, 2011); and, c) the critical importance of the firm's AC (Ceccagnoli et al., 2014), especially in APD environments.

Thus, the higher a firm's level of investment in internal R&D upstream in its chain, the greater its potential CA is (Spithoven & Teirlinck, 2015). Subsequently, its alliance portfolio may be more diverse or effective. Therefore, the positive moderation of investments in RDCA manifests as a "smoothing out" of the curvilinear relationship between a firm's APD and its innovative performance. In other words, despite their costs, such investments allow extending the advantageous condition of the innovative performance that diversified partners provide. Hence the second hypothesis proposed is as follows:

> H2: A firm's RDCA positively moderates the curvilinear relationship between the firm's APD and its innovative performance.

In innovation contexts, "almost all successful cases of commercializing an innovation require that the knowledge in question be used together with other complementary capabilities or assets" (Teece, 1986, p. 288). Complementary Assets (CA) are, therefore, activities related to specialized capacities in manufacturing, marketing, access to distribution channels, after-sales, service networks, and complementary technologies (Teece, 1986). In a framework of fragile intellectual property (such as the Brazilian framework), if the product is easily imitated and the CA are generic, the firm will not have to make large investments, as the product and CA will be available in the industry. However, if the CA are specialized, the firm that owns them will have a clearly advantageous position (Teece, 1986). Thus, cooperation emerges, either initiated by a small innovative firm that needs SCA (as in the biotechnology and pharmaceutical market) (Rothaermel, 2001) or by the large firm that owns the SCA. Among the main incentives to license an external technology, there are three categories of CA that positively moderate a firm's technological diversification strategy and the firm's performance: marketing resources, production resources, and human capital (Chiu, Lai, Lee, & Liaw, 2008).

Therefore, the more a firm invests in SCA—downstream in its value chain—the more effective its APD can be, which will positively impact its innovative performance. Because they are specialized, SCA take time to be developed or imitated (Teece, 1986) and are, therefore, important drivers of a firm's decision to engage in alliances. Thus, the positive moderation of investments in SCA manifests as a "smoothing out" of the curvilinear relationship between a firm's APD and its innovative performance. In other words, despite their costs, such investments allow extending the advantageous condition of the innovative performance that diversified partners provide. Thus, the third hypothesis proposed is as follows:

> H3: A firm's SCA positively moderate the curvilinear relationship between the firm's APD and its innovative performance.

In conclusion, if the two moderating variables are organizational factors located at different points in the firm's chain, the most likely way that synergistic activities are truly beneficial is that the relationship between these two factors should be complementary. If a firm adopts one strategy, the marginal return of another strategy also increases if the two strategies are complementary. Similarly, if these strategies are substitutes for each other, an increase in one activity reduces the marginal benefit of the other (Cassiman &Veugelers, 2006; Hagedoorn & Wang, 2012), which incurs costs for redundant results.

Teece (1986) attributed important implications to a firm's R&D strategy as a result of the firm's investments in SCA, reinforcing the concept of complementarity between these two variables. Therefore, a firm's SCA condition its decisions regarding investments in R&D (Teece, 1986) in response to technological changes, acting both as resources that lessen the effects of these changes and as prisms through which the firms visualize these changes. Thus, they determine the amount and direction in which the firm will invest in these resources (Wu, Wan, & Levinthal, 2014).

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The simultaneous search for knowledge at the various stages of the firm's value chain "provides the basis for unique resource combinations that can become sources of superior performance" (Hess & Rothaermel, 2011, p. 906). This statement also indicates the hypothesis of complementarity between upstream and downstream activities, which impacts the firm's innovative performance. This complementarity represents the effective connections between the organization's subunits, enabling firms to transition to a new technology (Taylor & Helfat, 2009). From these observations emerges the fourth and last hypothesis of this study:

> H4: Within the context of alliances between innovative firms, a firm's RDCA and SCAs are complementary variables to the extent that, when interacting, they have a positive impact on each other.

METHODS

Data

The database used in this study is Pintec, from IBGE. Until the data collection of this article, Pintec was composed of data from five trienniums, starting with 1998–2000 and ending with 2009–2011. Due to the limitations of the database related to the unavailability of research variables in older triennia, this study uses the last two triennia (2006–2008 and 2009–2011). Based on the third edition of the Oslo Manual and on the model proposed by the Eurostat and Community Innovation Survey, Pintec offers "information regarding behavior, activities undertaken, impacts, incentives, obstacles and other factors related to the company as a whole (the innovative agent)" (IBGE, 2011, p. 14).

