ISSN 1519-4612

Universidade Federal Fluminense

TEXTOS PARA DISCUSSÃO

UFF/ECONOMIA

Universidade Federal Fluminense
Faculdade de Economia
Rua Tiradentes, 17 - Ingá - Niterói (RJ)
Tel.: (0xx21) 2629-9699 Fax: (0xx21) 2629-9700
http://www.uff.br/econ

esc@vm.uff.br

The Role of the Network Coordinator in the Attraction of Foreign Investments in R&D: the Case of the Brazilian Oil and Gas Industry

Frederico Rocha*
Ana Urraca Ruiz**

TD 275
Setembro/2011

© *Associate Professor, IE-UFRJ, e-mail: fred.rocha@ufrj.br or fred@ie.ufrj.br.
**Associate Professor, Departamento de Economia, UFF, e-mail: anaruiz@economia.uff.br

ABSTRACT

This paper aims to analyze recent R&D investments undertaken by equipment and service supplies companies in Brazil, trying to identify their motivation and to capture the role played by international market characteristics and the main technology players in Brazil. Three main features attracted these companies' R&D investments to Brazil: the size of the pre-salt oil and gas province, Petrobras' accumulated capabilities and the existent of qualified personnel. The paper shows that companies follow different strategies. FMC adopts an asset exploiting strategy while Baker and Schlumberger follow more asset augmenting strategies. The paper then argues that the role of network coordinator and its technological capabilities are central for the location of suppliers' R&D investments in global production chains.

Acknowledgements

This paper was written during a research on Oil and Gas Industry undertaken by the Instituto de Pesquisa Econômica e Aplicada (IPEA). Some of the results were discussed in the seminars of that research. The authors are grateful for the comments received from the participants of these seminars and especially to João De Negri, Fernanda De Negri and Marcio Wohlers. The research also couldn't have been carried out without the support of Carlos Thadeu Fraga and José Roberto Fagundes Netto from CENPES that helped us to access managers of the interviewed companies. The paper has been written during the authors' stay at the University of Siena as visiting fellows. The authors would like to thank Professor Punzo. The final part of this research has been supported by CAPES/MEC.

1. Introduction

This paper aims to analyze recent R&D investments undertaken by oil and gas equipment and service supplies companies in Brazil, trying to identify their motivation and to capture the role played by international market characteristics and the main technology players in Brazil. The paper argues that network coordinators may play a key role in the determination of location of R&D investments of their main suppliers due to the need to interact and exchange information when developing new technologies.

Innovation economics literature has collected evidence about the increasing internationalization of multinational corporations' (MNC) R&D efforts (Granstrand et al.1993; Cantwell 1995; Dunning 1994; Florida, 1997, UNCTAD 2005). International efforts occupy an increasing share of MNC's total R&D efforts, while their share in host countries' total R&D effort also augments. These internationalized R&D efforts have been classified according to the localization of their main knowledge source. Criscuolo et al. (2004) argue that when firms, in their foreign located R&D, use knowledge assets, that were acquired, developed and accumulated in their home country they are undertaking *asset exploiting R&D.* This is reflected by the adaptation of technological knowledge existent in headquarters to the use of the specific foreign affiliate R&D labs. Most of what literature has defined as demand motives to internationalization (Zanfei 2000) may be framed in this category. If MNC foreign located R&D centers use knowledge that is produced by other agents in the host country, it is said that they are increasing their home base advantages and have an *asset augmenting strategy*, that is, the MNC foreign R&D lab is absorbing technological knowledge in the foreign country and is probably transferring it to headquarters and other subsidiaries. This occurs when the foreign affiliate R&D labs use local host country knowledge accumulated capabilities. Most of the supply motives for the internationalization of R&D are classified into this latter category.

Underlying the location choices are the requirements for proximity and their implications for the learning process, that is, the determinants of geographical location of knowledge production and sharing, usually associated with capturing and transferring codified and tacit knowledge (Howells 2002). There is plenty of work on the role played by proximity in absorbing knowledge spillovers. Jaffe, Trajtenberg and Henderson (1993) have shown a higher probability of citation of patents issued with inventors residing in the same country, state and metropolitan area. Jaffe and Trajtenberg (1999) find that, apart from the localization aspect for absorption of knowledge, there is an organizational dimension as well, as patents assigned to the same firm are more likely to be cited. Furthermore, location proximity reduces the time of diffusion of knowledge across firm boundaries, and the diffusion through intra-firm organizational mechanisms reduces the time of acknowledgement across national boundaries (Jaffe and Trajtenberg 1999, Howells 2002).

It should be clear that asset exploiting activities are mostly an intra-firm process, in the sense that knowledge is brought from headquarters and other subsidiaries and used to attend needs that have been identified by the local subsidiary's marketing or sales departments. The obstacles to knowledge transmissions are overcome therefore by organizational routines. In asset augmenting activities, spillovers from the environment have to be absorbed and therefore the building of inter-firm or face to face channels acquires greater importance. However, organizational routines procedures for diffusion of knowledge across subsidiaries are still required.

As a consequence, whenever MNC undertake asset exploiting activities, the pursuit for host country's capabilities is less likely to play a center role and the choice for the localization of the investment in more likely to be associated with local market characteristics such as scale of the market and the demand's rate of growth. In asset augmenting activities, demand and market size may not be as important as local capabilities. Scale requirements lie on the accumulated technological capabilities of the host country. In the latter case, it is more likely that firms elect only a few locations to undertake these activities, since the costs of creating absorptive capability are high due to the complexity of the task. Not surprisingly, while MNC's asset exploiting activities have been more evenly split worldwide with an important share located in large developing countries (market size requirement) such as China, India, Brazil and Mexico, asset augmenting R&D seems to be still concentrated in triad countries (UNCTAD 2005).

The presence of technology leaders and complementary national innovation systems are pointed as the main reasons for the choice of location of asset augmenting R&D and therefore the main causes for international concentration of such efforts. However, literature seems to have underplayed the role of user-producer relationships in inter-firm networks in the definition of R&D location and internationalization. Most of the effort for understanding the role of user producer links in the determination of the location of R&D has been undertaken by global production network (GPN) literature. In this case, attention is addressed to network coordinators' R&D investments in suppliers' countries. Ernst and Kim (2002) argue that R&D and engineering personnel may be displaced to local supplies networks in developing countries to carry out the necessary tasks for the transference of knowledge to be successful. This would take place when there were requirements for transference of tacit knowledge or when the learning process from codified knowledge would require close contact. Thus, network coordinators (flagships) would carry out production oriented technological activities in foreign locations.

