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The asymmetric pattern of fuel demand in Brazil

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Abstract

In Brazil, since most of the fleet consists of flexible-fuel vehicles, the ethanol-to-gasoline price ratio affect demand. In this study, we address the asymmetric behavior of demand estimating a dynamic panel with threshold effect. Based on municipal data from 2007 to 2017, we estimate a threshold close to 71% for ethanol and 66% for gasoline. The estimated elasticities differ from one regime to another, depending on the ethanol-to-gasoline price ratio. Our findings therefore contribute to an understanding of how price ratio affects the demand for both fuels, supporting the design of public policies aimed at a transition to biofuels.

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1. Introduction

Price elasticities measure the responsiveness of demand to changes in prices, with rare exceptions, we expected that they are negative: higher prices leads to lower demand, and vice versa. In fuel markets, this responsiveness is a central point to policies on urban mobility, environment, and energy matrix diversification. Therefore, several authors estimated the elasticity of demand for fuels with respect to its determinants, such as Lin and Zeng [7], Park and Zhao [8], and Pock [9] among others[1].

Over 70% of the light vehicle fleet in Brazil is composed of flexible-fuel vehicles, where hydrous ethanol[2] [6]. However, one liter of ethanol has about two-thirds of the energy content as one liter of gasoline, gas stations are required by The National Agency for Petroleum, Natural Gas and Biofuels (ANP) to publicize the ethanol to gasoline price ratio alongside a notification stating that ethanol is a better economic choice if its price is equal to or lower than 70% of gasoline.

In order to capture the threshold effects, some authors included a dummy related to the price ratio equal 0.7. Although intuitive, this strategy fixed the threshold arbitrarily, while there are several reasons to believe that indifference does not occur exactly at this point. For example, consumers with environmental concerns may prefer ethanol even if $\frac{P_e}{Pg} > 0.7$. In the same way, a persistent preference for gasoline may be due to past dependence or vehicle autonomy.

In this paper, we address this issue, estimating the threshold rather than taking it as given. Once the threshold is estimated, we expect two different regimes with two elasticity responses. As far as we know, this issue has not yet been investigated in prior research in detail. It therefore remains the case that this study could provide important support to public policies aimed at promoting renewables in Brazil.

To achieve our objective, the next section is concerned with the methodology and data used in this study. Section 2 presents research findings focused

[1] Surveys such as Graham and Glaister [3], Dahl [2], and Havranek and Kokes [5] provide a summary of the literature.

[2] Hydrous ethanol (5% water) is a substitute for gasoline, and vice versa. Anhydrous ethanol (maximum 0.4% water) is blended into gasoline to produce gasoline C which is sold in Brazilian gas stations. Henceforth, we use terms gasoline and ethanol to refer to the gasoline C and hydrous ethanol, respectively.

on the main implications. The final section summarizes our main conclusions and discusses policy implications.

2. Methodology and data

In line with Anderson [1], in order to endogenously estimate the threshold and elasticities in different regimes, we consider the following dynamic panel data model:

$$x_{it}^{j} = (x_{it-1}^{j}, p_{it}^{e}, p_{it}^{g}, w_{it}, v_{it})'\beta + \left(x_{it-1}^{j}, p_{it}^{e}, p_{it}^{g}, w_{it}, v_{it}\right)' \delta I\left(q_{it} > \tau\right) + \alpha_i + \gamma_t + \varepsilon_{it} \quad (1)$$

in which the subscripts $i = 1, \ldots, n$ indexes the groups, $t = 1, \ldots, T$ the time periods, α_i is the incidental parameter, γ_t a time trend, and ε the idiosyncratic error. $I\left(\cdot\right)$ is the indicator function and τ the parameter that divides the system behavior into two different regimes. Variable x^j, $(j = g, e)$ is the per capita consumption of ethanol (x^e) or gasoline (x^g), p^e is the real price of ethanol and p^g real price of gasoline, w the per capita income. We have also added v, the per capita number of light vehicles, as a control variable.

Two main characteristics of fuel demand in Brazil need to be considered: i) fuel consumption is strongly inertial; ii) as the true threshold is unknown, we must be consistently estimate it along with the other parameters or consistency assumption is violated. So, set the threshold variable q_{it} as $\frac{p_{it}^{e}}{p_{it}^{g}}$ and apply the dynamic panel threshold model proposed by Seo and Shin [10] who extend the model proposed by Hansen [4] to allow lagged dependent variables and endogenous covariates.

