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CIDE and elasticity oscillation on the ethanol and gasoline market: Brazilian taxation policy under discussion

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Abstract. The aim of this paper is to identify the path of the gasoline price elasticity, ethanol price elasticity, ethanol-gasoline cross-price elasticity and the gasoline-ethanol cross-price elasticity for the flex-fuel vehicle market, as well as to discuss the taxation policies impact of the Economic Domain Intervention Contribution (CIDE) on the ethanol and gasoline markets. Therefore, it was used the Structural Methodology model, as well as official data from 2003 to 2007. The results show great power of influence of the tax on the gasoline's price and on the costumer's choice between ethanol or gasoline. Thus, the CIDE is one of the most important reasons for ethanol consume, contributing to an effective reduction in the green house gases and atmospheric pollutants emissions.

Keywords: Brazilian taxation policy, price elasticity, ethanol, gasoline, consumer's choice.
JEL codes: Q42, Q48.

1. INTRODUCTION

The importance of the biofuel industry to the Brazilian economy, the urban environment and the country's strategic positioning in the world energy matrix is widely known (Brazil, 2006; Milanez *et al,*. 2012; Moraes, Bacchi, 2014; Santos, 2016). This importance dates back to the 1930s with the implementation of the Sugar and Alcohol Institute (IAA), gaining even greater relevance with the creation of the National Alcohol Program (PROÁLCOOL) in 1975, motivated by the petroleum crisis and the need to reduce its dependence. Since then, it has been important the Government participation in promoting competition, supporting technological innovation and improving policies for the biofuel industry (Shikida *et al.,* 2014).

Furthermore, there is the fact that biofuels are substitutes for petroleum derivatives, which have larger-scale production and more stable technological trajectory. Even though fossil fuels generate environmental pollution and damages to the health, which are not considered in their pricing, they have a lower cost than biofuels (Cardoso *et al.,* 2017; Santos, 2016; Neves, Conejero, 2010).

In this context, public policies have the purpose to actin the biofuels production viability, in such away that they would have conditions of competitiveness via price against fossil derivatives (Kutas *et al.,* 2007; Steenblik, 2007; Bentivoglio, Rasetti, 2015). It is not e worthy that PROÁLCOOL granted fiscal incentives for acquisition of exclusively ethanol driven cars to encourage the creation of the ethanol market. At that time, the decision for using one or other fuel was made at the car purchase time and not every refueling. At this stage, ethanol and gasoline were not substitutes (Moraes, Bacchi, 2014).

Although ethanol and gasoline are not perfect substitutes, consumers have been reacting to the hydrated ethanol price oscillations in relation to gasoline. Thus, consumers reaction to the fuel price oscillations with a specific tax, which is the Contribution of Intervention in the Economic Domain (CIDE-Fuels), is this paper's focus.

Before focusing specifically on this theme, it should be noted that historically government measures have been taken in four main thematic groups in attempt to favor biofuels, such as: i) establishment of a «market reserve» for the biofuel industry (for example, establishing a mandatory blend of 27% into gasoline); ii) the contribution of public resources to selected actions (such as research and an hydrous ethanol technology, credit subsidy, technology adoption programs); iii) supply regulation and diversification measures (storage support, ethanol supply obligation at pumps, support for the sugarcane-bagasse electricity generation); iv) exemptions and differentiation tax (Santos, 2016; Szmrecsányi, Sá, 2002).

In this context, this paper approaches the behavior of the ethanol and gasoline market in relation to only one thematic group – item iv. To this end, efforts are focused on CIDE-Fuels, or simply CIDE, because it is the main federal and the most oscillating fuel tax. Other aspects of the fuel production chain complexity – such as supply conditions, variations in other taxes, among others – are not focused in this paper.