Chen's (2004) work on Taiwanese first tier suppliers' foreign R&D investments in China shows how these companies have increased their production facilities and have carried out R&D investments as a result of the GPN movement towards China. Two important features of Chen's work are: (i) the distinctive role played by first tier suppliers who also undertake relevant R&D investment; and (ii) the dominance of production related R&D activities in China. In the latter point, Chen (2004) argues for a division of labor of R&D activities inside the GPN, where brand marketers (network coordinators or flagships in Ernst and Kim (2002) terminology) would carry out product concept technological activities, Taiwanese first tier suppliers would undertake product R&D activities at home and process R&D in China. However, GPN authors have not tackled location consequences of GPN for first tier suppliers' R&D labs.

The role played by first tier suppliers in innovation processes has been widely investigated by innovation economics literature. Womack et al. (1991) stressed the importance of suppliers participation in product concept in the lean production system. Bidault et al. (1998) analyze the determinants of early supplier involvement (ESI) practices in a large number of industries. They show that these practices have been widely spread and that they involve the sharing of information, suggestion for cost and quality improvements, participation in the design of parts and components, and the undertaking of full responsibility from the conception to the manufacturing of modules and parts of a system.

It is clear that the development of these practices requires the transference of tacit knowledge that may require contact. Then, one should expect that the presence of innovative environments that entail user-supplier interaction, proximity requirements will lead to the clustering of R&D labs and engineering crews. Whenever these user-supplier alliances have multinational participation this will end-up in foreign direct investments in R&D.

The paper is composed by five sections including this introduction. In the next section, we characterize the oil and gas industry and the type of relation operators have with equipment and services supplies companies, capturing the need and the occurrence of knowledge flows between users and suppliers. The section also deals with the Petrobras learning and capability process, stressing its role as network coordinator and the innovative challenges of the pre-salt oil province. Section three examines supplies companies' previous R&D internationalization strategies, using patenting data, and covers the motives that underlie R&D investments in Brazil through the use of interviews undertaken with Petrobras' R&D lab director and staff and with CEOs of the MNCs affiliates in Brazil. Section four discusses the results, trying to refer them to the literature and section five draws the main conclusions from the paper.

2. The Brazilian Oil and Gas Industry

2.1. The Organization of Upstream Oil and Gas Industry: Technological Imperatives

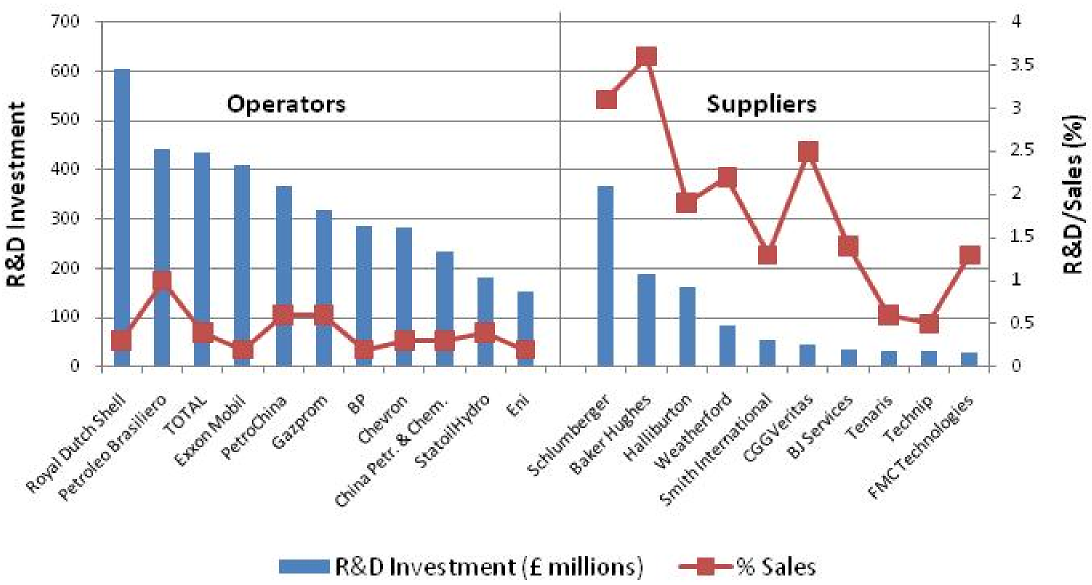
One important characteristic of the upstream oil and gas industry is its incapacity to differentiate product. This characteristic has driven the sector towards cost reducing technology trajectories. One of the main trajectories was the attempt to achieve scale economies. However, due to geographical imperatives associated with highly specific geological conditions, the achievement of economies of scale in production is quite difficult. As a consequence, economies of scope have become a more important driving force to cut costs (Bridge 2008). In order to achieve scope economies, the industry relied on specialized service and equipment suppliers that guaranteed the transference of technological capabilities across different geological scenarios. This important advance in organization became possible due to the pattern of competition between oil and gas operators. Oil companies compete through a process of risk control, managing the identification and acquisition of oil provinces, the rhythm of production in oil and gas reservoirs and logistics of supply. Service and equipment suppliers compete through service quality, innovation and the up-bringing of solutions in extreme exploration and production conditions and cost reduction (Acha and Cusmano 2005).

Jacquier-Roux and Bougeois (2002) argue that the tendency for the labor division across these two groups of firms increased since the 1980's, when oil prices went down and oil operators decided to reduce R&D efforts from an average of 1% to 0.5% of total sales. This decrease in R&D intensity has been accompanied by an increasing technological role played by service and equipment suppliers. On the other hand, service and equipment suppliers changed their strategies in some important ways. First, they engaged in a very aggressive movement of mergers and acquisitions resulting in greater diversification of their activities. This process generated the four large integrated companies (Schlumberger, Baker Hughes, Halliburton and Weatherford) and in some way it is still going on[1] (Iootty 2004). Second, these companies largely increased their

[1] The last large transaction involved the acquistion of BJ by Baker Hughes and took place in 2009.

technological intensity and diversified their technological portfolios (partially explained by the M&A process). The decrease in technological activity of oil operators has been compensated by the increase in technological intensity of service and equipment suppliers (Jacquier-Roux and Bougeois 2002). The relationship established between the two parties has changed from short run commercial relations towards long run partnerships. The main reason for the undertaking of long run partnerships is associated with geological and sea heterogeneity that may require development of specific solutions. Therefore, innovation is a constant theme in the relations between these actors and the sharing of information is central to their operations.
Figure 1 shows R&D expenditures of the major oil and gas companies and service and equipment suppliers. Some important observations may be derived from the values presented. First, service and equipment suppliers have greater technology intensity when compared to oil and gas companies. Second, the volume of expenditures of oil and gas companies is still very large, giving some evidence that oil and gas companies still perform an important role as network coordinators in the industry (Acha and Cusomano 2005).

