Price effects of spatial competition in Brazilian gas stations*

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Abstract

Our main goal in this study is to understand more about the fuel market's spatial price competition in Brazil. We investigated whether a marginal increase in spatial competition impacts prices. The study has a theoretical component, where we used the Hotelling and Salop models, and an empirical component, in which we used the entrance of a new firm to measure the impact of spatial competition. The empirical results are aligned with the theoretical models, where a new firm entrance reduces prices, and the reduction is greater the closer the new rival is. Moreover, the extent of spatial competition and branding matter for the outcome: firms that already faced intense spatial competition are not impacted by having a new firm nearby, while firms facing low spatial competition had a significant price reduction; the price reduction related to the spatial competition is higher if the incumbent firm is unbranded.
Keywords: spatial competition, gasoline prices, price dispersion.

Resumo

O principal objetivo deste estudo é entender mais sobre a competição espacial de preços no mercado de combustíveis no Brasil. Foi investigado se um aumento marginal na competição espacial tem impacto nos preços. O estudo possui um componente teórico, onde foram utilizados os modelos de Hotelling e Salop, e um componente empírico, no qual usamos a entrada de uma nova empresa rival para medir o impacto da competição espacial. Os resultados empíricos estão alinhados com os modelos teóricos, nos quais a entrada de uma nova firma reduz os preços, e a redução é maior quanto mais próximo esta nova rival está. Além disso, a intensidade da competição espacial tem importância para o resultado: aquelas empresas que já enfrentavam intensa competição espacial são pouco afetadas por ter um novo rival por perto, enquanto as empresas que enfrentam baixa concorrência espacial tiveram uma redução de preço maior. Por fim, a redução de preço relacionada à competição espacial é maior se o posto incumbente for não bandeirado.
Palavras-chave: competição espacial, preços de combustíveis, dispersão de preços.

JEL: D4, C23, L91, R32.

*The authors are grateful to Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for funding this work.
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1 Introduction

The law of one price states that, under free competition, there is no price dispersion for homogeneous goods. However, this result is hard to be verified empirically (Isard, 1977; Baye et al., 2006). Although it is a relatively homogeneous commodity, the prices of gasoline-c[1] have differences greater than 30 percentage points between the minimum and maximum prices during the same week in Brazil[2]. In the week of June 23 to 29, 2019, the maximum price for gasoline exceeds the minimum by more than 50 percentage points, for example. Tax differences among states may partially explain these differences. In Rio de Janeiro, for example, the Tax on Circulation of Goods and Services (ICMS) is 34% for gasoline, while São Paulo charges 25% [3]. However, even within the same state, in the same week, the price range is higher than 20 percentage points on average.

What would explain price differentials for homogeneous and repeatedly purchased goods such as fuels? Information asymmetries and search costs are great candidates. The seminal works to incorporate these explanations were Fetter (1924) and Hotelling (1929), arguing that transportation costs can create local markets. They are followed by Stigler (1961) and Varian (1980) that added information costs causing persistent price differentials.

After Hotelling (1929), a large number of theoretical and empirical works addressed directly the two main focus of the spatial competition[4]. First, the determinants of firms location. Second, its consequences to equilibrium prices (Clemenz and Gugler, 2006). We focused on the second issue, answering whether there are price effects correlated with spatial competition at the retail fuel markets in Brazil.

To answer the question, we took advantage of a georeferenced database with over a million observations for Brazilian gas stations, allowing access to the variation in the number of rivals at each gas station. While several works used density of gas stations and proximity to rivals as proxies for spatial competition, *e.g.* Pennerstorfer (2009), Clemenz and Gugler (2006), Barron et al. (2004), Lewis (2008) and Verlinda (2008), we preferred to use a set of dummy variables (1 in the case of the appearance of a new rival nearby) to capture a marginal increase in spatial competition. The main reason for the change is that the density of gas stations is closely correlated with the scale gains from the large cities, with a higher density of stations. Using the appearance of a new rival nearby as the variation of spatial competition and the nightlights as a proxy for economic activity, we were able to separate the effects of increased spatial competition from the agglomeration spillovers of the largest cities. As far as we know, there is no study using a similar approach.

Derived from the first question, we added three more. First, how quickly (and if) the price effects dissipate. Second, if branding plays a role in price response so that unbranded gas stations have different responses, as suggested by Hastings (2004). Third, if markets are somehow suited to the spatial competition, with firms that already participate in highly spatially competitive markets responding less to the entry of a new rival nearby.

[1]Brazilian gasoline have been sold with the addition of anhydrous alcohol since 1976, and this mixture is known as gasoline-c. Since March 2015, the proportion of anhydrous in gasoline has been 27%. For more details, see (MAPA, 2015).

[2]All data on fuel prices used in this study is found in the National Oil, Natural Gas and Biofuels Agency (ANP). See ANP (2019)

[3]Data on fuel taxation in Brazil can be found at Sindipeças (2020).

[4]Greenhut et al. (1975), Norman (1981), and Capozza and Van Order (1978) had important theoretical contributions.

In addition to this introduction, this paper has been divided into five sections, organized as follows. The second section describes the spatial competition models. The third describes how we modified the database to properly capt the competition variation. The fourth has the methodology. The fifth has the main results and discussion. Finally, the last section has some concluding remarks and suggestions for future research.

2 Spatial Competition Models

In this section, we describe models of spatial competition, linear Hotelling's market, and circular Salop's market, to understand the effects of location of the firms in the market and the number of firms operating in the market on linear and circular prices, respectively. Based on Hotelling (1929), Salop (1979) and Martin (2010) described below.

2.1 Spatial Hotelling's Model

Suppose two firms, 1 and 2, operate in a linear city market of length l, with the following location. Firm 1 is located in A from left to right at a distance a and firm 2 is located in B from right to left at a distance b, such that $a > b$ and $l-a-b = x+y$, where x is the distance from A to the center of $l-a-b$ and y the distance from B to the center of $l-a-b$.

Consider that consumers are uniformly distributed throughout linear market l, consumers incur a linear cost of transportation (t cost of transportation per unit distance), and that the consumer utilities found in $l-a-b-y$ and $l-a-b-x$ are $u-p_1-tx$, $u-p_2-ty$, respectively.

