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Making University-Industry Technological Partnerships Work: a Case Study in the Brazilian Oil Innovation System

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Abstract

This paper approaches the research topic 'university-industry interaction' based on a case study in the Brazilian oil innovation system (OIS). It discourses on the management of cooperative R&D projects, by the state-owned Operator, Petrobras, involving two Brazilian universities and one medium-sized locally owned supplier firm in the scope of the Thematic Network for Integration of Science and Technology-Industry at the National Productive Process (NISTI). The NISTI is a network of scientific and technological partnerships created by the Operator to foster competitive local content and innovation in the Brazilian OIS. The case study showed the learning processes generated by the actors' interactions were crucial to the effectiveness of the technological solutions developed by the partners. Despite the management challenges inherent in the institutional differences between academia and industry, this initiative reinforced the prominence of universities as sources of technological opportunities in science-based sectors. In addition, the adopted partnership model provided useful recommendations to the reassessment of the R&D portfolio's formation.

Keywords: university-industry interaction; technological partnerships; open innovation; impact evaluation; Brazilian oil innovation system.

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Introduction

The regulatory framework of the Brazilian innovation system has a recent formation. Since the late 1990s, new mechanisms have been created to foster university-industry interactions, e.g., Sectorial Funds of Science and Technology, the "Technological Innovation Law" (Law no. 10.973/2004) – stimulating the creation of technology networks and international research projects, entrepreneurial activities and science and technology parks and incubators - and the "Good Law" (Law no. 11.196/2005) – establishment of tax incentives for R&D investments made by firms. After these institutional changes, the subject of university-industry interactions has been receiving a growing attention of the Brazilian academia. Some scholars emphasize the positive influence and long-lasting role played by the oil sector and, in particular, by the state-owned company, Petrobras (hereinafter, Operator), in the creation and enhancement of those interactions (De Negri, Cavalcante and Alves, 2013; Garcia et al., 2011; Righi and Rapini, 2011; Suzigan and Albuquerque, 2011; Turchi, De Negri and De Negri, 2013).

The National Petroleum Agency (ANP) made a recent regulatory change in the Brazilian oil innovation system (OIS). In 1998, ANP included an "R&D clause" in the concession contracts for exploration and production (E&P) of oil and natural gas, which establishes that concessionaire companies (Operators) must invest in R&D a minimum of 1% of their gross revenue generated by high profitability or high production volume fields. At least half of that value must be invested in Brazilian R&D institutes and universities[1]. The investments include the creation of a portfolio of R&D projects, laboratory equipment procurement and the improvement of the infrastructure of science and technology (S&T) institutions. In order to deal with that obligation (and opportunity), in 2006, the Operator launched a model of scientific and technological partnerships, called Thematic Networks (TNs), as a new channel for investment in R&D projects with S&T institutions (Mendonça and Oliveira, 2013; Ramos, 2014; Ramos et al., 2013). According to ANP, during 2014 the R&D clause and the investment's rules are being re-evaluated. In addition, a new regulatory framework is under study by the agency with the intention of increasing the impact of the R&D projects in the competitiveness and innovative performance of the oil industry's productive chain. For this reason, the analysis of successful experiences of R&D partnerships would be of great value for ANP, E&P Operators, supplier firms, universities and research institutes.

Within this context, how should one measure the results of such technological partnerships? What factors could explain those results? This paper aims to report a case study on university-industry partnerships based on empirical evidences of one multi-partner R&D cooperation, in order to contribute to the debate of both innovation scholars and corporate managers and policymakers. The case study method is suitable for the paper's purposes, considering the explanatory nature of the research questions and the goal of presenting the main results of the experience (Yin, 2014). The approach to the subject of university-industry interaction is made from the perspective of the investments and the management experience of the Operator in cooperative R&D projects with two Brazilian universities and one medium-sized locally owned supplier firm. This multi-partner R&D cooperation integrates the portfolio of the Thematic Network for Integration of S&T-Industry at the National Productive Process (NISTI), one of the TNs created by the Operators (Ramos, 2014).

