GERENCIA DE POLÍTICAS Y ANÁLISIS ECONÓMICO

Bureau of Regulatory Policy and Economic Analysis

DOCUMENTO DE TRABAJO Nº 35

Working Paper Nº 35

Where are natural gas prices heading and what are the environmental consequences for Latin America?

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Lima, August 2016

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Gerencia de Políticas y Análisis Económico
(Bureau of Regulatory Policy and Economic Analysis)

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Working Paper N° 35, Bureau of Regulatory Policy and Economic Analysis

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Cite the paper as: Vásquez Cordano, Arturo L. and Abdel M. Zellou (2016). *Where are natural gas prices heading, and which are the environmental consequences for Latin America*? Working Paper N° 35, Bureau of Regulatory Policy and Economic Analysis - Osinergmin, Peru.

First Draft: July 2013. Second Version: May 2015. Update: May 2016. Revision: August 2016.
It is requested to indicate in a visible place the bibliographic reference of the paper.

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ISSN: 2307 – 4272 (Online)

Supervisory Agency of Investment in Energy and Mining of Peru – Osinergmin
Bureau of Regulatory Policy and Economic Analysis
Working Paper N° 35

Where are natural gas prices heading, and what are the environmental consequences for Latin America? [1]

Abstract

There was an upward trend in energy commodity prices since 2000, but with the surge in supply coming from unconventional oil and gas resources in North and South America, the trend in natural gas prices has become downward in recent years. However, the exploitation of these resources is generating public concerns due to the possible adverse environmental impacts of using hydraulic fracturing and other techniques on underground water.

The purpose of this paper is to address the following questions: are there super cycles in natural gas prices? What are the environmental consequences in Latin America of the exploitation of unconventional gas given the cyclical behavior of gas prices and how can governments implement environmental policies to regulate unconventional gas extraction?

Three super cycles in natural gas prices are identified with the last peak occurring in 2006. Our analysis indicates that the instable political situation and institutional weakness, the governmental intervention through asset nationalization and state-owned oil companies, the lack of transparent investment rules, high capital expenditures to develop LNG export projects and the exploration of shale resources, as well as the pre-salt discoveries in Brazil make uncertain that the shale gas boom achieve a large impact in Latin America during the current gas price super cycle.

JEL Classification: E32 (Business Fluctuations, Cycles), L71 (Mining, Extraction, and Refining: Hydrocarbon Fuels), Q41 (Energy: Demand and Supply), E37 (Forecasting and Simulation: Models and Applications), L51 (Regulation and Industrial Policy: Economics of Regulation), Q48 (Energy: Government Policy), Q58 (Environmental Economics: Government Policy).

Key Words: Super Cycles, Long Cycles, Exhaustible Resources, Natural Gas Prices, Environment, Shale Gas, Trend-Cycle Decomposition, Christiano-Fitzgerald Band-Pass Filter.

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Organismo Supervisor de la Inversión en Energía y Minería – Osinergmin
Gerencia de Políticas y Análisis Económico
Documento de Trabajo N° 35

A dónde se dirigen los precios del gas natural y cuáles son las consecuencias ambientales para Latinoamérica? [2]

Resumen

Desde el año 2000 ocurrió una tendencia creciente en los precios de los productos energéticos; sin embargo, con el surgimiento de la oferta proveniente de fuentes de hidrocarburos no convencionales en Norteamérica y Sudamérica, la tendencia de los precios del gas natural se ha tornado decreciente en los últimos años. No obstante, la explotación de estos recursos energéticos está generando preocupaciones públicas debido a los posibles impactos ambientales adversos del uso del fracturamiento hidráulico y de otras técnicas en las fuentes de agua subterránea.

El propósito de este artículo es evaluar las siguientes interrogantes: ¿Existen súper ciclos en los precios del gas natural? ¿Cuáles son las consecuencias ambientales en Latinoamérica de la explotación del gas no convencional dado el comportamiento cíclico de los precios del gas y cómo los gobiernos pueden implementar políticas ambientales para regular la extracción del gas no convencional?

Tres súper ciclos en los precios del gas natural han sido identificados, habiendo ocurrido el último pico de precios en el año 2006. Nuestro análisis indica que la inestabilidad política, la intervención gubernamental a través de la nacionalización de activos y la presencia de empresas petroleras públicas, la falta de reglas de inversión transparentes, los altos gastos de capital para desarrollar proyectos de exportación de GNL (gas natural licuado) y la explotación de recursos de esquito (*shale resources*), así como los descubrimientos petróleo en la zona del pre-sal en Brasil hacen incierto que el boom del gas de esquisto alcance un gran impacto en Latinoamérica durante el súper ciclo vigente en los precios del gas.

Clasificación JEL: E32, L71, Q41, E37, L51, Q48, Q58.

Palabras Clave: Súper Ciclos, Latinoamérica, Recursos Agotables, Precios del Gas Natural, Medio Ambiente, Shale Gas, Descomposición Ciclo-Tendencia, Filtro *Band-Pass* de Christiano-Fitzgerald.

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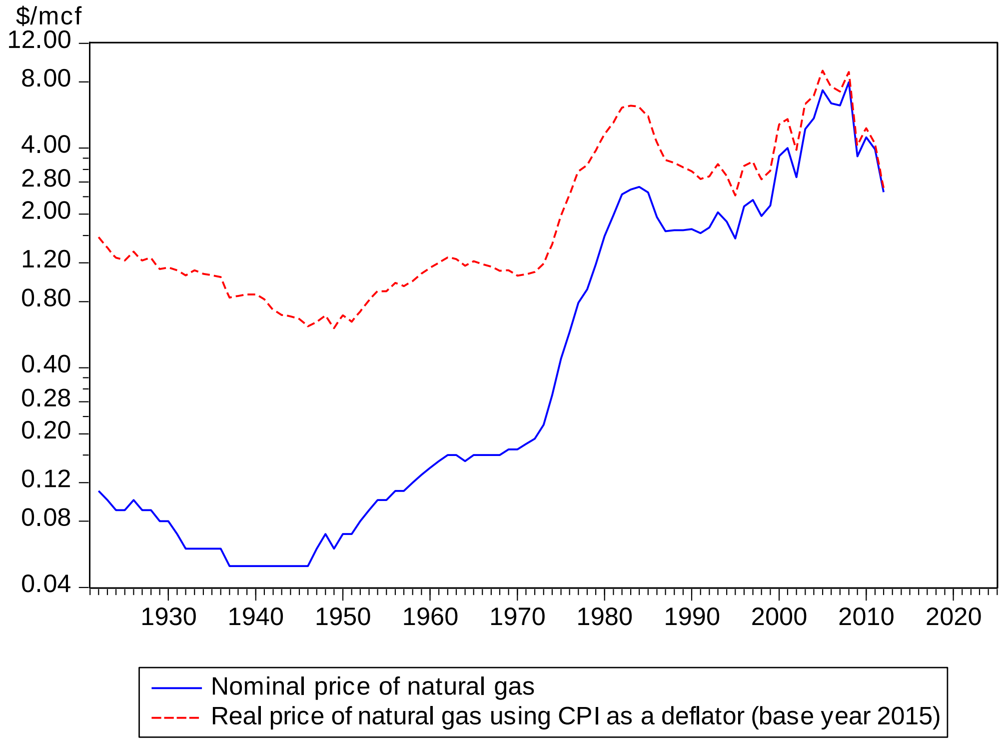
1. Introduction

Given the importance of energy resources in the global economy, it is hardly surprising that the prices of energy products have been extensively studied. Long-term trends, behavior over the business cycle, sensitivity to geopolitical developments and causes of short-run volatility have all been of keen interest to policy makers, producers, consumers, and investors. Figure 1 provides long-term annual data on real natural gas prices from 1922 to 2015 in the U.S.A.

Figure N° 1: Nominal and real prices of natural gas, 1922-2015*



* Real prices are obtained using the Consumer Price Index (CPI) (base year 2015) as the price deflator. The U.S. natural gas wellhead price series[3] spans the period 1922-2015 and is expressed in U.S. dollars per thousand cubic feet. The natural gas price for 2015 is a monthly average over the first 10 months of the year: no more data was available for 2015 at the time of writing this paper. Prices are displayed on a log scale. Source: U.S. Information Energy Administration.

The surge in prices in the early years of the 21st century has generated much discussion about both long-term trends (peak oil?) and possible 'super cycles' (SC) in commodity prices. See, e.g., Rogers (2004), Heap (2005), Cuddington and Jerrett (2008), Jerrett and Cuddington (2008).

[3] The natural gas wellhead price is defined by the EIA as the price of natural gas calculated by dividing the total reported value at the wellhead by the total quantity produced as reported by the appropriate agencies of individual producing States and the U.S. Bureau of Ocean Energy Management, Regulation and Enforcement. The price includes all costs prior to shipment from the lease, including gathering and compression costs, in addition to State production, severance, and similar charges.

Alan Heap (2005) defined SCs as “Prolonged (decades) long trend rise in real commodity prices.” The upswings of these SCs last 10 to 35 years as a large country or region goes through structural transformation associated with industrialization and urbanization. This structural transformation is accompanied by increased demand for energy commodities and metals as the manufacturing sector expands (see Kuznets 1973). Cuddington and Zellou (2012) provide a formal model of super cycles driven by the structural transformation of a typical economy during the development process. They show that the presence or absence of SCs will depend critically on the speed of capacity adjustment to surging mineral demand during industrialization. Cuddington and Jerrett (2008, 2010) found evidence of SCs in metals prices, while Zellou and Cuddington’ (2012a, 2012b) studies focused on super cycles in oil and coal prices.

The long-term behavior of natural gas prices for assessing energy projects is of current importance in Latin America where new conventional deposits of gas have been discovered during the last decades such as in Peru (Camisea), Bolivia (Tarija), Brazil (presalt deposits in the Santos basin), Trinidad & Tobago (offshore reservoirs) and Colombia. Large unconventional deposits of shale gas have been also assessed in Argentina (Vaca Muerta formation), Brazil and Mexico, suggesting that Latin America may become an important producer (and also an exporter) of natural gas in the coming years. However, the development of these unconventional gas projects require stable prices over the long run so as to improve their economics and guarantee their feasibility given the important capital expenditures required to put in production unconventional fields and set up the necessary infrastructure (e.g., pipelines, distribution networks, LNG plants) to deliver natural gas to domestic and international markets. This means that a careful assessment of whether super cycles characterize the behavior of natural gas prices (especially U.S. prices since they are used in the region as a reference to set up gas delivery contracts and take-or-pay agreements) is relevant to evaluate if Latin America will become a big player in the international natural gas industry.

Likewise, if a boom in shale gas extraction in Latin America happened due to a favorable long-term gas price cycle, it could also generate adverse environmental impacts as a result of the potential safety risks associated to hydraulic fracturing,[4] the construction of new gas infrastructure

[4] Hydraulic fracturing (also known as fracing, fraccing or fracking) is the propagation of fractures in a rock layer by a pressurized fluid. It is a technique extensively used nowadays to extract hydrocarbons trapped in

without careful management, weak regulatory institutions, unstable legal rules, corruption and little law enforcement in the region (O'Donnell 1993, Vásquez Cordano 2012, Levitsky and Murillo 2012).