Figure 1. R&D Expenditures (current million British pounds) and R&D Intensive (R&D/Sales) of Oil and Gas Major Companies and Service and Equipment Suppliers, 2008



Source: Department of Trade and Industry 2008.

2.2. Petrobras and the Brazilian Oil and Gas Technological Scenario

Petrobras has the second largest R&D budget amongst the oil and gas companies and the highest R&D intensity, reaching 1% of sales[2] (Figure 1). This position was achieved through a strong drive in recent years that took the company's R&D budget from £111 millions, in 2004, to £443 millions, in 2008. This drive was motivated by two factors: (i) the growth of sales as a consequence of increases in oil prices and production; and (ii) an increase in the R&D intensity from 0.7% in 2004 to 1% of sales in 2008. The increase in the R&D intensity of Petrobras in the period was partially influenced by

[2] Which used to be the industry average R&D expenditure before the 1990's.

regulatory measures that forced investments in R&D by oil and gas companies. In the bidding process for exploration of oil provinces, according to regulation by Agência Nacional do Petróleo (ANP), oil operators compromise to invest 1% of the rents from high productivity oil fields in R&D in Brazil. The regulation imposes that 0.5 percentage point should be directed to University research in oil and gas related investigations to be undertaken according to the desire of the oil operator.[3]

Petrobras has since long been a very R&D intensive company. It should be stressed however that the positioning of the company as a technological leader was straightly associated with two different trends. On the one hand, Petrobras benefited from the changes in the organization of the industry related to the increasing importance of suppliers as technological partners. Bridge (2008) argues that the knowledge accumulated in suppliers allowed state-owned oil companies located in developing countries to access technology and learning. Furtado and De Freitas (2000) document three cases associated with subsea technology in which Petrobras was able to develop new technologies to be used in its subsea operations through cooperative efforts with suppliers. They also show how through this process of cooperative agreements with suppliers and other oil companies, in pre-competitive phase, Petrobras developed from a position of cosponsor to that of network articulator. Dantas and Bell (2009) also show how Petrobras was able to learn from collaborative agreements adding that network participation has been made more complex. In this case, they show that the network configuration has evolved from what they call a *passive learning network* to *strategic learning innovation network.*

Table 1 ANP Regulation R&D Budget by Oil and Gas Operator, 1998-2008, US$ current*

	Oil and Gas Operator			
	PETROBRAS	SHELL	REPSOL	Total
1998	1,624,991	0	0	1,624,991
1999	15,988,766	0	0	15,988,766
2000	51,490,603	0	0	51,490,603
2001	54,167,790	0	0	54,167,790
2002	90,241,560	0	0	90,241,560
2003	105,053,341	0	0	105,053,341
2004	134,177,719	3,663,376	0	137,841,095
2005	208,072,498	937,270	0	209,009,767
2006	282,183,775	0	1,171,280	283,355,055
2007	313,418,522	0	3,214,655	316,633,177
2008	465,558,734	0	3,889,341	469,448,075

Source: Agência Nacional do Petróleo.
* Converted from Brazilian real to dollar by average dollar value, according to Banco Central do Brasil.

On the other hand, Petrobras has a history of undertaking important in-house R&D efforts with nationalistic approaches. These efforts involved personnel from its main R&D lab, CENPES, located inside the campus of the *Universidade Federal de Rio de Janeiro* (UFRJ), domestically located suppliers[4] and Universities. Though some of these

[3] The other percentage point may be directed either to Universities or to business R&D. Petrobras spends more than the 0.5 percentage point of these rents in its R&D center, CENPES (Leopoldo Miguez de Melo Research and Development Center)

[4] Some are national capital enterprises, others are multinational companies located in Brazil.

efforts resulted unsuccessful, they gathered large amount of learning and development of absorptive capacity (see Furtado and De Freitas, 2004).[5] Furthermore, they played an important role in developing linkages and collaborative capacity with Brazilian universities. Therefore, they were able to develop important industry-research institutions linkages. Domestic Universities became a central player in the *strategic learning innovation network* articulated by Petrobras.

The linkages with universities have straightened after the implementation of the ANP regulation on R&D. In order to use the resources from ANP, Petrobras developed a network type of organization called Thematic Networks. These networks enjoyed a large flow of resources until 2008 that has been used to establish an up to date laboratorial infrastructure distributed over many universities (see Table 1). Furthermore, these resources were also used to train personnel for the oil and gas business and to open new undergraduate and graduate specialties related to the oil and gas industry.

2.3. Changes in the Technological Scenario after Pre-Salt Discoveries

The capability accumulated by Petrobras made possible a strong expansion of the Brazilian oil and gas production (Figure 2). This has culminated in the discovery of the Pre-Salt province[6] that represents a very sizeable oil reservoir, equivalent to the North Sea province. The technology used to explore and produce in these regions was similar to that used in other offshore operations, such as North Sea and Gulf of Mexico, though, as stated above, adaptations to local geological characteristic were always necessary. However, the expansion of production from 2013 on will increasingly depend on the exploration of the new oil province at the Pre-salt.

The Pre-Salt has shown to have large potential with still open opportunities.[7] Furthermore, similar geological formations are present in other provinces, such as the Western African Coast. There are, however, some new technological challenges to be faced by oil companies. Bicalho et al. (2009) list five main areas where technological solutions are still to be found: (i) reservoir engineering and characterization; (ii) well drilling and completing, dealing with problems associated with drilling detours caused by the salt environment and corrosion management due to the presence of CO_2; (iii) working with risers in subsea areas with depth over 2000 meters; (iv) anchoring and managing floating devices, developing connections to risers to work in extreme conditions; and (v) associated gas logistics. The overcoming of the obstacles associated with these challenges will require more than the available technology. It is a new technological frontier where technology trajectories may not yet be established. Pioneer suppliers would be in an advantageous position in comparison to their rivals.

