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Demand for Ethanol considering Spatially Differentiated Fuel Retailers

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Demand for Ethanol considering Spatially Differentiated Fuel Retailers
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ABSTRACT: The document presents an innovative analysis of ethanol demand, emphasizing the significant role of spatially differentiated fuel retailers in shaping consumer preferences and fuel-switching behavior. Utilizing a nested logit model and data from Brazilian fuel retailers, the study reveals that ethanol demand is highly responsive to price changes, with relative price elasticity exceeding that of gasoline. Key findings indicate that retailer characteristics, such as branding and location, influence consumer preferences, highlighting the importance of considering spatial differentiation in demand estimation models. The study's results have profound implications for policy-making, suggesting that encouraging the use of ethanol as an alternative energy source can serve as an effective climate change mitigation strategy. The recommendations stress the need for policies that account for consumer price sensitivities and the competitive landscape of fuel retailers. This could enhance the adoption of cleaner fuels and reduce dependency on imported oil, aligning with broader environmental and economic objectives.

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WORKING PAPERS

Demand for Ethanol considering Spatially Differentiated Fuel Retailers

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Contents

I. Introduction

One recommended policy to act on climate change is incentivizing the switch from gasoline to other clean energy sources. The car sector, which is responsible for 7% of GHG emissions[1], has innovated toward electric vehicles and biofuels. Using alternative energy sources is also perceived as a policy to reduce dependency on imported oil, reducing vulnerabilities to external price fluctuations. In this regard, some countries could benefit twice from biofuel sources: it would contribute to the commitments signed in Paris in 2015 and promote the local value chain to supply biofuel sources such as ethanol.

Adopting new technology, however, is not straightforward since it depends on consumer preference, in particular price and perceived benefits. Even when flex-fuel vehicles (FFV) are available and the consumer has both fuel options, the choice over one fuel will consider not only perceived benefits expected to the utility maximization problem but aspects like the fuel retailer's proximity and relative prices.

This article aims to contribute to the increasing literature on demand estimation for ethanol in the context of consumer fuel-switching behavior. Using fuel station data and characteristics, I estimate a model of demand for differentiated goods using their locations to characterize consumers' heterogeneity and preferences. Inspired by Houde (2012), my estimation uses data from a condemned fuel retailer's cartel in the city of Londrina, in Brazil, where the price setting considered the relative gasoline and ethanol prices, attesting to the consumer's switching behavior. In Houde's discrete-choice model of demand, consumers' mobility is incorporated into the product space. Because this information is unavailable, I use a nested logit model to allow consumers' choices to vary across regions in the city of Londrina and Cambe. This tree structure implies that the consumer's choice of gasoline or ethanol depends first on their choice of a preferable region. Fuel retailers in the same region have the Independence of Irrelevant Alternatives (IIA) property, meaning that the cross elasticities of retailers in the same nest are higher than in other regions.

This article is divided into six sections, including this introduction: Section II reviews the current literature review on ethanol demand elasticity, and Section III details the model and the estimation strategy used. Section IV describes the data used and how I constructed the potential market for gasoline and ethanol. Section VI presents the estimation results, including the tests for instruments and the average price and cross elasticities. Finally, in Section VI, I conclude and raise points for policy discussion.

II. Literature Review

The literature on ethanol demand estimation, elasticity, and substitutability has gained momentum in the past ten years. Anderson (2012) was one of the first to investigate the question of ethanol as a gasoline substitute in Minnesota. Using a panel data structure, he estimates the volume sold of ethanol using the gasoline and ethanol relative price and station characteristics to control for consumers' preferences. He found that ethanol was relatively sensitive to prices and would be smaller if fuel-switching was concentrated around a single price. The estimation, however, does not account for product differentiation, assuming consumers would shift consumption without considering idiosyncrasies such as commuting paths and fuel retailers' locations. Even so, his work is necessary to understand preferences in a flex-fuel vehicle (FFV) scenario for possible policies.

