INNOVATIVE PERFORMANCE AND CAPABILITIES OF INTERACTING FIRMS

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ABSTRACT

The subject of this paper is the relationship between innovative performance and capabilities of firms that, in the search for external knowledge to innovate, interact with scientific and research institutions. The innovation capability is understanding as major capability formed by development, operation, management and transaction capability (ZAWISLAK *et al.*, 2012, 2013). Considering this, the aim of this paper is to understand the behavior of innovation capabilities and performance of firms that interact and the ones that do not interact with scientific and research institutions. For this, it was used data from a project survey ("Paths of Innovation in Brazilian Industry") that aimed at deepening the understanding of Brazilian industries' innovation dynamics. Data analysis for this study comprised 1,331 valid questionnaires. The interacting firms cluster, which encompasses firms that interact with scientific and research institutions, consists of 370 firms, and the non-interacting firms cluster, which has firms that do not interact, presents 949 firms. Results show that there are differences between innovation capabilities of firms that interact compared to those that do not interact with scientific and research institutions. Firms that establish interactions have more development, operations, management and transaction capabilities. Therefore, a significant difference between the two groups of firms relates with the development capability. This finding corroborates what had already been described in the literature, that the interaction is one of the mechanisms whereby firms can improve their development capability by developing new products and new technologies. Interacting firms also have higher innovative performance, measured by firm revenue, profit and market share growth. Thus, it is noted that interaction with scientific and research institutions does not only improve firms' development capability, but it also makes them obtain the innovative profit.

Keywords: University-Industry Interaction. Innovation Capabilities. Firm innovative performance. Brazil.

INTRODUCTION

In a world in which scientific and technological knowledge is increasingly specialized and complex, firms search for external knowledge to innovate. When firms do not have all knowledge and capabilities required to develop new products, processes and technologies internally, they may search for external sources to do so. In this sense, interaction between firms and other scientific and research[1] institutions have been appointed as promoters of innovations.

The interaction between firms and scientific and research institutions is a mechanism that facilitates and stimulates the innovative activities of firms, given that technological changes are usually derived from technological and scientific research in its state of the art, which highlights the growing importance of scientific knowledge participation in the generating of innovations (DOSI, 1988). In this sense, firms improve their innovation capabilities when interact with these institutions, this being a necessary condition for countries to fulfill their technological catching up process (MALERBA, NELSON, 2011).

Innovation policies are often part of national innovation systems. The theme related to innovation systems, especially at the national level, has been widely discussed in the literature. The main reason for this debate is the fact that the national context has a considerable influence to encourage, facilitate, delay or prevent the innovative activities of firms (FREEMAN, 1982). Thus, it is assumed that the national systems of innovation (NSI) influence the development, diffusion and use of innovations by forming connections between economic, social, political, organizational and institutional spheres (EDQUIST, 1997).

However, the interaction established between firms and scientific institutions shows different patterns according to the national system of each country. In developed countries, characterized by consolidated systems, the interaction between firms and scientific and research institutions is bidirectional with information and knowledge flowing in both directions (COHEN, NELSON, WALSH, 2002). In developing countries, there is little demand by firms for border technological knowledge (ARZA, 2010).

If firms want to be part of, or to take advantage of innovation systems, they might need internal capabilities to do so. It is our assumption that for interacting with scientific and research institutions and, hence, being able to innovate, firm should have some level of development, operations, management and transaction capabilities.

The aim of this paper is, therefore, to understand the behavior of innovation capabilities and performance of firms that interact and the ones that do not interact with scientific and research institutions. Thus, to analyze the capabilities to innovate of firms that perform different routines in the search and acquisition of knowledge contributes to understanding the behavior patterns

[1] The term *scientific and research institutions,* used in the paper, includes universities, research institutions, technological institutes and R&D laboratories, public and private.

and outcomes in terms of innovative activities. To know these elements allow reflect on important practices for firms develop more conditions to innovate.

Among the main arguments justifying the research include the absence of studies that seek to compare the firms that interact and the ones do not interact with scientific and research institutions. In addition, it is observed that the studies about this theme are focused mainly on investigating the determinants of these relations, without an interest to understand what are the characteristics of firms that engage in this type of relationship.

Aside from this introduction, the paper is organized into five sections. Section 2 contains the review of the literature on the importance of the interaction between firms and scientific and research institutions and the search for scientific and technological knowledge. Section 3 describes the research method. Section 4 presents and discusses the results. Finally, an overview of the study and the final remarks conclude the paper.