In a sense, it is similar to the situation faced by the North Sea industry when offshore production was at its birth and there was need to develop new technological solution to develop its whole oil and gas potential (see Furtado and De Freitas 2000). However, there is one key difference. In that context, the main oil and gas operators had their

---

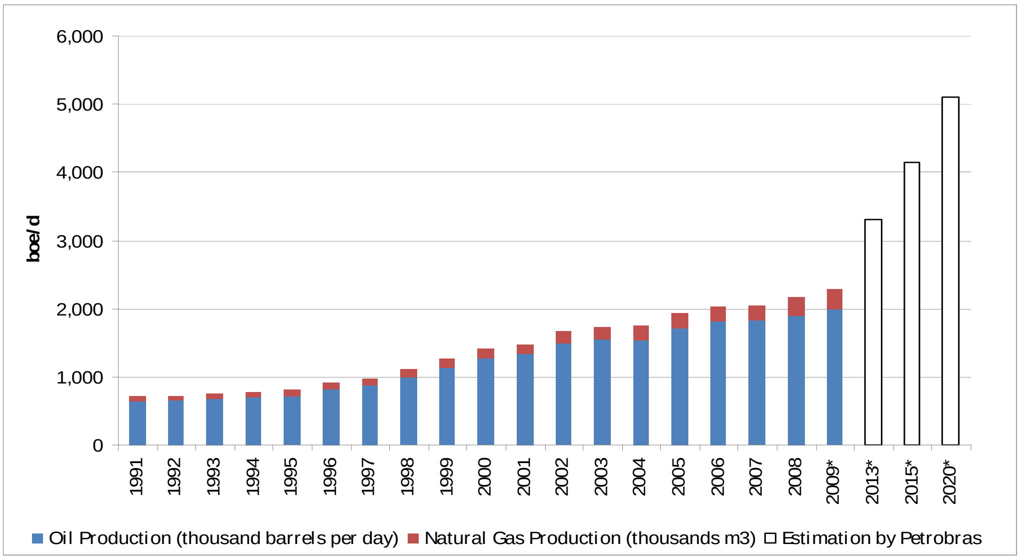
[5] Furtado and De Freitas (2004) document seven nationalist oriented projects in PROCAP 1000 only one of which resulted successful. They relate however these projects with future gains by Petrobras.

[6] The Pre-salt province covers an area of 120.000 km^2 at the Brazilian coast. The area begins in Santa Catarina, south of Brazil and follows for 800 km until it gets to Espirito Santo. It is called pre-salt due to its geological location underneath a salt layer. The oilfields are located in deep and ultra-deep waters beneath three thousands meters of rock and sand and up to 2000 meters of a salt layer.

[7] The recent discoveries announced by Petrobras seem to be large. The Tupi and Iara oil fields together seem to be sufficient to double Brazil's oil reserves from 12 billion barrels to 24 billion barrels (Bicalho et al. 2009). There have been some other discoveries with still unknown volumes such as Jupiter and Carioca that some speculate would take pre-salt oil reserves up to 50 billion barrels (Berman 2008).

headquarters and R&D labs located in the United States, near the Mexican Gulf, where service and equipment suppliers already held their main R&D facilities.[8] In that case, there was no need for displacement towards new locations. In the pre-salt province, the main operator is Petrobras that has located its R&D facilities in Brazil.

Figure 2. Brazilian Oil and Gas Production, barrels of oil equivalent per day (boe/d). 2001-2009, and Estimates for 2013, 2015 and 2020



Source: Agência Nacional do Petróleo, Anuário da ANP, 2001 and 2009.
*Data for 2009 and estimations for 2013, 2015 and 2020 were obtained from Petrobras in http://www.petrobras.com.br/pt/noticias/producao-de-petroleo_no-pais-aumentou-6-3-porcento-em-2009/.

After the announcement of the pre-salt discoveries, the pressure towards the development of a domestic industry increased. However, most of the service activities are quite complex and require previous knowledge accumulation and large scale of R&D activities. Nonetheless, the production in the pre-salt province will require new technological developments as has been argued above. The domestic development of adequate technological capabilities would take precious time that would compromise investment and production targets. In order to deal with these technological challenges, CENPES prepared a strategy that involved doubling its facilities and coordinating and promoting closer interaction with Petrobras' key suppliers .

Petrobras took the decision develop these technological solutions through a joint effort with major integrated service and equipment MNC. The need for full dedication and close exchange of information required the establishment of R&D facilities of these suppliers near CENPES. Petrobras coordinated the installation of R&D laboratories of these first tier suppliers to develop the new pre-salt solutions in cooperation given the competence distribution between players.

The R&D labs were to be located at the UFRJ campus in a site two kilometers away from CENPES. Three MNC have signed contracts with UFRJ: Schlumberger, Baker Hughes and FMC. Halliburton, Technip and Cameron have expressed some interest though no formal deal has already been established. Their sole activity in the site will be R&D, for the University forbids any other activity. This should therefore be an

[8] Hatakenaka et al. (2005) show that in the birth of North Sea the main operators came from the Gulf and the Dutch (Shell) provinces. Statoil engaged in operation later on, after the discoveries, and accumulated capabilities along the development of the province.

important R&D cluster in the oil and gas area. The following pages will reflect on the main factors of attraction for these entrepreneurships.

3. Technological Internationalization Strategies of the Supplies companies

3.1. Methodological Issues

This section uses information from interviews and from the European Patent Office (EPO) Bulletin Database to explore R&D internationalization strategies of the main oil and gas service and equipment suppliers. The nationality of the patent is defined by the residence of the inventor. The differences between the nationality of the applicant firm and the nationality of the inventor define the rate of internationalization of the firm's innovative activity. We have defined the nationality of the applicant firm by the nationality of the parent.[9]

Patel and Vega (1999) and Le Bas and Sierra (2002) elaborate a taxonomy according to the type of knowledge developed using patent statistics. The taxonomy classifies strategies according to two criteria: the revealed technological advantage of the firm at its home country in the technical field covered by the patent (RTA home), measured by the ratio of the share of company's patenting in that technical field to the share of EPO's patenting in the same technical field; and the revealed technological advantage of the host country in that technical field covered by the patent (RTA host), measured by the ratio of share of host country's patenting in that technical field to EPO's patenting in that technical field.

From these two criteria they obtain four classifications: (i) type 1 – *technology seeking FDI or home country exploiting*, RTA home<1 and RTA host >1 where the firm seeks to augment its technical base by exploiting a host country's technological advantage. This may be related to tapping in or monitoring motive for internationalization; (ii) type 2 – *home base exploiting* where RTA home>1 and RTA host <1, where the firm is more likely to be executing adaptive R&D; (iii) type 3 – *home base augmenting* R&D both RTA home and RTA host>1, which may also be associated with technology monitoring motive; and (iv) type 4 – *market seeking FDI in R&D*, where market specific needs may require firms to adapt their technologies. It is clear that types 1 and 3 match what has been called asset augmenting strategies, type 2, asset exploiting strategies and type 4 is out of any of the two types of strategies argued in the introduction of this paper and are mostly explained by acquisition of new subsidiaries.

In order to deal with the specific importance of each technology for the service and equipment suppliers here analyzed and to simplify exposition of the results, the paper uses a specific patent classification obtained from the aggregation of the 4-digits international patent classification according to patents distributions of firms, which permitted identify major and minor technical fields for their specific technological profiles (see annex 1).