It is easy to note that in the four groups of actions mentioned above, there are incentives for consumers to have the opportunity to choose between ethanol and gasoline for the price when arriving at the gas station. Given the other conditions and market dynamics, the hypothesis that justifies the actions in i, ii, iii and iv by the government is that they tend to balance ethanol-gasoline relative prices, mainly when there are petroleum and its derivatives price falls or macroeconomic policies changes. Such events, in this case, can make gasoline more competitive against hydrated ethanol, which demands public policies. Therefore, when approaching this issue from a stricter point of view to the economy, it is necessary to analyze the behavior of the ethanol price elasticity, gasoline price elasticity and the ethanol-gasoline cross-price elasticity. This is because the government actions tend to influence and, at the same time, to be influenced by decisions made involving the elasticities under analysis, even if not purposely.

Despite the well-known theses that are expected negative responses to tax rises, as well as the Government interference in the fuel industry, the justification for the government actions from the CIDE is to induce the consumption of a health-beneficial fuel – remembering that the CIDE is levied on gasoline and only occasionally on ethanol. Therefore, it is important to study the elasticities, so that the measures are improved in the context of the public spending optimization and the achievement of environmental and social aims (Costa, Burnquist, 2016).

Thus, the aim of this paper is to identify the path of the gasoline price elasticity, ethanol price elasticity, ethanol-gasoline cross-price elasticity, and the gasoline-ethanol cross-price elasticity for the flex-fuel vehicle market, using the Structural Model. In addition, it aims to verify the responses recorded by the market, expressed by the elasticities, on the government shock measures to induce price equilibrium. It is believed that, in this way, it can be offered one more way to assess the impacts of government policies on the fuel market, and to design more effective and efficient ethanol policies.

Considering that Brazil is one of the main ethanol producers and exporters worldwide, it is important to understand the ethanol price formation in Brazil, highlighting the Brazilian taxation policy. It can be an example for other countries since it represents an incentive for Brazilian people to consume a health-beneficial fuel. Other countries can adopt a similar system to help their economy.

2. BRIEF CONTEXT OF THE BRAZILIAN TAXATION POLICY ON FUELS

Since the Brazilian Revolution of 1930, government intervention has been strongly present in ethanol policies. In 1933 the Institute of Sugar and Alcohol

(IAA) was created, whose aim was to regulate the sugar and alcohol industry (Szmrecsányi, Sá, 2002). Another important fact for the boost of this industry was the institution of the National Alcohol Program (PROÁLCOOL) after the petroleum crises in the 1970s. It was from this Program that the ethanol production and use showed a significant increase, because the ethanol was consolidated as fuel, initially only an hydrous ethanol and, later, hydrated ethanol[1].

Brazil has been investing in the ethanol production since the 1970s, taking advantage of the natural competitiveness of sugarcane production in this country. Before that, the first incentive to boost ethanol production was through the Decree 19,717/1931, which determined the obligatory blend mandate of 5% of ethanol into imported gasoline; for vehicles of public agencies such obligation was 10% (Szmrecsányi, Sá, 2002).

In 1938 fossil fuel policies were set, with the creation of the National Petroleum Council (CNP), in which although it had federal scope, it gave the states and municipalities autonomy to create taxes on operations involving petroleum and its derivatives, such as production, distribution, marketing, consumption and import. However, in 1940, a new Law entrusted the Union to create such taxes, being levied on fuels the Import Tax (II), Sales and Consignments Tax (IVC) and Unique Tax on Fuels and Lubricants (IUCL) (Lima, 2016).

With the military dictatorship occurred in Brazil in 1964, there was a tax reform, which implied changes in the fuel prices formation. For example, the IVC was replaced by the Tax on Operations Related to the Goods Circulation and on Services of Interstate and Intercity Transport, and Communication Services (ICMS). As for the IUCL, Lima (2016, p.6) states that its rates «are now levied on tabulated amounts, fixed by the CNP. To these values, additional parcels have been added, denominated lines. The amount obtained with the sum of these lines constituted the billing price» (Lima, 2016). However, in 1980, the IUCL started to have a specific base for its computation, dissociating itself from the petroleum cost.

