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ARTICLE

Open Innovation and Implementation of Different Types of Innovation: An Analysis Based on Panel Data

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ABSTRACT

This work aimed to verify, based on the open innovation strategy, how different types of interactions with external actors (customers, competitors, suppliers, universities, and consultants) influence different types of innovations (general innovations, product innovations, and technological innovations) implemented by organizations. The panel data technique was used for analysis, based on PINTEC data, an innovation survey conducted by IBGE, which referred to the years 2003, 2005, 2008, 2011, and 2014. Regarding the innovations implemented by organizations, no type of interaction was significant for the general innovations or interactions with consultants, and suppliers were negative for product innovation. Finally, interaction with customers was positive while interaction with universities was negative for technological innovations. Thus, the results were essential to proving that different forms of cooperation have different impacts on the implementation of different types of innovation by organizations.

KEYWORDS

Open Innovation, Innovation, Cooperation, PINTEC, Panel Data Analysis

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1. INTRODUCTION

Innovation could be considered one of the essential factors for an organization to have a competitive advantage and market growth (Kühl & Cunha, 2013; Ibrahimov, 2018; Sivam et al., 2019). However, the idea of a closed innovation, used by organizations in past times, no longer can meet the demands of the current market, so the assumption that an organization can innovate while in isolation is increasingly in conflict with the generation of knowledge in the 21st century (Chesbrough, 2003a, b).

In contrast with the closed innovation, which is based on the "internal" resources of companies, an open innovation comprises an open system of research and development (R&D) and represents an important bond between organizations (Brockman, Khurana & Zhong, 2018). In this sense, the concept of open innovation, proposed by Chesbrough in 2003, is a new paradigm of innovation, which advocate that the knowledge, and the organization's external technologies, could corroborate with the internal process of innovation (Ghisetti, Marzucchi & Montresor, 2015).

Several researchers have been using the open innovation paradigm as a study scope (Van de Vrande, Vanhaverbeke & Gassmann, 2010), in a way that leads to growth in the field, making it an established research area, providing paths for research, education, and discussion about the theme (Chesbrough & Bogers, 2014). Nowadays, this is considered to be one of the most important topics that discuss innovation management (Sivam et al., 2019), several authors emphasize that it is possible to be optimistic when thinking that there is still room for the emergence of rich, diverse, and even unexpected ways to understand the process of open innovation (Van de Vrande, Vanhaverbeke & Gassmann, 2010; Abulrub & Lee, 2012).

In this sense, this study aims to corroborate with one of the main prerogatives of open innovation: interaction with external parties, for example clients, suppliers, competitors, or universities, among others (Chesbrough, 2003b; Dahlander & Gann, 2010), is essential to generating and promoting innovation for among organizations (Chesbrough & Crowther, 2006). However, according to Rauter et al. (2019), the effects of how the innovation partners influence the innovation performance are still not clear, in a way which, for Stefan & Bengtsson (2017) more studies on the matter are essentials for a better understanding of how the external interaction can influence in terms of creation and innovation appropriation.

Since many different types of corroboration are necessary for the development of different kinds of innovations, given that each type of partner has its own perspective and access to many sources of knowledge and information (Haus-Reve, Fitjar & Pose, 2019), more studies should seek to understand which external sources of knowledge have higher relevance in order to achieve different innovation outcomes (Beule & Van Beveren, 2019). In contrast to this background, the following research question emerged: does the interaction with external agents influence the implementation of different types of innovations in organizations? In this way, the main objective of the present research is to analyze the importance of interaction with external partners for the implementation of different types of innovation by the organization. Responding to this goal, this study aims to analyze how the interaction with different types of external agents can influence in a different manner many types of innovation, such as (i) general innovation, (ii) product innovation and (iii) technological innovation.

Still, many authors emphasize the need for more objective and quantitative research regarding open innovation (Al-Belushi et al., 2018; Beule & Van Beveren, 2019), especially in regards to research that determines the causality of interaction with external agents with greater reliability (Foege et al., 2019). For this purpose, seeking to fulfill this void, this research has employed the panel data technique to analyze how it is occurred the interaction of certain sectors of the

Brazilian economy from the data of the Industrial Survey of Technological Innovation (PINTEC), developed by IBGE, the Brazilian Institute of Geography and Statistics, from the years of 2003, 2005, 2008, 2011 e 2014.

2. OPEN INNOVATION AND HYPOTHESES FORMATION

In the present days, more and more, innovation has been constituting itself as an important source of competitive advantage, giving an ability to gain leadership in a competitive market, as well as determine the economic success of each organization (Abulrub & Lee, 2012; Sivam et al., 2019). To this end, according to Chesbrough (2003a), most large organizations during the (20th) twentieth century used the closed innovation paradigm as the foundation of their R&D laboratories, achieving, at that time, important achievements and commercial successes. In this type of philosophy, companies believed that for an innovation to be successful it would be essential to have control over it, so that organizations should generate their own ideas, as well as develop, manufacture, market, distribute, and provide services on their own (Chesbrough, 2003b).

However, given that this way of thinking is increasingly in conflict with the generation of knowledge in the 21st century (Chesbrough, 2003a), effective organizations are now emerging, which work together as a way to identify their key assets, processes, and capabilities (Walters & Rainbird, 2007), this being a better way to innovate than innovating in isolation (Wallin & Von Krogh, 2010). To this end, a new paradigm thought up by Chesbrough emerged in 2003 — the open innovation, which, despite the fact that several definitions of this term are known, is actually seen as undefined (Vanhaverbeke & Chesbrough, 2014). Several pieces of research have used this paradigm as a study scope, seeking mainly to understand the growing need to understand the simultaneous use of internal and external knowledge by organizations (Van de Vrande, Vanhaverbeke & Gassmann, 2010).