The second source of information used in the paper are interviews carried out with: (i) chief executives of Schlumberger, Baker Hughes and FMC; (ii) management of the Technological Park of UFRJ; (iii) head and main R&D managers of Petrobras R&D center (CENPES). The interviews followed a semi-structured questionnaire that covered the following points:

- general information of the company and its activities in Brazil – number of employees in Brazil, in the world, expected size of the laboratory in Rio de

[9] Schlumberger is here treated as a US firm.

Janeiro, laboratories around the world, planned total investment in R&D in Brazilian facilities, annual budget in R&D.

- technological strategies – the relative importance of R&D investment in Brazil and the type of efforts that were planned (adaptive, innovative, research, development or engineering, niche, core, complementary technologies), relation of the R&D lab in Brazil with parent R&D labs, role of the investments in the productive strategy of the MNC, main determinants of the investment (pre-salt scale, need to adapt products, cost of qualified labor, supply of specialized labor, need for interaction with suppliers, pressure from customer), sources of knowledge to be used in the lab;
- expected spillovers and local factors – share of Brazilian and foreign researchers, relative importance in the MNC of the foreign researchers allocated to the lab, the role of property rights, interaction with the University (labor hiring, use of R&D labs and local infrastructure, collaborative research, the role played by specific knowledge held by the University) the role played by competitors location, role played by supplier location, importance of the proximity with CENPES.

It should be stressed that the questionnaire worked with open answers and that there was no intention to tabulate results given the small number of corporations involved. Petrobras' executives and the technological park manager were interviewed in order to capture their perception about the investments of the MNC on the same topics. Additional questions were made in order to analyze their expectations about their own organizations and the interests that were involved.
Patent information was collected on four MNC of the oil and gas equipment and service supplies industry – Baker Hughes, FMC, Halliburton and Schlumberger – from 1980 to 2008. [10] Headquarters and subsidiaries were obtained from Iootty (2004) and from companies' websites information. Though Halliburton has not yet decided to invest in the Technological Park, it was an option to use the firm's data for contrast with Baker Hughes and Schlumberger, the other two integrated service and equipment suppliers.[11]

3.2. R&D Internationalization Strategies g of Equipment and Service Suppliers

Schlumberger is by far the company with greater rate of internationalization of its technological efforts, 67.5% of its total patenting have inventors resident outside its

[10] The patenting activity of other service and equipment suppliers was not so intense in order to include them.
[11] Patents have been widely used in the literature to analyze competence building at the firm and at national levels for several reasons; they provide detailed and reliable information for long time series, they can be grouped according to firm, nationality and technical fields, and they represent output measures of the innovative process from formal and informal efforts (Patel and Pavitt, 1991). However, patents do have some shortcomings. They limit the analysis to those results that can be patented and that applicants have chosen to patent in that specific national or international office. This means that there may be some biases related to differences in the propensity to patent across sectors and technologies and differences in market and appropriation strategies. Furthermore, some of the local and international spillovers of innovative activity may not be captured by patent statistics. This may limit the analysis of policy implications (Cantwell and Iammarino 2003). The advantages and justifications for the use of EPO's statistics over USPTO have been analyzed in Le Bas and Sierra 2002, Grupp and Schmoch 1999) and are related to the greater internationalization of EPO and the greater filter it represents for usually it is not the first patenting office and its filing fees are much higher. We ask the reader to refer to those papers for greater information.

home country (see 0). On the contrary, Halliburton has the lowest level of international technological efforts with only 13% of the total patenting having designated inventors resident outside the USA. FMC and Baker Hughes have intermediary levels of internationalization. FMC's and Baker's level of internationalization are similar to the average identified for USA MNC by UNCTAD (2005).[12]

Table 2 presents also the co-patenting activities of these firms, that is, patents that are filed together with other firms, research institutions or universities. This may be an indicator of the level of interaction with agents in systems of innovation, which is also related to the absorption of spillover and therefore to asset augmenting strategies, whenever done in foreign locations. It should however be stressed that the measure captures only formal activities, due to the legal consequences of patenting. The overall rate of co-patenting is very low but it is always greater in international locations. Schlumberger is the only firm with high level of co-patenting and mostly carried out in foreign locations. Almost a quarter of its patenting with foreign inventors occurs in cooperation with other firms or universities, while the other three have 5% or less of its foreign inventors patenting in cooperative efforts.

These data reveal important differences about the R&D internationalization strategies of these four firms and also of the mergers and acquisition processes they went through. In fact, only Schlumberger seems to have a conscious R&D strategy of internationalization. Its greater level of internationalization is due to two important characteristics. On the one hand, it is influenced by its French origin, what explains the high percentage of patenting with French inventors. On the other hand, the company adopts a more aggressive international strategy, trying to capture knowledge produced in host countries. According to the interviews, the aim of the company is to have an international distribution of R&D similar to the international distribution of its sales. They have three types of R&D labs:

(i) basic research labs, which was pointed out as being "almost a University", that develops knowledge to be used by the whole corporation. The company has five labs dedicated to this activity in the US, UK, Japan, Russia and Saudi Arabia;

(ii) development and engineering labs which are responsible for the elaboration of direct productive solutions. These labs solve global problems and solutions should be applied worldwide. There is a great number of laboratories with this characteristics in the corporation; and

(iii) regional technology centers which are responsible for the adaptation of solutions elaborated by the development and engineering labs.

Baker Hughes' R&D internationalization is a consequence of mergers and acquisitions process. Some of the R&D labs of acquired companies were kept open due to their high local capabilities. This occurred for instance with Eastman Christensen in Germany, explaining the high share German inventors' patents have in total Baker and Hughes international patenting (see Table 3). Baker Hughes did not have until now a clearly designed international R&D strategy and the interviewees were quite enthusiastic about this pioneering experiment in developing countries (Rio de Janeiro and Bahrein will be the first experience).[13]

---

[12] The level of internationalization shown by USA companies in UNCTAD (2005) is calculated using the UNCTAD survey and provide therefore information on 2004 R&D activities while R&D internationalization here measured uses patent and has effects accumulated since 1978. Therefore, it should be seen as having a bias towards underestimating the level of internationalization of R&D activities.

[13] Until now, R&D labs were concentrated in the US and Germany.

The more disperse international activity of FMC is explained by its reliance on user-producer interactions. It has also been affected by mergers and acquisitions. The Brazilian subsidiary is one example of an acquisition that had developments over R&D&E activities. Former CBV had a history of capability accumulation and learning through interaction with Petrobras. In this case, its acquisition by FMC maintained the technological capabilities accumulation strategy and the previously developed interaction with Petrobras, which resulted in the patenting activity with Brazilian inventors shown in Table 3. However, the main orientation of the company follows a more centralized model of production of knowledge with R executed in the home country and D in the destination.

