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Chapter 1

Proposing a Patent Information Approach for Identifying Technological Trends in the Brazilian Upstream Oil and Gas Industry

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.75377

Abstract

In recent years, Brazil has emerged as a leading offshore producer with extensive proven reserves yet to be explored. As a matter of fact, the discovery of huge oil deposits in the pre-salt layer of the country's Southeastern coast is motivating oil and gas exploration in great depths in Brazil, thereby also generating increasing demand for drilling capabilities. This study addresses the technological implications of this discovery by examining patent information. Here, we provide empirical evidence indicating an increased interest for patenting technologies designed to enhance not only ultra-deep drilling capabilities and build and maintain oil wells, but also technologies to increase oil production from formations.

Keywords: patent information, patent analytics, oil and gas, technology, drilling, technology trend

1. Introduction

Despite the strong increase in the use of renewable fuels and the substantial reduction in oil prices in recent years, crude oil is still considered an extremely important commodity [1, 2]. On the one hand, oil comprises the largest share in the world energy mix for several decades [3]. On the other hand, our society is heavily dependent on a well-established and complex infrastructure for exploitation and the use of oil to fulfill energy needs in industrial, commercial, and domestic scale [2].

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As consequence of the central role played by oil in our society, which was consolidated primarily from the second half of the twentieth century onward, the need to identify new reserves of this non-renewable fuel in order to ensure a reliable supply of this resource became a critical necessity worldwide [4]. As such, the combination of an increasing demand for oil and the growing technical challenges associated with the remaining oil reserves found in remote locations has motivated robust technological investments by oil firms that are constantly investing huge sums to find and exploit new reserves [5].

In recent years, Brazil has emerged as a relevant offshore oil producer with extensive proven reserves yet to be explored [6]. More specifically, in 2007, the Brazilian Federal Government announced the discovery of a huge oil and natural field in the pre-salt layer of the country's Southeastern coast. This discovery was accomplished by Petroleo Brasileiro S.A. (Petrobras) and was considered to be one of the world's largest in recent years [7]. However, despite the evident economic benefits associated with this huge oil discovery, substantial resources will need to be put in place to address the operational challenges coming from the ultra-deep water environment of the largest subsea project in the world [8].

Given the promising prospects generated by the pre-salt discovery, firms operating in the oil and gas industry rapidly perceived that the operational characteristics of the pre-salt reserve would generate a huge demand for technology-intensive services and equipment. As such, as pointed out by Cavalheiro et al. [9], there was a boom in patent filings in Brazil in response to the market opportunities for new upstream technologies to enable the development of the pre-salt fields. Increasingly, market opportunities associated with technologies determine the propensity of firms to file patent applications [10]. However, despite the awareness of the increased interest of firms in protecting innovative upstream oil and gas technologies in Brazil, extant literature remains silent on the most critical technical areas protected by firms.

Consequently, this study provides a contribution for understanding the most critical technological areas associated with the pre-salt exploitation by examining patterns of patent filings in Brazil regarding upstream oil and gas technologies. As such, this paper is aimed at improving understanding of the specific technological trends regarding the exploitation of the pre-salt reserves.

This paper is structured as follows Section 2 provides a literature review on patent information and examines the context of the oil and gas industry in Brazil. Then, Section 3 describes our research method. Section 4 examines the patterns of patent applications in Brazil concerning upstream oil and gas technologies. Finally, in Section 5, our conclusions are put forward.

2. Literature review

2.1. Patent information

A firm's innovation strategy is the central to fostering innovation competence, which in turn leads to the development of new products and technologies [11]. However, innovation is characterized by a high level of uncertainty, given the difficulties in forecasting the performance

and costs of a new technology, as well as the reaction of users to it [12]. As such, the logic behind the patent system assumes that firms invest in risky R&D activities in order to generate innovative technologies or products. As a consequence of the huge investments associated with the development of new technologies or products, it is certainly fair to assume that this investment should somehow be protected [13–15]. In this way, patents can be perceived as legal instruments providing exclusive rights to enable innovative firms to prosper in a challenging, risky, and dynamic business environment [10, 16]. Hence, these firms are able to protect their investment in new technologies by filing a patent in a Patent Office [17–19].

Fundamentally, a patent can be regarded as packaged knowledge that delimits and draws boundaries around a set of technical characteristics [20, 21] and concedes an effective instrument to prevent imitation by competitors [22]. Additionally, the value of a patent is dependent upon a number of factors such as the potential for licensing to other businesses, the quality of the patent [23], the importance of the market covered by the patent [15, 24], and the effectiveness and stringency of patent enforcement [25]. Moreover, as stated by Davies [26], technologies are subject to a life cycle that suggests a decreasing rate of innovation and economic value as technologies gradually become obsolete.

As a direct consequence of the growing number of protected technologies, various authors stress that the patent system is characterized by an increasing level of complexity [23, 27, 28]. Accordingly, it is common to have single products, like smartphones and tablets, incorporating hundreds or even thousands of patents, thereby creating legal disputes involving a large set of patents, rather than just one. Hence, the costs involved in negotiating and licensing the relevant patents is continuously increasing [29].