The final sample included only innovative companies—according to IBGE, those that implemented at least one new or substantially improved product and/or process in the period studied. This framework is consistent with the fact that the dependent variable in the proposed model is the firm's innovative performance. In addition, to minimize the potential occurrence of selection bias, companies that developed innovative projects were also considered innovative, even if these projects were incomplete or abandoned within the studied period. Pintec provides variables taking several types of values—percentages, Likert scales, absolute values, and dichotomous values—which reduces the possibility of common method bias. As the data are part of two independent trienniums also helps to prevent this type of bias. The response rate exceeds 90% (IBGE, 2011), which minimizes non-response bias (Laursen & Salter, 2004). Despite precautions of this type, Pintec exhibits limitations with regard to the specificities of the innovative organizational environment, which, to some extent, can impact the obtained results.

Investigating the repetition frequency of individual entities (companies) in the three-year periods studied resulted in identifying 10,524 distinct companies distributed across the trienniums. Matching these companies with those in the final sample (13,020 companies) was done to identify whether the data could be considered as panel data. As it was unfeasible to use the data in panel format, a transversal study (pooled cross-sectional) of the data was decided, with the 2006–2008 and 2009–2011 data being "stacked." Thus, the sample comprised 13,020 companies that met the "innovative" criterion. Based on another criterion, among the firms that developed an alliance portfolio as a cooperation strategy for innovation, those that considered this a high- or medium-magnitude strategy were selected. These companies are distributed across sectors CNAE 5 to CNAE 33 (National Classification of Economic Activities), with 5 and 24 sectors belonging to the extractive industry and the manufacturing industry, respectively.

Measurements

Dependent variable

Following Laursen and Salter (2006) and Berchicci (2013), the dependent variable—innovative performance—was defined as the percentage of the firm's internal net sales related to product innovation, obtained by summing the relevant variables. Three questions in the questionnaire addressed these innovations with respect to their levels of originality, considering the national and world markets. The sum of the values of the corresponding variables is converted to the total percentage of sales corresponding to two types of product innovation: incremental and radical (TOTAL_IN). Because it is in percentage form, the dependent variable assumes values between 0 and 1.

Independent variable

The independent variable is APD. This variable was measured in a similar way as in Duysters and Lokshin (2011), Faems et al. (2010), Oerlemans et al. (2013), and Leeuw et al. (2014).

First, a cut-off criterion identified the question that defined which companies had been involved in cooperative arrangements, in a "yes" or "no" format. Then, using a second criterion, based on the questions that defined the degree of importance of this type of arrangement, the companies that indicated significant

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involvement were chosen, based on four response options (non-relevant, low, medium, and high). The APD variable was defined for the companies that considered their external cooperation activities to be of high or medium importance, taking a value of 1 for high and medium importance and 0 for the other response options.

In relation to a firm's partners' locations, the questionnaire questions corresponding to national partners were combined into a value of 1, while 0 was assigned to international partners. Subsequently, this information was added for the group of respondents who classified the cooperation as high and medium importance. The same logic, conversely, was applied to the response option of international partners. Thus, the APD variable was measured by the percentage of the number of partner types in a firm's portfolio out of the maximum possible number of types of partners. There are seven possible types of partners in the questionnaire (customers/consumers, suppliers, competitors, another company in the group, consulting companies, universities/institutes, and training centers and testing and certification institutions) and two possibilities for partner location (national or international). Thus, the maximum possible number of types of partners is 14 (7 x 2). The present study recognizes the limitation in how this variable was measured, in terms of the possibility of obtaining the same score from different combinations of partner types. Another possible bias is related to the difference in effectiveness among the different types of partners. Partnerships with universities, for example, tend to generate more basic knowledge (Trajtenberg, Henderson, & Jaffe, 1997), that is, they are associated with more embryonic stages of technologies and, therefore, with more uncertainty (Ziedonis, 2007). However, the literature recognizes this form of measurement as valid, as in Oerlemans et al. (2013) and Leeuw et al. (2014).

Moderating variables

According to Berchicci (2013), Cassiman and Veugelers (2002), and Escribano, Fosfuri, and Tribó (2009), the variable RDCA is the ratio of two other variables from the Pintec questionnaire: a) the number of people dedicated exclusively and partially to R&D activities, according to their qualification levels (PhD, Master's, or Bachelor's degree) and b) the firm's net revenue. The ratio of these two variables aims to reduce the occurrence of sample bias due to firm size.