Furthermore, the Contribution to Social Integration Programmes (PIS), the Contribution to the Programme of Public Servants' Patrimony Formation (PASEP) and the Social Investment Fund (FINSOCIAL), which were created to be levy on business income, started to be accounted for in the fuels price in refineries (Lima, 2016).

In the 1970s, with the creation of PROÁLCOOL, the Brazilian government implemented fiscal policies to encourage the acquisition of ethanol-driven cars, since the technology did not allow the exchange of fuels. Ethanol-driven cars had lower tax, like ICMS, Taxes on Industrialized Products (IPI) and Motor Vehicle Property Tax (IPVA). In addition, the government committed to keep the ethanol price at 65% of the value paid for gasoline. With these incentives and the evolution of engine technology, sales of ethanol-driven cars grew exponentially until the late 1980s.

Currently, by Decree 9,101/2017, the main taxes which are levied on fuels are ICMS, PIS/PASEP and CIDE. CIDE was established in 2001 and has come to be considered the main instrument of government intervention to guarantee ethanol competitiveness, precisely because it was levied on gasoline.

It is worth noting that the tax burden varies according to the type of fuel and some also vary according to the Brazilian states. ICMS is an example; but, on average, its rate remains around 25% to 34% of the gasoline value; 12% to 25% of the diesel value; and from 12% to 30% of the ethanol value.

PIS/PASEP (unified in 1975) is a federal tax whose rate are R$ 0.7925/litre of gasoline, R$ 0.4615/litre of diesel and R$ 0.1309/litre of ethanol. CIDE, the focus of this study, is also a federal tax and its rate are R$ 0.10/litre of gasoline, R$ 0.05/litre of diesel and it is not levied on ethanol in the period here highlighted (2003-2007). Thus, taxes which are levied on gasoline correspond to 45% of its price, while taxes on ethanol represent 28% (National Federation of Fuels and Lubricants Trade – Fecombustíveis 2017).

Considering the taxation on fuels in São Paulo State at the beginning of 2017, it is estimated that the federal taxes value (CIDE, PIS and COFINS–Contribution for Social Security Financing) is R$ 0.652 for gasoline and R$ 0.242 for ethanol, remembering that CIDE aliquot is zero for ethanol; while the state tax (ICMS) is R$ 0.903 for gasoline and R$ 0.293 for ethanol. Thus, taxes total R$ 1.555 for gasoline and R$ 0.535 for ethanol (referring to October 2017). Considering the average selling price to consumers, the PIS/COFINS and CIDE values for gasoline correspond to approximately 73% of the value established by Decree 9,101/2017, due to the 27% of anhydrous ethanol present in the blend (Fecombustíveis 2017).

As for price formation, Lima (2016) argues that the final price paid by consumers is formed by the product value plus the taxes. In the case of gasoline, consumers also pay for the ethanol price added into gasoline. Luca and Barbosa (2016) corroborate adding that the taxes value considered in the final price paid by consumers is that in which is levied on the production, improvement, transportation, commercialization and resale of fuels. In

[1] It is emphasized that the hydrated type is the one used directly on the engines as fuel, while the anhydrous type is used in mixture with the gasoline.

this way, all or almost all of the tax burden is paid by consumers.

According to Costa and Guilhoto (2011), the final ethanol price paid by consumers is relatively more competitive vis-a-vis the gasoline price when considering CIDE rate and the differentiated ICMS rate. However, CIDE cannot be considered as the main factor in the increase of the ethanol competitiveness in relation to gasoline, since it has been used more as an inflationary control than a stimulus to the ethanol consumption. It was evident during the financial crisis of 2008, in which the CIDE rate decreased from R$ 0.28 to R$ 0.18 per liter.

In the early 2000s, with the introduction of the flex-fuel vehicle in Brazil, the ethanol use as a pure fuel without addition of gasoline was further expanded. For these vehicles, consumers could choose between ethanol or gasoline, or a mixture between both. Thus, assuming there is no price control and strong macroeconomic policy influences, when the petroleum and its derivatives prices are high, ethanol consumption is favored and, therefore, its production increases (Santos, 2016).