Halliburton has the lowest R&D intensity amongst the large integrated companies (see Figure 1). It is furthermore the most reluctant to internationalize its R&D. This may explain its reluctance to invest in an R&D lab in Brazil.

Firms adopt however very similar strategies with respect to the technical localization of their cooperative efforts with strong prevalence of type 3, home base augmenting R&D strategies, followed by type 2, home base exploiting, strategies, that is, they internationalize in fields they were previously specialized. In most cases, the host country also was it. This seems to be a general conclusion of previous studies (Le Bas and Sierra 2002 and Patel and Vega 1999): the large reliance on firms' home country competences. It is therefore very rare that firms internationally seek competences they do not hold in their home countries. Table 3 shows nonetheless that a not so low proportion of the competences developed abroad by Schlumberger and FMC are outside their home country's research revealed technological advantages (a little less than 1/3). However, neither FMC nor Schlumberger develop core technical fields outside their home countries that are not core technical fields in their home countries, that is, whenever a technical field plays a relevant role outside their home country in a way to say that the company is specialized in that technical field, it also plays a relevant role in their home countries. Core competences are therefore defined at home.

The question is *why did these MNC decide to operate R&D labs in Brazil?* In the interviews, we were able to identify three common answers. First, all MNC are attracted by the pre-salt scale. There is a wide understanding that the pre-salt opens an avenue of supply opportunities. In this case, market size and growth potential are playing a central role in the establishment of R&D efforts abroad. All companies report this as their most important motivation.

Second, MNC were attracted by CENPES' technological competences. The interest on CENPES' competences is nonetheless different amongst companies. On the one hand, the integrated companies want to learn about exploration and production conditions in the pre-salt because they are aware that knowledge developed for the Brazilian pre-salt will be able to be used elsewhere. Each of the integrated service and equipment suppliers, Schlumberger and Baker Hughes, have contracted at least one development project with CENPES that should be the main carrier of the R&D facility. This means the use of a team with full dedication to interact and produce solutions together with CENPES. It should be stated that this position matches CENPES' intention to have the full attention of researchers from these companies. This means that these companies are participating from the beginning of the design of Petrobras' operations in some conditions and that the solutions that are brought together will imply consequences to the operation of Petrobras as well, more similar to the early supplier involvement described in Bidault et al. (1998). On the other hand, FMC has a classic user-supplier relationship in which its main objective is to know the user needs to adapt its engineering solutions. In the words of the President for Brazilian operations of FMC "I would rather be inside CENPES, but 2 km away is okay". The main difference with the integrated companies is that FMC will mostly use information provided by Petrobras, but it does not seem that information from their R&D labs will be flowing into CENPES.

Third, all interviewees have stated that Brazil has skilled and qualified labor force to develop R&D activities.[14] In the case of FMC, they already have a robust engineering department in Brazil with about 150 people working. Therefore, they have experience with qualified personnel.

Companies differ, however, in the size and direction of their efforts. The investments by FMC should continue the already established strategy of adapting technology elaborated by the parent firm to Petrobras' purposes. Therefore, the center should be very intensive in engineering efforts. However, they should increase their investments in terms of size, reaching 250 engineers. They will also build a submarine measurement and test laboratory due to the privileged location of the UFRJ campus (by the sea). Due to the type of knowledge being acquired from CENPES and to the reliance on headquarters technology, one may say that it is a continuation, in a new site, of the relationship already established with Petrobras in recent years with a strong emphasis on *asset exploiting*.

Contrary to FMC, the establishment of these labs represents a disruption of the type of technological relations that the integrated services suppliers have with Petrobras. Schlumberger has the most ambitious project for the UFRJ site. It defined its R&D lab in Brazil as a mix of a regional technology center and a development and engineering center. In one large project with Petrobras, they should be developing technology to be used for local purposes and afterwards to be adapted for use in other parts of the world. It will begin acquiring local knowledge to produce for local purpose, but then this information should flow to other operation units of the MNC. In this sense, they are more likely to be establishing a *asset augmenting* strategy. Their lab is planned to have in a first phase 350 researchers and may increase to larger numbers afterwards. At the beginning, 30% to 40% of the researchers will come from other parts of the company with the rest being hired in Brazil. The company has a hierarchy of researchers in fellows (the highest level – only eleven in the company), advisers, principals and seniors. The Brazilian R&D facility should have one fellow and at least one adviser, which show the importance they are depositing in the lab. The fellow will be working in the development and engineering project with Petrobras. This shows the importance they are giving to the research center in Brazil.

According to Baker Hughes' managers, the R&D investments in Brazil change the company's internationalization strategy in the sense that it is a first step towards a more decentralized R&D. In this case, the company will be engaging in strategies that also incorporate *asset augmenting*. The lab should hold 100 researchers. The joint project with Petrobras will require an expenditure of around US$ 30 million in three years plus US$ 10 million of investments in equipment. Petrobras will be spending other US$ 10 million in the same project.

Firms also intend to interact with university, mainly with UFRJ. All of them have stated that the first step is to hire human resources that are prepared by the Universities and the hiring of personnel to take post-graduate degrees in the University in certain subjects. They are aware of the large infrastructure that has been acquired with ANP's resources and are willing to interact with the University in order to use its human and physical infrastructure and to take joint research. Baker Hughes already has agreements with

[14] According to CAPES, Brazil had, in 2009, more than 160 thousands PhD. Students.

some departments for maintenance and use of R&D labs. Furthermore, the University has changed its behavior towards companies and has started to establish policies for interaction with them.

Table 2 Cooperation and Internationalization Ratios for Selected Companies, 1978-2008.

	Total Number of Patents			Number of Patents with Foreign Resident Inventors			Internationalization Ratio (%)			Rate of Cooperation		
	Filed with Partners	Individually Filed	Total	Filed with Partners	Individually Filed	Total	Filed with Partners	Individually Filed	Total	National	International	Total
BAKER-HUGHES	4	488	492	2	116	118	50.0	23.8	24.0	0.5	1.7	0.8
FMC	14	567	581	9	164	173	64.3	28.9	29.8	1.2	5.2	2.4
HALLIBURTON	14	886	900	6	111	117	42.9	12.5	13.0	1.0	5.1	1.6
SCHLUMBERGER	146	808	954	145	499	644	99.3	61.8	67.5	0.3	22.5	15.3

Source: Own elaboration from EPO Bulletin.

