JOURNAL OF ECONOMIC DEVELOPMENT
Volume 47, Number 3, September 2022

RETAIL PRICES OF GASOLINE AND ASYMMETRIC ADJUSTMENT TO WHOLESALE PRICES IN COLOMBIA

JAIME CARABALÍ [a] , LUIS MENESES [b], ALEX PEREZ [c] AND MANUEL RODRIGUEZ [d],

[a] *Banco W, Colombia*

[b] *Universidad Cooperativa de Colombia, Colombia*

c Banco de la República, Colombia.

[d] *Consultor, Colombia.*

This study examines the pass-through between retail and wholesale prices of gasoline in Colombia. Data from 2017 to 2019 were available on prices and characteristics of gasoline sold by service stations in the main cities of Colombia. Information on the location of the stations is also available, which is used to georeference the stations and obtain the potential number of competitors for a station. The study results show an asymmetric pass-through behavior between retail and wholesale prices. Furthermore, the potential number of competitors of the stations has a direct effect on the retail prices and an indirect effect because it alters the stations' pass-through.

Keywords: Pass-Through, Asymmetric Price Adjustment, Gasoline Retail Markets
JEL Classification: Q40, D43, D82, D83

1. INTRODUCTION

Adjustment of gasoline prices to movements in international oil prices has long attracted academic attention on commodity markets. International literature has found evidence of an asymmetric adjustment by gasoline prices to changes in wholesale prices (Bacon, 1991; Borenstein et al., 1997; Bachmeier and Griffin, 2003; Chen et al., 2005; Radchenko, 2005; Grasso and Manera, 2007; Meyler, 2009; Honarvar, 2009; Lewis, 2011; Douglas and Herrera, 2014; Atil et al., 2014; Polemis and Tsionas, 2016; Blair et al., 2017; Apergis and Vouzavalis, 2018). Most of these studies used the error correction modeling approach to assess possible asymmetric effects. This approach allows controlling for the short- and long-term relationships between wholesale and retail prices of gasoline. These studies have found that wholesale and retail distributors of gasoline and its derivatives respond faster to increases than decreases in the international price of oil. When their input acquisition costs decrease, these firms do not decrease the final price to users because of the extraordinary profits that can be obtained from this strategy. Several theories have explained this behavior of retail gasoline prices. This study presents two recognized theories in the literature: search models and tacit collusion models.

This study focuses on the Colombia's gasoline market. It has a monopolistic production structure, centered on a mixed-ownership company with a majority state participation, called Ecopetrol. The main players in Colombia's fuel value chain are producers or suppliers (refiners and importers), stockers, intermediaries (transporters and wholesale or retail distributors), and consumers, who make up the demand. The Colombian market is regulated at various stages involved in supplying gasoline to final consumers. However, larger cities enjoy greater liberalization. Government, through the Ministries of Energy and Finance, establishes the reference prices for the fuels sold at the service stations, but these are not mandatory. The method for calculating fuel prices is a central issue in the country's economy, and recently, there has been a national clamor for the modification of its tariff formula.

Literature on the pass-through between wholesale and retail prices of gasoline, that is, the role of the number of competitors is scarce. Stations with numerous rival stations in close positions may have a different pass-through that of stations facing fewer rivals. This study proposes an empirical strategy to examine whether the number of competitors facing service stations affects the pass-through. The proposed strategy considers three types of shocks in the wholesale price: negative, neutral, and positive. To define the existence of a certain type of shock in wholesale prices, its growth is compared with that in the reference price of gasoline in each city. We consider that shocks whose absolute value is less than 1% are neutral, that is, relatively small shocks are different from the most significant shocks that we call positive or negative. We perform robustness exercises on the threshold with which we define a shock as neutral. Additionally, the study also examines the models that predict the existence of asymmetry in pass-through also predict the behavior of price dispersion. An empirical strategy is proposed to evaluate the theoretical predictions that relate movements in wholesale prices of gasoline to the dispersion of prices.

The study results show the existence of asymmetry in the adjustment of retail prices of gasoline in Colombia. When wholesale prices drop, retail prices fairly remain unaffected than when the wholesale price undergoes a neutral or positive change. When the wholesale price experiences a positive change, retail prices change significantly than during a neutral shock. However, the study results show that pass-through depends on the number of competitors facing the service station. Stations with several competitors have a lower pass-through than those with fewer competitors. The study found heterogeneity of pass-through by type of gasoline. Diesel-ACPM gasoline has a slightly higher pass-through than that of regular gasoline. Contrastingly, when the wholesale price experiences negative shocks, the dispersion of retail prices is higher. This evidence favors the hypotheses of the tacit collusion models.

The study is presented in four sections. Section 2 describes the Colombian gasoline market along with some applied works. Section 3 presents the two main existing theories to explain the asymmetry of the pass-through from wholesale prices to retail prices, the data, and the empirical strategy followed. Section 4 presents the main results of the investigation and Section 5 the conclusions.

2. COLOMBIAN GASOLINE MARKET

In recent decades, the normativity that governs the formation of retail prices of gasoline in Colombia has undergone major changes. This section follows the presentation of Mejia (2015). In 1998, the retail price was regulated regardless of any impact of international oil prices. In 1999, the regulations allowed retail prices of gasoline and its derivatives to adjust according to international crude oil price fluctuations. However, the State directly regulated the price and assumed the subsidies if the price went up. However, since 2009, the general increase in international crude oil prices has led to multiple adjustments to the gasoline retail price setting. Accordingly, continuous increases in international crude oil prices led to higher cost to the government than for other countries; therefore, it was finally decided to establish a tariff formula to determine its price from 2011.

In the scheme established as of 2011, according to Caicedo and Tique (2012), the retail price of gasoline in Colombia's main cities is composed of four major components: (1) the income to the producer of regular or oxygenated gasoline, (2) taxes (VAT, global tax, and gasoline surcharge), (3) transport costs, and (4) marketing margins along with other expenses. Besides, it considers the opportunity cost generated by selling it domestically, that is, it is calculated as if crude oil were sold in international markets to retain the profits of Ecopetrol, the national firm that exploits crude oil.

Specifically, for the national producer Ecopetrol, income is earned from the activity of refining or transforming crude oil into its derivatives. This income also includes (1) the corresponding items to cover oil exploration, expansion, and investment projects; (2) local or regional tax charged on fuel consumption; (3) national tax on gasoline and ACPM-Diesel created with the tax reform enforced from January 1, 2013; (4) the item corresponding to biofuels used in fuels[1]. (5) distribution margins that remunerate the investments required to carry out all the commercialization activities at both wholesale and retail levels; and (6) transportation from wholesale distributors to retail distributors and from retail distributors to service stations. This margin also includes the cost of ocean or land freight and other costs incurred to transport a gallon of gasoline. Table 1 presents the average share of each component in the retail price of regular gasoline for

[1] In Colombia, fuel alcohol (ethanol) is used to improve the octane number and deliver higher-quality fuels.

2020.

Table 1. Average Share of Components in the Retail Price of Regular Gasoline

Variable	%
National tax and surcharge on gasoline	25
Margin of continuity, marking and loss due to evaporation	1
Retail Distributor Margin	7
Wholesale distributor margin	4
Pipeline and land transport	5
Income to the ethanol producer	6
Income to the gasoline producer	52

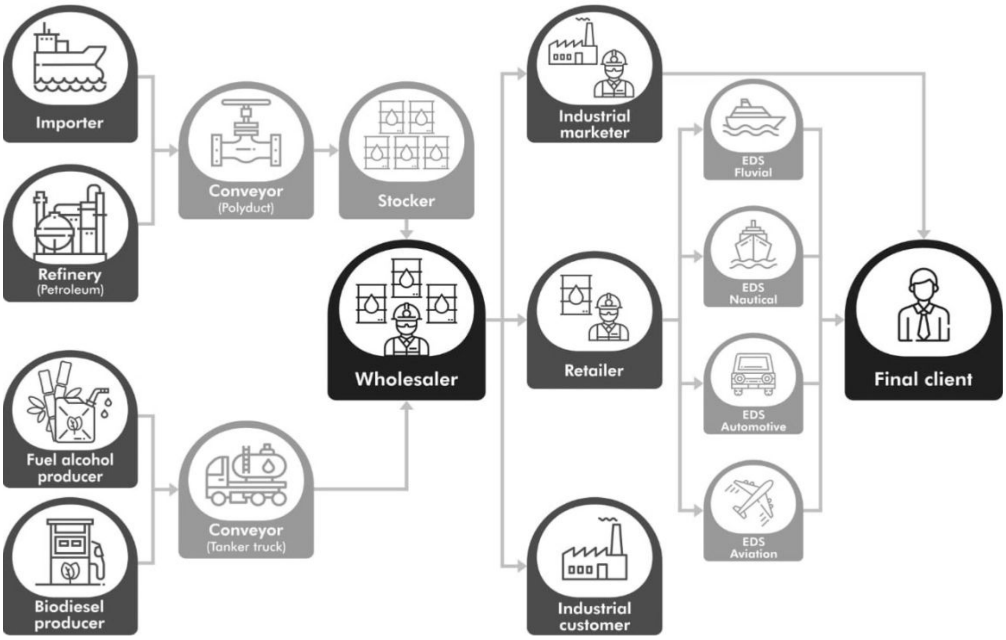
Source: Own elaboration based on information from Ministerio de Energía (2020).

The Colombian government establishes a reference price for the stations in the main cities (Hofstetter and Tovar, 2010). This price is published the first day of each month and specific to the city level and not mandatory for retailers, which implies that stations can set prices above or below the reference price. The government states that this price represents all costs in the production and distribution chain, which allows retailers to earn a reasonable profit.

In January 2019, the Constitutional Court of Colombia mandated that Congress, not the Ministry of Mines and Energy as since 1998, should establish the specific criteria for the collection of the gasoline surcharge. Judgment C-030/19 gave the Congress a maximum of two legislatures to establish the new calculation formula, which will take a minimum of two years for the value to be legally regulated. This implies, however, in this study, it does not reveal the establishment of retail prices of gasoline for study period.

Figure 1 illustrates the distribution process of fuels in Colombia from production or import to the final customer. This study focuses on fuels associated with gasoline. Gasoline in Colombia can be imported or produced locally. When imported, it either arrives completely refined or refined locally. When produced locally, an alcohol-based component is added to the gasoline. Similarly, in the case of national biofuel producers, these products are transported to wholesale distribution centers, which are in charge of negotiating directly with retail distributors or industrial consumers. Retail distributors cater to end consumers, such as fluvial, nautical, automotive, or aviation service stations (EDS for its initials in Spanish).

