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Article

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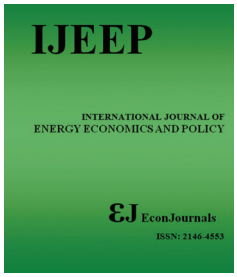
International Journal of Energy Economics and Policy

Provided in Cooperation with:
International Journal of Energy Economics and Policy (IJEEP)

Reference: Candelo Viafara, Juan Manuel/Oviedo-Gomez, Andres et. al. (2023). Exploring the effects of oil and gas prices on industrial production in Colombia : a quantile regression analysis. In: International Journal of Energy Economics and Policy 13 (6), S. 364 - 369. https://www.econjournals.com/index.php/ijeep/article/download/14607/7574/35037. doi:10.32479/ijeep.14607.



International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2023, 13(6), 364-369.

Exploring the Effects of Oil and Gas Prices on Industrial Production in Colombia: A Quantile Regression Analysis

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Received: 13 June 2023 **Accepted:** 14 September 2023 **DOI:** https://doi.org/10.32479/ijeep.14607

ABSTRACT

This study examines the impact of oil and gas prices on industrial production in Colombia between 1997 and 2022 using the quantile regression methodology (QR) to evaluate seasonality and nonlinear effects on the distribution of the industrial sector. The findings indicate that when industrial production is at low levels, fluctuations in gas prices have minimal impact. Conversely, gas prices have a significant negative effect when industrial production is at medium levels. In contrast, gas prices have negative but insignificant effects at high levels (above the sixth decile). On the other hand, oil prices generate positive and significant impacts at medium and high production levels. The study concludes that increasing gas production in the country would lead to a reduction in its price, decrease costs, and increase national production. Additionally, gas production can be a viable element in the energy transition, as it strengthens sectors of the economy other than oil.

Keywords: Oil Prices, Gas Prices, Industrial Production, GDP, Energy, Quantile Regression
JEL Classifications: E31, E32, E44

1. INTRODUCTION

Industrial production plays a crucial role in a country's economic development. Companies are vital economic agents whose performance impacts the growth or stagnation of Gross Domestic Product (GDP) (Gómez Niño, 2011). Energy use is essential for economic production, with fossil fuels such as oil, natural gas, and coal, as well as renewable sources like solar and biomass, being the primary energy sources used in the global economy (Batten et al., 2017). However, the dependence on fossil fuels increases the economy's vulnerability to fluctuations in oil and gas prices (Sari and Soytas, 2009). As a result, changes in the availability and prices of these natural resources can affect a country's economic growth (Adeosun et al., 2022)

The impact of oil prices on national economies has been studied in a large number of researches around the world, where it has been identified that an unexpected increase in oil prices impacts costs in energy production of energy sources such as fuels, triggering an increase in costs, and negatively impacting consumption (Baumeister et al., 2018). In Colombia, which is a developing country that exploits and exports oil, it has been identified that an increase in oil prices generates an increase in economic activity due to the improvement in the terms of trade (Oviedo and Candelo, 2022). On the other hand, different research has identified that gas and oil are substitute products and impact industrial production since the industry needs energy sources for its operation, such that an increase in their prices can generate industrial relocation (Hamilton, 1988; Vücel, and Guo, 1994; Davis and Haltiwanger, 2001).

In the same way, the price shocks of mining and energy products such as gas and oil affect the stock markets, as well as the exchange rate, import costs, export flows, the amount of investment, and production budgets (Huynh et al. 2020). Due to these impacts on production processes, a spillover effect is also generated towards

aspects such as inflation and the level of employment, causing fluctuations in social welfare (Zhang et al., 2022).

In this way, energy resources must be managed, which is as crucial for economic policymakers as energy portfolio managers and industrial operators. Accordingly, this paper studies the impact of oil and gas prices on Colombian industrial production, a country characterized by oil and gas production, but in different ways, since Colombia is an oil exporter but a domestic gas consumer. Therefore, this study can shed light on the energy policy of Colombia and countries with similar characteristics. To perform this analysis, quantile regression (QR) is used with time series from 1997 to 2022, because it allows modeling and evaluating seasonality and non-linear effects on the distribution of the industrial sector.