According to Chesbrough (2003a), open innovation means that valuable ideas can be originated both inside and outside organizations, where the external acquisition of knowledge acquires as much importance as the ideas developed internally. Therefore, the boundaries between the company and the external environment are more permeable, so that external technologies and knowledge can be integrated into internal projects, just as internal knowledge and technologies influence business outside the organization (Chesbrough, 2003b).

In this interaction process, there are several types of agents with whom companies can relate, among them suppliers, fund providers, consultants, partners, customers, universities, and competitors, among others (Ibrahimov, 2018). What is emphasized is that these external individuals are holders of important knowledge and represent an essential capacity for the generation of innovation by an organization, given that innovation has better competitive advantages when associated with the elements of the macroenvironment, mainly through cooperation with various agents (Sivam et al., 2019).

With valuable external knowledge, a company is able to increase its own strengths and speed during the implementation of innovations, as well as complement idle internal knowledge (Ibrahimov, 2018). In this context, this study focused on analyzing one of the main outcomes and benefits obtained from the interaction with external entities, this being the increase in the organization's ability to innovate (Shaikh & Levina, 2019).

In this context, the open innovation literature has mainly studied how open innovation practices can improve a company's innovation performance, focusing on the benefits of organizational openness and attributing innovation success to the extent of external connections and the range of R&D (Chesbrough, 2003a; Brockman, Khurana & Zhong, 2018), given that the open innovation approach aims to achieve strategic flexibility to allow firms to create more and better innovations from various cooperation strategies (Gassmann & Enkel, 2004). In this sense, considering that interaction with external agents can influence the development of innovations, one has:

- **H_{1A}:** The implementation of general innovations by the organization relates to the importance of cooperation with customers.
- **H_{1B}:** The implementation of general innovations by the organization relates to the importance of cooperation with universities.
- **H_{1C}:** The implementation of general innovations by the organization relates to the importance of cooperation with competitors.
- **H_{1D}:** The implementation of general innovations by the organization relates to the importance of cooperation with suppliers.
- **H_{1E}:** The implementation of general innovations by the organization relates to the importance of cooperation with consultants.

Innovation itself can be defined as the application of new ideas in products, processes, or other activities developed by a company (Kuncoro & Suriani, 2018), so it can be characterized in four types, those being of product, of process, of marketing, and of organizational innovation (OECD, 2005). As for product innovations, it has been observed that they are innovations employed by the company as a way for a new product to be created or improved (Kuncoro & Suriani, 2018), so studies about product innovation are an important subject for open innovation studies (Beugelsdijk & Jindra, 2018). To this end, with the emergence of open innovation, collaborative product innovation has become a new and promising product innovation model for the company (Lv & Qi, 2019), given that organizations, through interaction, are able to obtain external knowledge, which is essential to innovate their products from projects with other partners (Um & Asakawa, 2015; Anzola-Román, Bayona-Sáez & García-Marco, 2018; Haus-Reve, Fitjar & Pose, 2019). Thus:

- **H_{2A}:** The implementation of product innovations by the organization relates to the importance of cooperation with customers.
- **H_{2B}:** The implementation of product innovations by the organization relates to the importance of cooperation with universities
- **H_{2C}:** The implementation of product innovations by the organization relates to the importance of cooperation with competitors.
- **H_{2D}:** The implementation of product innovations by the organization relates to the importance of cooperation with suppliers.
- **H_{2E}:** The implementation of product innovations by the organization relates to the importance of cooperation with consultants.

Moreover, given that organizations need to adapt to rapidly changing environments, the ability to develop technological innovations is essential for these companies to respond quickly to market changes and to acquire innovative results (Ince, Imamoglu & Turkcan, 2016). To this end, technological innovation corresponds to efforts spent on R&D that will lead to the development of new technology-based products or services, or that will improve the productive efficiency of organizations (Cândido, 2011). In this sense, assuming that technological innovations result from the application by companies of scientific and technical knowledge to development and application of new technologies (Blanch et al., 2014; Geldes, Felzensztein & Palacios-Fenech, 2017), according to Jin et al. (2019) technological innovation can be considered a key element for the development of a country, since it benefits the development and application of new technologies, the optimization of traditional industries and the progress of industries. According to Anzola-Román, Bayona-Sáez & García-Marco (2018) a large amount of research has been showing positive effects from the implementation of collaborative innovation practices on the generation of technological innovations, so that, for Barañano (2005), the success of technological innovation also depends on the interaction and alliances with external agents. Thus,

- **H_{3A}:** The implementation of technological innovations by the organization relates to the importance of cooperation with customers.
- **H_{3B}:** The implementation of technological innovations by the organization relates to the importance of cooperation with universities.
- **H_{3C}:** The implementation of technological innovations by the organization relates to the importance of cooperation with competitors.
- **H_{3D}:** The implementation of technological innovations by the organization relates to the importance of cooperation with suppliers.
- **H_{3E}:** The implementation of technological innovations by the organization relates to the importance of cooperation with consultants.

For such, the three defined hypotheses for this study were synthesized on Figure 1, which represents the simplified theoretical model.

