www.cya.unam.mx/index.php/cya

Contaduría y Administración

Accounting & Management

Contaduría y Administración 66 (3), 2021, 1-30

The effects of natural gas market reforms in Mexico on natural gas prices, sales, and foreign trade

Los efectos de las reformas del mercado de gas natural en México sobre sus precios, ventas y comercio exterior

Francisco Ortiz Arango[1*], José Carlos Ramírez[2], Juan Rosellón[1,3]

[1]FCEE, Universidad Panamericana, México
[2]Profesor-investigador del Departamento de Estudios Económicos de El Colegio de la Frontera Norte, México
[3]Departamento de Economía del Centro de Investigación y Docencia Económicas, México
[3]German Institute for Economic Research, Germany
[3]Center for Energy Studies, Rice University, United States of America

Received February 6, 2020; accepted August 27, 2020
Available online January 18, 2024

Abstract

The objective of this article is to evaluate changes produced by regulatory reforms in the Mexican natural gas market between 2009 and 2018. For this purpose, various unit tests and structural breaks are carried out on the series of volumes and prices of natural gas that describe their behavior in national and international markets. The results of the statistical analysis support that all series are subject to structural changes in tendency and intercept between 2016 and 2017, so that they show a unit root. Consequences of such behaviors are relevant the since shocks on series are permanent and due to the start of the reform.

JEL Code: D21, D47, L50, L51, Q41
Keywords: regulatory reform; natural gas; time series analysis; structural change; Mexico

[*]Corresponding author.
E-mail address: fortizar@up.edu.mx (F. Ortiz Arango).
Peer Review under the responsibility of Universidad Nacional Autónoma de México.

http://dx.doi.org/10.22201/fca.24488410e.2021.2841

http://dx.doi.org/10.22201/fca.24488410e.2021.2841

Resumen

El objetivo de este artículo es evaluar los cambios producidos por las reformas regulatorias en el mercado del gas natural mexicano entre 2009 y 2018. Para tal efecto se realizan diversas pruebas unitarias y de quiebres estructurales a las series de volúmenes y precios del gas natural que describen su comportamiento en los mercados nacionales e internacionales. Los resultados del análisis estadístico sostienen que todas las series experimentan cambios estructurales en tendencia e intercepto entre 2016 y 2017 y, por tanto, presentan raíz unitaria. Las consecuencias de estos comportamientos son relevantes porque los shocks introducidos en las series son permanentes y atribuibles a la puesta en operación de la reforma.

Código JEL: D21, D47, L50, L51, Q41
Palabras clave: reforma regulatoria; gas natural; series de tiempo; cambio estructural; México

Introduction

The Mexican government undertook two regulatory reforms in 1995 and 2013 to develop a robust market in the natural gas sector. Unlike other international cases, from the outset these reforms have faced the political and legal limitations inherent to the regulation of a market dominated by state-owned companies: Petróleos Mexicanos (PEMEX), in the hydrocarbons sector, and the Federal Electricity Commission (CFE), in the electricity industry.

As is known, before the first reform, PEMEX had a monopoly on all phases of hydrocarbon production. The company then functioned as the national market's owner, operator, and regulator. This monopolistic position led it to privilege the most profitable products in its production portfolio, in this case crude oil, and to relegate others, such as natural gas. The lack of investment in the natural gas sector, which was strategically considered less important than crude oil, was partly explained by the existence of fuel oil which, at that time, represented the main substitute for natural gas for industrial consumption. However, although the latter energy source was cheaper than natural gas, it was very polluting due to its high sulfur content. The growing need for cleaner energy sources increased the demand for natural gas in the early 1990s (9% per year[1]) to such an extent that changes in the regulation of prices, tariffs, and permits were necessary to attract private investment in the distribution, storage, and commercialization of the product.

Specifically, in 1992, the first steps were taken to reform the energy sector when private investment in power generation was allowed. In October 1993, the Energy Regulatory Commission (CRE; Spanish: Comisión Reguladora de Energía) was created within the Ministry of Energy to regulate the electricity sector only for self-consumption, cogeneration, and independent energy projects that required

[1]The 1995 forecast growth rate for natural gas demand was 42% from 1997 to 1999, and 10% per year from 2000 to 2007.

selling their generation surpluses to the CFE. Two years later, the natural gas market reform opened the market to private participation. The liberalization of this market was particularly complex, as it combined natural monopolies with potentially competitive activities. Production was protected as a monopoly, even though competition was technically possible. Gas transmission and distribution were maintained as natural monopolies, and gas commercialization was recognized as a contestable market.

This reform was part of the changes brought about by the economic crisis of the 1980s, which forced some sectors, such as infrastructure, to undertake major transformations to promote economic growth. The transformations included a deregulation plan to eliminate artificial barriers to entry and exit in contestable markets such as transportation, ports and telecommunications, the privatization of state-owned companies, including the Telmex telephone company, and the opening of the natural gas sector to private investment.[2]

Years later, the 2013 reform substantially increased the liberalization of the natural gas sector by initiating an ambitious program aimed at addressing the growing demand for the product in a situation of low oil production, high electricity generation costs, lags in the production of renewable energies, and non-technical losses in electricity distribution and transmission. The magnitude of this reform was significantly more far-reaching than that of 1995 because it covered almost all the sector's activities: crude oil, petroleum products, and electricity. Its enactment required changes in three constitutional articles (25, 27, and 28), twenty-one transitory articles, and nine new laws regulating the activity of the parastatals (i.e., the Hydrocarbons Law, PEMEX Law, CFE Law, and Electricity Industry Law), as well as the reformulation of twelve additional laws.[3] The provisions promoted the vertical disintegration of PEMEX and CFE and the creation of state production entities, which allowed the establishment of contracts and joint ventures with private national and foreign companies in different fields of the country's energy sector.

The cumulative results of both reforms are not always easy to measure but are nonetheless impressive. For illustration purposes, it is worth noting, for example, that from 11 347 km of gas pipelines in 2012, the gas transportation network increased to 16 758 km by September 2019, with an additional 2 131 km under construction[4]. As part of this expansion, permits were granted to private companies to operate the network with a speed never seen before, as 566 permits were already in force by June 2017:

[2]A detailed discussion on the deregulation of the natural gas sector is Rosellón (1998). An interesting reference related to the privatization process is Rogozinski (1999).
[3]See Ramirez and Massa (2020)
[4]Report: Status of Natural Gas infrastructure. October 2019. Energy Secretariat. Pp. 4. https://www.gob.mx/cms/uploads/attachment/file/497827/Estatus_de_gasoductos_octubre_2019.pdf, accessed June 9, 2020.

461 in operation and 105 on hold[5]. Several of these transmission-pipeline permits were granted to supply gas to new independent power generation plants.

Notwithstanding the progress made, however, it is clear that there are many problems related to the country's production and supply of natural gas. Production has been falling since 2010, mainly due to low investment in exploration and drilling[6]. According to January 2018 data, Mexico has just 10 022 trillion cubic feet of proven natural gas reserves, yielding a reserve-to-production ratio of 5.4 years (Franco, 2019). Its volume depends on oil extraction in the country's southeast and offshore areas, where about 10% to 15% of the total gas extracted is vented. To meet the unsatisfied domestic demand, the country imports from the U.S.A. about 85% of the gas consumed at a cost of approximately 11.7 billion dollars in 2017.[7] This dependence is a risk not only for well-known geopolitical reasons but also because it may affect the supply at reasonable prices of a product that is essential for the country's energy matrix. In 2017, natural gas accounted for 39.25% of total primary energy consumption in Mexico (BP, 2019), of which Pemex consumed 7.1%, while the rest went to industry (33.5%), electricity generation (31.2%), and commercial and residential use (28.2%).

This paper aims to evaluate the impacts of the reform process of the natural gas market—initiated in 1995 and culminated in 2013—on its prices, values, and volumes of domestic sales and foreign trade. The statistical techniques included in the evaluation comprise stationarity and structural breaks tests (Andrews-Ploberger and Zivot-Andrews) for the different series between 2009 and 2018. The idea is to differentiate the series of variables that are reactive to changes in regulation and that modify their trend from those that are not or that maintain their trend. The paper's main conclusion is that all series experience breaks in intercept and trend that permanently modify the direction of the trajectories between 2016 and 2017.

The paper is organized into three additional sections. Section 2 presents the essential aspects of the 1995 and 2013 reforms. Section 3 analyzes and interprets the behavior of the series of real total prices, prices to the electricity sector, prices to industry and distributors, volume of imports, value, and volume of foreign trade in the Mexican natural gas market. Finally, the conclusions summarize the main results and implications of the study.