Thus, top revent the petroleum price instability from significantly affecting the sugar and alcohol sector, the government decided to obligate ethanol mixture into gasoline, guaranteeing part of the ethanol production and consumption. By Law 13,033/2014, such mixture is 27% of ethanol anhydrous into gasoline. Since 2016, the government also opted to defend the market autonomy regarding the practice of fuel prices in general, based on the PETROBRÁS autonomy as the main gasoline producer and distributor and an important stakeholder in the ethanol distribution.

3. METHODOLOGY

Most of the studies that address the issue of the fuel market elasticities in Brazil use traditional time series models focused on cointegration, which have the advantage of producing elasticities of both short-and long-term. However, the elasticities values are average values for a given period. In this way, this study uses the Structural Model, since it has the advantage of obtaining the point-to-point elasticities for the analyzed period. This information will be useful in identifying the intensity of consumers responses and behavior in relation to the government measures which impact some goods prices.

3.1. Theoretical model

According to Hughes *et al.* (2006), several studies on the gasoline price elasticity are based on microeconomic theory, being the quantity demanded of product as an inverse function of gasoline price and a direct function of income. More specifically, as stated by Sterner and Dahl (1992), the gasoline demand model is based on the hypothesis that the utility function of the consumer depends on gasoline demand (*GD*) plus aggregate demand for other goods (*OD*). Consumers know both the gasoline price (*GP*) and the other goods prices (*OP*) – hypothesis of full rationality, being the other goods prices represented by the consumer price index. Based on the assumption that consumers are rational, they choose *GP* and *OP* in such a way as to maximize their respective utility function, which is given by their respective budget constraint, represented as $(GP^*GD)+(OP^*OD)\leq Y$, where Y is the consumer's income.

Therefore, the equation to be maximized is the combination of the consumer utility function and its budget constraint, $U(GD,OD)+\lambda[Y-(GP^*GD)-(OP^*OD)]$, where λ is Lagrange multiplier. Based on the hypothesis of the traditional neoclassical microeconomic model, it is estimated that the quantity demanded of gasoline is a function of the gasoline price, the substitute good price and of the income. However, in the case of the non-existence of a substitute for gasoline, the determination of the gasoline price elasticity presents a more restricted econometric model, since the amount of gasoline consumed depends only on its own price and on the consumer's income. This model is written as:

$$lnGD_t=\beta_0+\beta_1\ lnGP_t+\beta_2\ lnY_t+\varepsilon_t \tag{1}$$

where GD_t corresponds to the quantity demanded of gasoline; β_0 is the constant; β_1 represents the price elasticity; GP_t is the gasoline price; β_2 is the income elasticity; and Y_t is the consumer's income. Finally, ε_t corresponds to the residues which, by hypothesis, are random. Considering that the variables are in the logarithmic format, the estimated coefficients correspond to the respective elasticities.

Alves and Bueno (2003) estimated the gasoline demand for Brazil using Engle-Granger's cointegration method (Engle, Granger, 1991) based on equation (1), which represents gasoline demand models. One item that distinguishes this model from the models applied in the international market is the introduction of the ethanol price as a substitute for gasoline. The econometric model for the gasoline demand has this composition:

$$lnGD_t=\beta_0+\beta_1\ lnGP_t+\beta_2\ lnY_t+\beta_3\ lnEP_t+\varepsilon_t \tag{2}$$

where β_3 is the cross-price elasticity and EP_t is the ethanol price, while the other variables and parameters remain the same as in equation (1).

However, when Alves and Bueno's study was developed, the flex-fuel car technology was not used on a commercial scale yet, since this technology started being commercialized only from 2003. On the other hand, from 2003 onwards, the use of flex-fuel vehicles showed an upward trend, reaching almost 80% of the new vehicles that went into circulation in São Paulo State in 2012.

