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Looking through the prism of shale gas development: Towards a holistic framework for analysis

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ABSTRACT

In consideration of the size and geographic concentration of proved conventional gas reserves and the potential role of natural gas to reduce the carbon intensity of energy demand, unconventional gas resources have become increasingly important to expand natural gas supplies. Shale gas in particular has gained international relevance in recent years, largely due to its rapid development and game-changing effects in the United States and its wider and larger distribution worldwide over conventional gas reserves; nonetheless, developing shale gas in other countries has been much slower, as it presents increased risks that span multiple interlinked dimensions and differ across the perceptions of an ample array of stakeholders in diverse contextual settings. The premises presented in this paper attempt to advance a holistic framework for shale gas development which comprises several factors grouped in three major interlinked domains: access to natural resources, industry capabilities and governance. To empirically test its premises under contextual variations, the framework is further used to consistently analyze the cases of Canada, China and Mexico. Findings confirm the interdisciplinary nature of shale gas development and suggest that governance is the most critical domain to bring about changes that improve the management of underlying risks.

1. Introduction

The energy landscape has changed rapidly and drastically in the last decades. In addition to the robust growth of energy demand, especially in developing countries, the rising importance of climate change has called for the use of fuels that emit less greenhouse gases, in particular carbon dioxide. To meet these goals, one of the major actions implemented in many countries consists of an increased use of natural gas in the primary energy balance, as it leads to lower carbon dioxide emissions over other fossil fuels and its use along with certain renewable energy sources fosters an energy mix less reliant on coal and oil and more supportive of cleaner technologies.

However, a larger natural gas supply in the world is currently constrained by the geographic concentration of proved reserves of natural gas in a small number of countries and by the economic and energy security trade-offs resulting from the growing dependency on imported supplies. In recent years, however, the outlook for natural gas markets was dramatically affected by the advent of gas volumes produced in the United States at an unprecedentedly large and rapid scale. These supplies are predominantly the result of shale gas, or unconventional natural gas produced from shale formations, which has transformed the economy of the United States and has brought about several positive effects that include lower carbon emissions, economic spillovers in local communities where development of this resource is taking place, and energy security benefits manifest in the country's emergence as an exporter of natural gas in the form of liquefied natural gas (LNG).

This experience in combination with preliminary geological assessments [15,16] indicating a more extensive and abundant global distribution of shale gas over current proved reserves of conventional gas spurred avid interest across the world in the last five years, with several countries embracing the potential development of their own shale gas resources. Nevertheless, considerable uncertainty remains, particularly in Asia and Europe [5,55], and by the end of 2015, shale gas production outside of the United States only entered commercial stage in Argentina, Australia, Canada and China [6]. In all these countries, shale gas was produced at insufficient low growth rates and volumetric magnitudes to produce any positive energy or economic effects, let alone to similar levels to the United States.

To date, the study of shale gas development predominantly follows two broad research lines. One strand centers on the analysis of single countries [11,13,34,64], but the outcomes of these studies

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are usually too specific and idiosyncratic to allow comparisons and identify common lessons and points of convergence among them. Given the role of the United States as the earliest, the most successful and the best documented example of shale gas production in the world, another major strand of research attempts to identify the underlying drivers of this experience that would facilitate its reproduction in other countries [55,58,60], notwithstanding the drastically different settings in the other jurisdictions interested in or already engaged in shale gas development. In consequence, the study scope of worldwide shale gas development remains too limited and fragmented, and a reconciliation of all these insights into a cohesive framework with validity beyond the United States is notably absent from the academic literature.

This paper aims to unify these approaches by examining the development of shale gas from a more consistent perspective. In so doing, this paper rests on the main premise that shale gas development is fundamentally an interdisciplinary activity; for which, its study must be inclusive, especially for comparative purposes. The development of this argument not only addresses the main topic of this special issue, but also several of the key areas pointed out by Sovacool [50] in the field of energy research and social sciences, namely about the effects on energy systems from social, political and economic configurations, from institutions and non-state actors, and from diverse social groups and stakeholders.

Section 2 of this paper examines the multidimensional nature of shale gas development and the challenges in devising a homogeneous view applicable worldwide, in order to propose in Section 3 a systemic and holistic approach in the form of a generic framework. Section 4 tests the framework empirically through its application in the brief analysis of shale gas development in Canada, China and Mexico, while Section 5 concludes with the main findings and implications.