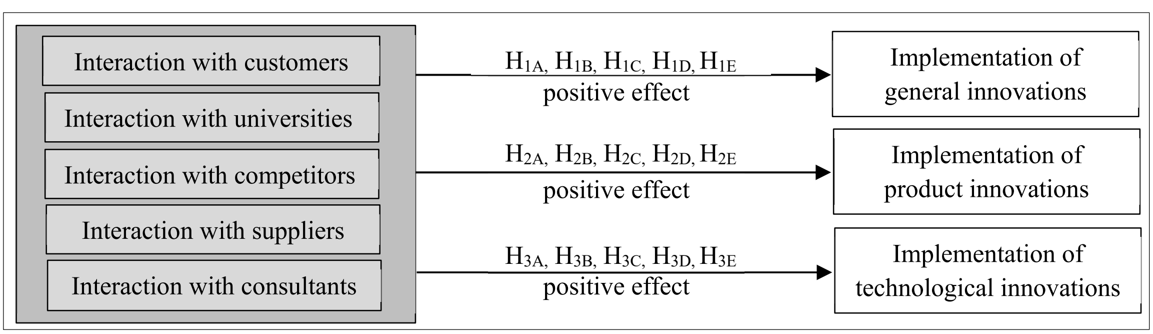

Figure 1. Simplified theoretical framework.
Source: Developed by the authors (2019).

3. METHODOLOGICAL ASPECTS

Seeking to answer the objective and develop the proposed hypotheses tests, the research has a quantitative approach, where statistical and mathematical methods were used in the research analyzes (Malhotra, 2012). Still, the research has a descriptive character, given that it sought to expose and study the characteristics of a phenomenon (Gil, 1999), corresponding to the implementation of various types of innovation based on the interaction with external actors.

The data used for analysis are secondary and were collected through free access to the editions of PINTEC, a survey about national indicators of innovation activities in some sectors of the Brazilian economy. PINTEC is a survey published by IBGE every 3 years, which, for the analysis, the editions of 2003, 2005, 2008, 2011 and 2014 were used. Still, it is emphasized that the number of sectors interviewed varied between PINTECs, requiring a standardization, selecting only sectors contained in all PINTECs. Thus, 28 sectors of the economy were considered for analysis, corresponding to a total of 140 cases analyzed.

As for the variables used to develop the study, the dependent variables are based on issues related to the implementation of some types of innovation, such as (1) implementation of general innovations; (2) implementation of product innovations; and (3) implementation of technological innovations. The independent variables represent the partnership with several external actors, these being (1) customers; (2) suppliers; (3) universities; (4) competitors; and (5) consultants. Given that the responses of the independent variables in PINTEC vary between 3 = High, 2 = Medium and 1 = Low, it is emphasized that only companies that answered 3 = High for the variables were considered, given that the objective of the study is to analyze how interaction with external partners interferes in implementation of innovation.

In addition, four control variables were used that are related to internal innovation activities, which are: (1) Internal Research and Development (Anzola-Román, Bayona-Sáez & García-Marco, 2018; Hsiao & Hsu, 2018); (2) Training (Barañano, 2005; Hsiao & Hsu, 2018); (3) Acquisition of Machinery and Equipment (Robertson, Casali & Jacobson, 2012; Lau & Lo, 2015); and (4) Net Sales Revenue (NSR) (Liu et al., 2018; Longhini et al., 2018).

Thus, Chart 1 presents a summary of the variables used for analysis.

As for data analysis, the procedure used refers to statistical techniques using panel data, using the “R” software, an open source environment for statistical computing and graphing, compiling, and running a wide variety of data.

For each dependent variable, two models will be estimated, and one more specified (Model 1, Model 3 and Model 5), with only independent variables, and another more complete (Model 2, Model 4 and Model 6), with independent and control variables. Below are the general notations, without tests and validations, of the proposed models:

$$\text{Model 1: } GenInnov_{it} = \beta_0 + \beta_1 Customer_{it} + \beta_2 Supplier_{it} + \beta_3 Competitor_{it} + \beta_4 University_{it} + \beta_5 Consultant_{it} + C_i + \varepsilon_{it} \quad (1)$$

$$\text{Model 2: } GenInnov_{it} = \beta_0 + \beta_1 Customer_{it} + \beta_2 Supplier_{it} + \beta_3 Competitor_{it} + \beta_4 University_{it} + \beta_5 Consultant_{it} + \beta_6 R\&D_{it} + \beta_7 Training_{it} + \beta_8 Acquisition_{it} + \beta_8 \ln(NSR)_{it} + C_i + \varepsilon_{it} \quad (2)$$

$$\text{Model 3: } ProdInnov_{it} = \beta_0 + \beta_1 Customer_{it} + \beta_2 Supplier_{it} + \beta_3 Competitor_{it} + \beta_4 University_{it} + \beta_5 Consultant_{it} + C_i + \varepsilon_{it} \quad (3)$$

$$\text{Model 4: } ProdInnov_{it} = \beta_0 + \beta_1 Customer_{it} + \beta_2 Supplier_{it} + \beta_3 Competitor_{it} + \beta_4 University_{it} + \beta_5 Consultant_{it} + \beta_6 R\&D_{it} + \beta_7 Training_{it} + \beta_8 Acquisition_{it} + \beta_8 \ln(NSR)_{it} + C_i + \varepsilon_{it} \quad (4)$$

$$\text{Model 5: } TecInnov_{it} = \beta_0 + \beta_1 Customer_{it} + \beta_2 Supplier_{it} + \beta_3 Competitor_{it} + \beta_4 University_{it} + \beta_5 Consultant_{it} + C_i + \varepsilon_{it} \quad (5)$$

$$\text{Model 6: } TecInnov_{it} = \beta_0 + \beta_1 Customer_{it} + \beta_2 Supplier_{it} + \beta_3 Competitor_{it} + \beta_4 University_{it} + \beta_5 Consultant_{it} + \beta_6 R\&D_{it} + \beta_7 Training_{it} + \beta_8 Acquisition_{it} + \beta_8 \ln(NSR)_{it} + C_i + \varepsilon_{it} \quad (6)$$