In order to achieve its goals, following this introduction, the paper is organized in six sections. In the next one, a literature review on innovation systems and university-industry technological partnerships is presented. Afterwards, the methodology applied to the case study is described. In the sequence, two sections describe the case: the first one highlights the context of emergence of the technological partnerships model of NISTI, the profile of the partners involved and the scope of their respective projects; the second one presents the main results and impacts generated, in the project manager's point of view. Following the case study details, management and policy recommendations are discussed and summarized from the standpoint of the literature. In the last section, general conclusions are offered.

[1]For additional and detailed information, see National Petroleum Agency at www.anp.gov.br.

Innovation Systems and University-Industry Technological Partnerships

The study of innovation systems began in the 1980s at Science and Technology Policy Research (SPRU) in United Kingdom from the concept of National Innovation System (NIS). The broader concept of NIS is offered by Freeman (1987, 1995) and Lundvall (1988, 1992), who consider the system as a network of public and private institutions to support innovation, that involves explicit and tacit knowledge and formal and informal relationships, in addition to the incentives and intellectual property systems, labour relations and policies and government institutions. The tacit dimension of knowledge is central to the learning processes and their nature is geographically and linguistically localized (Pavitt, 1998). Lundvall et al. (2002, p. 224) emphasize the importance of human resources development subsystem, including "the formal education and training, the labour market dynamics and the organization of knowledge creation and learning within firms and in networks". As the educational system is slow to absorb the technological, organizational and social changes, the university-industry technological cooperation needs to be stimulated. However, this cannot be generalized, because the relations are restricted to certain disciplines, technologies, sectors and firms.

According to the narrow concept advanced by Nelson (1992, 1993), the NIS is a set of institutions whose interactions determine the innovative performance of firms of a country. Universities and research laboratories and institutes play a major role, particularly in the fields of applied science and engineering (Mazzoleni and Nelson, 2007). Another highlight is the cooperation between universities and firms aiming at creating technological communities.

According to Klevorick et al. (1995), the most powerful and important source of new technological opportunities is the advance of scientific knowledge that takes place in universities. These organizations are recognized both as a repository of public scientific and technological knowledge and as a source of human capital to the industry (Freeman, 1995; Nelson, 1993). Nevertheless, most of the innovation efforts are driven by firms' strategic management, which should have the dynamic capabilities to integrate internal and external sources of information, knowledge and technology (Teece, 2007), hence the importance of absorptive capacity and prior investments in R&D (Cohen and Levinthal, 1989, 1990). In the context of developing countries, universities and public research organizations are key institutions supporting the process of catching up (Mazzoleni and Nelson, 2007).

Nelson (1993) and Pavitt (1998) emphasize the bidirectional flow between universities and firms involving the engineering disciplines, which are traditionally close to industrial application. In general, a successful innovation process involves collaboration among scientists and engineers with different approaches to problem solving. But as pointed out by Brooks (1994), the interactions between universities and firms vary considerably depending on the particular field of technology. According to Pavitt (1991, p. 113), "the nature of the impact of this relationships also varies widely from the generation of epoch-making new technologies (e.g. electricity, synthetic materials, semi-conductors)".

Salter and Martin (2001) stress the high importance of academic research in sectors heavily based on basic and applied research, as the oil sector. Based on the taxonomy of Pavitt (1984), Morais (2013) argues that the deep and ultra deep water oil E&P sector reached the level of innovative science-based sectors. In this case, the main source of innovation is the rapid development of the underlying sciences in the universities. According to Malerba (2002, 2003), the concept of Sectorial Innovation System provide a multidimensional, integrated and dynamic perspective, becoming an excellent tool for a descriptive analysis of the differences and similarities in the structure, organization and boundaries of sectors.

Salter and Martin (2001) also raise the subject of the knowledge spillovers that arise from the geographical proximity between universities and firms. Bochma (2005) argues that the geographical proximity plays a complementary role in building and strengthening social, organizational, institutional and cognitive proximity. Although geographical proximity facilitates interaction and cooperation, it is neither a prerequisite nor a sufficient condition for the interactive learning and the generation of knowledge spillovers. More effective cooperation involves personal contacts, movements, more informal communication, and participation in national and international networks (Katz and Martin; Pavitt, 1991, 1998).

Santoro and Chakrabarti (2002) consider that university-industry relationships usually encompass four dimensions: (i) research support, (ii) cooperative research, (iii) knowledge transfer and (iv) technology transfer. The authors draw attention to the firm's specific variables such as size, structure and technological characteristics. They highlight the role of the large firms to strengthen skills and knowledge, and to gain access to university facilities, while organization structure is important in a firm's ability to create and assimilate knowledge and to be innovative. They also highlight the role of leaders in stimulating new ideas, projects and partnerships.