THE INTERACTION BETWEEN FIRMS AND SCIENTIFIC AND RESEARCH INSTITUTIONS

In the technological economics literature, the interaction between firms and scientific and research institutions, concerning the development of knowledge, inventions, and innovations, promotes a debate that is hinged on the NSI dynamics. The concept of NSI was first proposed by Freeman (1987), who defined it as “the network of institutions in the public and private sectors whose activities and interactions initiate, import, and diffuse new technologies”. Later on, Lundvall (1992) and Nelson (1993) introduced other definitions for the term, focusing on different determinants, which indicates the different schools of thought regarding this topic. However, by and large, NSI can be understood as the network of economic, social, political, organizational, and institutional factors that influence the development, the dissemination, and the use of innovations (EDQUIST, 1997).

Within the context of NSIs, there comes the interaction between firms and scientific and research institutions as a mechanism whereby it is possible to connect two different spheres that make up this system. This interaction is aimed mainly at increasing innovation and the competition between the actors in the network, and also at encouraging countries’ economic, industrial, and technological development. In this respect, the advent of modern technology demonstrated the existence of a complex relationship between science and technology, drawing special attention to the interaction between academic research and industrial innovation (ROSENBERG, NELSON, 1994; ROSENBERG, 2000). Nelson and Rosenberg (1993) consider the existing link between science and technology to be the cornerstone of NSI, with science being the leader and follower of technological advancements. Klevorick *et al*. (1995) argue that university and science provide technological opportunities for business innovation.

Among the major reasons for this connection is the reduction of public investments in academic research activities, especially from the 1970s onwards (COHEN *et al*., 1998). This new scenario led research institutes to seek new sources of financing, strengthening their relationship with firms and allowing for a greater knowledge transfer between them (MOWERY, SAMPAT; 2005).

According to Freeman (1982), Nelson and Winter (1982) and Rosenberg (1982), in some sectors, research conducted by universitities or institutes may be regarded as one of the main sources of

new technological opportunities. Inspired by this statement, Klevorick *et al*. (1995) and Cohen, Nelson and Walsh (2002) sought, more specifically, to understand the contributions of academic research to the industry. They concluded that the contributions of these institutions to firms' innovation dynamics take place by different mechanisms, depending on the relevance of science to each sector and on the absorptive capacity of the involved parties. Moreover, big firms give greater value to the interactions established with scientific and research institutions than do small-sized firms (MEYER-KRAHMER, SCHMOCH, 1998).

In addition, the literature describes the heterogeneity between different NSIs, mainly with respect to the pattern of interaction between agents (JOHNSON, LUNDVALL, 1994). Thus, the different patterns of interaction are related to differences at the sectoral level, to firm size, to the reasons for interaction, to the level of maturity of the system, among others (LEVIN *et al*., 1987; COHEN, NELSON, WALSH, 2002).

In developed countries, there exists a positive feedback system between scientific and research institutions and firms, with information and knowledge flowing in both directions, and basic research is a source of suggestions for new projects, but it also helps finish ongoing organizational projects (COHEN, NELSON, WALSH, 2002). Conversely, in developing countries, firms often do not have enough internal capability to develop innovative activities, and the interaction with these institutions is one of the possible mechanisms for overcoming the limitation on existing assets (ZAWISLAK, DALMARCO, 2011). More specifically in Latin America, the interactions between these actors are limited to consulting activities, and there is low demand for sophisticated know-how; therefore, the process of knowledge transfer goes in one direction only (AROCENA, SUTZ, 2000; ARZA, 2010).

In the specific case of Brazil, NSI can be deemed to be complete, but the dynamics and interaction between actors are poor, which makes it typically immature (FERNANDES *et al*., 2010). So, the pattern of interaction between universities and firms in Brazil is limited to "points of interaction" or "spots of interaction." Notably, there are successful cases, but they are few and far between and also localized, with a regional and sector-wise concentration of innovative activities by the firms (ALBUQUERQUE, 2003; RAPINI, 2007; RAPINI *et al*., 2009; SUZIGAN, ALBUQUERQUE, 2011). Consistent with these analyses, Dalmarco (2012) claims that, in Brazil, the interactions between universities and firms are basically aimed at solving technical problems whereas research activities are in line with firms' needs. Schima and Scatolin (2011) found that although consulting activities are not the most frequent type of interaction, firms often seek to solve technical problems in terms of applied research through interaction.

It may then be said that the interaction between firms and scientific and research institutions is one of the determining factors for NSI performance, and that firms' innovative capacity relies upon the network of interactions firms are linked to (FREEMAN, 1995; EDQUIST, 2005). Besides, firms' innovative capacity requires one of the elements pointed out by Malerba and Nelson (2011) so that countries can go through the process of technological catch-up, but it should be recalled that these capabilities can be acquired or improved through linkages with these institutions. Mazzoleni and Nelson (2007: 1512) underline that "universities and public research organizations are key institutions supporting this process of catching up", as it is by way of

interaction with these institutions that firms have access to frontier knowledge and acquire skills in relevant scientific fields. The authors also underscore that universities and other public research institutions are supposed to provide training and education, which are essential in order for firms to improve their innovation capability.

