

How the Mexican Petroleum Industry Fell Behind in its Innovative and Absorptive Capacity and Why New Frontiers Are Not Likely to Be Unveiled for Some Time

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Abstract: This paper examines the causes behind the increasing technological gap between the Mexican oil industry and its international counterparts. Through an in-depth, inside-the-firm analysis, I document the evolution of the relationship between the Mexican government, Pemex, and its research branch, the Mexican Petroleum Institute (IMP) and conclude that misaligned incentives among these three entities contributed to a chronic underdevelopment of Mexican petroleum technological capacity. Whereas the conventional wisdom regarding Mexico blames constitutional restrictions on foreign participation as the main culprit for its lagging technology, I argue that the cumbersome institutional framework surrounding the Mexican Petroleum Institute—combined with an ideological bias against investment in research and development within the Mexican government—has been much more important. Moreover, given the errors committed in the past and the long time-frames involved in the oil industry, the adverse consequences for Pemex are likely to persist for several years before changes become noticeable. The implications for the company's entrance into areas such as deep-water exploration and production are discussed.

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1. Introduction

The Mexican petroleum industry has been identified among observers as a laggard in innovation, technological development, and absorption. To cite just one example from the upstream sector, while directional drilling was a widespread practice internationally by the early 1990s, the Mexican state-owned oil company, *Petróleos Mexicanos (Pemex)*, did not adopt the technology successfully until the early 2000s. In the refining industry, Mexico was a successful developer of catalysts in the late 1960s and 1970s, but efforts also lagged international norms severely soon after. Arguably, the gap between the Mexican petroleum industry and the technological frontier at the international level is most dramatic in the development of deep-water exploration and production expertise. As of the end of 2008, Pemex lacks the project management capacity to lead a project in the deep-water Gulf of Mexico. Moreover, the main research and development (R&D) entity in the Mexican petroleum industry, the Mexican Petroleum Institute (IMP), has been unable to evolve into a world-class center with the capacity to supply Pemex and other oil companies with state-of-the-art technologies and high quality project management capability.

This lag in technological capacity is puzzling for at least two reasons. First, the lag comes in contrast with the position that the Mexican oil industry has enjoyed in the international market for nearly three decades, since the discovery of the supergiant field Cantarell in the late 1970s. Throughout this time, Pemex has been one of the leading producing companies of crude oil in the world, coming in third—only behind Saudi Aramco and the National Iranian Oil Company—in total production in the first half of the

2000s. Despite being a major player in the world market, Mexico failed to develop its engineering and administrative capability.

Second, the lag is striking given that, unlike what happens in other exporting countries where foreign contractors take on a very large percentage of the technical work, in Mexico the bulk of the activities in the oil sector are run by Mexicans. In an industry where “learning-by-doing” plays such an overwhelming role in the development of expertise, it is striking that Mexicans successful in managing oil industry assets were unable to develop new technologies and lead projects to adopt those at the global frontier.

The analysis of the technological backwardness of Mexican oil must be nuanced by the realization that Mexican engineers have been able to explore and produce crude oil and refine it successfully, mostly without foreign participation, for several decades. They are far ahead of other countries in domestic technological capability, as they do not depend on foreign contractors to carry out many of the most important operations. Yet, when there are late-comer countries such as Norway and Brazil successfully developing cutting-edge products and processes (see, for example, Tryvge Laegreid, 2001, José Benedito Ortiz Neto and Armando Joao Dalla Costa, 2007), the question arises of what has happened to the Mexican oil sector and why it falls behind.

The conventional wisdom regarding the Mexican oil sector holds that the lag in technological development—as well as the cause of other performance inefficiencies—is due to three main causes. First, the legal restrictions on foreign participation in the sector are blamed for the absence of cutting-edge technology. Second, the rigidity and strength of the oil workers’ union is believed to thwart efforts at reforming existing structures and

introducing new ones. Finally, state ownership—in particular the absence of soft-budget constraints—is blamed for inefficiencies across the board, including in R&D.

