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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

About 70% of the fleet in Brazil is composed of Flex-Fuel Vehicles (FFV), meaning that most drivers can make a choice based on the price of ethanol or gasoline (International Energy Agency, 2019; Du & Carriquiry, 2013). However, since one liter of ethanol has about two-thirds of the energy content of one liter of gasoline, ethanol is a better economic choice when its price is equal to or lower than 70% of that of gasoline.

In order to capture this 70% effect, some authors have incorporated a dummy variable into the regression model. However, there are several reasons to believe that indifference does not occur at this point. For example, consumers with environmental concerns may have a predilection for ethanol. In this case, ethanol will be consumed even when its price is equal to or slightly higher than that of gasoline. In the same way, a persistent preference for gasoline may be based on a number of reasons, such as entrenched habits or autonomy.

Establishing the threshold that makes ethanol preferable to gasoline has become a key factor in the formulation of public policies for urban mobility, the environment, and energy matrix diversification. Although several authors, such as Lin & Zeng (2013), Park & Zhao (2010), and Pock (2010) among others[1], have estimated the price-elasticity of the demand for fuels, as far as we know no study has been dedicated to estimating the empirical value of this threshold. In this paper, we attempt to fill this gap by estimating the threshold, rather than taking it as given.

To achieve this goal, the next section is concerned with the methodology and data used in this study. Section 2 presents research findings focused on the main implications. The final section summarizes our main conclusions and discusses policy implications. It is hoped that this research will contribute to an understanding of the substitutability between gasoline and ethanol and provide important support for public policies to promote the use of renewable fuels in Brazil.

2. Methodology and data

In line with Anderson (2012), we consider the following dynamic panel threshold model for fuel demand

$$y_{it} = (1, x_{it}')\boldsymbol{\beta}_1 \mathtt{I}(q_{it} \leq \tau) + (1, x_{it}')\boldsymbol{\beta}_2 \mathtt{I}(q_{it} > \tau) + \alpha_i + \varepsilon_{it}, \tag{1}$$

in which the subscripts $i = 1, \ldots, n$ indexes the groups and $t = 1, \ldots, T$ the time periods, so that there are nT observations in sample, y_{it} is a scalar stochastic variable of interest, x_{it} is the $k \times 1$ vector of regressors, that may include the lagged dependent variable, $\mathtt{I}(\cdot)$ is an

[1]Surveys such as Graham & Glaister (2002), Dahl (2012), and Havranek & Kokes (2015) provide a summary of the literature.

indicator function, and q_{it} is the transition variable. τ is the threshold parameter, $\boldsymbol{\beta}_1$ and $\boldsymbol{\beta}_2$ the slope parameters associated with different regimes, $alpha_i$ is an unobserved individual fixed effect and ε_{it} a idiosyncratic error.

We employ Equation (1) to estimate the demands for ethanol and gasoline. To this end, we set response variables as the per capita consumption of ethanol (ec_{it}) and the per capita consumption of gasoline (gc_{it}). In both models the set of covariates contains the lagged values for gasoline (gc_{it-1}) and ethanol (ec_{it-1}) consumption, the real prices of gasoline (gp_{it}) and ethanol (ep_{it}), per capita income (w_{it}), and the per capita fleet of light vehicles (v_{it}). We set the threshold variable (q_{it}) as the ethanol-to-gasoline price ratio, that is, gp_{it}/ep_{it}.

The proposed regression model address two main characteristics of fuel demand in Brazil. First, as fuel consumption is strongly inertial, we include the lagged dependent variable to avoid omitted-variable bias. However, this inclusion violates the strict exogeneity assumption, since it is a covariate necessarily correlated with idiosyncratic error. Second, since the true threshold is unknown, we must estimate it consistently with the other parameters, in order not to violate the consistency assumption. Seo & Shin (2016) extend the model proposed by Hansen (1999) and introduced a novel method to estimate these types of models, which are known as dynamic panels with threshold effect and endogeneity.

In short, the procedure consists in removing the incidental parameter α_i by the first difference transformation and estimate the unknown parameters $\theta = (\boldsymbol{\beta}, \boldsymbol{\delta}, \tau)$ through the Generalized Method of Moments (GMM). However, given that q_{it} is a vector, there are nT potential thresholds and it is necessary to decide which is the most appropriate. Following the approach proposed by Seo & Shin (2016), we exclude the 15% most extreme values and estimate one model for each remaining value of q_{it}. The final estimate is the set $\hat{\theta}$ which minimizes the objective function and returns the closed-form $\hat{\theta} = \left(\hat{\boldsymbol{\beta}}(\tau), \hat{\boldsymbol{\delta}}(\tau)\right)$. Seo & Shin (2016), to whom we refer for further information, also proposed a test to address the linearity hypotheses.

A variety of sources and a data compilation process are utilized in order to construct the dataset, namely the National Agency for Petroleum, Natural Gas and Biofuels (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 2007 and 2017, totaling 5456 observations.

The ANP collects data regarding gasoline and ethanol in liters, and the nominal prices (in Brazilian Reals) for gasoline and ethanol, which it publishes on its website. Fuel consumption is recorded in per capita real terms, so prices are deflated using the National Consumer Price Index (IPCA). Fleet data is available on the DENATRAN website. In order to obtain an annual figure, the average number of automobiles per year is calculated and the result is divided by the number of inhabitants.