The international patent system gained significant importance toward the end of last century. Due to many significant technological developments associated with the Second World War, a plurality of innovative technologies was developed in fields such as computer science, materials, telecommunications, biotechnology, and nuclear energy [30]. As stated by Galini [29], the large-scale adoption of these technologies has transformed society into a knowledge-based society that generates an increasing amount of inventions needing to be protected against unauthorized copy. Moreover, given the fact that innovative firms are becoming increasingly dependent on their patent portfolios to remain competitive, patent information has become an evolving and important research area.

Alongside with the rapid growth of available patent data, modern information technologies have revolutionized patent information practice in terms of both speed of access and information comprehensiveness, thereby motivating the development of sophisticated patent analysis tools. As stated by Abbas et al. [31], currently, there are several IT-based patent analytic tools capable of performing tasks such as strategic technology planning, detecting patent infringement, determining patent quality, and identifying technological hotspots. Additionally, Ernst [20] pointed out that patent information can also be used for competition monitoring, R&D portfolio management, and identification of potential sources of technological knowledge. In order to analyze patent data from dynamic, heterogeneous, and scattered information sources, researchers in this realm count with increasingly sophisticated solutions, such as patent landscape, text mining, and digital mind mapping tools to address large data volumes [32, 33].

Given the tremendous advances in patent analytic tools in recent years, patent information can be used to support a wide range of analyses in different industries. For example, Huang [34] examined the evolution of the patent portfolio of mainstream firms of the cloud computing industry. Moreover, Dubaric et al. [35] employed patent application figures as performance indicators representing evolution and level of maturity of wind power technology. Huang and Cheng [11], in turn, proposed a patenting behavior framework to identify the primary factors determining the propensity to file a patent application. Beyond examining patent applications filed by firms, there are also relevant studies addressing how universities are protecting their inventions through patents. Accordingly, Drivas et al. [16] assessed patterns associated with the licensing process of university patents, while Siegel et al. [36] developed a framework to describe the transfer of scientific knowledge from academicians to practitioners. More recently, Arunagiri and Mathew [37] demonstrated the possibility of identifying relevant business and technical patterns by assessing patent classification of implant technology patents.

As a result of improved capabilities for analyzing patent information, policy makers started to rely on the number of patent applications as a critical performance indicator for patent office attractiveness [38], global level of economic activities, and the effort level on R&D activities [18, 24]. However, Boldrin and Levine [39] stress that there is no empirical evidence indicating that patents serve to increase innovation or productivity but rather to demonstrate power in a highly competitive environment. Despite the clear benefits associated with the current international patent system, there is also criticism regarding its current configuration. Although, scientific and technical communities in different countries are currently more connected than they used to be [40], nations that lack the capacity to innovate globally tend to consider intellectual property protection as nothing more than tax.

In addition, various scholars point out structural factors hampering firms in developing countries in generating revenue from patents, which include the limited quantity and intensity of links between firms and universities [40, 41], low rate of industrial technological accumulation in industry [13], public policy makers with limited understanding of intellectual property [42], as well as a partial lack of understanding about the consequences of academic engagement for scientific and economic objectives [43].

2.2. Brazilian context: pre-salt discovery

Brazil has already accumulated a long experience with the discovery and production of oil. As a matter of fact, the first oil discovery in Brazil was accomplished in 1939 in the State of Bahia, while the first offshore extraction project started in 1968 [44]. However, despite the history of oil production activities in the countries, for several decades, Brazil imported large amounts of oil to complement its internal production to supply the internal demand [8]. However, in 2007, the Brazilian Federal Government announced the discovery of huge oil and natural gas resources in the pre-salt layer of the country's Southeastern coast. This discovery was accomplished by Petróleo Brasileiro S.A. (Petrobras) and created the possibility of turning the country into one of the largest oil producers in the world [7].

In order to explore this huge oil field, substantial effort will be required to develop and integrate innovative technologies to address the challenges coming from operating in the ultra-deep water environment of the largest subsea project in the world [8]. However, until the present, total oil production in Brazil has been increasing at a small pace in recent years, as illustrated in **Figure 1**.

In practice, exploring the pre-salt reservoirs is a massive technical and organizational challenge that generates significant need of investments in new technologies. The distance between the surface of the sea and the oil reservoirs under salt layer can be as much as 7000 meters [7]. Consequently, exploration and production of hydrocarbons located in ultra-deep offshore waters require a plurality of innovative technologies destined for hostile, hard-to-reach environments characterized by extremely high pressures and temperature [46].

2.3. Patent applications in Brazil

Prior to examining patent applications related to upstream oil and gas technologies, it is also worthwhile to assess the trend regarding patent applications regarding all fields of technologies in recent years in Brazil. In this regard, we have opted to examine the total number of Brazilian patent applications between 2001 and 2013. Clearly, **Figure 2** displays a small and continuous increase in patent applications, which started in 2004.

