ETHANOL DEMAND IN BRAZIL: A CONTRIBUTION TO A BETTER ESTIMATE

1st Anderson Luís da Silva
Paulista School of Politics, Economics and Business
Federal University of Sao Paulo
Osasco, Brazil
alsi@outlook.com.br

2nd Juan Castañeda-Ayarza
Economic and Management Center
Pontificia Universidade Católica
Campinas, Brazil
juan.arturo@puc-campinas.edu.br

Abstract

Through the GMM method, this work proposes to advance the modeling of demand for anhydrous ethanol and hydrated ethanol in Brazil. Several previous studies with the same objective brought relevant contributions to estimate the demand for biofuels better. The models present in this article gathered those contributions that were previously seen in isolation. Further, new advances have been made. The results generated by this model have proven to be significant. This paper also identified contributions that could be relevant to further modeling demand for anhydrous and hydrated ethanol, but which are not possible given the limited data.

Keywords: *Fuel ethanol demand, GMM, Economic analysis*

I. INTRODUCTION

The first fifteen years of the 21st century were characterized by global concerns about energy supply and the acceptance of the need to address the effects of climate change [1]. These factors have aroused interest and significant investments in renewable energy by the international community. However, the global energy matrix is still composed almost entirely of fossil carbon sources - about 81% - while those of renewable energy represents only 14% of the total [2].

Because of high oil prices (fossil carbon source represents 33% of the global energy matrix and is the primary fuel source [2]), particular emphasis has been placed on liquid biofuels. They are direct substitutes for oil and allegedly contribute to rural development, emission reductions in the transport sector, and reduced oil imports [3].

Brazil, in addition to standing out from other countries for having the most sustainable energy matrix - renewable energy sources representing about 43.5% of the entire national energy matrix [2] - is also the third-largest producer and consumer of biofuels in the world, behind only the United States and China. However, unlike other countries, Brazil can increase biofuel production without causing apparent food supply damage [4].

Studies conducted by the Brazilian Sugarcane Industry Association (Unique, 2016) have shown that no country in the world produces ethanol with the same efficiency as Brazil due to the quality of the raw material and suitable weather conditions [4].

The sector's success has come from improvements in technology, the state incentive to increase renewable energy, and the introduction of flex-fuel vehicles in 2003. All of this gave a new boost to the sugar-alcohol industry and the reduction in production costs (around 70%), in addition to constant increases in the price of oil, which ended up making this biofuel highly competitive in the domestic and foreign markets [5].

The demand for ethanol fuel, produced from renewable resources, has increased considerably in Brazil in recent years. The projection of the Brazilian Energy Research Company (EPE, 2018), considering a high growth scenario, is that the demand for ethanol fuel in Brazil will reach 50 billion liters in 2030, meaning an increase of 87% compared to current consumption [6].

This heated scenario for the Brazilian ethanol industry demonstrates the importance of studies on fuel demand behavior. There are several papers on this subject, such as Buonfiglio and Bajay (1992) [7], Tokgoz and Eleboid (2006) [8], Junior et al. (2010) [9], Serigati et al. (2010) [10], Freitas and Kaneko (2011) [11] and Randow et al. (2013) [12] (Table 1).

Table 1. Precedents of demand modeling to Brazilian biofuel

Author	Keyword	Biofuel Demand Estimation
Junior et al. (2010)	Simple model	$D_e = f(P_e, P_g, Y)$
Buonfiglio and Bajay (1992); Serigati et al. (2010)	Complementary Good	$D_e = f(P_e, P_g, F, Y)$
Freitas and Kaneko (2011)	Seasonality	$D_e = f(P_e, P_g, F, Y, dummies)$
Tokgoz and Elobeid (2006)	Aspects of fleet	$D_{ae} = f(P_{eh}, P_g, Interaction, Blend, Y)$ $D_{he} = f(P_{eh}, P_g, Interaction, FF, Y)$

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About Brazilian ethanol, the simplest regression model found for this fuel was as seen in Junior et al. [9], which therefore took into consideration only the variables ethanol price, gasoline price, and consumer income. Buonfiglio and Bajay [7] and Serigati et al. [10], when estimating a demand model for Brazilian ethanol, in addition to the explanatory variables found in the simplest regression models, also considered it essential to include a new variable in the model, the 'fleet' variable (F), represented by the number of vehicles in circulation in the country.

Freitas and Kaneko [11] differentiated themselves from the former by taking into account in their ethanol demand model the seasonality in price and consequently in ethanol consumption.

