GEOGRAPHICAL PROXIMITY AND INNOVATIVE ACTIONS OF FIRMS IN THE OIL AND GAS INDUSTRIAL AGGLOMERATION OF THE CAMPOS BASIN

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This work analyzes the results of an empirical research involving 10 firms pertaining to the industrial agglomeration of oil and gas in the Campos Basin production region in Rio de Janeiro (RJ) state. Companies involved in this study operate in areas of intense technological dynamism and supply products and services of high technological complexity to oil and gas field operators in that region. Two groups of firms were given special attention: well equipment suppliers (wet x-mas trees) and well service suppliers (well technology). For this, a hybrid model was prepared to analyze agglomerations using aspects of clusters approach and (sectoral and technological) innovation systems approach. Focusing on the knowledge system and technological approaches of firms, this work aims to understand how they are implemented and what is the origin of the technological changes applied in the Campos Basin in recent years. Its main objective is to determine whether the geographical agglomeration by itself favors innovation of the firms located there. The results show evidence of the existence of groups of firms where geographical proximity has a positive influence on innovative activities.

Palavras-chaves: Oil and Gas; Clusters; Innovation Systems; Knowledge System; Technological Changes.
1. Introduction

In recent decades, the search for oil resulted in great technological advances in exploration, development and production. Situations like exploration of oil and natural gas in deep waters, once unimaginable, are now part of the reality for firms in this industry. All of these advances were possible because operators and suppliers of offshore equipment and services have applied substantial efforts in research and development (R&D) to make extraction of oil and gas in deep waters viable and reduce the operating costs of E&P (Exploration and Production) activities.

One can highlight a few basic questions that arise from the E&P stage and are present in the important technological challenges of the industry. They are: which equipment to use in a determined oilfield/oil well? Which production systems and structures would be necessary? Is there a technical/technological base for executing such an E&P project? If there is a technical/technological base for executing such a project, is it economically feasible? If there is no technical/technological base for executing the project, is it possible to develop systems that make it feasible?

To answer these questions, there is the need to apply large amounts of resources in R&D, development of new products, processes and concepts to overcome technical/technological barriers imposed by new discoveries. Thus, E&P of oil and gas has seen various technological changes and dynamism, and is the focus of interest in this research. Such a segment is, consequently, strategic for advances in offshore E&P in increasingly hostile environments.

The complexity and multidisciplinary base required for resolving problems and for developing new production structures and systems have led companies to organize themselves as agglomerations (being geographically close) for executing such tasks. This agglomerated structure creates a large supply network in which Petrobras plays the role of the ‘anchor company’ in the industrial agglomeration of the Campos Basin (BC). Since the industry in question can be classified as intensive in natural resources (oil and gas) and due to logistical issues, this concentration of firms is mostly organized close to the oil beds forming what is known as ‘oil province’.

The oil province of the Campos Basin (BC) consists of a geographical agglomeration of around 1,500 firms that operate in the offshore oil and gas exploration and production (E&P) segment. Of these, about 400 firms operate directly in offshore activities. Other firms provide support to the bigger suppliers and to operators of the oil and gas fields located in BC.

However, the firms operating as suppliers of highly complex technological goods and services in areas of high technological dynamism, have strong external linkages to the agglomeration, strong systemic features and globalization trends. Moreover, they use equipment that often brings elements in the frontiers of technology, thereby stressing the importance of knowledge, technological changes, innovations and the dynamism of its players.

These characteristics make it beneficial for firms to form relationships and partnerships among themselves because of the need to absorb knowledge and technology from other organizations and the fact that the oil provinces follow a natural cycle: birth, growth, maturity...
and decline. With this evolutionary structure, a success story among the firms in a determined oil province may represent continuation of this partnership in other provinces around the world, thus opening new markets and opportunities.

Based on the above-mentioned characteristics, this work aims to determine the process of formation and characterization of the agglomeration and, focusing on the knowledge system and technological approaches of firms, to understand how they are implemented and what is the origin of the technological changes applied in the Campos Basin in recent years. Its main objective is to determine whether the geographical agglomeration by itself favors innovation of the firms located there.

2. Data Collection Methodology

In this study, the research method adopted was case study because this type of approach is useful to investigate contemporary phenomena within a real life context, especially when the boundaries between the phenomenon and the context are not clearly evident (YIN, 2003).