Laursen and Salter (2004) shows that the firm size, the intensity of R&D expenditures and the adoption of the open innovation strategy are associated with the use of universities as external sources of knowledge. Indeed, the network of relationships between firms and the external environment plays an important role in shaping performance (Chesbrough, 2003; Teece, 2007). According to the open innovation approach (Chesbrough, 2003), the use of a wide range of sources and external actors extends technological opportunities and stimulates the acceleration of the rate of generation of innovations, which is particularly relevant in the context of the Brazilian oil industry, highly influenced by the Pre-salt discoveries since 2007.

The Brazilian OIS is an exception in the limited pattern of university-industry relations that characterizes the Brazilian innovation system, and Petrobras (Operator) is one of the companies that most interacts with universities in Brazil (De Negri, Cavalcante and Alves, 2013; Garcia et al., 2011; Righi and Rapini, 2011; Suzigan and Albuquerque, 2011; Turchi, De Negri and De Negri, 2013). In fact, the company has been adopting the open innovation strategy throughout its evolution for a long time (Alonso, Rovina and Martins, 2007; Dantas and Bell, 2009, 2011; Gielfi et al., 2013; Pellegrin et al., 2010; Pires et al., 2013; Ramos, 2014).

According to Du, Leten and Vanhaverbeke (2014), open innovation partnerships have to be managed in different ways, depending on the partners' nature. Applying the authors' concepts to the literature that studied the company, it is straightforward to say that the Operator created a network of partnerships with both science-based and market-based partners, which includes universities, research institutes and services and equipment suppliers. The efficient management of this network of interactions will be essential to overcoming the challenges that arose from the necessity to develop the Pre-salt's reservoirs. The organizational and institutional heterogeneity of the partners requires that those partnerships be managed in different ways (Alonso, Rovina and Martins, 2007; Ramos, 2014).

Challenges emerge when the long-term academic benefits need to fit the short-term needs of firms in joint R&D projects. Universities and firms have distinct missions and working guidelines as a reflection of cultures where different approaches prevail over confidentiality, intellectual property rights and management styles, which regularly results in different motivations to collaborate. Divergent interests frequently arise, despite the complementary nature of universities and firms. The technological partnerships constitute an opportunity for enhancing the inter-organizational learning for both sides, resulting in positive impacts in the long term (Cyert and Goodman, 1997; Katz and Martin, 1997; Perkmann, Neely and Walsh, 2011). In fact, coordination and managerial challenges abound, because results and impacts arising from the interaction are influenced by multiple factors (Barnes, Pashby and Gibbons, 2002; Mora-Valentin, Montoro-Sanchez and Guerras-Martin, 2004).

The availability of different types of resources, in addition to the qualification and motivation of the researchers involved are critical elements to the success of technological partnerships, although this also depends on organizational incentives (D'Este and Perkmann, 2011). This is why the partnership's process management to ensure its stability and continuity becomes critical, requiring multiple channels of interaction (Cohen, Nelson & Walsh, 2002; D'Este & Patel, 2007). It is important to mitigate the barriers and obstacles for cooperation, in order to lead to organizational learning, which not always raises the risk of predatory appropriation of knowledge. It means closer and more cooperative linkages (Bruneel, D'Este and Salter, 2010; D'Este and Perkmann, 2011). Thus, the process of university-industry technological partnerships "remain largely indirect, subtle and complex" (Laursen and Salter, 2004, p. 1212).

Methodology

This paper is based on an empirical research with a descriptive goal. The research method is the case study, which searches the comprehension of a complex and "contemporary phenomenon in depth and in its real-world context" (Yin, 2014, p. 237), by making use of multiple sources of evidence, both qualitative and quantitative. Although the method does not envisage statistical generalizations, it allows analytical ones, and often offers the opportunity of revealing universal truths, since no case is independent of its social context. According to Yin (2014), another important feature of the case study research is that it permits to enlighten the decisions of the actors involved and the reasons why these decisions are made and executed. Also, it is possible to investigate why the results are reached or not.