The SCA variable involves four ratios based on two variables from the Pintec questionnaire. The argument for applying these variables is justified by the theory presented in previous sections (Chiu et al., 2008; Teece, 1986). The numerator for each ratio is each of the expenditures or investments (in monetary units) in the four types of SCA: a) acquisition of machinery and equipment, b) training, c) introduction of technological innovations in the market, and d) other preparations for production and distribution. Each of the four denominators is the total number of persons employed by the firm, once again aiming to correct the bias caused by firm size. The four different ratios are added together to obtain the value of the SCA variable.

Control variables

Since the regional and specific characteristics of the companies in the sample can affect the dependent variables assessed here, to capture the net effect of RDCA and SCA, the present study also considered a set of control variables. Therefore, to control for factors specific to the companies included in the sample, a sectoral control dummy variable that represents the difference between the two types of industries in the sample—the extractive industry and the processing industry (IND_TRANS)—was first used (Laursen & Salter, 2006). "Firm size" was also considered, as the logarithm of the firm's total number of employed persons (Laursen & Salter, 2014). The variable "years" (YEAR), which defines one of the three-year periods as a basis for comparison, was also used. Another control variable was the role of the partnership or object of cooperation (RDFUN = R&D function), a variable controlled in the model, to account for the heterogeneity of the different types of accessed knowledge. The "origin of the controlling capital" (ORIGCAP) was another dummy control variable incorporated into the model to represent the impacts of the "internationalization" of the alliance portfolio on a firm's performance (Lavie & Miller, 2008). To control for the differences among R&D capacities, the variable "Internal R&D" (INTRD) was included, representing the firm's expenditures for internal R&D, in monetary units (Laursen & Salter, 2014). These expenditures were divided by the firm's total number of employed persons. Two other control variables included indicated whether the costs for the aforementioned activities were "financed by financial institutions" (FINPUB) or subsidized by the parent company (SUBSID). Another control variable indicated the "company's main market," that is, whether the firm was an exporter (EXPORT) or not. Finally, dummy variables (REGION) were used to capture time-invariant factors specific to each region.

Econometric model and estimation strategy

The dependent variable varies between 0 and 1 as it is a percentage; thus, it is a censored variable. A sample "where the

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returnee's information is only available for a few observations is known as a censored sample" (Gujarati & Porter, 2011, p. 571). Similarly, in the sample of innovative companies used in this study, there is a group of companies that declared themselves as innovative but did not declare any sales percentage related to innovative products. Such companies may have had other types of results corresponding to alternative responses in Pintec. For example, they may have reported an increase in the quality or variety of products offered, or a reduction in production costs. Therefore, a certain number of observations in the sample have no information about the respondent.

The econometric model suitable for this type of context is the Tobit model, a regression model with a censored dependent variable, estimated by maximum likelihood (Greene, 2003; Gujarati & Porter, 2011; Wooldridge, 2011).

With regard to the statistical inconsistency resulting from endogeneity caused by bidirectional causality, studies on portfolios of alliances and innovation such as Oerlemans et al. (2013) did not reject the hypothesis of exogeneity of the regressors using the Durbin–Wu–Hausman test, demonstrating that the results presented in the next section tend to be statistically consistent.

However, studies such as Lavie and Miller (2008) and Hashai et al. (2018) mention the unavailability of appropriate instruments (which, at times, are marginally relevant), which makes it difficult to assess possible endogeneity. In addition, the wide use of lagged dependent variables does not guarantee the exogeneity of the regressors. Therefore, as indicated by Bruyaka and Durand (2012), the careful assessment of possible endogeneity problems should be a subject for future studies.

RESULTS AND DISCUSSION

Sample

Table 1 indicates that 10,180 companies (78.19%) did not develop APD and may have realized some weak or not important partnerships. The innovative companies that developed APD (which attributed high and medium importance to their developed partnership(s)) totaled 2,840. Therefore, the present study was conducted based on the levels of variation in the "total sample" (13,020 companies) and a "subsample" (2,840 companies).

