THE OIL AND GAS INNOVATION SYSTEM IN BRAZIL: CHARACTERIZATION AND EVALUATION

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ABSTRACT

The exploration of fossil fuel involves great technical complexity, given the large number of interdependent technologies and the very extensive knowledge base needed. Furthermore, there is significant motivation in the use of advanced technologies in the upstream oil industry given the competitive pressures to reduce costs. On the other hand, there are estimates that there will be a large increase, in the near future, in Brazil´s oil production, resulting from increased production of fields for which expansions are planned or underway. This indicates a clear need for a major effort in innovation. This work will look at the Innovation System of the Brazilian oil and gas industry with two main objectives: (i) to map and characterize, through the theory of National Innovation Systems (NIS), the main dimensions and the integrating factors of this innovation system; and (ii) assess the perception of managers of supplier companies, about the effectiveness of such system, highlighting its advantages and difficulties.

To meet the first objective, we performed a literature search in order to characterize the main dimensions of the Brazilian System of Innovation in the chosen industry. Such search resulted in a framework that describes the interaction of companies with the six dimensions identified, i.e. , Productive Sector , Public Sector , Science & Technology System, Educational System , Financial System and External Sector.

Subsequently, we conducted a survey with the direct supplier companies of the industry, in order to (1) describe such companies; (2) understand their views about the level of development of the six subsystems identified in the literature review; and (3) understand their views about the importance of each subsystem for the innovation process.

The Productive Sector appears as the most relevant to this Innovation System, followed by the Educational System and the Financial System. At the lower end are the Science & Technology System, the Public Sector and the External Sector. This should not be confused with the level of development of each sector, as perceived by the 100 companies in the sample (response rate 35.6 %).

The Educational System is one of the biggest problems in the country. The main weaknesses identified relate to the low availability of skilled labor. In the Public Sector, the main problem identified was the issue of taxation. The System of Science & Technology is considered a central dimension in many NIS, but in the case of the oil and gas industry, what really drives innovation is learning-by-doing. The Financial System showed a low level of development due to the negative

perception of small and medium size companies. Finally, with respect to the External Sector, a large imbalance between imports and exports was identified.

The Productive Sector received the best evaluation in the study, with its performance being directly related to the degree of general cooperation in the sector. The Public Sector best feature has to do with the role of public policies established by PROMINP (a Federal program for the development of the Brazilian Oil and Gas industry.

Keywords: innovation systems, oil and gas, Brazil, education.

INTRODUCTION AND OBJECTIVES

The exploration and production of fossil fuel are activities of great technical complexity, since they include a large number of interdependent technologies and employ a very large knowledge base (BOHI, 1997). The significant motivation in the use of advanced technologies in the upstream sector of the oil and gas industry derives from the competitive pressure to reduce production costs and prices of oil and gas (PERSAUD et al, 2003).

Given that oil is a non-renewable good, its exploration and production costs tend to rise in the long run, since the best oil reserves will be depleted first. In this sense, technological innovations are the main device that oil companies have against this trend of increasing difficulties for production of hydrocarbons, particularly with regard to the depth in which they find new reserves. The deeper the reserve is, the more complex are the processes of exploration and production of oil (PERSAUD et al, 2003). This indicates not only the particularities of the oil industry, but also that companies that deliver goods and services to the oil industry have a key role. According to BAIN & COMPANY E ADVOGADOS TOZZINI FREIRE (2009), these companies see technology as a means to operate in the global oil market, with technological development being usually driven by accumulated knowledge, agreements with R & D institutes and by recruiting the best scientists in the market.

We will examine the Innovation System of the Brazilian oil and gas industry with two main objectives: (i) to map and characterize, through the theory of National Innovation Systems (NIS), the main dimensions and the integrating factors of this innovation system; and (ii) assess the perception of managers of supplier companies, about the effectiveness of such system, highlighting its advantages and difficulties.

In order to achieve such objectives, we have performed: (a) a review of the literature in order to characterize the main dimensions of the Brazilian System of Innovation that support exploration and oil production activities and (b) a quantitative analysis of the responses to a survey applied to suppliers of goods and services in the oil and gas industry, in order to understand how they evaluate the stage of development of the system as well as its advantages and difficulties.