Due to the non-existence of sugarcane stock (as it is a highly perishable agricultural good that cannot be stored), Brazilian mills have an average idleness per year of four months in biofuel production. In this interval, which corresponds to the inter-harvest period between November and March, the mills present a significant drop in ethanol supply, which leads to an increase in final consumer prices and lower fuel consumption [11, 15].

Therefore, Freitas and Kaneko [11] included in their model a dummy variable containing an observation for each month analyzed, which is intended to contribute to the discernment of the magnitude of the seasonal effects on ethanol consumption in Brazil.

Tokgoz and Elobeid [8], in their estimation model for the demand for ethanol in Brazil, trying to treat the fleet variable (F) in a certain way that aspects of it are considered. Their first contribution to a better estimation of ethanol demand in the country is that it is divided between the demand for anhydrous ethanol and hydrous ethanol. Hydrated ethanol is extracted in the distillation process. It is used by vehicles powered only by alcohol and by flex-fuel vehicles. Simultaneously, anhydrous ethanol derived from hydrated ethanol after the dehydration process is contained by state imposition in gasoline. It is used in vehicles powered only by gasoline and flex-fuel vehicles.

Thus, it is assumed that the demand for each type of ethanol responds to different incentives, so they should not be considered in the same equation. While anhydrous ethanol consumption is directly proportional to the gasoline price, hydrous ethanol has an inverse relationship.

The behavioral equation proposed by Tokgoz and Elobeid [8] for anhydrous ethanol consumption includes, in addition to the price of anhydrous ethanol and the price of gasoline, the imposition of blending, since anhydrous ethanol is used only as a blend at the level of imposition. The variation in this percentage of imposition influences the consumption of anhydrous ethanol. For the hydrated ethanol equation, the variable FF is added, representing the number of flex-fuel vehicles in the vehicle fleet since hydrated ethanol is used in these vehicles at any level. For both equations, a term of interaction is also included, which equals the price of gasoline times the ratio of flex vehicles in the total fleet of vehicles. According to the authors, this interaction term captures the higher sensitivity of demand for flex-fuel vehicles in gasoline prices.

With the increase in the flex-fuel fleet, demand for anhydrous and hydrous ethanol tends to become more sensitive to changes in gasoline prices. In the case of anhydrous ethanol demand, with the increase in gasoline prices, demand for ethanol declines as consumers who own flex-fuel vehicles replace gasoline blended with anhydrous ethanol with hydrous ethanol, so the coefficient of interaction in this equation is negative.

On the other hand, demand for hydrated ethanol increases if the price of gasoline increases, as consumers of flex-fuel vehicles prefer the use of hydrated ethanol over gasoline that has anhydrous blended. Thus, the interaction coefficient in the hydrous ethanol equation is positive.

Tokgoz and Elobeid [8] chose not to put the price of anhydrous ethanol in their model. In addition to being integrated with the price of gasoline, anhydrous ethanol has a high correlation with the price of hydrated ethanol and the fact that the cost of dehydration is constant.

However, these papers intersect to some extent. They have different and isolated contributions on the subject. This article aims to contribute to the advancement of ethanol demand modeling in Brazil by estimating one or more models that bring together these different contributions in the literature and beyond, from them also propose advances.

II. METHOD

Using the free software of RStudio integrated development environment, the regression of the models with multiple variables proposed by this work, which gathers the different contributions present in the existing literature, will be performed using the GMM econometric technique (Generalized method of moments). The data present in the models comprise the monthly period that goes from May 2013 to April 2020; this one is due to data limitation regarding the variables that consider the vehicle fleet that started to be separated by fuel only in May 2013.

As seen in Hayashi (2000) [13], the generalized method of moments (GMM) is a generalized form of estimation that equals a moment to a given value, which is nothing more than satisfying a sample mean. Taking two random variables z_t e m_t the generalized estimator of moments can be expressed as follows:

$$\hat{\beta}_1 = \frac{\sum_{t=1}^{T}\sum_{t=1}^{T} y_t x_j (m_t m_j + z_t z_j)}{\sum_{t=1}^{T}\sum_{t=1}^{T} x_t x_j (m_t m_j + z_t z_j)}$$

(1)

The estimator has asymptotic properties, and it is expected that the instruments generated and the additional moments have no correlation with the error term.