---

[5]Report: Number of permits and registrations by sector, by activity and by type. Energy Regulatory Commission. June 2017. https://datos.gob.mx/busca/dataset/numero-de-permisos-y-registros-por-sector-por-actividad-y-por-modalidad accessed August 12, 2019.
[6]According to the table Hydrocarbon production, reserves, and refining capacity in select countries (1st part). Energy Information System, Energy Secretariat. http://sie.energia.gob.mx/movil.do?action=back&node=PMXB2C03 accessed August 24, 2019.
[7]Ramírez and Massa (2020)

Energy reforms of 1995 and 2013

A relatively ambitious reform of the natural gas sector was carried out in 1995. It allowed private investment in new natural gas transmission, distribution, and commercialization projects but maintained PEMEX's monopoly on production. The reform also had an institutional scope by granting the CRE the powers of an independent regulatory agency, which allowed it to issue the statutes of the new design of this market through the Natural Gas Regulation. [8]

In 1995, the legal framework for the natural gas industry was amended to establish the general principles for its development. Thus, the Natural Gas Regulations became the regulatory framework specifying the organization, operation, and regulation of the industry in the long term. The most important market players in the sector were transporters, storage facility operators, distributors, marketers, consumers, and PEMEX. Incentives were then created for private companies to invest under CRE regulations. While the Energy Secretariat became the public policy leader of the Nation's energy resources, PEMEX was dedicated to operating activities in the sector, and the CRE was separated from the Energy Secretariat to function as an independent agency.

In 2013, a constitutional reform of the hydrocarbons sector, including oil and gas, was implemented to substantially increase private participation in the entire Mexican energy sector. This reform continued the 1995 reform by consolidating the National Hydrocarbons Commission (CNH; Spanish: Comisión Nacional de Hidrocarburos) and creating additional regulatory agencies: the Safety, Energy and Environment Agency (ASEA; Spanish: Agencia de Seguridad, Energía y Ambiente), and the National Natural Gas Control Center (CENAGAS; Spanish: Centro Nacional de Control de Gas Natural). The objective of the reform was to promote the complementarity of functions and responsibilities between the new public agencies and the CRE to establish an adequate legal framework that would foster the sector's growth by coordinating all areas of the industry. In particular, CENAGAS became the owner of PEMEX's gas pipeline system (breaking the vertical integration in the natural gas industry) and the agency in charge of carrying out the independent operation of this system.[9]

The 1995 and 2013 reforms are not, in fact, parts of the same political or institutional process. However, the 2013 reform can be understood as a continuation of the 1995 reform, especially in the institutional area. Each of these is discussed in more detail below.

[8]The 1995 reform was not a constitutional reform. See Halpern and Rosellón (2001).
[9]The PEMEX pipeline system coexists with other private and CFE subsystems.

Energy reform of 1995

From the outset, the 1995 Institutional Reform sought to have decision makers implement a public policy of divestiture and open access to natural gas transmission, distribution, and storage pipeline networks. In particular, the new private distributors were expected to allow open access to their distribution networks (commercial bypass). This spirit of the Reform was intended to ensure competitive conditions in the supply of goods and services throughout the natural gas industry.

One of the first actions undertaken by this Reform was the creation of the Natural Gas Regulation (or, simply, the Regulation), through which new operating rules were established in the natural gas market that, in the end, opened the doors to private participation. In that spirit, the Regulation sought to counteract PEMEX's dominant role by allowing other market participants a certain degree of vertical integration. However, vertical integration between transmission and distribution was restricted to cases where the transmission (distribution) permit was necessary for a distribution (transmission) project. Regarding international trade, the Regulation allowed free imports of natural gas from the United States without import licenses or duties.

Policymakers were then faced with the problem of deciding how to regulate the price of first-hand sales and how to distribute natural gas. After considering international experience, they chose the alternative of setting the price according to an international benchmark. This benchmark was given by the price of natural gas in a market in the southwestern United States (Houston Ship Channel or Henry Hub), adjusted for the cost of transmission and storage of gas in Ciudad Pemex, Tabasco. PEMEX had already used a similar mechanism before the 1995 reform, but the 1995 Regulation developed the details of this instrument intending to foster competition in the Mexican market.[10]

Additionally, there were barriers to entry in the construction of natural gas distribution networks that, according to the Regulation, had to be combated to achieve the harmonious development of the distribution systems in Mexico. The regulators then decided to grant exclusivity periods of 12 years from the initial auction of an exclusive natural gas distribution zone (franchise). However, the distributors' exclusivity only referred to the piping of natural gas within the zone. Consumers could then gradually perform a physical bypass of the distributor's network, or a commercial bypass of the distributor's network immediately.[11] True to the international practice of marketing activities promoting competition through

[10]One problem with this methodology was that Mexican consumers could be affected by externalities in the U.S. market involving, in some cases, bill increases for Mexican consumers. For example, natural gas prices increased by more than 100% in the winter of 1996 and in the summer and fall of 2000. Brito and Rosellón (2002) analyze the efficiency properties of this methodology.

[11]Bypassing" refers to the possibility for a consumer in a distribution zone to connect to the transmission network directly (physical bypass) or to contract the purchase of natural gas from a supplier other than the distributor by accessing the latter's networks through open access (commercial bypass).

price arbitrage, regulators allowed sellers to buy gas, transport it, and sell it to distributors or consumers within an area of exclusivity and directly connected to the transmission system.

To obtain a gas distribution franchise, bidders had to submit an economic and technical project, and then the CRE would choose one of them for the geographic distribution area, defining the consumption target to be covered at the end of the first five years. The distribution infrastructure that belonged to PEMEX and CFE in the distribution zones was privatized. In addition, to regulate monopoly prices of distribution and transmission pipelines, regulators chose a combination of two instruments: cost of service regulation and price cap regulation. At the beginning of each five-year period, a maximum price was determined based on the cost of the service. This maximum price would remain fixed for five years and would only be adjusted for inflation and efficiency factors (RPI-X). Likewise, to regulate the price structure of gas distribution, Mexico decided to use two variations of the maximum price: regulation by average revenue in the first five-year period, and regulation by tariff basket in the following five-year periods.[12]

The main success of the 1995 reform was the development of several natural gas distribution systems throughout the country. By the end of the 1990s, this process had attracted more than 2 billion dollars in investment.

Energy reform of 2013

Notwithstanding the progress achieved with the 1995 Reform, national and international issues still needed to be analyzed within the context of the energy sector. Therefore, in 2013 an ambitious Constitutional Reform of the Mexican energy sector was carried out, which included oil, gas, and electricity markets. This reform completely changed the institutional framework of the sector. Until then, PEMEX was the dominant investor in the hydrocarbon sector, but this growing investment was not reflected in increased production or hydrocarbon reserves. PEMEX's lack of technical and economic resources to exploit reserves in unconventional and deepwater reservoirs made it impossible for the state-owned company to take advantage of 76% of the Nation's prospective resources in these sites. Hence, the 2013 reform sought to establish a regulatory framework to complement PEMEX's investments with state-of-the-art technologies in the exploitation of deepwater and ultra-deepwater reserves, as well as in mature fields and unconventional reserves.

Thus, on December 20, 2013, the "Decree reforming and adding various provisions of the Political Constitution of the United Mexican States on Energy Matters" (Energy Reform) was published

[12]For a detailed analysis of the impacts of this methodology on the consumption surplus, see Ramírez and Rosellón (2002).

in the Official Gazette of the Federation. It amended the fourth, sixth, and eighth paragraphs of Article 25; the sixth paragraph of Article 27; the fourth and sixth paragraphs of Article 28; and added a seventh paragraph to Article 27 and an eighth paragraph to Article 28[13].

The fourth and tenth transitory articles of this Decree were formulated to complement the development of the legal framework required to initiate the effective operation of this Reform, in which a term of one hundred and twenty days was established for the Congress of the Union to make the necessary adjustments to the legal framework, in order to make the provisions of the Decree effective and, among them, regulating the contracting terms and conditions. They must be, among others: of services, of shared utility or production, or of license, to carry out on behalf of the Nation the activities of exploration and extraction of oil and solid, liquid, or gaseous hydrocarbons, including those that may be carried out by the production companies of the State with private parties, as well as the necessary adjustments to establish the responsibilities of the Ministry of Energy, the National Hydrocarbons Commission, and the Energy Regulatory Commission[14].