This paper presents the results of an in-depth, inside-the-firm analysis and questions the conventional wisdom regarding why the Mexican petroleum industry has fallen behind. It focuses on the state-owned enterprise charged with research and development, the IMP, and its relationship with Pemex and the Mexican government over the last three decades. The argument is that a cumbersome institutional framework surrounding the IMP is at the root of the problem. This institutional structure, which determines how the IMP is linked to its principals—mainly the Mexican government and, to a lesser extent, Pemex—places it at extreme vulnerability for variables of the political economy outside of its control. In particular, the IMP has suffered greatly from the absence of a demand-pull for Pemex to drive innovative activity and from an ideological disposition of the Mexican government against industrial policy. Over time, the workforce of the IMP has been unable to take full advantage of the scarce resources at its disposal due to the atrophy associated with chronic underdevelopment and to a research environment that fails to take full advantage of its potential as a multi-disciplinary research center.

This paper is structured as follows. Section 2 introduces the Mexican Petroleum Institute (IMP) and describes the institutional framework that connects it to Pemex and to the Mexican government. Section 3 presents the theoretical background for the study. Section 4 describes the methodology. Section 5 presents the results. Section 6 concludes.

While the focus of the paper is on the innovative and absorptive capacity of the Mexican petroleum industry in general (for a conceptual development of these terms, see

Shaker A. Zahra and Gerard George, 2002), the focus is on the entity charged with research and development, the IMP. In doing this, no claims are made regarding the desirability for an oil company such as Pemex to rely on a state-owned domestic supplier of technology rather than on purchasing it from foreign—mostly private—firms. This paper is agnostic regarding that important developmental question, and its scope is limited to explaining why the domestic industry fell behind. Nevertheless, even if it were believed that Pemex would be better off not relying on the IMP for its new technology, the findings from this paper are important for two additional reasons. First, given the importance of “learning-by-doing” in the petroleum sector and the fact that Pemex lacks an internal research-and-development unit, the oil company can only benefit from having a better trained workforce to draw upon. Second, given that the IMP has been a state-owned enterprise throughout this time, it is important to understand why state-owned enterprises can fail to develop properly.

2. The Mexican Petroleum Institute (IMP)

The Mexican Petroleum Institute was founded in 1965 to serve as the state-owned enterprise charged with research and development activities for the domestic oil industry. Its creation responded to several trends present at the time in the world and domestic stages. First, it was part of the broader economic policy strategy of the Mexican government which attempted to “deepen” import-substitution industrialization into the capital goods sector. Second, it occurred after years where the Mexican industry had faced challenges in the acquisition of technology from international actors, prompted by the animosity that followed the Mexican expropriation of 1938. Third, the creation of an

entity external to Pemex was seen as a desirable step to prevent the already powerful oil workers' union from demanding a strong presence in R&D activities.

While nominally independent of Pemex, the structure of the IMP reveals that the purpose of its creation was to meet the demands of the national oil company. This is evident from the fact that the chair of the Board of Directors of the IMP is the director-general of Pemex, who also appoints the director-general of the IMP. During most of the IMP's existence, its director-general has been a former employee of Pemex. Moreover, Pemex holds a virtual monopsony over the IMP, as it has historically been the client of 90% or more of the products and services sold.

The IMP's relationship with the Mexican government is not unlike that of other state-owned enterprises in the country, including Pemex. This is reflected mainly in its corporate governance, budgeting, and accountability regulations. Thus, the rest of the members of the Board of Directors are, in fact, representatives from government ministries or other public agencies. Its budget is appropriated each year via a two-stage process. The IMP first negotiates with the Ministry of Finance its budget for the following year, including decisions on new hires and investments on physical capital, and then the Ministry of Finance submits the general budget to the lower house of Congress for approval. Finally, oversight has been historically the responsibility of the federal comptroller's office. No congressional oversight has ever existed over the IMP, due to a lack of technical capacity to review the work of the oil sector intelligently and, until very recently, also due to lack of interest.