In this context, this paper analyses both the gasoline and the ethanol market, emphasizing that the introduction of the flex-fuel car was a watershed, allowing the consumer greater freedom in terms of which fuel to use. Thus, a second model was estimated aiming to determine the ethanol demand:

$$lnED_t=\beta_0+\beta_1\ lnGP_t+\beta_2\ lnY_t+\beta_3\ lnEP_t+\varepsilon_t \qquad (3)$$

where ED_t represents the quantity demanded of ethanol; and the other elements have already been defined previously.

From models (2) and (3),the respective long-run elasticities can be estimated as:

$$\frac{\partial lnGD_t}{\partial lnGP_t}=\beta_1;\ \frac{\partial lnGD_t}{\partial lnY_t}=\beta_2;\ \frac{\partial lnGD_t}{\partial lnEP_t}=\beta_3 \qquad (4)$$

where the first term corresponds to the gasoline price elasticity; the second represents the gasoline income elasticity, and the third represents the cross-price elasticity between ethanol price and the quantity demanded of gasoline. Similar reasoning applies to the calculations of the long-run elasticities of the ethanol demand model.

3.2. Data

This paper analyses price elasticities and cross-price elasticities in the gasoline and ethanol markets, using data from São Paulo State because it is statistically representative of Brazil. The series used were: gasoline average price (*Gasoline price*); amount of gasoline commercialized (*Gasoline sale*); hydrated ethanol average price (*Ethanol price*); and amount of hydrated ethanol commercialized (*Ethanol sale*). All these variables were obtained for retail in São Paulo State in the Price Survey System of the National Agency of Petroleum, Natural Gas and Biofuels (ANP, 2018). Brazilian Gross Domestic Product (GDP-BR) was used as proxy for income, whose source was the Institute of Applied Economic Research database (IPEADATA, 2017).

All variables were used in logarithm form, so their estimated coefficients represent their respective elasticities. To identify variables in logarithmic form, the letter *L* was added at the beginning of their acronym. The period analyzed is from January 2003 to May 2017.

In order to verify the impacts due to government measures, data about fuel tax were used (Tab. 1). Selected data refers to the months when there was some oscillation on taxes.

3.3. Structural Model

Traditional econometric methods, such as regression or time series models, for example, Transfer Function Models, Engle-Granger Cointegration and Vector Error Correction Model (VECM), among others, allow one to estimate the mean elasticity in both the short-and long-run period. However, such methods do not consider the unobservable components, which will be presented in detail in this subsection.

Tab. 1. Tax rates on gasoline and ethanol: Jan./2003 to May/2017 (R$ nominal).

Period	CIDE Gasoline	CIDE Ethanol	PIS Gasoline	COFINS Gasoline	PIS Gasoline	COFINS Ethanol
Jan./2003 – Dec./2003	0.38	0.007	0.058	0.2344	0.0508	0.2344
Jan./2004 – Dec./2004	0.41	0.007	0.058	0.2344	0.0508	0.2344
Jan./2005 – Dec./2008	0.21	0.000	0.058	0.2344	0.0508	0.2344
Jan./2009 – Dec./2009	0.14	0.000	0.058	0.2344	0.0508	0.2344
Jan./2010 – Jan./2011	0.17	0.000	0.058	0.2344	0.0508	0.2344
Feb./2011 – Apr./2011	0.11	0.000	0.058	0.2344	0.0508	0.2344
May/2011 – Dec./2011	0.17	0.000	0.058	0.2344	0.0508	0.2344
Jan./2012 – Oct./2012	0.14	0.000	0.058	0.2344	0.0508	0.2344
Nov./2012 – Jun./2013	0.07	0.000	0.058	0.2344	0.0508	0.2344
Jul./2013 – Apr./2015	0.00	0.000	0.058	0.2344	0.0508	0.2344
May/2015 – May/2017	0.10	0.000	0.058	0.2344	0.0508	0.2344

Source: Federal Senate (2018).