In compliance with the provisions of the fourth and tenth transitory articles mentioned above, on April 30, 2014, the Federal Executive sent the initiative of secondary laws to the constitutional reform approved in December 2013 to the Senate of the Republic. The Senate reviewed, modified, and approved the proposals, resulting in the package of secondary laws on energy matters being published in the Official Gazette of the Federation on August 11, 2014. These include the creation of new legal instruments to implement the new institutional design of the Hydrocarbons sector: the Hydrocarbons Law and the Law of the Coordinated Regulatory Bodies in Energy Matters, among others. These laws grant a new legal nature and new powers and responsibilities to the National Hydrocarbons Commission (CNH) and the Energy Regulatory Commission (CRE), and create a new regulatory body in the form of a decentralized agency of the Ministry of the Environment and Natural Resources: The Agency for Safety, Energy and Environment (ASEA), which was in response to the importance of industrial safety and environmental protection in the approved energy reform. The ASEA's main functions include regulating the industrial safety of oil and gas facilities and issuing environmental protection regulations. In particular, PEMEX, private companies, and even CENAGAS must comply with ASEA regulations.

Table 1 summarizes the secondary legislation published in the Official Gazette of the Federation on August 11, 2014, in which 9 new laws were issued, and 12 existing laws were amended[15].

---

[13]Decree reforming and adding various provisions of the Political Constitution of the United Mexican States, in Energy Matters. Official Gazette of the Federation December 20, 2013.
[14]Idem
[15]Decree enacting the Hydrocarbons Income Law, amending, adding, and repealing several provisions of the Federal Law of Duties and the Fiscal Coordination Law and enacting the Law of the Mexican Petroleum Fund for Stabilization and Development. Official Gazette of the Federation August 11, 2014.

Table 1
Changes in the Secondary Legislation of the Energy Sector, DOF 11/08/2014

New laws issued	• Hydrocarbons Law • Electricity Industry Law • Geothermal Energy Law • Law of the National Agency for Industrial Safety and Environmental Protection of the Hydrocarbons Sector • Petróleos Mexicanos Law • Federal Electricity Commission Law • Law of the Coordinated Regulatory Bodies in Energy Matters • Hydrocarbons Revenue Law • Mexican Petroleum Fund for Stabilization and Development Law
Amended laws	• Foreign Investment Law • Mining Law • Public-Private Partnerships Law • National Waters Law • Federal Law of Parastatal Entities • Public Sector Acquisitions, Leasing, and Services Law • Public Works and Related Services Law • Organic Law of the Federal Public Administration • Federal Law of Rights • Fiscal Coordination Law • Federal Budget and Fiscal Responsibility Law • General Law of Public Debt

It is worth mentioning that the Energy Reform created the National Energy Control Center (CENACE; Spanish: Centro Nacional de Control de Energía) as an independent operator to implement the National Electricity Market and also turned the CFE into a State Production Company, which allowed the association between the CFE and private companies in the generation, transmission, and distribution of electricity.

To summarize the Hydrocarbons changes of the 2013 Energy Reform, it:

- Reaffirmed the national ownership of hydrocarbons in the subsoil
- Opened the market to private participation in hydrocarbon exploration and extraction through hydrocarbon exploration and extraction contracts with the State
- Strengthened the regulatory bodies Energy Regulatory Commission (CRE) and National Hydrocarbons Commission (CNH)
- Established a new tax regime for PEMEX and private companies
- Converted Pemex into a State Production Company

- Reorganized PEMEX's personnel and administrative structure to increase its productivity and authorized farmouts[16] for oil extraction
- Created the Mexican Petroleum Fund for Stabilization and Development
- Strengthened the regulatory bodies CRE and CNH
- The CNH organized several rounds of auctions for the exploitation and production of oil fields

The creation of CENAGAS as a decentralized public agency should be highlighted. Based on the Reform, CENAGAS became the independent operator of the gas pipeline system and the owner of approximately 9 000 km of pipelines. Its function has two fundamental objectives: to maximize social welfare in its role as operator of the pipeline systems (which include those of private property and those of the CFE) and to maximize the benefits of managing its own pipelines. The creation of CENAGAS can also be seen as one of the main results of the 2013 reform, as it broke the vertical integration of PEMEX in the natural gas industry, favored competitiveness along the chains of this industry, and increased the capacity of gas pipelines in the country from 11 347 km in 2012 to 15 986 km in June 2018. In September 2019, 772 km more came into operation and an additional 2 131 km are under construction, which will soon bring the total number of gas pipelines to 18 889 km (SENER, 2019).

As can be seen, the 2013 reform sought to increase oil production, the capacity of gas pipeline networks, and also to expand the capacity for transportation and storage of oil and liquid fuels. In addition, based on these new legal and operational conditions, investments of around 50 billion dollars would be achieved in Mexico's hydrocarbon energy sector, among other objectives (Pérez and Zubicaray 2017, p. 6).

Analysis and results of prices, sales, and foreign trade in the Mexican natural gas market: Effects of the reform

Database and methodology

The data used come from the Energy Information System of the Mexican Ministry of Energy with information from PEMEX and include the most important variables of foreign trade and domestic natural gas sales between January 2009 and December 2018. The monthly series on values and quantities of domestic sales include total transactions and their division by sector (industrial distributors and electricity), while those of foreign trade are displayed in volumes and values of the net balance of trade.

[16]These are partnerships between public and private sector companies that allow a public company—in this case PEMEX—to share financial, technological, and geological risks with a private company to stabilize its oil production and gradually increase it.

Initially, the series dates back to 1993, but due to omissions in recording several variables over long periods, regular and reliable information was not available until September 2005. In this case, the starting point is January 2009 not only because this choice yields a backward-balanced (2009-2013) and a forward-balanced (2014-2018) sample of the 2013 energy reform observation period but mainly because it is the year in which domestic gas production reached its highest peak at 7 billion cubic feet. In other words, an exceptional start of the period is taken to observe the movement of the variables associated with the systematic fall in local gas production. Therefore, the resulting sample size is 120 observations for each series.

The value of monthly transactions in constant 2015 dollars is divided by the respective amounts in cubic meters to obtain the average real gas prices per cubic meter, in aggregate and by industrial and electricity sectors. Similarly, to make comparisons over time, the current peso values of the balance of trade are transformed into constant dollars of that year. In this way, the original series are re-expressed in constant prices, deflated values with the U.S. consumer price indexes, and gas quantities in cubic meters.

Once this has been done, the dynamics of each series are analyzed using two successive and complementary procedures. The first studies the behavior of their first differences based on the Kwiatkowski-Phillips-Schmidt-Shin test (KPSS), whose Null Hypothesis (H_0) states that the real-time series are stationary around a deterministic trend (Kwiatkowski, 1992). The idea is to determine its underlying stochastic process and, in the case of mean reversion, to calculate the average time to return to trend for each series after experiencing a shock. For this purpose, the scalar measure of persistence called shock half-life[17] (SHL), which is linked to the impulse-response functions of each auto-regressive equation, is used:

$$SHL = ABS\left(\frac{ln\, 0.5}{ln\, \alpha}\right), \tag{1}$$

where α is the unbiased estimator of the mean of the autoregressive coefficient of order 1.

The second step analyzes the possible structural changes of the series levels based on the tests of Andrews (1993), Andrews and Ploberger (1994), and Zivot and Andrews (1992). As is well known, adopting certain time series models and their corresponding types of tests to estimate structural changes remains controversial. There is such a diversity of models that choosing one requires empirical justification. There are, for example, models designed to capture extreme changes (outliers) or models that incorporate changes with continuous parameters. Likewise, there are models with regressions that accept sudden regime changes and others that, on the contrary, seek to estimate gradual changes. In each

[17] According to (Cheung & Lai, 2000), the half-life of a shock unit is defined as the length of time it takes for a unit of impulse to dissipate at half the intensity of the initial shock.

case, the tests are different because they depend on whether: (a) the breaks are known or unknown; (b) the breaks are single or multiple; (c) the relationships between variables are univariate or multivariate; or (d) the variables are stationary or nonstationary (Maddala & Kim, 1998).

Parallel to this problem of choice is the fact that tests such as the KPSS or the Augmented Dickey-Fuller (ADF) are not robust in the presence of changes or breaks in the series. The presence of breaks in series that are stationary can increase the value of the autoregressive estimator to the point of being unable to reject the unit root hypothesis, as happens for example, when using ADF (Perron, 1990). For this reason, it is important to build a strategy in the statistical treatment, including, on the one hand, tests of stationarity contrast without trend and, on the other hand, tests that capture breaks in stationary series or with unit root.