Studies on prices of gasoline in Colombia focus on macro- and microeconomic perspectives. From the macroeconomic perspective, Martínez (2016) studied the impact of the new context of international oil prices on the Colombian economy at a regional level and found that, since June 2014, the price of oil steadily declined from US$118 by barrel for Brent to US$37 by barrel in December 2015. This international price fluctuation of crude oil adversely affected the firms in the sector on the national income and territorial finances. The study evaluated the impact on territorial entities directly through transfers, royalties, and their own income and indirectly through changes in the investment budgets of oil firms and local contracting strategies. Additionally, they forecasted uncertainty about the evolution of gasoline prices and available quantities of fuels in the short and medium term.



Source: Author's elaboration.

Figure 1. Production Chain, Distribution, and Marketing of Fuels in Colombia

Another study is by Losada et al. (2018), who analyzed the relationship between international price of crude oil (WTI) and regular gasoline price for Colombia between 2012 and 2016. Therefore, they estimated a vector autoregressive model (VAR) and the impulse response function that characterizes each variable. This model showed that it is impossible to establish any relationship between regular gasoline prices and WTI reference oil in Colombia. They proposed that there is no causal relationship between two factors that can be explained by the rigidity of national prices to the movements of international prices. Thus, fuel prices have been steadily increasing since 2011, while international oil prices have suffered multiple fluctuations but not reflected in the movements of gasoline prices.

From the microeconomic perspective, in the context of energy markets, Bermúdez and Luengo (2018) contended that gasoline and oil prices are symmetrically related because gasoline is an oil derivative. However, they identified that positive and negative variations in the international price of crude oil affect gasoline prices differently. When crude oil price increases, gasoline prices increase significantly. However, when crude oil price falls, gasoline price does not change significantly, which implies an asymmetry in the pass-through from wholesale prices to retail prices. Thus, a simple linear regression was conducted to evaluate the effect of international crude oil prices on the price of gasoline, where the relationship between the two variables was evident. Subsequently, the study specified a distributed lag model to study the impact that changes in the crude oil price have on gasoline price between January 2010 and June 2018 and found that the price of the Brent did not have an immediate effect on the price of gasoline and approximately two months were taken to include the fluctuations in the international price of crude oil.

Finally, this study highlights the work of Hofstetter and Tovar (2010), who studied the retail gasoline market in Colombia to empirically validating the existence of asymmetric price adjustments. They used retail and wholesale prices in their study. The information on retail prices was obtained from the monthly survey carried out by the Mining-Energy Planning Unit (UPME for its abbreviation in Spanish), a subsidiary government agency of the Ministry of Mines and Energy. The wholesale price data were calculated considering the price regulations and monthly updates published by the Ministry of Mining and Energy for 10 main Colombian cities. The sample consisted of 173 stations per month during a 30-month analysis period between July 2003 and December 2006. Econometric modeling follows the two-phase cointegration approach, where the long-term relationship is established between prices and costs, and then error correction models are estimated to trace price adjustments to cost shocks (Borenstein et al., 1997; Lewis, 2011). Results suggest that when costs increase above the reference price, that is, a government-suggested retail price, retail prices increase less relatively to costs up to the threshold reference price, which implies asymmetry. The present study focuses on similar aspects with an extensive and updated database to conduct a georeferencing process of the stations to control for the potential number of competitors of the stations, an aspect that ignores the work of Hofstetter and Tovar (2010).

3. THEORETICAL FRAMEWORK AND METHODOLOGY

Two theories explain the asymmetric adjustment of retail gasoline prices to changes in wholesale prices. These studies include consumer search cost models (Tappata, 2009; Yang and Ye, 2008; Lewis, 2011) and focal point models of tacit collusion (Hong and Lee, 2018; Borenstein et al., 1997; Borenstein and Shepard, 1996). The seminal work of Borenstein et al. (1997) first identified the empirical relevance of both research areas. Theory on consumer search costs postulates that consumers' asymmetric search for retail prices implies an asymmetric adjustment of prices by retail firms. There is no Nash equilibrium under pure strategies in these models; therefore, equilibria are considered under mixed strategies, implying that the firms' equilibrium strategies are price distributions. Baye et al. (2006) provided an overview of the economics of search, focusing on price dispersion.

Tappata (2009) and Yang and Ye (2008) studied a dynamic search criterion under imperfect information by consumers who hypothesize about firms' production costs. These are a part of the nonsequential search models presented in the seminal works of Varian (1980) and Burdett and Judd (1983)[2]. In these models, wholesale prices evolve according to a Markov process to understand consumers. Tappata (2009) stated consumers' asymmetric response is because of the uncertainty in the wholesale prices; Yang and Ye (2008) claimed that the asymmetric response results from consumers' expectations based on previous wholesale prices. Assuming that retail firm marginal costs are constant, consumers expect the current retail prices to be high if the prices are high earlier, thereby reducing their search efforts. This implies that retail firms are disinclined to lower their prices when faced with unexpected negative shocks to their costs (i.e., fewer wholesale prices). Conversely, when retail prices are low and a positive cost shock occurs, consumer search intensifies as retail firms charge higher prices and the expected benefits of searching are higher, depending on the expectations formed. As consumers intensify search, retail firms pass on the positive cost shock immediately. This variability in search intensity associated with changes in retail firm costs (wholesale prices) is a reasonable explanation for the asymmetric response of retail prices to shocks in wholesale prices.

Lewis (2011) developed a search model in which consumers form expectations based on information on the price distribution of the previous period, that is, consumers form a search reference price. This model helps predict the setting of retail prices based on consumer search decisions. Search intensity increases when retail prices are set above the reference price in response to a positive cost shock, while search intensity is reduced when prices are lower than the reference prices (negative cost shock). Thus, increased search by consumers creates a more competitive environment for stations that are forced to adjust prices quickly along with less dispersion of prices. Conversely, inadequate search fosters a less competitive environment and stations use to adjust their prices gradually, which causes greater price dispersion. Thus, the model of Lewis (2011) suggests two testable predictions:

Predictions of Search Models: Positive (negative) cost shocks for retail firms, that is, changes in wholesale prices for gas stations, are related to a rapid (slow) pass-through

[2] Non-sequential search models postulate that consumers initially define the needed search effort and choose the lowest price given their choice of search effort. In contrast, sequential search models postulate that consumers when faced with a price decide whether to buy the said product or continue with the search; there is no prior choice of search effort in such a model.

to retailer prices and less (more) price dispersion.

Other models that explain the asymmetry in the adjustment of retail prices are based on the focal point tacit collusion theory. Following the Green and Porter (1984) model in which the coordination between firms is sustainable if and only if the market price is above a threshold or an activation price, Borenstein et al. (1997) argued that past prices set by retail firms served as a basis on which firms coordinate In these models, the sustainability of collusion between firms pertains to changes in profit margins resulting from cost shocks. When positive cost shocks occur, firms do not collude because profit margins decrease, thus reducing their incentives to collude. This implies that firms compete with each other and transmit the shock to retail prices faster. However, when negative shocks to costs occur, maintaining past prices favors firms' profit margins. Thus, sustainability of collusion is easier and retail prices do not respond as quickly to negative shocks to costs. Given these hypotheses, focal point tacit collusion models explain the asymmetric adjustment of station prices against changes in wholesale prices.

The tacit collusion theory helps establish a pattern of retail price behavior: prices are highly rigid with a few episodes of discrete changes related to significant changes in firm costs, which indicates that firms' decisions about altering their prices are not very sensitive to changes in costs, that is, small movements in costs are not reflected in changes in retail prices. Sustainability of collusion depends on not only changes in costs but also heterogeneity on the firms' costs. High-cost firms benefit from maintaining prices during high heterogeneity and declining wholesale prices, while low-cost firms benefit from breaking the collusion and setting competitive prices to gain a greater market share. Additionally, when costs rise, high-cost firms benefit from coordination, which means that their prices are rigid under positive shocks than the prices set by low-cost firms. This implies that low-cost stations quickly adjust their prices than high-cost companies in both positive and negative cost shocks scenarios.

Lewis (2011) highlighted the drawback of the focal point tacit collusion theory in that it cannot explain why past prices are a focal point for retail firms in the market. These models cannot endogenously explain the existence of a focal point at which firms collude. Hong and Lee (2018) stated that following the *Folk Theorem*, for low intertemporal discount rates, any price between competitive and monopoly price would be a Nash equilibrium of the game that allows maintaining collusive results. Tacit collusion models do not address this issue of equilibrium. Thus, how a focal point is generated as a form of coordination when companies collude tacitly is unclear. However, Schelling (1960) suggested that, given multiple equilibria, firms can recognize a focal point and use it to coordinate.

The focal point tacit collusion models are based on the model of Rotemberg and Saloner (1986). Rotemberg and Saloner (1986) provided a tacit collusion model that leads to price wars in which positive demand shock results in collusion sustainable and negative shocks under the assumption that demand shocks follow an independent and identical distributed process. Haltiwanger and Harrington (1991) showed similar results under a less restrictive assumption with cyclical demand shocks. Borenstein and Shepard

(1996) used these models to reinterpret demand shocks as dynamic cost changes and found that the profit margins associated with collusion increase with negative cost shocks and decrease with positive shocks. Thus, the sustainability of collusion contradicts cost changes, indicating an asymmetric price response to cost changes. However, Borenstein and Shepard (1996) claimed that tacit collusion models predict greater sustainability of coordination when fewer firms exist in the market; therefore, there is asymmetry in the adjustment of retail prices in markets with few established firms.

Tacit collusion models predict that market power has a positive effect on the asymmetry by promoting collusion between stations. Additionally, the tacit collusion models predict that prices disperse more against positive cost shocks, while coordination between firms leads to less price dispersion against negative cost shocks. This result contradicts that obtained using consumer search models. Thus, tacit collusion models suggest two testable predictions:

Predictions of Tacit Collusion Models: Positive (negative) cost shocks for retail firms, that is, changes in wholesale prices for gas stations, are related to a rapid (slow) pass-through to retail prices and more (less) price dispersion. Additionally, retail prices are sticky, that is, small changes in costs do not change prices.

These theoretical predictions are compared with the data from the Colombian gasoline retail market to assess which theory better explains firms' behavior. The following section presents the data and an empirical strategy to compare the theoretical predictions of the two theories discussed earlier.