This paper uses Structural Model to estimate the price elasticity, income elasticity and the cross-price elasticity in the gasoline and ethanol markets. However, the main advantage of Structural Model is to determine not only the average elasticity, but also the respective point-to-point elasticities over time. In this paper, the focus is on variable elasticities calculations rather than average elasticities, specifically on the gasoline price elasticity, ethanol-gasoline cross-price elasticity, ethanol price elasticity, and the gasoline-ethanol cross-price elasticity.

Structural Model allows time series decomposition into its four unobservable components: Trend, Seasonality, Cycle and Irregular component. Tendency component is decomposed into two parts, series level and its respective slope, allowing to determine whether series level is constant or not, and whether its slope is constant or not over time. It also allows us to determine if there is Seasonality, and once it is confirmed, whether it is stochastic or deterministic; the same occurs with the Cycle component. In relation to the Irregular component, Structural Model allows its modelling through the Autoregressive-moving-average Model (ARMA), for both regular and seasonal parameters.

Mathematically, Irregular component is represented as:

$$\phi(B)\Phi(B^s)\ \varepsilon_t=\theta(B)\Theta(B^s)\ a_t \quad (5)$$

where B corresponds to the lag operator, which is defined as $B\varepsilon_t=\varepsilon_{t-1}$. Thus, the greater exponent, the greater its time lag.ARMA model is represented by a set of polynomials. The term $\phi(B)$ is the regular autoregressive polynomial; $\Phi(B^s)$ is the seasonal autoregression polynomial; $\theta(B)$ is the regular moving average polynomial; $\Theta(B^s)$ is the seasonal moving average component; and s is the extent of seasonality.

Mathematically, complete Structural Model can be written as:

$$Ln(Y_t) = \mu_t + \gamma_t + \psi_t + \sum_{k=0}^{k}\big(\varepsilon_i ln(X_{t-k})\big) + \beta_t w_t + \phi_t + \sum_{t=2}^{t}\varphi_i Y_{t-1} + \epsilon_t \quad (6)$$

Trend (μ_t) can be subdivided into two components, level and slope, whose formulae are:

$$\mu_{t+1}=\mu_t+\nu_t+\xi_t \text{ (level)} \quad (7)$$
$$\nu_{t+1}=\nu_t+\zeta_t \text{ (slope)} \quad (8)$$

Variation in level and slope is managed by the variances of the terms ξ_t and ζ_t in the respective equations. If the variance ξ_t=0, the slope will be constant and equal to ν_0. On the other hand, if the variance ζ_t=0, it implies that μ_t will be a deterministic trend given by $\mu_0+\nu_0 t$.

Seasonal component can be represented by two ways: dummy variables or trigonometric terms. In the case of seasonality representation by dummy variables, with the extension of seasonality represented by s, we have the following stochastic equation:

$$\sum_{i=0}^{s-1}\gamma_{t-i} = \omega_t\ , \omega_t \sim i.i.d. N(0,\sigma_\omega^2) \quad (9)$$

Seasonality (γ_t), in the case of monthly data, implies that s=12. In this paper seasonality with trigonometric basis was used:

$$\gamma_t = \sum_{j=1}^{[s/2]}\gamma_{j,t} \quad (10)$$

where j = 1, 2, ..., [s / 2] and each $\gamma_{j,t}$ is generated by the following formulae:

$$\gamma_{j,t+1}=\gamma_{j,t}\ \cos\lambda_j+\gamma_{j,t}^{*}\text{sen}\lambda_j+\omega_{j,t} \quad (11)$$

$$\gamma^{*}_{j,t+1}=-\gamma_{j,t}\ \cos\lambda_j+\gamma_{j,t}^{*}\text{sen}\lambda_j+\omega_{j,t}^{*} \quad (12)$$

where $\lambda_j=\frac{2\pi j}{s}$ is the frequency in radians, and the terms ω_t and $\omega_t{}^*$ are mutually independent.