In the second procedure, the KPSS statistic without trend is used first, followed by the models and tests for breaks in intercept, trend and intercept, and trend, mentioned above. The reason is that trend-assessing statistics such as the modified KPSS require the setting of an exogenous shock, which contravenes the test objectives of Andrews (1993), Andrews and Ploberger (1994), and Zivot and Andrews (1992). The work of these authors estimates an unknown (or endogenous) break in sequential breaks for models without deterministic or stochastic trend (Maddala & Kim, 1998).

Specifically, the works of Andrews (1993) and Andrews and Ploberger (1994) propose different versions of the same test in which H_o establishes that the series has no structural change. Both provide the critical asymptotic values for various significance levels of a likelihood ratio test considering a structural variation with an unknown change point (similar to the Quandt test). These critical values are called SUP statistics or Chow tests (Maddala & Kim, 1998). In their more developed version, Andrews and Ploberger (1994) assume that if there is a structural change at an unknown time, it occurs between observations T_1 and T_2, where T_1 is an observation close to 1 and T_2 is an observation close to T of the sample period $t \in [1, T]$. When the change occurs within a known period, the authors recommend taking the interval in question to maximize the power of the test.

The test algorithm for N divisions between observations T_1 and T_2 requires, first, computing the value of χ^2 for the hypothesis of the existence of a structural change in T_1. This involves making three estimates for periods ranging from 1 to $T_1 - 1$, from T_1 to T, and from 1 to T. This value is denoted as $\chi^{2(1)}$. The same procedure is then repeated for the observation $T_1 + 1$ in order to obtain $\chi^{2(2)}$. By the time the hypothesis is tested in T_2, the procedure will have yielded $N = T_2 - T_1 + 1$

http://dx.doi.org/10.22201/fca.24488410e.2021.2841

values of χ^2, that is: $\chi^{2(1)}$, $\chi^{2(2)}$, ..., $\chi^{2(N)}$. With these values, the authors construct a weighted average (which is nothing more than the test statistic AP) to confront it with the table critical values and, thus, establish the criteria for rejection or acceptance of H_0. The AP statistic is defined as:

$$AP = \log\left[(e^{\frac{1}{2}\chi^{2(1)}} + ... + e^{\frac{1}{2}\chi^{2(N)}}) / N \right] \tag{2}$$

On the other hand, the Zivot-Andrews test (1992) proposes as H_0 the existence of a unit root with drift and, as an alternative hypothesis, the presence of stationary processes with breaks in trend. That is, it is a test that accentuates structural changes in the stationary series and, unlike the KPSS or ADF tests, detects unit roots robustly and independently of these changes. As in the Andrews and Ploberger (1994) test, the Zivot-Andrews test models the unknown break sequentially in either intercept (I), trend (Te), or both (I-Te). The procedure consists of estimating equations (I), (Te) and (I-Te) by least squares sequentially for the values of $T_B = 2,...,T-1$ when there are T observations. The break point in each of the three models occurs when one of the values of the statistics t associated with the last lag of T_B reaches its minimum point.

The equations for the three models are:

$$\text{Model (1): } Y_t = \beta_0 + \theta DU + \tau Y_{t-1} + \beta_1 t + \sum_{j=1}^{k} c_j \Delta Y_{t-j} + U_t \tag{3}$$

where the terms on the right are, respectively: the intercept, the dichotomous variable that takes the value of 1 or 0 after and before the structural change, the lagged endogenous variable, the linear trend, the lagged terms j of the first differences of the endogenous variable, and the error term.

$$\text{Model } (Te)\text{: } Y_t = \beta_0 + \lambda DT_t + \tau Y_{t-1} + \beta_1 t + \sum_{j=1}^{k} c_j \Delta Y_{t-j} + U_t \tag{4}$$

in which the only change is the inclusion of the dichotomous variable DT, that captures the structural break in trend with values of 0 and 1 to indicate changes before and after the break. Finally, the equation of the last model is obtained, which is no more than the linear combination of the two previous ones:

Model (I-Te):

$$Y_t = \beta_0 + \theta DU + \lambda DT_t + \tau Y_{t-1} + \beta_1 t + \sum_{j=1}^{k} c_j \Delta Y_{t-j} + U_t \tag{5}$$

In summary, the two procedures are used to combine conventional stationarity testing techniques with robust structural breaks methods to characterize more completely the dynamics of the natural gas price and quantity series in Mexico. Both procedures offer complementary and confirmatory information on the possible existence of a probable and unknown structural change produced by the energy reform. Therefore, the study of the levels and first differences of the series is a necessary resource for properly using the two types of procedures. Regarding the study of the two methods used here to estimate structural changes, Maddala and Kim (1998) consider that their parameter estimators have desirable asymptotic properties that make them efficient and unbiased concerning the sample size.

The following libraries programmed in R language are used for the two statistical procedures:

- library(dplyr). Hadley Wickham, Romain François, Lionel Henry, and Kirill Müller (2019). dplyr: A Grammar of Data Manipulation. R package version 0.8.3. https://CRAN.R-project.org/package=dplyr
- library(tseries). Adrian Trapletti and Kurt Hornik (2018). tseries: Time Series Analysis and Computational Finance. R package version 0.10-46.
- library(CPAT). Curtis Miller (2018). CPAT: Change Point Analysis Tests. R package version 0.1.0. https://CRAN.R-project.org/package=CPAT
- library(strucchange). Achim Zeileis, Christian Kleiber, Walter Kraemer and Kurt Hornik
- library(TSA). Kung-Sik Chan and Brian Ripley (2018). TSA: Time Series Analysis. R package version 1.2. https://CRAN.R-project.org/package=TSA

The results

The results in Table 2 show that, when considering their first differences, five of the six series under study have a stationary trend, and only one—that of foreign trade measured in values—follows a unit root process (see KPSS rejection and acceptance column). Contrary to unit-rooted series, the impulse-response functions used in tests of stationary series tend to vanish, or, in other words, the shocks on the time series are absorbed by the trend mean. Specifically, in some autoregressive processes associated with each of them, it can be observed that the half-life of a shock unit (SHL) is very short.

Equation (1) should be considered first to see this more clearly. According to this equation, the prices of the electricity sector and the volume of imports take between 5 and 29 months for temporary shocks to be absorbed by the trend, respectively; while, in the case of the foreign trade series in values, the shocks are permanent, because they cause the trend to change. In the remaining series, the return to its moving average (foreign trade volume) or to its trend after two lags (prices-Industrial-distributors) is indeterminate because, as they are not AR (1) processes, it cannot be calculated using the SHL. In any case, the conclusion does not change since most of the series follow a trajectory marked by their trends, which, as can be seen in the figures of the additive decomposition, differ in behavior depending on whether they are prices, quantities, or values (see Figures 1 and 2).

In total and electricity sector and distributors' prices, the series present a similar trend within a given range, with no greater changes than those observed between 2011 and 2016, although with seasonal differences. These include peaks in the use of the electricity system or distributors in the April-May and November-December periods. The import, value, and foreign trade volume series present, on the other hand, trend changes without a determined range, more accentuated than the price series around 2014 and 2016, with seasonal components in December-February (gas imports), May-June (foreign trade value), and June-October (volume and foreign trade). To better appreciate these changes with and without a given range, it is useful to compare, for example, the series of total prices with that of the total volume of imports. While total prices oscillate between a range of 0.08 and 0.18, with few peaks escaping that range in 2010, 2012, and 2016, the imported volume has no ranges of oscillation of the series, except for the period after 2016.

Table 2
Unit root tests for first differences (Δ) of the Mexican gas time series and calculation of SHL for the period January 2009 to December 2018[18]

SERIES	KPSS Test		ARIMA Process	TIME SERIES COEFFICIENTS				BIC criterion	SHL (months)
	Ho	p-value		AR(1)	AR(2)	MA(1)	Mean		
Δ Pricing - Total	No Rejection	0.1	(1, 0, 0)	0.8641 (0.0460)			0.1195 (0.0085)	-616.4	4.75
Δ Pricing - Electricity Sector	No Rejection	0.1	(1, 0, 0)	0.8722 (0.0445)			0.1179 (0.0089)	-619.63	5

[18]Both in the figures and in Chart 1, in all cases where prices are considered, they are expressed as "yields" R, where $R = \frac{p_t}{P_0} - 1$, p_t are the prices at time t, and P_0 are the base time prices. When the SHL value does not appear, it means that the series does not return to its trend during the period considered.