Although a small and continuous increase in patent applications in Brazil can be observed in recent years, this growth started prior to the pre-salt announcement. However, when it comes to upstream oil and gas technologies, Cavalheiro et al. [9] pointed out that the pre-salt announcement motivated increased interest for protecting upstream oil and gas technologies in Brazil. In this respect, the IPC subclass E21B covers a wide portion of technologies associated with upstream oil and gas exploration, such as earth or rock drilling obtaining oil, gas, water, soluble or meltable materials, or a slurry of minerals from wells. Clearly, the growth of

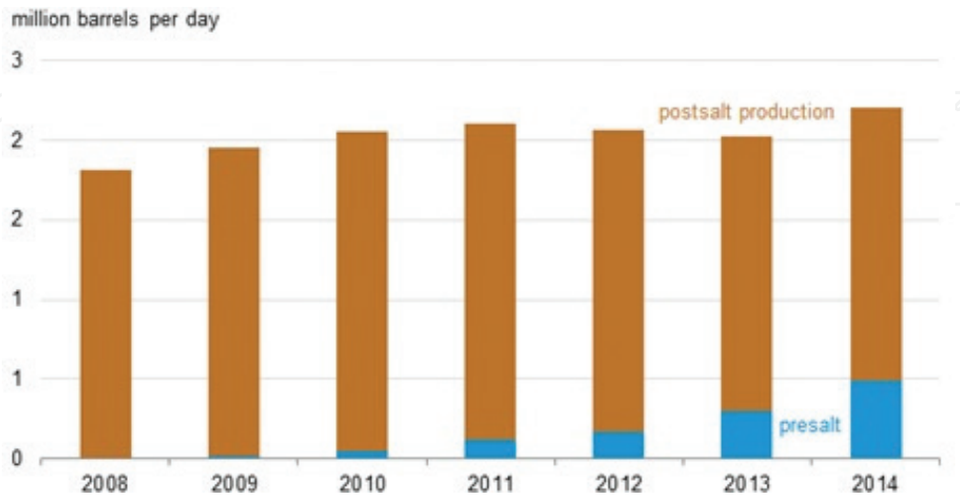


Figure 1. Brazil's total oil production by type: 2008–2014 (source: U.S. Energy Information Administration [45]).

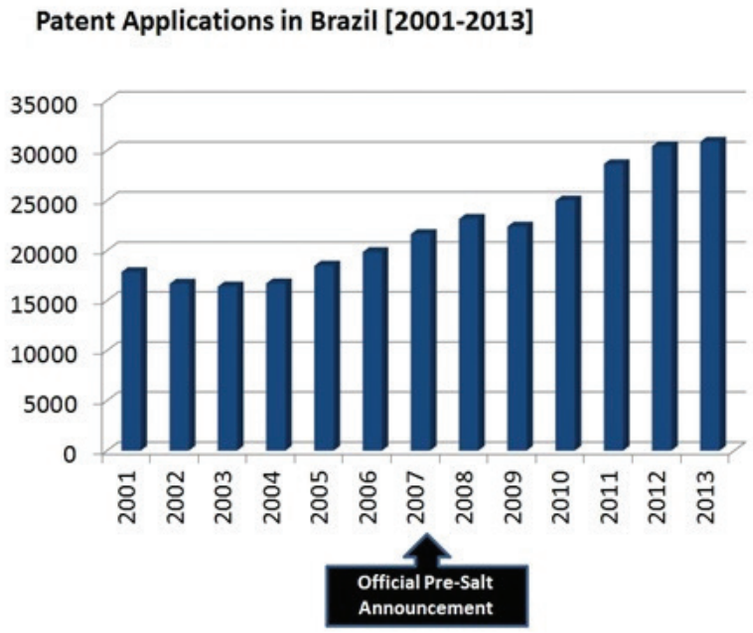


Figure 2. Brazil's total patent applications: 2001–2013 (source: WIPO Statistical Country Profile, Brazil, 2015).

E21B patent applications is much stronger, than the growth in both oil production and total patent applications in Brazil. Accordingly, E21B was selected for being a highly representative IPC subclass for the upstream oil and gas industry. As such, **Figure 3** displays a strong increase in patent applications in Brazil concerning the E21B.

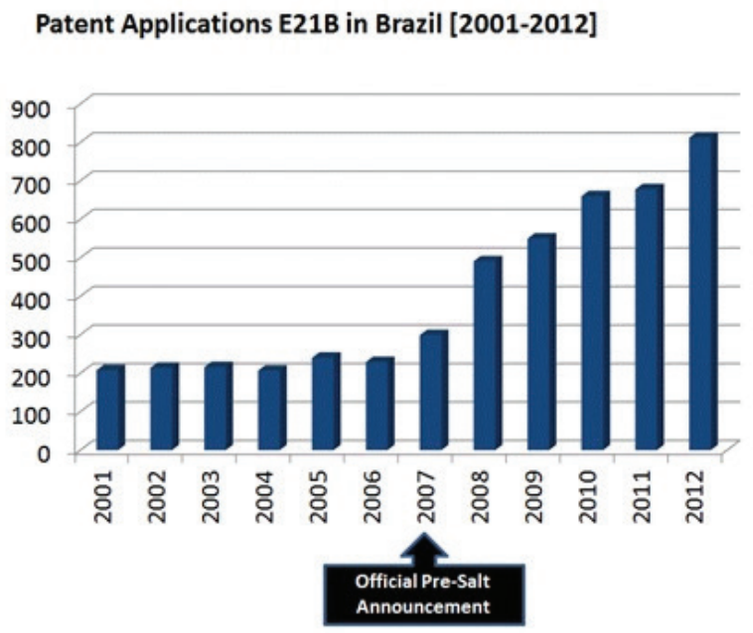


Figure 3. Patent applications related to upstream oil and gas technologies in Brazil: 2001–2012 (source: adapted from [9]).