In this context, the objective of this paper is to address the following questions: are there super cycles in natural gas prices? Is so, are we currently on the upside or downside of a cycle? What are the environmental consequences in Latin America of the exploitation of unconventional gas given the cyclical behavior of gas prices and how can governments implement environmental policies to regulate unconventional gas extraction in Latin America? In order to deal with these questions, in Section II we use the band-pass filter approach of Cuddington and Jerrett (2008) to study long-term trends in U.S. natural gas prices and to search for evidence of super cycles in natural gas prices. Taking into account the evidence from the super cycles analysis, in Section III we proceed to assess the environmental consequences in Latin America of the exploitation of unconventional gas given the cyclical behavior of gas prices and to define how governments can implement environmental policies to regulate unconventional gas extraction in Latin America. Section IV concludes.

2. Trends and Super Cycles in Natural Gas Prices

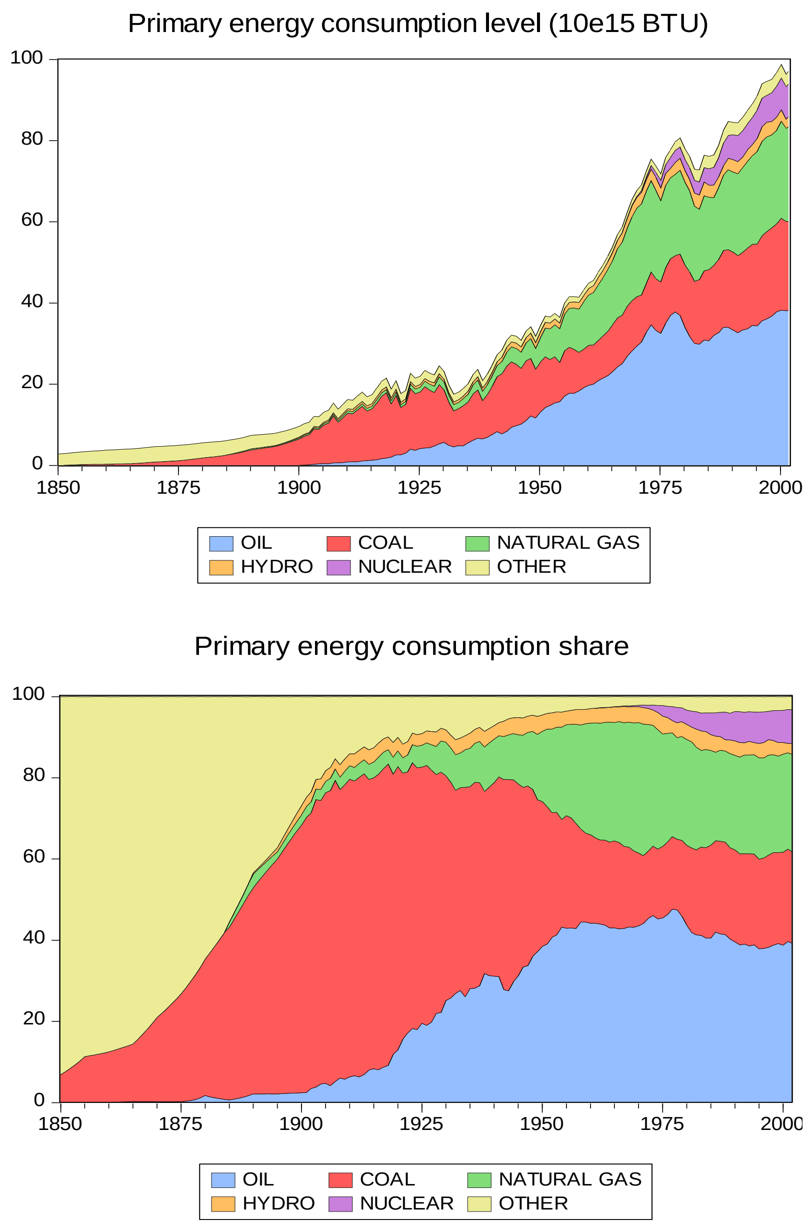
2.1. Background

Fossil fuels (coal, oil and natural gas) have been the main sources of energy since the Industrial Revolution. Figure 2 displays the evolving role of each fossil fuel in U.S. energy consumption since 1850. At the world level, fossil fuels represented about 80% of total primary energy supply in 2010, and this share is expected to remain roughly unchanged through 2035, according to forecasts by the IEA. The share of natural gas increased rapidly since World War II and remains constant at around 20% since the late 1970's. Alternative energy production is growing,

highly impermeable rock formations such as shale plays. It consists of injecting, at a high pressure, millions of gallons of water, sand and chemicals (i.e., fracturing fluids) to the formation located several hundred meters underground in order to fracture the rocks and allow the liberation of hydrocarbons to the surface. This procedure creates fissures from wellbores drilled into reservoir rock formations, allowing hydrocarbon fluids to flow to the wellhead for primary processing and distribution. The technique can allow exploiting unconventional resources such as shale gas, tight gas and coal seam gas. The first use of hydraulic fracturing was in 1947, but the modern technique, known as *horizontal slickwater fracturing*, that made the extraction of shale gas economical, was first used in 1998 in the Barnett Shale Formation in Texas. See King (2012) for further details.

but its share of global energy consumption is expected to remain roughly unchanged over the next 20 years. The bottom line appears to be that fossil fuels, including natural gas, will remain the primary energy resources for years to come and the evolution away from fossil fuels will be slow.

Figure 2: Primary energy consumption level (top panel) and share (bottom panel) for the United States between 1850 and 2010 *



* Fossil fuels (oil, coal and natural gas) represent about 80% of the total energy consumed since 1900. That consumption is for all sectors of the economy from transportation to the industrial sector. Source: Tol, Pacala y Socolow (2006). Information updated up to 2010.

2.2. Data and Band-Pass Filter Methodology applied to U.S. Gas Prices

The U.S. natural gas price series comes from the *U.S. Energy Information Agency*. [5] The series covers the period 1922 to 2015 and represents the price expressed in U.S. dollars per thousand cubic feet. Figure 3 displays the real prices of natural gas using the Consumer Price Index (CPI) as a price deflator. [6] An Oregon State University website publishes the longest span U.S. Consumer Price (CPI) Index series starting in 1774 on an annual basis used in this paper (Oregon State University 2013).

The ACF BP Filter is a univariate technique that allows the extraction of cyclical components from a given series.[7] The use of band-pass filters in economics has been promoted by Baxter and King (1999) and Christiano and Fitzgerald (2003).[8] The band-pass or frequency filter extracts cyclical components of a given time series that lie within a specified 'window' or range of frequencies or (conversely) periods. The user specifies the lower and upper bounds of the periods of the cycles of interest, e.g. cyclical components with periods within the 20-70 year interval.

Thinking of frequency filters in terms of time rather than frequency domain, Baxter and King (1999) explain that band-pass filters are sophisticated two-sided moving averages. They differ from the standard moving averages in two ways. First, the (ideal) weights of various leads and lags are chosen to filter out cyclical components that do not fall within the chosen window. By choosing symmetric weights on each lead and corresponding lag, phase shift in the extracted component is prevented. Second, there are asymmetric as well as symmetric filters. Although asymmetric filters invariably introduce some phase shift into the filtered series, they have the advantage of allowing computation of the filtered series over the entire data span rather than

[5] Sources: The full series is downloadable from the EIA website: http://www.eia.gov/dnav/ng/hist/n9190us3A.htm The CPI series is downloadable from the Oregon State University website: http://liberalarts.oregonstate.edu/spp/polisci/research/inflation-conversion-factors-convert-dollars-1774-estimated-2024-dollars-recent-year.

[6] Other price deflators such as the Producer Price Index for all Commodities (PPI) give similar results.

[7] Cuddington and Jerrett (2008) and Jerrett (2010) provide a good description of the use of asymmetric Christiano-Fitzgerald band-pass filter for SC analysis and apply it to the study of metals prices.

[8] Similar band-pass filter techniques are used in different fields, e.g. hard sciences such as electronics and physics. The second author of this paper has encountered it, for example, in spectral imaging and spectral decomposition in geophysics in the oil and gas industry to extract 3D images of reservoirs in the presence of oil, gas or water.

being limited to a trimmed data span caused by the number of leads and lags used in calculating the filtered series. This is obviously advantageous if one is particularly interested in studying cyclical behavior near the end (or beginning) of the available data span.

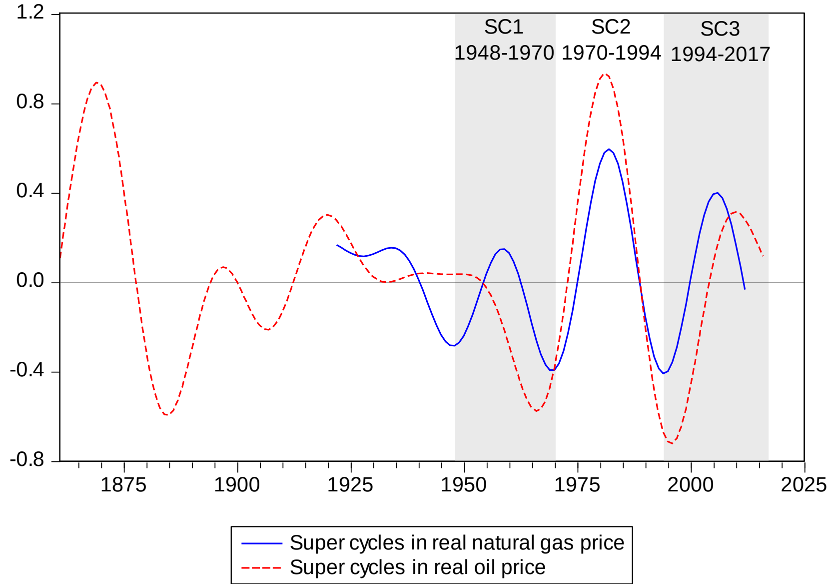
The four different components extracted are the super-cycle, an 'intermediate' cycle, the business cycle and the trend component. The period 'window' for these components is defined so that they are mutually exclusive and exhaustive (note that the seasonal component is not measurable with annual frequency data). The SC component, for example, has a window of 20 to 70 years. The trend component is defined to include all cyclical components beyond 70 years: $T(70, \infty) \equiv Actual - BC(2,8) - IC(8,20) - SC(20,70)$ where T , BC, IC and SC represent the trend, business cycle, intermediary cycle and super-cycle components respectively.