Nevertheless characterized as a single-case study, that has the Operator as the representative company and coordinator of the NISTI, other units of analysis are contemplated, such as two universities and one supplier firm. As a longitudinal study with a typically observational nature, the participant-observation is the main technique of source of evidence, allowing the project manager – one of the paper's authors – the direct observation of the facts, as well as the direct access to private data and information and to the explanations needed to follow the observed facts and individuals (Gil, 2011). It is worth mentioning that the project management's mechanisms used require the systematic observation of the experience by means of periodical technical reports and follow-up meetings that, whenever necessary, are also conducted on demand.

An Industry-Oriented Partnership Model to Foster Local Content and Innovation

The R&D collaboration described in this paper was negotiated and managed in the portfolio of the NISTI, a Thematic Network in the area of technology management, created in 2006, by the Operator. The NISTI aims to research and develop innovative technologies (equipment, systems and engineering solutions), in order to support the development of local firms and human resources training and to contribute to the increase of the industrial local content and the competitiveness of the Brazilian oil industry (Ramos, 2014).

The development initiatives of the NISTI shall include the Operator, at least one S&T institution (university or research institute, public or private) and a local firm or a consortium. The Figure 1 shows the typical contractual linkages structure of the network. Because of ANP's regulatory rules for every E&P Operator (valid in 2006)[2], the formal R&D agreements must be signed between Operators and universities. Therefore, in the NISTI's context, once a firm is (or firms are) selected to be a partner, the university is responsible for subcontracting that firm.

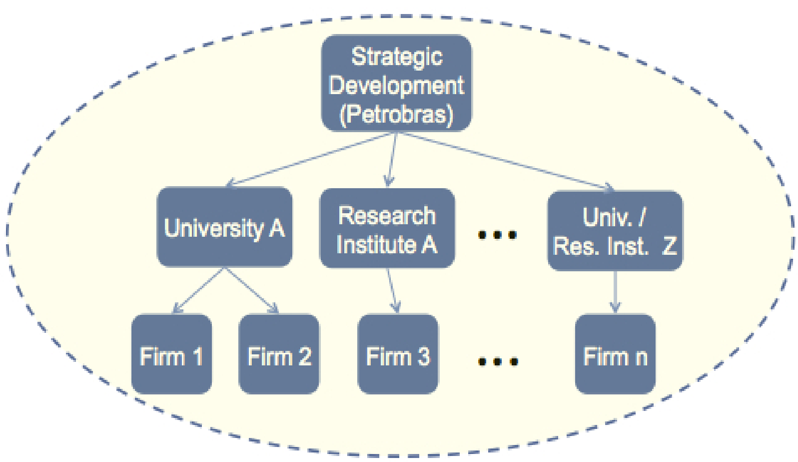

Figure 1. Contractual Arrangements of NISTI's Partnerships. Source: Authors' Own Elaboration.

[2]In 2011, the regulatory rules of the R&D clause were revised to allow that until 10% of the Operators' external R&D investment could be made in firms. For details, see www.anp.gov.br.