Chart 1
Variables used in regressions

Variables		Label	Description
Dependents	general innovations	GenInnov	Total of companies that declared to have implemented general innovation divided by the total of interviewed companies multiplied by one hundred.
	product innovations	ProdInnov	Total of companies that declared to have implemented product innovation divided by the total of interviewed companies multiplied by one hundred.
	technological innovations	TecInnov	Total of companies that declared to have implemented technological innovation divided by the total of interviewed companies multiplied by one hundred.
Independents	Customers	Customer	Companies that declared their interaction with customers as high divided by the total number of companies interviewed multiplied by one hundred.
	Suppliers	Supplier	Companies that declared their interaction with suppliers as high divided by the total number of companies interviewed multiplied by one hundred.
	Competitors	Competitor	Companies that declared their interaction with competitors as high divided by the total number of companies interviewed multiplied by one hundred.
	Universities	University	Companies that declared their interaction with universities as high divided by the total number of companies interviewed multiplied by one hundred.
	Consultants	Consultant	Companies that declared their interaction with consultants as high divided by the total number of companies interviewed multiplied by one hundred.
Of Control	Research and development	R&D	Companies that have implemented internal R&D divided by the total number of companies interviewed multiplied by one hundred.
	Training	Training	Companies that have implemented Training divided by the total number of companies interviewed multiplied by one hundred.
	Acquisition of Machinery and Equipment	Acquisition	Companies that Purchased Machinery and Equipment divided by the total number of companies interviewed multiplied by one hundred.
	Net Sales Revenue	NSR	Operationalized in a logarithmic way (ln) from the division of the NSR of each sector by the total number of companies interviewed in each sector.

Source: Developed by the authors (2019).

Where β_0 is the intercept; β_1 to β_8 represents the parameters to be estimated for the independent and control variables; the error term is divided between a fixed component $C_{i,}$, representing a possible heterogeneity existing between individuals and fixed in time, and a random component ε_{it}.

As a way to operationalize the results, tests were developed in order to ensure that the results were achieved in the best way. With the Hausman test, it was possible to identify the best option of a regression model with panel data to be used, as a way to choose between fixed effects and random effects. In addition, tests were developed to identify the problem of heteroscedasticity, using the Breush Pagan Test, and the short-panel autocorrelation problem, using the Wooldridge Test.

4. RESULTS

The descriptive statistics, accordingly to Wooldridge (2018), consist of a statistic that is employed to summarize a set of numbers, which are expressed in Table 1. Accordingly to the average of the dependent variables (GenInnov, ProdInnov e TecInnov), organizations in general develop more general and product innovations than technological innovation, so that the latter even present a minimum value of zero, which shows that some organizations do not even develop this type of innovation.

Table 1
Descriptive statistics

Variables	Median	Standard deviation	Minimum	Maximum	Observations
1. GenInnov	36,23	12,40	18,90	83,25	140
2. ProdInnov	20,70	13,64	5,95	83,25	140
3. TecInnov	6,32	7,96	0,00	44,80	140
4. Costumer	1,75	4,76	0,00	33,61	140
5. Supplier	2,04	6,48	0,00	41,62	140
6. Competitor	0,20	1,23	0,00	8,14	140
7. University	0,56	3,00	0,00	16,84	140
8. Consultant	0,39	1,74	0,00	9,68	140
9. R&D	5,06	11,29	0,15	60,22	140
10. Acquisition	22,57	7,87	6,47	54,28	140
11. Training	15,99	8,13	5,17	58,05	140
12. NSR	10,45	1,83	6,90	15,37	140

Source: Elaborated from research data (2019).

Regarding the independent variables, it was verified that cooperation with suppliers has a higher average than that of other variables, showing preference for an interaction with this agent. Still, the minimum value of all independent variables is zero, indicating that many organizations do not believe that the interaction with outside agents to be important, while the maximum value shows that the cooperation with suppliers and customers is more interesting to companies than competitors, universities and consultants, which presented a lower maximum value. Finally, the high dispersion in the data could be caused by the fact that the analyzed sectors are of various sizes.

As for multicollinearity, it can be problematic if it expresses a high, but not perfect correlation between two or more independent variables (Wooldridge, 2018). It represents the degree to which one variable can be predicted or explained by the other variables within the analysis, and the way multicollinearity increases it becomes more difficult to verify the effect of any variable due to their interrelationships (Hair et al., 2009). For this analysis, the correlation matrix was created, as well as the *Variance Inflation Factor* (VIF) measure, performed from the individual variable coefficient statistics (Wooldridge, 2018). Accordingly to Table 2, the correlation between variables, mainly the independent ones, usually are low and moderate, showing low risks for multicollinearity, given that the correlations above 0.8 can exhibit the presence of it (Gujarati & Porter, 2011). Thus, through the VIF, which represents an indicator of the effect that independent variables have on the standard error of a regression coefficient (Hair et al., 2009), it is confirmed that the removal of evidence of multicollinearity, since the maximum accepted value is 10 (Gujarati & Porter, 2011; Wooldridge, 2018) and the highest VIF value found was 7.97.

Table 2
Correlation matrix of dependent and independent variables

Variables	VIF	1	2	3	4	5	6	7	8	9	10	11	12
1. GenInnov		1,00											
2. ProdInnov		0,87	1,00										
3. TecInnov		0,78	0,82	1,00									
4. Costumer	7.97	0,62	0,68	0,79	1,00								
5. Supplier	7.67	0,62	0,68	0,84	0,92	1,00							
6. Competitor	2,02	0,45	0,41	0,54	0,64	0,61	1,00						
7. University	2.99	0,44	0,44	0,44	0,58	0,55	0,52	1,00					
8. Consultant	2,36	0,40	0,32	0,42	0,50	0,48	0,56	0,71	1,00				
9. R&D	4,07	0,77	0,87	0,82	0,78	0,77	0,50	0,61	0,43	1,00			
10. Acquisition	2,24	0,78	0,66	0,60	0,43	0,43	0,26	0,24	0,19	0,57	1,00		
11. Training	2,87	0,73	0,64	0,73	0,57	0,63	0,35	0,38	0,30	0,66	0,70	1,00	
12. NSR	1.99	0,52	0,50	0,57	0,62	0,61	0,37	0,58	0,44	0,62	0,37	0,48	1,00

Source: Elaborated from research data (2019).