3.1. Data

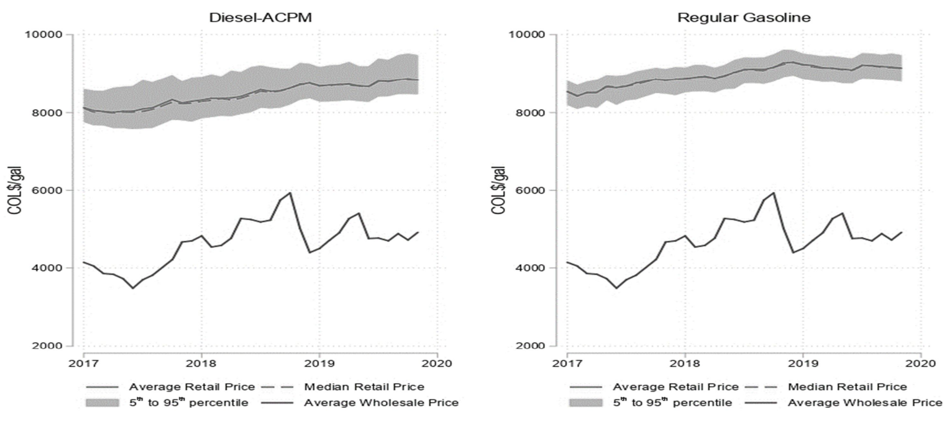
This study focuses on the dataset on fuel prices reported by service stations based on the regulated or market price (*retailers data*). Data are collected by the Ministry of Mines and Energy of Colombia from January 2017 to November 2019. Data on the municipality, department[3], name of the service station, type of gasoline, and the brand are included. Gasoline is categorized as Diesel-ACPM, regular gasoline, and premium gasoline. The stations report their price to the Ministry during the first days of the month. They can choose whether to modify it on another day of the month by reporting the new price to the Ministry. Therefore, we can have different prices during the month for a particular type of gasoline in a station. We take the monthly average of the prices set by the stations during the month for each type of gasoline[4]. The study uses the data from gasoline stations in the 35 main municipalities of Colombia and includes a database of 1664 gasoline stations. Additionally, municipal-level monthly data on the reference

[3] Departments are country subdivisions and granted a certain degree of autonomy, and municipalities are subdivisions of departments each one of them is led by a mayor.

[4] We do not focus on studying the intra-month price adjustment.

prices of fuels for stations suggested by the national government are included. Given that the reference price data are only available to regular gasoline and Diesel-ACPM, the study excludes premium gasoline data. Data on the daily closing prices of Brent futures are obtained from Investing. Data on the Colombian peso-dollar exchange rate with daily frequency from Banco de la República (Central Bank of Colombia) are available. The monthly average of the multiplication of these prices and the exchange rate are considered as a measure of the monthly wholesale price for Colombian retailers (*wholesale data*).

Data on retail and wholesale prices are deflated by the Monthly Consumer Price Index (CPI) by municipality using data from DANE (National Statistical Agency of Colombia). This index is available for 22 cities and a conurbation of 35 neighboring municipalities. Figure 2 shows the time series of average, median, and percentile 95th and 5th of retail prices by Diesel-ACPM and regular gasoline, and the average wholesale price for Bogota D.C. Data from Bogotá D.C. are used as an example of the municipality with a maximum number of service stations. The retail prices are more stable over time than the wholesale price and has been reported for different gasoline markets (Eckert and West, 2004). Figure 2 shows the distribution of retail prices for regular gasoline and diesel in Bogotá D.C. The difference between the median and the 5th percentile is less than the difference between the median and the 95th percentile. This price behavior has been documented in retail markets with costs consumer search (Baye and Morgan, 2001), which implies that consumers search more because of the expected profit from doing it (lower prices) offsets the cost of the search. However, this behavior is not observed in regular gasoline. Additionally, the mean and median are almost indistinguishable both types of gasoline, which shows a relatively symmetrical distribution for retail prices.



Source: Author’s elaboration.

Figure 2. Retail Prices and Wholesale Price

The API (application programming interface) of Google Maps is used to georeferentiate the stations of the municipalities because their locations are available through a reliable municipal address system and commercial names. A three-step procedure is used. First, API helps search for service stations by their commercial name or location, a conditional search was conducted on both criteria and thus 1029 stations were directly georeferenced. Second, the remaining 636 stations were searched by their commercial name, and third, by location. Stations with the same coordinates are identified and added to the 1029 of step 1. Further, the stations whose coordinates were obtained only using step 2 or 3 are identified and added as well. Subsequently, the coordinates with which we will stay of the stations that presented different coordinates under both steps 2 and 3. Additional information provided by the search on the characteristics of the search point that the API identifies is used. However, the coordinates for 36 stations could be identified using the three-step procedure and a manual search of their coordinates was conducted with the API. The number of competitors for each month of the sample was calculated from the coordinates of the stations within 1-2 km radius. Thus, the number of competitors was calculated in the municipality for each month of the sample.

Table 2 shows the descriptive statistics of retail prices by type of gasoline and wholesale price in the full sample, and number of competitors in municipality within 1-2 km radius. No relevant differences existed between the types of gasoline for their average values, variability, and minimum and maximum values. However, the average number of competitors for a station is 44.04 in the municipality, 12.3 for a radius of 2 km, and 4.02 for a radius of 1 km was significant. The number of competitors in the municipality is high because all stations in big cities such as Bogotá, Medellín, or Cali were considered potential competitors. This difference between competitors for a station shows the contribution of the georeferencing process by better identification of the potential number of competitors.

Table 2. Descriptive Statistics of Variables

	Mean	S.D.	Min	Max	Obs
Retail Price (COP$/gal)					
Diesel-ACPM	8371.43	712.56	4495.32	13038.24	51737
Regular Gasoline	8828.67	701.22	5070.36	13103.25	50607
Wholesale Price (COP$/gal)	4662.56	600.16	3476.78	5936.74	34
Competitors in Municipality	44.04	64.22	3	385	1190
Competitors in 2 km	12.30	8.04	0	37	52416
Competitors in 1 km	4.02	3.31	0	20	52416

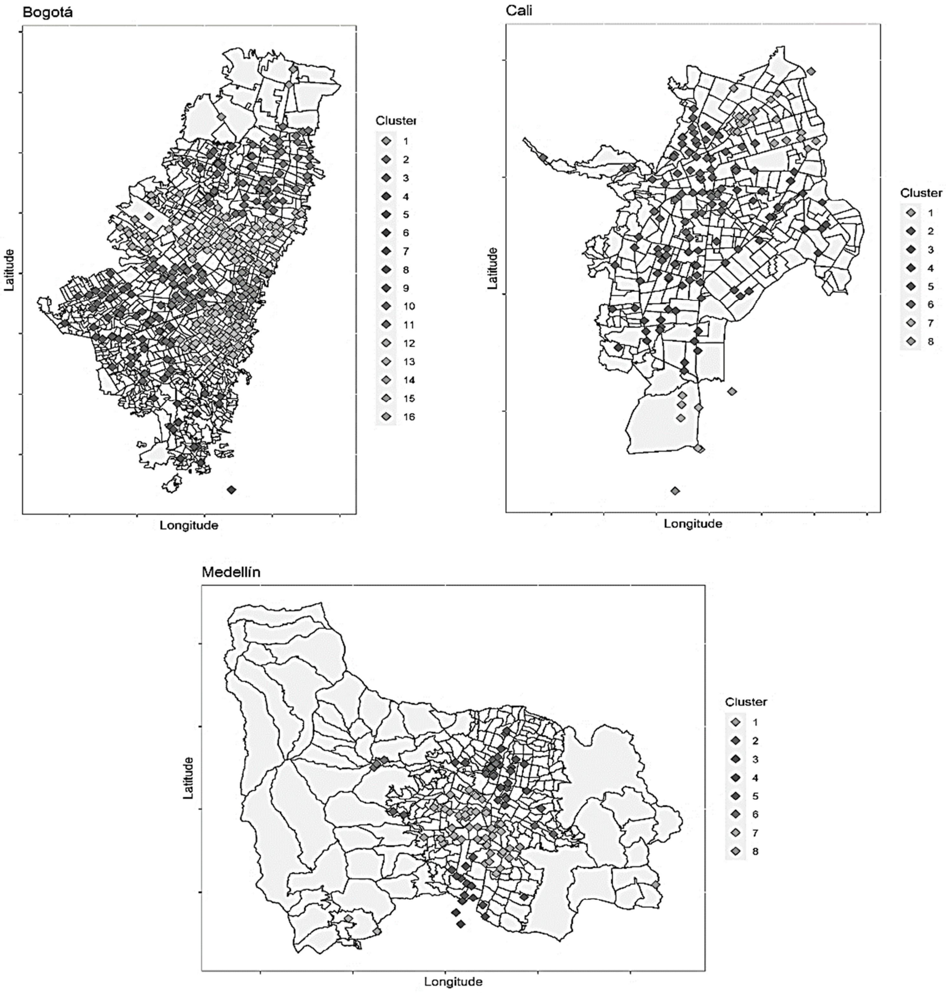
Source: Author's elaboration.

This study also focuses on the dispersion of retail prices of gasoline. Table 3 shows the median number of stations by municipality in a month for the sample period. Assuming that large municipalities make up a market is unrealistic, since they represent a large number of stations which do not necessarily compete with each other. For example, a station to the north of Bogotá is not a rival to a station to the south. For these large municipalities, we carry out a cluster analysis to define markets in a more reasonable way. Large municipalities are defined as those 50 or more stations on average from Table 3. To estimate the relative proximity between stations, hierarchical agglomerative cluster analysis is run based on the similarity of the station coordinates using the square of the Euclidean distance by centroid method. The Duda-Hart rule is used to select the number of clusters considered in municipalities. For Bogotá, 30 maximum possible clusters were considered and 20 possible clusters for the other cities. The study results show that for Bogotá D.C., 16 clusters are estimated, for Cali 8, Medellín 8, Barranquilla 8, Cartagena 6, and Bucaramanga 3. The rest of the municipalities are their own clusters, thus, we have a total of 78 clusters. Figure 3 presents the results of georeferencing and cluster analysis for the municipalities of Bogotá D.C., Cali, and Medellín. The study results show that the cluster sizes o are relatively different, ranging from a large numbers to just 3 or only one station. These clusters are further grouped into zones. For example, stations in Cali are grouped as north, east, and center, and the south zone has three large clusters. Medellín was clustered as north, center, east, west, and south. For Bogotá D.C., the division by zones is broader because of its size.

