The United States experience as a reference of success for shale gas development: The case of Mexico

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Highlights

- This paper illustrates the misleading effects in the employment of the United States experience as a benchmark to support shale gas development without accounting for the structural aspects and circumstances that made it possible.
- The findings suggest that the greater value of this benchmark lies in its use as a guide for the examination of the processes and factors conducive to those results, to ultimately develop adaptive knowledge oriented towards policies and strategies to fit other contexts and exploit unique opportunities in other countries.
- The development of domestic natural resources and shale gas in particular, is a complex task that requires appropriate planning, financial and technological capabilities, adequate infrastructure, favorable regulation and governmental support.
- In spite of Mexico's inferred shale gas resources and proximity with the United States, energy policy makers must first overcome several structural deficiencies in the Mexican natural gas industry to foster a more favorable environment for production to take off, as otherwise Mexico might be jeopardizing its energy security mandate, by depending on resources that might eventually be costlier or take much longer to develop in comparison with the initial expectations made.

Abstract

Shale gas has gained increasing attention worldwide in the light of the rapid production and significant effects in the United States. Using this case as a reference, several countries have taken the first steps to develop their own resources, with Mexico in particular including shale gas in its energy planning priorities and rushing towards its commercial production, although results have remained elusive. This paper argues that due to the intrinsic complexity embedded in the shale gas development of the United States, its use as a benchmark by Mexico for policy making purposes is misleading, given the challenges in reproducing the same factors of success on the basis of the contextual differences between both countries. The findings presented can ultimately be helpful for other countries looking forward to or in the process of developing their shale gas resources driven by the same reference.

Keywords

Shale gas; United States; Mexico

1. Introduction

The steady growth of energy demand, the rapid depletion of conventional energy resources and the significant contribution of energy production and consumption to global warming have resulted in a general transition towards fuels with lower carbon intensity. Given the predominance of fossil fuels in the primary energy composition, most countries have increasingly favored natural gas over oil and coal, entailing greater efforts to meet the rising gas demand from both conventional and unconventional sources.

Among these unconventional sources, shale gas in particular has drawn international attention in response to the fast pace recently observed in the United States output. With a modest average growth of 2.7% per year from 1995 to 2000, shale gas production in the United States started to increase much faster, reaching an average annual rate of 17.4% from 2000 to 2005 that escalated to 47.9% from 2005 to 2011. This growth with the decline of conventional gas production at an annual rate of 5% from 2000 to 2011 enlarged the share of shale gas into the total gas production of the United States, passing from 1.7% in 2000 and 4.1% in 2005 to as much as 34.1% in 2011 (EIA, 2013a). In consequence, the gap between natural gas demand and imports has decreased, with the share of net imports passing from 16% in 2007 to 8% in 2011. Moreover, its effects have transcended to prices, with the Henry Hub spot price driven down 55% from 2008 to 2011, shifting from 8.9 to 4 dollars per million BTU (EIA, 2013b).

In the middle of this momentum, that has been generally described as a "revolution" in terms of the transformation entailed for the energy balance and outlook of the United States, the World Energy Council (2010) highlighted the advantages of shale gas in terms of its increasing affordability and resource size, with estimations of its total economically recoverable resources amounting to 6,444 trillion cubic feet, in addition to its considerable potential to reduce CO_2 emissions by replacing other fossil fuels, especially in their use for power generation.

Nonetheless, an official report on the initial geological assessment for shale gas resources in 48 basins from 33 countries including the United States (EIA, 2011) became the milestone that spurred real interest to the worldwide development of this unconventional gas source, due to the resource estimations of nearly the size of the conventional gas proved reserves in 2010. As this information also indicated the shale gas resource base to be more widely dispersed than the proved reserves of conventional gas, of which more than half is held by three countries alone; several countries jumped on the shale gas bandwagon, hastening policies to foster the commercial development of their domestic resources in an effort to replicate or approximate the results observed in the United States (Selley, 2012; Lozano Maya, 2012; Gény, 2010).

Although some of these early efforts have been encouraging, evidence indicates shale gas production to be very complex, let alone to the extent reached in the United States. In Poland, where estimations of its shale gas resources were the highest in Europe with 187 trillion cubic feet (EIA, 2011), subsequent official re-assessments by the Polish authorities have reduced this potential significantly, to a range between 12.2 to 27.1 trillion cubic feet (Polish Geological Institute, 2012) that on average just represents 11% of the initial figures. It is noted that in spite of the positive expectations for shale gas in Poland, the underdeveloped infrastructure, regulatory deficiencies and little competition in its gas market along with the poor results in exploratory wells have resulted in some major companies abandoning their production plans (Johnson & Boersma, 2013, p. 295).

In the United Kingdom, in spite of shale gas production being considered decades ago due to the potential resources assessed, the lack of governmental support halted any further advance until the interest was revived recently and it is still uncertain the success in the application of the technologies used in the United States and the public response to them (Selley, 2012). In this regard, while the experience observed in the United States pushed shale gas development in Europe, in spite of the considerable volumes presumed for some countries its future is still questionable (Johnson & Boersma, 2013).

Among the countries that have shown interest in producing shale gas, Mexico in particular has expressed remarkable optimism pulled by the favorable early estimations of its resource base from EIA (2011) but especially by its territorial proximity with the United States that indicates geological formations spanning the borders of the two countries. This led top-level Mexican government officials to praise their country's shale gas potential and implement successive policies for its eventual development. In the practice though, results have been minor and are far from supporting the initial hype associated with the benchmark set with the United States, with subsequent efforts being more conservative and cognizant of the critical challenges ahead.