2.3. Trend and Super Cycles in Natural Gas Prices

Figure 3 displays the super cycles in real natural gas prices. For the purpose of comparison and analysis, the super cycles in real oil prices are provided as well. The units on the vertical axis represent percentage deviations from the trend. For example, +0.20 indicates 20% above the long-term trend. The shading corresponds to the super cycles in real natural gas prices with the corresponding dates (from trough to trough). Three different SCs in natural gas prices are identified from trough to trough: SC1: 1948-1970; SC2: 1970-1994; SC3: 1994-2017. The first two super cycles in natural gas price lasted 22 and 25 years respectively. If the current super cycle we are currently in should last as long as the previous two, one may expect the next trough to occur right before or around 2020. Moreover one may notice also a strong correlation between the super cycles in oil and natural gas prices (Table 1). Finally, the amplitudes of the super cycles in natural gas prices are smaller than the ones in oil prices. They are still quite significant with values at 59% above the trend for the peak in 1982 and 40% for the next peak in 2006 (Figure 3).

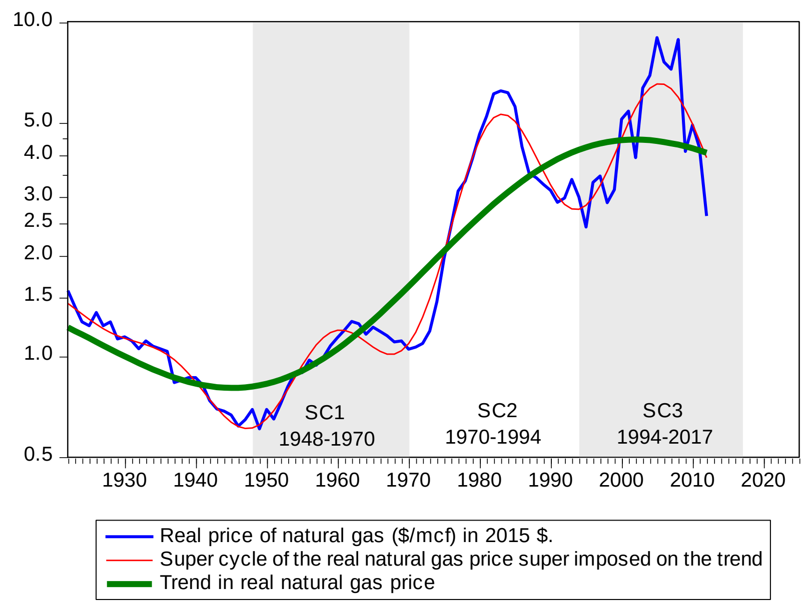
Figure 4 displays the super-cycle and trend components for the real natural gas price series. A comparison of the long-term trend components of the two energy commodities is interesting in light of ongoing discussions about increasing scarcity of nonrenewable resources, peak oil, etc.

Figure 1: Super cycles in the real natural gas prices



* For purpose of comparison and analysis, the super cycles in real oil prices are provided as well. The units on the vertical axis represent percentage deviations from trend. The shading corresponds to the super cycles in real natural gas prices with the corresponding dates (from trough to trough). Three different SCs in natural gas prices are identified from trough to trough: SC1: 1948-1970; SC2: 1970-1995; SC3: 1994-2017. Source: Own elaboration.

Figure 4: Real natural gas prices, along with their trend and super-cycle components *



* The shading corresponds to the different super cycles in real natural gas prices identified in Figure 3 above. An upward trend in real oil prices started after World War II and ended in 2002. In real terms, the trend in natural gas prices has increased by 171% between 1945 and 2002 (in log terms), representing an average annual increase of 3%. Note that the SC component is currently at the intersection of the trend component suggesting that the downward trend phase of the SC is far from over to reach the trough. The vertical axis is on log scale. Source: Own elaboration.

Table 1: Correlation between the super cycles in natural gas prices and oil prices *

Covariance Analysis: Ordinary
Date: 12/21/15 Time: 15:42
Sample (adjusted): 1922 2012
Included observations: 91 after adjustments
Balanced sample (listwise missing value deletion)

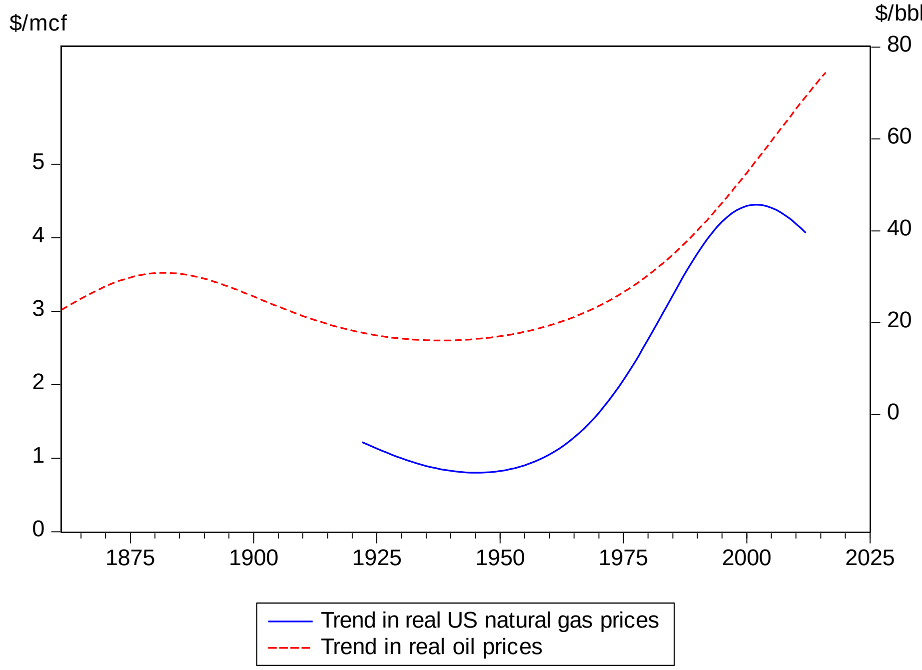
Correlation	LPRNG_SC	LPROIL_SC
LPRNG_SC	1.000000	
LPROIL_SC	0.753884	1.000000

* One may notice also a strong correlation (0.75) between the super cycles in oil and natural gas prices. Source: Own elaboration.

For the real price of natural gas, the trend is a U-shaped curve, up to 2002, as predicted by Slade (1982), but with a downward orientation for the past 9 years. In real terms, the trend in natural gas prices has increased by 171% between 1945 and 2002 (in log terms), representing an average annual increase of 3%, which represents a sharper increase than for real oil prices. Note that the SC component is currently at the intersection of the trend component suggesting that the downward trend phase of the SC is far from over to reach the trough. The recent downward trend in real natural gas prices started in 2006, showing evidence that technology is winning the race against depletion, mainly thanks to the production from shale resources (Tilton 2003).

The real oil price trend also has a U shape: downward until World War II and then upward at a rate of roughly 2% per year thereafter (Figure 5). Note that the trends of both series change direction more than once, in contrast to the predictions of Slade's theoretical model and empirical results. The trend component for natural gas we are currently experiencing since 2002 is indeed downward, but the slope is very gentle, and it is too early to assess how rapid the decline is going to be. The natural gas super-cycle component is downward as well and is already slightly under the trend (see figure 4). If a length of the current super cycle is assumed to be similar to the previous two, a trough could be expected to occur around or before 2020, before prices bottom out and start picking up again. This is more or less in line with current price forecasts, even though the current futures are on the high end of it.

Figure 2: Trend in real natural gas prices



For the purpose of comparison and analysis, the super cycles in real oil prices are provided as well. The trend component for natural gas we are currently experiencing since 2002 is indeed downward but the slope is very gentle and it is too early to assess how rapid the decline is going to be. The natural gas super-cycle component is downward as well and is already under the trend (see Figure 4). If a length of the current super cycle is assumed to be similar to the previous two, a trough could be expected to occur around or before 2020, before prices bottom out and start picking up again. This is more or less in line with current price forecasts, even though the current futures are on the high end of it. Source: Own elaboration.

After demonstrating the presence of super cycles in natural gas prices, we will focus on the environmental consequences in Latin America of the exploitation of unconventional gas given the cyclical behavior of gas prices. How can governments implement environmental policies to regulate unconventional gas extraction in Latin America? We will also examine whether the fact that super cycles characterize the behavior of natural gas prices (especially U.S. prices since they are used in the region as a reference to set up gas delivery contracts) is relevant to evaluate if Latin America will become a big player in the international natural gas industry.

3. Policy Implications for Latin America: The Future of Shale Gas and Environmental Impacts

The evidence shown in the previous section regarding the trend and super-cycle components of U.S. natural gas prices indicates that we are probably entering an age of downward prices that might last several years. Our results support the claim made by the International Energy Agency (IEA) that the world will experience a "golden age" of natural gas consumption (IEA 2011). The shale gas boom in the U.S.A.[9] and the accelerated increase of LNG international trade (global demand for LNG has increased by an average of 7% per year since 2000) appear to indicate that extraction and transportation technologies are overcoming the non-renewable nature of natural gas (Tilton 2003, BNAmericas 2015). IEA (2011) projects that in the coming twenty years the world energy matrix will shift toward a higher reliance on natural gas as a primary energy source (25% of total primary energy would be based on natural gas by 2035) and that over 40% of the new gas needed (1.8 trillion cubic meters) to satisfy the growing world energy demand will come from unconventional sources, mainly shale formations.[10] Therefore, both an increasing energy demand and a downward direction for gas prices due to technology improvement may be key factors explaining shale gas development in the coming years, which accounts for almost 60% of global supply growth (IEA, 2014).

In this context, Latin America has an expectant position. According to a recent study made by the U.S. Energy Information Administration (EIA), Latin America has the largest technically recoverable resources (TRR) of shale gas in the world. Figure 6 shows that Latin America would have TRR for 1,979 tcf (26% of world's total shale gas resources), less than double the resources of the US and Canada together (EIA 2015). Figure 6 also shows that three Latin American countries,

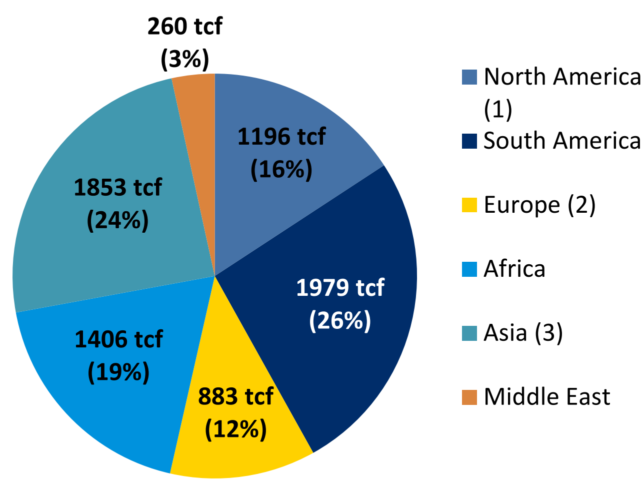
[9] Regarding this point, according to BNAmericas "Unconventional oil and gas resources trapped in shale reservoirs had been largely ignored by the industry until recently, with only research and development (R&D) departments focusing on the untapped wealth these formations might someday reveal. However, at the turn of the 21st century, sustained high energy prices and increasing import dependence in large consuming markets created incentives for the development of new technologies to exploit domestic shale potential. This was notably the case in the United States, the birthplace of the shale revolution, where the swift commercialization of these resources took many observers aback." (2012: 2).