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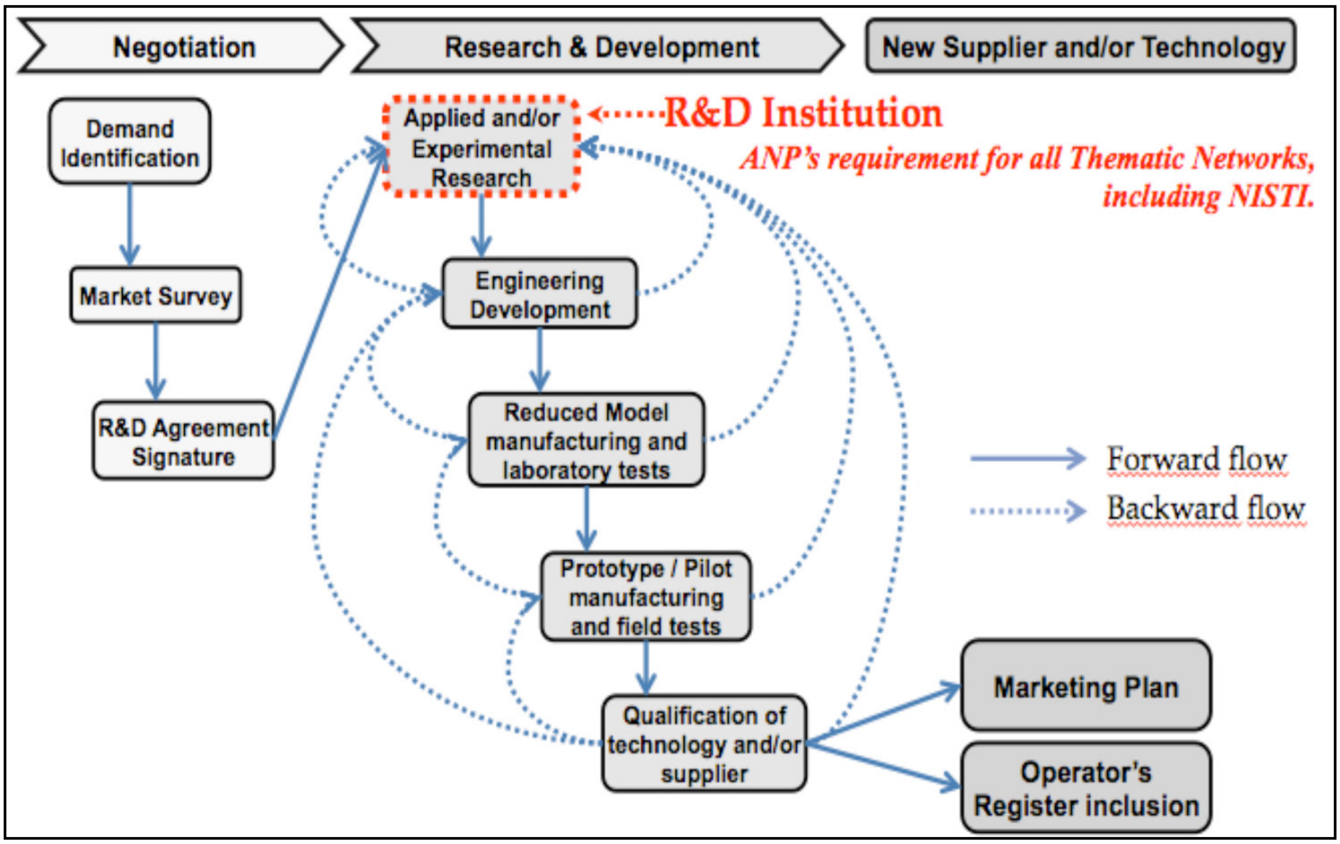

Figure 2. Typical Technology Development Model Applied to the NISTI's R&D Partnerships (the blue arrows represent the knowledge flows). Source: Authors' Own Elaboration.

The diagram in Figure 2 shows the typical technology development model adopted by the General Management for Strategic Development of the Supplier Market – Operator's Procurement Department responsible for the management of the NISTI's portfolio. The model is applied to negotiate and manage the R&D projects, especially those with the purpose of delivering product (or service) innovations. An important feature that distinguishes the partnerships negotiated and conducted by this model is the contractual linkages between partners (as shown in Figure 1). During the R&D phase, it is the university or the research institute that is responsible for the applied/experimental research step. It is a slight variation of a previous technology development model advanced by Alonso, Rovina and Martins (2007).

The partnerships described in this paper originated in 2005, following a demand of an Operational Unit (OU) for a technological solution consisting of an industrial network to integrate electrical valve actuators using wireless communication protocol. This OU's request was analyzed in order to fulfill the internal client's needs, and at the same time, ANP's requirements of R&D investments. After demand identification and during market survey stage, a medium-sized supplier firm of intelligent electrical valve actuators was identified.

The firm had prior background of joint technological partnerships with the Operator and was a traditional supplier in the oil and gas industry. In addition, science-based partner(s) should be invited into the collaboration due to the nonexistence (by that time) of standardized wireless communication protocols for automation and control in process industries with hazardous operational conditions, such as oil and gas, bringing forth the need for path-breaking knowledge research. The Table 1 lists a brief R&D background of each selected partner for the R&D venture, including the Operator's.