The indifference of the buyer found in $l-a-b$, to buy from firm 1 or firm 2 is given by.

$$p_1+tx = p_2+ty \Longrightarrow x = \frac{1}{2}\left(l-a-b+\frac{p_2-p_1}{t}\right). \tag{1}$$

From (1) we find the system of functions of demand functions for both firms expressed below.

$$D_1(p_1,p_2) = \frac{1}{2}\left(l+a-b+\frac{p_2-p_1}{t}\right), \tag{2}$$

$$D_2(p_1,p_2) = \frac{1}{2}\left(l-a+b+\frac{p_1-p_2}{t}\right). \tag{3}$$

Now consider that the firms, 1 and 2, operate at a constant marginal cost c. So the profit functions for firms are defined as.

$$\pi_1(p_1,p_2) = (p_1-c)D_1(p_1,p_2), \quad \pi_2(p_1,p_2) = (p_1-c)D_2(p_1,p_2). \tag{4}$$

The best simultaneous decision of the firms, 1 and 2, about prices, p_1 and p_2, respectively, leads to a Nash equilibrium, and this can be written in terms of their best response functions respectively.

$$BR_1(p_2) = p_1 = \frac{1}{2}(p_2+t(l+a-b)) \tag{5}$$

$$BR_2(p_1) = p_2 = \frac{1}{2}(p_1+t(l-a+b)) \tag{6}$$

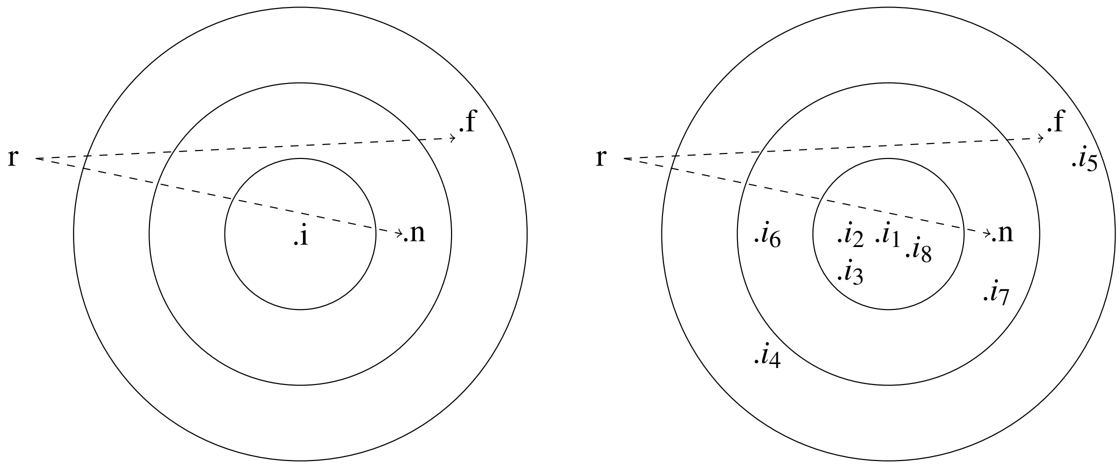
Solving the system of functions of best response we arrive at that the equilibrium prices for firms 1 and 2 are.

$$p_1^* = \frac{t}{2}(3l + a - b), \quad p_2^* = \frac{t}{2}(3l - a + b). \tag{7}$$

The competitive price reduction of firm 1 depends on the location of firm 2. Since $a > b$, the competitive price of firm 1 decreases if and only if t decreases or $3l + a - b$ decreases, as the length of the market l is given, the location B of the firms 2 would have to approach from the right the location A of the firms 1.

Considering a scenario where incumbent firms (i) can not change locations, the Hotelling's model indicates that the entrance of a new rival (r) leads to negative impacts on incumbents' prices. This impact will be higher the closer the rival firm will be installed related to (i). So, the entry in the near position (n) has higher price impacts than in the far position (f) (see illustration in Figure1).

Figura 1: Illustrating spatial competition.



Source: Authors, own elaboration. Notes: r states for rivals firms, i, i_1, and so on, are the incumbents firms. n and f represent the location where the new rival can enter, near and far from the incumbent location, respectively.

2.2 Salop's Circle Model

Consider that n firms operate in a circular market with distribution locations at each vertex of a regular polygon with n sides inscribed or circumscribed in the circle, such that they are ordered from 1 to n clockwise.

Taking as reference the firms 1 and 2, firm 1 competing with firm 2 from left to right and firm 2 of competing firm 1 from right to left over the arc length $\frac{l}{n}$. Suppose that consumers are evenly distributed around the circumference and that the prices charged by firm 2 from right to left or in the direction of firm 1 mean that they do not have lost sales by firm 1, reaching a distance market y, such that net profit equals zero, i.e.

$$\rho - p_c - ty = 0 \Longrightarrow y = \frac{\rho - p_c}{t}, \tag{8}$$

where ρ is the consumer's reserve price, p_c the circular price, and t the cost of transportation per unit of distance.

Given the location of firms, 1 and 2, in the circular market such that the distance is $\frac{l}{n}$. Then firm 1 sells at a distance.

$$x = \frac{l}{n} - y = \frac{l}{n} - \frac{\rho - p_c}{t}. \tag{9}$$

On the other hand, firm 1 sells at a price p_1 along distance x, making the price equal to the right side x of the firm. Consequently, we have the following expression.

$$\frac{\rho - p_1}{t} = \frac{l}{n} - \frac{\rho - p_c}{t} \Longrightarrow p_1 = 2\rho - p_c - \frac{tl}{n}. \tag{10}$$

On the arc length between firm 1 and 2, consumers may be indifferent between consuming from firm 1 or consuming from firm 2 based on price, i.e.

$$\rho - tx - p_1 = \rho - t\left(\frac{l}{n} - x\right) - p_c. \tag{11}$$

Solving for x of equation (11).

$$x = \frac{l}{2n} - \frac{p_c - p_1}{2t}. \tag{12}$$

Since the market is circular, firm 1 competes with firm 2 on the right and with firm n on the left. So the quantity demanded firm 1 is.

$$q_1 = 2x = \frac{l}{n} - \frac{p_c - p_1}{t}. \tag{13}$$

Solving for p_1 of equation (13), then the inverse function of demand for the firm 1.

$$p_1 = \frac{tl}{n} + p_c - tq_1. \tag{14}$$

such that this inverse function demand $p_1 \in \left[p_1 - \frac{tl}{n}, 2\rho - p_c - \frac{tl}{n}\right]$.