Under this method, ten case studies were conducted in firms operating in areas of intense technological dynamism located in the agglomeration.

The strategy of conducting multiple case studies has involved two groups of suppliers in the agglomeration being studied. Both groups of firms are located in the same geographical area (oil and gas production region of the Campos Basin) and pertain to the same industry: the Brazilian oil and gas industry. Firms included in the field study operate in the development stage of oil and gas fields. The first group is composed by firms that provide well services (installation, maintenance and repair of wellhead systems and well structures, besides other well technology solutions). The second group is composed by firms that provide wellhead equipment, specifically wet x-mas trees. Apart from these groups, Petrobras was also the object of field research in face of its particular importance within this agglomeration.

Data was collected from primary as well as secondary data sources. The main data collection technique employed was that of personal interviewing. Interviews were made with key informants, selected among those in more contact with the technology employed in the firms. Some interviews were held with directors, base managers, technology managers or experienced engineers. Other valuable information to this study was collected in informal contacts and conversations with other workers of the firms and through direct observation. Secondary data was acquired through researching the companies’ annual publications, publications of support institutions (associations, organizations), newspapers, specialized magazines, internet, etc.

The firms analyzed in this study were chosen from ONIP’s suppliers database (Organização Nacional da Indústria de Petróleo – National Organization of the Petroleum Industry), both national and international, with a common characteristic: they should be providers of goods and services with significant technological complexity and in areas of relevant technological dynamism. This choice was based on characteristics of this agglomeration and on information gathered from IBP (Instituto Brasileiro de Petróleo – Brazilian Oil Institute), Rede-Petro (network of firms from the oil and gas agglomeration studied), Petrobras and ONIP.
The data collection unit consists in technological changes implemented by the firms in the industrial agglomeration. This approach was adopted for the sake of practicality during this stage. During the interviews, the focus was directed at specific technological events (technological changes implemented) rather than at the firms as a whole, according to the methodology used by Athreye (2001) and Baldwin & Hanel (2003). These events were identified by the interviewees (key informants) themselves, and therefore represent key technological changes implemented in recent years by that company in the agglomeration. As much as possible, the relevance of these events was checked with other managers of these firms, with their competitors and with Petrobras, in subsequent interviews. Such a strategy helped attenuate some potential problems identified before the empirical work, namely the small number of firms in each group and the risk of loss of focus during the interviews. Thus, by increasing the number of analyzed items (by means of events) and directing the interviews toward a single event, the precision of the answers was improved.

The efficacy of the strategy adopted is more evident through the verification that interviews were carried out in 5 firms supplying well services and 4 well equipment suppliers, besides Petrobras, thus totaling 10 firms. Nonetheless, by focusing on technological changes implemented by the firms, a total of 25 valid events were determined, as each company has identified between 1 and 4 technological events. In the 25 events studied, 75 knowledge linkages were identified so that technological changes could be implemented in the agglomeration (varying between 1 and 5 linkages in each event).

3. Theoretical Framework

The clusters approach is generally used in a context that presents a few specific characteristics: structure of the sector focused on manufacturing, industrial aspects and connections based on the flow of goods and services. Such characteristics are basically found in production/transformation agglomerations of manufactured products. Some examples are these sectors: footwear, ceramic coating, bricks, furniture, wine, etc (Schmitz and Nadvi, 1999; Bell and Albu, 1999; Giuliani, 2004). That is why it can be said that while analyzing clusters, the economic sector in which they are present is relevant, i.e., it must compulsorily be considered in the analysis. In this case, if the sector is to be taken into account, differences among the sectors can represent an important characteristic to be highlighted in analyses and, especially, in comparisons among industrial clusters (Pavitt, 1984). However, studies that use the clusters approach focus on the structure of connections but with little emphasis on the evolution of knowledge linkages, technological changes and innovation (Giuliani, 2004; Malmberg, 2003; Malmberg and Maskell, 2002). In this situation, in industrial agglomerations of technologically dynamic sectors, the clusters approach may present a few limitations.