As previously predicted by the theoretical and empirical literature, the differences of institutional culture of each partner (internal – Operational Unit, Strategic Development Management – and external – universities, supplier firm) introduced management and coordination challenges to the project leader from the beginning. The adopted strategy aiming to mitigate the difficulties consisted of:

Partner	**Size**	**R&D Background Prior to Technological Partnerships' Start**
Operator	Large transnational corporation. Internal R&D Center.	Long history of R&D investment (internal and external), including collaborations with science-based and market-based partners.
University 1 (automation research group)	*PhDs in the R&D project:* 2 researchers (project's whole duration). 3 researchers (project's specific phase).	Experienced in R&D collaborations with industry. Previous development of successful firmware solutions for industrial applications (e.g. industrial network's protocols). Previous collaboration with the Operator in educational programs (short duration courses). Master's and Doctoral degree programs.
University 2 (automation research group)	*PhDs in the R&D project:* 3 researchers (project's whole duration). 1 researcher (project's specific phase).	Experienced in academic R&D (automation and intelligent systems). Previous collaboration with the Operator in educational programs (dissertation supervision). Master's degree program.
Locally-owned supplier firm	Medium-sized firm. Internal R&D department.	R&D annual investment between 5-7% of total revenues (since 1999), increasing to near 10% of total revenues in 2012-2013. R&D background in urban mobility solutions. Previous collaboration with the Operator to develop intelligent electrical valve actuators (traditional wired communication).

Table 1. Partners' R&D Background. Source: Ramos (2014).

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i. Arranging periodical follow-up meetings (two months period) with each research group (universities and supplier firm) to deal with project's specific tasks;
ii. Organizing workshops (six months period), during the research phase, in order to exchange technical information and to promote integration between all partners;
iii. Involving the operational team of the refinery in the research reports' analyses and approvals, and bringing relevant information to everyone's knowledge immediately;
iv. Relaxing the permission for scientific publication of the academic researchers (to keep a high level of motivation and commitment), as long as the core knowledge for the new product development was kept in secrecy (the formal agreement has a secrecy clause – all publications shall be authorized by Operator's project leader and managers).

R&D Projects' Scope and Impact Evaluation

The collaboration's general objective was set in accordance with the OU's demand and was designed to research, develop and test innovative communication technology for wireless industrial communication networks to be applied in an oil refinery. The specific joint R&D projects, its main objectives and expected results, as well as the duration and the project management mechanisms are shown in Table 2. The technological partnerships, including its associated technical and knowledge-creating challenges, were qualified as a perfect opportunity to be among the first partnerships of the NISTI's portfolio. The new Thematic Network had a budget looking for projects. The joint R&D projects' scope matched the partnership model adopted for the NISTI's projects. Finally, by early 2008, the Operator, two universities and a local supplier formally joined to research, develop and test a technological solution for the OU's demand.

Attribute	University 1	University 2
Project title	Valve Control System with Wireless Communication	Performance Analysis and Integration of Wireless Networks in Industrial Plants
Main objectives	To develop, test and install in an oil refinery a pilot of a control system of 50 intelligent valve actuators with wireless communication capability with the support of a subcontracted supplier firm. To transfer knowledge and technology by close interaction with the supplier firm. To qualify the supplier firm in the new technology through specific training of human resources.	To develop new performance evaluation methodologies and procedures for the integration of wireless networks in industrial plants. To build critical mass to qualify human resources to specify, install and configure wireless industrial networks systems.
Main expected results	A full operational pilot of a wireless control network consisting of 50 intelligent valve actuators to be tested and installed in a refinery. The characterization and identification of the performance limits of the wireless technology applied to the system. Educated and trained human resources, including the supplier firm's personnel, capable of specifying, installing and configuring wireless industrial networks systems.	A technical feasibility study of projects for application of wireless technology in industrial plants. New performance evaluation methodologies and procedures for the integration of wireless networks. Educated and trained human resources capable of specifying, installing and configuring wireless industrial networks systems.
Duration	24 months (plus 2 amendments of 24 months).	24 months (plus 1 amendment of 24 months).
Project management mechanisms	PMI approach with flexibility for scope adjustments. Follow-up meetings (2 months period; also on demand, when needed). Technical reports (2 months period; also on demand, when needed).	

Table 2. R&D Projects' Scope. Source: Ramos (2014).