After the initial descriptive statistics and multicollinearity analyses, the panel data analysis of the proposed models was conducted. Table 3 presents the performed tests, as follows: (i) Hausman test, which allowed for the identification of which is the best option for the model with panel data between the fixed effects and random effects methods, where, in the face of a p-value lower than 0.05, the fixed effect is opted for, given that it rejects the null hypothesis that the random effects are consistent, (ii) The Breush Pagan test as a way to identify heteroscedasticity problems, where a p-value of less than 0.05 indicates that we reject the null hypothesis of homoscedasticity, and (iii) Wooldridge test to identify autocorrelation problems in short panels, where a p-value of less than 0.05 indicates the rejection of the null hypothesis of absence of autocorrelation.

Table 3
Tests performed for the proposed regressions

Dependent Variable	Model	Tests Performed			Estimator
		Hausman (p-value)	Breush Pagan (p-value)	Wooldridge (p-value)	
GenInnov	1	$2{,}08\ e^{-13}$	0.37190	0.8142	Fixed effect
	2	$5.209e^{-09}$	0.00117	0.4312	Fixed effect with robust estimation
ProdInnov	3	$2.2e^{-16}$	$3.69e^{-05}$	0.6404	Fixed effect with robust estimation
	4	0.00010	0.00010	0.3929	Fixed effect with robust estimation
TecInnov	5	$2.2e^{-16}$	$4.62e^{-05}$	0.0958	Fixed effect with robust estimation
	6	$3.009e^{-05}$	$3.239e^{-09}$	0.0613	Fixed effect with robust estimation

Source: Elaborated from research data (2019).

As a way for the correction of possible heteroscedasticity problems, when identified in the models, it was chosen to estimate the model considering the robust standard errors, as it can be observed at Table 3, since, according to Wooldridge (2018), by obtaining and using the robust standard errors, it is possible to build a robust t-statistic regarding the heteroscedasticity problem.

Consequently, with the exception of Model 1, all the other models were estimated from the estimation using the robust standard errors, as they presented heteroscedasticity problems.

Regarding the Implementation of innovation variable (GenInnov), Table 4, it can be observed two estimated models, being those the Model 1, that contain only the independent variables and the Model 2, which contain the independent and the control variables.

Table 4
Panel regression for the dependent variable GenInnov

	Model 1		Model 2	
	Coefficient	Standard Error	Coefficient	Standard Error
Costumer	0,57	0,36	-0,07	0,29
Supplier	0,36	0,30	0,25	0,27
Competitor	-1,39	1,09	-0,32	0,60
University	0,08	0,44	0,06	0,28
Consultant	0,08	0,58	-0,06	0,40
R&D			0,31**	0,13
Acquisition			0,63***	0,08
Training			0,17*	0,10
NSR			6,90***	1,59
R^2	0,06		0,58	

Note: *significance level:* *p<0,10; **p<0,05; ***p<0,01.
Source: Elaborated from research data (2019).

According to Table 4, for the dependent variable GenInnov, in the complete model (Model 2), with significance at the level of 1% and with an R^2 of of 58%, and in the Model 1, no independent variable was significant, not supporting the hypotheses H_{1A}, H_{1B}, H_{1C}, H_{1D} and H_{1E}, which states that the implementation of innovations by organizations is related to the importance of cooperation with external agents. However, it was observed that all the control variables were significant, expressing that the generation of innovation by the analyzed organizations is much more associated with internal resources, such as Research and in-house Development (β=0.31, p<0.05), staff training (=0.17, p<0.10), acquisition of machinery and equipment (β=0.63, p<0.01) and net sales revenue (β=6.90, p<0.01), than related to the interaction with external agents.

As for the implementation of the product innovation variable (ProdInnov) found in Table 5, two estimated models were verified, with one of them being Model 3, which contains only the independent variables, and Model 4, which contains the independent and control variables.

In Table 5, it was shown that Model 3, with significance at the level of 1% and with R^2 of 14%, and the Model 4, with significance at the level of 1% and with R^2 of 31%. It was observed that two of the variables were significant, but negative, for both the Model 3, supplier (β= -0.96, p<0.05) and consultant, (β= -1.77, p<0.05), as for the Model 4, supplier (β= -0.92, p<0.05) e consultant (β= -1.35, p<0.10). This result corroborates with the presented hypotheses H_{2D} and H_{2E}, in which the implementation of product innovation is related to the importance of cooperation with suppliers and consultants, but with a negative sign.

Table 5
Panel regression for the dependent variable ProdInnov

	Model 3		Model 4	
	Coefficient	Standard Error	Coefficient	Standard Error
Costumer	0,49	0,38	0,16	0,35
Supplier	-0,96**	0,47	-0,92**	0,40
Competitor	-0,05	0,32	0,09	0,36
University	0,71	0,39	0,47	0,36
Consultant	-1,77**	0,81	-1,35*	0,73
R&D			0,37**	0,19
Acquisition			0,28**	0,12
Training			0,02	0,15
NSR			2,49	1,90
R^2	0,14		0,31	

Note: *significance level:* *p<0,10; **p<0,05; ***p<0,01.
Source: Elaborated from research data (2019).