Accordingly, we understand that, if firms want to be part or take advantage of innovation systems, they might need internal capabilities to do so. Hence, when firms do not have all the knowledge necessary for innovation, they seek external sources of scientific and technological knowledge, which allow them to acquire some level of development, operations, management, and transactions capabilities. This topic will be addressed in further detail in the subsequent section.

The Search for Scientific and Technological Knowledge

By taking into consideration the specialization and complexity of knowledge, it is then analyzed whether the participation of scientific and technological knowledge is important in developing innovative activities. Dosi (1988) corroborates this finding by showing the growing importance of scientific knowledge to innovations, since technological changes occur as a result of state-of-the-art technological and scientific research. Therefore, firms try to establish interactions with external sources of knowledge and technology with the aim of ameliorating their learning processes and the development of innovations (GIULIANI, RABELLOTTI, 2012).

Among several external sources of knowledge, special attention should be paid to academic research institutions (BERCOVITZ, FELDMAN, 2007; GIUALIANI *et al*., 2010), which are supposed to qualify human resources, test materials in laboratories, jointly develop new ideas, among others (MOWERY, SAMPAT, 2005). This way, it is argued that firms which use external sources of knowledge intensively tend to focus some internal capabilities on certain areas of knowledge and utilize external sources to develop areas they are not good at (MIOTTI, SACHWALD, 2003; VELHO, SAEZ, 2002; VEUGELERS, CASSIMAN, 2005). On the other hand, Brusoni, Prencipe and Pavitt (2001) suggest firms need to develop internal capabilities in several areas of knowledge, because some of the difficulty in the interaction with external sources involves the control over the transfer of knowledge or technology between the actors.

Thus, scientific and research institutions are assumed to be central in the process of capability acquisition, as these capabilities allow firms to meet and anticipate market requirements both in developed and developing countries (AROCENA, SUTZ, 2000; ARZA, 2010; KUNC, TRIFFIN, 2011). To have some understanding about the relationship between the process of interaction with external sources of knowledge, especially in regard to those interactions with scientific and research intitutions, and about the development of innovations by the firms, it is necessary to observe firms' innovative activities by looking at their set of innovation capabilities.

Firms innovation capabilities, composed by development, operations, management and transaction capabilities, allows for a better understanding of firms innovation process. When firms do not have all knowledge and capabilities required to develop new products, processes and technologies internally, they may search for external sources to do so, as pointed out earlier. According to Zawislak *et al*. (2012), development capability and operation capability may be

understood based on their technological aspect, while management capability and transactions capability involve business activities.

First of all, development capability may be understood as the ability to interpret the current state of affairs, incorporate and, occasionally, transform some given technology in order to develop new products, processes, methods, and techniques with the aim of attaining higher levels of technical and economic efficiency (ZAWISLAK *et al*., 2012). The main evidence that firms seek to improve their development capability is observed in their reasons for interacting with scientific and research institutions. The development of new products and of new knowledge and ideas aimed at improving the solution of problems not solved by the firms' R&D is, according to numerous studies, the major reason for the interaction of firms with these institutions (BONACCORSI, PICCALUGA, 1994; LEE, 2000; EOM, LEE, 2010; SCHIMA, SCATOLIN, 2011; FREITAS, MARQUES, SILVA, 2013).

The second element that supports the existence of a relationship between development capability and the interaction between firms and scientific and research institutions is the fact that firms with better R&D activities are those which interact with universities on a more frequent basis (SCHARTINGER *et al*., 2002; FONTANA, GEUNA, MATT, 2003; ARUNDEL, GEUNA, 2004; LAURSEN, SALTER, 2004; GIULIANI, ARZA, 2009). It may then be inferred that firms which interact with scientific institutions are those with better development capability and greater focus on the exploration of their R&D activities (BERCOVITZ, FELDMAN, 2007), eventually having easier access to new and state-of-the-art scientific and technological knowledge.

Hypothesis 1. Investments in R&D activities are higher in firms that interact than the ones that do not interact with scientific and research institutions.

Nonetheless, the attention given by the literature to technological capabilities does not explain how firms turn their newly developed inventions into market transactions and, consequently, into innovations (ZAWISLAK *et al*., 2013). Thus, even though firms are fulfilling their knowledge gap through interaction, they still need other innovation capabilities to understand, transform and reach market with something new. For example, to produce and later commercialize a new product developed through the interaction with scientific institutions, a firm will need its own operations, management and transaction capabilities to complete its innovation process.