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As mentioned in prior literature, R&D technological partnerships involving universities generates outputs that are often intangible and not easily measurable. In this way, it's important to distinguish outputs from impacts, as shown in Table 3. As the university 1 had a direct contractual relationship with the supplier firm, the level of interaction was much higher than that of university 2. As the former was responsible for the development and implementation of the firmware solution of the wireless communication protocol, a closer and more frequent relationship between its researchers and the supplier firm was nurtured. This firmware solution was integrated into the (off the shelf) intelligent valve actuator, resulting in the main innovation of the project (a copyright protection for the firmware solution was obtained in the National Industrial Property Institute - INPI). In addition, as the control system of the valve actuators had to be installed in the Operator's oil refinery, the OU's technical team also interacted more frequently with both the supplier firm and the researchers from university 1.

Outputs	**University 1**	**University 2**
Technology (patents or other IP)	1 (software's copyright)	0
New knowledge (all research group's peer-reviewed publications in the area of wireless industrial networks - conferences and journals)	29	7
Staff skills and training 1 (number of doctoral positions in the area of wireless industrial networks)	3	NA
Staff skills and training 2 (number of master positions in the area of wireless industrial networks)	8	2
Impacts	**University 1**	**University 2**
New ideas (number of new R&D projects planned or initiated)	2	1
Solution concepts	5	2
Innovations (product or process improvements implemented)	1	0
Human capital (recruitment of staff from university by the Operator)	0	1

Table 3. Summary of the Partnerships' Results. Source: Adapted from Ramos (2014).

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Discussion

As a result of this collaboration, an innovative system was developed, expanding market opportunities for the supplier firm, as well as new methodologies and procedures for the evaluation and integration of industrial communication networks. As shown in the Table 3, a significant amount of scientific knowledge was generated, new human resources were trained, a software solution was copyrighted and new solution concepts were developed. The new electrical valve actuator with wireless communication capabilities achieves an estimated local content index[3] of more than 95%.

From an R&D management point of view, in line with prior theoretical literature, the case provided evidences of the importance of the evaluation of individual characteristics of researchers before initiating a partnership. Prior experience in interactions with firms is an important feature for both individual researchers and institutions, because it reflects on institutional learning and technological path dependence, in line with the innovation systems' literature. In addition, on every project's phase (research, development, engineering, manufacturing), it is strongly recommended to reassess the participants' interests periodically, including organizational and individual levels. Firms' personnel involved in the university-industry interaction should have considerable technical knowledge in order to capture all the benefits of academic research. The nature of the work and results of university-industry partnerships may be too complex and tacit, requiring a close and intense face-to-face interaction.

From the strategic and policymaking points of view, the adopted partnership model could be used as an example for a larger number of R&D projects under ANP's R&D investment clause in order to generate more industrial innovations and to contribute to the increase of the local content index (as per Brazilian industrial policy). Nevertheless, the partnership model should not be applied without a prior thorough analysis of the characteristics of the technological demand during the negotiation stage. Project managers should have the ability and be allowed to set up the most adequate arrangement for the partnerships, considering partners capabilities, technology status (mature/radical) and market opportunities.

R&D partnerships involving public research institutions should not be too restrictive regarding publications – which was a feature of the partnerships at hand – because this could restrict "the flow of knowledge, and [reduce] the multiplier effect that arises from the use and reuse of ideas in a wide array of situations, often in areas never envisioned by those who made the initial discoveries" (Chesbrough, 2003, p. 191). The same recommendation should apply to R&D programs promoted by the State, mainly in incomplete NIS for which the widespread diffusion of knowledge and inventions are crucial to increase the rate of industrial innovation and, as a consequence, to the process of catching-up.

In Table 4, the authors organize the main insights from the case study discussed above, and also add new ones, connecting them to the prior literature and the theoretical dimensions of analysis.

[3]The Local Content Index (LCI) reflects the percentage of goods and/or services that are effectively produced in Brazil. Details about the industrial policy regulations that deals with local content rules in the Brazilian oil industry can be found at www.anp.gov.br.