This paper proposes that the use of the United States experience as a reference to validate the performance of any shale gas policies undertaken is unreliable, given the complexity in reproducing the contextual conditions embedded in other countries. For this reason, the use of such benchmark and its major implications for policy making are discussed in the following section. Next, the major factors of success for the United States shale gas experience are discussed to highlight its divergences with Mexico. The paper concludes with a proposal conducive to the design of policies for shale gas development adapted to Mexico's characteristics.

2. The use of international benchmarking as a source of public policies

Because of its success as the major developer and being the example best documented so far, the United States is generally regarded as the major benchmark to guide shale gas development, which is reminiscent to the way in which firms measure their own performance by tracking the successful results of their competitors or their exemplar performers to try catching up with them. At international levels, benchmarking aims to identify specific indicators in particular fields for systematic measurement and comparison among countries (Dominique, et al., 2013, p. 1) and thus, it provides a reference to contrast and assess a country's performance against what is considered best.

Less common but increasing with the pace of globalization, policy making has been influenced by benchmarking, entailing different levels of impact depending on the type of practice adopted. Mexico's interest for shale gas was publicly announced after the publication of the preliminary results (EIA, 2011) that suggested the country's potential to be fourth worldwide, equivalent to roughly 10% of the total resource base estimated, with part of it belonging to the neighboring geological formations in the United States, where production is taking place. By the end of 2011 this preliminary information was used by the Mexican Minister of Energy at the time to tout shale gas as a game changer for improving domestic energy security and bringing economic prosperity, linking it to the successful experience seen in the United States (Secretaría de Energía, 2011). However, the implicit assumption that the sole existence of resources in Mexico would reproduce the benchmark employed ignores the strong divergence in the structural and transitory characteristics between both countries, not to mention the fact that the information on which this official optimism stemmed from (EIA, 2011) is the only one of its type, with further dedicated research and studies being required to contrast or confirm it.

The predominant aspirational and quantitative scope encompassed in this international benchmarking practice is evocative of its utilization for political advantages, by "citing results that are favorable and eschewing those that are unflattering" (Dominique, et al., 2013, p. 6). This practice, also termed as "naïve benchmarking" (Lundvall & Tomlinson, 2002) is aimed at copying practices considered remarkable from another country but without accounting for their specific context and hence, limiting their real adaptability to another environment. This exercise may imply that "[t]he same 'best practice' instrument in one country-specific systemic context may fail to bring good results in another, if the complementary environment does not exist or is radically different" (Paasi, 2005, p. 23) but is carried out anyway to bring legitimacy and credibility to political decisions (Dominique, et al., 2013). While this type of benchmarking is mostly based on results and performance, it is possible for it to shift towards a more qualitative approach centered on the analysis and knowledge of the practices and methods involved in obtaining those results, to make it more adaptive to other environments (Dominique, et al., 2013; Huggins, 2010; Papaioannou, et al., 2006; Paasi, 2005).

In Mexico's case, the relevance of shale gas passed from official speeches to energy policy priorities, with two scenarios of production included in the Energy Strategy 2012. The Strategy is the major legal instrument of long-term energy planning submitted annually to the Mexican Congress for approval and is developed upon three major elements: a) energy security, to meet the country's energy demand competitively and reliably; b) economic efficiency, to provide cost-effective energy resources and c) environmental sustainability. With five shale basins preliminarily identified, the business-as-usual scenario in the Strategy encompassed the development of only one shale gas play, with the more favorable scenario adding another play. For each scenario, production would start by 2016 with the output expected amounting to 15% and 29% from the total gas production expected by 2026 (Secretaría de Energía, 2012b), however, the total preliminary shale gas potential estimated was between 150 and 459 billion cubic feet, which is respectively lower in 78% and 33% from the benchmark employed from EIA (2011).

In compliance with these policies, other operational objectives were set, encompassing geologic studies, 20 exploratory wells up to 2014 and the identification of the most promising geologic plays and areas (Pemex, 2011). Nonetheless, up to February 2013, only seven wells had been drilled, with two not being commercially productive, three being dry gas producers, two being gas and condensate producers and only one being successful as an oil and gas producer (CNH, 2012). These results are relevant since as further discussed in Section 3.2, the economics of shale gas production have recently depended on the ability to switch gas production to "wetter" reservoirs with larger contents of heavier hydrocarbons linked to higher oil prices. By early 2013, the thrill of shale gas started to transform, with less fanfare in the newer edition of the Strategy, which recognized that in spite of the considerable shale gas potential, the path of development chosen would be constrained by Mexico's legal and economic framework, with more favorable opportunities depending on the implementation of measures of promotion more ambitious (Secretaría de Energía, 2013). To make matters worse, the structural limitations of the Mexican natural gas market manifested during 2012, with serious shortages of natural gas as a result of infrastructure bottlenecks to meet the peaking demand derived from the lower Mexican gas price linked to the descending Henry Hub. Needless to say, these market conditions are distant from the ones prevalent in the United States, emphasizing the divergence between both countries.

As stressed in Paasi (2005), contextual differences amplify the limitations of performance-based benchmarking, with many institutional and structural conditions that cannot be easily changed such as economic settings, endowment of resources and cultural and historical backgrounds. More important, context determines the timeframes and resources required in adopting a benchmark, which is of utmost importance, as the process must be cost-effective to be considered for policy making purposes. In this way, while benchmarking may be limited to selecting few key countries with outstanding performers of which their success is assumed to be entirely reproducible, once contexts are recognized, the emulation involved in the political speech requires further modifications in order to achieve some degree of applicability (Dolowitz & Marsh, 2000).

Since detaching the benchmark from its context is very complex and costly, it thus represents the main driver of the level of success from implementing the practices gained from a benchmark in a domestic context and determines the resources and timeframes potentially involved. The understanding of the context embedded however, requires a more qualitative and multifaceted approach that transcends a comparative stage towards the development of a learning and adaptive experience leading to better policies and performance (Paasi, 2005; Lundvall & Tomlinson, 2002). It is noted in Huggins (2010) that due to the reproduction of practices but not contexts, benchmarking efforts have evolved towards the understanding of the processes that make these operations effective, paving the road for a more ambitious approach that ultimately employs international experiences as an input for a learning process of policy making.