CONCEPTUAL MODEL

This research is based on the National Innovation Systems approach (FREEMAN, 1987, LUNDVALL, 1992, NELSON AND NELSON, 2002), according to which the innovative performance of a country, region or even one given sector of the economy, should not be assessed focusing only on efforts and achievements of individual companies. Instead, innovation is a process that results from the interaction between the players of similar and dissimilar institutional types. By definition, innovation systems not only cover companies and R & D laboratories, but also government agencies, education

and training organizations, financial institutions, policies for industry, for science and for technology, etc. All these elements are concerned with the generation and dissemination of knowledge for innovation within a national economic system (FREEMAN, 1987).

Over the years, several authors have developed models for the analysis of National Innovation Systems, considering the main actors that interact in the generation of systemic innovation. LUNDVALL (1992) presented one of the first efforts in this direction, stating that an NIS would consist of institutions and relationships which interact in the production of new knowledge. Among the components of this system he highlights the productive structure of the country, since the very definition of innovation - first commercial application of a product or process - presupposes the existence of enterprises. Following Lundvall´s work, several other studies were conducted to understand the complexity of the generation of innovation in the national context. What these studies have in common is the attempt to describe and compare the most important institutions, organizations, activities and interactions of public and private actors participating in or influencing the innovation process of a country.

In this paper, we propose a model of National Innovation System consisting of six dimensions:

Productive Sector: The first dimension treated in the proposed conceptual model is the Productive Sector, consisting of companies that are operating in the country. According to LUNDVALL et al. (2002), companies play the most important role in the innovation system, since they are primarily responsible for bringing to market the end result of the innovation process. LUNDVALL (2001) suggests that firms innovate in a collaborative way, since there is no company that can bring together all the elements needed for the development of a new product or service. Accordingly, companies are not isolated and need a great deal of knowledge from other companies in order to survive in the market (LUNDVALL, 1988). According to PELLEGRIN (2005), the system of innovation in the Brazilian oil and gas industry has two distinct groups of companies: operators, who take the various stages of the production chain of oil and gas that ranges from extraction to distribution of final processed product; and suppliers, which are a heterogeneous group of companies that provides a wide range of goods, from materials to complex equipment.

Public Sector: On top of being the largest user of innovation at the national level, the public sector still has a regulatory role, by providing policies and guidelines to the innovation system. Public institutions have an important role in formation and functioning of Innovation Systems. Indeed, collaboration between companies is not usually natural, and the public sector can create favorable conditions for such collaborations (FURTADO, 1997). According to NELSON (1993), innovation in a NIS depends on the interaction between the public and private sectors. While the public sector would be responsible for the circulation of knowledge, by producing explicit knowledge, the private sector would produce more tacit knowledge, which is more easily appropriated. According to BARBOSA (2005), the public sector, in its regulatory action, defines the scope for innovation activities in companies by setting technical standards, setting the timing of introduction of such standards, type of enforcement instruments and adaptation to international standards (GREGERSEN, 1992). In addition to public sector organizations, other institutional elements such as laws and public policies are important elements in the collective learning within a country. As such, the Brazilian innovation policy has its base in the Lei da Inovação (Law regulating technological partnerships between universities, technological institutes and companies; regulating/encouraging the participation of science and technology institutions in the innovation process, and

regulating/encouraging innovation in enterprises) and Lei do Bem (the law that regulates tax incentives to companies that conduct research and development for technological innovation) (see BNDES, 2010).

Science and Technology System (S&T): The Science and Technology System is comprised of public and private R&D institutions and universities. Industrial laboratories and R&D companies play an important role in the development and marketing of major technologies, while universities are usually concerned with inventions that can turn into innovations (BARBOSA, 2005). These are usually key actors in the innovation process. For the OECD (1997), the quality of such actors is critical to any national innovation system, not only because of the generic content and basic research produced, but also because of new methods and tools of analysis. Freeman and Soete (1997) emphasize the importance of partnerships between private companies and public research institutes as one of the most important method to access the results of public research in a country.