Houde (2012) innovates on the empirical model of spatial competition applied to the gasoline markets using consumers' location in a Hotelling-style model. Using data from Quebec, he looks for the gasoline demand and supply model considering the retailers' competition, whose anticompetitive behavior could affect prices, contrary to the desired goal of policymakers. He incorporates consumers' mobility in the product space into a discrete-choice demand model. He observes that the elasticity of substitution between stations mimics the distribution of traffic in cities. Therefore, price competition spills over locations that potentially include all the metropolitan area's neighborhoods, which is the case for the data I analyze in Londrina and Cambé. He

[1] Victor, D. G., Geels, F., & Sharpe, S. (2019). Accelerating the low carbon transition. The Case for Stronger, More Targeted and Coordinated International Action. Brookings Institution. Available online at: https://www. brookings. edu/wp-content/uploads/2019/12/Coordinatedactionreport. pdf (accessed January 24, 2021).

concludes that commuting behavior affects retailers' competition and gasoline prices better than considering the consumer's home address and destination model.

Salvo and Huse (2013) provide evidence that consumers may choose ethanol even if the price is above the energy-adjusted gasoline price. The authors interviewed 2160 FFV drivers to obtain a revealed-preference survey in Brazil, where FFVs were broadly available. They observe that wealthier consumers and extensive commuters are willing to pay more for gasoline to avoid stopping to refuel.

Cardoso, Bittencourt, Litt, and Irwin (2019) also use data from Brazil to estimate gasoline and ethanol demand using monthly data from July 2001 to December 2014. Their estimation indicates that ethanol and gasoline own-price elasticities are approximately −1.5 and −0.9, respectively. In addition, the authors stress that the elasticities obtained in the literature are usually higher in the Brazilian market than in the US and Europe, and these differences are commonly explained by differences in income levels and preferences. However, they show that introducing flex-fuel cars increased both fuels' own-price and cross-price elasticities after three years following the flex-fuel car technology, increasing consumers' welfare.

Cuiabano (2019) estimated the fuel retailer cartel damages in Londrina, south of Brazil, using reduced and structural forms for supply and demand and used the cartel documentation documents to characterize the ethanol and gasoline retailers involved in the collusion. In the paper, the author details the facts that triggered the organization of the cartel in the first place when one of the retailers, located on a highway in the municipality of Cambe, about 15 km from Londrina center, dropped ethanol prices at the beginning of 2007. In response, one of its competitors, located 12.5 km from the center, also dropped ethanol prices, reaching the lowest level of R$ 0.94 per liter. This 'price war' started to attract drivers who used the market in Londrina city center to the neighboring city, Cambe[2]. Results showed that, to end the 'price war', the cartel set an overcharge of 3.6% to 6.6% in the gasoline market and up to 12% in the ethanol market.

III. Model and estimation strategy

Demand for ethanol in a flex-fuel context: following Anderson (2012), I assume that each household owns a single flexible-fuel vehicle, and its utility is quasilinear in transportation services u(·) and other goods:

$$u(e + rg) + x \qquad (1)$$

e being the consumption of ethanol, *g* of gasoline, *x* the consumption of all other goods. The term *r* is the rate at which the household converts gasoline into ethanol-equivalent liters. If ethanol and gasoline are perfect substitutes, utility is defined over a linear combination denominated ethanol-equivalent fuel as per Anderson (2012). By embodying the fuel-efficient differences in terms of relative kilometers, *r* summarizes household preferences for ethanol as a gasoline substitute. The household budget constraint is:

$$y - p_e e - p_g g - x \qquad (2)$$

where p_e and p_g are the prices of ethanol and gasoline, *y* is income, and the price of the composite good is normalized to $1. As ethanol and gasoline combine linearly in the utility function, the household will be at a corner solution. She will purchase ethanol exclusively when $p_e < p_g = r$ and gasoline exclusively when $p_g = r < p_e$. That is, the household will choose the fuel with the lower ethanol-equivalent price, meaning that if a household cares only about mileage, this amounts to choosing the least costly fuel per mile/kilometers.

While relative prices determine the type of fuel a household chooses, the quantity demanded depends on absolute price levels. The household equates the marginal utility of gasoline-equivalent fuel consumption to the gasoline-equivalent price of whichever fuel it chooses. Assuming that ethanol and gasoline are perfect substitutes, households that own flexible-fuel vehicles sort into ethanol buyers and gasoline buyers according to their fuel-switching price ratios. However, the consumers' choice of fuel retailers selling both products depends on preferences associated with the location and commuting paths, as Houde (2012) detailed. Therefore, spatially differentiated goods need to *consider the market's geography, namely the road network and the direction of traffic flows* (HOUDE, 2012*)*.