As for the other independent variables (customer, competitor, and university) there was no evidence for any significant relations with product innovation, not supporting the hypotheses H_{2A}, H_{2B} e H_{2C}. Regarding the control variables, it was verified that both the internal R&D (β=0.37, p<0.05) and the acquisition of machinery and equipment (β=0.28, p<0.05) were significant in the Model 4, which showed that certain, more internal, innovation activities are fundamental to the generation of new products.

Regarding the implementation of technological innovation (TecInnov), at Table 6, two estimated models were observed, being those Model 5, which only has independent variables and Model 6, which has independent and control variables.

Table 6
Panel regression for the dependent variable TecInnov

	Model 4		Model 5	
	Coefficient	Standard Error	Coefficient	Standard Error
Costumer	0,56***	0,18	0,45***	0,16
Supplier	0,43	0,32	0,40	0,28
Competitor	0,29*	0,15	0,01	0,12
University	-0,42***	0,09	-0,33***	0,11
Consultant	-0,93**	0,39	-0,57	0,40
R&D			-0,01	0,09
Acquisition			0,02	0,03
Training			0,21***	0,05
NSR			1,83*	1,02
R^2	0,23		0,42	

Note: *significance level:* *p<0,10; **p<0,05; ***p<0,01.
Source: Elaborated from research data (2019).

According to Table 6, it can be observed from the complete model (Model 6), with a significance at the 1% level and with an R^2 of 42%, that the customer independent variable (β= 0.45, p<0.01) has a positive and significant relationship regarding the TecInnov variable. This supports the hypothesis H_{3A}, while the university (β= -0.33, p<0.01), despite having a significant relationship, supports the hypothesis H_{3B} that the implementation of technological innovations is related to the importance of cooperation with universities, has a negative interaction. Still regarding the complete model, the other independent variables (competitor, supplier and consultant) were not verified to have any significant relationships with TecInnov, which do not support the hypotheses H_{3C}, H_{3D} and H_{3E}. On the other hand, when analyzing the restricted model (Model 5), with a significance of 1% level and with an R^2 of 23%, it was verified that, besides the customer and the university already verified in the complete model, the supplier (β=0.29, p<0.10) presents a positive and significant relationship, supporting the hypothesis H_{3D}. As for the competitor variable (β= -0.42, p<0.05), despite having a significant relationship, has a negative result, supporting the hypothesis H_{3C}, but with a negative interaction. As for the control variables, it was observed that both Employee Training (β=0.21, p<0.01) and net sales revenue (β=1.83, p<0.10) have shown a positive and significant relationship, demonstrating that certain innovation activities are fundamental to TecInnov.

Therefore, accordingly to the results, it can be verified that the hypotheses H_{1A}, H_{1B}, H_{1C}, H_{1D} e H_{1E} were not supported, given that none of the independent variables, from the agents of interaction, was significant. As for the hypotheses H_{2D} e H_{2E}, it was observed that they were supported, since the consultant and supplier variable were identified for being related to the development of product innovation, but with a negative interaction. Lastly, as for the Technological Innovations, in the complete model, the hypothesis H_{3A}, which refers to the client cooperation, was supported with a positive interaction, and the hypothesis H_{3B}, consistent with universities, was supported with negative interaction. Still regarding Technological Innovations, considering the restricted model, the hypothesis H_{3D} was supported with a positive interaction, while hypothesis H_{3E}, which was also supported, showed a negative relationship. Figure 2 presents the summarized results.

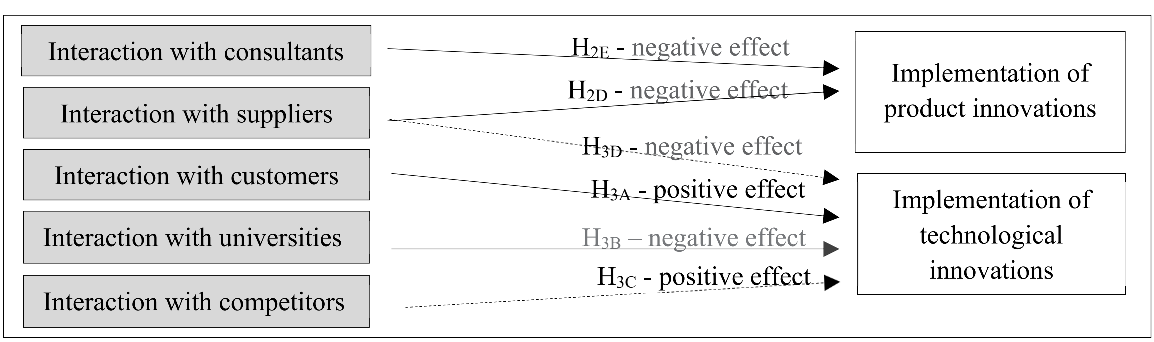

Figure 2. Result of the proposed hypotheses
Source: Developed by the authors (2019).

5. DISCUSSION

The presented results were essential to meet the proposed objective to analyze the importance of the interaction with external partners for the implementation of different types of innovations. It was identified that different types of external agents could have influence on the types of innovation within the organizations (Rauter et al, 2019; Haus-Reve, Fitjar & Pose, 2019), showing that not necessarily all kinds of collaboration could be beneficial for the innovation of the organization. Thus, it is understood that the innovation partners bring different types of knowledge to the company, so that different types of collaborations play different roles in the innovation process (Haus-Reve, Fitjar & Pose, 2019).