Educational System: the Brazilian Educational System consists of universities (both private and public) and public organizations sponsored by the state. Its main function is to educate and train people in key areas for the development, absorption and use of technology. According SUZIGAN and ALBUQUERQUE (2008), the interaction between universities and companies in Brazil is still very fragile. For RAPINI et al (2009), although research and training institutions are consolidated in Brazil, they fail to provide researchers, scientists and engineers to meet the needs of the NIS.

Financial System: the Financial System should promote an enabling environment for innovation through a capital market or even the development of credit generating activities. Public financing institutions in Brazil are important actors in the innovation process, since they fund much of the research needed (SANTOS, 2008). This is specially so in the exploration and production of oil and gas, whose activities are capital intensive and where investments are very risky. Companies need external sources of funding to bear part of the expenses for machinery and equipment or even R&D activities (PELLEGRIN, 2005). Accordingly, the financial system is another dimension with strong relevance for the NIS. TIRONI (2005) emphasizes the existence in Brazil of different mechanisms for funding innovation activities, plus great diversity of institutions with the role of providing this type of service (commercial banks, capital markets and funding agencies).

External Sector: the External Sector has to do with the flows of knowledge, goods and money between countries. Historical and social differences mean that companies from different countries use international collaboration for the acquisition of new technologies in different ways (MANSFIELD, 1988). It follows that the use of foreign technologies may be essential for companies in late developing countries (HIKINA and AMSDEN, 1994). As such, in the case of Brazil, the External Sector will probably bring many benefits such as: acquisition of capital goods and intermediate products of high technology; alliances and promotion of foreign direct investment in Brazilian companies (OECD, 1997). According to LUNDVALL (2001), both at the regional level and the national level, networks with the outside world are essential to keep at the forefront of knowledge.

Figure 1 presents the dimensions of the NIS identified in this work: the Productive Sector (LUNDVALL, 1988, LUNDVALL, 2001, PELLEGRIN, 2005); the Public Sector (GREGERSEN, 1992, NELSON, 1993, FURTADO, 1997, BARBOSA, 2005); the S&T System (BARTHOLOMEW, 1997, FREEMAN and SOETE, 1997, OECD, 1997, BARBOSA, 2005); the Educational System (LUNDVALL,

2001); the Financial System (PELLEGRIN, 2005, TIRONI, 2005, SANTOS, 2008) and the External Sector (MANSFIELD, 1988, HIKINA and AMSDEN, 1994, OECD, 1997, LUNDVALL, 2001, SANTOS, 2008).

Figure 1 - The Oil and Gas Innovation System in Brazil

In order to identify the stage of development of each sector, different variables were analyzed in each case. Table 1 presents the most important variables identified in the literature for each sector. Table 1 is the basis for the questionnaire used in the survey with the supplier companies of the oil and gas industry.

Table 1 - Key variables in the Brazilian Oil and Gas Innovation System

Sector	Variable	References
Productive Sector	Technology Acquisition from other companies	Lundvall (1988), Lundvall (2001)
	Industrial knowledge networks	Tidd, *et al.* (1997), Silvestre e Dalcol (2009)
	Partnerships with operators	Dantas (1999), Oliveira (2008)
	Partnerships with other direct supplier companies	Dantas (1999), Oliveira (2008)
	Partnerships with other companies	Dantas (1999), Oliveira (2008)
Public Sector	Legislation	List (1841), REPETRO (2011)
	Regulations	Barbosa (2005)
	Government policies	Furtado (1997)
	Role of Prominp	Pellegrin (2005), Prominp (2011)
Science and Technology System	Intellectual property	BNDES (2010)
	Basic and Applied Research	Bartholomew (1997), OECD (1997)
	Research partnership with universities	Freeman e Soete (1997)
	Partnership with public research institutes	Freeman e Soete (1997)
	Role of the National Institute of Industrial Property	INPI (2011)
	Registration of patents and scientific publications	Arundel (2003), Ross *et al.* (2005)
Educacional System	Technical man power	Rapini *et al.* (2009), IPEA (2011)
	Graduate man power	Rapini *et al.* (2009), IPEA (2011)