Operation capability is the ability to achieve some productive capacity by means of a set of daily routines, which involve quality standards, expedition, flexibility, and work flows. Dutrénit and Arza (2010) conducted a study on interactions between scientific and research institutions and firms in Latin America and concluded that, within this specific context, the main benefits of interaction for the firms are short-lived and contribute towards the maximization of production activities. It is then inferred that, even though development capability is the major focus of the interactions, operation capability is also important in the relationships between Latin American countries.

The goal of management capability, on the other hand, is to turn the outcomes of the development stage into coherent operations and into transactions arrangements. Transactions capability involves the ability to reduce costs associated with commercialization, outsourcing, negotiation, logistics, and delivery, i.e., transactions costs. (ZAWISLAK *et al*., 2012, 2013).

Therefore, based on the joint analysis of these capabilities, as depicted in Figure 1, it is possible to observe firms' innovative performance, contingent on each of the innovation capabilities. It is taken for granted that, as occurs with development capability, other innovation capabilities will also be higher at firms which interact with scientific and research institutions.

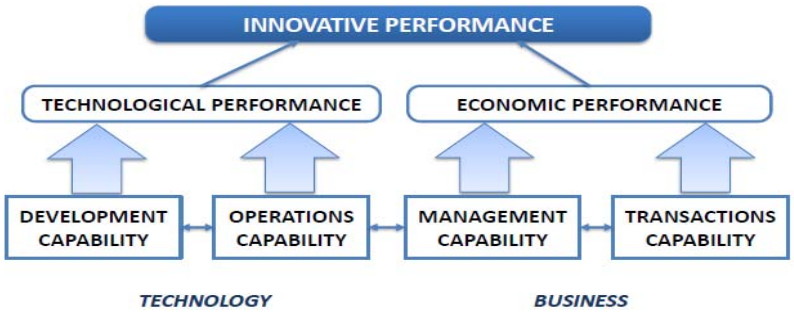

Figure 1: Nitec Innovation Model, Source: Zawislak et al. (2013).

Hypothesis 2. Development capabilities are stronger in firms that interact than the ones that do not interact with scientific and research institutions.

Hypothesis 3. Operations capabilities are stronger in firms that interact than the ones that do not interact with scientific and research institutions.

Hypothesis 4. Management capability is stronger in firms that interact than the ones that do not interact with scientific and research institutions.

Hypothesis 5. Transaction capability is stronger in firms that interact than the ones that do not interact with scientific and research institutions.

Accordingly, Kaufmann and Tödtling (2001), as well as Caloguirou, Kastelli and Tsakanikas (2004), declare that interaction with academic research has a positive impact on firms' innovative performance. However, in both studies, innovative performance was measured by indicators that assess the development of new products and/or services from the interaction with scientific and research institutions. While Kaufmann and Tödtling use the development of new products for the market or for the firm, Caloguirou, Kastelli and Tsakanikas (2004) use the percentage of sales of new products/services that have been significantly new for the firm for the past three years.

It may thus be inferred that firms which interact with research institutions have a better innovative performance. Nevertheless, the method used to measure this performance focuses mainly on the improvement of the development capability, as mentioned earlier. As the goal of firms with the innovation process is to obtain Schumpeterian profits, measures that deal with profits made with this process and that assess the interaction between the four types of innovation capabilities would better fit the purposes of the present study.

Hypothesis 6a. Innovative performance is higher in firms that interact than the ones that do not interact with scientific and research institutions.

Hypothesis 6b. The interaction between firms and scientific and research institutions are positively associated with innovative performance.

That being said, the research method used to test the hypotheses outlined earlier is described in what follows.

Chart 1 – Hypothesis of the study

Dimensions	Hypothesis
Investments in R&D	**1.** Investments in R&D activities are higher in firms that interact than the ones that do not interact with scientific and research institutions.
Innovation Capabilities	**2.** Development capabilities are stronger in firms that interact than the ones that do not interact with scientific and research institutions.
	3. Operations capabilities are stronger in firms that interact than the ones that do not interact with scientific and research institutions.
	4. Management capability is stronger in firms that interact than the ones that do not interact with scientific and research institutions.
	5. Transaction capability is stronger in firms that interact than the ones that do not interact with scientific and research institutions.
Innovative Performance	**6a.** Innovative performance is higher in firms that interact than the ones that do not interact with scientific and research institutions.
	6b. The interaction between firms and scientific and research institutions are positively associated with innovative performance.

RESEARCH METHOD

The database used in this paper is the result of a research project coordinated by NITEC – Innovation and Research Center (Federal University of Rio Grande do Sul), that aimed to identify the "Paths of Innovation in Brazilian Industry". After pre-tests, the questionnaire's final version was applied to 6,142 companies with five or more employees, listed in the Rio Grande do Sul Industries Federation – FIERGS' Industry Registry (2010). From 1,470 respondent firms, 1,331 were valid.