Δ Pricing - Industrial Distributors	No Rejection	0.1	(2, 0, 0)	0.6430 (0.0936)	0.2152 (0.0939)		0.123 (0.009)	-583.99	
Δ Imports - Volume	No Rejection	0.1	(1, 0, 0)	0.9766 (0.0190)			1118.82 (351.66)	1333.47	29.3
Δ Foreign trade - Volume	No Rejection	0.1	(1, 0, 0)	0.9886 (0.0152)		-0.1908 (0.109)	-1105.3 (424.9)	1356.4	
Δ Foreign trade - Value	Rejection	0.01	NA			UNIT ROOT PROCESS			∞

Note: The numbers in parentheses in the coefficient column are the standard errors.
Source: Energy Information System, with information from Petróleos Mexicanos http://sie.energia.gob.mx/movil.do?action=back&node=PMXB2C03

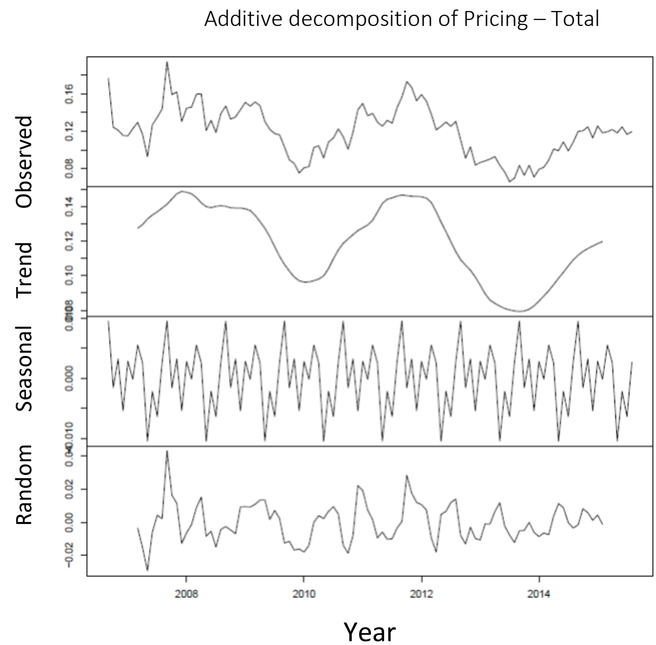

Figure 1(a). Additive decomposition of the Total Natural Gas Price Series

http://dx.doi.org/10.22201/fca.24488410e.2021.2841

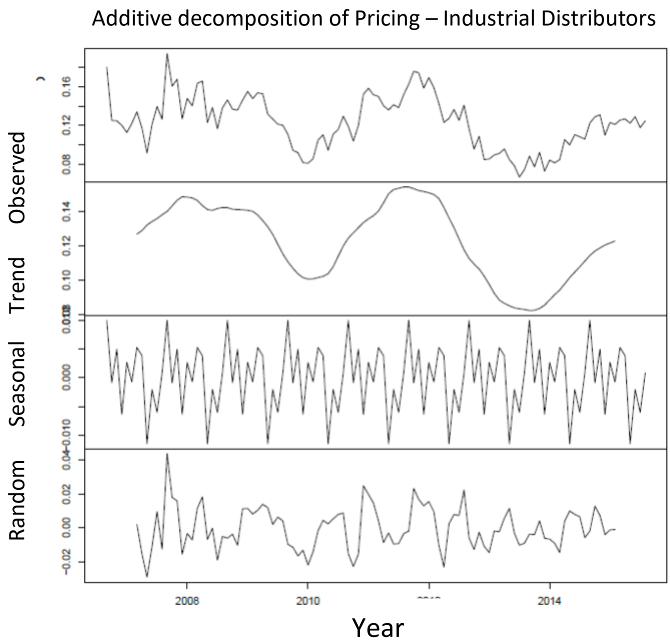

Figure 1(b). Additive decomposition of the natural gas price series to industry and distributors

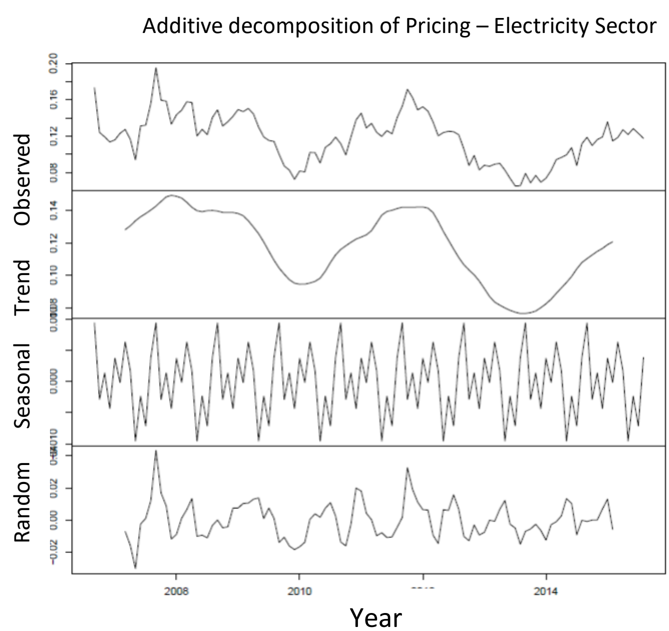

Figure 1(c). Additive decomposition of the natural gas price series to the electricity sector

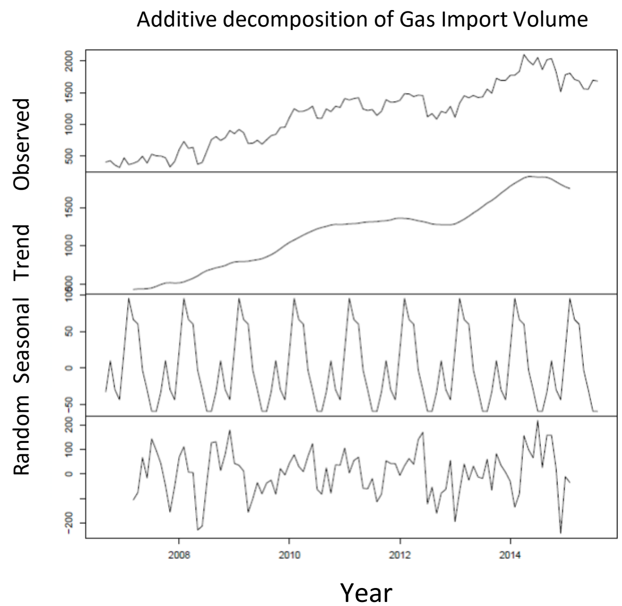

Figure 1(d). Additive decomposition of the series of natural gas import volume

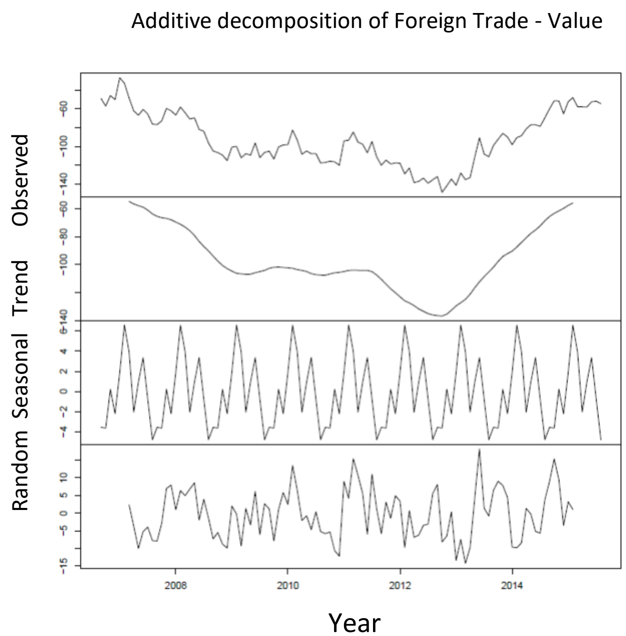

Figure 1(e). Additive decomposition of the natural gas foreign trade value series

http://dx.doi.org/10.22201/fca.24488410e.2021.2841

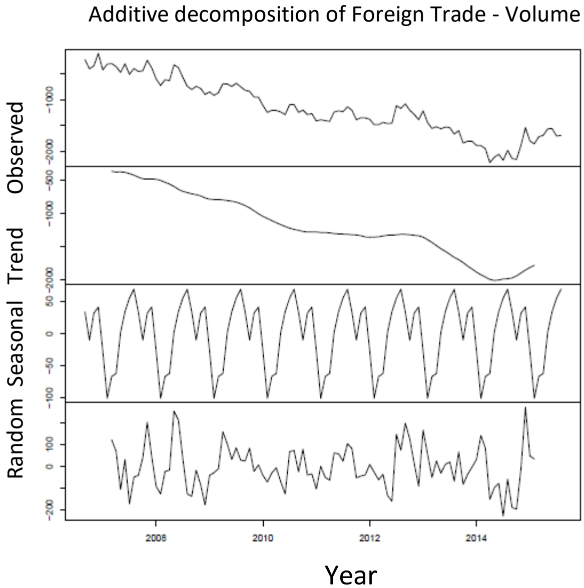

Figure 1(f). Additive decomposition of the natural gas foreign trade volume series