Sector	Variable	References
	Post-graduate man power	Suslick e Iatchuk (2006), Rapini *et al.* (2009)
	Training institutions in the oil and gas industry	Suzigan e Albuquerque (2008)
	Government training of skilled manpower	Gall (2011), Suslick e Iatchuck (2006)
	Government Financing Programs	Pellegrin (2005), FINEP (2011),
Financial System	Public funding	Pellegrin (2005), Tironi (2005)
	Private funding	OECD (1999), Tironi (2005)
	Capital Market funding	Tironi (2005)
	Innovation Agencies funding	FINEP (2011)
	Cooperation with other countries	Mansfield (1988), Hikina e Amsden (1994)
External Sector	Imports	IPEA (2011)
	Exports	IPEA (2011)
	Use of foreign manpower (research)	Santos (2008), Gall (2011)
	Man power training abroad	Santos (2008), Gall (2011)

SURVEY

In order to assess the perception of managers of supplier companies, about the effectiveness of the NIS, we conducted a survey such companies. The survey involved (1) characterization of the companies; (2) data on the views of companies about the six sectors of the NIS; and (3) data on the views of companies about strengths and weaknesses in the innovation process.

The population of the survey consisted of 281 direct suppliers of goods and services for the upstream activities of the industry. These companies were selected from the Register of Suppliers of Goods and Services-ONIP (National Organization of the Petroleum Industry).

The questionnaire was posted in the internet. The person responsible for answering the questionnaire was the general director or person responsible for production/operations or person responsible for technology in each company. There were three different sections. The first section had questions concerned with general information about the companies that participated in the survey (size, percentage of foreign capital and segment of the industry). The second section was based on the analysis of the National Innovation System in the oil and gas industry and involved the six sectors discussed above: Productive Sector, Public Sector, S & T System, Educational System, Financial System and External Sector. Each participant was asked to assign a score ranging from 1 to 6, indicating the extent to which he/she agreed with statements concerning each variable (see Table 1) in each sector. In the third section of the questionnaire, respondents were asked to classify, in descending order of relevance - the most relevant to least relevant - the main sources of knowledge and innovation to the company, as well as the main difficulties or impediments to innovation in the oil and gas industry.

RESULTS AND DISCUSSION

Sample characterization

The final sample had 100 companies (response rate of 35.6 %). A comparison between sample and population can be seen in Table 2.

Table 2 - Distribution of companies by size, capital and segment of activity

Type of company	Sample		Population	
	Number	%	Number	%
Size (Gross Operational Income)				
Small (up to R$ 15,9 million)	49	49%	128	44%
Medium (R$16 to R$300 million)	29	29%	98	35%
Large (over R$300 million)	22	22%	59	21%
Percentage of Foreign Capital				
0 a 50%	87	87%	226	81%
51% a 100%	13	13%	55	19%
Segment of Industry				
Reservoir Survey	11	11%	53	15%
Well Drilling	7	7%	36	10%
Well Completion	10	10%	26	7%
Production Infrastructure	38	38%	196	56%
Production and Maintenance	34	34%	39	11%

Stage of development in different sectors

The following sections present only the most relevant results obtained. The "Overall Sector Average" is the average of the scores received by all the variables included in the given sector. It is a measure of the development (in the view of responding companies) of each sector. Table 3 presents the level of development of the 6 sectors, in the view of the respondent companies.

Table 3 – Level of development in the Brazilian Oil and Gas Innovation System, in the view of the respondent companies

Sector	Variable	Average Score
Productive Sector (4.17)	Technology Acquisition from other companies	2.70
	Industrial knowledge networks	4.21
	Partnerships with operators	4.67
	Partnerships with other direct supplier companies	4.52
	Partnerships with other companies	4.68
Public Sector (3.49)	Legislation	3.49
	Regulations	3.32
	Government policies	3.40
	Role of PROMINP	3.82
	Intellectual property	3.44
Science and Technology System (3.25)	Basic and Applied Research	3.25
	Research partnership with universities	3.58
	Partnership with public research institutes	3.33
	Role of the National Institute of Industrial Property (INPI)	3.14
	Registration of patents and scientific publications	3.26
Financial	Government Financing Programs	3.35