The appropriations process has affected the IMP's research budget in one very specific way. The Ministry of Finance does not directly subsidize R&D activities in the

petroleum industry, and thus the IMP historically has not had a research budget allocated *a priori* each year. Instead, the IMP relies on the sale of services to Pemex in order to fund its operational expenses and, if any earnings are available at the end of the year, then it can negotiate with the Ministry of Finance to devote them to strict R&D during the following year. This framework changed slightly in 2006 when, at the insistence of several opposition members of the legislature, the IMP is now assured to receive a small percentage of revenues from oil sales for R&D.

Thus, the IMP evolved through time from an R&D institute into a services company but with inverted drivers of innovation. A services company conducts R&D in order to sell services and licenses and advance its business goals. The IMP, on the other hand, sells services in order to raise cash so that it can pursue its R&D activities. The R&D can certainly be useful in selling services to Pemex, but this is not a driver for the Institute's innovation. As a former director of the IMP mentioned, Pemex demands so many services that the IMP has its hands full at all times.

The IMP has developed expertise across the different areas of the petroleum industry, from the upstream to the downstream. Its workforce mainly includes petroleum engineers, geologists and geophysicists, and chemical engineers, although those are not the only specialities that converge at the Institute. The number of employees in 2006 was 3,733, although since 1970 it had ranged from a minimum of 1,316 (in 1970) to a maximum of 6,249 (in 1987). In fact, the 1980s saw the largest growth in personnel, in striking contrast to the stagnant number of staff members with doctoral degrees (which stayed between 38 and 57 throughout that decade). In the late 1990s, a major initiative focused on increasing the number of doctors and by 2006 the IMP counted 270 Ph.D.s

and Sc.D.s in its ranks. Recruiting, however, is limited to the Mexican industry. While on occasion current employees are funded to study graduate degrees abroad, the IMP does not seek to recruit scientists from overseas to work in Mexico.

While the IMP has never been a global leader in technological innovation, at certain points in time it has come close to the worldwide technological frontier. In particular, the 1970s were a successful time in the development of catalysts for the refining industry. However, the refining research group at the IMP had difficulty keeping up with the changes in the development of catalysts and the technology was soon rendered obsolete. In exploration and production, the IMP has not had much more success. As one veteran IMP petroleum engineer described in an interview:

I am sad to say that Mexico has not been a [technological] leader in anything... If the Mexican petroleum industry has ever been close to the frontier, it would be on naturally fractured reservoirs, due to the particular need of the Mexican fields. But only in some respects of those reservoirs, not in everything... You can see it in terms of the amount of technology that we have had to buy. Another aspect where we have been good worldwide is on the issue of asphaltenes. We did good things there and worked closely with the world leaders..."

The performance of the IMP in the services that it provides, however, receives more satisfactory reviews. A chemical engineer in a PEMEX refinery attested that IMP service crews were considerably more skilled and more reliable than private counterparts when called to the refinery, a characteristic that he attributed to the fact that the IMP has a more intimate knowledge of PEMEX's facilities. The expertise that IMP personnel have developed has often gone hand-in-hand with the needs of PEMEX, which gives them an edge when competing with foreign services companies.

The emphasis of the IMP's activities, not surprisingly, has been shaped by the orientation of the directors-general that have led the organization. Perhaps the most

important difference has been between directors who formerly worked in Pemex (1965-1994 and 2005-present) and directors who previously worked in academia (1994-2005). The former tended to favor meeting the operational needs of Pemex first; the latter tended to give precedence to research projects with longer time horizons. In fact, the current history of the IMP cannot be understood without paying special attention to the administration of Gustavo Chapela (1995-2005), a former rector of the Metropolitan University of Mexico City who drastically ramped up the hiring of workers with doctoral degrees, supported long-term research projects (in particular the naturally-fragmented reservoirs project referenced above and a project to enhance heavy crudes), and promoted work leading to publications in academic journals by IMP researchers. His time was not without controversy, however, as he was criticized for arriving without an understanding of the oil industry and for under-emphasizing applied technological work at the expense of theoretical work.

