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North American natural gas model: Impact of cross-border trade with Mexico

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ABSTRACT

Natural gas gained significant attention due to its low carbon emissions and competitive prices in North America relative to other energy sources. The Annual Energy Outlook 2015 projects the U.S. as a net exporter by 2017. Recently, Mexico launched its energy reform, aiming to expand domestic production by opening the market to private investors. The success or failure of these policy changes will impact the development of the natural gas market in North America.

To analyze possible pathways of the Mexican energy reform, we develop the North American Natural Gas Model (NANGAM). NANGAM is a long-term partial equilibrium model that allows for endogenous infrastructure expansion and non-linear cost functions. NANGAM is calibrated using the most recent data available from U.S., Canadian, and Mexican sources.

We find that, in order to reduce pipeline imports, Mexico depends on economic incentives that lower barriers to infrastructure investment and keep production costs at competitive levels. If reforms to guarantee these incentives are not successfully implemented, growing gas demand in Mexico will be satisfied by further supply from Texas and neighboring states. This will cause a ripple-effect of increasing production in other regions in the U.S. and a shift in trade flows across the continent.

1. Introduction

The shale boom and new power plant regulations recently announced by the U.S. Environmental Protection Agency (U.S. EPA), aiming to curb greenhouse gas emission and mitigate global warming, have stimulated substantial academic debate and numerical simulation exercises to understand the future role of natural gas in North America [e.g., 1, 2]. Furthermore, the U.S. is expected to become a significant net exporter of natural gas over the next years [3], as China and Mexico are shifting from its reliance on coal to cleaner alternatives [3,4]. However, to date, there is very little academic focus on the role of Mexico on the North American natural gas market.

Natural gas demand grew by 64% in Mexico between 2004 and 2013, primarily led by the increasing consumption from the electricity sector. Due to a lack of investment incentives, production did not increase at the same pace as demand, and proven gas reserves in Mexico decreased from 2.0 trillion cubic meters in 1993, to 0.4 tcm in 2003 and 0.3 tcm in 2013 [5]. Production growth of natural gas in the South-Southeast Mexican region is projected to be 0.4% per year through 2019 [6]. Mexico's state-owned petroleum company, PEMEX, consumes increasing portions of this gas production for exploration, production, and refining activities.[1] Combining these circumstances with limited future LNG importing capacity, cheaper pipeline imports from the U.S. are crucial to meet growing national demand [7,8]. Natural gas from the U.S. accounted approximately 69% of total imports in 2014 [9]. Pipeline flows from the U.S. to Mexico averaged 2 billion cubic feet per day (Bcf/d) that year. Projects in Mexico to increase pipeline capacity are underway. These new pipelines are expected to import more than 5 Bcf/d of

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[1] See further details at https://www.eia.gov/todayinenergy/detail.cfm?id=16471. Accessed on January 19, 2016.

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natural gas by 2020 [8,10].

In order to promote natural gas production in Mexico and reduce reliance on U.S. imports, on December 20, 2013, the energy reform was approved by the Congress of the Union, modifying articles 25, 27 and 28 of the Mexican Constitution [11]. The legal framework established under this reform involves not only a transformation of the hydrocarbons (oil and gas) sector, but also a structural change of the national power sector [12]. In this manuscript, we mainly focus on the reforms in the natural gas sector. Details of the regulatory framework for oil and natural gas markets can be found in the annual SENER (*secretaria de energia*) report [13], Section 1.

The energy reform initiative opened up new opportunities for the private sector in the upstream (exploration, development, and production) and downstream (refining and marketing of the resource) sector of the oil and gas industry. The energy reforms also call for empowering the regulatory agencies of SENER and The National Hydrocarbon Commission (CNH), and for creating the *Agencia de Seguridad, Energia y Ambiente* (ASEA), which seeks to guarantee safety of the population and the integrity of the environment[2] [8].