The research contributes to the existing literature by applying quantile analysis to identify the impact of oil prices on different levels of industrial production, which has been rarely done before, additionally, few studies have analyzed the impact of gas on national production. This study could form the basis for developing an energy policy to increase the country's competitiveness, with gas as a cleaner fuel being the foundation for migration to an energy system with less environmental impact. In summary, this study aims to examine the impact of oil and gas price fluctuations on different levels of industrial production in Colombia. Therefore, the paper is divided into the following sections: literature review, methodology, results and discussion, and finally, conclusions.

2. LITERATURE REVIEW

2.1. Industrial Production

Energy plays a critical role in industrial production, as the industrial sector consumes approximately 50% of the world's energy supply, with a high dependence on oil and natural gas (Rangel Jiménez and Portilla Salazar, 2016). Oil is not only the most widely traded raw material, but it also accounts for 94% of the energy used in the transportation sector and 33% of the world's energy consumption, making oil prices a crucial factor that can impact production (Van Eyden et al., 2019; Yang et al., 2017; Aguiar and Wen, 2007). In recent years, the increased purchase of energy commodities has resulted in greater involvement of oil and gas in production systems (Mahmoud and Hazar, 2018; Hamilton and Wu, 2015). The price of oil and gas is determined by the interaction between supply and demand.

While natural gas prices are generally less volatile than oil prices, fluctuations in natural gas prices can still impact production, particularly in industrialized economies(Ahmed, Kashif, and Ahmed, 2018). There is an interrelationship between oil and gas prices, and an increase in oil prices will also affect natural gas prices. In some countries, the price of natural gas is linked to the price of crude oil. Seth (2015) found that the correlation between oil and natural gas prices is significant during periods of upward movement, and Hulshof et al. (2016) discovered that the price of oil has a small positive impact on the price of gas, with supply not affecting the movement of gas prices.

Jiménez-Rodríguez (2011) analyzed the impact of oil prices on the economies of OECD countries, including France, Germany, Italy, Spain, the United Kingdom, and the United States. Through a structural autoregressive vector model, Jiménez found that oil prices affect the industrial sectors of these countries, with a positive shock in oil prices generating a negative effect on industrial production. Similarly, Hahn and Mestre (2011) used a vector auto-regressive (VAR) model with stochastic volatility to investigate the impacts of oil prices in the Euro Zone, finding a significant and positive relationship between oil prices and the level of prices, production, exchange, and consumption of goods. Nusair (2016) also examined the effects of oil prices on the GDP of Gulf Cooperation Council countries using an empirical model of autoregressive lag of nonlinear cointegration (NARDL) proposed by Shin et al. (2013), finding that an increase in oil prices leads to a rise in GDP, and a decrease in oil prices leads to the decline in national production.

Rotemberg and Woodford (1996) explored the effects of an increase in oil prices on the US economy, concluding that an increase in oil prices leads to a decrease in production by 2.5% after five or six quarters. For economies such as Colombia, Quero-Virla (2016) used the methodology of Blanchard and Galí (2010) to evaluate the effects of variations in the price of oil, finding that an increase in the price of oil results in positive variations in GDP.

2.2. The Price of Oil, Gas, and Energy

Oil is the most widely traded commodity on a global scale, with the United States being the largest consumer of this hydrocarbon. Gas, another hydrocarbon, is extensively used in industries, particularly for electricity generation. Kırca et al. (2020) conducted a study on the relationships between oil and gas prices and economic growth in Turkey, concluding that variations in oil and gas prices impact on economic growth. Asche et al. (2006) also found that changes can influence fossil fuel prices in electricity prices.