Table 3. Median Number of Stations in Municipalities

Bogota D.C.	376	Neiva	34	Dosquebradas	20
Cali	152	Manizales	33	Florencia	18
Medellin	111	Soledad	31	Envigado	16
Barranquilla	89	Armenia	28	Cucuta	14
Cartagena	59	Sincelejo	28	Floridablanca	12
Bucaramanga	50	Yumbo	27	Los Patios	12
Pasto	46	Valledupar	26	Copacabana	9
Pereira	45	Popayan	25	Sabaneta	9
Ibague	43	Riohacha	24	Jamundi	9
Villavicencio	42	Soacha	24	La Estrella	6
Santa Marta	40	Bello	22	Villa del Rosario	3
Monteria	38	Tunja	21		

Source: Author’s elaboration.



Source: Author's elaboration.

Figure 3. Cluster Analysis for Municipalities

Table 4. Descriptive Statistics of the Price Dispersion

	Dispersion of Fuel Prices	
	Municipalities	Cluster of Stations
Mean	0.034	0.028
Std. Dev.	0.028	0.025
Min	0.000	0.000
Max	0.190	0.236
Obs	2380	5249

Source: Author's elaboration.

Table 4 shows the descriptive statistics of dispersion of fuel prices within municipalities and cluster of stations by type of gasoline in the full sample. The dispersion of fuel prices is measured using the coefficient of variation of prices within municipality or cluster of stations at a time for one type of gasoline. For each municipality or cluster of stations we calculate the measures of dispersion, in particular, the coefficient of variation of prices. Then, we calculate the descriptive statistics of this measure of dispersion between the municipalities or cluster of stations and report them in Table 4. The coefficient of variation of 1 indicates a high dispersion of prices, while a value close to 0 indicates a low dispersion of prices. The cluster of stations within large municipalities sharing a relative proximity is grouped. We shows that the average value of the dispersion of prices in a particular month is approximately zero when dispersion is considered within municipalities or cluster of stations. The average value of the dispersion of prices within municipalities or clusters of station is approximately 0.03, which is nearly zero. The maximum values of the price dispersion indicators are between 0.25 and 0.3, which shows a relevant variability in the dispersion of prices between municipalities or cluster of stations. These descriptive measures do not control for differences in price levels based on the type of gasoline being sold nor for the possible number of competitors against the retailers within municipalities or cluster of stations.

3.2. Empirical Strategy

Let $\Delta P^{w}_{mt} \equiv 100 \times (\ln P^{w}_{mt} - \ln P^{w}_{m,t-1})$ the change (%) in wholesale price in time t in municipality m. For the reference price we define $\Delta R_{mpt} \equiv 100 \times (\ln R_{mpt} - \ln R_{mp,t-1})$ for type of gasoline p. Following (Hofstetter and Tovar, 2010), in the Colombian market, the relevant shock on retail prices is the difference between the growth of Brent and the growth of the reference price. We define $\Delta W_{mpt} = \Delta P^{w}_{mt} - \Delta R_{mpt}$. Table 5 shows the descriptive statistics of the distribution of ΔW. The mean value of the distribution is close to -0.22 and the median value is 0.58. Figure 4 shows the density of the distribution of change in wholesale prices. The observed distribution is asymmetric and approximately to 0. An empirical strategy is proposed to define the existence of shocks in wholesale prices.

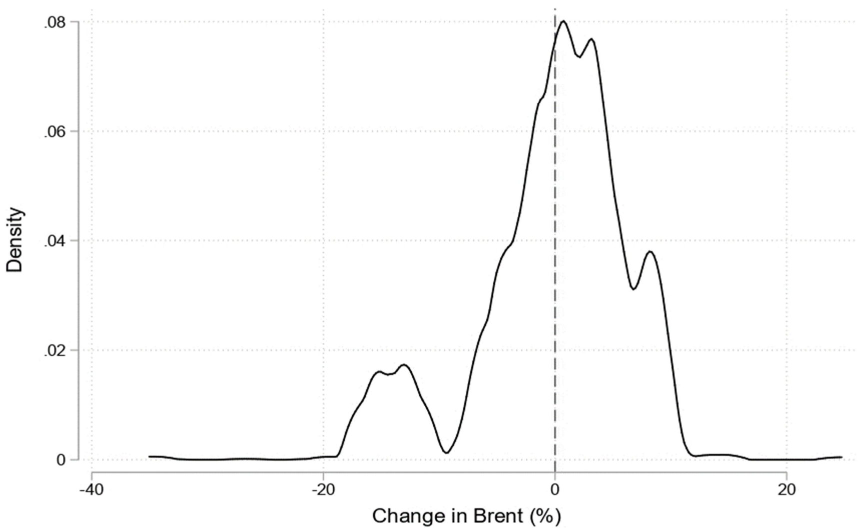
This study proposes that retailers face three types of shocks in the market: positive, neutral, and negative and adopts the zero value of the change in difference between Brent and reference price. It is assumed that shocks to wholesale prices differ from the reference price. Thus, from this value we form an interval over which we define neutral shocks, that is, shocks to which retailers do not react because they consider them relatively low. In a neutral shock, Brent is similar to the reference price. Thus, the shocks in the wholesale price are defined as follows:

$$Shock^{+}_{mpt} \equiv \mathbf{1}_{mpt}(\Delta W_{mpt} \geq 1\%), \tag{1}$$

$$Shock^{-}_{mpt} \equiv \mathbf{1}_{mpt}(\Delta W_{mpt} \leq -1\%), \quad (2)$$

$$Shock^{o}_{mpt} \equiv \mathbf{1}_{mpt}(-1\% < \Delta W_{mpt} < 1\%), \quad (3)$$

where $\mathbf{1}_{mpt}$ is a function that takes the value of 1 if the condition between brackets is true, 0 in other case.



Source: Author's elaboration.

Figure 4. Density of Change (%)

Table 5. Descriptive of Change (%)

Obs	2024	1%	-16.46
Mean	-0.22	10%	-11.90
Std. Dev.	6.59	25%	-3.22
Skewness	-0.96	Median	0.58
Kurtosis	4.84	75%	4.17
Largest	24.74	90%	7.82
Smallest	-35.03	99%	9.45

Source: Author's elaboration.

A positive shock occurs when the change (%) in the wholesale price is equal to or greater than 1% with respect to the growth of the reference price and a negative shock when the change is equal to or less than -1%, otherwise it is a neutral shock. The study data show that at the municipality-gasoline level, 36.12% of the changes in Brent correspond to negative shocks, 16.11% are neutral shocks, and 47.78% are positive shocks. Thus, a nonlinear relationship exists between pass-through on retail prices and shocks on wholesale prices. Based on this strategy to define shocks in wholesale prices, static and dynamic versions of the model were developed. Each version shows relevant aspects of the pass-through from wholesale prices to retailers.

3.2.1. Static Model

Retail firms follow a pricing strategy such that positive shocks on wholesale prices are transmitted more than negative shocks. This asymmetric determination of retail prices can be contrasted with the data for the Colombian market. Conversely, the following specification is proposed for the price of the retailer i, in the municipality m, type of gasoline p of brand b, at time t:

$$\begin{aligned} \ln P^r_{impbt} &= \beta_0 + \beta_1 \ln P^w_{m,t-1} + \beta_2 Shock^-_{mp,t-1} \ln P^w_{m,t-1} \\ &\quad + \beta_3 Shock^+_{mp,t-1} \ln P^w_{m,t-1} + \boldsymbol{z}_{impbt}{}'\boldsymbol{\delta} + \boldsymbol{\theta} + \varepsilon_{impbt}. \end{aligned} \tag{4}$$

β_1 captures the pass-through and β_2, β_3 the asymmetric behavior in the prices of the retailer when the wholesale price changes. Additionally, β_1 confirms that the retail prices are sticky since this pass-through is associated with neutral cost shocks, that is, small movements in wholesale prices. $\boldsymbol{z}$ is a vector of control variables as the population around the station and the average income of the population. $\boldsymbol{\theta}$ is a vector of fixed effects by time, station, the type of gasoline, and brand.

The model also predicts the change in the price dispersion due to changes in the wholesale prices. The study proposes the next econometric specification to evaluate the relation between retail price dispersion D^r and changes in wholesale prices:

$$D^r_{lpt} = \gamma_0 + \gamma_1 Shock^-_{m,t-1} + \gamma_2 Shock^+_{m,t-1} + \boldsymbol{w}_{lpt}{}'\boldsymbol{\alpha} + \boldsymbol{\eta} + u_{lpt}. \tag{5}$$

The dispersion in the retail prices is measured as(1) coefficient of variation, (2) max-min range, and (3) a measure of the value of the information (Belleflamme and Peitz, 2015, p. 165). The value of the information is measured as the difference between the average and minimum retail price and a greater difference indicates that the prices are more dispersed and consumers earn more by searching for the lowest price. γ_1, γ_2 captures the change in prices dispersion by shocks in wholesale prices. $\boldsymbol{w}$ are control variables such as average retail price by type of gasoline p in location l (municipality or cluster of stations) in time t and the number of stations in location l in time t. $\boldsymbol{\eta}$ are fixed effects considered by municipality/cluster and type of gasoline.

