

Innovation Policy for the Oil Industry in Brazil: an Analysis in the Light of New Technological Trends

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The search for new oil and gas reserves during the cycle of high oil prices between 2005 to 2014 has led the oil industry to new and more challenging geological frontiers such as the so-called unconventional resources and the exploitation in deep and ultra-deep waters. The high oil price has allowed the world oil industry to invest in innovations to face important technological challenges linked to the new geological frontiers.

The collapse of the price of oil in 2014 has created new technological challenges to the oil industry. Companies operating in high cost areas such as the shale oil and gas in the US and the Brazilian presalt zone had no other option than to invest heavily in technological solutions related to cost reduction. More generally, the new market environment of low prices, forced the world oil industry to seek new vectors of cost reduction, both upstream and downstream.

The emergence of competitive technological solutions

Considering the challenges posed by the current context, two main trends related to the adoption of technological solutions in the oil industry deserve to be analyzed:

The first trend concerns the growing adoption of new disruptive technologies, especially those associated with the Industry 4.0 concept of so-called digital transformation in all segments of the oil industry. This trend encompasses several layers of technology such as Internet of Things (IoT), Intelligent and Connected Production (PIC), Big Data, Cloud Computing, all of which are strongly related to Artificial Intelligence systems and different Communication Networks.

The second trend includes the development of technological solutions aimed at overcoming critical bottlenecks of the industry. The main critical bottlenecks are associated with the conditions of access to the most difficult geological frontiers, combined with the need to deal with the economic characteristics of the "low price" context. As a result, the development and adoption of new technologies have significantly impacted all segments of the oil industry.

In the upstream segment, the adoption of new technologies has provoked a radical transformation in the design of E&P projects. This transformation is associated to a cluster of innovations due to:

- 1 Intelligent management of complex systems using data analytics.
- 2 Increasing process automation by the replacement of mechanical components by electronic ones.

- 3 Increasing equipment sensing of allowing the intensification of data collection and predictive maintenance.
- 4 And the introduction of new materials and nanomaterials.

This cluster of innovations has allowed the companies to reduce their costs and to achieve efficiency gains in a short space of time.

Similarly, in the refining segment, the incorporation of digital technologies has allowed the reduction of operational costs by the retrofit of many existing refineries, as well as in the Greenfield refineries. The downstream segment, in addition to the implementation of digital technologies, has also undergone the incorporation of process systems engineering and the so-called "smart manufacturing", understood as the means of combining information and technology to revolutionize the industrial intelligence to gain agility, flexibility, productivity and quality gains.

Petrobras' role in innovation in the O&G sector and recent public policy efforts in Brazil

The effort to develop innovation capabilities in the Brazilian O&G sector is linked to Petrobras' trajectory and its coordinating role in the Sectorial System of Innovation, since the beginning of the second half of the 20th century. This innovation effort allowed Petrobras to play a leading role in the technological development in deep and ultradeep waters.

The end of Petrobras oil monopoly and the sector reforms in the late 1990s inaugurated a new phase for the innovation policy in the Brazilian O&G sector. This time, the National Agency for Petroleum, Natural Gas and Biofuels (ANP) and other government agencies assumed an important role in the coordination of the innovation policy. Since then, in addition to Petrobras innovation efforts, the government formulated a policy of innovation for the country. This policy was made up of a regulatory framework with obligations and incentives for the investment in R&D. The cooperation between universities and oil companies was promoted. The main tools to foster this cooperation was the innovation funds (such CT-Petro and Inova Petro) and the obligatory investment in R&D clause in the oil lease contract.

In the specific case of Brazil, efforts to develop

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technological skills in deepwater E&P operations were reinforced by the discovery of pre-salt reserves, prompting Petrobras and other Brazilian industry players to reformulate their technological programs to tackle this new geological frontier.

Balance and prospects

The implementation of the different policy instruments has had a positive impact on the inclusion of new actors in the Brazilian System of Innovation for the O&G industry. These policies also played a structuring role of new and more robust interactions among the agents of the system.

The R&D clause represent the main policy instrument to promote innovation in Brazilian oil sector. Oil and gas operators have invested about R\$ 12 billion has been invested in R&D between 2006 to 2017, allowing the development of more than 10 thousand projects. However, about 69% of the projects and 50% of investments made between 2006 and 2017 were dedicated to the development of laboratory infrastructure.

Petrobras' own investments in R&D has also increased substantially. During the 1990s, the company disbursed an average of \$ 160 million per year. In the period of 2001 to 2016, Petrobras invested more than US\$ 11 billion. Because of this effort, Petrobras is today the Brazilian company with the highest number of patents registered and granted in the country. In 2014, the state oil company registered 1604 patents in Brazil and 2885 abroad (PETROBRAS, 2013, PETROBRAS, 2014).

However, the innovation policy for the national petroleum sector was projected into a context that could be called a "stable technological regime", with the search and incorporation of incremental innovations, where there were no challenges associated with the development of the Pre- Salt. In addition, the sectorial innovation policy was confounded with Petrobras' technological strategy.

Currently, the incorporation of disruptive innovations is fundamental for the competitiveness of Brazilian reserves vis-à-vis other geological frontiers. In addition, the participants in the innovation process are more numerous and diversified. However, the innovation policy instruments implemented to date do not seem to be adapted to the dynamics of the technological innovation process of the oil and natural gas industry.

The government initiatives to support innovation in the energy sector have proliferated in recent decades. It is crucial to evaluate existing programs, and to promote a greater synergy and convergence of efforts to support innovation.

Current programs of innovation support should be revised considering its effectiveness; it is important to verify if there are overlaps between programs;

if there is a proper articulation and coordination between them; and whether the financing instruments and conditions are adequate to the proposed objectives (Almeida et al., 2017). After revising the programs, it is important to monitor and evaluate the them permanently, elaborating and implementing performance indicators.

With the experience already accumulated by the traditional relations of cooperation between petroleum companies, the supply chain and research institutions, the Brazilian innovation policy for O&G most advance on the improvement of existing mechanisms and their orientation seeking to integrate, more rapidly, the set of technological solutions, with more intensive use of digital tools.

As a result, the sector's innovation system should start to integrate the main companies that provide digital technologies (Google, Microsoft, IBM, GE, Siemens, among others). Given the size and specificities of the Brazilian offshore, it is natural for these companies to see in the Brazilian oil industry business opportunities and a fertile ground for the application of technological solutions and potentially disruptive technologies.

It is also important to include initiatives to include small businesses in the sectoral innovation ecosystem, both in the implementation and in the periodic review of programs to support innovation in the energy sector. Several new tools could be contemplated such as seed capital funds, venture capital and corporate venture. Those tools may insert small businesses, including startups and scale-ups, in the process of open innovation in large companies that operate in the energy sector.

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