The full questionnaire mixed a variety of measures and scales: dichotomous, five-point Likert-type scale and visual analogue scales. Blocks are divided as follows: block one are questions related to each of the four innovation capabilities (development, operations, management and transactions); block two are questions about performance; and block three cover firm's general information.

Since our aim is to understand the behavior of innovation capabilities and performance of firms that interact and the ones that do not interact with scientific and research institutions, we divided these 1,331 firm in two groups. In the development capability block, there was a question seeking information on whether the firm *develops products in partnerships with scientific and research institutions*. According to their score (where 1 means totally disagree and 5 means completely

agree) in this question, we classified each firm as interacting or non-interacting. Those who answered 1, 2 or 3 were classified as non-interacting firms, while those who marked 4 or 5 were considered interacting firms. A K-means cluster analysis was carried out to confirm if the grouping was appropriate for this sample. Tables 1 and 2 show that de division is valid.

Table 1: Number of cases in each cluster as a result of K-means test

Number of Cases in each Cluster		
Cluster	1	949
	2	370
Valid		1319
Missing		12

Table 2: Answers in each cluster

Cluster Number of Case *							
Develops products in partnerships with scientific and research institutions							Total
Likert-scale		1	2	3	4	5	
Cluster Number of Case	1	**337**	**260**	**352**	0	0	949
	2	0	0	0	**276**	**94**	370
Total							1319

From this point on, cluster 1 will be called **non-interacting firms** (*n*=949) and cluster 2 will be called **interacting firms** (*n*=370).

It is expected that there are differences between innovation capabilities of firms that interact compared to those that do not interact with scientific and research institutions, more precisely, that they are stronger in the interacting firms. To verify that, we present descriptive analysis (based mostly on frequencies tests) comparing both groups, as well as compare means (using t-test) of the two groups, for each innovation capability, to analyze any significant difference. T-test "can be used to test a hypothesis that states that the means for the variables associated with two independent samples or two groups are equal" (HAIR *et al.*, 2005: 297). To verify if there is a relation between the interaction of firms and scientific and research institutions and their performance, we performed Pearson correlation tests, which is an associative technique that determines whether there is a consistent and systematic relationship between two variables (HAIR *et al.,* 2005).

DATA ANALYSIS AND DISCUSSION

Descriptive Analysis

Results from the entire project (*n*=1331) show that Brazilian manufacturing firms have quite simplistic processes, since 80% of them belong to medium-low and low-technology intensity industries (based on OECD, 2011 classification[2]). Brazilian companies are micro and small (90%)

[2] According to OECD (2011, 2014), (i) low-tech industries are those that has less than 1.0% of R&D expenditures over revenue (e.g. wood, pulp, paper products, food, beverage, tobacco, textile and

and are managed by family members (70%). In other words, a smaller portion of them have professional management models. They focus on their operations capability and have a strategy that prioritizes cost reduction instead of value aggregation actions. When they develop new products or improve existing ones, it is after a client's request, which means that they are not proactive in developing new products. These firms are mostly reactive to already existing trends and do not focus on internal R&D activities.

This last characteristic lead us to further analyze firms' new product development in partnership with scientific and research institutions. The average behavior of only developing something new upon client's request represents a basic development capability. Since our aim is to understand the behavior of innovation capabilities and performance of firms that interact and the ones that do not interact with scientific and research institutions, we have compared both groups.

The group of non-interacting firms is aligned with the sample regarding companies' size: 93% of non-interacting firms are micro and small, while in the interacting group, there are fewer micro and small companies (78%).

Both groups also differ in relation to firms' management model. While in the non-interacting group 40% are personalized, centered on the figure of the owner (family-based businesses), this is the management model of only 27% of interacting firms.

Both findings indicate larger and professionalized companies are more inclined to interact with scientific and research institutions to develop new products than the smaller and family-based ones.

Regardless of the group, Brazilian firms do not focus on aggregating value to their products. They do not focus on branding for example, and the majority of them determine their products' price according to their costs. This is the case in 83% of non-interacting firms and in 77% of interacting firms. Also, comparing means (table 3 and 4), it is clear that interacting firms invest more in R&D activities than the non-interacting ones. Interacting firms invest 5.68% of their revenue in R&D activities, while non-interacting firms invest 3.42%. Therefore, although interacting firms strategy may still focus on cost reduction, they are inclined to invest more in activities that have a potential to add value to their products.

It is interesting to highlight that, although OECD (2011) understands high-tech companies are more innovative than the low-tech ones, in terms of their investments in R&D activities, there were no statistical significant difference between interacting and non-interacting firms in relation to their industry classification.

This finding validates hypothesis 1, which proposes that investments in R&D activities are higher in firms that interact than the ones that do not interact with scientific and research institutions.