Towards a better understanding of the future of the natural gas sector in North America, models need to account for a better representation of Mexico. Better depiction of Mexico is needed due to its increasing role in North America driven by the energy reform. Also, models need to be able to endogenously determine new infrastructure development as new pipelines and expansion of existing ones are underway. For models to be a valid representation of current trends, they need to be calibrated to up-to-date conditions, in particular focusing on new capacity investment and the shift of regional trade patterns, as the natural gas market is continuously changing. The main goal of this effort is to present a model with these features, entitled the North American Natural Gas Model (NANGAM). We use NANGAM to study the impacts (e.g., new capacity built and change of flows in the network) of the Mexican energy reform on North America. NANGAM is a long-term partial-equilibrium model of the natural gas markets of Canada, the U.S., and Mexico. This is the first natural gas model that considers a high granularity in terms of geography (regions) and infrastructure (pipelines and supply) in North America, specifically for Mexico. Details of NANGAM are presented in Section 2. The main characteristics that make NANGAM suitable for this study are:

1. Endogenous infrastructure capacity expansion for all players (suppliers, storage operators, and arc operators) with better representation of the cost (supply) function.
2. Representation of the Mexican gas market by five consumption-production regions and infrastructure (pipelines and supply).
3. Up-to-date data used for calibration and base case scenario (e.g., shale gas boom, higher Mexican demand and imports, and increased projected natural gas production in Alaska).

1.1. Literature review: natural gas models for North America and the world

Existing models in the literature, while also being large-scale numerical applications, do not consider a sufficiently high level of detail of the infrastructure in North America, in particular for Mexico. For instance, one of the first natural gas models with focus in North America is the Gas Trade Model [GTM, 14]. The GTM was developed in the late 80's and considered Mexico as a single demand-production node. A large scale linear complementarity model for North America was presented in Ref. [15]. Even though the model has a high granularity of the U.S., the Mexican gas market was not taken into account. Also, this model did not consider endogenous capacity expansion decisions. The World Gas Model (WGM) described in Refs. [16], an extension of the work developed in Refs. [15,17], considered six regions in the U.S and treated Mexico as a single region. The authors in Ref. [18] used the WGM to study the impact of a shale producer having market power. Authors expanded the number of regions in the U.S. to 10, but kept Mexico and Canada as single regions. A model similar in scope to the WGM is the Global Gas Model [GGM, 19], but it includes more features and functionality with regard to stochastic scenarios. The Rice World Gas Trade Model (RWGTM) [20] attempted to better describe Mexico. However, only two regions were considered. Of all these models, none of them was developed to study policy implications and regulations in Mexico. Their particular focus was on the U.S. or global market.

Table 1
Comparison of models.

Model	Mexican regions	Capacity expansion	Market power
NANGAM	Five regions	Endogenous[a]	Yes
GTM [14]	Single node	None	No
Gabriel et al. [15]	Not considered	None	Yes
WGM [16]	Single node	Endogenous[b]	Yes
GGM [19]	Not considered	Endogenous[b]	Yes
GaMMES [21]	Not considered	Endogenous	Yes
FRISBEE [22]	Not considered	Endogenous[c]	No
GASMOD [24]	Not considered	Endogenous	Yes
GASTALE [25,26]	Not considered	Endogenous[c]	Yes
ICF GMM	Not considered	Exogenous	No

[a] Endogenous capacity expansion is modeled for all market participants.
[b] Endogenous capacity expansion is not considered for natural gas suppliers.
[c] Endogenous capacity expansion is considered for natural gas suppliers only.

The Gas Market Modeling with Energy Substitution (GaMMES) developed in Ref. [21] (a generalized Nash Cournot model) did consider endogenous decisions for capacity expansion and long-term contracts but it was used to study the northwestern European natural gas trade. The FRISBEE model [22] is a recursively dynamic partial-equilibrium model with 13 global regions. However, Mexico is not considered among them. The model developed in Ref. [23] represents Europe by 15 nodes, of which eleven are European union (EU) member states (or aggregates thereof). The rest of the world is aggregated into thirteen nodes by continent or major regions. Models that have a focus on the European market include GASMOD [24], GaMMES [21], described earlier, and GASTALE [25,26]. Other models with a European focus that analyze imperfect competition a la Cournot among gas producers include [27–29]. Finally, Gridnet (www.rbac.com) and ICFs Gas Market Model (ICF GMM[3]) offer high details on U.S. coverage, but are designed to support short- and medium-term decisions. See Table 1 for a summary of the most relevant models discussed here. A different comparison of gas market models can be found in Ref. [30].

As mentioned above, different models have been used to study the global and the North American gas market (e.g., [15–18,30]). However, all of these models treat Mexico as a single node, or exclude it completely. A model with a better representation of the Mexican natural gas industry and infrastructure is essential to study the implications of the Mexican energy reform on North America. For instance, to date, none of the models currently available can determine the regional implications of production capacity

[2] http://www.asea.gob.mx/?pageid = 9894.

[3] http://www.icfi.com/insights/products-and-tools/gmm.