The interesting point in the analysis is to determine whether the presence of structural changes alters this behavior of the series. Stated as a question: is it possible to rely on the traditional calculation of stationarity to ensure that any shock produced in the five stationary series, for example, by the energy reform, is temporary? To answer the question, it is necessary to first test the levels of the series, since Equations (2), (3), (4), and (5) are models that fit the data for different lags. Therefore, if the Table 2 series are incorporated, the adjustments would involve lags on the first differences. The aforementioned break tests do not accept estimates of series with trends such as those included in this table.

Table 3 reports the results of the KPSS statistic with their respective p-values. It shows that all variables present unit root, as is common in most economic series expressed in levels. Is this behavior a sign of inconsistency with the results of Table 2? A review of the Andrews and Ploberger (1993) and Zivot and Andrews (1994) tests for intercept, trend and intercept, and trend, provides information in this regard. According to the left side of Table 4 (Andrews Ploberger test), all series present structural breaks between 2009 and 2018. In particular, five series experienced breaks in trend and intercept in 2016 (August and December) and only one in 2015 (January), i.e., in the post-energy reform period. Of these series, those relating to foreign trade volume and total price first recorded a break in trend (2016) and then in intercept (in 2017), indicating that the shocks were more sudden in these variables than in the remaining ones. These results are largely confirmed by the Zivot and Andrews test since, except for some small differences in dates, the same pattern is observed on the right side of Table 4. The significance of this pattern is that all series exhibit permanent structural changes in trend and intercept in the years of the reform (2014, 2016, and 2017) that provide a unit root characterization of the series.

Thus, the answer to the two questions posed above is straightforward: in the absence of structural breaks, the traditional stationarity criteria for gas series in Mexico are doubtful when H_0 is not rejected because they do not provide a way to detect the nature of the shocks. A shock in an originally stationary series that affects its trend can permanently alter the return to its mean and, therefore, render the use of indicators such as the SHL useless. Hence, the tests on first difference series in Table 2, where H_0 is not rejected, are suspect because they underestimate the impact of structural changes. Not only the meaning of stationarity is different, but also the sense of the specification changes, since with shocks that favor the presence of unit root, it is not advisable to associate the same model of a time series before and after the structural change. Therefore, the ARIMA processes described in Table 2 have limited validity because it is unknown to what extent they are affected by structural changes.

Table 3
KPSS tests for gas series (in levels) in Mexico between 2009 and 2018

Variable	Conclusion	KPSS
Volume of natural gas imports (millions of cubic meters per day)	Unit root	0.20 (0.017)
Foreign Trade of Natural Gas (millions of cubic meters)	Unit Root	0.19 (0.028)
Foreign Trade of Natural Gas (millions of dollars)	Unit root	0.18 (0.036)
Total Natural Gas Pricing (dollars/cubic meter per day)	Unit root	0.62 (0.031)
Industrial-Distributor Service Pricing (dollars/cubic meter)	Unit Root	0.56 (0.045)
Electric service pricing (dollars/cubic meter per day)	Unit Root	0.61 (0.033)

Note. The p-value in parentheses is shown next to the test statistic.
Source: Energy Information System, with information from Petróleos Mexicanos http://sie.energia.gob.mx/movil.do?action=back&node=PMXB2C03

The economic intuition from the results in Table 4 is that natural gas prices, values, and quantities tend to be inflexible downward or upward after their series experience breaks in trend and intercept. Figures 2(a-f) show that, while one series is persistently trending downward in October 2016 (import volume), the remaining ones are trending upward in the different months of 2016 and 2017. These breaks in direction are associated with changes in the level or mean of the trend (due to changes in the intercept).

The consequences of these behaviors for the energy reform are important because the effects of the shocks are permanent and attributable to their period of operation. The causes of these changes are of local and international origin. In particular, the hikes in total gas prices after the 2016 break are persistent because they are fixed in international markets, in which the Mexican government acts as a price-taker.

However, this does not mean that in the absence of structural changes, these prices have not presented in some years reversion to the mean with some structural breaks in intercept, as happened, for example, between 2007 and 2011 (Hu et al. 2019).

On the other hand, the volume series or the prices of electricity and industrial services are more volatile because they are strongly dependent on variations in domestic demand and erratic local production. Specifically, U.S. natural gas import volumes increased at a rate of 2.4 times between 2014 and 2017 following the completion of the Los Ramones pipeline project, increasing from 728 692 million cubic feet in the first year to 1 712 627 million cubic feet in the last year (Ramirez & Massa 2020). Notwithstanding that as of 2017 these import figures began to decrease, these still represent approximately 65% of national consumption, equivalent to a daily purchase of 4 800 million cubic feet involving an outlay of more than 12 million dollars (Russo, 2017).

Therefore, it can be concluded that the recent effects of the energy reform are long-lasting because they reverse the trend. Nevertheless, one should bear in mind that other changes not captured by the Zivot-Andrews test may reveal other behaviors. As mentioned in the previous section, this test records the break point where the values of the statistics t associated with the last lag of T_B reach their minimum point between 2009 and 2018. This means that if the interval is subdivided into periods before and after the major structural breaks, it is possible to find stationary behavior associated with mean-reverting processes, such as those described in Table 2. However, this type of exercise is beyond the scope of this paper.

Table 4
Andrews-Ploberger and Zivot-Andrews tests

Variable	Andrews-Ploberger			Zivot-Andrews		
	Intercept	Slope	Both	Intercept	Slope	Both
Volume of natural gas imports (millions of cubic meters per day)	06/2012 (43.65)[0.009]	08/2016 (17.52)[0.000]	08/2016 (46.67)[0.000]	11/2012 (-3.42)[0.217]	10/2016 (-4.43)[0.059]	10/2016 (-4.78)[0.097]
Foreign Trade of Natural Gas (volume in million cubic meters per day)	Intercept	Slope	Both	Intercept	Slope	Both
	07/2017 (53.47)[0.000]	08/2016 (87.18)[0.000]	08/2016 (37.12)[0.000]	06/2016 (-3.37)[0.223]	01/2017 (-4.81)[0.069]	01/2017 (-5.24)[0.074]
Foreign Trade of Natural Gas (value in millions of dollars)	Intercept	Slope	Both	Intercept	Slope	Both
	03/2013 (67.92)[0.000]	01/2015 (76.65)[0.000]	01/2015 (76.65)[0.000]	11/2013 (-4.35)[0.114]	10/2014 (-4.41)[0.061]	10/2014 (-4.42)[0.137]
Natural gas price (dollars per cubic meter)	Intercept	Slope	Both	Intercept	Slope	Both
	01/2017 (22.34)[0.000]	11/2016 (22.83)[0.000]	11/2016 (23.10)[0.000]	06/2014 (-4.17)[0.134]	04/2016 (-3.86)[0.119]	04/2016 (-4.68)[0.108]
Industrial	Intercept	Slope	Both	Intercept	Slope	Both

service - distributors (dollars/cubic meter per day)	01/2015 (31.27)[0.000]	12/2016 (14.58)[0.003]	12/2016 (15.21)[0.001]	12/2014 (-4.69)[0.077]	05/2016 (-4.14)[0.089]	05/2016 (-5.29)[0.068]
Electric service (dollars/cubic meter per day)	Intercept 12/2014 (18.91)[0.000]	Slope 12/2016 (24.7)[0.005]	Both 12/2016 (21.48)[0.008]	Intercept 07/2014 (-3.79)[0.175]	Slope 04/2016 (-3.74)[0.133]	Both 04/2016 (-4.42)[0.138]

Note. The p-value in parentheses is shown next to the test statistic.