Table 1. **Number of observations by number of partner type, for companies that developed APD.**

Number of partner type	Frequency	Percent
0	10,180	78.19
1	813	6.24
1	576	4.42
2	452	3.47
3	355	2.73
4	281	2.16
5	192	1.47
6	88	0.68
7	28	0.22
8	22	0.17
9	22	0.17
10	8	0.06
11	0	0
12	3	0.02
13	0	0
14	0	0
Total	13,020	100.00

In Table 2, the percentage of sales from incrementally and radically innovative products reaches an average of 17% when all 13,020 observations are considered. The average number of people employed by the companies is 475; this variable exhibits a high standard deviation, which indicates a large dispersion in its values. The average of the APD variable is 0.047. This value can be explained as follows: in Table 2, this variable was based on the total sample (13,020 observations), including the 10,180 companies that did not attribute importance to their developed partnerships, which means they did not achieve APD.

Table 2. **Descriptive statistics and correlation matrix**

	Variable	Average	Standard D.	Obs.	1	2	3	4	5	6	7	8	9	10	11	12	13
1	TOTAL_IN	0.166	26.96	13,020	1												
2	Specialized complementary assets	9.27	119.88	12,874	0.025*	1											
3	Alliance Portfolio Diversity	0.047	0.112	13,020	0.090*	0.001	**1**										
4	R&D Capacity	0.607	10.54	12,915	0.001	0.001	0.14*	**1**									
5	R&D function	0.280	0.858	13,020	0.086*	-0.00	0.74*	0.15*	**1**								
6	Number of Persons Employed	475.78	1,893.26	13,020	0.008	-0.004	0.22*	0.47*	0.21*	**1**							
7	Internal R&D	0.096	5.73	12,874	-0.003	0.012	0.01	0.001	0.02*	-0.00	**1**						
8	Exporter	0.054	0.226	13,020	- 0.011	-0.001	0.08*	0.04*	0.07*	0.09*	-0.00	**1**					
9	Controlling Capital Origin	0.131	0.338	13,020	0.033*	0.016	0.14*	0.05*	0.16*	0.13*	-0.00	0.19*	**1**				
10	Financed Financial Institutions	5.06	18.96	13,020	0.005	0.03*	0.04*	0.01	0.06*	0.01	0.00	-0.01	0.05*	**1**			
11	Subsidiary	0.213	0.409	13,020	0.040*	0.010	0.16*	0.06*	0.16*	0.18*	-0.00	0.12*	0.40*	-0.01	**1**		
12	Transformation Industry	0.992	0.085	13,020	0.028*	-0.004	-0.02*	-0.001	-0.007	-0.01	0.00	-0.03*	-0.00	-0.01	-0.03*	**1**	

Significant correlations: * denotes p ‹ 0.01

Table 3 shows the descriptive statistics, highlighting the differences between the total sample (all innovative firms) and the subsample (innovative firms that developed APD).

Table 3. **Means and standard deviations of variables in the sample and subsample**

	Innovators = 13,020 observations				Innovators/APD = 2,840 observations			
	2008 (n=6,848)		2011 (n=6,172)		2008 (n=1,217)		2011 (n=1,623)	
	Average	SD	Average	SD	Average	SD	Average	SD
TOTAL_IN	16,793	26,634	16,411	27,333	19,845	26,154	21,299	29,153
Alliance Portfolio Diversity	0.034	0.095	0.062	0.128	0.195	0.140	0.236	0.147
R&D Capacity	0.533	10,004	0.689	11.120	2,140	23,508	2,067	21,491
Specialized Complementary Assets	8,085	43,305	10,598	168,204	12,441	78,307	7,371	22,732
R&D function	0.219	0.759	0.348	0.952	1,231	1,413	1,322	1,467
Employed People	475	1,772	475	2,018	1,045	3,130	945	3,443
Internal R&D	0.119	7,294	0.071	3,218	0.062	0.466	0.207	6,286
Exporter	0.056	0.231	0.051	0.220	0.082	0.274	0.074	0.261
ORIGCAP	0.137	0.344	0.125	0.331	0.240	0.427	0.195	0.396
Financed Financial Institutions	6,677	22,213	3,283	14,324	6,959	22,025	5,891	18,600
Subsidiary	0.250	0.433	0.171	0.376	0.403	0.498	0.280	0.449
Industry Transformation	0.985	0.117	1	0	0.984	0.124	1	0
Region	4,310	1,003	4,205	1,058	4,378	0.992	4,210	1,067

SD: Standard deviation

Companies in the Brazilian industry seem to be incorporating the APD strategy. In 2008, the average number of types of partners was 2.73 (0.195 x 14) and, in 2011, this average increased to 3.30 (0.236 x 14). The average percentage of sales of innovative products was 19.84% in 2008, increasing to 21.30% in 2011. The average number of employees is higher in the subsample, which indicates that companies that develop APD tend to be larger.