Killian (2008) asserts that changes in the price of oil can affect a country's economy by reducing the demand for other goods since oil is an inelastic commodity. Multiple studies have demonstrated a significant relationship between fossil fuels and the electricity market, which varies significantly depending on the country and the target market. Shafiee and Topal (2010) establish long-term correlations between the world prices of fossil fuels, showing a positive and significant relationship with their respective prices. Nick and Thoenes (2014) utilized a VAR model for the German market. They found that the natural gas prices are impacted in the long run by oil prices, indicating the substitution relationship between different energy products.

Jiménez (2010) and González (2015) discovered that positive changes in oil prices affect economic growth at both the aggregate and sectoral levels in Colombia. Bernal et al. (2019) explored the impact of oil and natural gas prices on electricity prices in Mexico, finding a significant and positive impact in the short term. Nakajima (2013) examined the electricity market in Japan and found that oil and gas prices do not cause Granger causality to the price of electricity.

Ding et al. (2020) analyzed peak electricity prices, finding a short-term bidirectional spillover effect between thermal energy fuels and the electricity market, with natural gas playing a critical role in transmitting information to electricity prices. Muñoz and Dickey (2009) highlighted the volatility between oil and electricity prices in Spain. Uribe et al. (2018) established that natural gas prices can be used to forecast electricity prices and vice versa.

In summary, there is a robust relationship between oil and natural gas prices and their impact on the electricity market, which in turn affects a country's economic production. These relationships have been analyzed through various methods, such as Granger causality tests and VAR models, and are significant in the short and long term. Figure 1 illustrates the relationship between the variables, emphasizing their impact on electricity prices.

3. METHODOLOGY

During the research period from 1997 to 2022, the connection between the industrial sector and international gas and oil prices was examined utilizing the quantile regression approach. This technique is appropriate for analyzing and assessing the impact of seasonality and non-linear effects on the distribution of the industrial sector.

Quantile regression is an approach that is partially based on parameters and can depict the non-linear impacts of predictors on a reliant variable. It also offers excellent approximation in modeling the stochastic correlation between factors with few requirements on distribution (Koenker, 2004; Ma and Koenker, 2006; Uribe and Guillen, 2020).

Koenker and Bassett (1978) introduced a linear model that can be written as follows:

$$Q_{\mathrm{q}}\left(Y_{\mathrm{I,t}}|X_{\mathrm{I,t}}\right)=X_{\mathrm{I,t}}^{'}\beta_{\mathrm{i}}^{\mathrm{q}} \tag{1}$$

Where $Y_{i,t}$ is a vector of T observations (t=1,2,3,…T) and represents the dependent variable. For its part, $X_{i,t}$ is a matrix of Txd dimensions and contains the explanatory variables, the variable β^{q} is a vector of $dx1$ dimensions and explains the unknown parameters for each quantile $q\in(0,1)$., The coefficients ($\widehat{\beta}^{\mathrm{q}}$) were estimated for each quantile q, following the following minimization problem:

$$\min_{\beta_i^q}\frac{1}{T}\sum_{t=1}^{T}\left[q-I\left(Y_{i,t}<X_{i,t}^{'}\beta_i^q\right)\right][Y_{i,t}-X_{i,t}^{'}\beta_i^q], \tag{2}$$

Where,

$$I\left(Y_{i,t}<X_{i,t}^{'}\beta_i^q\right)=\begin{cases}1,\ Y_{i,t}<X_{i,t}^{'}\beta_i^q\\ 0,\ in\ other\ ways\end{cases}, \tag{3}$$

furthermore, $Y_{I,t}$ must be found through separate estimates for each i, i=1,…N. According to Mosquera-López et al. (2017), the QR is a special case of the Least Absolute Deviation (LAD) estimator, which allows robust estimates to be made when the data has heavy tails. In this case, Equation (1) can be written as:

$$Q_{\mathrm{q}}\left(IPI_{\mathrm{I,t}}\right)=\beta_{\mathrm{I,1}}^{\mathrm{q}}+\beta_{\mathrm{I,2}}^{\mathrm{q}}PG_{\mathrm{t}}+\beta_{\mathrm{I,3}}^{\mathrm{q}}PP_{\mathrm{t}} \tag{4}$$

Where $IPI_{I,t}$ is the dependent variable and represents the industrial production index (IPI), while PG_t are international gas prices, and PP_t are international oil prices. To estimate the QR model, the variables were transformed to logarithmic returns to observe possible changes in the distribution of the IPI, which are associated with changes in international price shocks of these fossil fuels.