Based on this argument, the global element (without geographical boundaries defined) and the systemic element of the innovation systems approach are added to the model. The term ‘systemic’ introduces the diversity of players and complexity of the relations and connections as two of the main characteristics. ‘Diversity of players’ in the sense of carefully analyzing not only the firms but also the role of diverse organizations (support institutions) that contribute to the development of the agglomeration’s activities, such as: universities, research institutes, regulatory bodies, public organizations, financing organizations etc. ‘Complexity of
relations and connections’ in the sense of emphasizing intra-agglomeration relations and connections (among the firms or between firms and support organizations within the agglomeration) and extra-agglomeration relations and connections (between firms or organizations located within the agglomeration and firms or organizations situated outside the agglomeration – cross-boundaries), without favoring the former, which is a focus found in many studies that use clusters approach (BATISTA and SWANN, 1998; BEAUDRY and BRESCHI, 2003; MALMBERG, 2003).

Thus, due to the limited approaches presented in the literature as isolated cases, a Hybrid Model was developed as an analytical structure that satisfies studies on technologically dynamic industrial agglomerations. It uses elements of the clusters approach (GIULIANI, 2004) and sectoral and technological innovation systems (FREEMAN, 1995; MALERBA, 2004; CARLSSON, 1995), due to the need for collecting complex dimensions like territoriality, learning, technological capabilities, technological changes and innovations.

From the proposed hybrid model, two key dimensions were determined based on the approaches selected for analyzing the agglomeration. They are: knowledge linkages (from studies that use clusters approach) and the technological approach of the firms (from studies that use both sectoral and technological innovation systems approach) (SILVESTRE, 2006).

Knowledge linkages, which jointly form the knowledge system, can allow the firms to develop relationship networks and a series of stable relations based on trust that facilitate the access to new markets, both national and international (BELL and ALBU, 1999). This strategy can be critical in sectors like E&P of oil and gas where the tendency of globalization seems to be essential for the long-term sustainability of firms. This is because oil and gas production provinces born, grow, mature and decline, undergoing a natural cycle, until a new province appears somewhere else in the globe.

Therefore, well-established and stabilized knowledge linkages, both internal and external, can contribute to the firms’ learning process, allowing them to acquire technological capabilities to face the challenges imposed by the market and to carry out technological changes and innovations, which are nowadays some of the major resources for the long-term sustainability of firms (FIGUEIREDO, 2003; BELL and ALBU, 1999).

For the purpose of this work, the term 'technological capabilities' refers to the sense used by Figueiredo (2003): as the resources necessary for generating and managing technological changes like abilities, knowledge and experience and organizational systems. According to the author, the different types of technological capabilities were first classified by Lall (1992) and successfully used by Bell and Pavitt (1995). This classification makes a distinction between “routine” technological capabilities, known as the abilities needed to use technology, knowledge and organizational mechanisms, and “innovative” technological capabilities that consist of creating, modifying or improving products and processes.

4. Results

The field work of the ten firms, as already mentioned, generated 25 valid events (technological changes), according to table 1.
The integration of productive chain with an approach to sustainable manufacturing.

Table 1: Valid events per company

<table>
<thead>
<tr>
<th>Groups</th>
<th>Firms</th>
<th>Events</th>
<th>Event Code</th>
<th>Total Events / Subgroup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suppliers of Equipment (ANM)</td>
<td>Cooper Cameron</td>
<td>2</td>
<td>1 and 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>VetcoGray</td>
<td>3</td>
<td>3, 4 and 5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aker Kvaener</td>
<td>1</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FMC Technologies</td>
<td>3</td>
<td>7, 8 and 9</td>
<td></td>
</tr>
<tr>
<td>Suppliers of Well Technology</td>
<td>Baker Hughes</td>
<td>2</td>
<td>10 and 11</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>BJ Services</td>
<td>2</td>
<td>12 and 13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Schlumberger</td>
<td>2</td>
<td>14 and 15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Weatherford</td>
<td>3</td>
<td>16, 17 and 18</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Halliburton</td>
<td>3</td>
<td>19, 20 and 21</td>
<td></td>
</tr>
<tr>
<td>Main Operator</td>
<td>Petrobras</td>
<td>4</td>
<td>22, 23, 24 and 25</td>
<td>4</td>
</tr>
</tbody>
</table>

Some examples of the events considered can be highlighted for illustration, such as HCMF (Horizontal Coated Multi-fractured), equipment that brought huge benefits in stimulation of oil wells and better utilization of oil found there (optimizing well production), development of Multiplex Control System (MCS), which allow electronic control of the valves located at depths of 3,000 meters (considering specific tidal conditions, characteristics of water, temperature and pressure the equipment is submitted to) and the Acoustic Control System (ACS), eliminating the use of umbilical (cables that connect to the submersed equipment), still under testing.