Research projects at the IMP are selected following a “stage-gate” process analogous to that proposed by Robert G. Cooper. A committee of high ranking PEMEX and IMP managers attempts to “align” the research strategy with the needs of PEMEX in the field. Thus, projects must have a technical counterpart in the oil company who is willing to agree to support the research and follow up on it.

3. The Theory of Successful Innovation

The premise of this theoretical section is that the chances of successful innovation in an R&D enterprise such as the Mexican Petroleum Institute depend on three main factors: (1) the amount of resources devoted to R&D, (2) the effectiveness with which those resources are employed, and (3) contextual political and sociological variables that

facilitate or obstruct the deployment and adoption of new technologies. Each of these is in turn explained.

3.1 Amount of resources devoted to R&D

Arguably the central theoretical debate on the determinants of the amount of resources devoted to R&D activities deals with the question of market structure. One side of the argument is held by those who believe that a competitive market provides the incentives for innovative activity. Under competition, economic profits are limited, and thus firms seek to innovate in order to gain an edge over their rivals. This can be accomplished through a process innovation that cuts costs or through a product innovation that opens a new market for their sole—albeit normally temporary—possession. The opposing viewpoint, however, is associated with the writings of Joseph Schumpeter (1942) and makes the point that under competition firms are already minimizing costs in order to survive and thus have few, if any, resources to devote to serious innovative activity. Accordingly, it is the possession of market power which leads firms to successful innovation, since only monopolists have the amount of resources that are needed.

Independent of this debate, there is an additional argument in the literature regarding the drivers of investment in R&D. The “demand-pull” tradition of Griliches (1957) sustains that technological development is most rapid in those places where it is profitable to do so. Thus, the process of innovation is led by rational actors aware of opportunity costs who devote their resources elsewhere if the expected profits of R&D do not outweigh the costs. This theory thus applies not only to the development of new products and processes but also to the adoption of existing ones.

3.2 Effectiveness with which resources are employed

It is reasonable to expect that, given similar levels of R&D investment, different research centers will succeed at different levels. This empirical variation is likely to be due to how the resources are employed. A well managed firm with highly qualified personnel is better able to take advantage of the resources that come its way. Several theories have been advanced to address this question, usually from an inside-the-firm approach.

One theory, developed by Lester and Piore (2004), emphasizes the way in which innovation managers organize their workforce and frame their activities. In their view, there are two types of styles to manage R&D activities: analytical and interpretative. “Analysis” entails the following: the focus is a project, with a well-defined beginning and end; the thrust is to solve problems; managers set goals, convene meetings, and negotiate to resolve different viewpoints and eliminate ambiguity; communication is the precise exchange of chunks of information; designers listen to the voice of the customers; means and ends are clearly distinguished and linked by a causal model. “Interpretation” entails that the focus is a process, which is ongoing and open-ended; the thrust is to discover new meanings; managers set directions, invite conversations, and translate to encourage different viewpoints and explore ambiguity; communication is fluid, context-dependent, and undetermined; designers develop an instinct for what customers want, and means and ends cannot be clearly distinguished (pp. 97, 98). The authors, through their detailed fieldwork in companies that developed cellular telephones, medical devices, and fashion blue jeans, argue that “interpretation” is much more conducive to breakthrough innovation, whereas “analysis” produces merely incremental gains within the existing technological paradigms.

A different set of theories focuses on the workforce and its capacity to apply past knowledge to solve new problems. Perhaps the best known among these is the theory of “learning-by-doing” (Kenneth J. Arrow, 1962), which points out that past experience greatly increases the productivity of the workers. A more developed version of this theory is that of “knowledge-based assets” (Alice Amsden, 2001), which emphasizes that manufacturing experience cannot be purchased “off-the-shelf” and is indeed crucial for workers to solve new tasks. When applied to the innovation literature, these approaches suggest that, *ceteris paribus*, firms with more seasoned researchers will make better use of the resources employed.