Although benchmarking is relatively recent for policy making purposes, it bears a considerable potential as a vehicle of knowledge towards designing and implementing policies for performance improvement (Papaioannu, 2006; Paasi, 2005). While a focus on performance favoring the imitation and replication of ideas might best suit political interests, it gives little room to a deeper knowledge of the complexity, dynamics and contextual differences necessary for adaptive policy learning. This was eventually acknowledged by Mexico's energy policy makers on its newest Strategy, highlighting the constraints imposed by the environment and thereby, the need to adapt the strategies and policies derived. For this to happen though, it depends on the country's ability to learn from the processes and practices of the benchmark adopted, its capability to translate the knowledge acquired into policy making for its own environment, and the costs and efforts involved in the modification of its structural and institutional frameworks (Paasi, 2005).

3. Factors for the shale gas success in the United States

As the influence of shale gas has grown worldwide, attention has been drawn to determining the factors that made possible the success observed in the United States, in the hope to reproduce it elsewhere. However, as structural conditions, long-matured processes and transitory conditions underlie this success, in the practice taking off commercial production of shale gas in other places has been very complex.

Although shale gas in the United States can be traced long back ago, the technical constraints and the abundance of cheaper conventional gas resources discouraged its production, until the energy shocks in the 1970s revived the interest to explore energy alternatives to strengthen domestic energy supply and avoid the shortages resulting from depending on foreign energy supplies. Within this environment, the United States looked to several unconventional sources of energy, promoting technological breakthroughs that could allow their eventual commercial utilization, being one of them shale gas. Once the support to technological research and development from the government passed to and was refined by private companies, structural factors such as the expertise and infrastructure of a mature gas industry, competitive free-market conditions and an institutional framework providing regulatory certainty converged with transitory market dynamics and high price levels to make production economic and allow shale gas to flourish in the 2000s. The factors influential to this success can be broadly classified in the categories discussed below.

3.1 Technical

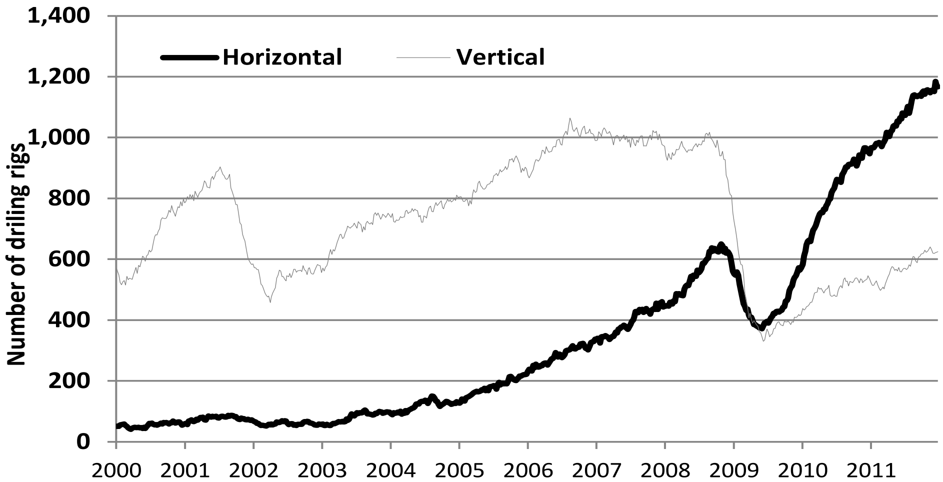
As technology development and application are fundamental to develop those resources that were not previously accessible, the combination of horizontal drilling and hydraulic fracturing is usually credited as the most influential element allowing the economic production of shale gas in the United States; nonetheless, other factors have been just as important to reduce the technical uncertainty associated. These elements include a generous endowment of resources with adequate geological characteristics, the availability of accurate geological information, the expertise developed over decades by the industry, the ample distribution of infrastructure, a widespread supportive service sector and the availability of water to perform the particular production techniques associated to shale gas.

Favorable geological characteristics. In spite of shale being the most abundant type of sedimentary rock, most of them will not bear any gas unless there is enough organic content from which hydrocarbons can be generated and to be considered for gas production, shale reservoirs need to hold appropriate characteristics of total organic carbon, thermal maturity, rock thickness, porosity, depth and pressure (Binnion, 2012, p. 4). The geological characteristics in the United States resources have contributed to the growth of shale gas production, unlike other regions such as Europe where conditions are less favorable (Gény, 2010, p. 27).

Precise geological information. Another factor supportive of shale gas production refers to the availability of resource assessments. By means of the accurate information on the resources that can be actually produced, more certainty is brought to the industry as the geological knowledge is improved to help producers optimize their projects, map prospective more accurately and find more easily "sweet spots", i.e. those particular areas within the shale in which the potential of production is larger. More important, as this information is periodically updated on the basis of the technology employed and the productivity of the wells in operation, the estimated resource base of shale gas has grown nearly fivefold from 2006 to 2010 (EIA, 2012).

Technological expertise. The development and application of directional –horizontal– drilling in shale, massive hydraulic fracturing and 3D microseismic mapping of deposits (Trembath, et al., 2012) made shale gas extraction economically viable, as larger volumes in the shale formations could be accessed in comparison to the conventional methods of production. As seen in Figure 1, the number of horizontal rigs increased steeply from 2005 and started growing again even after the drop in 2009, in contrast to conventional vertical rigs, which have been much less dynamic. Moreover, the development of the above technologies since the 1970s on one hand and the long experience and pooling of resources of the gas industry on the other, have favored the assimilation of the knowledge conducive to a rapid and efficient shale gas expertise in the United States. This aspect is critical, as shale gas formations differ from each other, even within the same play (EIA, 2012) and "what works in one reservoir or well probably will not be as effective in the next [...needing] a high degree of understanding to reach its full economic potential" (Parker, 2009, p. 50).