3.2.2. Dynamic Model

The cointegration method proposed by Borenstein et al. (1997) and Lewis (2011) is followed to analyze the asymmetric adjustment of retail prices over time. The method establishes a long-term relationship between retail prices and wholesale price and, then, using an error correction model, the dynamic adjustment of retail prices to negative, positive, and neutral shocks in wholesale price is estimated. The equation of the first stage corresponds to

$$\ln P^r_{impbt} = \beta_0 + \beta_1 \ln P^w_{mt} + \zeta + \mu_{impbt}. \tag{6}$$

ζ represents the combination of fixed effects by time, retail, brand, and type of gasoline. In this equation, the correction error term is extracted, $\epsilon_{impb,t-1}$, which is included as an independent variable in the equation of the second stage. The latter corresponds to

$$\begin{aligned}\Delta p^r_{jt} = \alpha &+ \textstyle\sum_{h=1}^{H} \left(\lambda_h \Delta p^r_{jt-h} + \gamma^1_h Shock^-_{mpt} \Delta p^r_{jt-h} + \gamma^2_h Shock^+_{mpt} \Delta p^r_{jt-h} + \kappa_{1h} N_{jt-h} \Delta p^r_{jt-h}\right) \\ &+ \textstyle\sum_{h=0}^{H} \left(\phi_h \Delta p^w_{mt-h} + \delta^1_h Shock^-_{mpt} \Delta p^w_{mt-h} + \delta^2_h Shock^+_{mpt} \Delta p^w_{mt-h} + \kappa_{2h} N_{jt-h} \Delta p^w_{mt-h}\right) \\ &+ \eta \Delta N_{jt} + \theta\left(\hat{\mu}_{jt-1}\right) + \omega_1\left(Shock^-_{mpt} \hat{\mu}_{jt-1}\right) + \omega_2\left(Shock^+_{mpt} \hat{\mu}_{jt-1}\right) + \theta_t + \xi_t, \end{aligned} \tag{7}$$

where $p^r_{jt} = \ln P^r_{impbt}$, $p^w_{mt} = \ln P^w_{mt}$, $\hat{\epsilon}_{impb,t-1} = \hat{\mu}_{jt-1}$. N_{jt} represents the number of competitors and θ_t are fixed effects by time. In this model, retail price changes depend on its own lags, wholesale price changes along with its lags, the change in the number of competitors, and the correction error term. Furthermore, the effect of these independent variables on the retail price is mediated by the type of shock and the number of competitors. Conversely, the model is restricted so that the number of lags including p^r_{jt-h} and p^w_{mt-h} are equal to H. Moreover, H is selected such that it minimizes the AIC and BIC information criteria. To derive the algebraic form of the impulse response, the model is evaluated on the average of the number of competitors ($\overline{N}$), and some terms are reorganized:

$$\begin{aligned}\Delta p^r_{jt} = \alpha &+ \textstyle\sum_{h=1}^{H} \left((\lambda_h + \kappa_{1h}\overline{N}) \Delta p^r_{jt-h} + \gamma^1_h Shock^-_{mpt} \Delta p^r_{jt-h} + \gamma^2_h Shock^+_{mpt} \Delta p^r_{jt-h}\right) \\ &+ \textstyle\sum_{h=0}^{H} \left((\phi_h + \kappa_{2h}\overline{N}) \Delta p^w_{mt-h} + \delta^1_h Shock^-_{mpt} \Delta p^w_{mt-h} + \delta^2_h Shock^+_{mpt} \Delta p^w_{mt-h}\right) \\ &+ \eta \Delta N_{jt} + \theta(\hat{\mu}_{jt-1}) + \omega_1(Shock^-_{mpt} \hat{\mu}_{jt-1}) + \omega_2(Shock^+_{mpt} \hat{\mu}_{jt-1}) + \theta_t + \xi_t. \end{aligned} \tag{8}$$

Renaming parameters

$$\begin{aligned}\Delta p^r_{jt} = \alpha &+ \textstyle\sum_{h=1}^{H} \left(\lambda^*_h \Delta p^r_{jt-h} + \gamma^1_h Shock^-_{mpt} \Delta p^r_{jt-h} + \gamma^2_h Shock^+_{mpt} \Delta p^r_{jt-h}\right) \\ &+ \textstyle\sum_{h=0}^{H} \left(\phi^*_h \Delta p^w_{mt-h} + \delta^1_h Shock^-_{mpt} \Delta p^w_{mt-h} + \delta^2_h Shock^+_{mpt} \Delta p^w_{mt-h}\right) \\ &+ \eta \Delta N_{jt} + \theta(\hat{\mu}_{jt-1}) + \omega_1(Shock^-_{mpt} \hat{\mu}_{jt-1}) + \omega_2(Shock^+_{mpt} \hat{\mu}_{jt-1}) + \theta_t + \xi_t. \end{aligned} \tag{9}$$

Following Mirza and Bergland (2012), β_1 is the long-term marginal effect. The response of the dependent variable is a negative impulse in the wholesale price, which is as follows:

$$
\begin{aligned}
S_0 &= \phi_0^* + \delta_0^1,\\
S_1 &= S_0 + (\phi_1^* + \delta_1^1) + (\theta + \omega_1)(S_0 - \beta_1) + (\lambda_1^* + \gamma_1^1)S_0,\\
S_2 &= S_1 + (\phi_2^* + \delta_2^1) + (\theta + \omega_1)(S_1 - \beta_1) + (\lambda_1^* + \gamma_1^1)(S_1 - S_0) + (\lambda_2^* + \gamma_2^1)S_0,\\
S_3 &= S_2 + (\phi_3^* + \delta_3^1) + (\theta + \omega_1)(S_2 - \beta_1) + (\lambda_1^* + \gamma_1^1)(S_2 - S_1)\\
&\quad + (\lambda_2^* + \gamma_2^1)(S_1 - S_0) + (\lambda_3^* + \gamma_3^1)S_0,\\
&\vdots \qquad\qquad\qquad \vdots \qquad\qquad\qquad \vdots\\
S_k &= S_{k-1} + (\phi_k^* + \delta_k^1) + (\theta + \omega_1)(S_{k-1} - \beta_1) + (\lambda_k^* + \gamma_k^1)S_0\\
&\quad + \sum_{i=1}^{k-1} (\lambda_i^* + \gamma_i^1)(S_{k-i} - S_{k-i-1}).
\end{aligned}
$$

When there is a positive shock, the impulse response is obtained by exchanging the parameters δ_h^1, ω_1 and γ_h^1 by δ_h^2, ω_2 and γ_h^2. When the shock is neutral, they are exchanged for zero.

4. RESULTS

4.1. Estimates for the Static Model

Two theoretical predictions can be contrasted with the data: (1) the relationship between the dispersion of retail prices of gasoline and shocks in wholesale prices and 2) the pass-through between retail prices of gasoline and wholesale prices. Consequently, equations 4 and 5 are estimated using OLS correcting for a cluster at an individual level: stations-gasoline for the regression on retail prices and municipality-gasoline or group of stations-gasoline level for the regression on dispersion of prices. First, the prediction associated with the dispersion of retail prices is presented. Table 6 presents the estimation of equation 5 at the level of municipalities and a cluster or group of stations. For each municipality or cluster of stations, the dispersion of prices by type of gasoline is considered the dependent variable. Columns (1)-(3) of Table 6 represent the municipality-level data and columns (4)-(6) at the cluster of stations level. In columns (1) and (4), the dispersion of prices is measured using the coefficient of variation; in columns (2) and (5), the max-min range is used; and in columns (3) and (6), the difference between the average and minimum value is used. All columns are regressions that include fixed effects using time, municipality or cluster of stations, and type of gasoline. The number of stations in the municipality and the average retail price of the municipality in the previous month are used as controls.

The results show that the dispersion of retail prices of gasoline within municipalities or a cluster of stations decreases with negative shocks in wholesale prices and no significant positive shocks are evident for the choice of the measure of price dispersion, which is consistent with the tacit collusion theory. When wholesale prices suffer a negative, firms set similar prices because a drop in wholesale costs implies a greater profit margin for the firms, thus making it profitable. However, the average prices of gasoline and the dispersion of prices are significantly correlated. When retail prices are high for a municipality or cluster of stations, consumers can choose from a broad range of retail prices but not when retail prices are low. No significant relationship was found for dispersion of prices and the number of stations, thus implying no relationship between competition measured as the potential number of rival stations and price dispersion.

Table 6. Price Dispersion and Shocks in the Wholesale Price

	(1)	(2)	(3)	(4)	(5)	(6)
	Municipalities			Cluster of Stations		
	Var. Coef.	Range	Value Info.	Var. Coef.	Range	Value Info.
Shock(-)	-0.0133***	-0.0329**	-0.0110**	-0.0099***	-0.0304***	-0.0065**
	(0.0046)	(0.0158)	(0.0047)	(0.0030)	(0.0100)	(0.0027)
Shock(+)	-0.0021	0.0005	-0.0014	-0.0013	0.0013	-0.0006
	(0.0034)	(0.0173)	(0.0048)	(0.0023)	(0.0122)	(0.0036)
Avg Retail Price	0.0266**	0.0393	0.0198**	0.0165**	0.0254	0.0101
	(0.0121)	(0.0366)	(0.0097)	(0.0078)	(0.0180)	(0.0062)
Stations	0.0001	-0.0017	0.0002	0.0007	0.0015	0.0016*
	(0.0005)	(0.0049)	(0.0010)	(0.0006)	(0.0030)	(0.0009)
Constant	-0.1890*	-0.0682	-0.1110	-0.1240*	-0.1220	-0.0736
	(0.1070)	(0.3920)	(0.0996)	(0.0721)	(0.1740)	(0.0585)
Observations	1888	1888	1888	4245	4245	4245
R-squared	0.4100	0.5050	0.6720	0.4580	0.4880	0.6680

Note: Standard errors corrected by cluster at municipality-gasoline or cluster-gasoline level in parentheses. All columns contain fixed effects by time, municipality/group and type of gasoline. The average retail price of gasoline is lagging one month. *** p<0.01, ** p<0.05, * p<0.1 Source: Author’s elaboration.

This study predicts the pass-through between retail and wholesale prices. The results of equation 4 are presented in Table 7. The dependent variable is the retail prices set by the stations for each type of gasoline in each month. The wholesale prices interacted with the dummy variables for positive and negative shocks are the explanatory variables. Columns (3) and (4) contain fixed effects for time, station, brand, and type of gasoline. Columns (1) and (2) exclude fixed effects. Column (4) tests the heterogeneity of the pass-through between stations in municipalities with less than 30 stations and stations of the other municipalities. Stations with less than 30 competitors in a municipality are called dominant stations due to the low competition that they face.

Table 7. Pass-Through of Wholesale Price to Retail Prices

	(1) Retail Price	(2) Retail Price	(3) Retail Price	(4) Retail Price
Brent	0.1750***	0.1720***	0.4280***	0.4240***
	(0.0016)	(0.0017)	(0.0546)	(0.0543)
Shock(-) x Brent		0.0021***	0.0004***	0.0004***
		(0.0000)	(0.0001)	(0.0001)
Shock(+) x Brent		0.0010***	0.0000	0.0000
		(0.0000)	(0.0001)	(0.0001)
Dominants x Brent				0.0130***
				(0.0038)
Dominants x Shock(-) x Brent				-0.0001
				(0.0001)
Dominants x Shock(+) x Brent				0.0000
				(0.0000)
Constant	7.5760***	7.5990***	5.4410***	5.4520***
	(0.0137)	(0.01480)	(0.4620)	(0.460)
Observations	95775	82806	82805	82805
R-squared	0.0590	0.0500	0.8640	0.8640

Note: Standard errors corrected by cluster at station-gasoline level in parentheses. Columns (1) and (2) contain fixed effects by time. Columns (3) and (4) contain fixed effects by time, station, brand and type of gasoline. *** p<0.01, ** p<0.05, * p<0.1 Source: Author's elaboration.