Sector	Variable	Average Score
System (2.93)	Public funding	2.60
	Private funding	3.31
	Capital Market funding	2.57
	Innovation Agencies funding	2.81
	Cooperation with other countries	4.06
External Sector (2.84)	Imports	3.04
	Exports	1.72
	Use of foreign manpower (research)	2.31
	Man power training abroad	3.09
	Technical man power	2.21
Educacional System (2.70)	Graduate man power	2.39
	Post-graduate man power	2.29
	Training institutions in the oil and gas industry	3.34
	Government training of skilled manpower	3.25

Productive Sector

The Productive Sector received the highest Overall Sector Average in the survey (4.17), with emphasis on "partnerships with operators", "partnerships with other direct supplier companies" and "partnerships with other companies". We would suggest that the Productive Sector presents a high level of development. It is clear that direct supplier companies in the oil and gas industry have reached a well developed sense of cooperation with other companies. As a consequence, cooperation with other companies may be the main factor explaining the innovativeness of the sector. The only variable that showed a low level of development was the "acquisition of technology from other Brazilian companies"; the low average (2.75) can perhaps be related to the intensive use of foreign technology in this industry in Brazil. We found no evidence of significant differences between companies because of size, origin of capital or segment. (Kruskal Wallis test).

Public Sector

The Public Sector received the second highest Overall Sector Average (3.49). This suggests that the Public Sector presents a medium level of development. Respondent companies seem to believe that Government regulations (implemented by the National Agency for oil and gas – ANP) could be improved, as well as some Government policies (e.g. research funding). With respect to intellectual property, respondent seem to consider that conditions (laws and regulations) could be improved. SANTOS (2008) has suggested that the time it takes to grant patents (average of 5.4 years) is too long, not encouraging researchers and companies to look for intellectual property. On the other hand, it seems that PROMINP (Mobilization Program of the National Oil and Natural Gas Industry) is seen as a very good initiative of the Brazilian government. As in the case of the Productive Sector, we found no evidence of significant differences between companies because of size, origin of capital or segment. (Kruskal Wallis test).

S&T System

The S&T System received an Overall Sector Average of 3.25. This suggests that the Brazilian oil and gas industry may be in danger of becoming dependent of foreign S&T. All variables received low scores (just above 3). The highest score was for “Research partnership with universities” (3.58). But

such score is not high enough to indicate a good level of collaboration with Brazilian universities, which seem to be failing to mobilize researchers, scientists and engineers to meet the needs of the NIS (RAPINI et al., 2009). Freeman and Soete (1997) highlight the importance of "business partnerships with public research institutes", indicating that the direct relationship of the staff of these companies with their peers in public laboratories is the most important method of access to public research results the host country. Again, the score obtained in this case was 3.33, lower than the average obtained for the relationship of companies with university research centers. Another important variable is the "Role of the National Institute of Industrial Property (INPI)". The INPI has a fundamental importance in the NIS, since it is responsible for issuing patents that prevent competitors from copying innovations developed by companies (INPI, 2011). The average score for this variable in our study was 3.14, the lowest within the S&T System!

Finally, we found evidence of significant differences between companies because of size (Gross Operational Income). Large companies tend to better evaluate "research partnership with universities" as well as "partnership with public research institutes". This may be due to a larger group of R&D personnel in larger companies.

Educational System

The Educational System received the worst evaluation of the six sectors. Its Overall Sector Average was 2.70, indicating a very poor performance among the respondent companies. Technical man power, graduate man power and post-graduate man power received very low scores. This indicates that supplier companies in the of oil and gas industry have difficulties to hire professionals in this area. SUZIGAN and ALBUQUERQUE (2008) suggest that the main reason for this lack of qualified labor force is the late, limited and problematic start of higher education and research institutions in Brazil.

Size, participation of foreign capital and segment did not show any impact the perception of the companies about the Educational System.

Financial System

According to the literature, the Financial System is one of the most important systems for the development of innovation activities in any NIS. But the oil and gas industry has a rather poor view of such system in Brazil. The Overall Sector Average was 2.93, almost as poor the Educational System. This is very concerning since in the oil and gas industry activities are capital intensive and investments carry a rather high risk. Fortunately, it seems that "Government Financing Programs" (e.g. PROMINP) are, to a certain extent, helping companies in this regard.