Now assuming that firm 1 operates in the circular market with a marginal cost equal to c, then its profit function is given as follows.

$$\pi_1 = (p_1 - c)\left(\frac{l}{n} - \frac{p_c - p_1}{t}\right). \tag{15}$$

Since firms 2 and n (or all other firms) charge a circular price, the equilibrium price for firms 1 can be written as in terms of the best response function. For first-order conditions to p_1 we have.

$$(p_1 - c)\left(-\frac{l}{t}\right) + \frac{l}{n} + \frac{p_c - p_1}{t} = 0. \tag{16}$$

As the firms are equidistantly located in the circular market and assuming that all the firms operate at the same marginal cost c, the symmetry of the firms is observed, so solving (16), the price for firm 1 with $p_1 = p_c$ is.

$$p_c = c + \frac{tl}{n}. \tag{17}$$

Note that if n converges to infinity, then $p_c = c$. This means that if n or $n+m$ firms operate in the market since m is finite, then prices differ. The price reduction depends on the number of incumbents. Also, trying to illustrate it, the marginal impact of an extra rival (r) is higher when the incumbent (i) is close to a situation of local monopoly (Figure 1-a), than when the incumbent already faced intense spatial competition (Figure 1-b).

3 Database

For this study, we obtained data from the *Sistema de Levantamento de Preços* of the National Agency of Petroleum, Natural Gas and Biofuels (ANP) (ANP, 2019). The entire database covers a total of 555 cities, including all 27 Brazilian state capitals, released every week. Each observation has the social name of the gas station, full address (state, municipality, street, number and zip code), gasoline and ethanol wholesale prices, gasoline and ethanol retail prices, and the gas station brand.

Unfortunately, we have an unbalanced panel. The i firm sampled in week w may not appear in $w+1$, making it difficult identifying the entrance of a new firm, and causing two measurement errors. First, pointing a firm as a new rival when it has just not been sampled yet. Second, hiding a true new firm, since only a proportion of gas stations is sampled.

To overcome panel unbalancing, we used the rules of the sample from ANP (2019). ANP does not research the prices itself, there is a public auction with a public notice about, among other rules, the proportion of gas stations sampled in each city (PS). These shares vary among cities, but they remain fixed within the same contract. The research started in 2001, but we choose the years between 2005 and 2012 because it is the sub-sample with the highest coverage within the same contract[5]. The results reported are for the six most populous states in Brazil, São Paulo, Minas Gerais, Rio de Janeiro, Bahia, Rio Grande do Sul and Paraná. These correspond to 60% of the population (IBGE, 2019) and about 70% of the fleet and gas stations (Sindipeças, 2020). Our sub-sample has 329 cities and more than 1 million observations.

In our chosen contract, the PS goes from 17.67% in São Paulo, the largest city in Brazil, and with the largest number of gas stations, to 100% in some small cities (see Table 1). After 2015, the new contracts dropped the PS in São Paulo to only 7%.

Taking São Paulo as an example, the chance that a true new firm does not appear in the sample in its first week is 82.33% $(100-17.67)$. However, overlapping two weeks, this probability reduces to 67.78% (0.8233^2). We can generalize the chance of a new firm does not appear $(P(na))$ in its first period as a function of the number of weeks overlapped (wo), and the proportion of gas stations sampled in each city (PS).

$$P(na) = (PS)^{wo} \tag{18}$$

[5]Contract 6035/01 ANP-005.126, third amendment.

We then overlapped weeks until the probability of not appearance is less than 5%. The aggregation depended on the PS, with São Paulo being the extreme example in which we need to append 28 weeks, and cities where all stations have been sampled, the other extreme. In this last, there is no need to overlap.

Table 1: Proportion of gas stations sampled in each city (PS)

Variable	Obs.	Mean
Sampled gas stations each week (A)	329	15.89
Total of gas stations (B)	329	37.60
Proportion of gas stations sampled in each city (A/B)	329	0.61
Number of weeks overlapped	329	6.76

Source: Authors, own elaboration based on Brazilian Government (2010) – Contract 6.035/01-ANP-005.126.

Table 2: Summary statistics

Variable	mean	Std. Dev.	Min.	Max.	Obs.
Gas stations	27509.90	13054.60	14.00	51027.00	1124535
Weeks	17662.04	794.08	16439.00	19247.00	1124535
Brands	81.80	59.54	1.00	223.00	1124535
Latitude	−22.13	4.01	−34.60	41.43	1124535
Longitude	−46.54	3.82	−62.01	−8.24	1124535
Gasoline prices (retail)	2.53	0.18	1.70	3.45	1124535
Gasoline prices (retail)	1.65	0.33	0.79	3.14	1124535
Gasoline prices (wholesale)	2.19	0.14	1.38	3.00	1124535
Ethanol prices (wholesale)	1.39	0.32	0.48	2.94	1124535
States	36.05	12.12	10.00	48.00	1124535
Nightlights	56.76	10.55	0.00	63.00	1124535
Dummy 0 to 100	0.05	0.22	0.00	1.00	1124535
Dummy 100 to 250	0.06	0.24	0.00	1.00	1124535
Dummy 250 to 500	0.09	0.29	0.00	1.00	1124535
Dummy 500 to 1000	0.16	0.37	0.00	1.00	1124535
Dummy 1000 to 1600	0.19	0.39	0.00	1.00	1124535
Cities	312.22	164.93	5.00	585.00	1124535

Source: Authors, own elaboration.