Table 7 shows an asymmetric transmission of shocks in wholesale prices over retail prices. Column 1 estimates the pass-through assuming that there is no asymmetry and without controlling for other possible factors explaining the relationship between retail and wholesale prices. The results show a relatively low pass-through of 17.5%. Column 2 controls for potential asymmetry. The pass-through increases relatively little and asymmetry is evident in both positive and negative shocks. However, when a large set of fixed effects is controlled, the pass-through increases to 42.8% and only an asymmetry for negative shocks is evident. Considering the estimates in column 3, for a 1% change in wholesale prices, stations transfer 0.428% to the retail price when the price experiences a positive, neutral, or negative shock. A greater magnitude of pass-through exists to negative shocks of approximately 0.0003%, which is relatively small.

Table 8. Pass-Through Including Competitors

	(1) Retail Price	(2) Retail Price	(3) Retail Price
Brent	0.3580***	0.4210***	0.4130***
	(0.0554)	(0.0545)	(0.0544)
Shock(-) x Brent	0.0004***	0.0004***	0.0004***
	(0.0001)	(0.0001)	(0.0001)
Shock(+) x Brent	0.0000	0.0000	0.0000
	(0.0001)	(0.0001)	(0.0001)
Competitors in Mun	0.0683***		
	(0.0127)		
Competitors in Mun x Brent	-0.0035***		
	(0.0010)		
Competitors 1 km		0.0286**	
		(0.0137)	
Competitors 1 km x Brent		-0.0028*	
		(0.0016)	
Competitors 2 km			0.0419***
			(0.0129)
Competitors 2 km x Brent			-0.0040***
			(0.0014)
Constant	5.8620***	5.4930***	5.5490***
	(0.4640)	(0.4610)	(0.4600)
Observations	82805	82805	82805
R-squared	0.8640	0.8640	0.8640

Note: Standard errors corrected by cluster at station-gasoline level in parentheses. All columns contain fixed effects by time, station, brand and type of gasoline. *** p<0.01, ** p<0.05, * p<0.1 Source: Author's elaboration.

Column 4 of Table 7 evaluates the possible heterogeneity of the pass-through between stations with dominant positions. Thus, a dummy variable that takes the value of 1 is used for stations in municipalities with less than 30 stations, and 0 otherwise. This variable is termed *Dominants* and its pass-through and asymmetry terms between the behavior of stations with and without a dominant position are compared. The data help select the value of 30 stations. Municipalities with less than 30 stations represent approximately 20.29% of the sample. Our results show a difference between the pass-through of stations with a dominant position and those that do not. Non-dominant stations carry a pass-through of 42.4%, while dominant ones carry a pass-through that is 1.3% higher, that is, 43.7%. Moreover, stations with dominant and nondominant positions load the pass-through asymmetrically similarly.

Table 9. Robustness Analysis of the Definition of Shocks

	(1) Shock 1	(2) Shock 2	(3) Shock 3	(4) Shock 4
Brent	0.4130***	0.4490***	0.4460***	0.4380***
	(0.0544)	(0.0449)	(0.0450)	(0.0447)
Shock(-) x Brent	0.0004***	0.0008***	-0.0001	
	(0.0001)	(0.0002)	(0.000)	
Shock(+) x Brent	0.0000	-0.0002*	-0.0007***	-0.0009***
	(0.0001)	(0.0000)	(0.0001)	(0.0001)
Competitors 2 km	0.0419***	0.0515***	0.0519***	0.0513***
	(0.0129)	(0.0125)	(0.0124)	(0.0124)
Competitors 2 km x Brent	-0.0040***	-0.0052***	-0.0053***	-0.0052***
	(0.0014)	(0.0014)	(0.0014)	(0.0014)
Constant	5.5490***	5.2430***	5.2720***	5.3460***
	(0.4600)	(0.3800)	(0.3800)	(0.377)
Observations	82805	95775	95775	95775
R-squared	0.8640	0.8680	0.8680	0.86800

Note: Standard errors corrected by cluster at station-gasoline level in parentheses. Columns contain fixed effects by time, station, brand and type of gasoline. Shock 1 defines neutral shock as those changes in the wholesale price between -1% and 1%, Shock 2 defines it as between -2% and 2%, Shock 3 between -3% and 3%. For Shock 4 we do not define neutral shock, instead, we define a dummy that takes the value 1 when the change is non-negative, and zero when the change is negative. *** $p<0.01$, ** $p<0.05$, * $p<0.1$ Source: Author's elaboration.

These results show the potential competition affects the pass-through the stations carry, implies that the potential competition should be controlled to obtain consistent estimators of the pass-through and its asymmetry. Table 8 uses georeferenced station data to justify an additional control for the potential competitors of the station. Columns (1)-(3) are estimates of the equation 4 including as a control the logarithm number of competitors at the station in municipality and within 1-2 km radius, respectively. The logarithm number of competitors is entered directly and interactively with the pass-through.

The results show approximately 40% pass-through and the asymmetry against negative shocks are robust to the inclusion of the number of potential competitors. The number of competitors has a positive and significant relationship with the retail prices of gasoline. The interaction between pass-through and competitors has a negative relationship, that is, when the number of competitors increases, then the pass-through becomes weaker only for competitors within 1 km and 2 km. This result validates that in column 4 of Table 7 and indicates a lesser increase in prices when there are more competitors in close proximity because stations facing competition are more cautious of modifying their prices and turning consumers away to other stations.

In this study, the definition of neutral shock is logical but discretionary. Thus, an alternative definition is proposed to assess the robustness of results. Table 9 presents the robustness of the econometric specification on the alternative definition of neutral shock. Initially, column 1 shows our base case with a neutral shock defined as growth in the wholesale price between -1% and 1% already to the growth of reference price, including the controls associated with the number of competitors. In columns 2 and 3, the definition of neutral shock is changed at intervals about zero of ±2% and ±3%, respectively. Column 4 does not define a neutral shock; instead, a dummy variable that takes the value 1 is used for nonnegative changes, and 0 for negative changes.

The coefficients of the pass-through of the wholesale price to the retail prices, along with the number of competitors and their interaction with pass-through, are robust to the definition of neutral shock. Thus, the coefficients do not change significantly between definitions. However, the results are not robust for the asymmetry of the pass-through.

Heterogeneity of Pass-Through in Static Model

The heterogeneity of the pass-through between retail and wholesale prices are examined based on the type of gasoline sold by the stations. A dummy variable of value 1 is defined when the retail price corresponds to the type of gasoline Diesel-ACPM, and 0 otherwise.

Table 10. Heterogeneity of Pass-Through by Type of Gasoline

	Retail Price
Brent	0.3970***
	(0.0526)
(Gasoline = Diesel) x Brent	0.0335***
	(0.0028)
Shock(-) x Brent	-0.0004***
	(0.0002)
Shock(+) x Brent	-0.0004***
	(0.0001)
(Gasoline = Diesel) x Shock(-) x Brent	0.0004***
	(0.0000)
(Gasoline = Diesel) x Shock(+) x Brent	0.0003***
	(0.0000)
Competitors 2 km	0.0412***
	(0.0125)
Competitors 2 km x Brent	-0.0039***
	(0.0014)
Constant	5.5420***
	(0.4450)
Observations	82805
R-squared	0.8640

Note: Standard errors corrected by cluster at station-gasoline level in parentheses. Column contains fixed effects by time, station, brand and type of gasoline. Base category corresponds to regular gasoline. *** p<0.01, ** p<0.05, * p<0.1 Source: Author's elaboration.

Subsequently, this dummy variable is correlated with the wholesale price and the asymmetry in the Equation 4 to verify heterogeneity in the pass-through and its asymmetry by type of gasoline. Table 10 shows the results of adjusting this model and heterogeneity in the pass-through according to the type of gasoline. Diesel-ACPM gasoline has a pass-through 3.35% higher than that of regular gasoline. Moreover, the pass-through asymmetry is different for both types of gasoline and the asymmetry is stronger for retail prices for regular gasoline than for that of Diesel-ACPM gasoline.

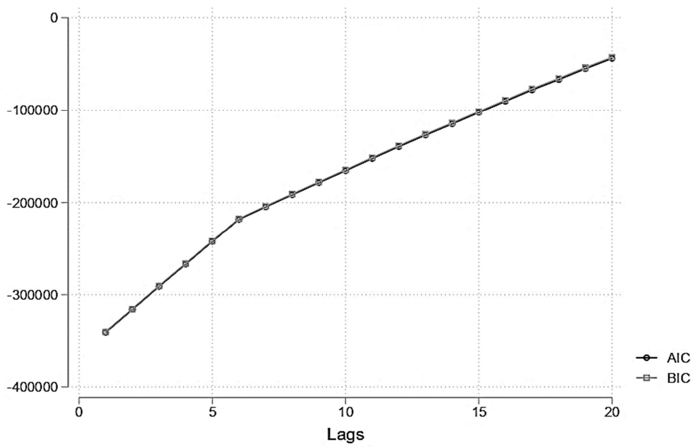
4.2. Estimates for the Dynamic Model

Considering a slow or rapid adjustment to a potential long-term relationship between retail and wholesale prices, thus a model other than the static version should be estimated. This section presents the results of estimating the dynamic model on retail prices of gasoline. Table 11 presents the estimation of the long-term relationship in equation 6. The Appendix shows that the variables in this equation have a unit root and are cointegrated in Panel (see Tables A1 and A2). From this Table, it can be deduced that in the long term, the pass-through is incomplete, because on an average 1% increase in Brent, producers transfer approximately 0.6% to the retail price of gasoline. Subsequently, the residuals of this estimate are used and included as an independent variable in the short-term relations model of the equation 7. We tested with 20 lags of the variables of interest in the short-term model. Figure 5 shows the magnitude of the AIC and BIC information criteria associated with the number of lags included in the model (the differences between the two criteria are tiny, therefore, both lines tend to overlap). The number of lags that minimizes the two criteria is 1; therefore, in the dynamic model it is fixed at $H = 1$. Table A3 shows the results of the estimation of the dynamic model with $H = 1$.

Table 11. Estimation of Long-Term Relationship

	Retail Price
Brent	0.598***
	(0.044)
Constant	4.008***
	(0.367)
Observations	102343
R-squared	0.868

Note: Standard errors corrected by cluster at station-gasoline level in parentheses. We include fixed effects by time, station, brand and type of gasoline. *** p<0.01, ** p<0.05, * p<0.1.
Source: Author's elaboration.