In short, the procedure consists of estimating the (1) by First Difference GMM for each value of the potential threshold value. At every step, the model is estimated assuming a value of q_{it} as threshold and a set of parameters is obtained. The final estimates is the set $\hat{\theta}$ that minimizes the objective function and returns the closed-form $\bar{\theta} = \left(\hat{\beta}(\tau), \hat{\delta}(\tau)\right)$. Seo and Shin [10] also proposed a test to address the hypotheses of linearity and the validity of the instruments set, to whom we refer for more information.

To construct the dataset, it was necessary to utilize a variety of sources and a data compilation process, namely the ANP, the Brazilian Institute of Geography and Statistics (IBGE), and the Brazilian National Traffic Department (DENATRAN). The full sample is composed of records from 493 Brazilian municipalities registered between 2004 and 2017, totaling 6902 observations.

The ANP collects data regarding gasoline (x^g) and ethanol (x^e) in liters, as well as the nominal prices (in Brazilian Reals) for gasoline (p^g) and ethanol (p^e), which it publishes on its website. Fuel consumption was recorded in per capita real terms and prices were deflated using the National Consumer Price Index (IPCA). Fleet (v) data, that is the monthly number of vehicles per municipality, is available on the DENATRAN website. In order to obtain a yearly figure, we calculated the average number of automobiles per year and divided the result by the number of inhabitants.

Gross Domestic Product (GDP) and number of inhabitants are available on the IBGE website. With respect to number of inhabitants, it is important to note that the last population count occurred in 2010. For non-decennial years we used intercensal estimates of the number of residents per municipality. Since yearly income data is not available at municipal level, GDP data was used as a proxy for income. Despite its limitations, this is perhaps the only way to obtain an annual income measure per municipality. With this in mind, we deflated GDP using the IPCA, also measured by the IBGE, and divided it by the number of inhabitants in order to derive real GDP per capita.

3. Main results

We estimate (1) in the log-log form to capture the relationship between demand and factors. Table 1 shows the estimates for price elasticities of demand for ethanol and gasoline. We treat prices as endogenous variables and per capita fleet as exogenous. Note that we add a linear trend to control time effects as a more parsimonious specification. The inclusion of this linear trend is justified by the fact that the steady and sustained growth in consumption.

The estimated threshold for both demands are statistically significant and equal to $\exp(-0.3995) = 67.07\%$ and $\exp(-0.4014) = 66.94\%$, respectively for ethanol and gasoline. This estimate should not be treated as the true value that makes consumers prefer ethanol to gasoline, but that over the analyzed period, the value that divides the behavior of both elasticities is close to 67%, therefore below the 70% that would be expected.

Current consumption is influenced by consumption in the recent past, but the sign depends on the state of the system. For example, the lagged coefficient for gasoline consumption shows a positive impact of 0.7806 on the current level of consumption if the price ratio is lower or equal to the estimated threshold of 67%. However, gasoline consumption in previous period has a negative sign so that will lead to decrease current consumption of 0.4089. The same interpretation is applicable for ethanol consumption if we change coefficients by 0.6335 and -0.4354.

Consumption is also affected by movements in its short-run determinants. The price elasticity for ethanol 2.0339 in the lower regime and 4.1339 in the upper regime, that is, the elasticity is twice as high if the price ratio is above the threshold. This is an expected result, since if the price ratio is greater than 67% gasoline is a more advantageous option compared to the ethanol. Moreover, price elasticity for ethanol is greater than 1 and that of gasoline less than 1 in both regimes, which shows that ethanol is an elastic good.

The same reasoning is applicable to gasoline. If the price ratio is lower or equal to 67%, the price elasticity is equal to 0.9669 and the ethanol is a best option. In the lower regime the price elasticity is 0.3422, what makes it a much more inelastic product. Note that in both regimes gasoline behaves like an inelastic good. This result should be considered in the adoption of public policies to promote the use of ethanol as a biofuel. For example, if the upper regime tends to remain a tax increase aimed to reduce gasoline consumption and carbon emissions should be viewed with caution because consumers should not opt for ethanol. As expected to the case of substitute goods, the cross-price elasticities for ethanol have positive signs. A 1-point increase in gasoline price is associated with an increase in ethanol consumption of 4.9038 in lower regime compared with an increase of 0.9734 in upper regime. Cross-price elasticities for gasoline is changes is positive (0.6313) but turns negative (-0.0305), although insignificant, in upper regime. What stands out from these results is that the ethanol is a close substitute good for gasoline. However, gasoline seems to be an independent good.