3. Research method

Fundamentally, we adopt a qualitative and quantitative approach based on a combination of literature review and empirical analysis of patent filings. As a matter of fact, adopting a pure quantitative approach is not feasible, as the extant literature does not offer clear conventions for analyzing patent information related to upstream oil and gas technologies, such as the widely accepted and well-known rules of algebra through which the validity of mathematical deductions is known [47]. A fundamental characteristic of a qualitative approach, in turn, is that researchers may have less a priori knowledge of what the variables of interest will be and how they will be measured [48]. Accordingly, qualitative researchers are sometimes disposed toward causal determination of events but more often tend to perceive events not simply and singly caused (Stake [50]). Consequently, the combination of qualitative and quantitative approaches can be very synergistic [49].

In practice, we collected data representing the patent applications in Brazil for the period between 2001 and 2012. The choice for this period was motivated by the research objective of this study, which is aimed at improving understanding of the major technological trends associated with the upstream oil and gas industry in Brazil. Additionally, given the fact that the Brazilian patent legislation establishes that a patent application must be published 18 months after the filing date in combination with administrative delays to classify patent applications, patent data concerning the years 2013, 2014, and 2015 were not completely available during of the data collection phase of this study.

The figures regarding Brazilian patent applications were retrieved by executing queries within a system named "Sistema Integrado da Propriedade Industrial" (SINPI). SINPI regards an internal information system that processes administrative information for "Instituto Nacional da Propriedade Industrial" (INPI), which is the Brazilian national patent office. The queries concerned patent applications with filling dates between January 1, 2001, and December 31, 2012. These queries specified the patent applications classified with the International Patent Classification (IPC) scheme in the technical area of E21B, as this particular area covers a wide portion of technologies associated with upstream oil and gas exploration, such as earth or rock drilling obtaining oil, gas, water, soluble or meltable materials, or a slurry of minerals from wells.

Accordingly, E21B was selected for being a highly representative IPC subclass for the upstream oil and gas industry. The collection of patent information on patents describing technologies used in the upstream oil and industry, which are classified as E21B, was analyzed based on patent classification listed in the documents. More specifically, we have examined the total number of documents further classified in terms of the groups that belong to the E21B subclass. This decision enabled us to identify the most active technical fields within the E21B subclass.

4. Results

After examining the characteristics of the patent system and the context associated with the pre-salt discovery, we take up the patent applications in Brazil for the period between 2001

and 2012. As stated by Cavalheiro et al. [9], market opportunities for the oil and gas industry in Brazil associated with the pre-salt announcement motivated a substantial increase in patent filings in Brazil concerning upstream oil and gas technologies. As such, we applied the following search strings within INPI's SINPI environment to select all patent applications of interest concerning the period between 2001 and 2012—"Filing date: 01012001-31122012" and "IPC:E21B." In total, 4804 patent applications were retrieved. **Table 1** lists all groups belonging to the E21B subclass and also provides a distinction of subfields within the upstream oil and gas technologies, as proposed by WIPO's IPC diagram.

4.1. Most protected technologies

Beyond the six technical subareas within upstream oil and gas technologies listed in the table, it is also worthwhile to zoom in further into the IPC groups that attracted the largest number of patent applications. In order to better illustrate the dominant technical areas, we have also opted to graphically represent the most active groups. As such, **Figure 4** displays the groups that account for more than one percent of all E21B patent applications.

Since **Figure 3** indicates significant differences in terms of the number of patent application per IPC group, it is worthwhile to examine the technical characteristics of each group. As such, **Table 2** displays the total number of applications for the most active IPC groups. To this end, we selected the subgroups that received more than one percent of total E21B patent applications, which corresponds to IPC groups with more than 48 patent applications, to draw histogram.

According to Ernst [20], the information available in patent data reveals strategic decisions of firms regarding a market for a certain technologies. Accordingly, the IPC groups listed in **Table 2** can be regarded as the most strategic technologies for exploring the pre-salt reserves

Technical subareas within upstream oil and gas technologies	IPC groups	Number of patent applications
Methods for drilling	E21B 1, E21B 3, E21B 4, E21B 6, E21B 7	268
Drilling tools	E21B 10, E21B 11, E21B 12	198
Well equipment or well maintenance	E21B 15, E21B 17, E21B 19, E21B 21, E21B 23, E21B 25, E21B 27, E21B 28, E21B 29, E21B 31, E21B 33, E21B 34, E21B 35, E21B 36, E21B 37, E21B 40, E21B 41	2521
Obtaining fluids from wells	E21B 43	1080
Automatic control of wells	E21B 44	77
Surveying or testing	E21B 45, E21B 47, E21B 49	660
Total number of E21B patent applications		4804

Source: the authors

Table 1. Total number of patent applications concerning upstream oil and gas technologies between 2001 and 2012 in Brazil.