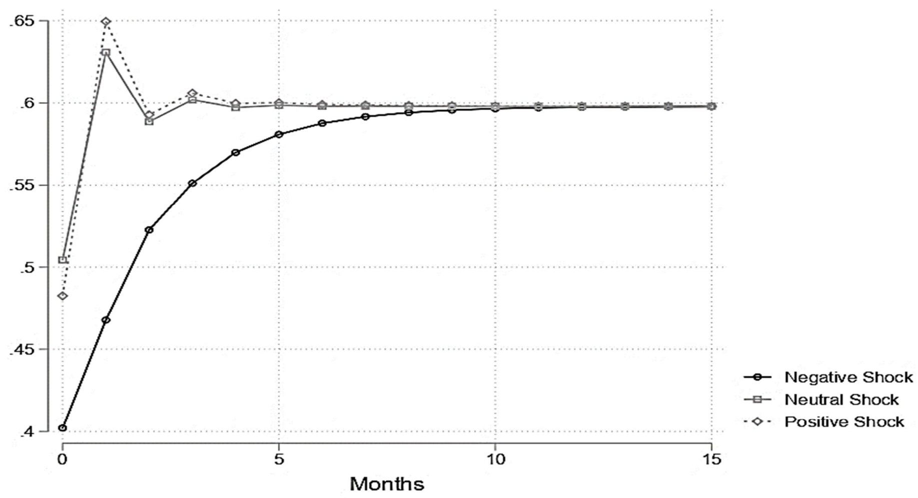
Source: Author's elaboration.

Figure 5. Information Criteria and Number of Lags of the Model

Figure 6 shows the impulse-response functions derived from the estimated dynamic model using the average number of competitors within 2 km and first definition of shock in wholesale prices. The results support the hypothesis of this work, that is, there is asymmetry depending on the origin of the shock. Initially, the effect is greater when the shock is positive or neutral, and lowest against negative shock. There is no evident gap between positive and neutral shocks. With regard to the IRF of negative shocks, the gap with positive and neutral shocks narrows down. From the 5th month, three types of shocks have relatively similar IRFs, which tend to the long-term relationship between retail prices and wholesale prices.

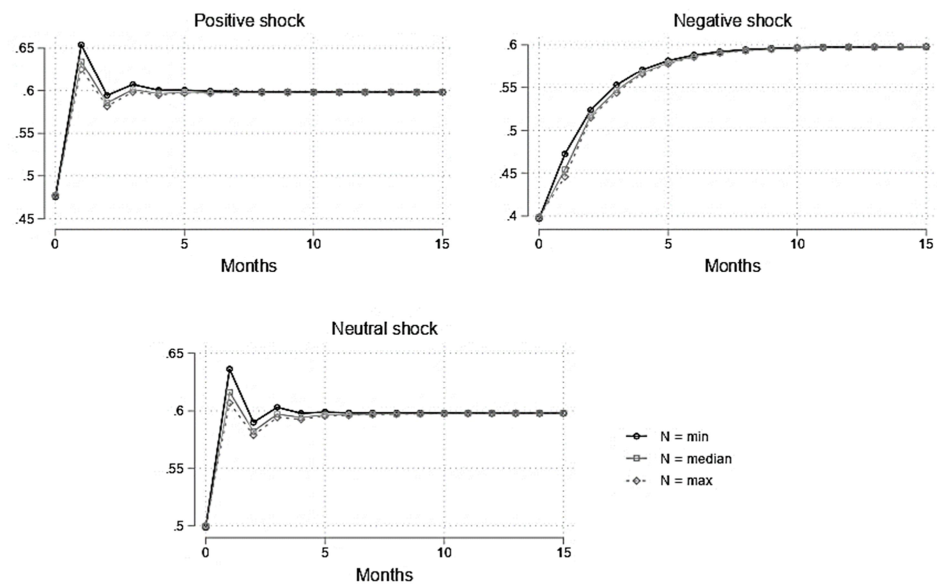
Asymmetry of retail price adjustment is significant in Figure 7 related to Tables in Subsection 4.1. Negative shocks have a higher pass-through than positive and neutral shocks in the static model, although this difference is insignificant. The static model shows a negligible asymmetry. The pass-through coefficient is approximately 0.4 for all types of shocks. However, this asymmetry changes significantly when the model is estimated in its dynamic form. Initially, a positive shock to wholesale prices implies a pass-through more than 0.5, for a neutral shock lesser than 0.5, for a negative shock 0.4. Later, shock IRFs tend to approach the long-term value of 0.598.

The study examines how IRFs change according to the potential number of competitors facing stations. The static model shows that the potential number of competitors reduces the pass-through from the wholesale to retail prices, which implies that IRFs change according to the potential number of competitors. Figure 8 shows the IRFs of Figure 7 for three levels of number of competitors: Minimum, Median (p50), and Maximum. The study results show that for all shocks an increase in the number of competitors negligibly decreases the magnitude of the IRF.



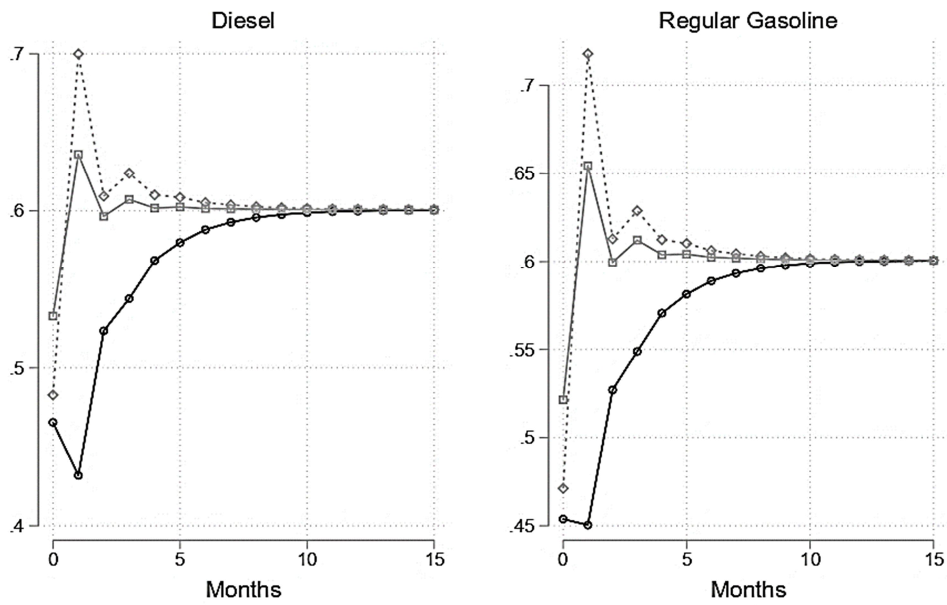
Source: Author's elaboration.

Figure 6. Dynamic Adjustment of Retail Prices



Source: Author's elaboration.

Figure 7. Dynamic Adjustment of Retail Prices by Number of Competitors



Source: Author's elaboration.

Figure 8. Dynamic Adjustment of Retail Prices by Gasoline

The figures show IRFs for the average of the types of gasoline; however, the pass-through was found to be heterogeneous according to the type of gasoline, that is, diesel or regular gasoline. The study examined the first stage for the differences in the long-term relationship, conditional on the type of gasoline, but no significant difference was found. Therefore, only the short-term dynamic adjustment model with heterogeneity by type of gasoline was examined. Figure 9 showed the IRFs for both types of gasoline. The results show no relevant differences in the dynamics of the IRF for the three types of shocks, according to the type of gasoline. There are no significant differences in the levels.

5. CONCLUSIONS

This study examined the pass-through between retail and wholesale prices of gasoline, while studies have focused on the asymmetric response of retail prices, given the changes in wholesale prices. When wholesale prices rise, retail prices rise rapidly; however, when wholesale prices fall, retail prices decline slowly and do not reflect that in wholesale prices. Consumer search models and tacit collusion models explain this behavior of retail prices. Both models agree on asymmetric pass-through between retail and wholesale prices. However, these models have different predictions regarding the dispersion of retail prices in response to changes in wholesale prices. Similarly, this study examines how the dispersion of retail prices responds to changes in wholesale prices.

To compare the theoretical predictions about pass-through and dispersion of retail prices, data obtained from the Ministry of Energy for the Colombian gasoline market between January 2017 and November 2019 are used. The data contain information on prices, type of gasoline, and brand sold by Colombian service stations, registered in the Ministry of Energy with the address and municipality where stations are located. Data on the wholesale price were obtained from the international price of Brent oil. Considering that international price does not vary between stations, we deflate retail and wholesale prices by the CPI found at the main 22 metropolitan areas calculated by DANE monthly. Therefore, the wholesale price varies between the different municipalities.

The stations are referenced by address and municipality, thus their coordinates are georeferenced using Google API. This helped in finding the number of potential station competitors within 1-2 km radius and clustering the stations within large cities such as Bogotá D.C., Cali, or Medellín. The potential number of competitors is used to assess the impact on pass-through and cluster analysis is used to evaluate the dispersion of prices within large cities. Thus, the two theories were compared.

The study results regarding pass-through are consistent with those of (Hofstetter and Tovar, 2010). Asymmetry exists in the pass-through between Brent and retail prices of gasoline in Colombia. Negative shocks tend to transmit more slowly than positive or neutral shocks. Moreover, the number of potential competitors affects the pass-through from wholesale to retail prices. However, in practice, these changes are irrelevant. The study found that heterogeneity exists in the pass-through between diesel and regular gasoline. Finally, the evidence on the dispersion of retail prices favors the theory of tacit collusion. When there are negative shocks on the wholesale price, retail prices are less dispersed; however, against positive shocks, retail prices do not show changes in their dispersion.

This study showed that the potential number of competitors had statistically significant effects on the pass-through between wholesale and retail prices. Therefore, it is necessary to control for the potential number of competitors to obtain consistent estimators of the relationship between retail and wholesale prices of gasoline. Moreover, the dispersion of retail prices affected the relationship with wholesale cost shocks, which is consistent with the tacit collusion theory. Studies comparing the two theories are limited to examining the existence of asymmetry in the pass-through, exclusively. Given that both consumer search, and tacit collusion models predict asymmetry, these studies do not compare the theories in explaining the formation of retail prices of gasoline. This study uses a rich database to compare both theories in relation to their predictions on price dispersion.