Figure 1
Rotary drilling rig count for oil and gas production by type in the United States, 2000-2011



Source: Baker Hughes (2013)

Extensive infrastructure. In step with the development of the gas industry over decades, the scale of the available infrastructure allowed the transport of shale gas output from the producing areas to the processing facilities and the consumers. Located across the United States territory, the extension, diversity, capacity and access conditions of this infrastructure are remarkable. By the end of 2008, there were more than 210 pipeline systems with an approximate length of 491,000 kilometers, numerous underground storage facilities as well as several international trade points, encompassing both pipeline interconnections with Mexico and Canada and several liquefied natural gas –LNG– facilities to receive and ship gas (EIA, 2007). More significant, the market's

competitive conditions and the prevalent regulatory framework provide a better access to infrastructure, ensuring an efficient allocation of gas to the markets.
Well-developed auxiliary and supporting services. In addition to the capabilities of the domestic gas industry, the existence of a strong oilfield services and equipment industry has supported the specific requirements of shale gas production, which include more drilling and fracturing, intensive mobilization of personnel, rigs, pressure equipment and transport of water and fluids to the well pad to perform hydraulic fracturing. On average, the truck trips associated over the different stages of a typical shale gas well, from the site termination until gas is produced, can range from 800 to 2,000 (European Parliament, 2011).

Water usage. For fracturing to be carried out, water is essential to keep the fractures open and let the gas flow from the rock to the wellbore. In the United States not only water has been generally available, but it has met the different requirements from the diverging shale gas regions across the United States, with estimations of typical wells demanding 10 million liters of water in the Barnett Shale, 12 million liters of water in the Fayetteville Shale and 15 million liters of water in the Marcellus Shale (Jenner & Lamadrid, 2013).

3.2 Economic

In addition to the technological breakthroughs allowing the extraction of shale gas, the capabilities of a competitive industry reacting to the forces of the market have been fundamental to drive the growth of production. As shale gas entails different requirements in comparison to conventional gas production, the plethora of producers, site builders and service providers in the market has been decisive to sustain the dynamism of the industry.

Competitive market structure. Unlike other countries with monopolistic or oligopolistic structures, decades of development and straightforward regulation have shaped a flexible and competitive gas industry in the United States that is predominantly made up by numerous small and medium independent firms. To provide an approximate idea of this level of atomization, as seen in Figure 2, nearly all of the 16,122 oil and gas producing firms in 2009 were considered small (less than 100 employees) and medium (more than 100 and less than 499 employees), and jointly accounted for 44% of the total employment in the oil and gas production, drilling and supporting activities (DOC, 2009). The role played by these independent firms was fundamental to take off output on a commercial scale, as they refined technology, established new practices, endured the market risks and performed intensive drilling across large areas with diverging geological characteristics. Furthermore, as these smaller independent operators became first-movers, it was until production was climbing that the largest oil and gas companies –the majors– started to get attracted to the business in spite of their initial lack of interest (Kaiser, 2012; Gény, 2010).

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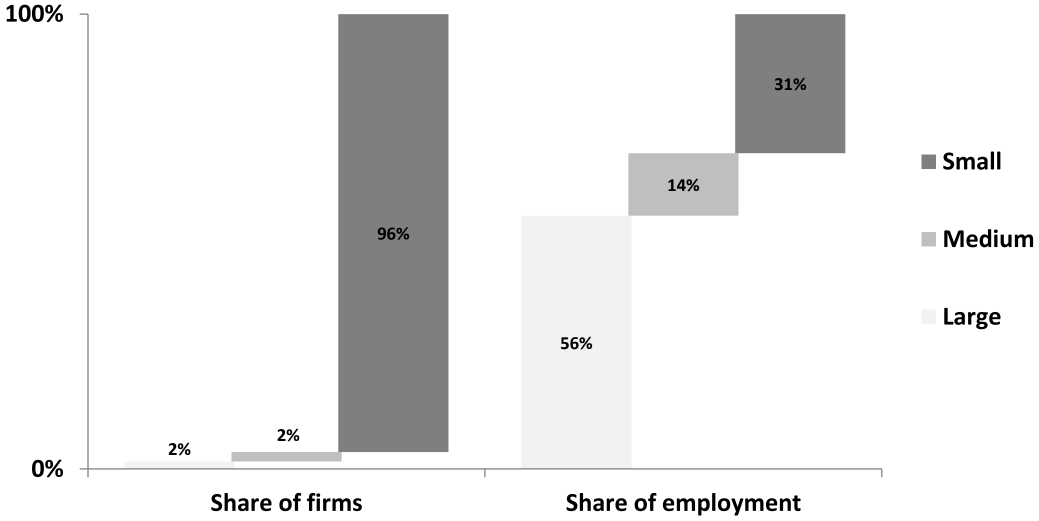
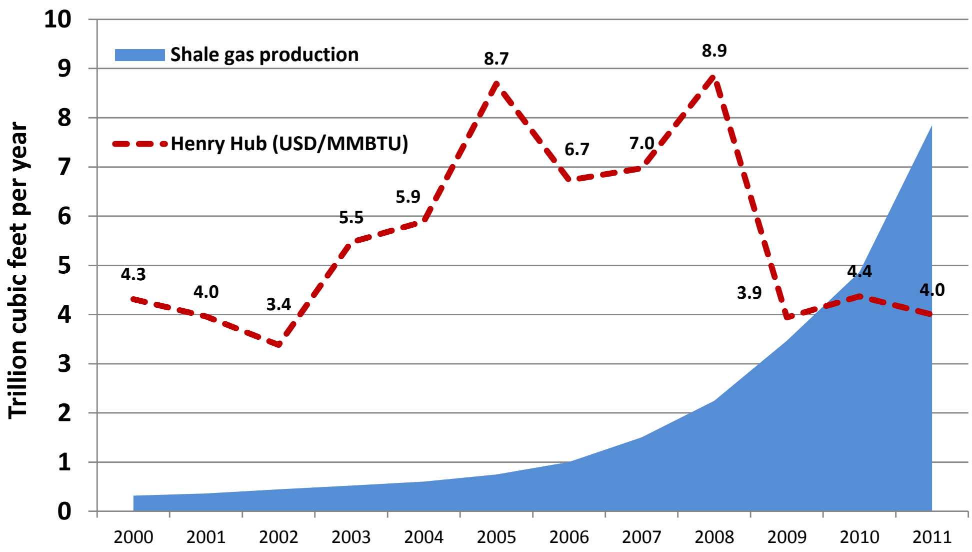
Figure 2
Oil and gas producing firms' structure and employment in the United States, 2009