[10] Other benefits of shale gas extraction can show up at a regional and local level inside producing countries. These benefits are associated with, for example, the increase in local employment and economic activity related to complementary services for gas production (e.g., consulting and engineering services, drilling activities, transportation of materials and waste, etc.) However, Kinnaman (2011), who has conducted a review of several studies on the subject in the U.S., argues that these benefits can be overstated due to methodological problems related to the measurement of the effects of shale gas production on the local and regional economies. Thus, these benefits should be assessed with care.

Argentina, Mexico and Brazil, are among the top ten countries with shale gas TRR in the world. Around 80% of the region's shale gas is concentrated in these countries: Argentina (41%), Mexico (28%) and Brazil (12%). Table 2 presents the status of shale TRR of Latin American countries. As we can see, some countries with smaller shale deposits may also have incentives to exploit these resources given the size of their economies and their energy needs to foster economic development.

Figure 6: Shale Resource Estimates

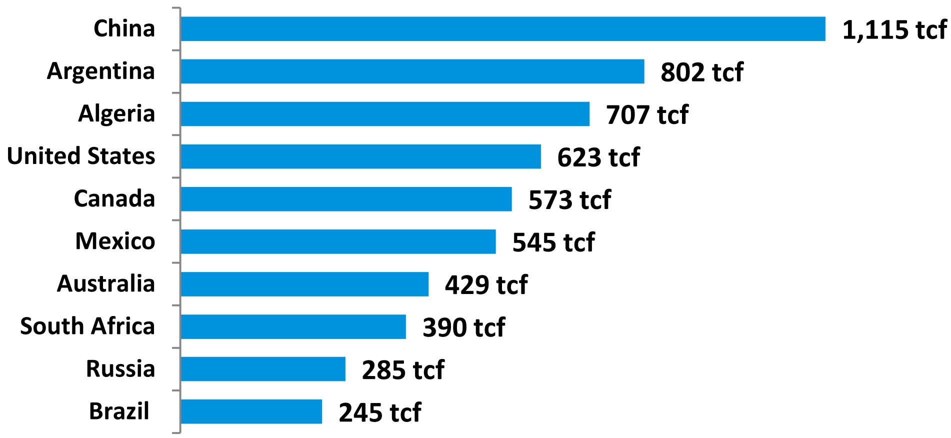
Unproved wet shale gas technically recoverable resources*



*Total World Recoverable Resources: 7,577 tcf. South America include Mexico

(1) North America includes the United States and Canada
(2) Europe includes Russia and Ukraine.
(3) Asian Includes Australia and Kazakhstan
Source: EIA (2015).

Top 10 Countries with technically recoverable shale gas resources



Source: EIA (2015).

In addition, Latin America can also benefit from already available technologies to hit untapped shale gas resources that have been developed during the last decade when high gas prices in the United States stimulated the perfection of horizontal drilling and hydraulic fracturing (IEA 2012, Rahm 2011). In this sense, countries in the region only need to promote clear investment rules and a good business climate to foster foreign direct investment and technology transfer to develop their shale resources. Given the magnitude of the shale gas potential in Argentina, Mexico and Brazil, in the next section our analysis will focus on these countries in order to assess whether a shale gas boom can start as a consequence of a growing energy demand and lower prices over the super cycle.

Table 2: Technically Recoverable Shale Gas Resources in Latin America (TCF)

Country	**Shale gas (tcf)**
Argentina	802
Mexico	545
Brazil	245
Venezuela	167

Paraguay	75
Colombia	55
Chile	49
Bolivia	36
Uruguay	5

Source: EIA (2015)

3.1. Argentina: A shale gas powerhouse in the South America?

In 2004 Argentina experienced a severe energy crisis because its domestic consumption increased rapidly due to widespread gas price subsidies, while its domestic production declined due to the contraction of foreign investment in the upstream gas industry after the debt crisis of 2002 and the persistent governmental intervention in the Argentinean energy market. The Argentinean government had to cut exports to Chile, initiate energy rationing and start importing gas from Bolivia (Isbell 2006). This energy crisis motivatedthe Argentinean government to look at unconventional resources. According to EIA (2015) and BNAmericas (2012), of the 802 tcf of TRR in Argentina, the Neuquen basin (where formations of good potential such as Vaca Muerta, Los Molles and Agrio are located) contains 73% of the total. Other basins of importance are Austral-Magallanes (16%) and Golfo San Jorge (11%). This large potential has attracted international oil companies (IOCs) including U.S. firms such as Petrogas, Apache, Exxon Mobil, Pan American Energy (controlled by BP) and the French major Total.

Currently, Argentina has a system where the control and ownership of hydrocarbon resources reside with the provinces where they are located[11]. The Hydrocarbons Law Reform, published on 31 October 2014, has the aim to create incentives to encourage long-term foreign investment in the oil and gas sector. Furthermore, a standardization process was initiated of tax issues and methods of awarding contracts to exploitation and exploration of conventional and non-conventional hydrocarbons to be applied in each of the Argentine provinces in order to avoid the competition between them.

[11] Art. 124 of the Constitution of 1994.

Even though the Reform incorporates the technical concept of non-conventional hydrocarbons, it does not establish a distinction between tendering processes for conventional and non-conventional hydrocarbons. Under the Reform, an oil company is awarded a certain area where it can perform commercial exploitation of all hydrocarbons within its extension but, in case of non-conventional hydrocarbons, it must inform its willingness to exploit those resources and present a pilot plan to the corresponding province. Another way of awarding an area of non-conventional resources is through partnerships with provincial companies (state-owned enterprises at the provincial level) (CEPAL, 2015).

The Argentinean state enterprise YPF, nationalized in 2012,[12] plans to invest US$ 6.5 billion during 2013-2017 to foster national gas production, of which US$ 1.8 billion are intended for the exploration and exploitation of unconventional resources and well stimulation. To finance this amount, in 2013, YPF signed investment agreements to explore for shale gas with Chevron ($1.24 billion) and Dow Chemical ($120 million) for the areas of Loma Campana and Orejano, respectively (YPF 2012).

Regarding the tax system, under an investment promotion scheme, concessionaires that invest more than $250 million over a three-year period will be permitted to sell 20% of their production on international markets free of export duties or sell it to the local market at international prices. Also, oil concessionaires have the right to freely get the foreign exchange earned from the export of these hydrocarbons. In addition, they have the right to a reduction of 25% of oil royalties for a period of ten years.

On the other hand, the period of exploration and exploitation is fixed 8 and 35 years, respectively. It represents an additional2 and 10 years over conventional concessions, respectively. Also, it reinforces the “Gas Plus” program, introduced in 2008, at to encourage the production of unconventional natural gas. This scheme allows selling output from unconventional deposits at much higher prices than the regular ones.

Other factors affecting the future of shale gas development in Argentina include the increase in gas transportation taxes, the end of tax breaks in Tierra del Fuego, policies to promote

[12] El País (2012).

energy self-sufficiency, steps to discourage exports (including LNG), restrictions on the repatriation of dividends and foreign exchange controls.[13]

With the election of the new president, Mauricio Macri, Argentina expects a number of reforms oriented towards policies to attract foreign investment. One of the proposals of Macri was to establish clear rules to attract and stabilize foreign investment in productive sectors. In his first days as president, Macri cuts taxes on farm and lifted restrictions on the foreign exchange market (BBC News 2015). On the other hand, Moody's Investor Service (Moody's) changed Argentina´s outlook from stable to positive, because Macri's election would increase the chances of implementing positive credit policies (Moody´s 2015).

With respect to the energy sector, Macri has promised to put in order the regulation of public services and energy subsidies in order to restore confidence in the institutions, since the renationalization of YPF has damaged the country's reputation in the international energy and financial context (La Nación 2015). Also, he promised to create a Ministry of Energy to manage energy policy. Overall, the election of Mauricio Macri has generated positive expectations worldwide and reforms are expected to boost confidence of foreign investors in Argentina.

3.2.Mexico: Old ghosts may affect shale gas development

According to British Petroleum (2014), Mexico is the world's 13th gas producer and its 11th largest oil producer. Nonetheless, its status as an important hydrocarbons exporter is weakening because of declining production and an increasing energy demand. Mexico's oil exports have fallen on average of 4.3% annually since 2011, having reached 1,290 thousand barrels per day in 2014, while natural gas production has not kept with the strong demand (production fell 0.2% year on year since 2011, while demand grew at 4.3% on average). Thus, Mexico will have to open new basins to obtain oil and natural gas. PEMEX, the Mexican National Oil Company (NOC), is now increasingly looking at following the shale success of the US.[14] According to Table 2, Mexico has

[13] See Roig (2012) for more details regarding the problems associated with exploiting shale gas resources in Argentina, including the challenges of applying hydraulic fracturing techniques in the Argentinean formations.

[14] In March 2011, PEMEX announced the beginning of the production of its first shale gas well in Coahuila after having drilled 10 wells. PEMEX plans to invest US$ 15 million to drill 175 wells in the coming four years.

TRR of 545 tcf which are divided between five basins: Burgos (72%), Sabinas (23%), Tampico (4%), Tuxpan Platform (0.5%) and Veracruz (0.5 %).

Although the Mexican shale gas formation share some geological similarities with the ones in the U.S.A., the development of them might be technically more difficult because they are structurally more complex and many of them are located very deep in the ground (5 km), factor that increases extraction costs. In this context, the Mexican government introduced in 2014 an energy reform by promulgating addendums on twelve existing laws and creating nine new secondary laws. This reform was characterized by maintaining state control and sovereignty over hydrocarbons and the modernization of the industry through greater private investment in capital and technology (CEPAL 2015). In this regard, two ways were established for the private participation in the exploration and exploitation of hydrocarbons: direct assignment (zero round) and tenders.

Before the energy reform, PEMEX was responsible for exploration in Mexican territories. Through the Round Zero, PEMEX requested the State to reserve exclusive areas for its operation before the entry of the private sector. As a result, the Energy Secretariat (SENER) assigned PEMEX 83% of probable reserves[15] and 21% of prospective resources.[16]

With respect to tenders, it generates four types of contracts with the State: i) licenses, where the State transfers total exploration and exploitation rights of hydrocarbons to private companies, ii) risk sharing contracts, where the State shares the profit with private companies, iii) production sharing contracts, where private companies are remunerated by a percentage of production, and finally iv) service contracts,, in which the State hires a company for the exploration and exploitation of hydrocarbons and pays it when products are marketed.