4. DATA

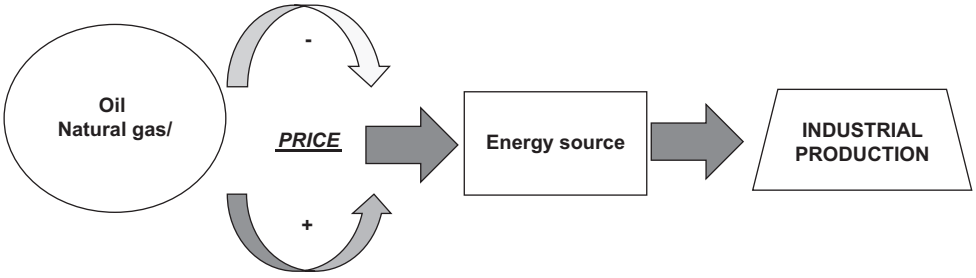
The data utilized in this research was gathered from the Federal Reserve Bank of St. Louis (FRED Data) and the Bank of the Republic de Colombia. The price of Brent oil, a benchmark for Colombia, and the spot price of Henry Hub gas, reported by FRED data, were used in conjunction with the IPI obtained from the Bank of the Republic of Colombia.

Table 1 illustrates the descriptive statistics of the variables, where the standard deviation reveals that oil and the IPI are more unstable than gas prices. The kurtosis value suggests the presence of extreme values in the variables since the IPI and oil present platykurtic distributions, while gas has leptokurtic distributions. Similarly, the skewness values indicate that the distributions are skewed to the right.

Figure 2 shows the standardized variables of the study, showing that the IPI experienced growth in 1997, followed by a decline until early 1999. It then grew until 2008, when it fell due to the crisis, and increased again in early 2009 until the end of 2019, when the COVID-19 pandemic started. Since April 2020, it has been showing a growing trend. It is worth noting that the IPI exhibits inter-annual cyclical behavior with peaks varying depending on the month.

In contrast, the gas price shows an average rotation of 4.2, with different peaks in December 2000, February 2003, October 2005,

Figure 1: Relationship between the prices of fossil fuels, the variation in electricity prices and industrial productivity



Source: Own elaboration.

Table 1: Descriptive statistics

Statistic	IPI	PG	PP
Mean	138,924	4,233	59,391
Median	141,667	3,600	57,435
Standard deviation	24,787	2,167	31,986
Skewness	0,194	1,469	0,380
Kustosis	2,550	5,488	2,090
Jarque-Bera	4,546	190,368	18,061
Observations	308	308	308

Source: Own elaboration. IPI: Industrial production index

Table 2: Correlation of variables

Variable	IPI	PG	PP
IPI	1		
PG	−0.01	1	
PP	0.62	0.29	1

Source: Own elaboration

and June 2008, followed by a significant decline during the crisis. From 2010 to 2020, it generated cycles with lower amplitudes, featuring peaks in January 2010 and February 2014. The price of gas began to increase in May 2020, reaching 8.8.

On the other hand, the price of oil exhibited a growing trend from 2000 to 2008, followed by a decline due to the crisis. Likewise, it showed a recovering growth trend from early 2009 to April 2011, causing relative stability until May 2015. After this date, it collapsed until February 2016. Relative growth was driven until August 2018, followed by a decline until April 2020 to its lowest levels due to COVID-19. Since then, it has been gradually growing until June 2022.