ψ_t represents the cyclic component. Stochastic equation that manages the Cycle component of period p and the damping factor ρ is:

$$\begin{bmatrix}\psi_t\\ \psi *_t\end{bmatrix} = \rho\begin{bmatrix}\cos\lambda \sin\lambda\\ -\sin\lambda\cos\lambda\end{bmatrix}\begin{bmatrix}\psi_{t-1}\\ \psi *_{t-1}\end{bmatrix} + \begin{bmatrix}\upsilon_t\\ \upsilon *_t\end{bmatrix} \quad (13)$$

where υ_t and υ^*_t represent independent Gaussian errors with zero mean and variance σ^2_υ; and $\lambda=\frac{2\pi}{p}$ is the cycle angular frequency. Any period (p) greater than 2 is permissible, while damping factor (ρ) may assume any value in the interval (0, 1], i.e. including one, but excluding zero. Values of ρ smaller than one produce stationary cycle, while ρ = 1 produces non-stationary cycle.

ϕ_t is the autoregressive term; $\beta_t\ w_t$ allows to use dummy variables to treat structural breaks due to the presence of outliers; and $\varphi_i\ Y_{t-1}$ represents the lagged dependent variable.

After the Structural Model estimation, it is necessary to analyze residues in order to verify the effectiveness of the filtering process.

Among the statistics used to verify if the estimated model is suitable or not, we have the Mean Squared Error (or Error Variance), whose formula is:

$$MSE = \frac{\sum_{t=0}^{T}(y_t-\widehat{y_t})^2}{T-k} = \frac{SSR}{T-k'} \quad (14)$$

where *SSR* corresponds to the sum of squared residuals and is given by the following formula: $SSR = \sum_{t=0}^{T}(y_t - \hat{y}_t)^2$; being y_t the value observed in period *t*; $\hat{y}_t$ the predicted value within the sample at time *t*; *T* is the number of sample observations; and *k* is the number of estimated parameters. The closer to zero the *MSE*, the more predicted values approach the observed values, and the better the model fit. A second indicator used was the Root Mean Square Error (RMSE), whose formula is:

$$RMSE = \sqrt{SSR} = \sqrt{\frac{SSR}{T-k}} \qquad (15)$$

As in previous statistics, the closer to zero the *RMSE*, the better the model fit. Another important statistic is the Mean Absolute Percentage Error (MAPE), which determines the accuracy of the model. The closer to zero the *MAPE*, the better the model fit. Its formula is as follows:

$$MAPE = \frac{100}{T}\sum_{t=0}^{T}\left|\frac{(y_t - \hat{y}_t)}{y_t}\right| \qquad (16)$$

Other indicators used to evaluate the model estimated in this paper were: Coefficient of Determination (R^2), adjusted R^2, Random Walk R^2 and Amemiya's adjusted R^2.In general, R^2 is the most commonly used measure of adjustment and consists of a squared correlation coefficient ranging between 0 and 1. The closer to the unit, the better the model fit.

Mathematically, R^2 is represented as:

$$R^2 = 1 - \frac{SSR}{TSS} \qquad (17)$$

where TSS is the total sum of squares.

According to Brooks (2002), it should be noted that R^2has some problems. Given that R^2 is defined in terms of variation around the mean of *y*. If the model is reparametrized and the dependent variable is modified, the value of R^2 will also change. Therefore, R^2 values should not be compared between models with different dependent variables. R^2 value also never decreases if more regressors are added to the model. Thus, it is impossible to use R^2 as a determinant whether one variable should be present in the model or not.

To solve problems related toR^2, we often consider the loss of degrees of freedom associated with including more variables in the model. It is known as adjusted R^2:

$$\overline{R^2} = 1 - \left[\left(\frac{T-1}{T-k}\right)(1 - R^2)\right] \qquad (18)$$

If an extra regressor is added to the model, *k* increases and, unless R^2 more than compensates for this increase, the value of the adjusted R^2 will decrease. Consequently, the adjusted R^2 can be used to make decision whether a given variable should or should not be included in the model.