As can be seen in Figure 1, out of the 25 technological events analyzed in the empirical study, 11 – 44% (plotted in the hachured area) show evidence that technological proficiency (which leads to innovation) is positively influenced by the fact that the firms are agglomerated in the same geographical space, i.e., are physically close to one another. On the other extreme, 56% of the events do not present any evidence that this influence takes place, whether because the structures have no linkages whatsoever with players located inside the agglomeration or because their technological proficiency is restricted.

In relation to the horizontal axis, it can be noticed that out of the 25 events, 4 – 16% – display an approach of being mere users of that given technology (column 1 in Figure 1). Firms in this column have no technological proficiency in the technology used. In these events (11, 13, 14 and 25), firms either are unable to change the technology or have no interest in doing so.

In the first case, firms do not have means to ‘control’ technology, in face of their capacity to absorb technological capabilities. In the second case, the firms prefer to hire a third party to provide this technology and are not concerned about absorbing this technological knowledge because it is not the focus of their interest (there is no interest in investing in the absorption of innovative technological capabilities in the province). Thus, technology is developed outside the agglomeration where the company maintains its R&D centers, while the base of the company located in the province is an agent for the execution of tasks (a mere implementer of technological changes).
Out of the 25 events analyzed in the empirical study, 9 – 36% – display an approach of being able to perform only minor adaptations in that given technology (column 2 in Figure 1). Firms in this column have limited proficiency over the technology related to a given event. In these events (2, 10, 12, 15, 18, 19, 20, 21 and 24), firms are able to change the technology only superficially (smaller adaptations) or have little interest in doing so.

From the total number of events analyzed in the empirical study, 7 – 28% – display an approach of being able to perform design adaptations in that given technology (column 3 in Figure 1). Firms in this column have significant proficiency over the technology related to a given event. In these events (1, 3, 6, 8, 9, 16 and 17), firms are able to change the technology extensively (design adaptations) and have significant interest in it. Firms have considerable technological proficiency and may be investing even more to increase it (see the horizontal axis in Figure 1).

From the total number of events analyzed in the empirical study, 5 – 20% – show an approach of being able to innovate in that given technology (column 4 in Figure 1). Firms in this column have thorough proficiency over the technology related to a given event. In these events (4, 5, 7, 22 and 23), firms are able to change the technology radically (innovations) and are fully interested in doing so. They have implemented technological changes based on innovations developed inside the company.

In relation to the vertical axis, which establishes the characteristics of the structure of knowledge linkages, of the 25 events, 14 (56% of the events) show a structure of linkages connected internally and externally (open knowledge system) – row A. In these events (1, 3, 4, 5, 6, 7, 8, 9, 12, 15, 17, 18, 22 and 23), one can observe the relationship of firms with organizations located both inside and outside the industrial agglomeration.

Similarly, 2 out of the 25 events (8%) show a structure of knowledge linkages internally connected and externally not connected (closed knowledge system) – row B. In these events
(24 and 25), one can observe a relationship of firms with organizations located within the agglomeration, but without connections with organizations located outside the industrial agglomeration.

Of the 25 technological events studied, 9 (36%) show a structure of knowledge linkages internally not connected and externally connected (open knowledge system). In these events (2, 10, 11, 13, 14, 16, 19, 20 and 21), one can observe a relationship of firms with organizations located outside the agglomeration, but without connections with organizations located within the industrial agglomeration.

Analysis of the intensities of the linkages has shown the same tendency displayed by the knowledge linkages structures. Well service suppliers have presented a tendency to establish strong and moderate knowledge linkages in the same proportion as weak and very weak linkages. However, extra-agglomeration linkages have significant predominance over intra-agglomeration linkages. Well equipment supplier showed a larger number of strong and moderate linkages (which indicates a more active approach in relation to absorption of technology). Half of them were established with players located within the agglomeration, which shows the importance of geographical concentration for innovative activities (technological changes) of the firms in this group (Table 2).