Regressions

In Table 4, model 1 includes only the main variables for the empirical model. In model 2, the independent variable APD squared is added. Model 3 includes the interaction of APD and the SCA variable, reflecting the moderating function of the latter variable. In Model 4, the interaction APD and the RDCA variable is inserted, reflecting the moderating function of the latter variable. Model 5 incorporates the last interaction term, of the moderating variables SCA and RDCA, reflecting the combined effect of these variables on the dependent variable. Finally, model 6 includes all the variables of the empirical model proposed above.

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Table 4. **Tobit regressions – Dependent variable: TOTAL_IN**

Dependent Variable: TOTAL_IN (sum of sales percentages for incremental and radical product innovations)						
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
Alliance Portfolio Diversity (APD)	31.12***	56.68***	57.31***	56.69***	56.65***	57.29***
Specialized Complementary Assets (SCA)	0.008**	0.008**	0.0002	0.008*	0.008*	-0.0004
R&D Capacity (RDCA)	-0.044**	-0.024	-0.024	0.831***	-0.027	0.988***
APD squared		-75.53***	-82.71***	-70.24***	-75.39***	-78.37***
APD squared x SCA			0.982*			1.140*
DPA x SCA			-0.136*			-0.145*
APD squared x RDCA				2.764***		2.981***
DPA x RDCA				-3.380***		-3.725***
RDCA x SCA					0.0004	-0.005**
R&D Function						2.748***
Number of Employed Persons						0.000
Internal R&D						0.003
Exporter						-7.923***
Controlling Capital Origin						4.723***
Financed Financial Institutions						-0.009
Subsidiary						3.568*
Transformation Industry						18.308*
Region						
2						-0.463
3						-5.710**
4						-2.955
5						-5.375**
Year						
2011						-4.465***
CONSTANT	-12.107**	-10.632**	-10.581**	-10.435**	-10.630**	-10.417**
Number of Obs	12.874	12.874	12.874	12.874	12.874	12.874
F	(16, 12,858) 21.11	(17, 12,857) 21.02	(19, 12,855) 19	(19, 12,855) 19	(18, 12,856) 19	(22, 12,852) 17
Prob › F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