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footwear); (ii) medium-low-tech, invest between 1.0% and 2.5% (e.g. rubber and plastic products, refined petroleum products, non-metallic products, and basic metal products); (iii) medium-high-tech, between 2.5% and 7% (electrical machinery, motor vehicles, chemicals, and transport equipment); and (iv) high-tech, invest more than 7% (e.g. aircraft and spacecraft, pharmaceuticals, computing machinery, communication equipment, and medical instruments).

As described in the literature, firms with better R&D capabilities are those which most often interact with research and scientific institutions (SCHARTINGER *et al*., 2002; FONTANA, GEUNA, MATT, 2003; ARUNDEL, GEUNA, 2004; LAURSEN, SALTER, 2004; GIULIANI, ARZA, 2009), supporting the means differences detected between interacting and non-interacting firms. In addition, Bercovitz and Feldman (2007) affirm that interacting firms focus more on the exploration of their R&D activities, as their goal is to have access to new and state-of-the-art scientific and technological knowledge.

Table 3: Average investment in R&D

Cluster		N	Mean	Std. Deviation	Std. Error Mean
Average investment in R&D	Non-interacting	903	3.42	6.303	.210
	Interacting	357	5.68	6.905	.365

Table 4: T-test of average investment in R&D

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Average investment in R&D	Equal variances assumed	6.133	.013	-5.581	1258	.000	-2.261	.405	-3.055	-1.466
	Equal variances not assumed			-5.365	603.318	.000	-2.261	.421	-3.088	-1.433

In terms of what triggers the development process, the non-interacting firms reproduce the same results as the sample, in other words, non-interacting firms only develop products upon custom request. Instead, interacting firms develop products when they see the need to improve existing products. Neither option represents an innovative behavior, however, the interacting firms seem to be more proactive than the non-interacting ones.

Table 5 summarizes general information that characterizes both types of firms.

Table 5: Comparison of general information of interacting and non-interacting firms

	Interacting firms	Non-interacting firms
N	370	949
Size (micro and small)	78%	93%

	Interacting firms	Non-interacting firms
Business model (family-based businesses)	26,8%	40,1%
Products' price based on costs	77%	83%
Average investment in R&D	5.68%	3.42%
Triggers for new development	to improve existing products	upon custom request

Although the entire sample represents micro and small firms, managed by family members, with little development of new products, it is important to remark that this is mostly the case of non-interacting firms. Interacting firms seem to have more chances to develop their innovation capabilities, since they are larger companies, more professionalized and invest more in development-related activities. In the next section, we discuss the innovation capabilities of both groups.

Innovation Capabilities

We used t-test to verify the difference between means of the innovation capabilities of interacting and non-interacting firms. The results are summarized in the table 6 and 7.

Means from all indicators of the development capability were significantly different (p=0,000). In all instances, interacting firms presented higher means than the non-interacting firms. In other words, interacting firms perform, to a higher extent, activities such as design of own products, monitor the latest tendencies in technology, adapt the technology to own need, prototype products, use formal project management methods and launch their own products. By jointly analyzing all these variables, used for the assessment of development capability, it is possible to verify, as shown in Table 6, that the mean of this capability was 4.20 for interacting firms and 3.27 for non-interacting ones. Therefore, the biggest difference between the means of both clusters yields the development capability.

According to previous studies on the interaction between firms and scientific and research institutions, the development of new products, knowledge, and ideas is one of the major reasons for the interaction of firms with other institutions (BONACCORSI, PICCALUGA, 1994; LEE, 2000; EOM, LEE, 2010; SCHIMA, SCATOLIN, 2011; FREITAS, MARQUES, SILVA, 2013). So, the finding obtained here confirms that development capabilities are stronger in interacting firms than in non-interacting ones, as demonstrated in hypothesis 2. Furthermore, this finding corroborates what had already been described in the literature, as interaction is one of the mechanisms whereby firms can improve their development capability by developing new products and new technologies.

Similarly to the development capability, means were higher in all interacting firms answers for the operations capability. In this case, interacting firms perform the following activities to a larger extent: formalize the PPC procedures, keep statistical control of the process, use leading edge technology, maintain adequate material stock levels, carry out productive process as planned, do not generate rework, deliver the product promptly, manage to expand the installed capacity

whenever necessary, and manage to ensure the process does not lead to products being returned. By comparing both clusters, the means are 4.14 for interacting firms and 3.81 for non-interacting firms ones. Besides the differences between the means, note that they are significantly different, a result that supports hypothesis 3, i.e., operations capabilities are stronger in firms that interact than the ones that do not interact with scientific and research institutions.

In this respect, this finding is related to those observed by Dutrénit and Arza (2010), who assessed the interactions between scientific and research institutions and firms and concluded that the major benefits of the interaction for Latin American firms have to do with the maximization of production activities, i.e., for the operation capability.