Table 3 R&D Internationalization Strategies Adopted by Oil and Gas Service and Equipment Suppliers MNC by Host Country, %

Host Country	Schlumberger						Halliburton						FMC						Baker Hughes					
	Type 1	Type 2	Type 3	Type 4	Total	Share	Type 1	Type 2	Type 3	Type 4	Total	Share	Type 1	Type 2	Type 3	Type 4	Total	Share	Type 1	Type 2	Type 3	Type 4	Total	Share
BE	6.8	62.7	20.3	10.2	100	8.4	0.0	100.0	0.0	0.0	100	3.8	0.0	59.4	3.1	37.5	100	20.3						
BR													7.1	42.9	50.0	0.0	100	8.9	0.0	66.7	33.3	0.0	100	2.8
CA	20.0	45.0	35.0	0.0	100	2.9	4.3	26.1	60.9	8.7	100	22.1	18.8	31.3	43.8	6.3	100	10.1	15.4	7.7	38.5	38.5	100	12.1
DE	15.4	15.4	30.8	38.5	100	1.9	0.0	100.0	0.0	0.0	100	3.8	33.3	33.3	22.2	11.1	100	5.7	6.1	51.5	36.4	6.1	100	30.8
FR	6.2	38.7	22.0	33.1	100	43.6	0.0	75.0	25.0	0.0	100	3.8	45.5	0.0	45.5	9.1	100	7.0						
GB	5.7	6.8	74.4	13.1	100	25.1	2.9	0.0	88.6	8.6	100	33.7	16.1	6.5	61.3	16.1	100	19.6	0.0	0.0	93.2	6.8	100	41.1
JP	17.6	70.6	11.8	0.0	100	2.4																		
NL	5.9	52.9	29.4	11.8	100	2.4	4.5	68.2	0.0	27.3	100	21.15	54.5	45.5	0.0	0.0	100	7.0	0.0	80.0	0.0	20.0	100	4.7
NO	13.4	3.7	67.1	15.9	100	11.7	0.0	0.0	91.7	8.3	100	11.5	23.5	11.8	64.7	0.0	100	21.5	0.0	0.0	55.6	44.4	100	8.4
RU	0.0	0.0	90.9	9.1	100	1.6																		
Total	7.7	28.9	41.9	21.6	100	108.7	2.9	30.8	54.8	11.5	100	88.89	19.6	27.8	39.9	12.7	100	91.3	3.7	22.4	59.8	14.0	100	90.7

Source: Own elaboration from EPO Bulletin.

4. Discussion

The importance of user-supplier relations in complex industries has been well documented by literature. In fact, as shown by Bidault et al. (1998), complexity of the environment is a key aspect for the determination the closeness and the intensity of early supplier involvement. As has been shown in section 2, the oil and gas industry fit into this description and the strategies pursued by oil and gas operators since the 1980's has contributed to increase the need of interaction, as suppliers acquired greater importance in industry's technological development.
The Brazilian pre-salt brings about two important novelties to the industry's technological scenario. First, the Brazilian pre-salt province harbors new technological challenges. The solution of these challenges will determine cost reduction in future explorations in the province, that has prospects of being very large, and in other pre-salt geological conditions, such as those present in the Gulf of Mexico and West Africa. This scenario implies that supplies companies carry out R&D investments in order to overcome technological obstacles and achieve leadership. Second, there has been an entry of a new technological leader amongst operators in the sense that technological knowledge accumulated by Petrobras is necessary for the development of these areas. This leader is not located in the usual oil and gas cluster. Therefore, the development of technology by service and equipment suppliers is associated with interaction with Petrobras and has to be accompanied by foreign investments in R&D as long as the development of the interaction requires proximity, be it originated by tacit or codified knowledge.
Proximity seems also to appear as a requirement when one analyzes location choices. All investments have been directed to the exact same location as the Petrobras R&D Center, CENPES. Furthermore, the two large integrated suppliers have well defined projects where they should be working on directly with Petrobras and that should accumulate knowledge and expertise to be used elsewhere. These aspects characterize the investments in Brazil as *asset augmenting.*
The point to be stressed is that if the operator were to be located elsewhere, investments would be brought to this location. This is the main reason why R&D investments in foreign sites are not as widespread as it would be if one accounted for the high geological heterogeneity of exploration and exploitation activities. Most of the industry has been located in the Gulf and therefore interaction is done with those R&D labs. The effort undertaken by Petrobras to acquire and develop technological capabilities has fostered its role as network coordinator and has rendered possible the announced R&D investments in Brazil.
These features may have one important consequence to studies of GPN: the location of the network coordinator and most of all of its core R&D labs are not neutral to the location of R&D efforts undertaken by suppliers as they upgrade functionally in the GPN, that is, as they increase their technological intensity. This sounds as good news to those countries that are able to harbor network coordinators but not to those countries that search in the functional upgrade of its small and medium enterprises a road towards technological leadership. In this case, it may pose some important constraints to the technological development of nations through the insertions of their small and medium enterprises in GPN.

5. Conclusions

The purpose of this paper was to analyze the R&D internationalization strategies of MNC in the oil and gas service and equipment supplies industry that are installing R&D laboratories in Brazil, trying to capture the main factors of attraction of these companies. The paper has shown that historically these companies have followed different R&D internationalization strategies. Schlumberger has displayed the most aggressive strategies, presenting greater levels of internationalization and of cooperation with host country's local agents. Baker and Hughes and FMC have exhibited lower level internationalization and low level of interaction with local agents. In the case of Brazil, companies have different starting points and different aims.

Three main features have attracted these companies' R&D investments in Brazil: the size of the pre-salt oil and gas province, Petrobras' accumulated capabilities and the existent of qualified personnel. However, the types of R&D investments to be carried out by these companies appear to be different. FMC, the only company with previous technological investments in Brazil, aims to consolidate its position as equipment supplier of Petrobras. In this sense, R&D facilities in Brazil should understand customer's needs and adapt headquarter accumulated knowledge to be transferred to local subsidiary, displaying a clear *asset exploiting* strategy. The two integrated service companies have specific projects to be developed with Petrobras. They will dedicate personnel to work together with Petrobras and intend to use the knowledge produced in these projects in local production and afterwards intend to transfer it to other subsidiaries, which seems to adapt to the definition of *asset augmenting* strategies.

The paper then stresses the role played by the network coordinator in attracting those investments. Previous literature has emphasized the importance of customer-supplier relation and the role played by early supplier involvement in innovative projects. This paper calls attention that this role may be associated with implementation of R&D internationalization strategies.

6. References

1. Acha , V. and Cusmano, L. (2005) - Governance and Co-ordination of Distributed Innovation Processes: Patterns of R&D Co-Operation in the Upstream Petroleum Industry. *Economics of Innovation and New Technology,* Vol. 14(1–2), January–March, pp. 1–21.