* p‹0.10, **p‹0.05, and ***p‹0.01

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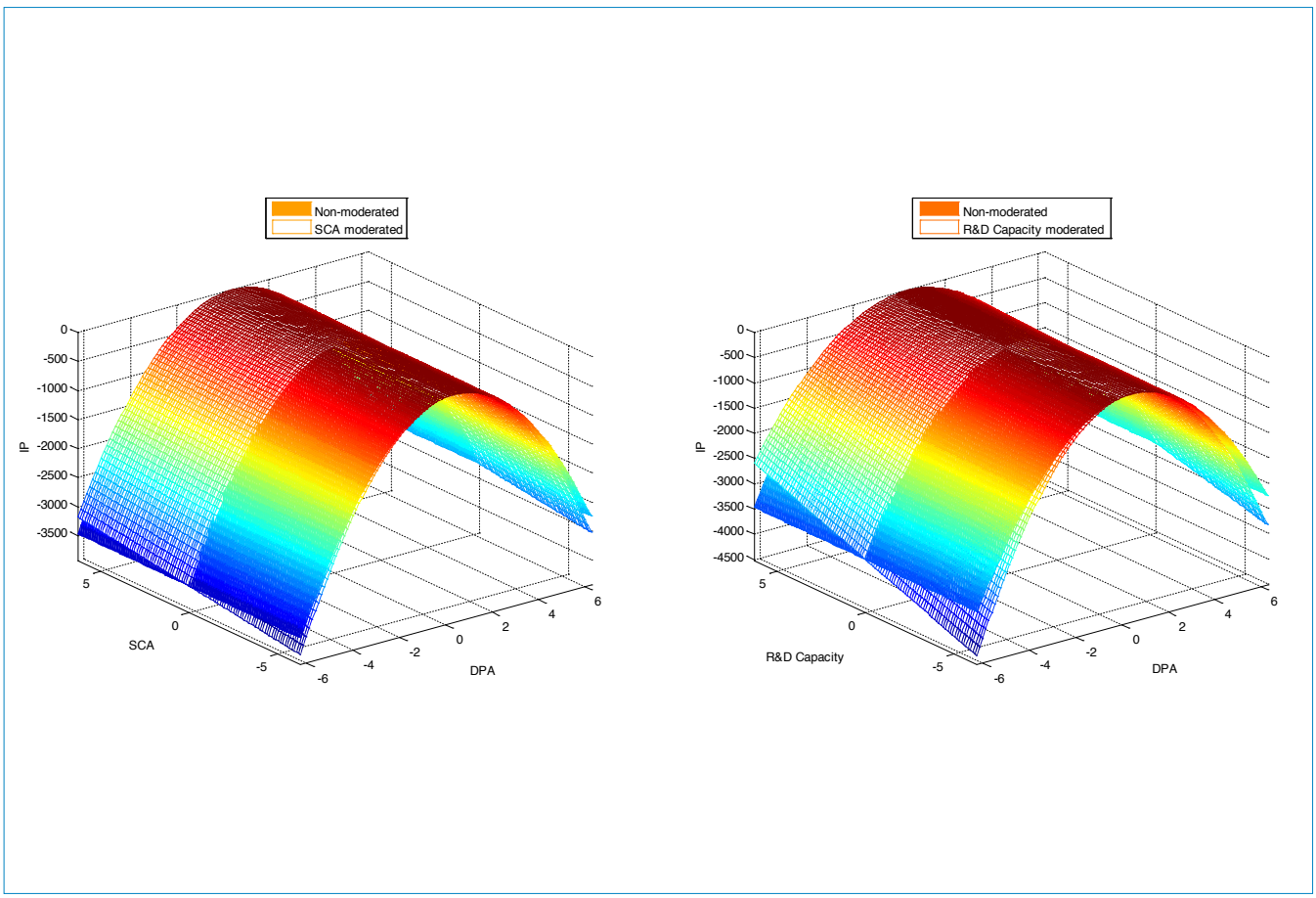
In model 1, APD has a positive and statistically significant relationship with innovative performance. However, as APD increases, the benefits from this strategy do not outweigh the costs involved. This is shown by the significantly negative sign of the quadratic term of APD in model 2. This result confirms the inverted U-shaped relationship between APD and innovative performance, in line with hypothesis 1. The six estimated Tobit models confirm the signs of the relationships stated in hypothesis 1, as well as show their high degree of statistical significance.

Based on model 4, hypothesis 2 is also confirmed. The curvilinear relationship between APD and the firm's innovative performance is smoothed (flattened) if the firm invests in RDCA. The moderation of RDCA is indicated by the positive sign of the interaction between this variable and the quadratic term of APD. Model 6 also confirms this relationship.

Model 3 shows a significantly positive relationship between the quadratic term of APD and SCA. This finding supports hypothesis 3, confirming that, in the presence of SCA, the curvilinear relationship between APD and innovative performance is softened (flattened). This relationship can also be seen in model 6.

Hypothesis 4 was not confirmed. The positive sign of the relationship between the moderating variables SCA and RDCA was expected. In model 6, the interaction term between these two variables significantly negative. This result contradicts complementarity and substitutability between these two variables. The curvilinear relationship and the moderating effects are shown in Graphs 1 and 2.

Graphs 1 and 2. **Impact of RDCA and SCA on the (APD X Innovative performance) relationship**



Similar to the Tobit models, six OLS (Ordinary Least Squares) models were also fit, to test the stability of the results (Table 5). The results for the relationships between the variables of interest remained stable. Hypotheses 1, 2, and 3 were also confirmed by the OLS models. The only exception was the interaction term of the moderating variables RDCA x SCA (hypothesis 4), which lost statistical significance in the complete model (model 6).