Concerning the management capability, once again, interacting firms have higher scores compared to non-interacting firms. Therefore, interacting firms perform, to a larger extent, the following activities: formally define their strategy, include social and environmental responsibility on strategic agenda, use technology on integrate all sectors, have standard work procedures, update their management tools and techniques, maintain the personnel adequately trained, and use modern financial management practices.

Finally, in relation to transaction capability, means of all indicators were also significant different and interacting firms presented higher means in all of them: conduct research to measure customer's satisfaction, conduct formal research to monitor the market, impose negotiating terms on suppliers, impose negotiating terms on customers, impose prices on the market, and use formal criteria to select supplier.

These two findings validate hypotheses 4 and 5, respectively, i.e., management and transactions capabilities are stronger in firms that interact than the ones that do not interact with scientific and research institutions. Hence, in order to produce and later sell the product or the technology developed through interaction, firms need other capabilities. Management capability allows them to turn the outcomes of the development stage into coherent operations and into transactions arrangements, while transactions capability permits reducing the costs associated with commercialization, outsourcing, negotiation, logistics, and delivery (ZAWISLAK *et al.,* 2012, 2013). In order for firms to turn what was previously developed through interaction into outcomes, they need these other two capabilities, which allow them to reach the market with something new and to complete the innovation process. So, in addition to higher development and operations capabilities, firms that interact with scientific and research institutions have more management and transactions capabilities.

The results indicate, therefore, that firms innovation capabilities (ZAWISLAK *et al.*, 2012) based on four specific capabilities, are more developed in firms that have in their routines the practice of interaction with scientific and research institutions, when compared to those that do not interact. When interacting with institutions in searching of scientific and technological knowledge, a firm needs to translate their needs, understand them, acquire, assimilate and transform new knowledge to improve or create new processes and products. Such activities require skills that, as observed in this study, go beyond the development capability, and encompass the operations, management and transaction capabilities. These results corroborate

with the literature and highlight the existence of a direct and positive relationship between the interaction with scientific and research institutions and the innovation capabilities of the firms.

Finally, given the statistically significant differences between the innovation capabilities of firms that interact and do not interact with scientific and research institutions, the innovative performance results for interacting and non-interacting firms are shown and discussed in what follows.

Table 6: Innovation Capabilities and Firm Innovative Performance

Cluster		N	Mean	Std. Deviation	Std. Error Mean
Development Capability	Non-interacting	911	3.2769	.72776	.02411
	Interacting	354	4.2038	.47109	.02504
Operations Capability	Non-interacting	900	3.8177	.56947	.01898
	Interacting	350	4.1419	.44999	.02405
Management Capability	Non-interacting	903	3.6806	.59598	.01983
	Interacting	348	4.0591	.50768	.02721
Transaction Capability	Non-interacting	915	3.3064	.70422	.02328
	Interacting	357	3.7988	.60717	.03213
Innovative Performance	Non-interacting	940	3.4060	.80836	.02637
	Interacting	363	3.8310	.62502	.03280

Table 7: T-test of Innovation Capabilities and Firm Innovative Performance

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Development Capability	Equal variances assumed	66.391	.000	-22.219	1263	.000	-.92686	.04172	-1.00870	-.84502
	Equal variances not assumed			-26.664	983.288	.000	-.92686	.03476	-.99507	-.85865
Operations Capability	Equal variances assumed	23.740	.000	-9.554	1248	.000	-.32425	.03394	-.39083	-.25767
	Equal variances not assumed			-10.582	798.824	.000	-.32425	.03064	-.38440	-.26410
Management Capability	Equal variances assumed	18.835	.000	-10.473	1249	.000	-.37852	.03614	-.44943	-.30762
	Equal variances not assumed			-11.241	733.823	.000	-.37852	.03367	-.44464	-.31241
Transaction Capability	Equal variances assumed	13.676	.000	-11.631	1270	.000	-.49241	.04233	-.57546	-.40936
	Equal variances not assumed			-12.409	747.564	.000	-.49241	.03968	-.57031	-.41451
Innovative Performance	Equal variances assumed	24.740	.000	-9.028	1301	.000	-.42501	.04708	-.51736	-.33266
	Equal variances not assumed			-10.098	844.823	.000	-.42501	.04209	-.50762	-.34240

Innovative Performance

In relation to firm performance, regarding growth of profit, of market share and of revenue, it was observed that there is a significant difference between interacting and non-interacting firms. In that sense, firms that interact with scientific and research institutions have shown larger growth in all performance indicators when compared to firms that do not interact with such institutions. Hypothesis 6a, which proposes that firms that interact with scientific and research institutions have higher innovative performance than the non-interacting firms, is then validated.