The addresses were used to find the geographic coordinates of each gas station, allowing them to generate the variables related to spatial competition. First, we calculated the number of rivals nearby for different distances (100, 250, 500, 1000, and 1600 meters). Second, we performed the first difference in these variables to determine which stations had variations in the number of rivals. The set of dummy variables takes one every time that the number of rivals increased. If the incumbent firm has a new rival within a 100m radius, the $D_{00 \text{ to } 100}$ takes on value 1. If the incumbent has a new rival in a range between 100 and 250, then $D_{0100 \text{ to } 250}$ is one, zero otherwise. In Table 2, we can see the summary of these and other variables. To be clear, we used the database with overlapping weeks to check for new rivals, our measurement for increasing spatial competition. Nevertheless, the effects on price are verified in the weekly database.

Related to the most often brands in the Brazilian market, we have Petrobras (21%), Ipiranga (11%), and Shell (9%) as the biggest brands. The market share of unbranded gas stations is 34%. The information about brands is interesting because we will also test whether the incumbent firm's response is stronger when the incumbent is unbranded. Hastings (2004) indicated that the share of unbranded firms in fuel markets could be related to prices because unbranded usually compete on price with little product differentiation. Indeed, in our database, unbranded firms have 2.4 percentage points lower prices than branded firms (see Figure 7, in Appendix).

We use nightlights as a proxy for economic activity.[6] Nightlights data came from the Defense Meteorological Satellite Program's Operational Linescan System (DMSP/OLS) provided by the National Oceanic and Atmospheric Administration's (NOAA). Each satellite observes each place on Earth every night between 8:30 to 10:00 pm local time. The data are collected and saved in a digital number (DN), which ranged from 0 to 63 with a resolution of 30 arc-second area pixel, or approximately 0,86 square kilometers at the equator[7]. The dataset is covering 75°N to 65°S latitude and 180°W to 180° longitude. Data are processed overlaying all daily images obtained during the calendar year, and they are filtered removing ephemeral lights like lightning and forest fires, those light that are shrouded by cloud or overpowered by the aurora or solar glare (near the poles), and other factors that can confound the exact luminosity.

We use raster calculator tools to construct our proxy of income in the surrounding areas of each gas station of our sample. Accurately, we identify the exact pixel where the gas station is located, and we extract the pixel value or digital number, which represents the degree of luminosity in that area (0.86 km^2). We implement this process for each gas station through all the years of our analysis.

4 Methodology

Besides the questions related to the effects of spatial competition in prices, and if theses effects change as the level of the previous spatial competition differs. We also added a question regarding the duration of these price effects, to understand whether the shock indicates only a short-term movement or a new long-term equilibrium. And a question regarding the characteristics of the incumbent firm, as we have already mentioned, Hastings (2004) indicates that unbranded gas stations tend to compete for prices only. Therefore,

[6]Nighttime intensity data are documented and tested as a good proxy for economic activity (see e.g., Henderson et al., 2012; Pinkovskiy and Sala-i Martin, 2016). One might expect that more human activities at night, represented as more consumption or production, required more artificial luminosity due to most consumer goods or production equipment used at night require artificial light. Thus, one can assume that places with more luminosity at night are places with more economy activity (Lessmann and Seidel, 2017)

[7]Note that the luminosity intensity ranking between 0 and 63, where a value of 0 mean no light and 63 the largest luminosity.

we ask whether the incumbent is an unbranded gas station that generates different spatial competition responses.

4.1 Does spatial competition decrease prices in Brazilian fuel market?

To measure the impact of more spatial competition on fuel prices, we consider the following Fixed Effects (FE) model:

$$\begin{aligned} \ln(P_{it}) = \alpha + \beta_1 D_{0 \text{ to } 100} + \beta_2 D_{100 \text{ to } 250} + \beta_3 D_{250 \text{ to } 500} + \\ \beta_4 D_{500 \text{ to } 1000} + \beta_5 D_{1000 \text{ to } 1600} \beta_6 Nightlights_{it} + \\ City(FE) + State(FE) + \varepsilon_{it} \end{aligned} \tag{19}$$

in which $\ln(P_{it})$ is the log of fuel price at pumps (retail) explained by five dummies indicating if there is a new competitor in the market within the radius in the subscript and $Nightlights_{it}$ are the Earth's night lights used as a proxy for income and land prices. The subscript i indexes the gas station and t refers the weekly time index, α is the constant, City(FE) and State(FE) are, respectively, the city and state of location fixed effects, and ε_{it} is the idiosyncratic error term.

Spatial competition is expected, so the new rival reduces the price. Therefore, negative signals to dummy variables related to spatial competition are expected. Moreover, in theory, the reduction would be greater the closer the new rival ($|D_{0 \text{ to } 100}| > |D_{100 \text{ to } 250}| > |D_{D250 \text{ to } 500}| > |D_{D500 \text{ to } 1000}| > |D_{1000 \text{ to } 1600}|$).

4.2 Do the effects on prices long-lasting?

An approach close to Waldinger (2016) is used here to verify if impacts are long-lasting. Waldinger (2016) verified the possibility of Jewish dismissals during World War II may be causing harmful effects on the university department level of publication up to 40 years after the event. Dummy variables (t) interacted with a dummy indicator that is equal to 1 for observations from $(t-1)$. In other words, it is as if the shock (the rival's entry) was taken a period behind, testing if it still impacts prices one week after the event. We created interactions up to 10 lags.

4.3 Do unbranded gas stations have more intense price responses?

Brands can be a form of product differentiation. Anderson and De Palma (1988), for example, indicate that differentiation can occur via different consumer tastes. So, although gasoline is a homogeneous good, consumers can assign different values to different brands.