Table 5. **OLS regressions - Dependent variable: TOTAL_IN**

Dependent Variable: TOTAL_IN (sum of sales percentages for incremental and radical innovations)						
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
Alliance Portfolio Diversity (APD)	15.09***	23.58***	24.08***	23.36***	23.56***	23.85***
Specialized Complementary Assets (SCA)	0.005***	0.005***	-0.001	0.005***	0.005***	-0.001
R&D Capacity (RDCA)	-0.020*	-0.013	-0.014	0.399***	-0.016	0.494***
APD²		-25.60**	-31.44**	-22.40*	-25.51*	-28.84**
APD² x SCA			0.797**			0.891*
APD x SCA			-0.109*			-0.113**
APD ² x RDCA				1.317***		1.451***
DPA x RDCA				-1.625***		-1.834***
RDCA x SCA					0.0002	-0.003
R&D Function						1.299***
Number of Employed Persons						-0.0002*
Internal R&D						-0.023*
Exporter						-2.558**
Controlling Capital Origin						1.082
Financed Financial Institutions						-0.002
Subsidiary						1.376**
Transformation Industry						6.109***
Region						
2						2.346
3						-1.789
4						-1.555
5						-2.700**
Year						
2011						-0.942**
CONSTANT	12.08***	12.58***	12.62***	12.65***	12.58***	12.67***
Number of Obs	12.874	12.874	12.874	12.874	12.874	12.874
F	(16, 10,523) 9.40	(17, 10,523) 9.23	(19, 10,523) 8.58	(19, 10,523) 15	(18, 10,523) 8.7	(22, 10,523) 1
Prob › F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
R²	0.0136	0.0140	0.0144	0.0151	0.0140	0.0157
Root MSE	26.689	26.685	26.681	26.672	26.686	26.666

* p‹0.10, **p‹0.05, and ***p‹0.01

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Discussion, implications, and limitations

The confirmation of hypothesis 1 indicates that companies in the Brazilian industry have been diversifying their alliance portfolios and have been benefiting from this strategy in terms of innovation. However, the industry faces the issue of APD costs neutralizing benefits after a certain point. On average, the number of partner types has increased from 2.73 in 2008 to 3.30 in 2011. Within the group that adhered to APD, the sales percentage corresponding to product innovations increased by almost two percentage points in the same period. According to Graphs 1 and 2, the inflection point of the curve indicates that five is the "ideal number" of different types of partners. The data suggest that there is still room for APD in the Brazilian industry, since 65% of the companies that adhered to APD developed up to two types of partners and 87.21% of all companies developed between one and four types. Thus, although companies in the Brazilian industry have been assimilating the cooperation strategy, they seem to be doing so cautiously.

The types of innovation that have impacted sales are "only process" and "product and process." "Product only" innovation has significantly decreased (IBGE, 2011). Thus, the general classification of the Brazilian industry as exhibiting imitation and incremental innovation seems to be a coherent conclusion (Carvalho & Avellar, 2015; Cavalcante & Negri, 2011; Kannebley, Porto, & Pazello, 2004; Mendes, Lopes, & Gomes, 2012).

Although APD is spreading, companies—and their partners—have not been able to make the Brazilian innovation environment more dynamic with disruptive innovations. The emphasis on suppliers and customers/consumers as being the most and second-most important reinforces incremental and process innovation (Leeuw et al., 2014; Sobrero & Roberts, 2002). It can also be considered that this behavior reflects companies' accommodation to the needs of the domestic market. This possibility helps one understand why the significantly negative coefficient of the export control variable in the 6 regression models. The low percentage of exporting companies (5%) and of companies with foreign capital (13%) in the sample and the sharp drop in the percentage of companies belonging to the largest business group—25% to 17%—reinforce this perception.

Regarding hypothesis 2, when comparing innovative companies with innovators that developed APD, the latter's investments in RDCA are significantly (three times) higher than those of the former. This finding explains the stability of the results related to the moderating effect of RDCA shown by the regression models. However, when analyzing the estimated standard deviations, this variable exhibited high variation among the companies that adhered to APD, suggesting that this strategy still lacks maturity and consistency.

CA, together with the intellectual property regime and the dominant product paradigm, form part of the theoretical scenario supported by hypothesis 3. According to Teece (1986), these are the elements that define who benefits from an innovation: the innovative firm or the imitating firm. Based on the current consideration of the Brazilian industry as an imitator, this study suggests that companies invest in CA not only to compete internally, offering good market access structures, but also to become attractive partners for innovative companies. Thus, in a competitive environment where the ownership regime is not strong, a firm with a good market-access structure (production, distribution, and marketing) can capture the profits of an innovation via cooperation or imitation, even if entering the market late.

Not confirming the fourth hypothesis reinforces the substitutability relationship between RDCA and SCA. Further analyzing this relationship, this study corroborates the contributions of Lane and Lubatkin (1998) and Teece (1986). At the beginning of the firm's value chain, the firm's R&D area involves skills and competencies linked to access to knowledge or technologies, with the firm seeking new combinations of ideas and establishing the "dominant product paradigm" (Teece, 1986). At the end of the firm's value chain, SCA provide skills and competencies to access the market and to establish efficient production and marketing structures, which is the company's "dominant logic" (Lane & Lubatkin, 1998).