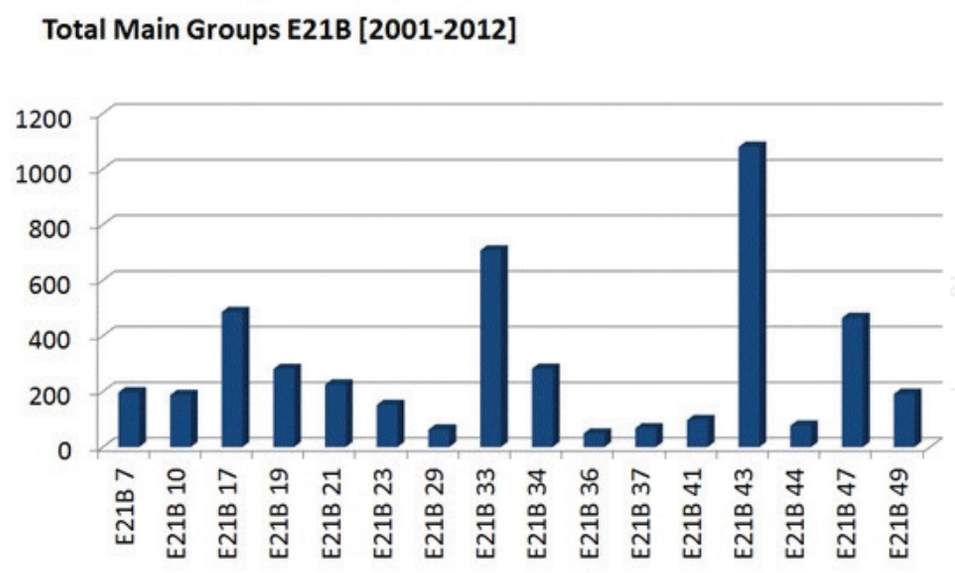


Figure 4. Total number of patent applications per IPC group (source: the authors).

in Brazil. Here it is worthwhile to mention that two IPC groups received special attention from firms operating in the upstream oil and gas industry. In particular, E21B 43 "Methods or apparatus for obtaining oil, gas, water, soluble or meltable materials or a slurry of minerals from wells" accounts for 1080 patent applications, representing approximately 22% of all E21B applications. Similarly, E21B 33 "Sealing or packing boreholes or wells" was responsible for 707 patent applications, or approximately 15% of all E21B applications. As such, these figures can be interpreted as an indication of the strategic importance of these technologies for exploring the offshore ultra-deep reserves of the Brazilian Pre-Salt.

Another IPC group that received substantial attention from firms regards E21B 17 "Drilling rods or pipes; Flexible drill string" and E21B 47 "Survey of boreholes or wells," as both IPC groups obtained approximately 10% of total E21B patent applications. It is possible to deduce that technologies for drilling pipes and surveying boreholes are also key areas for the companies involved in the pre-salt exploration.

4.2. Least protected technologies

Despite the strong increase in E21B patent applications reported by Cavalheiro et al. [9], several IPC groups belonging to E21B did not attract a large number of patent applications at all. As such, we have selected the IPC groups that received less than one percent of the total E21B applications between 2001 and 2012, which corresponds to a number of patent applications lower than 48.

As indicated in **Table 3**, several IPC groups received less than one percent of the patent applications related to upstream oil and gas technologies. Typically, these groups represent technical areas that do not attract the attention of both operating and service companies and, as a result, are not active. More specifically, a more technical interpretation of these results points out a mismatch between the requirements posed by the pre-salt reserves and the solutions

IPC groups	Description	Number of patent applications
E21B 43	Methods or apparatus for obtaining oil, gas, water, soluble or meltable materials, or a slurry of minerals from wells (applicable only to water; obtaining oil-bearing deposits or soluble or meltable materials by mining techniques; pumps)	1080
E21B 33	Sealing or packing boreholes or wells	707
E21B 17	Drilling rods or pipes, flexible drill strings, kellies, drill collars, sucker rods, casings, tubings	486
E21B 47	Survey of boreholes or wells (monitoring pressure or flow of drilling fluid)	465
E21B 34	Valve arrangements for boreholes or wells (in drilling fluid circulation systems, blowout preventers, oil flow-regulating apparatus, valves in general)	282
E21B 19	Handling rods, casings, tubes, or the like outside the borehole, e.g., in the derrick; apparatus for feeding the rods or cables (surface drives)	281
E21B 21	Methods or apparatus for flushing boreholes, e.g., by the use of exhaust air from motor (freeing objects stuck in boreholes by flushing, well-drilling compositions)	225
E21B 7	Special methods or apparatus for drilling (supports for the drilling machine, e.g., derricks or masts)	197
E21B 49	Testing the nature of borehole walls, formation testing, methods or apparatus for obtaining samples of soil or well fluids	191
E21B 10	Drill bits (specially adapted for deflecting the direction of boring, with means for collecting substances)	187
E21B 23	Apparatus for displacing, setting, locking, releasing, or removing tools, packers, or the like in boreholes or wells	152
E21B 41	Equipment or details not covered by groups	97
E21B 44	Automatic control systems specially adapted for drilling operations, i.e., self-operating systems which function to carry out or modify a drilling operation without intervention of a human operator, e.g., computer-controlled drilling systems	77
E21B 37	Methods or apparatus for cleaning boreholes or wells	68
E21B 29	Cutting or destroying pipes, packers, plugs, or wire lines, located in boreholes or wells, e.g., cutting of damaged pipes and of windows (perforators)	63
E21B 36	Heating, cooling, or insulating arrangements for boreholes or wells, e.g., for use in permafrost zones (drilling by the use of heat, secondary recovery methods using heat)	49