Note: Includes firms in oil and gas extraction, drilling and support activities
Source: DOC (2009)

Competitive price setting. The competitiveness of the gas market industry is extensive to prices, which are deregulated and promote a more efficient transmission of information among producers and customers. Since the late 1970s and 1980s when policies were implemented to decontrol gas prices and with the eventual establishment of the Henry Hub as a reference for spot and future transactions, producers are highly responsive to the gas price. In consequence, shale gas production was able to prosper in response to the steady growth in gas prices from 2000, even in spite of the fall of prices from 2009, as shown in Figure 3.

Figure 3
Shale gas production in the United States and Henry Hub price, 2000-2011

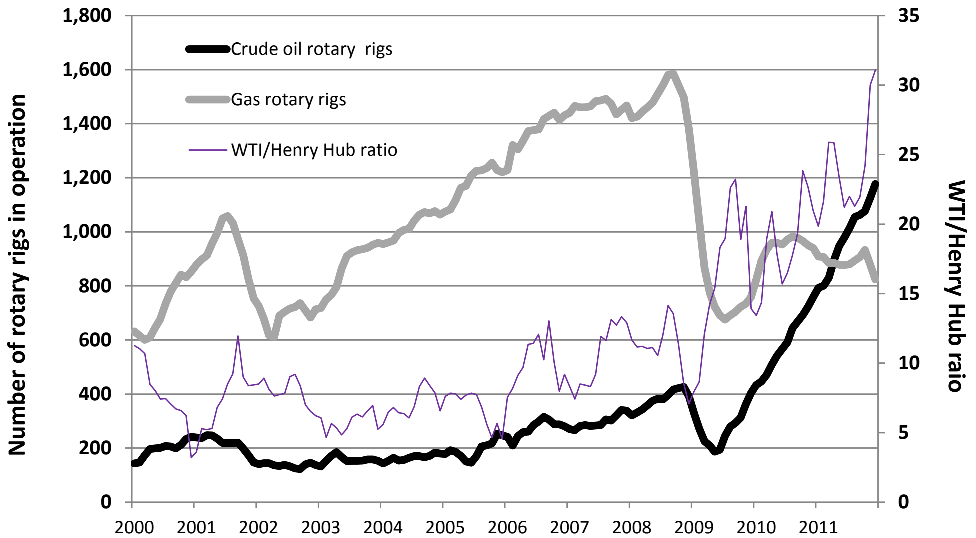


Source: EIA (2013b)

Production economics. In general, shale gas is more complex to produce than conventional gas and since shale gas wells decline more rapidly, not only wells need to produce at profitable levels, but a larger number of them is required to sustain output levels and recover the capital costs associated which are mainly exerted on well drilling and completion (Kaiser, 2012). Additionally, since the properties of shale reservoirs are very heterogeneous, accurate geological information and advanced technology conducive to the location of sweet spots to increase productivity are essential, adding up to the costs of production. Moreover, in an effort to make production cost-effective and minimize the land disturbance from the intensive drilling required, shale gas producers have devised a manufacturing-like process in which numerous shales are drilled from a single well pad, requiring an adequate provision of oilfield services, equipment and infrastructure. As explained above, the availability of water is fundamental to shale gas production, which not only increases costs, but requires appropriate road infrastructure for the numerous trucks carrying water and equipment to the production site. It is estimated that to surmount the lack of underground aquifers to source water for fracturing, producers may require between 350 and 1,000 truck tips to carry water to each well pad (European Parliament, 2011).

Owing to these costs, shale gas is profitable above certain price levels. As shown in Figure 4, in step with the ascending price environment from 2002 to 2008 shale gas production grew considerably, but due to the economic recession and the rising domestic gas supply that made prices fall, producers have gradually shifted their efforts towards wetter shale reservoirs in order to maintain the profitability of their operations and overcome the falling gas prices, underscoring the price sensitivity of shale gas economics and the flexibility of the industry in adapting to market conditions.

Figure 4
Rotary rigs in operation by production type and oil/gas price ratio in the United States, 2000-2011



Source: EIA (2013b)

3.3 Institutional

Within the context of the United States shale gas boom, other elements embedded are less salient but equally relevant as they have favored a suitable framework for the technical and economic factors to evolve. Specifically, a land regime that extends the private ownership to the resources in the subsoil; a well-established regulatory framework and the governmental support in diverse forms, have collaborated to bring certainty and stability to the industry and the different stakeholders involved.