2. The multidimensionality of shale gas development

Shale gas is generally more complex and multifaceted to produce than conventional gas, and although the first commercial natural gas well drilled in the United States in 1821 was actually a shale gas well [12], the technology and production methods at the time could not make the extraction of shale gas economical, particularly when compared with relatively inexpensive, easy-to-extract and abundant conventional gas. The advent of horizontal drilling and hydraulic fracturing and their parallel deployment in the 1980s finally helped to release the gas in the shale formations in a cost-effective manner.

Despite these advances, shales show ample geological heterogeneity and a steeper declination rate, with shale gas wells typically exhausting more than half of their gas output in the first few years [10]; additionally, the quality and quantity of shale resources inferred in resource assessments and the exact location of the zones with the highest productivity (‘sweet spots’) or richer content in liquids of higher economic value remain uncertain until actual exploratory drilling occurs [7]. In order to maintain or increase gas production levels cost-effectively, developers must drill and hydraulically fracture a larger number of wells over shorter lead times, which exceeds the amount of technology inputs, water, chemicals, surface facilities and human resources typically observed in conventional gas production, demanding in turn the creation of agile supply chains formed with external suppliers of specialized services [20]. In sum, because of this profile, early shale gas development generally presents more intricate technical and operational challenges, with higher economic costs and lower profitability margins [2,5].

More relevant, a faster pace and larger scale of development amplifies land, water and environmental impacts, and even though some of these impacts are common with conventional gas development, what makes shale gas distinctive is that the intensity, magnitude and extent of its operations pose cumulative risks with effects still not fully understood that are insufficiently addressed by conventional risk management and regulatory approaches [18,62]. Performed at a large scale as in shale gas production, even a long-established industry practice like hydraulic fracturing creates a non-point source effect whereby the density and length in the rock fractures complicates the accurate traceability and assignment of liabilities to incumbent operators in case of groundwater pollution [24]. Furthermore, shale resources are more widely dispersed, for which development stretches over more extensive areas and tends to take place in proximity to communities with high population densities that had little to no previous involvement in equivalent activities. These issues increase social tensions and the potential to result in conflicts.

Compared with conventional gas, the risks derived from shale gas development span quantity and quality issues in groundwater and surface aquifers, including those apt for human use; emissions of toxic pollutants and greenhouse gases (most noticeably methane) that affect overall air quality; induced seismicity; ecological damage to natural habitats and wildlife; occupational hazards for workers and personnel adjacent to production sites; public health effects; and impacts to community life from the increased noise, dust and road traffic generated by ongoing operations. Other negative externalities refer to boom-and-bust cycles, and losses in the quality of life, property value and visual aesthetics [22,47,62].

In essence, shale gas development transcends purely technical and economic domains, to interweave environmental, social, and political risks that interlink a larger number of stakeholders. Therefore, to sever any of these links from shale gas development renders incomplete the prism of risks and stakeholders involved, which has deleterious effects, especially for comparative, strategy-making and policy-making purposes. In spite of this, the academic discussion about shale gas development largely centers on specific attributes that only capture part of these risks, overlooking several relevant domains and their corresponding interrelations. A study of the academic literature devoted to shale gas between 1990 and 2014 confirms that most research has been highly concentrated on engineering, technical and geological subjects [59].

In line with these arguments, scholars have stressed the need for a multidisciplinary approach different from that applicable to conventional gas, in order to overcome the multiple challenges and risks associated with shale gas development [2,47] and favor the shift of energy research from a few specific domains towards a more inclusive problem-based approach [51]. In addition to this fragmented scope, the majority of academic studies, including those attempting to identify the major forces behind shale gas development [1,5,58,60,53] are usually restricted to the discussion of single countries, which has further contributed to hamper the applicability of their findings to other settings.

In particular, deliberately or tacitly, the United States became the reference for shale gas development around the world. Deliberately, the United States federal government formally launched in 2010 its ‘Global Shale Gas Initiative’ to provide help to countries looking forward to developing their own unconventional gas resources for energy security and environmental reasons [43]. Tacitly, the pioneering experience of the United States became a role model in countries like Mexico [33] and the United Kingdom [22].

Empirical evidence however, has demonstrated the increasing difficulty in making shale gas production commercially viable beyond the United States. Despite the early positive expectations about shale gas, the experiences in the last few years in a number of countries with significant inferred volumes of shale gas have yielded poor results and have presented more considerable risks than conventional gas production. Examples of challenges spanning