[2] In Londrina, the average price of ethanol ranged from R$ 1.39 to 1.74 per liter, and from R$ 2.39 to 2.55 per liter for gasoline..

Therefore, a discrete choice problem over J fuel retailers in the metropolitan area of Londrina will consider the relative price of ethanol and gasoline as a market characteristic the consumer considers maximizing its utility. I assume the consumer problem is buying gasoline or ethanol but choosing from one of the *J* retailers or using an alternative mode of transportation (option *0*). The indirect utility of buying from store j for consumer *i* is:

$$u_{ij} = X_j\beta - \alpha\left(\frac{p_e}{p_g}\right) + \xi_j + \epsilon_{ij} \text{ if } j\neq 0 \quad (3)$$

Where X_j is the set of characteristics attributed to the choice of retailer *J*, $\frac{p_e}{p_g}$ is the ethanol to gasoline relative price, ξj is an index of unobserved (to the econometrician) fuel retail attributes, and *ϵij* is the independent and identic distributed (i.i.d). random utility shock associated with other consumers' preferences. Following the discrete choice demand literature (McFadden (1978), Athey and Imbens (2007), Ackberg and Crawford (2009), Bjornerstedt and Verboven (2016)), the fuel choice is associated with fuel retailers' characteristics, including distance to downtown and its location nested by regions. The more flexible logit-based utility model generates an estimating equation of the following form:

$$ln\left(\frac{s_{ej}}{s_0}\right) = X_j\beta + \alpha ln\frac{p_{gj}}{p_{ej}} + \sigma ln\left(s_j(g+e)_{j/R}\right) + \xi_j + \epsilon_{ij} \quad (4)$$

Where s_{ej} is the share of ethanol sold by retailer J considering the outside option s_0And the expression $\ln\left(s_j(g+e)_{j/R}\right)$ is the probability of fueling at station *j* once the region *R* is chosen. The β coefficients related to retailer characteristics X represent the marginal utility of each attribute for an alternative. A positive coefficient indicates that an increase in the attribute increases the utility of the alternative, while a negative coefficient indicates a decrease in utility. The α coefficient, related to price, is expected to be negative, reflecting the disutility of higher prices. The nest parameter σ represents the correlation between the unobserved components of the utilities of alternatives within the same nest and typically ranges from 0 to 1. A higher σ implies that alternatives within the same nest are substitutable for each other.

The objective is to obtain the parameters α and σ to calculate the ethanol relative price elasticities for retailers belonging to the same region and across regions as defined in Berry (1994)[3,4]:

$$\begin{cases} \frac{ds_j}{dp_j} = -\alpha s_j\left(\frac{1}{1-\sigma} - \frac{\sigma}{1-\sigma}s_{j/R} - s_j\right) & (5) \\ \frac{ds_j}{dp_k} = -\alpha s_k\left(\frac{\sigma}{1-\sigma}s_{\frac{j}{R}} + s_j\right) \; if\ j\ and\ k\ are\ in\ the\ same\ nest; \text{ otherwise} & \\ \frac{ds_j}{dp_k} = \alpha s_j s_k & (6) \end{cases}$$

IV. Data

The following subsections describe the data sources used to estimate ethanol and gasoline demand. First, I describe the detailed survey of fuel retailer stations; second, I detail the construction of the nests based on the Londrina geographic regions because there is no detailed survey of consumers' locations. Then, I detail the construction of the outside good (s0) for the ethanol and gasoline markets.

Fuel retailers data: using the same dataset as in Cuiabano (2019), I aggregated three databases with information regarding fuel retailers in Londrina and Cambe[5] obtained from the Brazilian Fuel Regulator (Agencia Nacional do Petroleo, Gas Natural - ANP): (1) an unbalanced weekly panel of retailers and wholesale prices for gasoline

[3] The time index t is implicit in all equations.

[4] s_(j/R) is the share of retailer j in the region.

[5] ANP price collection methodology does not include n Ibipora or Jataizinho due to its sample size. Price and quantity information for each gas station are not available in the disclosed process files.

and ethanol from 2007 to 2009, including brand characteristics and georeferenced locations; (2) a monthly panel of retailers acquired quantities of gasoline and ethanol also spanning from 2007 to 2009; (3) a cross-section of retailers characteristics such as numbers of pumps and tankage. Because these last are only available from 2014, I cross-checked information on the ANP website[6] regarding retailers who were no longer operating.