In the following figures, the solid line represents the Zivot-Andrews structural changes and the dashed line the Andrews-Ploberger structural changes.

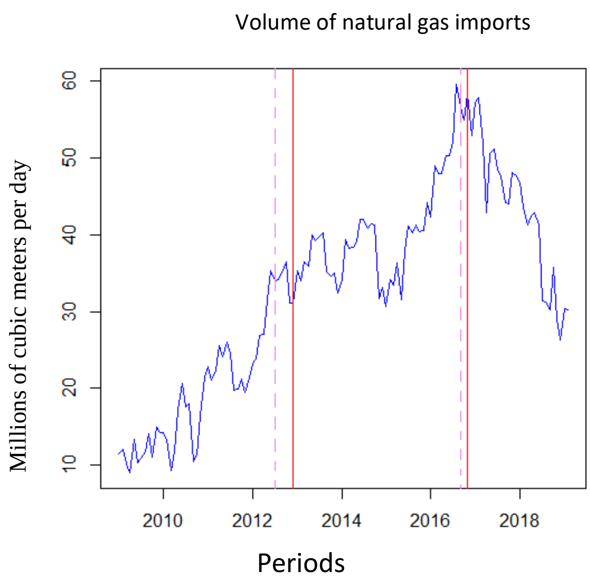

Figure 2(a). Structural change points in the natural gas import volume series

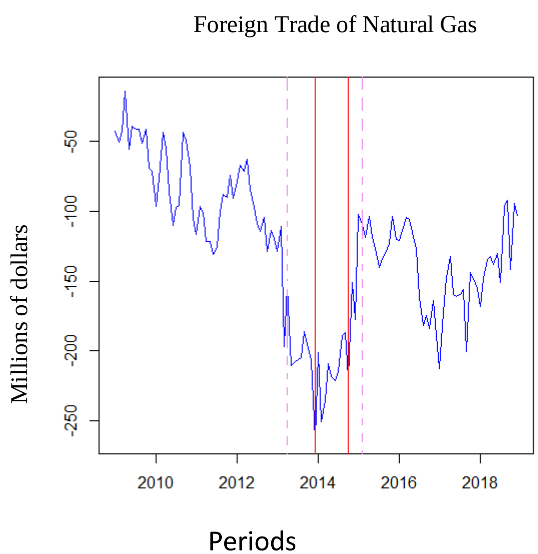

Figure 2(b). Structural change points in the foreign trade series in dollars of natural gas

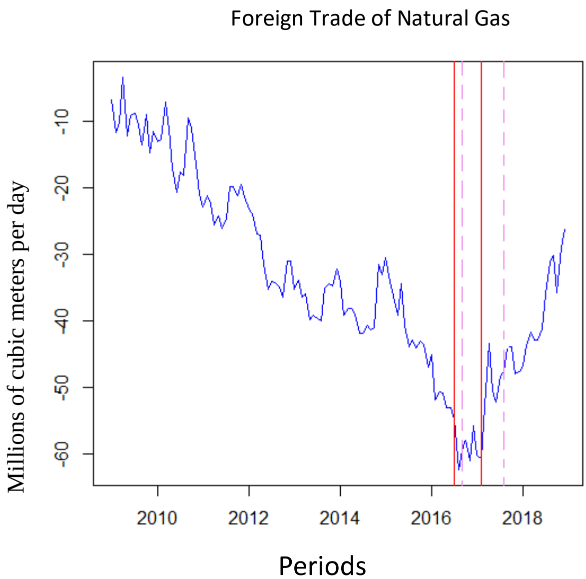

Figure 2(c). Structural change points in the foreign trade series in natural gas volumes

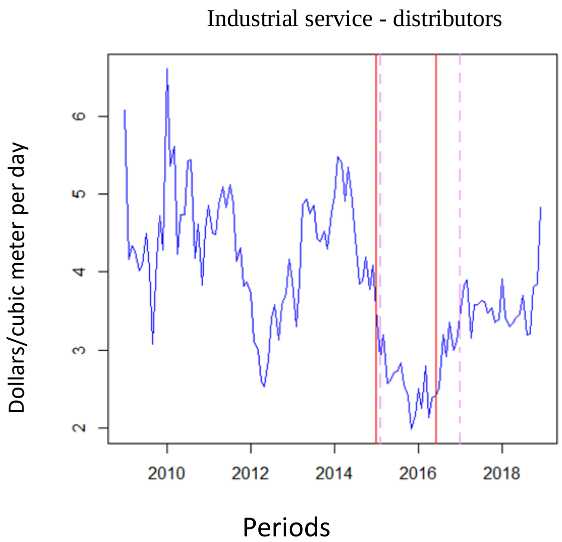

Figure 2(d). Structural change points in the series of natural gas used in industrial and distribution services

http://dx.doi.org/10.22201/fca.24488410e.2021.2841

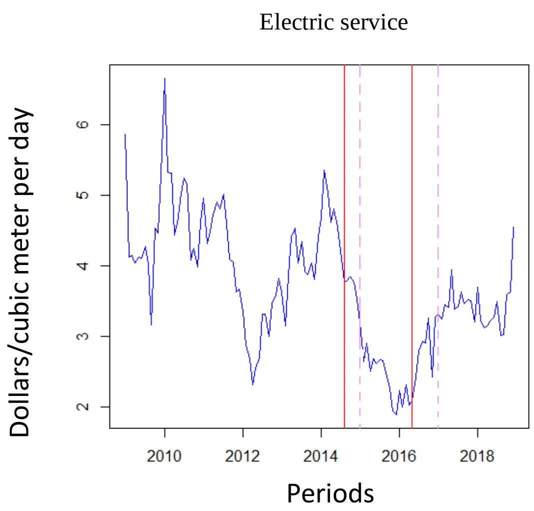

Figure 2(e). Structural change points in the series of natural gas used in power generation

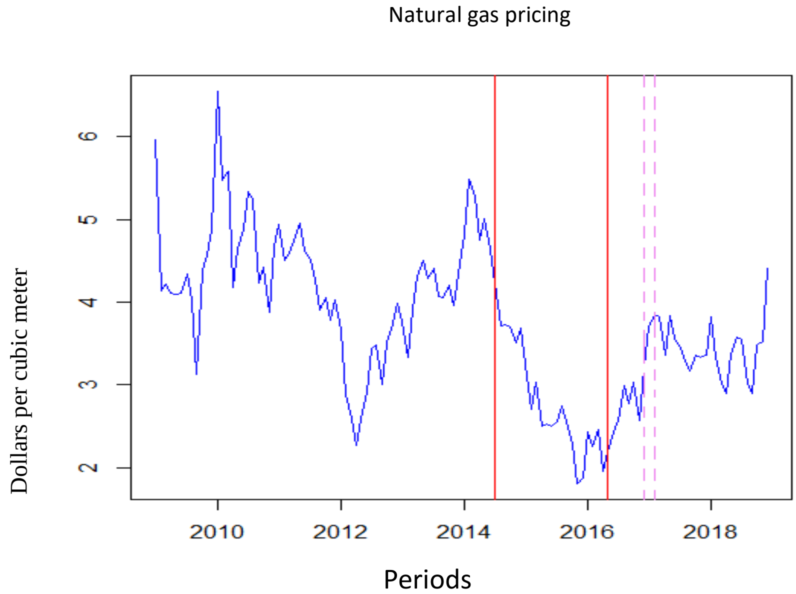

Figure 2(f). Structural change points in the total natural gas price series

Conclusions

This paper analyzed the effects of the regulatory reform of the natural gas market, initiated in 1995 and culminated in 2013, on the behavior of its prices, sales, and foreign trade. Even though this reform is part of a process, the changes in 1995 differ in nature from those recorded in 2015. While the 1995 reform maintained PEMEX's monopoly and allowed the participation of private agents in distribution projects and the development of gas pipeline networks throughout various cities in the country, the 2013 reform substantially deepened the institutional liberalization of the natural gas sector. In fact, the last reform is the most far-reaching because it not only covered the crude oil, petroleum products, and electricity industries, but also achieved, at least formally, the vertical disintegration of PEMEX and CFE. In addition, this reform favored contracts and alliances with domestic and foreign private companies and created or consolidated various regulatory agencies to provide a stable and credible regulatory framework for investors.