<table>
<thead>
<tr>
<th>DEGREE OF INTENSITY</th>
<th>STRONG</th>
<th>MODERATE</th>
<th>WEAK</th>
<th>VERY WEAK</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>WELL EQUIPMENT</td>
<td>25</td>
<td>0</td>
<td>5</td>
<td>11</td>
<td>41</td>
</tr>
<tr>
<td>WELL TECHNOLOGY</td>
<td>8</td>
<td>7</td>
<td>19</td>
<td>0</td>
<td>34</td>
</tr>
<tr>
<td>TOTAL</td>
<td>33</td>
<td>7</td>
<td>24</td>
<td>11</td>
<td>75</td>
</tr>
</tbody>
</table>

Table 2: Intensity of Knowledge Linkages

<table>
<thead>
<tr>
<th></th>
<th>Routine Technological Capabilities</th>
<th>Innovative Technological Capabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internally Connected</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>Internally Not Connected</td>
<td>8</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 3: Intra-agglomeration Linkages and Technological Capabilities

It can be noticed that for a few firms, intra-agglomeration knowledge linkages favor a more innovative approach and the use of innovative technological capabilities by firms (Table 3).

Regarding the hachured area (Figure 1), 11 events are plotted there. Of these events that show a structure of knowledge linkages connected internally and the use of innovative technological capabilities, 8 are related to suppliers of well equipment, 2 relating to Petrobras and only 1 related to the suppliers of well services.

Therefore, it can be observed that most events of well equipment suppliers are located in the area where geographical proximity seems to have a large influence on the behavior of firms (hachured area). In this area, there is the identification of intra-agglomeration knowledge linkages and technological approaches that demonstrate a deliberate effort to absorb the technologies used and the use of innovative technological capabilities, which show a certain
degree of technological proficiency. These firms are capable of making design adaptations and innovation in relation to the technology studied, showing evidence that geographical proximity can be playing the role of facilitator of innovative activities of the firms located there.

5. Final Remarks

In the empirical study, one can notice that the connections of firms located within the agglomeration with organizations outside the agglomeration (extra-agglomeration knowledge linkages) are quite numerous (92% of all the events). This situation is partly explained by the fact that it is a group of firms with many global players, i.e., multinationals with strong extra-agglomeration knowledge linkages (open structures and directed to outside the agglomeration).

Despite the presence of other operators in the province, Petrobras still plays the central role in the agglomeration, both in governance and in the percentage of orders made in the Campos Basin. This configuration gives the agglomeration a verticalized structure composed of several levels of suppliers and degrees of responsibilities.

Firms that display intra-agglomeration knowledge linkages of strong intensities and are capable of making changes in the design and innovations in technology represented by technological events, show indications that the agglomeration may be contributing positively to technological proficiency and, consequently, to innovation.

On the other hand, firms that have few intra-agglomeration knowledge linkages of strong intensities and are mere users of that technology, represented by technological events, show indications that the agglomeration may not be contributing so effectively to technological proficiency and, consequently, to innovation.

Yet, of the total of 9 events studied among the well equipment suppliers, 8 present intra-agglomeration knowledge linkages (89%). This situation shows that intra-agglomeration knowledge linkages (generated within the agglomeration itself) have significant importance for this group of firms and that these firms developed some innovative technological capabilities (represented by the second key dimension) which give them the technological proficiency that can consequently be used to alter the technology (capable of making design adaptations and innovation).

Of the total of 12 events studied among the well services companies, only 4 present intra-agglomeration knowledge linkages (33%). This situation indicates that intra-agglomeration knowledge linkages (generated within the agglomeration) have little importance for this group and that these firms developed only routine technological capabilities (represented by the second key dimension) which give them a small proficiency in the technologies, not allowing them to alter the technology significantly (being mere users of technology or capable of making minor adaptations only).

These results suggest that the suppliers of well equipment display evidences of being benefited (in terms of innovation) by being geographically clustered in the industrial agglomeration of the BC production region. This can be evidenced by their greater knowledge of the distinctive productive and operational features of the Campos Basin and thus being
encouraged by Petrobras to develop innovative technological capabilities within the agglomeration. On the other hand, suppliers of well services do not show evidence of being benefited (in terms of innovation) by being clustered in the industrial agglomeration. Petrobras' approach, more active in relation to the technological changes in well equipment and less active in relation to the technological changes in well services, strengthens this evidence.

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