Nests and drive distances: as origin-destination individual data is unavailable in Londrina, I construct a demand system for fuel retailers as a nested logit model with one level of nest divided by regions. Fuel retailers are aggregated into 6 regions: central, north, south, east, west, and Cambe. Cambe is a municipality belonging to the Londrina metropolitan area. It was considered a "dormitory" city for its cheaper housing prices and a hub for manufacturing industries[7].

Figure 1. Londrina Regional Division

Source: *Atlas Ambiental de Londrina 2008* in Zulim, Claudemir & Lolis, Dione. (2011).
Regions: Center(white); West(green); East(blue); North(yellow); South(beige).

I obtained travel and time distances using Google API for each station from one fuel retailer in Londrina city center[8]. I also added information regarding the regional inflation rate for the period and control variables such as the total number of personal vehicles. For inflation, I consider the State of Parana index for Consumer Price (IPCA) provided by the Brazilian Institute of Statistics (IBGE). Other general price cost shifters, such as the international sugar price and petrol, were obtained through the International Monetary Fund (IMF) statistics. Licensed vehicles in the city of Londrina and Cambe were provided by the Parana State Department for Traffic Control (Detran/PR).

[6] http://www.anp.gov.br/postos/consulta.asp

[7] The article published by the Folha do Parana, a local newspaper, narrates how local inhabitants of Cambe keep their routine in Londrina: https://www.folhadelondrina.com.br/cidades/cambe-ainda-traz-o-estigma-de-uma-cidade-dormitorio-37437.html (consulted on September 08, 2022).

[8] Posto Transamerica, cnpj 07.775.477/0001-98. This fuel station was not part of the cartel scheme.

The dataset includes prices and quantities for the sale of gasoline and ethanol in 154 fuel retailers in Londrina for 36 months, totalizing 5,544 observations. However, complete matched information on price and quantity was available only for 443 observations, in the case of gasoline, and 440[9]. The 154 fuel retailers are divided into the following: 68 are in Londrina city center (1); 24 in the east region (2); 12 in the west (3); 12 in the north (4); 19 in the south (5); 31 in Cambe (6). From the descriptive statistics in Table 1, we can observe that ethanol prices, on average, were 15 cents lower in Cambe than in Londrina city center, and stations had a larger storage capacity (tankage – tank_ethanol). In terms of service, retailers in all regions had, on average, the same size – except gasoline in the center, where more pumps are available ('bicos_gas').

Table 1. Fuel Retailers Statistics per Region

	Center (1)		Est (2)		West (3)		North (4)		South (5)		Cambe (6)	
Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
qtd_gas	73763	45652	71165	546015	92068	48474	73738	34987	100316	91142	64296	47332
qtd_etha	48574	34358	46600	42921	69785	50204	45267	29008	63764	75629	44647	46253
Gas_post_price	2.48	.084	2.45	.11	2.44	.09	2.44	.11	2.47	.08	2.38	.079
Etha_post_price	1.50	.20	1.49	.22	1.46	.18	1.46	.22	1.49	.18	1.35	.148
bicos_gas	5	2.96	4	2.40	3	1.72	4	2.21	4	4.57	4	3.03
bicos_ethanol	3	1.49	3	1.43	2	1.29	3	2.11	3	3.83	3	1.46
tanks_gas	33.92	10.76	30	13.45	27.14	13.35	29.44	7.25	33.33	19.46	26.66	11.25
tank_ethanol	20.44	7.69	23.46	14.07	17.85	9.60	19.44	5.99	23.88	14.70	24.04	11.39
Distance (in km)	2.09	0.91	3.42	1.06	5.42	1.84	6.75	4.19	12.13	12.40	15.34	2.79

Construction of s0 and market shares: an important feature for the discrete demand model estimation is the definition of *s0* or market size, representing the potential drive distance from the consumers' location to their desired destination. The potential market will support the design of the consumer's probability of having to use their own cars to drive the wished distance or choosing an alternative transportation mode (public transport, taxi, co-sharing). First, I built the total market size for gasoline per region, considering the total amount of vehicles in Londrina and Cambé. Then I used the Census information for population size in each region of Londrina as a weight to calculate the proportions of cars. Considering the traffic in the region, I estimated the average distance from each region to the city center and doubled the number of trips during weekdays (except holidays).