2. Bicalho, R. 2009 *Perspectivas do investimento em energia.* Relatório integrante da pesquisa "Perspectivas do Investimento no Brasil", Pesquisa realizado no IE-UFRJ em parceria com o IE-UNICAMP, financiada pelo BNDES, http:www.projetopib.org.

3. Bidault, F., Depres, C. and Butler, C. (1998) The drivers of cooperation between buyers and suppliers for product innovation. *Research Policy,* 26, 719-732.

4. Bridge, G. (2008) Global production networks and the extractive sector: governing resource-based development. *Journal of Economic Geography* 8 pp. 389–419.

5. Cantwell, J. (1995). "The globalisation of technology: what remains of the product cycle model?" *Cambridge Journal of Economics*, 19, 155-174.

6. Chen, S. (2004) Taiwanese IT firms' offshore R&D in China and the connection with the global innovation network. *Research Policy,* 33, 337-349.

7. Criscuolo, P., Narula, R. and Verspagen, B. (2004) "Host country innovationsystems in r&d internationalisation: apatent citation analysis". *Economics of Innovation and New Technology*. 14(5), 417-433.

8. Dantas, E. and Bell, M. (2009) Latecomer firms and the emergence and development of knowledge networks: The case of Petrobras in Brazil. *Research Policy* 38, p. 829–844.

9. Dunning, J.H 1994. "Multinational enterprises and the globalization of innovatory capacity". *Research Policy*, 23, 67–89.

10. Ernst, D. and Kim, L. (2002) Global production networks, knowledge diffusion, and local capability formation. *Research Policy* 31, 1417-1429.

11. Florida, R. 1997. The globalisation of R&D: results of a survey of foreign-affiliated R&D laboratories in the USA, *Research Policy*, vol. 26, no. 1, 85–10

12. Furtado, A. and Freitas, A. (2000) The Catch-up Strategy of Petrobras through Cooperative R&D. *Journal of Technology Transfer* 25: 23-36.

13. Furtado, A. and Freitas, A. (2004) Nacionalismo e Aprendizado no Programa de Águas Profundas da Petrobras. Revista Brasileira de Inovação. Vol. 3(1) 55-86.

14. Granstrand, O., Hakanson, L. and Sjolander, S. 1993. "Internationalization of R&D—a survey of some recent research". *Research Policy*, 22, 413–30.

15. Grupp, H. and Schmoch, U., 1999. "Patent statistics in the age of globalisation: new legal procedures, new analytical methods, new economic interpretation". Research Policy 28, 377–396.

16. Hatakenaka, S. Westnes, P., Gjelsvik, M., Lester, L. (2006) *A Comparative Case Study of the Transition from a Resource-Based to a Knowledge Economy in Stavanger and Aberdeen*. MIT Local Innovation Systems Working Paper 06-002.

17. Howells, J. (2002) Tacit knowledge, innovation and economic geography. *Urban Studies*, 39(5-6), 871-884.

18. Jacquier-Roux and Bougeois (2002) New Networks of Technological Creation in Energy Industries: Reassessment of the Roles of Equipment Suppliers and Operators. *Technology Analysis & Strategic Management*, Vol. 14 (4), 399-417.

19. Jaffe, A. B., Trajtenberg, M. and Henderson, R. (1993) Geographic localization and knowledge spillovers as evidenced by patent citations, *Quarterly Journal of Economics*, 108,pp. 577–598.

20. Jaffe, A. B. and Trajtenberg, M. (1999) International knowledgeflows; evidence from patent citations, *Economics of Innovation and New Technology*, 8, pp. 105–136.

21. Le Bas, C. and Sierra, C., (2002) 'Location versus home country advantages' in R&D activities: some further results on multinationals' locational strategies. *Research Policy*, 31, 589–609.

22. Patel, P. and Vega, M. (1999). "Patterns of internationalisation of corporate technology: location vs. home country advantages". *Research Policy*, 28. 145-155.

23. UNCTAD (2005) *Transnational Corporations and the Internationalization of R&D*. World Development Report 2005. UNCTAD, United Nations, Geneve.

24. Womack, J.P., D.T. Jones, D. Roos, 1991. The machine that changed the world: The story of Leau production. New York: Harper Collius.

Annex 1

Number of Patents, Share of Patents per Technical Field and Revealed Technological Advantage of Baker & Hughes (BH), Schlumberger (SLB), Halliburton (HB) and FMC (FMC). 1978-2008.

IPC CODE	IPC classification	Number of Patents				Share of Each Technical Field				Revealed Technological Advantage			
		BH	FMC	HB	SLB	BH	FMC	HB	SLB	BH	FMC	HB	SLB
A	Human Necessities	4	133	3	9	0.8	22.9	0.3	0.9	0.1	1.6	0.0	0.1
B0	Separating and mixing	31	24	15	46	6.3	4.1	1.7	4.8	2.1	1.3	0.5	1.6
C09K	Materials for Miscellaneous Applications	21	3	69	55	4.3	0.5	7.7	5.8	13.6	1.6	24.3	18.3
D	Textiles; Paper	1	16	-	9	0.2	2.8	-	0.9	0.1	1.5	0.0	0.5
E21B	Earth or Roch Drilling	166	52	524	216	33.7	9.0	58.2	22.6	91.7	24.3	158.2	61.5
F	Mechanical Engineering	19	55	19	34	3.9	9.5	2.1	3.6	0.5	1.1	0.2	0.4
G01	Measuring and Testing	126	21	121	234	25.6	3.6	13.4	24.5	4.9	0.7	2.6	4.7
G06	Computing, Calculating and Counting	14	1	29	108	2.8	0.2	3.2	11.3	0.6	0.0	0.7	2.4
H	Electricity	17	16	20	113	3.5	2.8	2.2	11.8	0.2	0.2	0.1	0.7
Other B	Other performing operations	13	94	10	20	2.6	16.2	1.1	2.1	0.2	1.1	0.1	0.1
Other C	Other Chemistry and Metalurgy	44	21	8	8	8.9	3.6	0.9	0.8	1.6	0.7	0.2	0.2
Other C0	Other Organic Chemistry	32	126	63	44	6.5	21.7	7.0	4.6	0.5	1.8	0.6	0.4
Other E	Other Fixed Constructions	2	12	7	1	0.4	2.1	0.8	0.1	0.1	0.7	0.3	0.0
Other G	Other Physics	2	7	12	57	0.4	1.2	1.3	6.0	0.0	0.1	0.2	0.7
	Total	492	581	900	954	100.0	100.0	100.0	100.0	1.0	1.0	1.0	1.0
	Herfindahl-Hirchsman Index (HHI)	-	-	-	-	0.202	0.149	0.371	0.152	-	-	-	-

Source: Own elaboration from EPO Bulletin.