Open innovation supports that organizations could increase their innovation activities if they engage with external agents, given that cooperation renews and complements the internal knowledge of the organizations, as well as to broaden external paths to commercialize the internally generated knowledge (Chesbrough, 2003b; Beule & Van Beveren, 2019; Sivam et al., 2019). However, even though companies are increasingly engaging with external partners (Shaikh & Levina, 2019), according to Al-Belushi et al. (2018) many companies have still been ignoring opportunities to collaborate with external agents, as verified by the rejection of hypotheses H_{1A}, H_{1B}, H_{1C}, H_{1D} and H_{1E}, in which it was found that cooperation does not interfere with the implementation of innovations (GenInnov) by companies. According to Kühl and Cunha (2013, p. 8) “difficulties in developing, maintaining and using relationships with partners have become obstacles, since, in some way, innovations are related to customers, suppliers, partners and even competitors, among others”.

As for the implementation of product innovation (ProdInnov), it was found that both the interaction with suppliers and with consultants were considered to be significant, supporting the hypotheses H_{2D} and H_{2E}, but with negative interaction, which means that the interaction with external agents interferes with the implementation of product innovations (Um & Asakawa, 2015; Anzola-Román, Bayona-Sáez & García-Marco, 2018; Lv & Qi, 2019). As such, intensifying the relationships with suppliers and consultants decreases the implementation of product innovations for companies. Regarding the suppliers, it was observed that the results were divergent from the literature, which considered this to be a vertical and not competitive cooperation, where suppliers can be a source of innovative and technological ideas for the innovation process of companies, given that they have specific knowledge and skills (Fernandes, Cesário & Barata, 2017). Therefore, companies that create cooperation strategies with their suppliers can improve their innovation performance, both in quality and adaptation and availability of the product in the market (Fernandes, Cesário & Barata, 2017; Ardito et al., 2018). For this, the interaction with suppliers must happens at all stages of the innovation development, i.e., from the initial stage to the market introduction, otherwise the interaction will not have possible benefits (Homfeldt, Rese & Simon, 2019).

Regarding the cooperation with consultants, which was negative for ProdInnov, it was found that, although consultants are considered to be sources of expertise and skills for the development of innovation, since they have different points of view from the company (Wright, Sturdy & Wylie, 2012; Back, Parboteeah & Nam, 2014; Fernandes, Cesário & Barata, 2017), it was found that the interaction cannot be beneficial if the innovation process from the organization is more closed. In that case, the role of the consulting becomes idle, since the company relies more on internal ideas than on the interaction with consultants (Tether & Tajar, 2008), a fact observed in the results of this research, where internal innovation activities, such as internal R&D, was also significant. There are also other problems, such as the possibility that consultants only perform standardized processes based on old experiences (Wright, Sturdy & Wylie, 2012), or that they are not interested in committing to innovation (Tether & Tajar, 2008). In addition, there is the difficulty of managing contracts, as well as the possibility that consultants only perform what the companies expect of them, and don't show any significant results for innovation (Back, Parboteeah & Nam, 2014).

Lastly, regarding the implementation of technological innovations (TecInnov), a positive relationship with customers was found (hypothesis H_{3A}) and a negative relationship with universities (hypothesis H_{3B}). As for customers, it was observed that they can positively interfere in the development of this type of innovation (Sivam et al., 2019), especially when customer needs are complex (Haus-Reve, Fitjar & Pose, 2019). Given that the interaction with customers is vertical and not competitive (Fernandes, Cesário & Barata, 2017), collaborating with customers is considered to be a method to develop products accordingly to market needs (Eiteneyer, Bendig & Brettel, 2019), especially regarding the development of products that change rapidly, such as new technologies, where more direct interaction with customers force companies to renew their innovation strategies and activities (Barañano, 2005; Fernandes, Cesário & Barata, 2017; Ardito et al, 2018; Haus-Reve, Fitjar & Pose, 2019).

The universities, on the other hand, showed a negative relationship in the implementation of technological innovations (TecInnov), so that intensifying the relationship with these agents decreased the implementation of technological innovations of companies. Even though universities are receiving an increasing attention in the interaction for innovation of companies (Saito, 2010), representing one of the main means of cooperation in terms of innovative outcomes (Howells, Ramlogane & Cheng, 2012; Sivam et al., 2019), it was observed that often companies may not be prepared to exploit this type of knowledge (Haus-Reve, Fitjar & Pose, 2019). Mainly due to the cultural difference between these agents, which have opposite purpose and goals (Howells, Ramlogane & Cheng, 2012), universities perform a type of research not developed by companies (Saito, 2010), with a more basic nature and without the intention of commercialization of their results and discoveries (Miotti & Sachwald, 2003). For this, companies need to develop an internal capacity to interact with this agent, otherwise they will not have a positive cooperation (Fernandes, Cesário & Barata, 2017), as well as perform, at the same time, an interaction with other agents within the supply chain, as a way to complement the knowledge of universities (Haus-Reve, Fitjar & Pose, 2019).

Still, the results did not elucidate the importance of cooperation with competitors for any of the complete models (Model 2, Model 4 or Model 6). It went against the research in the area, which shows that cooperation with competitors, a horizontal cooperation form, is important to intensify the competitiveness of companies in the market failures and technological deficiencies (Fernandes, Cesário, & Barata, 2017; Ardito et al., 2018). However, for the restricted model (Model 5) and for the variable TecInnov, the relationship with the competitor was significant, but negative. This demonstrated that companies only have positive results when interacting with competitors, as long as they are able to reconcile this interaction as a way of not harming competition in the market in which they operate, such as in the disclosure of secrets of the innovation processes, since, even though there is a cooperation, they are still competitors in the same market (Fernandes, Cesário & Barata, 2017; Ardito et al., 2018; Sivam et al., 2019).