In 2015, the Mexican government initiated the first round of tenders (Round One) of new contracts for exploration and exploitation of hydrocarbons in which Mexico will auction 169 blocks, whose 98 blocks are no conventional. Round One was divided into five phases and each phase included blocks more difficult to extract.

[15] Hydrocarbons with at least 50% chance to be extracted from underground.

[16] Prospective resources are hydrocarbons that have not been discovered yet, but they are assessed to be potentially recoverable through future projects.

By December 2015, Mexico conducted three tenders. Table 3 shows a summary of the blocks offered and assigned in each tender. In the first tender, only 14% of the blocks were allocated. The general causes were: lower oil prices, the unattractiveness of the tendered blocks and high government claims given market conditions (Forbes 2015). Given these results, the Mexican government published a document of “lessons learned” and amended contractual terms to make them more attractive for private investors[17]. As a result, the second and third tender had more favorable results.

Table 3: Results of the tenders of Round One

Tenders	Blocks offered	Blocks allocated	% Total Supply
First tender	14	2	14%
Second tender	9	6	60%
Third tender	25	25	100%

Source: SENER, National Hydrocarbon Commission (CNH) y SHCP, 2015.
Elaboration: Own elaboration.

The fourth tender includes ten deepwater blocks under license contracts. Each block is expected to bring in around $4.4 billion in investment over the life of the contract. The data room will remain open for nine months. It is expected to award the contracts in January 2017. The last tender will include unconventional exploration in Chicontepec and Tampico-Misantla.

It is necessary to wait and see whether the reform is successful to attract enough investment to develop Mexican shale resources. In any case, Mexico will have to confront its old demons and public opposition against foreign investors if it wants to exploit its shale deposits effectively.[18]

3.3. Brazil: Presalt reservoirs and political issues overshadow shale gas

Brazil’s oil and gas industry experienced in recent years an accelerated development thanks to the discovery of its deepwater presalt reservoirs. Brazil produced 3.2 million bpd of oil

[17] The Mexican government relaxed the corporate guarantee and the ability to integrate or not a consortium. Also, the Secretariat of Finance and Public Credit (SHCP) published ahead the expected investment. See El País (2015a, 2015b) for more details about the impact of the energy reform on PEMEX.
See BNAmerica (2013a) for further details.

and 1.9 bcf in 2014, according to British Petroleum, and it has recently become a net oil exporter. Brazil's presalt boom started with the discovery of Tupi field (now known as Lula), with a total potential of 50 billion barrels of oil equivalent (boe). Brazilian presalt oil wealth has eclipsed the country's shale gas potential. Additional investment in shale gas would add more pressure on budgets and an already stretched oilfield services industry. Petrobras itself, the Brazilian national oil company (NOC), is struggling to face the presalt challenge: it recorded a net loss of more than US$7billion in 2014, of which US$ 2 billion were lost to corruption between 2004 and 2014. It is unlikely that private investors take the risk of investing heavily in shale gas because of the profitable opportunities in the Brazilian offshore. Another factor that may deter foreign private investment in shale gas is the fact that the government through Petrobras holds a tight grip on the oil and gas industry which leaves small room for international oil companies (IOC) and smaller independent oil companies (BNAmericas 2013b). Finally, in spite of large capital expenditures, the exploitation of presalt reservoirs exhibit low operational expenditures helping to decrease breakeven costs down to an interval of US$30-US$40/bbl, which is competitive with even the lowest costs of US shale projects. Thus, a shale rush is less likely, unless the Brazilian government introduces alternative incentives to promote shale gas development.

In November 2013 the Brazilian government launched tender round N° 13 on gas concessions on land. One of the requirements was the obligation to explore and investigate the existence of unconventional hydrocarbons in the referenced areas. If the company found unconventional resources and wants to exploit it, it must notify the National Petroleum Agency (ANP) and then apply for the corresponding concession contract (CEPAL, 2015).

Currently, Brazil is facing a severe economic and political crisis due to the corruption scandal of Petrobras, which involves the most important construction companies in the country and in Latin America. The scandal also involves important public officials and private investors in the country[19]. This crisis has paralyzed the main infrastructure projects[20] because of the reduction

[19] El País (2015). *Operación Lava Jato*: *El escándalo de corrupción de Brasil se extiende por las empresas públicas*. Available at http://internacional.elpais.com/internacional/2015/07/28/actualidad/1438112993_870001.html (last access: 06/06/2016).

[20] El País (2015). *El "caso Petrobras" pone en riesgo las grandes obras de Brasil para 2015*. Available at http://internacional.elpais.com/internacional/2015/01/13/actualidad/1421180516_022574.html.

of Petrobras' investments explained by its lack of liquidity[21]. As a result, Petrobras reduced exploration activities to the "minimum necessary". This reduction in investment has affected the productive chain of the Brazilian oil and gas sector, which in turn has reduced tax revenues and increased unemployment.

On the other hand, Moody's Investors Service ("Moody's") downgraded all ratings for Petrobras and withdrew its investment grade[22]. Likewise, Standard & Poor's lowered its credit rating. In that sense, Petrobras has become the largest corporate issuer of non-investment grade bonds worldwide. This situation is affecting Petrobras's ability to obtain external funding and foster new investments in unconventional deposits. The higher financing costs, falling oil prices and the corruption scandal have reduced the growth possibilities of the gas industry in Brazil.

3.4. Balance of the situation in Argentina, Mexico and Brazil

Our analysis in the previous section indicates that Latin America has a great geological potential to develop its shale gas industry, but the region faces many economic obstacles and political challenges to develop its gas industry. The US experience shows that the development of shale gas requires large investments to access the technology and the skills to extract it. The attraction of these investments will depend on the policy of each country, the rules regarding the energy market and the State´s ability to provide a safe environment for exploration and production.

Unfortunately, the unstable political situation and corruption cases, the nationalist attitude regarding natural resources, the lack of transparent investment rules, high capital expenditures to develop LNG export projects and the exploration of shale resources, as well as the presalt discoveries make uncertain that the shale gas boom achieve a large impact in Latin America during the current gas price super cycle.

[21] El País (2015). *Petrobras bribery scandal has cost oil firm €1.8 billion, says CEO*. Available at http://elpais.com/elpais/2015/04/23/inenglish/1429798373_430651.html.

[22] Moody´s (2015) *Moody's downgrades Petrobras' to Ba3 and places ratings on review for downgrade*. Available at https://www.moodys.com/research/Moodys-downgrades-Petrobras-to-Ba3-and-places-ratings-on-review--PR_340722.

A situation that may arise is the consolidation of regional markets in the area. For instance, regional pipelines may be built from countries with abundant shale gas to countries with insufficient reserves to supply their energy demand. An example of this is the case of Chile which needs cheap gas to fuel its thermoelectric plants to satisfy the electricity needs of world-class copper mines that are planned to be opened in the next decade. Chile installed Quinteros and Mejillones LNG regasification plants in 2010 and 2011, respectively in order to counteract the gas shortages it experienced in 2004 when Argentina cut gas exports. Also, Brazil put into operation Guanabara LNG import facility in 2012 and the Bahia plant in 2014 (BNamericas, 2015). If Argentina developed its shale resources, it could increase gas exports to Chile and build new pipelines to supply the Chile's new mining regions. Another example is the case of Bolivia which currently exports vast quantities of natural gas to Brazil and Argentina. If both countries exploited their shale gas, it is possible that they cut their imports from Bolivia, leaving the Bolivian gas stranded. In that scenario, the Bolivian government might want to negotiate with Peru an access to the Camisea pipeline to export its gas through the LNG export plant of Pampa Melchorita near Lima, which is the only LNG export terminal in South America.

Therefore, the future of shale gas in Latin America is not clear at all. It seems that there are more possibilities during the current super cycle to observe an increase in the degree of integration of regional markets. Given the high CAPEX involved in the exploration of shale resources and in the construction of LNG export plants, as well as the political instability and nationalism in the countries analyzed, it is uncertain whether financially strong IOCs with technological expertise will take the risk to invest high amount of capital during the current super cycle.

Another factor related to the possibility to develop shale gas resources in Latin America are the environmental risks related to the extraction technology to exploit shale gas and the institutional capabilities to control these risks in Latin America. We analyze this issue in the following section focusing on Argentina, Brazil and Mexico.

3.5. Challenges for environmental regulation in Latin America in a worldwide shale gas boom

Despite the favorable panorama for shale gas exploitation deduced from our super cycle analysis, some studies have pointed out that the production of natural gas from shale plays implies several environmental risks. The cases of water pollution, air pollution and earthquakes have been attributed to shale gas extraction activities in places where fracking technologies have been used. Table 3 summarizes the most important environmental risks associated with shale gas extraction identified in the literature. Many of the risk identified in Table 3 are associated with the process of hydraulic fracturing.

Regarding this point, there is currently an intense debate about the environmental effects of extracting shale gas, especially focused on the impacts of hydraulic fracturing,[23] well completions and wastewater. First, the risk with fracking is that the fractures generated to stimulate shale deposits may expand beyond the formation, allowing methane to flow to aquifers and polluting underground water. Hence proper seismic monitoring is important to assure that the fracturing process produce micro-seismic activity only in the shale bed. Another concern with respect to shale gas extraction is the issue related to the well injection. Construction issues, sustained casing pressure, and the presence of natural faults and fractures may work together to create pathways for fluids to migrate toward drinking water resources. An accident in Bainbridge in the U.S. in 2008 showed that improper monitoring of completion of shale gas wells may pollute water in the surroundings.[24]

Explosions in shale gas wells due to a mismanagement of operations like the ones in Pennsylvania and West Virginia indicate that it is necessary to have well-trained personnel to conduct shale gas extraction (Zoback, Kitasei and Copithorne 2010). Second, wastewater[25] that comes out from wells may contaminate superficial soil, ground aquifers, lakes and rivers if operators do not use proper care regarding transportation, storage and deposition of residual

[23] In a report about the topic, Colley and Donnelly point out that “hydraulic fracturing has generated a tremendous amount of controversy in recent years. There are daily media reports on this topic from outlets across the United States and in a host of other countries, including Canada, South Africa, Australia, France, and England. It is hailed by some as a game-changer that promises increased energy independence, job creation, and lower energy prices. Others are calling for a temporary moratorium or a complete ban on hydraulic fracturing due to concern over environmental, social, and public health concerns.” (2012: 4).

[24] See for further details about this case *Report on the Investigation of the Natural Gas Invasion of Aquifers in Bainbridge Township of Geauga County, Ohio.* September 1, 2008. Ohio Department of Natural Resources, Division of Mineral Resources Management. Available at http://s3.amazonaws.com/propublica/assets/natural_gas/ohio_methane_report_080901.pdf.