Using Equation (19), we included an unbranded dummy (1 for unbranded gas stations) in the regression. We also included an interaction between the spatial competition dummies and unbranded dummy to understand if the two categories (branded and unbranded) differ on price response, given that there is a new rival nearby. Given a negative relationship between prices and spatial competition, also a negative signal of the interaction means that an unbranded firm responds even strongly to the presence of a new rival nearby.

$$
\begin{aligned}
\ln(P_{it}) = \alpha + \beta_1 D_{0 \text{ to } 100} + \beta_2 D_{100 \text{ to } 250} + \beta_3 D_{250 \text{ to } 500} + \beta_4 D_{500 \text{ to } 1000} + \\
\beta_5 D_{1000 \text{ to } 1600} + \beta_1 Unbranded\#D_{0 \text{ to } 100} + \beta_2 Unbranded\#D_{100 \text{ to } 250} + \\
\beta_3 Unbranded\#D_{250 \text{ to } 500} + \beta_4 Unbranded\#D_{500 \text{ to } 1000} + \\
\beta_5 Unbranded\#D_{1000 \text{ to } 1600} + \beta_6 Nightlights_{it} + \\
City(FE) + State(FE) + \varepsilon_{it}
\end{aligned} \tag{20}
$$

4.4 Does the intensity of price effect differ across levels of spatial competition?

How exposed to competition the firm was previously can impact its response to prices. A firm that is already much exposed, as shown in the second section, in the Salop's model, tends to respond less than a practically monopolistic firm. Therefore, we used the Equation (19) and measured if there are different results according to the degree of competition to which the incumbent firm is submitted (measured by the density of gas stations in a 1000m radius). We calculate the marginal effect for the typical firm, given its number of neighbors, starting at zero and going up to 15.

5 Results and Discussion

Below are the results of the four questions made in the previous section. We advance that the answer is "yes" for all of them. The question subsection matches the answer subsection. That is, the question asked in the first subsection of Methodology will be answered here in the first subsection of Results, and so on. After that, we discuss the results.

5.1 The price effects of spatial competition

The emergence of new rivals is associated with the price reduction of incumbent firms. The first column in Table 3 represents a 4% reduction in prices when the new rival is very close, at a distance lower than 100m away. If the new rival is further away, this reduction decreases monotonically until it reaches approximately 1% (reduction when the location of the new rival is between 1000 and 1600 meters) (Table 3).

The nightlights parameter had positive impacts on prices. This result was expected since the variable controls the income of the nearby population and land prices. This result is found after city fixed-effects are accounted for. Before that, the positive correlation between prices and nightlights is negative, probably because the most populous cities (high values of nightlights) have a scale effect on fuel sales.

In column 6 (Table 3), by including all dummies at the same time, the effects on prices are reduced, but they remain to behave the same: new rivals induce a price reduction, and the reduction is stronger the closer the incumbent firm is.

Table 3: The price effects of spatial competition on gasoline prices

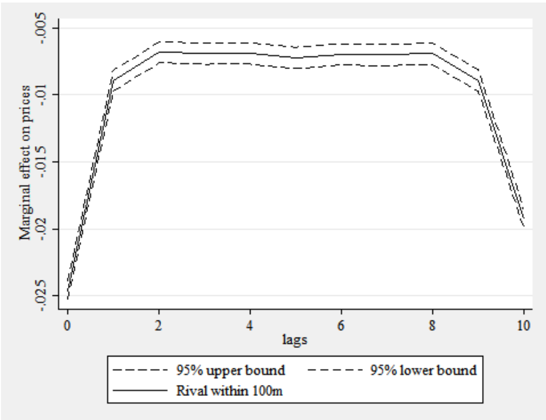
	(1) $\ln(pg)$	(2) $\ln(pg)$	(3) $\ln(pg)$	(4) $\ln(pg)$	(5) $\ln(pg)$	(6) $\ln(pg)$
D_{100}	-0.040^{***}					-0.024^{***}
	(-154.59)					(-59.20)
$D_{250\text{ to }100}$		-0.034^{***}				-0.012^{***}
		(-142.56)				(-34.21)
$D_{500\text{ to }250}$			-0.023^{***}			-0.005^{***}
			(-115.48)			(-18.03)
$D_{1000\text{ to }500}$				-0.014^{***}		-0.002^{***}
				(-90.19)		(-12.29)
$D_{1600\text{ to }1000}$					-0.012^{***}	-0.001^{***}
					(-80.46)	(-7.87)
$Nightlights$	0.001^{***}	0.001^{***}	0.001^{***}	0.001^{***}	0.001^{***}	0.001^{***}
	(200.02)	(201.34)	(204.27)	(205.77)	(205.60)	(201.63)
N	1124535	1124535	1124535	1124535	1124535	1124535

Source: Authors, own elaboration. t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. These results are based on Equation (19), and so city and state fixed effects are included.

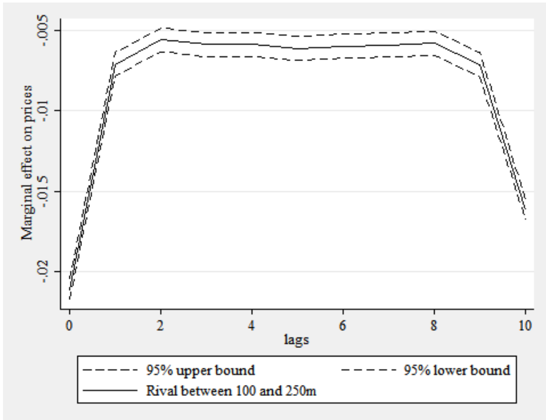
5.2 Dynamic effects of spatial competition

Following Waldinger (2016), we included all the lags of the dummy variables sponsored to measure spatial competition at the same time. It leads to small coefficients[8] but still negatives and with statistical significance. And, even after ten weeks, all five variables that measure spatial competition remain reducing prices (the fifth graph has been suppressed, but it behaves very close to the graph in Figure-2c). The location of the rivals again plays a role: closer rivals are related to long-run price reductions.