Source: the authors

Table 2. Most protected upstream oil and gas technologies in Brazil.

provided by the technologies belonging to the IPC groups listed in **Table 3**. As an illustration of this interpretation, Hu et al. [2] stress that the technologies belonging to E21B 1 "Percussion drilling (drives used in the borehole)" are suitable to explore onshore oil reserves with very small depths, as opposed to the offshore ultra-deep pre-salt conditions.

Consequently, given the particular conditions of the Brazilian oil reserves, only five patent applications were filed in Brazil between 2001 and 2012 related to percussion drilling. Our interpretation is that the less protected technologies within the E21B group result from the fact that these technologies are to some extent inadequate to be deployed in the Brazilian

IPC groups	Description	Number of patent applications
E21B 15	Supports for the drilling machine, e.g., derricks or masts	37
E21B 4	Drives for drilling, used in the borehole	33
E21B 3	Rotary drilling (drives used in the borehole, rotary drilling machines in general)	28
E21B 31	Fishing for or freeing objects in boreholes or wells (provisions on well heads for introducing or removing objects, locating or determining the position of objects in boreholes or wells)	27
E21B 25	Apparatus for obtaining or removing undisturbed cores, e.g., core barrels, core extractors (core bits, using explosives or projectiles in boreholes, side-wall sampling or coring)	25
E21B 27	Containers for collecting or depositing substances in boreholes or wells, e.g., bailers for collecting mud or sand, drill bits with means for collecting substances, e.g., valve drill bits	12
E21B 28	Vibration generating arrangements for boreholes or wells, e.g., for stimulating production (for drilling, for transmitting measuring signals, for geophysical measurements)	8
E21B 12	Accessories for drilling tools	7
E21B 1	Percussion drilling (drives used in the borehole)	5
E21B 6	Drives for drilling with combined rotary and percussive action (drives used in the borehole, portable percussive machines with superimposed rotation)	5
E21B 11	Other drilling tools	4
E21B 45	Measuring the drilling time or rate of penetration	4
E21B 35	Methods or apparatus for preventing or extinguishing fires (cutting or deforming pipes to control fluid flow, controlling flow of fluid to or in wells, firefighting in general)	1
E21B 40	Tubing catchers, automatically arresting the fall of oil-well tubing	1

Source: the authors

Table 3. Less protected upstream oil and gas technologies in Brazil.

conditions or, in some cases, may even be perceived as obsolete in the oil and gas industry, thereby not motivating firms to commit R&D resources to further develop these technologies.

5. Discussion

The effective management of a patent portfolio is an increasingly complex challenge in our current knowledge-based society, especially for firms with a large number of patent applications. As such, using patent information as secondary data, we have provided rich insights regarding the specific technical interest of technology-based firms operating in the Brazilian upstream oil and gas industry [20]. More specifically, we have employed patent application figures as a performance indicator representing technological hotspots [35]. To this end, we have explored a large number of patent documents by carrying out pattern analysis to identify relevant business insights (Madani and Weber [51]).

Our detailed examination of the E21B subclass has shown evidence of substantial differences in terms of the commercial potential of different types of upstream oil and gas technologies in the context of the Brazilian market. In addition, the findings on the robust growth of patent filings regarding upstream oil and gas technologies have provided evidence of a growing interest of firms operating in this particular industry in developing technical solutions to address specific operational challenges associated with the pre-salt exploration [9].

As mentioned above, it is possible to determine that within the scope of the E21B subclass, there are technologies that received greater attention from firms in the oil and gas industry, motivating more patent applications to protect inventions belonging to a small set of technical areas [39]. Clearly, we have identified a small number of highly active technical subareas that represent key technologies. However, the findings also point to several IPC classifications that comprise upstream oil and gas technologies, but did not motivate a growing number of patent applications. This was due to the existence of areas containing technologies not suitable to the Brazilian operational context of the pre-salt but also due to obsolete technologies that are not motivating patent applications anymore [26].

In practice, it was possible to identify technological hotspots within upstream oil and gas technologies [31]. Clearly, the technical subareas attracting the largest number of patent applications concern technologies designed to build and maintain wells, as well as technologies dedicated to increase productivity of existing wells. This can be seen as a strong evidence that operating companies are interested in improving technologies for building wells as maximizing production from oil formations. However, the findings also point out to that there are several technical areas attracting modest industry attention in a pre-salt context, such as percussion drilling, measuring the drilling time, preventing or extinguishing fires downhole in offshore conditions, and automatically arresting the fall of oil-well tubing.