3.3 Sociological and political contextual variables

There are two additional elements that determine the success of innovations. The first deals with sociological phenomena which may allow a “superior” technology to be displaced by a weaker one, much as it has been exemplified in the case of the QWERTY keyboard in the innovation literature (Paul David, 1985). This approach is useful when determining why a single instance of technological innovation is widely adopted, but it is less relevant for the overall capacity of a research center that is continuously attempting to develop innovative processes and products throughout forty years.

The second deals with political asymmetries across nations and follows from dependency theory, a well-known framework advanced to understand the lag of nations in the 1970s and 1980s (see, for example, Fernando Henrique Cardoso and Enzo Faletto, 1979). The claim would be that “the underdevelopment of the Third World is perpetuated by deep conflicts of interests or contradictions embedded in the international capitalistic economy which systematically favor the developed nations more than the

underdeveloped ones” (Gary Gereffi, 1978, p. 239). Without making normative judgments regarding the desirability of industrial policy, dependency theory is helpful to determine to what extent the viability of local firms in underdeveloped countries necessitates active support from their governments even when having superior products.

4. Methodology

A total of sixty-five in-depth interviews were conducted at the Mexican Petroleum Institute and at PEMEX between the months of April and August of 2008 in order to ascertain the conditions under which research and development activities have taken place in the Mexican oil sector. This approach was complemented with archival research to obtain a more comprehensive perspective on the innovative capability of the IMP.

The selection of the interviewees in the IMP was done before field research began, following several criteria. First, attempts would be made to speak with respondents from different hierarchical echelons of the company. The premise was that learning from front-line workers would reveal insights as important as talking with directors-general. This objective was met, since besides interviewing three former directors-general of the IMP, the sample also included a good number of research staffers. Second, interviewees would be drawn from the different areas in the company, including at least one from upstream research, one from downstream research, one from petrochemicals, one from finance, and one from the graduate school. This goal was also met. Finally, the research focused on employees both with several decades of experience at the IMP—who could provide a historical account of the changes in their workplace—and recent entrants who could bring an outside perspective. While some of the respondents were recent hires, most of the current employees interviewed had over two

decades of work experience at the IMP. Overall, the fieldwork constitutes a comprehensive qualitative dataset with which to describe the current state of the IMP.

Careful attention has been devoted to safeguarding the rights of respondents as participants of a scientific inquiry. Some interviewees requested that their responses be kept completely anonymous and hence are used only as background information. Others agreed to allow direct quotes to be cited but without providing any identifying information. In these cases, the names and titles of the interviewees are not released.

5. Results

The most fundamental problem with the performance of the IMP concerns the institutional framework which does not promote the investment of resources in research and development. The success of the IMP is overly dependent on the behavior of two other entities with very different performance objectives—PEMEX and the Ministry of Finance—for whom the development of the IMP is not the primary concern. Since these two entities are the ones responsible for the funding of R&D activities, it is natural that scarcity of resources will arise.

The concerns of the PEMEX management are with the operational and financial performance of their own company, already stressed for resources. To the extent that they actively support the IMP, it is out of sympathy with the struggles that it faces to conduct research or with the fact that services sold to the IMP do not have to enter the cumbersome public bidding process. “When the IMP tries to sell us a research project,” explained one petroleum engineer in a production facility, “people usually say: ‘You know that it’s not going to be very useful, but let’s give them something so that the IMP can survive.’”

In the view of IMP researchers, the link with PEMEX could hardly be more problematic. They feel that by having to sell services to survive, they constantly have to ask for money for projects that PEMEX managers do not necessarily want. The asymmetric relationship between the oil company and the research branch is exacerbated by the power conveyed to PEMEX managers to have the final say as to whether an IMP project gets funding. This situation was expressed best by a manager at the IMP:

Unlike what happens with other oil companies, the IMP is not part of Pemex. Petrobras has its research arm, CENPES, within the company... That is the origin of the failures of the IMP and of Pemex. Imagine what it's like when I go to Pemex to request projects and they say 'well, I'm going to see what I give you.' It would be very different if negotiations were made between managers of equal standing within Pemex, and where the IMP manager could speak with the people in Pemex on different terms.