Land and subsoil property rights. In contrast to most countries, where the State is the absolute owner of all the hydrocarbons on the territory, in the United States the private property of land is extensive to the mineral and hydrocarbons deposited in the subsoil, which allows landowners to lease or sell their land directly to producers. This foundation has been central to the rapid shale gas development, as producers are able to access land and resources with less difficulty. Furthermore, the economic retributions perceived by landowners foster less social opposition in comparison to places like Europe. The role of land access is so critical to the development of shale gas that even in the United States the influence of use patterns and local regulations on land access diminishes significantly the potential production, with approximately 31% of each county's land in Pennsylvania and up to 84% of each county's land in New York not being accessible to commercial production at the Marcellus shale formation (Blohm, et al., 2012).

Stable regulatory framework. The existence of a well-established and stable regulatory framework as a result of decades of evolution of the gas industry has reduced the uncertainty associated to the development of hydrocarbons, including shale gas. The deregulation of the gas industry commenced in the 1970s has allowed a more intensive use of natural gas for power generation purposes as well as the introduction of market-based prices and intense competition to drive production efforts. Currently, regulations applicable are mostly enforced by each State's legislation, with the federal authority in charge of the federal lands and transmission through interstate pipelines. As mentioned by Gény (2010), in spite of the divergent criteria from each state, these institutional arrangements have allowed the regulatory framework to adapt to local conditions, creating adequate conditions for shale gas development.

In terms of environmental regulation, shale gas production produces less greenhouse gas emissions and a smaller land surface impact than coal, but it still poses a larger threat in terms of water management and greenhouse gas emissions when compared to conventional gas (Jenner & Lamadrid, 2013). While it is up to the legislation of each State whether to allow shale gas development, the federal regulatory framework on environmental matters has been generally favorable, and particularly for the case of water, the exemption of hydraulic fracturing from the Safe Drinking Water Act has fostered a less stringent environment for water use that has sped up shale gas production.

Governmental support. Shale gas production would not have been possible without the participation from the government over decades, fostering the necessary technological development and providing incentives for producers when shale gas was still unfeasible to produce. The context of rising energy demand and shortages produced from relying on foreign energy suppliers during the 1970s draw the interest on exploiting unconventional resource bases that at the time were not commercially accessible. In consequence, the Eastern Gas Shales Project was a federal program that run up from 1975 to 1992 with the aim of finding technologies to make shale gas production economical. The program had a fundamental role in providing the technological basis that was later implemented and refined by producers, and as stressed in Soeder (2012, p. 10), it was composed by resource characterization, development of production technology and their transfer to the industry. In addition to these technological advances and borne from the Crude Oil Windfall Profit Act of 1980, the Alternative Fuel Production Credit, –known as Section 29 Credit– was a transitory subsidy set to promote domestic energy from unconventional sources. By providing USD 0.50 per thousand cubic feet of natural gas obtained from certain unconventional sources including shale, the Section 29 Credit allowed commercial shale gas production to sustain after its expiration in 2002.

4. Shale gas development in Mexico

Mexico started to push shale gas development more actively in the light of the initial assessment from EIA (2011) that suggested a resource base of 681 trillion cubic feet, a volume approximately 57 times larger than the country's proved reserves of natural gas in 2010. On the basis of these estimations alone, Mexico's energy authorities were enthusiastic about the outlook of shale gas for their country. With the United States as a reference and assuming this potential for granted, the Mexican Minister of Energy at the time stressed the role of shale gas to ensure gas supply in the long-term and touted it as a game changer, with significant economic effects entailed for job creation, attraction of investments and the competitiveness of the energy sector (Secretaría de Energía, 2011).

However, in comparing the factors leading to shale gas production, the United States and Mexico are worlds apart. On an institutional dimension, under the Mexican law, the State is the exclusive owner of all hydrocarbons deposited in the subsoil, including private lands. Accordingly, oil and gas activities are undertaken by the state-owned company Pemex, which is the exclusive operator of the oil and gas industry and is spread across the entire value chain. Nonetheless, Pemex's operations are very complex, as the company is driven in two directions: on one hand, as any other major oil and gas company, it aims to maximize the value of the hydrocarbons produced and meet the domestic fast-growing demand under increasing economic, environmental and technical constraints. On the other hand, with the current tax regime skimming off most of Pemex's profits to provide nearly one third of the government's revenue, the company must struggle with budgets that are increasingly insufficient to improve its economic efficiency.

These issues in combination with the power of the oil workers union –one of the most powerful in Mexico, if not the most powerful– and the historical political interference in Pemex's management have weakened its operational capacity and flexibility to meet all its challenges effectively.

In terms of the regulatory framework, the law forbids Pemex from associating with private operators in any scheme different to the payment of services, such as joint-ventures or production sharing agreements. In such an environment, investment is mainly restricted to subcontractors of services and equipment under Pemex's guidance. In the natural gas market, a major legal reform in 1995 strived for deregulation and the abolition of the vertical integration of Pemex and allowed more activities open to private participation, including distribution, transmission, storage –as LNG– and more recently, limited upstream activities in the form of a multiple services scheme. However, international experience shows that instead of paid contracts, operators prefer to share the risk with national oil companies in order to access and book reserves for the benefit of their shareholders. Stojanovski (2012) notes that when these blocks were opened, interest from operators was scarce, given the unattractive rates of return offered by Pemex. Regarding the government's role, its interest has been high as explained in Section 2, and its efforts are focused on supporting initiatives favorable to shale gas development.

From an economic perspective, in order to match Pemex's limited budget and operational capacity with its objective of value maximization, the company favors the more profitable oil projects over non-associated gas –not to mention unconventional gas which entails higher risks. Moreover, unlike the United States where private operators make their economic decisions depending on the prices and market dynamics, in Mexico, the oil and gas projects are centralized at the federal government through Pemex, and are afterwards subject to the approval of the Ministry of Finance. According to Stojanovski (2012) this situation has caused a higher concern with short-term performance and objectives at the Ministry of Finance, to the expense of investments on efficiency or technology with longer maturation timeframes but which ultimately are more important to the long-term viability an oil and gas company. This short-sighted vision might be also explained in terms of the preference for projects occurring within the presidential term of 6 years so to reap political advantages.