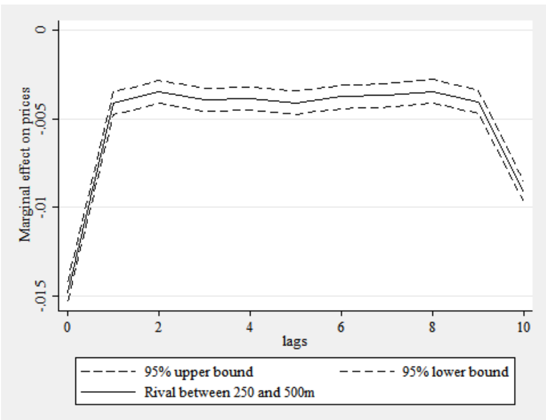
Figure 2: Dynamic effects of spatial competition



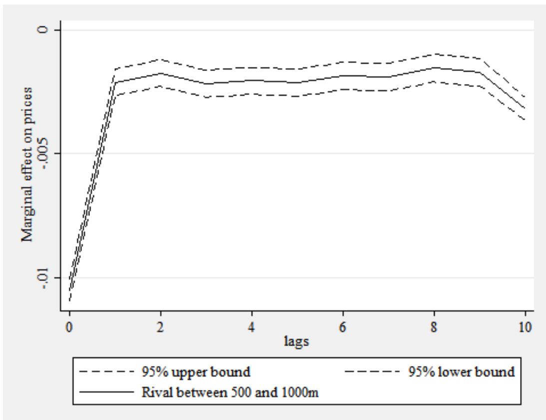
(a) Distance: 0 to 100 meters



(b) Distance: 100 to 250 meters



(c) Distance: 250 to 500 meters



(d) Distance: 500 to 1000 meters

5.3 The response of unbranded gas stations

The inclusion of the interaction between a binary variable unbranded (1 for unbranded gas stations) and the set of binaries that measure spatial competition allows different price responses for the two groups of firms (branded and unbranded). Here the separation is made only between the unbranded (34% of the sample) and all other brands.

[8]It is valid for the most regressions procedure here, when we included all dummies variable at the same time, the magnitude of results decreases. It is also true that none of the coefficients change signals.

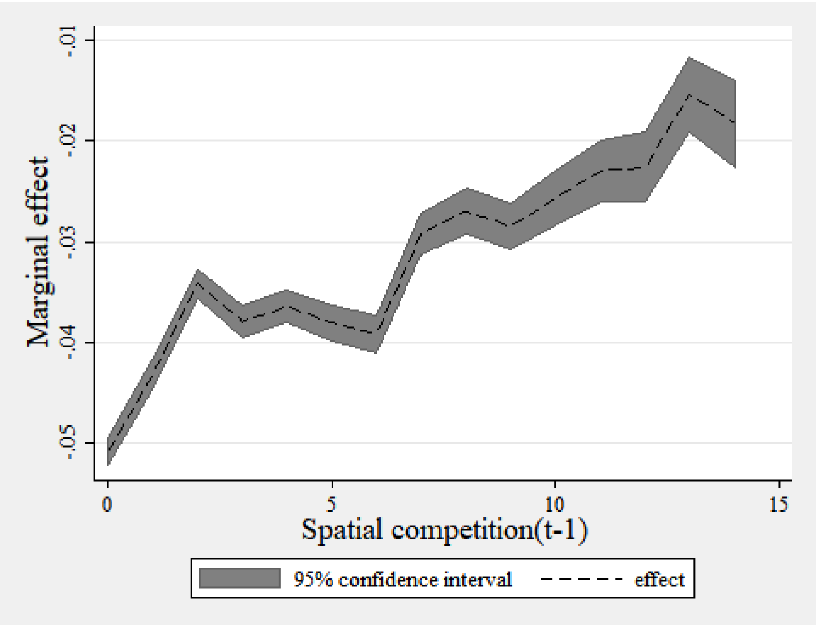
In Table 4, the basis of comparison is to have no new rivals nearby. he parameters with “branded” in the end measure the impact of increased spatial competition for branded incumbent firms, and those with “unbranded”, naturally, are those measuring the impacts for unbranded firms. Furthermore, the y parameters measure the impact of new rivals for unbranded incumbent firms. The results indicate that, regardless of the distance between the new rival and the incumbent, unbranded incumbents compete for price more intensely, since the parameters have a greater magnitude for unbranded firms. The response to the presence of a new rival within a radius of 100 meters, for example, is the reduction of 4.2% by the branded incumbent firms, and the reduction of 5.1% by the unbranded incumbent firms.

5.4 Results depend on the level of spatial competition

Considering a radius of 1000 meters, in our sample, 25% of firms have one or none rival, half of them have up to three rivals, and only 10% of firms have nine or more rivals. Do firms that already have more rivals respond weakly to the even higher spatial competition? To answer that question, we look at the results in Table 19 for different spatial competition levels. We performed the Equation (19) for the group with no rivals, the group with two rivals, and so on, up to the group with 15 rivals nearby.

We have these results for each spatial competition dummy variable in Figure 3. Having a new rival closer than 100 meters, given that the incumbent firm has none rivals nearby previously, reduces incumbent prices by 5%. However, for those firms that already faced intense spatial competition (15 rivals nearby), the reduction related to one new rival within 100 meters is only 1%. This result is the same for other spatial competition dummy variables. The observed price reduction is greater when firms were less exposed to spatial competition previously. captionEffect of a new rival

Figure 3: Effect of a new rival within a 100 meters radius.



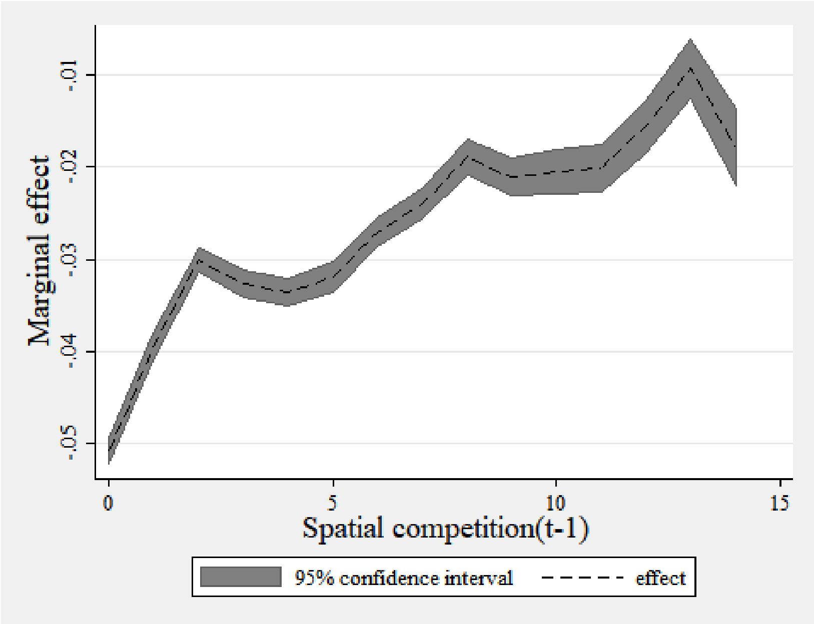
Source: Authors. Spatial competition (t-1) stands for the numbers of rivals nearby (within 1000 meters) that incumbents had in (t-1).