APPENDIX

Table A1. Breitung Unit-Root Test in Panel for Retail Prices and Brent

Lags	Retail Prices in levels	Retail Prices in first differences	Brent in levels	Brent in first differences	Competitors in levels
1	29.1796	-75.8708***	-6.0448***	-13.6264***	-7.6707***
2	28.0057	-46.5418***	-2.3870***	-18.7595***	-4.2618***
3	30.9201	-16.4869***	-1.1996	-10.1302***	-3.9027***
4	22.2939	-17.6522***	-0.2638	-4.4112***	-5.2633***
5	16.0574	-9.1417***	2.3589	-6.0370***	0.6930

Note: The Breitung test have as the null hypothesis that all the panels contain a unit root, alternative hypothesis is some panel is stationary. *** p<0.01, ** p<0.05, * p<0.1 Source: Author's elaboration.

Table A2. Tests for Cointegration in Panel

Test	Criteria for Lags	Statistic test
Modified Dickey-Fuller t	AIC	2.1771**
Dickey-Fuller t	AIC	-19.288***
Augmented Dickey-Fuller t	AIC	76.6119***
Unadjusted modified Dickey Fuller t	AIC	-270***
Unadjusted Dickey-Fuller t	AIC	-140***
Modified Phillips-Perron t	AIC	-29.1192***
Phillips-Perron t	AIC	-47.7968***
Augmented Dickey-Fuller t	AIC	-369.8448***
Westerlund		-25.5516***

Notes: The null hypothesis is that some panel are not cointegrated, and alternative hypothesis is all panels are cointegrated. For the Dickey-Fuller family the Kao statistic is used, for the Phillips-Perron family the Pedroni statistic is used. *** p<0.01, ** p<0.05, * p<0.1

Source: Author's elaboration.

Table A3. Results of Estimation of Dynamic Model

	(1) D(Retail Prices)
D(Retail Prices)$_{\{t-1\}}$	-0.198***
	(0.0124)
Shock(-)$_{\{t-1\}}$ x D(Retail Prices)$_{\{t-1\}}$	0.0202**
	(0.0102)
Shock(+)$_{\{t-1\}}$ x D(Retail Prices) $_{\{t-1\}}$	0.0143
	(0.00979)
Competitors 2 km$_{\{t-1\}}$ x D(Retail Prices) $_{\{t-1\}}$	-0.00639*
	(0.00367)
D(Brent)	0.504***
	(0.0704)
D(Brent) $_{\{t-1\}}$	0.192***
	(0.0689)
Shock(-) x D(Brent)	-0.102***
	(0.0173)
Shock(+) x D(Brent)	-0.0218
	(0.0159)
Shock(-)$_{\{t-1\}}$ x D(Brent) $_{\{t-1\}}$	-0.145***
	(0.0165)
Shock(+)$_{\{t-1\}}$ x D(Brent) $_{\{t-1\}}$	0.0199
	(0.0156)
Competitors 2 km x D(Brent)	0.000436
	(0.00213)
Competitors 2 km$_{\{t-1\}}$ x D(Brent) $_{\{t-1\}}$	-0.00507**
	(0.00213)
D(Competitors 2 km)	0.00777***
	(0.00287)
Error Correction$_{\{t-1\}}$	-0.489***
	(0.00914)
Shock(-)$_{\{t-1\}}$ x Error Correction$_{\{t-1\}}$	-0.0270**
	(0.0112)
Shock(+)$_{\{t-1\}}$ x Error Correction$_{\{t-1\}}$	0.0127
	(0.0108)
Constant	0.00197***
	(0.000236)
Observations	82309
R-squared	0.341

Notes: Standard errors corrected by cluster at station-gasoline level in parentheses. Regression contains fixed effects by time, station, brand and type of gasoline. *** p<0.01, ** p<0.05, * p<0.1.
Source: Author's elaboration.

REFERENCES

Apergis, N. and G. Vouzavalis (2018), "Asymmetric Pass Through of Oil Prices to Gasoline Prices: Evidence from a New Country Sample," *Energy Policy*, 114, 519-528.

Atil, A., A. Lahiani and D.K Nguyen (2014), "Asymmetric and Nonlinear Pass-Through of Crude Oil Prices to Gasoline and Natural Gas Prices," *Energy Policy*, 65, 567-573.

Bachmeier, L.J. and J.M. Griffin (2003), "New Evidence on Asymmetric Gasoline Price Responses," *Review of Economics and Statistics*, 85(3), 772-776.

Bacon, R.W. (1991), "Rockets and Feathers: The Asymmetric Speed of Adjustment of UK Retail Gasoline Prices to Cost Changes", *Energy Economics*, 13(3), 211-218.

Baye, M.R., J. Morgan and P. Scholten (2006), "Information, Search, and Price Dispersion," *Handbook on Economics and Information Systems*, 1, 323-375.

Baye, M.R. and J. Morgan (2001), "Information Gatekeepers on the Internet and the Competitiveness of Homogeneous Product Markets," *American Economic Review*, 91(3), 454-474.

Belleflamme, P. and M. Peitz (2015), *Industrial Organization: Markets and Strategies*, Cambridge University Press.

Bermudez, A. and A. Luengo (2018), "Efecto de las Variaciones de los Precios Internacionales del Petroleo sobre el Precio de la Gasolina en Colombia", Pontificia Universidad Javeriana, Bogotá D.C., Colombia.

Blair, B.F., R.C. Campbell and P.A. Mixon (2017), "Price Pass-Through in US Gasoline Markets," *Energy Economics*, 65, 4249.

Borenstein, S., C. Cameron and R. Gilbert (1997), "Do Gasoline Prices Respond Asymmetrically to Crude Oil Price Changes?" *Quarterly Journal of Economics*, 112, 305-339.

Borenstein, S. and A. Shepard (1996), "Dynamic Pricing in Retail Gasoline Markets," *RAND Journal of Economics*, 27, 429-451.

Burdett, K. and K.L. Judd (1983), "Equilibrium Price Dispersion," *Econometrica*, 51, 955-970.

Caicedo, E. and E. Tique (2012), "La Nueva Formula de la Gasolina y su Potencial Impacto Inflacionario en Colombia," *Borradores de Economía*, 698.

Chen, L.H., M. Finney and K.S. Lai (2005), "A Threshold Cointegration Analysis of Asymmetric Price Transmission from Crude Oil to Gasoline Prices," *Economics Letters*, 89(2), 233-239.

Douglas, C.C. and A.M. Herrera (2014), "Dynamic Pricing and Asymmetries in Retail Gasoline Markets: What Can They Tell Us About Price Stickiness?" *Economics Letters*, 122(2), 247-252.

Eckert, A. and D.S. West (2004), "A Tale of Two Cities: Price Uniformity and Price Volatility in Gasoline Retailing," *Annals of Regional Science*, 38(1), 25-46.

Grasso, M. and M. Manera (2007), "Asymmetric Error Correction Models for the

Oil-Gasoline Price Relationship," *Energy Policy*, 35(1), 156-177.

Green, E.J. and R.H. Porter (1984), "Noncooperative Collusion Under Imperfect Price Information," *Econometrica*, 52, 87-100.

Haltiwanger, J. and E.J. Harrington (1991), "The Impact of Cyclical Demand Movements on Collusive Behavior," *RAND Journal of Economics*, 22, 89-106.

Hofstetter, M. and J. Tovar (2010), "Common Knowledge Reference Price and Asymmetric Price Adjustments: Evidence from the Retail Gasoline Market in Colombia," *Review of Industrial Organization*, 37(2), 141-159.

Honarvar, A. (2009), "Symmetry in Retail Gasoline and Crude Oil Price Movements in the United States: An Application of Hidden Cointegration Technique," *Energy Economics*, 31(3), 395-402.

Hong, W.H. and D. Lee (2018), "Asymmetric Pricing Dynamics with Market Power: Investigating Island Data of the Retail Gasoline Market," *Empirical Economics*, 27, 1-41.

Lewis, M. (2011), "Asymmetric Price Adjustment and Consumer Search: An Examination of the Retail Gasoline Market," *Journal of Economics and Management Strategy*, 20, 409-449.

Losada, O., S. Muñoz and W. Gomez (2018), "Relación entre el Precio del Petróleo y la Gasolina para Colombia," *Revista Finanzas y Política Económica*, 10, 373-387.

Martínez, A. (2016), *Impacto de un Nuevo Panorama de los Precios del Petróleo en las Diferentes Regiones de Colombia*, Bogotá PNUD.

Mejia, J. (2015), "Determinantes de los Precios de la Gasolina en Colombia e Impacto de la Volatilidad de los Precios Internacionales del Petróleo sobre los Mismos," Pontificia Universidad Javeriana, Bogotá D.C., Colombia.

Meyler, A. (2009), "The Pass Through of Oil Prices Into Euro Area Consumer Liquid Fuel Prices in an Environment of High and Volatile Oil Prices," *Energy Economics*, 31(6), 867-881.

Ministerio de Energía (2020), *Documento Técnico del Ingreso al Productor de Gasolina Motor Corriente y de ACPM Vigentes*, Available in: https://www.minenergia.gov.co/precios-de-combustible.

Mirza, F.M. and O. Bergland (2012), "Pass-Through of Wholesale Price to the End User Retail Price in the Norwegian Electricity Market," *Energy Economics*, 34(6), 2003-2012.

Polemis, M.L. and M.G. Tsionas (2016), "An Alternative Semiparametric Approach to the Modelling of Asymmetric Gasoline Price Adjustment," *Energy Economics*, 56, 384-388.

Radchenko, S. (2005), "Oil Price Volatility and the Asymmetric Response of Gasoline Prices to Oil Price Increases and Decreases," *Energy Economics*, 27(5), 708-730.

Rotemberg, J.J. and G. Saloner (1986), "A Supergame-Theoretic Model of Price Wars During Booms," *American Economic Review*, 76, 390-407.

Schelling, T.C. (1960), *The Strategy of Conflict*, Harvard Business School Press.

Tappata, M. (2009), "Rockets and Feathers: Understanding Asymmetric Pricing," *RAND*

Journal of Economics, 40, 673-687.
Varian, H.R. (1980), "A Model of Sales," *American Economic Review*, 70, 651-659.
Yang, H. and L. Ye (2008), "Search with Learning: Understanding Asymmetric Price Adjustments," *RAND Journal of Economics*, 39, 547-564.

Mailing Address: Alex Perez, Banco de la República, Cali, Colombia, E-mail: alex.perez@correounivalle.edu.co

Received February 10, 2021, Revised March 06, 2022, Accepted April 14, 2022.