Given the higher capital investments required in comparison to conventional gas production and the current market environment of low gas prices in North America, profitability is more complex to achieve for shale gas projects. In any case, Pemex would need to find and develop wetter shale gas reservoirs to increase the value of the output and the return of its investments. Nonetheless, the slow pace of Pemex's exploratory activities and its operational and financial hurdles complicate the allocation of adequate funding to step-up its shale gas activities. As mentioned in Shields (2012), for shale gas production to be feasible there must be a minimal price to allow for cost recovery or a larger content of liquids at the reservoir, which raises the question as to whether oil or gas prices should drive shale gas development in Mexico and whether Pemex should maintain its efforts in pursuing shale gas or leave them once and for all to private operators, assuming this alternative is allowed through legal changes to the regulatory framework.

Adding to this complexity, the linkage to the Henry Hub in Mexico's natural gas rates in combination with the country's limited infrastructure, led to serious bottlenecks in the gas supply during 2012. Mexico is a natural gas net importer; with its natural gas demand growing 78% from 2000 to 2010, equivalent to an annual rate of 5.9% and with almost 20% being met by imports in the form of pipeline flows from the United States and as LNG (Secretaría de Energía, 2012c). As combined-cycle technology has been favored due to its environmental and efficiency advantages, In consequence, power generation has become the main driver for natural gas demand and the anchor of many infrastructure projects. Yet, in response to the descending Henry Hub prices in the United States, natural gas demand in Mexico surged during 2011 and 2012 especially from industrial consumers, that were unable to get more gas imported from the United States due to the limited range of the existing pipeline systems and their capacity saturation, bringing about major shortages of gas and the discontent of the customers, who were unable to rise their gas consumption in spite of the low prices. Just as with the main argument of this paper on the incompatibility of assuming other situations as replicable, the market failure on prices may be largely attributed to the use of a price reference with a context opposite to that embedded in Mexico. As pointed out in Michot Foss (2012, p. 119), the "static organization" prevalent in Mexico's energy sector has neither been able to design an internal price mechanism to replace the volatility of Henry Hub or to bypass the market power of Pemex and the power sector.

These issues reveal the natural gas market failures of Mexico and the technical limitations to be overcome if shale gas production is going to take off. Moreover, this issue evidences the chronic underinvestment of Pemex across the value chain of the oil and gas industry given its historical financial pressures and vertical integration (Tordo, et al., 2011). More specific, the legal restrictions to partner with other companies and the historical allocation of upstream investments on current production projects over exploration activities have eroded Pemex's expertise, technological capacity (Stojanovski, 2012; Tordo et al., 2011) and infrastructure.

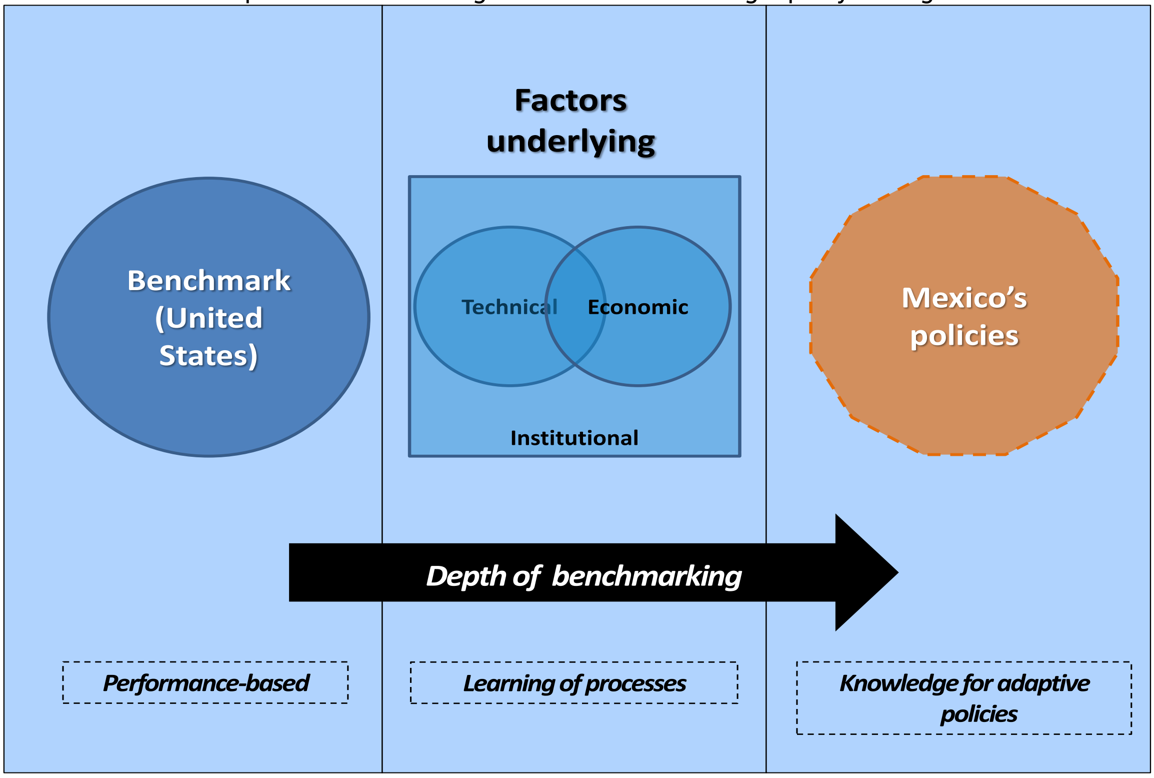
In addition, Mexico lacks of accurate geological information to assess the volume of shale gas resources that can be economically recoverable to reduce the risks associated to their production. In late 2012 it was announced that a geological assessment of shale gas resources would be carried out by Mexico's Petroleum Institute, in a project worth 244 million dollars drawn from a public trusting fund (Secretaría de Energía, 2012a) but given the nature and scale of this effort, the results will still take years to manifest. In comparison to the United States, where competition and attraction of talent provide competitive advantages to independent firms and shorten their learning curves, the lack of human capital has hindered Pemex's efficiency and access to technology, and as underscored in Stojanovski (2012, p. 318), "not only inadequate investment but also lack of human capital" represents the most critical constraint faced by the company. The lack of skilled workforce is the result of Pemex reaching its peak of employment (Tordo, et al., 2011), relying more on external services companies and contractors (Stojanovski, 2012) and having to pay bulky pension obligations.