[25] Shale gas wastewater contains high concentrations of total dissolved solids (salts) and various organic chemicals, inorganic chemicals, metals, and naturally occurring radioactive materials (NORM).

water and other pollutants from the drilling and fracking process.[26] Popkin, Duke, Borchers and Ilvento (2013) provide evidence, from an economic choice experiment, that in New York State (U.S.A.), on average, households incur a welfare loss from in-state hydraulic fracturing as the source of their electricity. Household in shale counties would bear more costs from hydraulic-fracturing electricity than households out of shale counties. In addition, the authors show that the relative proximity to hydraulic-fracturing well sites can also increase external costs borne by households.

Table 4: Risk for Shale Gas Production

Risks	Potential impacts
Release to water resource	- Water use: Fracking has the potential to alter the quality of drinking water resources. Withdrawals may lower water levels and alter stream flows, potentially decreasing a stream's capacity to dilute contaminants. - Groundwater pollution: operation under surface could contact aquifer which would be contaminated by drilling fluids and methane. If spills occur, ground water impacts may persist longer than surface water impacts because of lower flow rates and decreased mixing. - Water transportation logistics: the process of hydraulic fracturing by well required on average 15,000m^3 of water, or its equivalent to 500 tankers load. This process can congest the roads and generate traffic. - Flowback and produced water: potential impacts from spills or releases of produced water depend on the volume, timing and composition of the produced water. Inadequately treated hydraulic fracturing wastewater may increase concentrations of TDS, bromide, chloride, and iodide in receiving waters.
Seismicity	- Hydraulic fracturing and/or produced water disposal can lead earthquakes of low magnitude.
Chemical Mixing	- Fracking using hazardous chemicals in significant quantities which can be harmful to humans when exposed to the ground and surface water.[27]
Methane pollution	- The physical properties of methane gas, low viscosity and low density, facilitate their migration towards surface when the well integrity is deficient.

Source: EPA (2015), CEPAL (2015).

[26] An example of the risk associated to waste water from shale gas production is what happened in Pennsylvania in 2009. The Pennsylvania Department of Environmental Protection discovered two leaks from one pipeline carrying waste water from two shale gas wells to a waste storage. Both leaks spilled 4,200 gallons of waste waters to Cross Creek Lake, causing the dearth of fish and vegetal life. There have been also studies carried out by the U.S. government indicating that waste water may also contain large quantities of radioactive material such as radium, which could pose a large threat to human health. See "Fracking brine: Gas-well waste full of radium." *The Columbus Dispatch*, 02/27/2013. Available at http://www.dispatch.com/content/stories/local/2012/09/03/gas-well-waste-full-of-radium.html. See also Rahm (2011) who explains the environmental impacts generated by shale gas production in Texas.

[27] EPA have identified a list of 1,076 chemicals used in hydraulic fracturing fluids but only the physicochemical properties of 453 are known. This is a gap that limits the hazard identification and understanding of the ways in which can affect people and the environment.

According to the U.S. Environmental Protection Agency (EPA), shale gas wastewater is currently forbidden from being directly discharged to waterways and other waters in the U.S.. To abide by this rule, some of the shale gas wastewater is reused or re-injected, but a significant amount still requires disposal. Some companies reinject the wastewater into disposal wells. Other companies transport wastewater to public and private treatment plants, which may not be equipped to treat this type of wastewater, resulting in the discharge of pollutants to rivers, lakes or streams where they can impact drinking water or aquatic life.

Finally, according to Howarth, Santoro and Ingraffea (2011), shale gas extraction also has a green-house-gas (GHG) footprint which is significantly larger than that from conventional gas production because of methane emissions with flow-back fluids and from well drilling during the completion stage. The authors show evidence supporting the argument that the large GHG footprint of shale gas undercuts the logic of its use as a bridging fuel over the next years, if the target is to reduce global warming.

Because of the environmental risks associated with shale gas mentioned before, the EPA has started a comprehensive rulemaking to control wastewater and GHG emissions generated by gas extraction from underground shale formations. Likewise, the EPA is also conducting a study of the effects of hydraulic fracturing on groundwater. The draft assessment, released recently, does not find evidence of systemic impacts on drinking water resources in the U.S.A., but it identifies potential mechanisms by which hydraulic fracturing could affect it. These mechanisms includes water withdrawals at times or in locations of low water availability, spills of hydraulic fracturing fluid and chemicals or produced waters and inadequate treatment and discharge of hydraulic fracturing wastewater (EPA, 2015).

Also, the Department of Energy is collecting new information related to shale gas wastewater and its disposal. [28] On April 7, 2015, the EPA published proposed pre-treatment

[28] In Europe, environmental regulations has evolved to become in many respects the most demanding ones in the world, which make difficult to exploit unconventional resources in this region. For instance, in May of 2012 France, Bulgaria, Romania and the Czech Republic have suspended the operation of its deposits of shale gas for environmental reasons. Therefore, gas imports via LNG tankers and pipelines will still be needed to complement Europe's indigenous gas production for the foreseeable future. See Weijermars et al. (2011), Shale Gas Europe (2013) and Algañaraz (2012) for further details.

standards for the oil and gas extraction category. This regulation would strengthen existing federal controls on pollutant discharges from certain oil and gas extraction facilities by establishing pre-treatment standards that would prevent the discharge of pollutants in processing wastewater from on-shore unconventional oil and gas extraction facilities to publicly-owned treatment works (POTWs). [29]

Moreover, the International Energy Agency and the European Union have issued recommendations for the manufacturing of non-conventional resources (see Table 4).

Figure 7: Golden Rules to address the environmental impacts

Measure, disclose and engage	• Integrate engagement with local communities. • Establish baselines for key environmental indicators. • Measure and disclose operational data .
Watch where you drill	• Properly survey the geology of the area. • Assess the risk that deep faults could generate earthquakes.
Isolate wells and prevent leaks	• Put in place robust rules on well design, construction, cementing and integrity testing. • Take action to prevent and contain surface spills and leaks from wells.
Treat water responsibly	• Reduce fresh water use by improving operational efficiency. • Store and dispose produced and waste water safely. • Minimise the use of chemical additivies .
Eliminate venting, minimize flaring and other emissions	• Target zero venting and minimal flaring of natural gas. • Minimise air pollution from vehicles, drilling rig engines, pump engines and compressors.
Be ready to think big	• Seek opportunities for realising the economies of scale. • Take into account the cumulative and regional effects of multiple drilling, productions, etc. on the environment.
Ensure a consistently high level of environmental perfomance	• Find an appropiate balance in policy-making between prescriptive regulation and performance based regulation. • Pursue continuous improvement of regulations and operating practices.

Source: IEA (2012a).

[29] See http://www2.epa.gov/eg/unconventional-extraction-oil-and-gas-industry.

Latin American countries have not started yet to exploit their shale gas resources commercially, so there is no previous experience of this activity in the region. However, it is likely that a shale gas boom would generate a large requirement for water which could put considerable pressure on water supplies at the local level in Latin American countries. Besides, exploiting shale gas within Latin America is likely to give rise to a range of additional problems. First, the risk of aquifer water supply pollution by the hazardous chemicals involved in shale gas extraction is likely to be an important source of local objections. Second, most unconventional gas deposits are located in indigenous territories, so any decision to implement a project must consider the consultation and consent of indigenous people affected[30]. Third, there are areas in Latin America which are densely populated and consequently wells associated with shale gas extraction could be relatively close to population centers. The proximity of such extraction will give rise to a number of local concerns. For instance, drilling will require many months if not years of surface activity leading to potentially intrusive noise pollution; high levels of truck movements during drilling and completion will have a major impact on already busy roads; and the considerable land-use demands of shale gas extraction will put further pressure on already scarce land-use resources. Given institutional weaknesses in many Latin American countries (O'Donnell 1993, Laffont 2005, Levitsky and Murillo 2012), their regulatory systems would not be ready to deal with massive shale gas extraction and its consequences mentioned before.

In this regard, Latin American countries should take into account the U.S. experience and strengthen their institutional capabilities around two important issues: a) the creation of a specific regulation related to technical aspects of exploration and exploitation of hydrocarbons using hydraulic fracturing, and b) the creation of a specific environmental standard which allows achieving optimal levels for the preservation and care of the environment and biodiversity.

Therefore, we will briefly analyze how regulations are currently applied in Argentina, Mexico and Brazil so as to assess whether their institutional systems can handle a boom in shale gas activity. On the first point, Argentina and Brazil have issued technical standards related to the exploration and exploitation of unconventional hydrocarbons which regulate aspects related to the well structure and water injections. On the second point, they do not have yet specific

[30] International Convention No. 169 on Indigenous and Tribal Peoples of the International Labour Organisation (ILO) in 1989.

environmental legislation to regulate in a holistic manner the potential environmental impacts of shale gas exploitation (CEPAL, 2015).

As we mentioned before, in Argentina gas resources are administrated by provincial governments in their own territory, which are also in charge of regulating water issues. Underground water resources in Argentina are widely used for agricultural irrigation. Shale gas operators would have to be careful when handling wastewater discharge and develop adequate wastewater treatment capacity to avoid social conflicts related to the agricultural use of water. However, given the ongoing political and economic crisis in Argentina, provincial governments would not have the capabilities to monitor and control the complex process of shale gas extraction due to the lack of trained personnel and funding.

Unregulated flowback water from shale gas wells containing high levels of salt would increase soil and surface water contamination if they were disposed inappropriately, affecting agricultural and cattle rising. Another problem that might affect shale gas regulation is the lack of a national water law. Without a water law, inter-provincial water conflicts would be more difficult to resolve if shale deposits were exploited across various regions. Finally, the diversity of environmental regulations in different provinces makes it difficult to accomplish the demand for more stringent wastewater discharge regulations and the disclosure of chemicals use in the fracking process (Stratfor Global Intelligence 2012).

Therefore, as explained before, the political environment in Argentina could be self-defeating for the development of shale gas. This situation could also make it difficult to develop and apply new environmental regulations for shale gas activities given the legal differences across provinces. In addition, the likely participation of the Argentinean state-owned company in the shale gas business would not guarantee that environmental standards be met if obscure political interests were behind shale gas extraction.

This situation is similar in Brazil, where the government is using its control over Petrobras to boost natural gas production based on conventional or unconventional resources. Even though the absolute control of Petrobras over the Brazilian energy sector has legally ended in the 1990s, it still has a virtual monopoly, which makes it difficult for smaller independent companies to operate in the shale gas industry (NewsBase 2012). In a report of Business News Americas, the executive secretary of Brazilian independent oil producers association (ABPIP), Anibal Santos, claims the lack of interest of the Government to increase their participation in the country's natural gas sector. ABPIP was expecting an announcement to increase the participation of small and medium-size independent companies, but it did not happen, even though it is a legal obligation. This situation benefits the dominant position of Petrobras (BNamericas 2013b).