To confirm such finding, we performed Pearson bivariate correlation. The correlation coefficient measures the strength of the relationship between variables (PESTANA, GAGEIRO, 2003). For Hair *et al.* (2005) this strength of correlation is divided into five levels: mild, almost imperceptible (0.01 to 0.20); small (0.21 to 0.40); moderate (.41 to .70); strong (0.71 to 0.09) and; very strong (0.91 to 1).

Table 8 shows that, although small, the interaction between firms and scientific and research institutions are significant and positively associated with firm innovative performance, as proposed in hypothesis 6b. This finding is consistent with the studies of Kaufmann and Tödtling (2001) and Caloguirou, Kastelli and Tsakanikas (2004), according to which the firms' innovative performance is positively influenced by academic research. However, the result described here goes way beyond, since our goal was not to measure innovative performance using indicators such as the percentage of sales of new products or services that have been significantly new for the firm for the past three years. By jointly analyzing three indicators, including growth of profit, of market share and of revenue, it is noted that interaction with scientific and research institutions does not only improve firms' development capability, but it also makes them improve all their innovation capabilities and, therefore, obtain the Schumpeterian profit, which is the prime goal of the involvement of firms with innovation processes.

Table 8 – Pearson correlation between firm interaction with scientific and research institutions and firm performance

Correlations		Firm Innovative Performance
Develops products in partnerships with scientific and research institutions	Pearson Correlation	.259**
	Sig. (2-tailed)	.000
	N	1303

In sum, all capabilities' indicators are significantly different between interacting and non-interacting firms. Firm performance is also different and positively related with the interaction with scientific and research institutions. Therefore, in addition to verifying that there is a positive and direct relationship between interaction and the four innovation capabilities, as discussed in the previous section, the study also points the same relationship between interaction and creation of new products and processes.

Thus, we understand that to interact a firm must have and develop search, assimilation and transformation of new knowledge skills. These skills contribute in the development of capabilities to innovate and, hence, to achieve positive performance once they are in the market. To interact with scientific and research institutions show a routine (considering routine in the concept of Nelson and Winter, 1982) essential for a firm that wishes to innovate and to obtain positive results.

Chart 2 shows that all hypotheses are supported. In other words, firms that interact with scientific and research institutions have more advanced capabilities when compared to those firms that do not interact. As a result of it, their performance is also better.

Chart 2 – Results of Hypotheses

Dimensions	Hypotheses	Result
Investments in R&D	**1.** Investments in R&D activities are higher in firms that interact than the ones that do not interact with scientific and research institutions.	Supported (table 3 and 4)
Innovation Capabilities	**2.** Development capabilities are stronger in firms that interact than the ones that do not interact with scientific and research institutions.	Supported (table 6 and 7)
	3. Operations capabilities are stronger in firms that interact than the ones that do not interact with scientific and research institutions.	Supported (table 6 and 7)
	4. Management capability is stronger in firms that interact than the ones that do not interact with scientific and research institutions.	Supported (table 6 and 7)
	5. Transaction capability are stronger in firms that interact than the ones that do not interact with scientific and research institutions.	Supported (table 6 and 7)
Innovative Performance	**6a.** Innovative performance is higher in firms that interact than the ones that do not interact with scientific and research institutions.	Supported (table 6 and 7)
	6b. The interaction between firms and scientific and research institutions are positively associated with innovative performance.	Supported (table 8)

FINAL REMARKS

The aim of this paper was to understand the behavior of innovation capabilities and performance of firms that interact and the ones that do not interact with scientific and research institutions. After several statistical analysis applied to a set of 1,319 firms, which 370 interact and 949 do not interact, the results show that the interaction between firms and scientific and research institutions is a mechanism that is positive related with firms' innovative capabilities, and these capabilities and firms' innovative performance are high when they interact with scientific and research institutions.

Furthermore, it was verified that the four innovation capabilities of the firm - development, operations, management and transaction - are higher in firms that interact. It confirms when a firm

has a routine in place favoring its interaction with scientific and research institutions, it also has higher levels the four capabilities separately - as supported in the hypothesis 2, 3, 4 and 5. This reinforces the importance of this set of capabilities for understanding the innovation capability of the firm.

Finally, the study advances the understanding of innovation capability and its results, highlighting the importance of two aspects: 1) the interaction of the firm with other actors in the search for knowledge; and 2) the development of different capabilities, forming the innovation capability, to assimilate and transform new knowledge into innovations. In doing so, a firm that interacts should have superior innovative performance when compared to those firms that do not have a routine of interaction.

These results also require a reflection on the Brazilian situation, as only 28% (370) of the firms surveyed reported interacting with scientific and research institutions. The fact that such practice shows higher innovative results for the firms suggests that this practice should be stimulated in different ways, either through public policies or the dissemination of inspiring management practices. Expanding the information to the actors of the Brazilian national system of innovation regarding where to seek for knowledge, how to interact and the results of this process is important for increasing the potential benefits of such practice.

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