Finally, I used the energy-efficiency rate of gasoline to ethanol to assess the quantities in liters - gasoline makes 0.1 liters per kilometer, and ethanol is 0.14[10]. However, as the number of flex-fuel cars during the analyzed period is not available[11], I proxied the market size for ethanol as a proportion of the quantity of ethanol and gasoline sold each year[12] (see appendix 1 for the descriptive statistics).

V. Estimation Results

Instruments: I constructed different sets of instruments for the relative prices of ethanol and gasoline and $ln\left(s_j(g+e)_{j/R}\right)$ As in equation (4), I construct the first set of instruments using the average of the characteristics

[9] ANP does a weekly price surveillance in a 10% sample fuel stations randomly chosen. Therefore, the dataset has missing information because some stations' price and quantity are not available for all periods. Detailed information is available at the agency website: https://www.gov.br/anp/pt-br/assuntos/precos-e-defesa-da-concorrencia/precos/precos-revenda-e-de-distribuicao-combustiveis/arquivos-metodologia/metodologia-pesquisa-publica-resumida-09082020.pdf (consulted on September 08, 2022).

[10] See Salvo and Huse (2013) for the ethanol to gasoline price equalization.

[11] For more information on the introduction of the FFV technology in Brazil, see do Nascimento (2014).

[12] The detailed statistics for FFV in Londrina are not available for the analyzed period. Losekann and Vilela (2010) show that FFV grew exponentially from 2003 to 2009 reaching one third of the total fleet in 2007.

and relative prices of other fuel retailers in the same region and the average distance to the city center. The second set of instruments includes the number of competitors in the same region and the sugar price because of its linear correlation - changes in the price of sugar are completely transmitted to the price of ethanol in the long run, according to Rapsomanikis and Hallam (2006). For gasoline, I added the barrel price of oil as another price shifter. In the third set, I exclude the number of competitors to check whether the correlation is improved or not. Finally, I have the acquisition cost from each retailer from the distributor, which is an important cost-price shifter for the relative price.

Table 2. Comparison between Different Specifications

		Ethanol			Gasoline		
Variable		(1)	(2)	(3)	(1)	(2)	(3)
Price	F-test	16.5	41.32	45.09	5.96	5.52	12.85
	P-value	0	0	0	0	0	0
$Ln(s_j(g+e)_{(j/R)})$	F-test	27.02	26.61	24.92	55.29	60.22	55.23
	P-value	0	0	0	0	0	0
The different specifications include the following instruments							
		(1) $\overline{bicos_{eta}}, \overline{tank_{eta}}, \overline{relpeta}, \overline{time}, ethanol\ aquisition\ cost$			(1) $\overline{bicos\_gas}, \overline{tank\_gas}, \overline{Relgas}, \overline{time}$, *gasoline acquisition cost*		
		(2) $\overline{bicos\_eta}, \overline{tank\_eta}, \overline{relpeta}, \overline{time}$, *ethanol acquisition cost, number of competitors in the same region, sugar price*			(2) $\overline{bicos\_gas}, \overline{tank\_gas}, \overline{Relgas}, \overline{time}$, *gasoline acquisition cost competitors*		
		(3) $\overline{bicos\_eta}, \overline{tank\_eta}, \overline{relpeta}, \overline{time}$, *ethanol acquisition cost,, sugar price*			(3) $\overline{bicos\_gas}, \overline{tank\_gas}, \overline{Relgas}, \overline{time}$, *gasoline acquisition cost competitors, oil price*		

The F tests are improved in the second and third specifications, in which I include the sugar price. However, for the 2 stages instruments regression (2sls), I will keep the third set of instruments because the number of regional competitors does not seem to improve the results.

Regression results: the empirical results for the nested logit model are detailed in Table 3. I used three different specifications to assess better model adherence: the first (1) includes retailers' characteristics by pumps ('bicos') and size ('tanks') for ethanol, but they seem to be correlated. In the second (2) and third (3), I include the tankage for gas, as it seems to be a better control for preferences. Finally, in the third (3) specification, I removed the dummy indicating if the retailer belongs to a brand or not, as it is not significant. All specifications control for the income and drive distance to the center of Londrina.