Thus, the IMP's income is determined by the incentives faced by PEMEX to innovate. Generally, these incentives are small for the following reasons. First, PEMEX has a guaranteed monopoly in the upstream and the downstream sectors in Mexico, eliminating the need to develop new products to obtain an edge from competitors. While holding a monopoly, however, rents are appropriated by the Mexican state via an onerous taxation policy on oil revenues. Hence, the possibility of Schumpeterian innovation due to the investment of spare resources on R&D is also eliminated.

Second, the geological conditions of the country have made oil production relatively straightforward for many years, thus diminishing the pressing need for innovative technology. The bulk of the Mexican oil production in the last quarter century has come from the supergiant field Cantarell, located in the shallow-water Gulf of Mexico. Cantarell, a naturally-fractured reservoir with very low extraction costs, has been blamed by several analysts to have contributed to the technological lethargy of the

Mexican upstream sector. Given such favorable extraction conditions, there was simply little demand from PEMEX engineers for new technologies.

Third, the oversight regulations have made it dangerous for PEMEX managers to support IMP innovations. According to the law, originally designed to combat corruption, the comptroller's office could prosecute a manager in PEMEX who acquired faulty technology, under the argument that it wasted public money. However, the deployment of new technologies is usually an inherently risky endeavor. Faced with the dilemma of giving the IMP an outlet to demonstrate their innovations—risking a possible lawsuit—or purchasing technology tested internationally, most PEMEX managers choose the latter.

The outcome is a lose-lose innovative game where PEMEX only purchases technology that has been in the market for years and the IMP does not have demand for innovative work. Given that incentives are stacked against devoting large resources to R&D, a natural mechanism to break the vicious cycle would be government intervention in the form of a subsidy. Yet, between the early 1990s and 2006, the government provided no subsidies; before then, the subsidies were granted only because the company operated at a loss.

The Mexican government, through the Ministry of Finance, has implemented an economic policy since the late 1980s that rejected industrial policy as an efficient use of government expenditures. According to the tenets of neoliberalism, espoused fervently by high ranking members of the government, subsidies in favor of a particular industry distort the market mechanism in ways that, in the long run, almost certainly lead the domestic economy away from its comparative advantage. Moreover, in the short run, the claim is that there is no guarantee that industrial subsidies will work, since government

bureaucrats can hardly be expected to choose to support those industries with the most potential.

The result of these two elements—cumbersome institutions and ideological disposition against subsidies to industrial R&D—is a chronic underinvestment in innovation in the oil sector. A technological manager with twenty years of experience phrased it eloquently: “We have the worst of both worlds: we do not receive funding from the federal government, but we do receive their guidelines regarding spending limits in salaries, materials, services, investments.”

Given the amount of resources spent, it is not surprising that major breakthroughs in oil technology have not originated in Mexico. Researchers lamented this situation and often pointed to the Brazilian case and its development of deep-water technological know-how as a path deliberately not taken by Mexico. “It is not that what the Brazilians did was a secret,” said an experienced PEMEX petroleum engineer with a deep interest in new technologies. “They sent many people to get doctorates in American universities, over many years, and they threw buckets of money into their deep-water program. And now we sit around in Mexico wondering why we fell behind. The Brazilians didn’t invent the wheel on R&D. They just followed the obvious steps.”

The IMP suffers from two additional conditions that prevent it from making the best use of the scarce resources at hand. First, the events of the last couple of decades have hindered the development of expertise and learning-by-doing in specific areas. Overstretched research areas have had to juggle researchers to areas outside of their specialty, in accordance to what types of services PEMEX is demanding at a given time. If a research unit is deemed unprofitable, it is closed and the personnel transferred to

another area. Other researchers complain about the long periods of time they have spent in their careers more as sales representatives than conducting scientific work. Even those who have been able to address similar questions during their tenure have not had access to the best equipment and materials. In consequence, the workforce of the IMP appears to have atrophied at small increments each year, but at more considerable amounts over several decades.