In this context, how can it be guaranteed that a given firm aligns the "dominant product paradigm" with the "dominant logic"? Non-alignment between these two theoretical elements can bring about the Schumpeterian occurrence of "creative destruction," where the dominant product paradigm can destroy the competencies established at the end of the firm's value chain, and the latter can discourage the search for the former. To place this discussion in the context of APD, one can see that these efforts, at the beginning and at the end of the chain, are developed through alliances with external partners.

Another possible explanation comes from Andrevsky et al. (2016), who tested and proved that portfolio configuration disproportionately influences a firm's strategic competitive actions (product development) and tactical competitive actions (commercialization). This possible explanation also corroborates the approach of Milagres et al. (2017), who emphasized the importance of the functions and relationships developed between the area that manages alliances and other areas of the organization.

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The forces that exist in this type of context exert "inertial pressures," because the individual who conducts the research may not be the same individual who decides whether the research will continue (Kapoor & Klueter, 2015). In the specific context of this study, the lack of alignment between these pressures may explain the negative sign of the interaction term between RDCA and SCA. The "creative destruction" is not fully realized in the creation of new competencies or radical skills, since, on average, companies in the Brazilian industry innovate incrementally. In terms of APD, the importance of suppliers and customers may be causing this situation. Partnerships with universities/research institutes, only appearing in third place and at a much smaller proportion than the first two partnership types, also support this conclusion. However, even if these forces are not completely aligned, their individual effects on the relationship between APD and innovative performance were detected, which validates the theoretical/empirical model proposed here.

In general, based on Graphs 1 and 2, one can perceive the weak moderating effects stated in hypotheses 2 and 3, even though such effects were statistically significant. The weak "flattening" of the curve appears to reflect the Brazilian innovative environment. Corporate R&D initiatives still seem immature while SCA, to be more effective, may need an environment where greater legal certainty exists since these assets are included in categories of activities less subject to normative institutional controls. In other words, RDCA and SCA positively moderate an innovative result but this still needs to be consistently kept in mind. Finally, the weak flattening of the curve may reflect the substitutability between RDCA and SCA.

The contribution of this study to the theory of open innovation is that it identifies APD as a strategy that benefits a firm's performance. The present study also extends AC theory as it considers APD not as an element that has more than one dimension only in terms of skills and competencies but also in terms of a spatial dimension. Thus, AC, when used by a firm's other internal subunits, can be indirectly connected to the vision of the firm's knowledge and learning. From a managerial perspective, the importance of the firm's senior management performance is explicit, in terms of its emphasizing synergies and neutralizing conflicts that may emerge between the subunits that act like radars in the competitive environment, seeking useful alliances.

The limitations of this study relate to the sample's high heterogeneity, as well as the treatment of APD as a homogeneous strategy, that is, without considering, for example, the level of internationalization of this strategy. In addition, due to Pintec's data limitations, this study did not use a more effective approach for attributing causality between the variables, which require using panel data. Other limitations related to the Pintec database, which may have impacted the sample, involve the specificities of the innovative organizational environment. In the case of the variable measuring a firm's R&D efforts—which was a sample selection criterion—the study's scope indicated the option of using this variable as a moderating variable (level of investments and external environment) and as a control variable (level of investments and internal environment). This option proved to be the best among other alternatives.

However, it is recognized that such limitations, either due to the database or the scope of the research, may have impacted the results. For instance, they may have caused the modest moderation effect of the curvilinear relationship captured by the figures, as well as the cases of marginal statistical significance, especially that of the SCA moderating variable.

Thus, there are opportunities for future research related to sample segmentation strategies, for example, using the criterion of technological intensity or a regional analysis. It is also possible to consider the insertion of variables specifically relevant to the relationships between the subunits of the firm, or the specific evaluation of the effects of joint ventures on innovative performance. Finally, innovative performance can be measured in ways that are less obvious than those normally found in the literature, such as the impacts of this performance on costs, market share, and also environmental issues.

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AUTHORS' CONTRIBUTIONS

The authors declare that they participated in all stages of development of the manuscript, including the conceptualization and theoretical-methodological approach, the theoretical review (literature survey), the data analysis, and finally, the writing and final review of the article. The data collection was conducted by the first author.