Dimensions of Analysis	**Remarks on the Case**	**Prior Literature (not exhaustive)**
Structural factors of the partners	Large transnational Operator with a high intensity of R&D expenditures and absortive capacity, and which adopts the open innovation strategy with science-based and market-based partners. Universities with experience in academic R&D and previous collaboration with the Operator. Medium size supplier with internal R&D department and increasing intensity of R&D expenditures, in addition to absortive capacity and previous collaboration with the Operator.	Chesbrough (2003); Cohen and Levinthal (1989, 1990); Dantas and Bell (2009, 2011); Du, Leten and Vanhaverbeke (2014); Laursen and Salter (2004).
Structural factors of the oil sector	Scale intensive and heavily based on basic and applied research, dominated by a large transnational operator with a dinamic organizational structure and a strong engineering culture in co-evolution with dinamic capabilities and knowledge networks.	Morais (2013); Pavitt (1984, 1998); Salter and Martin (2001); Santoro and Chakrabarti (2002); Teece (2007).
Challenges of university-industry technological partnerships	Differences in organizational and institutional cultures, misalignment of incentives and difficulties related to project management, which depends on multiple success factors.	Barnes, Pashby and Gibbons (2002); Cyert and Goodman (1997); Mora-Valentin, Montoro-Sanchez and Guerras-Martin (2004); Perkmann, Neely and Walsh (2011).
Evaluation of university-industry technological partnerships	Outputs that are often intangible and not easily measurable bring forth the necessity of identifying realistic proxies and distinguishing outputs from impacts.	Cyert and Goodman (1997); Katz and Martin (2007); Perkmann, Neely and Walsh (2011).
Management of university-industry technological partnerships	In order to be effective and successful, university-industry technological partnerships, in general, and R&D projects, in particular, need to be adequately structured and managed.	Du, Leten and Vanhaverbeke (2014); Perkmann, Neely and Walsh (2011).
User-producer interaction	Despite the challenges of user-producer interaction stressed by the innovation systems literature, without the active involvement of user (Operator), most probably, the producer (supplier firm) would not have accomplished the new and complex product with the required functionalities and performance to be applied in process industries.	Lundvall (1988, 1992). Mazzoleni and Nelson (2007).

Table 4. Dimensions of Analysis, Remarks on the Case and Prior Literature. Source: Authors' Own Elaboration.

Conclusions

The oil innovation system (OIS) is in line with the international trend of R&D networks formation, differing from the low level of interaction between universities and firms that is observed in countries with an incomplete National Innovation System (NIS), such as Brazil. As it exploits the national and international science and technology (S&T) infrastructure by means of technological partnerships, the OIS shows a distinguished feature. Notwithstanding the building of local capabilities in specific activities, some caution is required before concluding that the Brazilian oil industry has evolved into a fully consolidated sectorial innovation system. There are evidences of dependence on imported technologies, mainly the knowledge-intensive ones.

Despite the already known challenges, the Thematic Network for Integration of S&T-Industry at the National Productive Process (NISTI) has been working as an effective instrument to fostering cooperative activities to generate local innovation and knowledge. Such activities has shown a great potential to increase the competitiveness and the technological local content of the oil productive chain, which is embedded in Brazil, and to strengthen the national engineering. The results of the case at hand reveal the importance of the interaction between user, producer and S&T institutions to enhance the innovative performance, especially when adequate criteria are used in relation to technology, partners' choice, partnership's governance and project management.

The research topic of university-industry interaction, including the technological partnerships, is in the core of the interdisciplinary literature on innovation. In this paper, it was treated from the standpoint of the Operator's investments in joint cooperative R&D projects with two universities and one medium-sized locally owned supplier firm, in the scope of the NISTI. The evidences suggest those partnerships are indispensable for enhancing the performance of innovative process designed to develop high complexity products, once the technological solutions generated here have integrated knowledge bases and technologies of two knowledge-intensive sectors: ICT (industrial automation networks) and the electromechanical (intelligent electrical valve actuators). For this reason, it is essential to firms making use of the expertise of academic research groups and the learning processes that arise from the interactions.

The joint work of individuals envisaging the generation of new scientific knowledge may result in future innovations, spillovers and technological spin-offs, which is more fertile in applied fields such as engineering, usually the sector most coupled to practical problems. In line with the literature review and the case study, the partnerships obey technological, sectorial and firm-related specificities. Even though, universities constitute a great source of technological opportunities.

For those partnerships, management is a critical element, inasmuch as the efficient course of the cooperation depends on the adjustment of expectations, motivations, goals and results, in order to generate benefits for every actor. The intention to cooperate precedes the common search for consensus in the direction of effective cooperation and the partners' commitment is a fundamental feature, so that expected results and benefits are reached, what this paper tried to demonstrate.

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