Second, the project management structure of the IMP hampers its ability to use its scarce resources to develop breakthrough innovation. The approach to innovation at the IMP is “analytical,” to use the language of Lester and Piore (2004), to the extreme. The staff of the IMP is multidisciplinary—drawing from many research fields—and staffers have acquired knowledge of many different areas of the oil industry due to the frequent reallocations of personnel into more profitable areas. However, the selection of projects and evaluation of performance runs counter to this comparative advantage.

This can be observed at all levels of the innovation chain. In order to be approved, project proposals must address a tangible, existing need of the oil company, be “sponsored” by a manager at PEMEX, and obtain the consent of the PEMEX executives who sit in the committee charged with the “alignment” of the IMP’s agenda with that of PEMEX. The evaluation of performance at the IMP, moreover, prevents cooperation across research units that could lead to out-of-the-box thinking. Each research unit at the IMP is evaluated independently, making managers reluctant to “lend” their top staffers for task forces that draw expertise from different departments so that they can meet their own goals. Finally, this is all exacerbated by the barriers to the casual exchange of ideas within the IMP. Researchers from the same units are scattered in many buildings, all

working in offices without inside windows and, almost always, with their doors closed. Unable physically and organizationally to interact with their colleagues from other research units, IMP staffers are further relegated to devote their time to incremental innovations geared to solve short-term operational needs of PEMEX.

Finally, the preliminary evidence from the research at the IMP suggests that sociological or dependency issues are not to blame for the technological lag. The researchers interviewed never mentioned cases where good technologies failed to be absorbed internationally due to external, non-technological or non-economic factors. The reality is that the IMP has seldom reached a point where its technology could even be vulnerable at that level, since it has not developed any potential paradigm-shifting technology. Instead, the IMP's problems are mostly found beforehand, in the underinvestment and underemployment of resources.

6. Conclusion

The technological outlook for the Mexican petroleum industry thus is pessimistic, although there are elements of hope. Fortunately for Mexico, the country has a large group of committed researchers with experience working on the problems affecting PEMEX. Moreover, Mexico has a long tradition of training petroleum engineers at its universities since the 1920s, and that educational infrastructure can be used to develop the expertise needed in the upcoming decades. Nevertheless, in the next several years, Mexico will hardly reach any new frontiers.

As explained above, the amount of resources devoted to R&D and the way in which those resources are employed does not suggest that major innovations will come

from Mexico anytime soon. This is an important issue to understand the lagging performance of the IMP, but the reasons for pessimism go beyond this. The more fundamental problem for Mexico is that, even if it is assumed that developing the technology domestically is not better than purchasing it in the international market, Mexico still has a long way to go.

A major consequence of the underdevelopment of the R&D sector in the oil industry in Mexico is that the country now lacks the expertise to manage the deployment of major projects involving new technologies, whether these come from Mexico or are bought “off-the-shelf” abroad. Neither the PEMEX nor the IMP staffers are accustomed to dealing with high-risk mega-projects with state-of-the-art technologies.

In the case of deep-water technology, an important new frontier in the Gulf of Mexico for PEMEX, the outlook is particularly problematic. As practitioners knowledgeable on the issue will readily acknowledge, “learning-by-doing” is a fundamental aspect of successful deep-water activity, and it is precisely there that Mexico lags farthest behind. According to Gustavo Chapela, former director of the IMP, if Mexico started today with an honest, all-out effort to develop deep-water expertise, it would take the country ten years before successful deployment. The current ideological disposition of the Mexican government, however, suggests that the industrial policy push needed to achieve that objective will not be forthcoming in the immediate future.

Thus, the innovative capability of the Mexican oil industry has lagged behind not because of restrictions on foreign participation. After all, much of the technology can be acquired abroad and foreign services companies operate with a certain degree of freedom in Mexico. It has not lagged behind either due to the rigidity of the labor union, since the

IMP is not influence by the powerful oil workers' union. Instead, its underdevelopment is a result of a poor institutional framework that makes the IMP overly dependent on entities for which R&D is not a primary concern.

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