Table 4: Comparing the response of branded and unbranded gas stations.

	(1) $\ln(pg)$	(2) $\ln(pg)$	(3) $\ln(pg)$	(4) $\ln(pg)$	(5) $\ln(pg)$	(6) $\ln(pg)$
$D_{100\text{ to }0\text{ branded}}$	-0.042^{***}					
	(-133.75)					
$D_{100\text{ to }0\text{ unbranded}}$	-0.051^{***}					
	(-116.67)					
$D_{250\text{ to }100\text{ branded}}$		-0.035^{***}				
		(-121.53)				
$D_{250\text{ to }100\text{ unbranded}}$		-0.046^{***}				
		(-116.08)				
$D_{500\text{ to }250\text{ branded}}$			-0.023^{***}			
			(-97.22)			
$D_{500\text{ to }250\text{ unbranded}}$			-0.038^{***}			
			(-112.59)			
$D_{1000\text{ to }500\text{ branded}}$				-0.014^{***}		
				(-73.85)		
$D_{1000\text{ to }500\text{ unbranded}}$				-0.030^{***}		
				(-114.98)		
$D_{1600\text{ to }1000\text{ branded}}$					-0.012^{***}	
					(-65.81)	
$D_{1600\text{ to }1000\text{ unbranded}}$					-0.028^{***}	
					(-113.92)	
N	1124535	1124535	1124535	1124535	1124535	

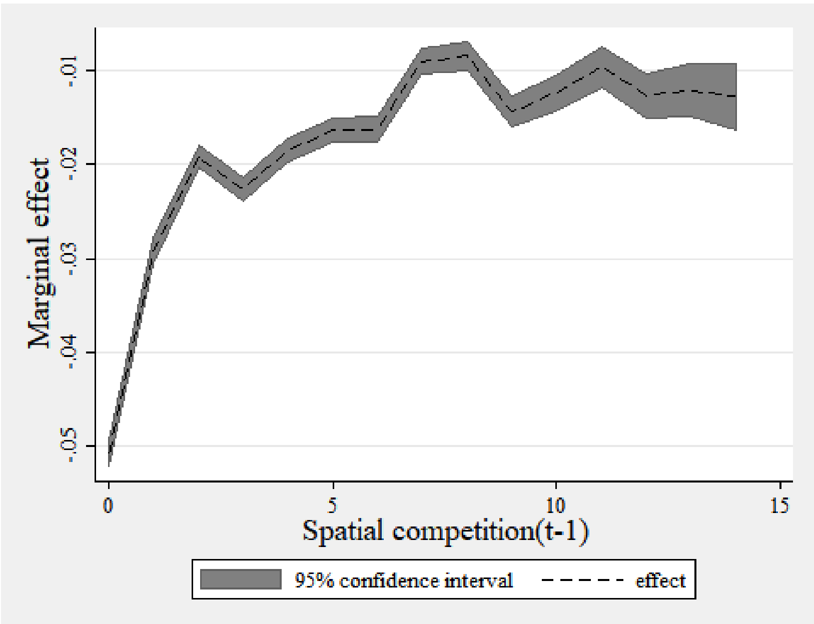
Source: Authors, own elaboration. t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Figure 4: Effect of a new rival between a 100 and 250 meters range.



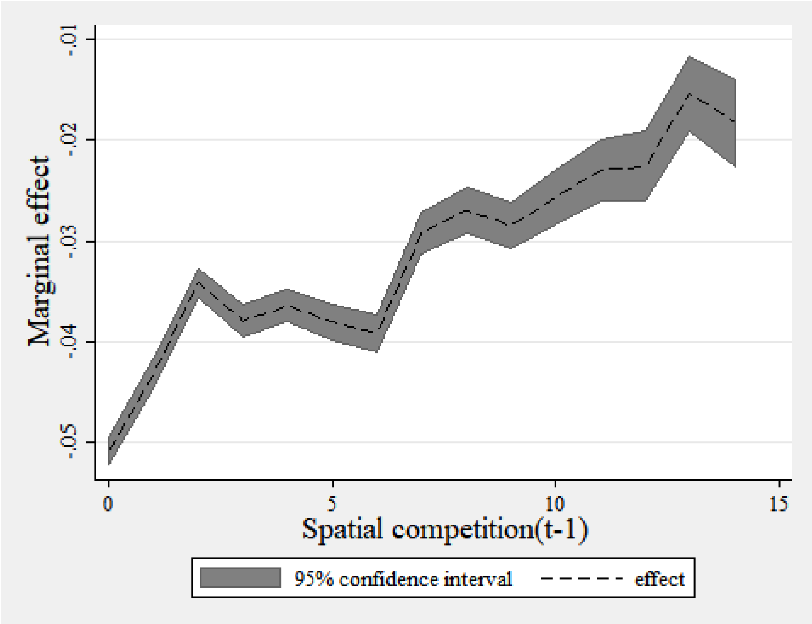
Source: Authors. Spatial competition (t-1) stands for the numbers of rivals nearby (within 1000 meters) that incumbents had in (t-1).

Figure 5: Effect of a new rival between a 250 and 500 meters range.



Source: Authors. Spatial competition (t-1) stands for the numbers of rivals nearby (within 1000 meters) that incumbents had in (t-1).

Figure 6: Effect of a new rival between a 500 and 1000 meters range.



Source: Authors. Spatial competition (t-1) stands for the numbers of rivals nearby (within 1000 meters) that incumbents had in (t-1).