Moreover, in terms of the supportive service industry required to carry out shale gas production efficiently, while Pemex has long had contracted diverse services for its own conventional gas operations and with an energy reform passed in 2008, to grant a little more flexibility for its contracting schemes, it is yet uncertain if specialized oilfield services and equipment would be fully available for Mexico's shale gas production due to the lack of incentives and sharing schemes. Furthermore, to perform the necessary hydraulic fracturing, there is considerable scarcity of water in the northeast part of Mexico, where the first exploratory shale gas wells have been drilled and prospective shale gas areas have been identified. Official sources (Conagua, 2012) deem the hydrological capacity as unavailable and rank the underlying hydrological region as the second lowest in Mexico in terms of its mean availability of water per capita.

On the basis of the contextual divergences and structural deficiencies in the gas industry in Mexico in comparison to the United States it is proposed that in order to use effectively the latter's experience as a benchmark for shale gas development, an examination of its processes and factors should be carried out to generate knowledge that can be ultimately applied to devise a shale gas strategy adapted to the Mexican context.

Although the discussion of the most suitable strategy for Mexico's shale gas development is beyond this paper's scope, while in a preliminary stage the benchmark of the United States shale gas experience has been used for aspirational purposes or performance monitoring, a further transition oriented to learning its particular factors and processes underlying could lead eventually to the development of a knowledge capable of differentiating its structural and transitory elements to assess what can be transplanted and must be changed in order to obtain the objectives desired for Mexico. For graphical purposes, the ideal result is shown is depicted graphically in Figure 5, with a different color and a more diffuse shape compared to the benchmark, to suggest that at the end is not replication what is sought –in terms of a same shape with the same color–, but rather an own policy stemmed from the knowledge gained with the benchmark selected, allowing the implementation of policies adapted to particular settings to obtain results more effectively. As an example, China has devised a holistic strategy reminiscent of the background presented in the United States and although commercial production has still not been achieved, China's growing energy needs and vast shale gas resources have elicited the government's support, deploying a multifaceted strategy adapted to its own context, of which results will take some years to come. The strategy encompasses resources assessment, applied research and development, fostering of international cooperation, improved regulation, promotion of investments and the establishment of joint ventures abroad to gain expertise and resources; altogether these efforts profile China as the most promising candidate for shale gas production after the United States (Lozano Maya, 2012).

Figure 5
Proposal of benchmarking evolution towards shale gas policy making



5. Conclusions

The findings of this paper illustrate the misleading effects in the employment of the rapid shale gas experience in the United States as a benchmark without accounting for the structural aspects and circumstances that made it possible. These challenges call for a deeper understanding of those factors, so that instead of striving for their imitation, they serve as an input to develop knowledge from which better policies and strategies are formulated to fit other contexts. Therefore, rather than using the United States experience alone as a performance-based benchmark supportive of political interests, its greater value lies in its use as a guide for the examination of the processes and factors conducive to those results, to ultimately develop adaptive knowledge oriented towards policies and strategies to fit other contexts and exploit unique opportunities in other countries.

In this particular case, in spite of Mexico's inferred shale gas resources and its proximity with the United States, energy policy makers must first overcome several structural deficiencies in the Mexican natural gas industry to foster a more favorable environment for production to take off, let alone to the extent of the United States. More important, in supporting shale gas without an adaptive strategy, Mexico jeopardizing its energy security mandate, by depending on resources that might eventually be costlier or take much longer to develop in comparison to the expectations and initial plans stemmed from a strictly performance-based approach. To avoid such failure, the use of this benchmark should aim to "look to other political systems for knowledge and ideas about institutions, programs and policies and about how they work in other jurisdictions" (Dolowitz & Marsh, 2000, p. 7) in order to build knowledge and capabilities adapted to Mexico's context.

The development of domestic natural resources and shale gas in particular, is a complex task that requires appropriate planning, financial and technological capabilities, adequate infrastructure, favorable regulation and governmental support. Although the use of the United States as a benchmark was initially used to hype the potential benefits of shale gas production for Mexico's energy security and economy, once the first steps were carried out, the complexity in achieving similar results was realized, as the context between the two countries is very different. This case illustrates that the use of a benchmark may mislead policy makers to assume replicable outcomes without considering the processes involved. On the other hand, the use of a benchmark as a source of knowledge and parameter of the costs and timeframes associated in achieving a certain outcome on another environment might be more helpful.

This paper might be helpful in providing a framework of analysis to the use of such reference and in presenting evidence on its effects from an actual case. While this paper might be more relevant for stakeholders related to Mexico's energy policies or shale gas development, it might as well offer valuable insight for policy makers and officials in other countries driven by the same benchmark towards the strategic development of its shale gas resources. Finally, this paper hopes to strengthen the academic research on the United States shale gas development and its effects in other places.

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