Table 3. Empirical results from nested logit model

ETHANOL

	(1)		(2)		(3)	
	Parameter	St. Error	Parameter	St. Error	Parameter	St. Error
price (α)	-1.68	.416	-1.25	.241	-1.04	.263
group (σ)	.016*	.112	0.19	.011	.23	096
Income	.000	.000	.0002	.000	.000	.000
bicos_eta	.002	.028*	-.007*	.011	-.010*	.012
tanks-eta	.000	.003*	-	-	-	-
tanks_gas			-.007	.001	-.012	.002
d_branca	.105	.095	.189	.138	-	-
time	-.009	.009	-.009	.005	-.008	.007
constant	-4.78	.093	-3.03	.897	-2.87	.753
R2	0.64		0.62		.56	
Region						
2 (East)	0.27		-.153		-.216	
3 (West)	-0.01		-.388		-.459	
4 (North)	0.13		-.244		-.320	
5 (South)	0.22		-.104		-.211	
6 (Cambe)	0.29		.13		-.073	

*Nonsignificant

GASOLINE

	-1		-2		-3	
	Parameter	St. Error	Parameter	St. Error	Parameter	St. Error
price (α)	-0.362	0.077	-1.25	0.241	-1.04	0.263
group (σ)	0.07	0.19	0.19	0.011	0.23	96
Income	0	0	0	0	0	0
bicos_gas	0.004	0.004	0.012	0.003	0.031	0.018
tanks-gas	0	0.001	0.003	0.001	0.018	.003*
d_branca	0	0.023	0.47	0.024	0.01	0.061
time	-0.004	0.003	0.002	0.002	-0.004	0.007
constant	4.23	0.463	5.172	0.65	4.58	0.69
R2	0.24		0.26		0.04	
Region						
2 (East)	0.056		0.288		0.379	
3 (West)	-0.034		0.355		0.541	
4 (North)	-0.018		0.385		0.578	
5 (South)	0.022		0.406		0.59	
6 (Cambe)	0.144		0.336		0.465	

All specifications point to a greater preference for the relative price of ethanol to the gasoline coefficient (on average -1.2). On the other hand, income does not show to affect the preferences for either ethanol or gasoline. The number of pumps, reflecting the retailer's size, also does not affect ethanol preferences; however, the unbranded retailer (*d_branca*) is associated with an increased preference for ethanol. The same applies to the gasoline tankage; the larger the storage, the less ethanol is sold. Finally, drive distance is negative, reflecting fuel efficiency preferences and search costs.

The regional coefficients illustrate an interesting dynamic: the ethanol relative prices are more elastic in the West and North regions but almost inelastic in Cambé. This fact could indicate dislocation dynamics in the city traffic, for which detailed information is not available. The nest coefficient is positive and significant, implying similar substitution patterns of stations in the same region but not across regions.

The average ethanol and gasoline relative price elasticities for retailers following equations (5) and (6) are described in Table 4. A one percent increase in relative ethanol prices (a higher ethanol price than the gas price) points to a reduction of -1.07 in ethanol sales in all regions. A greater change in the gasoline price to ethanol, decreases the quantity sold by -1.33 on average in all regions.

Table 4. Empirical results from nested logit model

	Mean	
Region	Ethanol Price elasticity	Gasoline Price elast.
1	-1.076025	-1.336256
2	-1.077502	-1.337671
3	-1.076606	-1.337581
4	-1.076294	-1.337218
5	-1.074284	-1.335045
6	-1.072395	-1.334865

VI. Policy Implications and Final Considerations

This article aims to contribute to the increasing literature on demand estimation for ethanol in the context of consumer fuel-switching behavior, considering retailers' locations to characterize consumer preferences. Specifications point to a larger elasticity of the relative price of ethanol to the gasoline coefficient (on average -1.07), which is in line with the literature in a flex-fuel setting. Still, these elasticities are lower than the gasoline relative price, point to a larger consumer switch from gasoline to ethanol when the gas price is higher than ethanol (on average -1.33).

Although the relative price elasticity is higher than 1, demand for ethanol does not change in the same proportion given a rise in gasoline prices. Gasoline demand, however, can decrease in a higher proportion if ethanol prices decrease. Policies directed to reduce carbon emissions, in the context of flex-fuel vehicles such as in Brazil, should keep this in mind. Increased taxes on gasoline consumption could increase tax revenue and, at the same time, divert drivers' choice to use a less polluting fuel. On the other hand, any small increase in ethanol prices leads to more gasoline consumption and, therefore, higher GHG emissions. This relationship between ethanol and gasoline preferences should be key in future taxation policies and fuel pricing.