5.5 Discussion

The main focus of spatial economics is the location choice of the economic agents; in this work, the firms. However, we do not know the location determinants for a new gas station. We avoid using the correct word, but the fact is that the entry of a new rival is endogenous. Entry can be determined by price, locations with higher prices increasing the chance of having a new gas station. However, prices charged ten weeks before the new gas station's appearance show only 2 p.p. in favor of those who did not have a new rival. When we control this gap for city fixed-effects, the difference is not significant.

There is a pattern in the results: spatial competition reduces prices. Digging deeper into this result, we performed the Equation 19 using margins as the dependent variable (results not reported here). The results remain the same using margins, *i.e.*, more spatial competition reduces margins.

We mentioned ethanol prices only in the section dedicated to data. As Brazil has a unique fuel market, it could be that the findings of this work are valid for gasoline, but not for the ethanol market. However, all conclusions remain if we change the gasoline price for the price of ethanol in regressions. See, for example, Table 5 for the ethanol market. Because the two markets did not differ to spatial price findings, we showed only the gasoline market results. Nevertheless, again, findings remain for both light fuels in Brazil.

6 Conclusion

The objective of the work was to investigate spatial competition in the light fuel market in Brazil. On the way to answer the question correctly, we believe that we have made some methodological advances. First, our database was georeferenced so that it was possible to calculate the numbers of rivals nearby. Second, the aggregation of weeks in order to measure more accurately variations in spatial competition. Third, instead of using gas station density as a proxy for spatial competition, we preferred the entry of a new rival as a measure of increased competition. Although it is not yet the ideal measure, since the entries are not random, it is a better measure than the density of the gas stations. Fourth, and not least, we have better-measured income and land prices when using nightlights as a control.

Regarding the results, it is possible to summarize them as follows. First, there seems to be spatial competition in the Brazilian fuel market, the entry of a new rival reduces prices, and this reduction is greater the closer the new rival is. Second, this reduction does not dissipate in the short-run; the effects appear to be lasting. Third, unbranded firms respond even more to the entry of a new rival than branded gas stations. Fourth, the local density of the gas stations matters; incumbent firms in a low-intensity spatial competition context have higher price reductions than firms in high-intensity competition context.

As usual, we do have caveats. Unfortunately, the Brazilian database is not on a daily basis. So, there may be price movements dissipated in the very short-run. We only look at whether unbranded firms differ from others in response to more spatial competition. Nevertheless, among the gas station brands, there may be other heterogeneities in pricing that we have not studied. We do not have features as the existence of convenience stores, the size of service stations, or any other that can be used as a proxy for the degree of differentiation in services. ANP does not collect this information.

It is possible to research the characteristics of the new rivals. Having this information allows us to respond to whether the new rival's brand matters for the incumbent's response, whether the new firms enter undercutting prices or not. It is also possible to verify that the price ranking of firms does not change over time. Maintain price ranking is essential to allow consumers to learn about the price distribution of their surroundings as they buy repeatedly. All of these are possibilities for a future research agenda.

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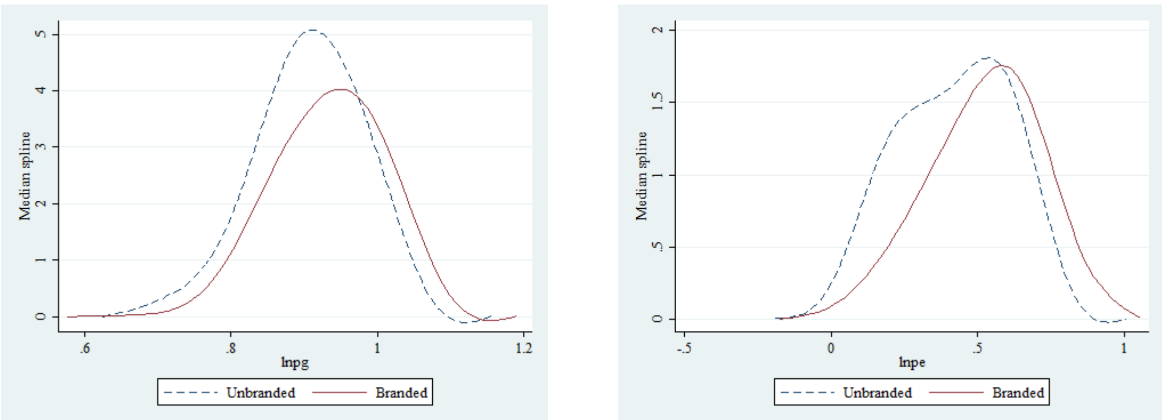
Appendix

Figure 7: Fuel price distribution (branded and unbranded firms)



(a) Gasoline

(b) Ethanol

Source: Authors, own elaboration. Note: The points in the graph used the medians as knots, and the fitted curve is continuous and smooth at the knot boundaries. For more information see Orsini and Greenland (2011).

Table 5: The price effects of spatial competition on ethanol prices

	(1) $\ln(pg)$	(2) $\ln(pg)$	(3) $\ln(pg)$	(4) $\ln(pg)$	(5) $\ln(pg)$	(6) $\ln(pg)$
$D_{\text{extra 100 to 0}}$	-0.054^{***}					-0.015^{***}
	(-79.46)					(-13.69)
$D_{\text{extra 250 to 100}}$		-0.050^{***}				-0.018^{***}
		(-80.25)				(-18.70)
$D_{\text{extra 500 to 250}}$			-0.038^{***}			-0.012^{***}
			(-73.33)			(-17.21)
$D_{\text{extra 1000 to 500}}$				-0.030^{***}		-0.012^{***}
				(-70.22)		(-24.13)
$D_{\text{extra 1600 to 1000}}$					-0.026^{***}	-0.011^{***}
					(-68.14)	(-25.36)
$Nightlights$	0.002^{***}	0.002^{***}	0.003^{***}	0.003^{***}	0.003^{***}	0.003^{***}
	(134.76)	(135.52)	(137.55)	(139.26)	(139.47)	(138.17)
N	1124535	1124535	1124535	1124535	1124535	1124535

Source: Authors, own elaboration. t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. These results are based on Equation 19, and so city and state fixed effects are included.