The use of patent application figures helps us to claim that that the particular characteristics of the Brazilian pre-salt reservoirs generated specific perceptions of potential market demand for different technical areas. The concentration of patent applications in certain IPC groups, such as E21B 43 and E21B 33, highlights the value of these patents for business (Madani and Weber [51]). In fact, these patents can be perceived as instruments providing exclusive rights to commercialize critical technologies in an emerging and large-scale market. This way of perceiving decision-making regarding patenting leads us to the importance of highlighting the need to protect technologies that are perceived as strategic and generate expectations of high revenue potential in the coming years.

Thus, our research has revealed that despite the tremendous growth in patent applications concerning upstream oil and gas technologies in Brazil from 2007 onward, only a small set of very specific technical areas encompassed the wide majority of the patent applications. As such, this study contributed to the value of patent application figures as a robust performance indicator for monitoring competitive technology development efforts in the upstream oil and gas industry of a developing country.

6. Conclusion

This study provides further evidence of the value of exploring patent information. By exploring a sample of patent data related to upstream oil and gas technologies protected by different players in Brazil, valuable patterns were revealed. In practice, we have observed that the value of patent information goes beyond its role as a source of technical information by revealing insights of the attractiveness of certain technologies in a country. Evidence was also found that rival firms in the upstream oil and gas industry attempted to increase their competitiveness by reinforcing their patent portfolio with strategic technologies comprising high potential market value. Additionally, we believe that the paper is also valuable for readers without technical knowledge of upstream oil and gas technologies, as our study reveals patterns related to the relationship between market demand for technologies and the strategic use of patents.

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References

[1] Coleman L. Explaining crude oil prices using fundamental measures. Energy Policy. 2012;**40**:318-324

[2] Hu W, Bao J, Hu B. Trend and progress in global oil and gas exploration. Petroleum Exploration and Development. 2013;**40**(4):439-443

[3] Brown SPA, Huntington HG. Evaluating U.S. oil security and import reliance. Energy Policy. 2015;**79**:9-22

[4] Shafiee S, Topal E. When will fossil fuel reserves be diminished? Energy Policy. 2009;**37**(1): 181-189

[5] Hayashi SHD, Ligero EL, Schiozer DJ. Risk mitigation in petroleum field development by modular implantation. Journal of Petroleum Science and Engineering. 2010;**75**(1-2): 105-113

[6] Mendes PAS, Hall J, Matos S, Silvestre B. Reforming Brazil's offshore oil and gas safety regulatory framework: Lessons from Norway, the United Kingdom and the United States. Energy Policy. 2014;**74**:443-453

[7] Haddad E, Giuberti AC. Economic impacts of pre-salt on a regional economy: the case of Espírito Santo. Brazil: Instituto de Pesquisa Economica Aplicada. Perspectivas de desenvolvimento do setor de petroleo e gas no Brasil. Comunicados do IPEA 55, (June 1). Brasília; 2010. http://agencia.ipea.gov.br/images/stories/PDFs/100601_comunicadodoipea_55.pdf [Accessed September 10, 2015]

[8] Oliveira R. Dealing with plenty: Brazil in the era of surplus oil [Master Thesis]. University of Illinois; 2011

[9] Cavalheiro GMC, Joia LA, Gonçalves AC. Strategic patenting in the upstream oil and gas industry: Assessing the impact of the pre-salt discovery on patent applications in Brazil. World Patent Information. 2014;**39**:58-68

[10] Emodi NV, Murthy GP, Emodi CC, Emodi ASA. A literature review on the factors influencing patent propensity. International Journal of Innovation and Technology Management. 2017;**14**(3):1750015

[11] Huang KF, Cheng TC. Determinant's pf firms'patenting or not patenting behaviors. Journal of Engineering Technology Management. 2015;**36**(C):52-77

[12] Pavitt K. Innovation process, in Fagerberg J, Mowery David C, Nelson, Richard R (Orgs.) The Oxford Handbook of Innovation. New York: Oxford University Press; 2005

[13] Bell M, Pavitt K. Technological accumulation and industrial growth: Contrasts between developed and developing countries. Industrial and Corporate Change. 1993;**2**(2):157-211

[14] Joia LA. Measuring intangible corporate assets: Linking business strategy with intellectual capital. Journal of Intellectual Capital. 2000;**1**(1):68-84

[15] Wang MY, Lo HC, Liao YY. Knowledge flow determinants of patent value: Evidence from Taiwan and South Korea biotechnology patents. International Journal of Innovation and Technology Management. 2015;**12**(3)

[16] Drivas K, Economidou C, Karamanis D, Zank A. Academic patents and technology transfer. Journal of Engineering and Technology Management. 2016;**40**:45-63

[17] Bessen J, Meurer MJ. What's wrong with the patent system? Fuzzy boundaries and the patent tax. First Monday. 2007;**12**(6)

[18] Godinho MM, Ferreira V. Analyzing the evidence of an IPR take-off in China and India. Research Policy. 2012;**41**:499-511

[19] Scherer FM. Nordhaus´ theory of optimal patent life: A geometric reinterpretation. American Economic Review. 1972;**62**(3):422-427

[20] Ernst H. Patent information for strategic technology management. World Patent Information. 2003;**25**:233-242

[21] Mouritsen J, Koleva G. Packing and unpacking knowledge: Patents and intellectual capital. Journal of Intellectual Capital. 2005;**6**(3):308-321