The estimated elasticities show a promising market to be developed in other countries with similar land and climate to produce sugar cane ethanol in substitution for gasoline. In addition, countries with a higher share of fuel imports, such as in West Africa, could have an improved trade balance, be part of the transportation value chain and use ethanol as a cleaner energy source contributing to their mitigation commitments.

Finally, the location and competition of fuel retailers are important in the cleaner fuel option strategy. In the case of Londrina, the cartel increased ethanol prices by 12%, leaving consumers with no option and higher gasoline consumption. Future competition penalties should also consider environmental and climate change harm while defining the amount of damage's claim, being a public good.

Annex I. Descriptive Statistics

1. Population in Londrina, per region, in 2000

Region	Population	Share (%)
Center	84 733	19,95
East	80 247	18,90
North	106 759	25,14
West	82 723	19,48
South	70 234	16,54
Total	424 696	100

Source: IBGE (Brazilian Institute of Geography and Statistics), National Census 2000

2. Market Size

	Londrina	Car's share per region					Estimated quantity of gasoline per region (m. lt)[1]					Cambé		***Gasoline Total (m. lt)***	***Ethanol[3] Total (m. lt)***
Period	# cars	Center	East	North	West	South	Gas_centro	Gas_leste	Gas_norte	Gas_oeste	Gas_sul	# cars	Q (lt)[2]		
2007m1	136 190	27 172	25 733	34 235	26 527	22 522	0,652	1,235	2,876	1,592	2,162	17 784	2,56	***11,08***	***4,74***
2007m2	136 474	27 229	25 787	34 306	26 583	22 569	0,653	1,238	2,882	1,595	2,167	17 878	2,57	***11,11***	***4,75***
2007m3	137 040	27 341	25 894	34 449	26 693	22 663	0,656	1,243	2,894	1,602	2,176	18 005	2,59	***11,16***	***4,78***
2007m4	137 732	27 480	26 025	34 623	26 828	22 777	0,660	1,249	2,908	1,610	2,187	18 084	2,60	***11,22***	***4,80***
2007m5	138 197	27 572	26 113	34 740	26 918	22 854	0,662	1,253	2,918	1,615	2,194	18 128	2,61	***11,25***	***4,81***
2007m6	138 580	27 649	26 185	34 836	26 993	22 918	0,664	1,257	2,926	1,620	2,200	18 245	2,63	***11,29***	***4,83***
2007m7	139 182	27 769	26 299	34 987	27 110	23 017	0,666	1,262	2,939	1,627	2,210	18 337	2,64	***11,34***	***4,85***
2007m8	139 854	27 903	26 426	35 156	27 241	23 128	0,670	1,268	2,953	1,634	2,220	18 433	2,65	***11,40***	***4,88***
2007m9	140 446	28 021	26 538	35 305	27 356	23 226	0,673	1,274	2,966	1,641	2,230	18 590	2,68	***11,46***	***4,90***
2007m10	141 367	28 205	26 712	35 536	27 536	23 379	0,677	1,282	2,985	1,652	2,244	18 631	2,68	***11,52***	***4,93***
2007m11	141 631	28 257	26 761	35 603	27 587	23 422	0,678	1,285	2,991	1,655	2,249	18 814	2,71	***11,57***	***4,95***
2007m12	143 241	28 579	27 066	36 008	27 901	23 688	0,686	1,299	3,025	1,674	2,274	19 010	2,74	***11,70***	***5,00***
2008m1	143 236	28 578	27 065	36 006	27 900	23 688	0,686	1,299	3,025	1,674	2,274	19 122	2,75	***11,71***	***6,23***
2008m2	143 375	28 605	27 091	36 041	27 927	23 711	0,687	1,300	3,027	1,676	2,276	19 236	2,77	***11,74***	***6,24***
2008m3	144 049	28 740	27 218	36 211	28 058	23 822	0,690	1,306	3,042	1,683	2,287	19 412	2,80	***11,80***	***6,28***
2008m4	144 646	28 859	27 331	36 361	28 174	23 921	0,693	1,312	3,054	1,690	2,296	19 561	2,82	***11,86***	***6,31***
2008m5	145 458	29 021	27 485	36 565	28 333	24 055	0,697	1,319	3,071	1,700	2,309	19 678	2,83	***11,93***	***6,35***
2008m6	146 450	29 219	27 672	36 814	28 526	24 219	0,701	1,328	3,092	1,712	2,325	19 854	2,86	***12,02***	***6,39***
2008m7	147 348	29 398	27 842	37 040	28 701	24 368	0,706	1,336	3,111	1,722	2,339	19 976	2,88	***12,09***	***6,43***
2008m8	148 226	29 573	28 008	37 261	28 872	24 513	0,710	1,344	3,130	1,732	2,353	20 123	2,90	***12,17***	***6,47***
2008m9	149 079	29 743	28 169	37 475	29 038	24 654	0,714	1,352	3,148	1,742	2,367	20 278	2,92	***12,24***	***6,51***
2008m10	149 639	29 855	28 275	37 616	29 147	24 747	0,717	1,357	3,160	1,749	2,376	20 383	2,94	***12,29***	***6,54***