The regression models for anhydrous ethanol demand and hydrated ethanol demand were estimated in the log-log functional form to obtain coefficients that can be interpreted as the variables' elasticity.

$$\log C_{eh_t} = \beta_{0_t} + \beta_1 \mathrm{logP_{eh_t}} + \beta_2 \mathrm{logP_{gc_t}} + \beta_3 \mathrm{logIt_t} + \beta_4 \mathrm{logAF} + \beta_5 \mathrm{logY}$$

(2)

$$\log C_{ea} = \beta_0 + \beta_1 \mathrm{logP_{eh}} + \beta_2 \mathrm{logP_{gc}} + \beta_3 \mathrm{logIt} + \beta_4 \mathrm{logHF} + \beta_4 \mathrm{logHBlend} + \beta_5 \mathrm{logY}$$

(3)

The variables present in the above models refer to: Ceh (hydrated ethanol consumption); Peh (the price of hydrated ethanol); Pgc (the price of C gasoline); It (term of interaction that is equal to the ratio of the fleet of flex-fuel vehicles times the price of gasoline, which aims to capture the consumer preference of the flex-fuel fleet between gasoline and ethanol); AF (Anhydrous fleet; Y (GDP); Cea (consumption of anhydrous ethanol); HF (Hydrated Fleet); and Blend = Levels of the imposition of blending of anhydrous ethanol in gasoline.

III. RESULTS AND DISCUSSION

The models proposed in this work, based on the researched literature, are presented below:

$$D_{ae} = f(P_{eh}, P_g, Interaction, Blend, AF, Y, Seasonality)$$

$$D_{he} = f(P_{eh}, P_g, Interaction, HF, Y, Seasonality)$$

For the anhydrous ethanol demand equation, it essential to include the variable 'Anhydrous Fleet' (AF), equivalent to the fleet of vehicles using anhydrous ethanol, being composed of the fleet of vehicles powered by gasoline plus the fleet of flex-fuel vehicles, and for the hydrous ethanol equation, in place of the variable FF (Flex Fleet), the inclusion of the variable 'Hydrated Fleet' (HF), composed of the fleet of vehicles powered by hydrous ethanol, equivalent to the fleet of vehicles powered by alcohol, and the fleet of flex vehicles.

Table 2. Model 1 results from GMM regression

Variable	Coefficient	Std. Error	t-test	p-value
LNCEH	0,48	0.047	10.288	0.0000
LNPEH	-1,83	0.32	-5.7137	0.0000
LNPGC	1,19	0.36	3.3089	0.0014
LNIT	0,69	0.28	2.4358	0.0172
LNHF	0,22	0.98	0.9840	0.3282
LNY	0,96	0.14	6.6558	0.0000
R-square		0.93	J-test	13.56427
Adjusted R-square		0.93	Prob. (J).	0.258048

The R square of the regression was very high (Table 2), showing that the instrumentalized variables explain the model well. Except for ln Hydrated, all variables were statistically significant, at least 5%. Ethanol demand presents an expected variation of -1.83% when Ln Peh increases by 1%. The other interpretations are analogous.

The GMM minimizes a function representing the conditions of duly weighted moments. If these moment conditions are correct, they will average 0. It leads to a super-identification test using the minimized value of the function; this is the J test, which has the moment conditions correct when the null hypothesis. As shown in Table 3, the test was not rejected.

The rejection of the test represents moments that are not equal to zero; that is, one rejects the model because the condition of moments is not valid. That is, the instruments were not valid. What was not the case, the instruments were valid.

Table 3. Model 2 results from GMM regression

Variable	Coefficient	Std. Error	t-test	p-value
LNCEA	0,42	0.095	4.436274	0.0000
LNPEH	0.99	0.16	5.975518	0.0000
LNPGC	-1,68	0.35	4.699009	0.0014
LNIT	0,83	0.33	2.482698	0.0172
LNBLEND	2,27	0.23	9.721190	
LNAF	-1,49	0.33	-4.4325	0.3282
LNY	1,6	0.12	13.72629	0.0000
R-square		0.74	J-test	17.14020
Adjusted R-square		0.72	Prob. (J).	0.103796

The interpretation of results is similar to the previous one. All coefficients were statistically significant, and the J statistic was not rejected.

IV. LIMITATIONS

As noted by Randow et al. (2013) [12], although the available supply and transportation structure allows ethanol to be sold at all service stations in the country, Brazil's fuel market is relatively concentrated.

Given the concentration of production, the vast distance between most Brazilian states and the largest ethanol producers, the consequently high costs of transaction of ethanol produced, and the poor conditions of Brazilian roads, ethanol's price in most Brazilian states is very high. It exceeds 70% of the price of gasoline [12].