Petrobras operates in 19 countries; in some countries of Latin America there are cases in which the company has not complied with environmental standards. For example, in Argentina, Petrobras has been accused of donating a lot of money to some communities to silence complaints against its operation. In Bolivia, Petrobras-Bolivia suspiciously won a license to operate in an area considered natural reserve in 2001. Finally, in Colombia, where Petrobras-Colombia operates in Guando field, the population has reported that the irrational exploitation of water resources has destroyed its water supply (Servindi 2012). There have also been problems with the environmental regulator, the Brazilian Institute of Environment and Natural Resources (IBAMA), which has been blamed for not enforcing properly the environmental laws because of political interference and corruption. [31] Therefore, as in the case of Argentina, in a shale boom scenario the Brazilian stated-owned company might not comply with environmental standards in order to achieve the political objectives of the governing political party.

In México, there is also a state-owned company, PEMEX, which is heavily focused on developing oil resources, despite the fact of the large Mexican shale gas potential mentioned before. PEMEX has a history of having caused several environmental disasters. In 1979 there was a blowout in the Bay of Campeche; in 1984 a series of explosions at PEMEX storage facility in San Juan Ixhuatepec killed about 500 people; in 1992 there was a massive gasoline leak in Guadalajara. In March of 2012, Greenpeace detected high levels of hydrocarbon contamination in five points of the Coatzacoalcos River as a result of the oil spill of December of 2011. In January of 2013 there was another explosion caused by gas accumulation. Finally, in March of 2015, there was other explosion in Abkatun-Alfa oil platform that cause environmental damage in the Gulf of Mexico.

[31] See "Corrupción Deforestadora," available at http://www6.rel-uita.org/agricultura/ambiente/corrupcion-desforestadora.htm.

These examples indicate that PEMEX has weak record of environmental regulation compliance (Barneda 2012).

According to Jacott et al. (2011), the environmental damages caused by PEMEX are due to some problems like the bad conditions of old state-owned pipelines and irregular licenses with companies that conceal oil spills. This might be reflecting the lack of incentives that PEMEX has to achieve environmental standards, since it has the constitutional mandate to afford the national budget by all means. Some analysts have suggested that it is necessary to privatize PEMEX to enhance its financial capabilities to develop deepwater offshore oil reservoirs in the Gulf of Mexico and shale gas deposits.

Although PEMEX has not been privatized, the energy reform has made possible the participation of private investment in exploration and exploitation activities. This investment will bring economic and human capital required for extraction in deepwater reservoirs. During 2015, PEMEX posted losses of over 20 billion dollars. To overcome its crisis, the company is seeking resources through procurement of services and leasing assets (El País, 2015).

In summary, it seems that the most important countries in Latin America with shale gas resources are not ready in the current gas price super cycle to push forward policies oriented to attract foreign investors to develop shale gas projects. In addition, the institutional capabilities of regulatory institutions and the energy nationalism sentiment in these countries are not strong enough to guarantee a minimum level of environmental monitoring to avoid accidents such as explosions, gas leaks and wastewater contamination associated with shale gas exploitation. Authors like Laffont (2005) and Vásquez Cordano (2012) have pointed out that government failures such as corruption,[32] tight budgets to support regulatory agencies, weak compensation schemes for regulators, inadequate liability limits and a lack of coordination among regulatory agencies are important factors that weakens the enforcement of environmental laws, especially in developing countries such as the ones analyzed in this paper.

[32] If we look at the Corruption Perception Index elaborated by Transparency International, which categorizes 174 countries from the most transparent (position 1) to the most corrupt (position 174), we notice that Argentina, Brazil and Mexico are ranked 102, 69 and 101. This indicates that these countries are perceived as suffering from moderate to high levels of corruption. Further information is available at http://www.lavoz.com.ar/noticias/politica/corrupcion-argentina-reprobada-indice-transparencia-internacional

Reforms in Argentina and Mexico have somehow opened the possibility to develop unconventional reservoirs either through direct allocations to private operators or through state-owned companies participating in competitive auctions with the private sector. It is important that these reforms are implemented in conjunction with a strategic environmental assessment; otherwise, it is likely that government failures when regulating shale gas exploitation may cause higher risks of having accidents with adverse environmental consequences.

Taking into account the U.S. and European experience, we consider that the measures needed to increase the environmental regulatory capabilities in Latin America to face a shale gas boom would be the following: first, regulators should have data collection and management systems in order to monitor in advance critical aspects of shale gas extraction. This measure would be valuable for operators working on several shale gas regions since simplification and standardization of reporting across states would lead to reductions of regulatory compliance costs. On the other hand, regulators would want more data and disclosure from operators regarding their water use and cumulative assessments of the environmental impacts of shale gas operations in order to improve their monitoring capabilities. The availability of data upon which to base regulations has been a key challenge for U.S. and European regulators (Accenture 2012, AEA 2012), and it is expected that the same situation will be an issue of concern in Latin America.

Second, in Latin American countries, such as Argentina, Mexico and Brazil which have federal systems, environmental regulations vary considerably between states, with different requirements for well casing, disposal of drilling fluids and wastewater management. Therefore, national and local regulators should achieve a balance between their policies to enforce national and local environmental regulations. Coordination across regulatory agencies (natural resources, environmental and water agencies) within a region should be also important to achieve regulatory coherence for shale gas exploitation (Vásquez Cordano 2012).

Third, differences in the geology of a particular shale play will determine waste management options available to operators for a particular region since the very beginning of operation. Factors to consider include the local regulatory landscape, the geology of the shale play and its water management characteristics, the local infrastructure and the regional water availability.

Thus, to establish an efficient and effective regulatory environment in this context, regulators should require that operators set early clear directions for development of shale gas. Regulators should also explain to operators that investment in water treatment is economically worthwhile and likely to give them a competitive advantage in the long run, because having water treatment management at an early stage of shale gas extraction would mean less penalties and requests for liability compensations in court in the future.

Finally, Latin American governments should reinforce the autonomy and the technical capabilities of its safety and environmental regulators to strengthen the enforcement of regulations affecting shale gas production. This can be achieved i) by providing regulators with enough budgetary resources to implement adequate monitoring system to control the safety and environmental risks associated with shale gas, ii) by improving the capabilities of the regulators' personnel through training and education, iii) by reinforcing the compensation schemes of the public officials in charge of supervising and monitoring shale gas activities to attract the most talented people for the job and to avoid regulatory capture, iv) by increasing the technical capabilities of the regulators by providing them with relevant monitoring technologies, and v) by shielding the regulators from the political interference of the government through measures of administrative autonomy from the executive power (Vásquez Cordano 2012, Quintanilla 2006).

4. Conclusions

Our statistical analysis in this paper have allowed us to detect super cycles in the U.S. natural gas prices, which are strongly correlated with the super cycles found in the oil prices after World War II. The current super cycle indicates that Latin America may have an economic opportunity to develop its unconventional gas deposits in the coming decade; however, weak institutions in countries with large unconventional gas reserves may generate a fragile regulatory framework, discouraging investment and increasing the probability of accidents producing adverse environmental impacts. A well-thought regulatory reform may be needed in some countries to attract the necessary investment to develop unconventional gas and reduce the risk of having large environmental impacts due to technology, mismanagement and government failures (such as regulatory capture).

There has been a renewed interest in commodity prices over the past decade. Evidence on the presence of super cycles in energy commodities should be valuable for national and state governments, financial institutions and oil and gas companies in Latin America alike. On the government level, countries that rely on the import or export of energy commodities such as Chile, Peru, Argentina, Venezuela, Colombia and Brazil need to take into account the presence of super cycles in energy commodities in order to define their investment and environmental policies. At the firm level, the exploration-development-production-distribution-research-and-development cycle of energy projects often spans several decades, as do super cycles. Hence the investment decision made by these oil and gas companies and the regulatory policies implemented by Latin American states should take into account the presence of such cycles.

Our analysis indicates that the instable political situation, the governmental intervention through nationalization and state-owned oil companies, the lack of transparent investment rules, high capital expenditures to develop LNG export projects and the exploration of shale resources, as well as the presalt discoveries make uncertain that the shale gas boom achieve a large impact in Latin America during the current gas price super cycle.

5. References

Accenture (2012). *Water and Shale Gas Development. Leveraging the US experience in new shale developments.* Available at http://petrofed.winwinhosting.net/newsletter/WR-290_04Jan13/w290_08a.pdf (last access: 06/06/2016).

AEA (2012). *Support to the identification of potential risks for the environment andhuman health arising from hydrocarbons operations involving hydraulic fracturing in Europe*. Report for the European Commission, DG Environment. Available at http://ec.europa.eu/environment/integration/energy/pdf/fracking%20study.pdf (last access: 06/06/2016).

Algañaraz, Julio (2012). "Países de Europa congelan la explotación de shale gas por temor a la contaminación." *Diario Clarín*, Economía, Petróleo no Convencional. Available at http://www.ieco.clarin.com/economia/Paises-Europa-congelan-explotacion-contaminacion_0_700130149.html (last access: 06/06/2016).

Barneda, Daniel (2012). "Shale en Latinoamérica, la revolución menos pensada." *Oil&Gas Journal Latinoamericana*, 18 (4): 10-15. Available at https://issuu.com/gsalip/docs/prensa_energetica_38/26 (last access: 06/06/2016).

Baxter, Marianne, and Robert G. King (1999). "Measuring Business Cycles: Approximate Band-Pass Filters for Economic Time Series." *Review of Economics and Statistics,* 81 (4): 575-593.

BBC News (2015) *Argentina to relax foreign exchange controls*. Available at http://www.bbc.com/news/business-35114972 (last access: 06/06/2016).

Business News Americas (2015). "LNG Continues Expansion in Latin America". *Oil and Gas Intelligence Report Series*. Available at http://www.bnamericas.com/en/intelligence-series/oilandgas/lng-continues-expansion-in-latin-america/ (last access: 06/06/2016).

Business News Americas (2013a). "Mexican left launches campaign to defend Pemex from privatization." *Oil and Gas Perspectives*. Available at http://subscriber.bnamericas.com/Subscriber/en/news/oilandgas/mexican-left-launches-campaign-to-defend-pemex-from-privatization1 (last access: 06/06/2016).

Business News Americas (2013b). "Brazil independent oil producers facing extinction, says association." *Oil and Gas Perspectives*. Available at http://subscriber.bnamericas.com/Subscriber/en/news/oilandgas/brazils-independent-oil-producers-facing-extinction-says-association1/ (last access: 06/06/2016).

Business News Americas (2012). "Shale resources in Latin America." *Intelligence Report Series*.

Christiano, Lawrence J., and Terry J. Fitzgerald (2003). "The Band Pass Filter." *International Economic Review*, 44 (2): 435-465.

Cooley, Heather and Kristina Donnelly (2012). *Hydraulic Fracturing and Water Resources*: *Separating the Frack from the Fiction*. Pacific Institute Working Paper. Available at http://www.pacinst.org/reports/fracking/ (last access: 06/06/2016).

Cuddington, John, and Daniel Jerrett (2008). "Super Cycles in Real Metals Prices?" *IMF Staff Papers,* 55 (4): 541-565.

Cuddington, John T., and Abdel M. Zellou (2012). "A Simple Mineral Market Model: Can It Produce Super Cycles in Prices?" *Resources Policy*, 38 (1): 75-78.