Another interesting result has to do with the impact of size and participation of foreign capital on the evaluation of the Financial System. It is possible to suggest that the larger the size of the company, the better the perception of the financial system as a whole. This is especially true in the case of "Public funding", "Capital Market" funding and funding via "Innovation Agencies". On the other hand, companies with strong participation of foreign capital seem to benefit more of "Capital Market" funding than Brazilian owned companies

External Sector

The External Sector received a rather poor evaluation. Its Overall Sector Average was 2.84, indicating a very poor performance among the respondent companies. This is due to the performance in exports (1.72), which was the lowest of all variables analyzed. On the opposite side, one will find "cooperation with other countries," which received a fairly high score (4.06), indicating that many Brazilian companies have been trying to develop strong ties with foreign companies. It is worth noting that the exchange of national and foreign researchers (represented by the last two variables), suggests that there is a much stronger policy of training Brazilians abroad than of importing foreign manpower.

Our results indicate that foreign capital has an influence on the perception of direct suppliers about the External Sector (while size and market segment do not). Indeed, the relationship of foreign companies with the external sector is stronger than the relationship of domestic companies, which may explain the results.

Factors affecting Innovation

The last section of the questionnaire deals with the most important factors affecting innovations in the oils and gas industry in Brazil. In each sector of the NIS, we listed some of the most commonly mentioned sources of innovation as well as hindering external factors, asking respondents to rank them in order of importance.

Sources of Innovation

Table 4 shows the most important sources of innovation for the respondent companies.

Table 4 – Sources of Innovation in the oil and gas industry in Brazil

NIS Sector	Sources of Innovation	Rank
Productive Sector	Clients, suppliers or other direct supplier companies	4.28
Educational System	Universities, training centers, employees	3,90
Financial System	Public and private financing	3,60
S&T System	R&D, technology transfer, licensing, technical assistance	3,24
Public Sector	Laws, regulations and public policies	3,10
External Sector	Partnerships with foreign companies and foreign research institutes	2,88

The Productive Sector appears as the most relevant to the respondent companies (4.28), followed by Education Sector (3.90), and the Financial System (3.60). At the lower end, we find the Public Sector and External Sector as less relevant. The fact that the External Sector appears as a dimension of less importance is perhaps the result of government control measures in providing local industry content, which has been strongly encouraged in recent years.

Another important aspect to be highlighted is the fact that the activities of research and development (R & D) are considered by suppliers in the oil and gas industry as (only) the fourth main source of technological knowledge. This result corroborates OLIVEIRA (2008) suggestion that the main source of technological knowledge for suppliers´ companies is learning-by-doing.

Hindering factors

Table 5 shows the most important factors hindering innovation.

Table 5 – Hindering Factors

NIS Sector	Hindering Factors	Rank
Public Sector	Laws, public policies and taxation	4.24
Educational System	Lack of appropriate skilled labor	4.17
Financial System	Lack and/or difficulties in obtaining of financial resources	3.58
S&T System	Poor technological infrastructure	3.45
Productive Sector	Difficulty in cooperation between companies	2.79
External Sector	Import/export barriers in the external market	2,88

In the view of the respondent companies, the Public Sector is responsible for the most important barriers to innovation (laws, public policies and, in particular, direct and indirect taxation). The Educational System is responsible for another very important impediment to innovation in the oil and gas industry: the unavailability of skilled labor. Also of considerable importance is the Financial Sector (lack of financial resources) and the S&T System (lack of technological infrastructure). The difficulty of cooperation between the companies in the sector appears as one of the least significant impediments. Finally, the external sector does not seem to be an important sector with respect to impediments to innovation.

CONCLUSIONS

Conceptual framework

The results of the quantitative survey lead us to propose a new conceptual framework that synthesizes the functioning of the NIS, according to the perception of the respondent companies. The diagram in Figure 2 is intended to represent how such companies see the National Innovation System, based on the importance of the different constituent dimensions and difficulties imposed by each of them. The supplier companies appear at the center of the scheme, indicating the fundamental importance to the functioning of the National Innovation System.