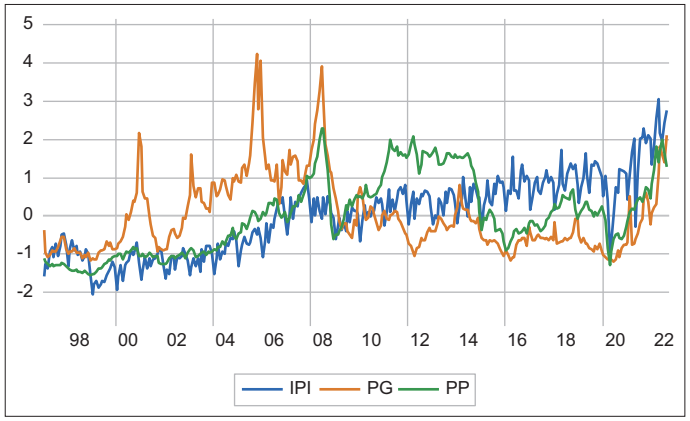
Table 2 presents the correlation analysis of the variables under study. The results show a negative correlation between the industrial production index (IPI) and the gas price, while the IPI positively correlates with the oil price. On the other hand, the correlation between the two hydrocarbons is positive. These findings can provide insights into the potential impacts of each variable on industrial production.

5. EMPIRICAL RESULTS AND DISCUSSION

The findings of the QR analysis are presented below, explicitly focusing on the percentiles of the industrial production index distribution. The main results are summarized in Table 3, while Figure 3 illustrates the coefficients of the estimated linear regression. The analysis reveals that the gas price adversely affects industrial production, but the impact is significant only in the fifth and sixth deciles, which indicates effects on the mean level. Therefore, oil prices positively affect industrial production, with significant impacts observed in the fourth to the eighth decile, reflecting effects on the average and high production levels.

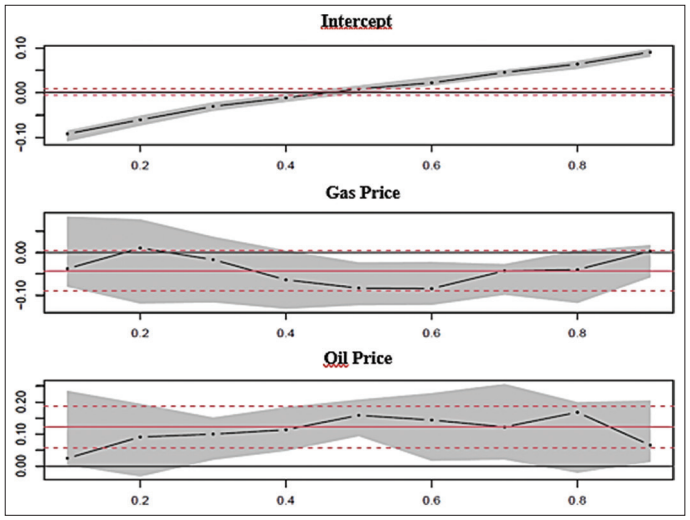
Specifically, the analysis shows that a 1% increase in the price of gas reduces industrial production by 0.084% and 0.085% in the fifth and sixth deciles, respectively. On the other hand, a 1% increase in oil prices raises industrial production by 0.11%, 0.16%, 0.14%, 0.12%, and 0.17% from the fourth to the eighth decile, respectively.

Figure 2: Industrial production index, PG and PP behavior



Source: Own elaboration.

Figure 3: Effects of international gas and oil prices on the industrial production index for the period 1997–2022



Note: in each graph, the y-axis indicates the impact of changes in international prices of fossil fuels on the industrial production index, while the x-axis represents each percentile. The dashed black lines represent the quantile regression coefficients, and the gray shaded area indicates the 95% confidence interval. The solid red line represents the OLS-estimated linear regression coefficient, and the dashed red lines show the 95% confidence intervals.

The above paragraph highlights the impact of fluctuations in the prices of mining and energy goods on industrial production, showing that these impacts vary depending on whether a supply shock or a demand shock causes them. The analysis results indicate that fluctuations in oil and gas prices do not generate significant impacts when industrial production is at low levels. However, when industrial production is at average grades, the gas price has a negative and significant effect, indicating a gas supply shock toward industrial production. Similarly, when industrial production is at high levels, gas prices have a negative impact but are insignificant. In contrast, an increase in oil prices has a positive and significant impact on industrial production at medium and high levels. Colombia is recognized as an oil-producing country.