Sugarcane ethanol-producing states present different climatic conditions. Due to these different climatic conditions, the sugarcane harvest and consequently the idleness in ethanol production in these states is not homogeneous either.

While the interstate sugarcane harvest and the idle production of mills in the center-south region occur between November/December and March/April, in the northeastern region, they are seen between April/May and August/September [14].

We point out that ethanol prices and their consumption are not homogeneous because of the fuel production seasonality. However, the only way to consider such heterogeneity in a model is to observe each Brazilian state. Beyond that, these observations need to be monthly, which cannot yet be done due to limited information.

After consulting several databases about proxy data for consumer income, such as GDP, per capita GDP, average household income, disposable income, and energy consumption, although monthly data are available, data from each state or even municipality were not founded.

V. CONCLUSION

Two models for Brazilian ethanol demand were proposed. These models and their variables were based on the combination of antecedents re-search.

This work is the first that brought together different and relevant contributions in a single model and is the first that for each ethanol demand function, in the variable that refers to the vehicle fleet, only the vehicles that use that fuel was taken into consideration. The results returned by regression using the GMM method show that this estimate's models are generally significant.

It is concluded that more comprehensive and analytical modes of national ethanol demand would be possible. Both dependent and independent variables were based on observation for each Brazilian state instead of a single national observation. However, these advances are not possible due to data limitations.

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VII. REFERENCES

[1] Castañeda-Ayarza, J.A. et al (2017). Final and B molasses for fuel ethanol production and some market implications, *Renewable and Sustainable Energy Reviews*, vol. 70, n. 1, p.1059-1065.

[2] EPE – Energy Research Company. ABCDEnergy: Energy and Eletric Matrix, acessed *on-line* in 20/06/2019, available at <*http://epe.gov.br*>.

[3] Silva, F.B. (2017). *Feasibility analysis of corn-based ethanol: a comparative study*, Undergraduated Thesis, Rio Verde University, Rio Verde, GO, Brazil.

[4] Miotello, W.; Hoffmann. W. A. M. (2010). Apontamentos de estudos sobre Ciência, Tecnologia & Sociedade, Pedro e João Editores, 431 p.

[5] Leite, R.C. Cortez. L. A. B. E. Ministério das Relações Exteriores (MRE), acessed *on-line* in 12/07/2019, available at <*http://www.agencia.cnptia.embrapa.br/Repositorio/etanol3_000g7gq2cz702wx5ok0wtedt3xdrmftk.pdf*>.

[6] EPE – Energy Research Company. Cenários de Oferta de Etanol e Demanda do Ciclo Otto, acessed *on-line* in 13/05/2019, available at <*http://epe.gov.br*>.

[7] Buonfiglio, A. Bajay, S. V. (1992). As demandas do álcool e da gasolina no Brasil, *Revista Brasileira de Energia*, vol. 2, n. 2.

[8] Tokgoz, S, Elobeid. A. E. (2006). Na analysis of the link betwenn Ethanol, Energy and Crop Markets, *CARD Working Papers*, vol. 06.

[9] Junior, L. J. C. et al (2010). Análise da demanda brasileira de cana-de-açúcar, etanol e açúcar, *Marinha em Revista*, vol. 2.

[10] Serigati, F. C. et al. *Impacto dos veículos flex-fuel sobre o mercado de combustíveis no Brasil*. In: XLVIII Congresso da SOBER, 2010, Campo Grande-MS. Anais do XLVIII Congresso da SOBER, 2010

[11] Freitas, L. C., Kaneko, S. (2011). Ethanol demand under the flex fuel technology regime in Brazil, *Energy Economics*, vol. 33, n. 6, p.1146-1154.

[12] Randow B. M. V. (2013). Os determinantes da oferta e da demanda de etanol nos estados brasileiros, *Revista Brasileira de Energia*, vol. 19, n. 2, p.287-319.

[13] Hayashi, F. (2000). *Econometrics*, Princeton University Press, New Jersey, USA.

[14] Banco Nacional do Desenvolvimento Econômico. Centro de Gestão e Estudos Estratégicos. Sugarcane-based bioethanol: energy for sustainable development. 1st ed. Rio de Janeiro: Banco Nacional de Desenvolvimento Econômico e Social, 2008. 300 p.

[15] Azevedo R. G. N. G. (2018). Análise econômica da produção de etanol pela integração do milho nas usinas flex e full no estado do Mato Grosso. Undergraduate thesis, Universidade Federal do Paraná, Brazil.