The supplier companies in the oil and gas industry establish different relationships with the dimensions proposed in this study. The Productive Sector includes the operating companies of oil wells and direct suppliers. The Public Sector is responsible for developing rules and actions to support innovation and intellectual property. The Educational System is formed by universities and training institutes and provides the intellectual resources required by industry. The External Sector involves import and export as well as exchanges of human capital with foreign countries. The S&T System involves R & D efforts in the national context. The Financial System creates conditions for the functioning of the NIS, by providing funds and rules for financing. Graphically, the dimensions were represented with different sizes according to the degree of importance given to them by the respondent companies. The light arrows indicate that there is a difference of perception about the dimensions of S & T System, Financial System and External Sector depending on the size and participation of foreign capital in the respondent companies.

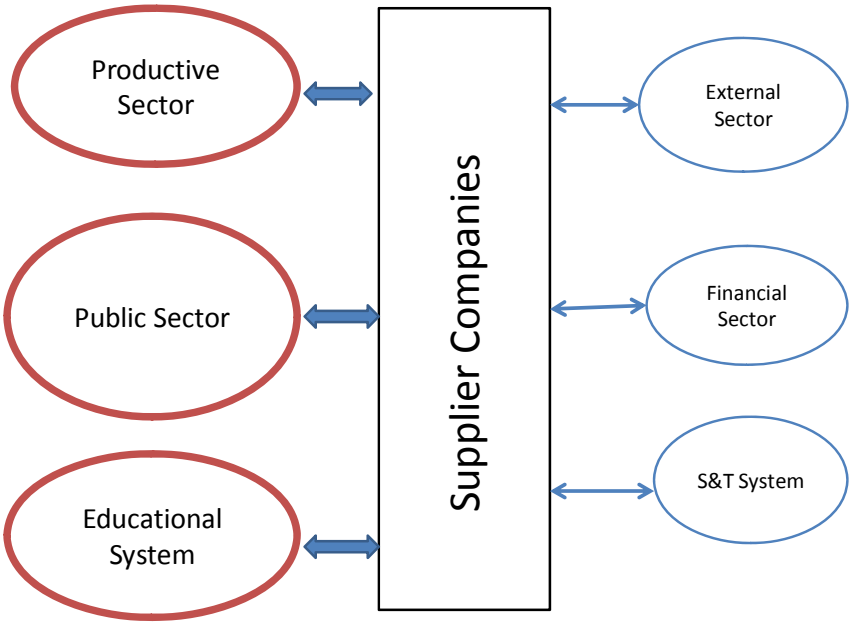

Figure 2 - The importance of relationships in NIS supply companies in the oil and gas industry

Key limiting aspects of the dimensions analyzed

The Educational System is possibly the largest problem in the Oil and Gas Innovation System in Brazil. Almost all aspects were considered underdeveloped. The main weaknesses are the lack of skilled labor, at operational, graduate and post-graduate levels.

The S&T System is considered a central dimension in many NIS, but in the case of the oil and gas industry, R&D is not considered as the main source of innovation. What really drives innovation - as perceived by the suppliers to the oil and gas industry - is probably the learning-by-doing.

The Financial System usually has a determining role in the pace of technological development, especially in activities of the oil and gas industry which requires considerable expenditures in all of its segments. In the Brazilian case, the Financial System is negatively evaluated by respondent companies. Overall, it presents a low level of development. This may be due to the negative perception of small and medium size companies. For whatever reasons, large companies seem to make a better job in getting financing for innovations.

With regard to the Public Sector, the main problem identified was the tax issue, capable of inhibiting the competitiveness in the industry.

Although the Productive Sector was considered the most developed dimension of NIS, there are some aspects that can be improved. Thus, there is room for a greater involvement of companies, especially those producing technology, with their partners and competitors in the innovation process.

Finally, with respect to the External Sector, it was identified a significant imbalance between imports and exports. While the volume of imports remains relevant to the sector, exports are almost negligible among the suppliers of oil and gas chain. One could also suggest that the import of skilled labor should be considered.

Suggestions for future research

We suggest that specific studies on each of the major dimensions of this Innovation System will help to better understand the shortcomings identified in this study. This will help to improve the framework presented as well as to identify actions to correct such shortcomings. We also suggest that similar work could be done in other sectors of the Brazilian industry as well as in other countries (for the sake of comparisons).

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