[22] Blind K, Cremers K, Mueller E. The influence of strategic patenting on companies' patent portfolios. Research Policy. 2009;**38**:428-436. http://dx.doi.org/doi:10.1016/j.respol.2008.12.003

[23] Picard PM, van Pottelsberghe B. Patent office governance and patent system quality. Center for Research in Economic Analysis, Discussion Paper 2011-06. 2011

[24] Fabry B, Ernst H, Langholz J, Koster M. Patent portfolio analysis as a useful tool for identifying R&D and business opportunities: An empirical application in the nutrition and health industry. World Patent Information. 2006;**28**:215-225

[25] Lang JC. Management of intellectual property rights: Strategic patenting. Journal of Intellectual Capital. 2001;**2**(1):8-26

[26] Davies A. The life cycle of a complex product system. International Journal of Innovation Management. 1997;**1**:1192-1216

[27] Bonino D, Ciaramella A, Corno F. Review of the state-of-the-art in patent information and forthcoming evolutions in intelligent patent informatics. World Patent Information. 2010;**32**:30-38

[28] Van Pottelsberghe B, Mejer M. The London agreement and the cost of patenting in Europe. European Journal of Law and Economics. 2010;**29**(2):211-237

[29] Galini NT. The economics of patents: Lessons from recent U.S. patent reform. Journal of Economic Perspectives. 2002;**16**(2):131-154

[30] Castells M. The Information Age: Economy, Society and Culture. Updated ed. Oxford: Blackwell; 2000

[31] Abbas A, Zhang L, Khan SU. A literature review on the state-of-the-art in patent analysis. World Patent Information. 2014;**37**:3-13

[32] Dirnberger D. The use of mindmapping software for patent search and management. World Patent Information. 2016;**47**:12-20

[33] Pargaonkar YR. Leveraging patent landscape analysis and IP competitive intelligence for competitive advantage. World Patent Information. 2016;**45**:10-20

[34] Huang JY. Patent portfolio analysis of the cloud computing industry. Journal of Engineering and Technology Management. 2016;**39**:45-64

[35] Dubaric E, Giannocaro D, Bengtsson R, Ackermann T. Patent data as indicators of wind power technology development. World Patent Information. 2011;**33**(2):144-149

[36] Siegel DS, Waldman DA, Atwater LE, Link AN. Toward a model of the effective transfer of scientific knowledge from academicians to practitioners: Qualitative evidence from the comercialization of university technologies. Journal of Engineering and Technology Management. 2004;**21**(1-2):115-142

[37] Arunagiri S, Mathew M. Exploring technology evolution using patent classification: A case of cochlear implant technology patents. International Journal of Innovation and Technology Management. 2017;**14**(1)

[38] Galini NT. Patent policy and costly imitation. RAND Journal of Economics. 1992;**23**(1): 52-63

[39] Boldrin M, Levine DK. The case against patents. Journal of Economic Perspectives. 2013;**27**(1): 3-22

[40] Nelson RR. The changing institutional requirements for technological and economic catch up. International Journal of Technological Learning, Innovation and Development. 2007;**1**(1):4-12

[41] Chiarini T, Silva ALG. Intellectual property rights and innovation system: Some lessons from Brazil. International Journal of Innovation and Learning. 2016;**20**(3):265-288

[42] Lall S. Technological capabilities and industrialization. World Development. 1992;**20**(2): 165-186

[43] Perkmann M, Tartari V, McKelvey M, Autio E, Broström A, D'Este P, Fini R, Geuna A, Grimaldi R, Hughes A, Krabel S, Kitson M, Llerena P, Lissoni F, Salter A, Sobrero M. Academic engagement and commercialisation: A review of the literature on university–industry relations. Research Policy. 2013;**42**:423-442

[44] Rodriguez MB, Suslick SB. An overview of Brazilian petroleum exploration lease auctions. Terrae. 2009;**6**(1):6-20

[45] United States Energy Information Administration. Brazil is the 8th-largest total energy consumer and 9th-largest liquid fuels producer in the world; 2015. Available from: http://www.eia.gov/beta/international/analysis_includes/countries_long/Brazil/brazil.pdf [Accessed July 26, 2016]

[46] National Petroleum Council. Oil and gas technology development. Topic Paper #26, National Petroleum Council Global Oil & Gas study. 2007. Available from: http://downloadcenter.connectlive.com/events/npc071807/pdf-downloads/Study_Topic_Papers/26-TTG-OGTechDevelopment.pdf [Accessed: February 17, 2014]

[47] Lee A. A scientific methodology for MIS case studies. MIS Quarterly. 1989;**13**(1):33-50

[48] Benbasat I, Goldstein D, Mead M. The case research strategy in studies of information systems. MIS Quarterly. 1987;**11**(3):369-386

[49] Eisenhardt KM. Building theories from case study research. Academy of Management Review. 1989;**14**(4):532-550

[50] Stake RE. Case studies. In: Denzin NK, Lincoln YS, editors. Handbook of qualitative research. Thousand Oaks, CA: Sage; 1988. pp. 236-247

[51] Madani F, Weber C. The evolution of patent mining: Applying bibliometrics analysis and keyword network analysis, World Patent Information. 2016;**46**:32-48