The estimated parameter for income elasticity in demand for ethanol is negative in the upper regime. This result leads us to conclude that, if the price ratio favors the gasoline consumption, ethanol is considered as an inferior good. On the other hand, gasoline is a normal good, whatever the regime, which is a significant difference between two goods and regimes should be taken into account by policy makers. Another point to note is that income elasticity for gasoline is close to zero compared to ethanol, notably

Table 1: Dynamic panel threshold model estimates for fuel demand. Dependent variable is log of per capita ethanol (x^e_{it}) or gasoline (x^g_{it}) consumption.

Dep. Variable	$\log(x^e_{it})$		$\log(x^g_{it})$	
Regime	$\log(q_{it}) \leq \tau$	$\log(q_{it}) > \tau$	$\log(q_{it}) \leq \tau$	$\log(q_{it}) > \tau$
τ	-0.3995^{***}		-0.4014^{***}	
	(0.0024)		(0.0026)	
$\log(x^j_{it-1})$	0.7806^{***}	-0.4089^{***}	0.6335^{***}	-0.4354^{***}
	(0.0110)	(0.0111)	(0.0102)	(0.0102)
$\log(p^g_{it})$	4.9038^{***}	0.9734^{***}	-0.9669^{***}	-0.3422^{***}
	(0.1287)	(0.1345)	(0.0376)	(0.0435)
$\log(p^e_{it})$	-2.0339^{***}	-4.1339^{***}	0.6313^{***}	-0.0305
	(0.0674)	(0.0721)	(0.0176)	(0.0222)
$\log(w_{it})$	0.6441^{***}	-0.6408^{***}	0.0647^{***}	0.2306^{***}
	(0.0373)	(0.0409)	(0.0121)	(0.0132)
$\log(v_{it})$	-0.0085	0.8988^{***}	0.5696^{***}	0.0018
	(0.0329)	(0.0269)	(0.0120)	(0.0104)
Trend	0.1172^{***}	-0.1089^{***}	-0.0597^{***}	0.0397^{***}
	(0.0033)	(0.0032)	(0.0013)	(0.0013)
Constant		9.1544^{***}		1.7558^{***}
		(0.2834)		(0.0898)
Lin. test (p-value)	(0.000)	(0.000)	(0.000)	(0.000)
Regime obs. (%)	30.83	69.17	30.15	69.85
n	493.000	493.000	493.000	493.000
T	14.000	14.000	14.000	14.000

Source: Authors. Estimates from a log – log specification with standard errors in parentheses. *, **, and *** are significance at the 90%, 95%, and 99% levels, respectively. 'L-test is a linearity test with null hypothesis of no threshold effects.

in the lower regime when the quantity bought is almost constant regardless of changes in income. Similar to income, an increase of fleet vehicles is associated with an increase in demand, but this effect is only seen in one of the regimes. It's 0.8988 in the ethanol (upper regime) but 0.5696 in the gasoline demand equation (lower regime).

4. Concluding remarks

The empirical findings in this study provide a new understanding of the demand for ethanol and gasoline in Brazil. Consumer choice is strongly affected by the ethanol-to-gasoline price ratio and this relationship should be taken into consideration. To increase the use of ethanol, a renewable and cleaner energy source, policy makers should pay dedicated attention to this issue. Pricing and tax policies should consider ethanol to be an inferior good – there is no point in making ethanol cheaper if the price ratio is kept below the 67% threshold.

Overall, our results demonstrate a more general picture than previous analyzes based on linear models. Price elasticity is highly asymmetric, as is cross-price elasticity, although, in general, gasoline remains much more inelastic than ethanol. The ethanol-to-gasoline price ratio has a much greater impact on the demand for ethanol, notably in the income elasticity of demand. These findings therefore contribute in several ways to our understanding of how price ratio affects the demand for fuels and enable improved public policy planning for the transition from fossil to biofuels.

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