Table 3: Coefficients of the quantile regression for the different percentiles of the distribution of the industrial production index

Variable	$\beta^{0.1}$	$\beta^{0.2}$	$\beta^{0.3}$	$\beta^{0.4}$	$\beta^{0.5}$	$\beta^{0.6}$	$\beta^{0.7}$	$\beta^{0.8}$	$\beta^{0.9}$
Intercept	−0.092***	−0.060***	−0.030***	−0.011*	0.0086*	0.023***	0.046***	0.064***	0.091***
Gas prices	−0.038	0.011	−0.017	−0.064	−0.084***	−0.085***	−0.043	−0.040	0.0035
Oil prices	0.025	0.091	0.010	0.11**	0.16**	0.14**	0.12*	0.17**	0.07

*, ** and *** indicates the significance levels of 10%, 5% and 1%, respectively

Despite consistently maintaining high levels of oil production, the country also experiences the positive side effect of benefiting from elevated oil prices. This correlation can be attributed to the incentive for continued production.

These findings have significant implications for the industrial development of Colombia, as they suggest that increasing gas production could be a strategic element for enhancing the competitiveness of the country's industry, given that it would lower prices and generate an increase in production due to lower costs. Additionally, the research aligns with previous studies conducted by authors such as Hamilton (1988), Davis and Haltiwanger (2001), Yang et al. (2017), and Aguiar□Conraria and Wen (2007), which also found that fluctuations in the prices of mining and energy goods have a significant impact on industrial production.

6. CONCLUSIONS

This article analyzes the effects of oil and gas prices on Colombian industrial production using quantile regression to examine the impacts at different production levels. The results show that gas and oil prices impact industrial production differently and at different deciles. Specifically, an increase in gas prices negatively and significantly impacts industrial production at average production levels, indicating a supply shock. Therefore, high oil prices positively affect industrial production due to increased demand, as Colombia is a significant oil exporter.

The study highlights the need to improve national production efficiency from an energy policy perspective. Increasing gas production in the country could reduce its price and lead to a boost in national production. This would enhance the country's competitiveness, as Colombia is a gas producer. Incentives should also be given to the oil production sector, positively impacting national production. However, given the environmental implications of oil production, gas production could be a promising alternative for the energy transition to strengthen other sectors of the economy.

Furthermore, this study highlights the importance of considering the heterogeneity of industrial production when analyzing the impact of energy prices. Using quantile regression, we can observe that the effect of energy prices on industrial production is not constant across all production levels. This suggests that energy policies should be tailored to specific sectors of the economy rather than being applied uniformly across all industries. For instance, policies that aim to increase gas production would likely benefit sectors that are more sensitive to changes in gas prices. In contrast, policies incentivizing oil production would be more effective for industries more dependent on oil. Considering the industrial output's heterogeneity, energy policies can be designed to maximize their impact on the economy while minimizing their unintended consequences.

The study has some limitations. Firstly, the analysis is based on monthly data, which may not be sufficient to capture the effects of the prices of these goods on industrial production in the long term. Future research could use quarterly or annual data to provide more accurate estimates of the relationship between these variables. Secondly, the study focuses only on the prices of oil and gas. Still, other variables may influence industrial production, such as the prices of other inputs or macroeconomic variables, which were not considered in this study. Thirdly, the study does not differentiate between the use of gas and oil in different industries, which may impact production differently. Finally, the study does not consider the environmental impacts of using these fossil fuels, which are relevant for sustainable development. Future research could explore the effect of the transition to renewable energy sources on industrial production and economic growth in Colombia.

7. ACKNOWLEDGMENTS

This research was financed by the Vicerrectoría de Investigaciones de la Universidad del Valle, Cali, Colombia. Research Project CI 9066 "Analysis of the Impact of Oil Price Variation and Exchange Rate on the Inventory Policy of a Chemical Importing Industry. Case study".

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