(CONT).

	Londrina	Car's share per region					Estimated quantity of gasoline per region (m. lt)[1]					Cambé		***Gasoline Total (m. lt)***	***Ethanol[3] Total (m. lt)***
Period	# cars	Center	East	North	West	South	Gas_centro	Gas_leste	Gas_norte	Gas_oeste	Gas_sul	# cars	Q (lt)[2]		
2008m11	150 217	29 970	28 384	37 761	29 260	24 842	0,719	1,362	3,172	1,756	2,385	20 561	2,96	***12,35***	***6,57***
2008m12	151 149	30 156	28 560	37 995	29 441	24 996	0,724	1,371	3,192	1,766	2,400	20 624	2,97	***12,42***	***6,61***
2009m1	151 400	30 206	28 607	38 059	29 490	25 038	0,725	1,373	3,197	1,769	2,404	20 852	3,00	***12,47***	***8,73***
2009m2	151 809	30 288	28 685	38 161	29 570	25 105	0,727	1,377	3,206	1,774	2,410	20 950	3,02	***12,51***	***8,76***
2009m3	152 407	30 407	28 798	38 312	29 686	25 204	0,730	1,382	3,218	1,781	2,420	21 103	3,04	***12,57***	***8,80***
2009m4	152 964	30 519	28 903	38 452	29 795	25 296	0,732	1,387	3,230	1,788	2,428	21 253	3,06	***12,63***	***8,84***
2009m5	153 890	30 703	29 078	38 684	29 975	25 450	0,737	1,396	3,249	1,798	2,443	21 404	3,08	***12,71***	***8,89***
2009m6	154 756	30 876	29 241	38 902	30 144	25 593	0,741	1,404	3,268	1,809	2,457	21 520	3,10	***12,78***	***8,94***
2009m7	155 446	31 014	29 372	39 076	30 278	25 707	0,744	1,410	3,282	1,817	2,468	21 654	3,12	***12,84***	***8,99***
2009m8	156 319	31 188	29 537	39 295	30 448	25 851	0,749	1,418	3,301	1,827	2,482	21 786	3,14	***12,91***	***9,04***
2009m9	157 168	31 357	29 697	39 508	30 613	25 992	0,753	1,425	3,319	1,837	2,495	21 990	3,17	***13,00***	***9,10***
2009m10	158 210	31 565	29 894	39 770	30 816	26 164	0,758	1,435	3,341	1,849	2,512	22 175	3,19	***13,09***	***9,16***
2009m11	158 978	31 718	30 039	39 963	30 966	26 291	0,761	1,442	3,357	1,858	2,524	22 344	3,22	***13,16***	***9,21***
2009m12	160 295	31 981	30 288	40 295	31 223	26 509	0,768	1,454	3,385	1,873	2,545	22 469	3,24	***13,26***	***9,28***

Source: Denatran PR

[1] Multiplying the number of cars per region by the quantity needed in case of gasoline (0.1 lt per 1 km), four trips during 30 days following the average distances to downtown: C:2km, N:7km, W:5km, E:4km, S:8km.

[2] Multiplying the number of cars by the quantity needed per km (0.1l), four trips for 30 days using the 12km distance to Londrina.

[3] Using the ethanol to gasoline sales share per year: 2007: 0.43, 2008: 0.53, 2009: 0.74.

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