EIA, U.S. Energy Information Administration (2015). World Shale Resource Assessments. Available at https://www.eia.gov/analysis/studies/worldshalegas/ (last access: 06/06/2016).

EIA, U.S. Energy Information Administration (2013). *Technically Recoverable Shale Oil and Shale Gas Resources*: *An Assessment of 137 Shale Formations in 41 Countries outside the United States.* Available at https://www.eia.gov/analysis/studies/worldshalegas/archive/2013/pdf/fullreport_2013.pdf (last access: 06/06/2016).

EIA, U.S. Energy Information Administration (2012). *Annual Energy Outlook*. Available at http://www.eia.gov/forecasts/archive/aeo12/pdf/0383(2012).pdf (last access: 06/06/2016).

El País (2015a). La reforma energética es una tsunami para Pemex. Available at http://economia.elpais.com/economia/2015/12/10/actualidad/1449769838_193166.html (last access: 06/06/2016).

El País (2015b). Pemex saca al mercado sus activos para financiar la crisis. Available at http://economia.elpais.com/economia/2015/12/09/actualidad/1449698655_268997.html (last access: 06/06/2016).

El País (2012). *Argentina announces expropriation of Repsol oil subsidiary YFP*. Available at http://elpais.com/elpais/2012/04/16/inenglish/1334595212_305415.html (last access: 06/06/2016).

EPA, U.S. Environmental Protection Agency (2015). *Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources.* External Review Draft EPA/600/R-15/047a, June 2015. Available at https://www.epa.gov/sites/production/files/2015-07/documents/hf_es_erd_jun2015.pdf (last access: 06/06/2016).

Forbes (2015). *8 Lecciones para la Segunda Licitación de la Ronda 1* . Available at http://www.forbes.com.mx/8-lecciones-para-la-segunda-licitacion-de-la-ronda-1/ (last access: 06/06/2016).

Heap, Alan (2005). *China: The Engine of a Commodities Super Cycle*. New York City: Citigroup Smith Barney. Available at http://www.fallstreet.com/Commodities_China_Engine0331.pdf (last access: 06/06/2016).

Howarth, Robert; Santoro, Renee and Anthony Ingraffea (2011). "Methane and the greenhouse-gas footprint of natural gas from shale formations. A letter." *Climate Change Letters*, 106 (1): 1-12.

IEA, International Energy Agency (2012). *Key World Energy Statistics*.

IEA, International Energy Agency (2012a). *Golden Rules for a Golden Age of Gas.* World Energy Outlook Special Report on Unconvetional Gas.

IEA, International Energy Agency (2011). *Are we entering a golden age of gas*? World Energy Outlook, Special Report.

Isbell, Paul (2006). *El gas: Una cuestión conflictiva en América Latina*. Working Paper, Real Instituto Elcano. Available at http://www.realinstitutoelcano.org/analisis/958/Isbell_958.pdf (last access: 06/06/2016).

Jacott, Marisa, José M. Arias, Hugo I. Guzmán and Azucena Franco (2011). “Impactos de la actividad petrolera y en la salud humana y el ambiente.” *Fronteras Comunes*. Available at https://www.yumpu.com/es/document/view/12733105/impactos-de-la-actividad-petrolera-y-en-mexico-toxico (last access: 06/06/2016).

Jerrett, Daniel (2010). *Trends and Cycles in Metals Prices*. Thesis (Ph.D.), Colorado School of Mines, Golden.

Jerrett, Daniel, and John T. Cuddington (2008). "Broadening the Statistical Search for Metal Price Super Cycles to Steel and Related Metals." *Resources Policy* 33 (4):188-195.

King, George (2012). "Hydraulic Fracturing 101: What every representative, environmentalist, regulator, reporter, investor, university researcher, neighbor and engineer should now about estimating frac risk and improving frac performance in unconventional gas and oil wells." SPE Paper 152596. *SPE Hydraulic Fracturing Technology Conference*, The Woodlands, Texas, February. Available at http://www.kgs.ku.edu/PRS/Fracturing/Frac_Paper_SPE_152596.pdf (last access: 06/06/2016).

Kinnaman, Thomas (2011). "The economic impact of shale gas extraction: A review of existing studies." *Ecological Economics,* 70 (7): 1243-1249.

Kuznets, Simon (1973). "Modern Economic Growth: Findings and Reflections." *American Economic Review*, 63 (3):247-258.

Laffont, Jean-Jacques (2005). *Regulation and Development*. Cambridge: Cambridge University Press.

La Nación (2015). El equipo de Macri prepara un plan de medidas urgentes para el sector energético. Available at http://www.lanacion.com.ar/1841073-el-equipo-de-macri-prepara-un-plan-de-medidas-urgentes-para-el-sector-energetico (last access: 06/06/2016).

Levitsky, Steven and Maria Murillo (2012). *Building Institutions on Weak Foundations: Lessons from Latin America*. Paper presented at the conference "Guillermo O'Donnell and the Study of Democracy." Buenos Aires, March. Available at http://kellogg.nd.edu/odonnell/papers/LevitskyMurillo.pdf (last access: 06/06/2016).

Moody´s (2015). *Moody's changes Argentina's outlook to positive from stable; Caa1/(P)Caa2 ratings affirmed*. Available at https://www.moodys.com/research/Moodys-changes-Argentinas-outlook-to-positive-from-stable-Caa1PCaa2-ratings--PR_339171 (last access: 06/06/2016).

NewsBase (2012). *Brazilian shale potential struggles to emerge*. Mimeo.

O'Donnell, Guillermo (1993). "On the State, Democratization, and Some Conceptual Problems: A Latin American View with Some Postcommunist Countries." *World Development*, 21(8): 8:1355–1369.

Oregon State University (2013). *Inflation Conversion Factors Website.* College of Liberal Arts-School. Available at http://liberalarts.oregonstate.edu/spp/polisci/research/inflation-conversion-factors-convert-dollars-1774-estimated-2024-dollars-recent-year (last access: 06/07/2016).

Quintanilla, Edwin (2006). *Autonomía del Organismo Regulador de Energía de Perú*: *Un Estudio de Caso*. Thesis (DBA), Universitat Ramón Llull. Available at http://www.osinergmin.gob.pe/seccion/centro_documental/Institucional/Estudios_Economicos/Otros-Estudios/Tesis/Autonomia-Organismo-Regulador-EnergiaPeru.pdf (last access: 06/07/2016).

Popkin, Jennifer; Duke, Joshua; Borchers, Allison and Thomas Ilvento (2013). "Social costs from proximity to hydraulic fracturing in New York State." *Energy Policy*, 62(1): 62-69.

Rahm, Dianne (2011). "Regulating hydraulic fracturing in shale gas plays: The case of Texas." *Energy Policy*, 39 (5): 2974-2981.

Rogers, Jim (2004). *Hot Commodities: How Anyone Can Invest Profitably in the World's Best Market*. New York: Random House.

Roig, Diego (2012) "Los hidrocarburos no convencionales en el escenario energético argentino." *Theomai*, 25 (1): 113-127.

SENER, Energy Secretariat; CNH, National Hydrocarbon Commission; SHCP, Secretariat of Finance and Public Credit (2015) Ronda 1. Procesos Licitatorios. Available at http://ronda1.gob.mx/ (last access: 06/07/2016).

SERVINDI (2012). *El desempeño de Petrobras en América Latina: ¿Responsabilidad social?* Available at http://servindi.org/actualidad/77058 (last access: 06/07/2016).

Shale Gas Europe (2013). *The European Resource Centre for Shale Gas, Tight Gas & Coalbed Methane*. Available at http://www.shalegas-europe.eu/en/

Slade, Margaret (1992). *Do Markets Underprice Natural-Resource Commodities?* Washinton D.C: The World Bank.

Stratfor Global Intelligence (2012). *Argentina: Obstacles to Shale Gas Production.* Available at http://www.stratfor.com/sample/analysis/argentina-obstacles-shale-gas-production (last access: 06/07/2016).

Távara, José and Arturo Vásquez Cordano. 2008. *La industria del petróleo en el Perú*: *Contexto Regional, Condiciones de Competencia y Asimetrías en las Variaciones de los Precios de los Combustibles*. Final consulting report prepared for the Peruvian Antitrust and Consumer Protection Agency, INDECOPI, Project N° 0042-2007/GAF-ADS-INDECOPI. Published by the International Development Research Center. Available at http://reseau.crdi.ca/uploads/user-S/12074952831INFORME_FINAL_rev.pdf, http://s3.amazonaws.com/zanran_storage/www.eepsea.org/ContentPages/1605388565.pdf (last access: 06/07/2016).

Tilton, John (2002). *On borrowed time*? *Assessing the threat of mineral depletion*. Washington D.C: Resources for the Future.

Tol, Richard; Pacala, Stephen and Robert Socolow (2006). *Understanding Long-Term Energy Use of Carbon Dioxide Emissions in the U.S.A.* Nota di Lavoro 107.2006. Fondazione Eni Enrico Mattei. Italy.

Vásquez Cordano, Arturo (2012). *The Regulation of Oil Spills and Mineral Pollution: Policy lessons for the U.S.A. and Peru from the Deep Water Horizon blowout and other accidents*. Berlin: Lambert Academic Publishing. A summary is available at http://www.osinergmin.gob.pe/seccion/centro_documental/Institucional/Estudios_Economicos/Otros-Estudios/Tesis/Optimal-regulation-market-power-mineral-energy-usaperu.pdf (last access: 06/07/2016).

Weijermars, R., G. Drijkoningen, T.J. Heimovaara, E.S.J. Rudolph, G.J. Weltje, K.H.A.A. Wolf (2011). "Unconventional gas research initiative for clean energy transition in Europe." *Journal of Natural Gas Science and Engineering* , 3 (2): 402-412.

YPF -Yacimientos Petrolíferos Fiscales de Argentina- (2012). *Estrategia de gestión 2013-2017*. *Plan de los 100 días.* Available at https://www.ypf.com/inversoresaccionistas/Lists/Presentaciones/30-08-2012%20Presentaci%C3%B3n%20Plan%20Estrat%C3%A9gico.pdf (last access 06/07/16).

Zellou, Abdel and John T. Cuddington (2012a). "Is There Evidence of Super Cycles in Oil Prices?" *SPE Economics & Management Journal*, 4 (3): 171-181.

Zellou, Abdel and John T. Cuddington (2012b). "Trends and Super Cycles in Crude oil and Coal Prices." Working Paper N° 2012-10. Division of Economics and Business, Colorado School of Mines. Available at http://econbus.mines.edu/working-papers/wp201210.pdf (last access 06/07/16).

Zoback, Mark; Kitasei, Saya and Brad Copithorne (2010). *Addressing the Environmental Risks from Shale Gas Development*. Briefing Paper 1, Worldwatch Institute. Available at http://www.worldwatch.org/files/pdf/Hydraulic%20Fracturing%20Paper.pdf (last access 06/07/16).

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