The main conclusion of this article is that the application of statistical tests supports the existence of breaks in intercept and trend that modify the direction of the trajectories of all series between 2016 and 2017. As is known, the Zivot-Andrews structural break test used here detects the most important break of the period but not those of lower rank. Hence, the document does not explain (because that is not its objective) the changes before or after that break. Therefore, it is likely that the statistical analysis developed here omits some behaviors of the series that present stationarity and reversion to the mean, such as those described in Table 2. Thus, a fruitful future line of research would undoubtedly be the study of these series for periods before or after the big breaks, which would reveal behaviors different from those of the unit root.

The main events in the Mexican natural gas industry associated with these trend changes during 2016-2017 have to do with the increase in the transportation capacity of the national gas pipeline network after the start-up of Los Ramones II (north and south sections, with a length of 738 km) in 2016, and San-Isidro-Samalayuca, El Oro-Mazatlán, Ojinaga-El Encino, and Guaymas-El Oro (with a length of 1 006 km) in 2017. This new pipeline capacity, coupled with the new inland pipelines (Trans-Pecos Pipeline, Comanche-Trail Pipeline) also introduced in 2017, meant the addition of 2 272 km to the transportation network.[19] That is, more than 50% of the new gas transportation capacity of the 2012-2019 period was added between 2016 and 2017. It is also important to note that during these years, the Los Ramones pipeline began operating in the country's center: a nodal arbitration point in the system that is critical for determining the prices and volumes of natural gas throughout the country. (Brito & Rosellón, 2002, 2005, 2010)

[19]See Sener (2019)

Additionally, the structural change registered in natural gas import volumes during 2016 is particularly meaningful to evaluate the performance of the energy reform and, in particular, to ponder the real possibilities of decreasing external dependence on this key commodity. This last aspect is of the utmost importance because it should not be forgotten that half of Mexico's energy consumption and two thirds of the country's electricity are supplied by this fuel. In addition, it should be considered that, in the face of declining oil sales to the U.S.A., the trade deficit in oil, diesel gasolines, and natural gas has been increasing considerably to reach 12.5 billion dollars in 2017 or, if petrochemicals are considered, it rises to 23 billion dollars in 2018 (Ramirez & Massa 2020). Obviously, the energy reform is a process in the making, and it would still have to be assessed whether this structural change is capable of breaking the trade pattern established in the last years of NAFTA's operation, consisting of exporting less and less crude oil and importing more and more refined oil products from the U.S.A.

The document also provides statistical evidence of the permanent impact that natural gas reforms in Mexico have had on the value of foreign trade of this hydrocarbon. What could be the public policy implications of this finding? A first interpretation would be that the market opening reforms have implied an increasing dependence in Mexico on U.S. shale gas due to an economic logic based on liberalization, competition, and cost minimization. That is, importing shale gas from the U.S.A. would be an economically efficient solution to meet the growing demand for natural gas in Mexico, particularly that linked to the development of combined cycle power generation. The reforms should then be kept in place and allowed to evolve until the expected positive economic effects are achieved, particularly on gas prices.

Furthermore, this public policy rationale would coincide with minimizing the environmental costs of gas fracking in Mexico, which would fall mostly on the Texas natural gas industry. However, a disadvantage would be the high dependence of the Mexican electricity system on an imported energy input. Would the latter, then, be a sufficient reason to reverse the logic of openness of the reforms to the sector and, consequently, accept the existence of a vertically integrated national monopoly in natural gas production? Such a public policy would not be cost-minimizing (or environmentally friendly), especially if it were not based on adequately regulated fracking processes in Mexico. Sarmiento et al. (2019) state that a perhaps more sensible policy—harmonizing energy sovereignty with economic and environmental efficiency in Mexico—could be based on accelerated decarbonization with solar and wind renewable energy (Mexican Green New Deal).

References

Andrews, D., (1993). 'Tests for parametric instability and structural change with unknown change point', Econometrica 61(4): 821-856. https://doi.org/10.2307/2951764

Andrews, Donald (2003). "Tests for parameter instability and structural change with unknown change point: A Corrigendum". Econometrica. 71 (1): 395–397. https://doi.org/10.1111/1468-0262.00405

BP Statistical Review of World Energy 2019. British Petroleum, 2019, pp. 9.

Brito D.L. and J. Rosellón (2010), "Pricing Natural Gas in Mexico: An Application of the Little-Mirrlees Rule — The Case of Quasi-Rents", Southern Economic Journal, Southern Economic Association, vol. 76(4), pages 1131-1136, April. https://doi.org/10.2307/27866747

Brito D.L. and J. Rosellón (2005), "Price Regulation in a Vertically Integrated Natural Gas Industry: The Case of Mexico", Review of Network Economics, De Gruyter, vol. 4(1), pages 1-18, March. DOI: https://doi. org/10.2202/1446-9022.1067

Brito, D. L., and J. Rosellón, (2002), "Pricing Natural Gas: An Application of the Little-Mirrlees Rule", Energy Journal, vol. 23, no. 3, pp. 81-93. https://doi.org/10.5547/issn0195-6574-ej-vol23-no3-4

Cheung, Y.W., and Lai, K.S., (2000), "On cross-country differences in the persistence of real exchange rates", Journal of International Economics, vol. 50 (2000), pp. 375-397. DOI: https://doi.org/10.1016/S0022- 1996(98)00079-8

Franco, G. (2019). "Reservas de hidrocarburos en México. Conceptos fundamentales y análisis 2018", Comisión Nacional de Hidrocarburos, México, 2019.

Halpern, J. and Rosellón, J. (2001), "Regulatory Reform in Mexico´s Natural Gas Industry: Liberalization in the Context of a Dominant Upstream Incumbent", Policy Research Working Paper Series, 2537. The World Bank. https://doi.org/10.1596/1813-9450-2537

Hu, H. Wei, W. and Chang, C., (2019). "Do shale gas and oil productions move in convergence? An investigation using unit roots with structural breaks". Economic Modeling, Vol.77 pp 21-33. https://doi.org/10.1016/j.econmod.2018.12.006

Kwiatkowski, D.; Phillips, P. C. B.; Schmidt, P.; Shin, Y. (1992). "Testing the null hypothesis of stationarity against the alternative of a unit root". Journal of Econometrics. 54 (1–3): 159–178. https://doi.org/10.1016/0304- 4076(92)90104-y

Maddala, G., y Kim, In-Moo (1998). Unit roots, cointegration and structural change. Cambridge University Press.

Pérez, D. y Zubicaray, G. (2017), "El impacto urbano de la Reforma Energética en las ciudades del Golfo de México", Working paper. World Resources Institute. Septiembre 2017, pág. 6.

Perron, P. (1990). "Testing for a Unit Root in a Time Series with a Changing Mean", Journal of Business and Economic Statistics, Vol 8. https://doi.org/10.2307/1391977

Ramírez, J.C and R. Massa, (2020). Mexico's energy reform in the context of a new trilateral agreement (T-MEC-USMCA). International Trade Journal, Vol 34 (1) pp. 55-73. https://doi.org/10.1080/08853908.2 019.1693939

Ramírez, J.C. and J. Rosellón, (2002), "Pricing Natural Gas Distribution in México", Energy Economics, 24(3), 231-248. https://doi.org/10.1016/s0140-9883(02)00037-3

Rogozinski, J. (1999). High Price for Change: Privatization in Mexico, The Inter-American Development Bank and the Johns Hopkins University Press, 1999. https://doi.org/10.5465/ame.1999.2210322

Rosellón, J. (1998). "Price and Rate Regulations for the Mexican Natural Gas Industry: Comments on Policy Decisions", Economía Mexicana, vol. VII, núm. 2, CIDE.

Russo, T. (2017). Will NAFTA renegotiation stop greening of Mexico's power sector? Natural gas & Electricity. volume 34 issue 2, pp. 30-32. https://doi.org/10.1002/gas.22006

Sarmiento, L., T. Burandt, K. Löffler, P-Y, Oei (2019), "Analyzing Scenarios for the Integration of Renewable Energy Sources in the Mexican Energy System—An Application of the Global Energy System Model (GENeSYS-MOD)", Energies, 12(17), 3270; https://doi.org/10.3390/en12173270

SENER (2019). Estatus de infraestructura de gas natural. Octubre 2019. Secretaría de Energía, México. https://www.gob.mx/cms/uploads/attachment/file/497827/Estatus_de_gasoductos_octubre_2019.pdf accessed June 19, 2020.