As for the control variables, it was observed that the internal R&D has a direct influence at both the generation of general innovations (GenInnov) and technological innovations (TecInnov), demonstrating that organizations that invest in internal R&D have significant effects on the performance of new innovations (Hsiao & Hsu, 2018) and technological innovations (Anzola-Román, Bayona-Sáez & García-Marco, 2018). However, Ramadani et al. (2019) emphasize that not all R&D spending results in new products, a fact that may relate to the findings of this study, where the internal R&D did not interfere with the development and implementation of product innovation. Still, even though internal R&D is important for the innovative process of organizations, it was found that it is currently difficult for companies to maintain competitive advantage only with investments in internal R&D, and they must seek ways to collaborate with other organizations (Fernandes, Cesário & Barata, 2017; Anzola-Román, Bayona-Sáez & García-Marco, 2018).

The training variable proved to be important, mutually for the implementation of innovation (GenInnov) and for the technological innovation (TecInnov), since it constitutes an obstacle, "the lack of personnel with innovative capacity or even the lack of qualified personnel to deal with innovations, in addition to the need to know how to deal with new technologies" (Kühl & Cunha, 2013, p. 7). In this sense, one of the needed factors for innovation to occur, among them technological innovation, concerns the structure of the workforce, since the knowledge and skills of the organizational human capital influence the company's ability to constantly innovate, and companies must empower, train and educate their employees (Barañano, 2005; Blanch et al. 2014; Hsiao & Hsu, 2018).

Furthermore, the acquisition of machinery and equipment were also significant for the implementation of innovations (GenInnov) and of product innovations (ProdInnov), proving to be an important element in certain innovation processes (Robertson, Casali & Jacobson, 2012; Lau & Lo, 2015). Finally, the net sales revenue was significant for development of general innovations (GenInnov) (Longhini et al., 2018) and of technological innovation (TecInnov) (Liu et al., 2018), given the implementation of innovations has a strong connection with the growth of company values, which can cause greater investments in production efficiency and other innovation-related elements later on (Liu et al., 2018).

6. CONCLUSION

This article verified how different types of interaction with external actors influence different types of innovation implementation by organizations. Thus, it was analyzed how the interaction with customers, competitors, suppliers, universities, and consultants influences the implementation of general innovations (GenInnov), product innovations (ProdInnov) and technological innovations (TecInnov). Using panel data analysis, we analyzed how cooperation for innovation occurs in certain sectors of the Brazilian economy based on data from PINTEC, an IBGE innovation survey for the years 2003, 2005, 2008, 2011 and 2014.

Regarding the general innovations (GenInnov) implemented by organizations, it was found that no type of interaction with external actors was significant, while the control variables (Internal R&D, Training, Acquisition of Machinery and Equipment, and Net Sales Revenue), which correspond to internal capacities to innovate, were significant. As for product innovation (ProdInnov), it was observed that interactions with consultants and suppliers were negative, demonstrating that cooperation with these actors is not being well managed by organizations, while some control variables (Internal R&D and Acquisition of Machinery and Equipment) were significant. Regarding technological innovation (TecInnov), interaction with customers was positive and with universities it was negative, as well as some control variables (Training and Net Sales Revenue) were significant.

The results contribute to the literature in different ways. We highlight the evidence that different types of cooperation corroborate, or not, differently in the implementation of certain types of innovation. Thus, although it is currently recommended that interaction with external actors is essential for organizational innovations, we found that such interaction may not be significant in the implementation of certain innovations, just as there are times when they can be harmful, since some relationships have been negative. Still, while the majority of interactions were not significant, or were negative, it appears that organizations seek to innovate by improving their own internal innovation capabilities, since the control variables, which represent the internal capabilities of companies, were significant. We emphasize that it was not for the study to understand how interactions occur, but whether they corroborate in the innovation processes. New research should seek to understand more deeply each type of influence from external actors, be it positive, negative or non-existent, in the implementations of innovations.

Proving that not necessarily all types of cooperation can be beneficial to the innovative process of companies, the results do not prove the most current theories of innovation, such as open innovation, which emphasizes that organizations must relate to different types of partners to acquire ideas and external resources to innovate and remain competitive in the sector in which they operate. Thus, the analysis of Brazil as an empirical field, a developing country, was essential to demonstrate that innovation practices can be different from developed and industrialized contexts in which most theories are developed. Further studies and new approaches should continue to explore the perspectives of innovation in different contexts, looking for peculiar and distinct findings for such processes.

In terms of practical contributions, for the managerial context, this study corroborates by presenting which types of cooperation are most significant for different ways that an organization has to innovate. Managers can take advantage of the results to make better innovation decisions and choose the best partners for their innovative processes, since the relationships with different actors and the innovation results of organizations are heterogeneous. As for the contributions of public policies, from the results found, governments can develop more effective policies, capable of improving and boosting the essential interactions for the innovation process, as well as improving relations that have not been beneficial, strengthening the national innovation system.

Finally, as for the limitations of the study, only three types of innovations developed by organizations were analyzed, namely: general innovations, product innovations and technological innovations. New research can expand the results, addressing other types of innovations existing at PINTEC, such as process innovations, marketing innovations and organizational innovations. Another limitation corresponds to the unit of analysis, since an aggregate analysis was carried out using data from Brazilian business sectors. In this way, future research can carry out more precise analyzes with microdata from each company, obtaining more peculiar findings. Still, next research may include, in the analysis, other cooperation actors not analyzed in this work, such as training centers and other companies of the group itself.

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CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR'S CONTRIBUTION

Author 1 - Conceptualization; Data curation; Formal analysis; Investigation; Application of the method using the R software; Methodology; Writing and editing
Author 2 – Supervision; Formal analysis; Methodology; Content validation.
Author 3 – Data curation; Data curation; Formal analysis; Methodology.
Author 4 – Supervision; Project administration; Content validation.

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