Gross Domestic Product (GDP) and number of inhabitants are available on the IBGE website. For non-decennial years, intercensal estimates of number of residents per municipality are used. Since annual income data is not available at municipal level, GDP data is used as a proxy for income. In order to derive the real GDP per capita, GDP is deflated using the IPCA and divided by number of inhabitants.

3. Main results

Table 1 shows the threshold estimates and elasticities of demand for ethanol and gasoline. To alleviate the endogeneity problem, we consider the proposals of Liu (2016) and Uchôa et al. (2020) which, roughly speaking, provide an index composed of taxes and distance from state capital. Note also that we have added a linear trend as a more parsimonious specification to control time effects. The inclusion of this linear trend is justified by a steady and sustained growth in consumption.

The estimated thresholds for both demands are significant and equal to $\exp(-0.3490) =$ 70,54% and $\exp(-0.4108) = 66.31\%$, for ethanol and gasoline respectively. The resulting linearity test soundly rejects the null hypothesis, which indicates that a linear model is inadequate. This estimate should not be treated as a true value which makes consumers prefer ethanol to gasoline. However, for the analyzed period, this value is a more accurate measure of the price ratio value that separates the behavior of both elasticities. It is also important to note that the test clearly rejects the null of linearity, given that the $p-$value is virtually 0.

Current consumption is influenced by consumption in the recent past, although its sign and significance depends on the state of the system. For example, the lagged coefficient for gasoline consumption demonstrates a positive impact, of 0.2073, on the level of current consumption in the upper regime. However, gasoline consumption in the previous period is not statistically significant if the price ratio is lower than or equal to the estimated threshold. The same interpretation is applicable to ethanol consumption if we change the coefficients to 0.2194 and 0.2778. Current gasoline consumption is affected by ethanol consumption in the previous year, while ethanol consumption is not. Note also that in the lower regime, gasoline consumption is negatively affected by ethanol consumption in the previous year.

The estimated price elasticity for ethanol is 1.1263 in the lower regime and 1.8628 in the upper regime, that is, the elasticity is high if the price ratio is above the threshold. This is expected, since when the price ratio is greater than 71%, gasoline is a more advantageous option than ethanol. Moreover, price elasticity for ethanol is greater than 1, while that for gasoline is less than 1 in both regimes, demonstrating that ethanol is an elastic good.

The same reasoning applies to gasoline. If the price ratio is lower or equal to 66%, the price elasticity is equal to 0.8768 and ethanol is the best option. In the lower regime, the price elasticity is 0.5052, making it a much more inelastic product. Note that both regimes report that gasoline behaves as 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 remains consistent, a tax increase aimed at reducing gasoline consumption and carbon emissions should be viewed with caution, since consumers may not opt for ethanol.

A 1-point increase in the gasoline price is associated with an increase of 1.5587 in ethanol consumption in the upper regime, compared to an increase, albeit insignificant, of 0.2071 in the lower one. Cross-price elasticities for gasoline are only positive and significant (0.3012) in the upper regime. These results suggest that both fuels are substitute goods in the upper regime.

The estimated parameter for income elasticity is always positive. This leads us to conclude that both fuels are normal goods. Another point worth noting is that, compared to ethanol, the income elasticity of gasoline is always lower than that of ethanol. This demonstrates that gasolines responsiveness to income is considerably less than ethanols. An increase in fleet vehicles is associated with an increase in demand only in the upper regime. Lastly, we note that ,in the lower regime, an increase in fleet vehicles is not statistically significant for either fuel.

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 focus their attention on this issue.

Overall, our results demonstrate a better overview 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 on the income elasticity of demand.

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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	-0.3490^{***}		-0.4108^{***}	
	(0.0104)		(0.0038)	
$\log(x^g_{it-1})$	0.0514	-0.0319	0.0235	0.2073^{***}
	(0.0565)	(0.0424)	(0.0196)	(0.0173)
$\log(x^e_{it-1})$	0.2194^{***}	0.2778^{***}	-0.1607^{***}	0.1730^{***}
	(0.0245)	(0.0241)	(0.0133)	(0.0136)
$\log(p^g_{it})$	0.2071	1.5587^{***}	-0.8768^{***}	-0.5052^{***}
	(0.4352)	(0.1957)	(0.1035)	(0.0993)
$\log(p^e_{it})$	-1.1263^{***}	-1.8628^{***}	-0.1062	0.3012^{***}
	(0.1122)	(0.3475)	(0.0724)	(0.0645
$\log(w_{it})$	0.1913^{***}	0.8854^{***}	0.0248^{*}	0.1349^{***}
	(0.0329)	(0.0625)	(0.0119)	(0.0142)
$\log(v_{it})$	-0.0232	0.8298^{***}	-0.0253	0.3981^{***}
	(0.0486)	(0.0878)	(0.0277)	(0.0335)
Constant		-0.7588		1.9533^{***}
		(0.5787)		(0.2310)
n	496		496	
T	11		11	
Lin. test (p-value)	(0.000)		(0.000)	
Regime obs. (%)	45.09	54.91	23.57	76.43

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