A variant of adjustedR^2 is Amemiya's adjusted R^2. According to Yaffee and McGee (2000, p. 219), «adjusted R^2 and Amemiya's adjusted R^2 use different adjustments to compensate for the number of parameters which are being estimated». The formula for Amemiya's adjusted R^2 is:

$$Amemiya's\ adjusted\ \overline{R^2} = 1 - \left[\left(\frac{T+k}{T-k}\right)(1 - R^2)\right] \qquad (19)$$

For both the adjusted R^2 and the Amemiya's adjusted R^2, the best model fit occurs when their respective values approach the unit.

Finally, the last indicator used was the Random Walk R^2, which compares R^2 of the estimated model with R^2 of a random variable. Its formula is as follows:

$$Random\ Walk\ R^2 = 1 - \left(\frac{T-1}{T}\right)\frac{SSR}{SSRRV} \qquad (20)$$

where: $SSRRV = \sum_{t-2}^{T}(y_t - y_{t-1} - \mu)^2$ and $\mu = \frac{1}{T-1}\sum_{t=2}^{T}(y_t - y_{t-1})$, in which *SSRRV* is the sum of squared residuals of the random variable; and μ is a constant or mean value of the series.

It is important to highlight that in the Structural Model, the first step consists in verifying that each of the unobservable components of the time series, Trend (level and slope), Seasonality, Cycle and Irregular component, presents stochastic or deterministic behavior.

In this paper, instead of removing all the non-statistically significant parameters at once, we opted for the individual removal of each parameter. After this removal, the model was estimated again, and so on, until the model with all the statistically significant parameters.

4. RESULTS AND DISCUSSION

In this section, we present empirical data and the results obtained with the application of the Structural Model. Demand models and elasticities of ethanol and gasoline are considered according to the consumer's options on fueling their flex-fuel car.

4.1. Gasoline demand model

Results for this model are presented in Table 2 and should be interpreted from the point of view of both means and variances.

Tab. 2. Structural model's estimates results for the gasoline market, São Paulo State: Jan./2003 to May/2017.

Component	Parameter	Estimate	Standard Error of the Estimate	*t*-value	*p*-value
LGDPBR	Coefficient	0.91384	0.16363	5.58	< 0.0001
LS99[1]	Coefficient	0.23318	0.04786	4.87	< 0.0001
AO01[2]	Coefficient	0.14541	0.03718	3.91	< 0.0001
AO100[3]	Coefficient	0.13405	0.03885	3.45	0.0006
LS05[4]	Coefficient	0.11693	0.03731	3.13	0.0017
AO03[5]	Coefficient	-0.06994	0.02549	-2.74	0.0061
Lgasolineprice	Error Variance	0.00131	0.0002921	4.49	< 0.0001
Lethanolprice	Error Variance	0.00151	0.0008440	1.79	0.0739

Source: Research results.
[1]Dummy, Level Shift in March 2011; [2]Dummy, Additive Outlier in January 2003, [3]Dummy, Additive Outlier in April 2011, [4]Dummy, Level Shift in April 2003 and [5]Dummy, Additive Outlier in March 2003.

In general, all the estimated parameters are statistically relevant at the significance level of 10%. In relation to the means, it can be observed that 1% variation in income, represented by Brazil's GDP, induces an average change of 0.9138% in the quantity sold of gasoline in São Paulo State, forming an inelastic relation. In addition, to estimate the model, it was necessary to insert five intervention variables, being three of the Additive Outlier (AO) and two of the Level Shift (LS) type, according to Table 2. On the variance point of view, both gasoline price and ethanol price are statistically significant, considering the significance level of 10%. This implies that both variables have stochastic behavior over time.

Different indicators produced, which show the results robustness, are adequate, since MSE, RMSE and MAPE are close to zero (Tab. 3). This fact indicates that differences between the observed and estimated values are very close and, therefore, the model is well-adjusted.

Indicators based on the R^2 criterion are also adequate, since the adjusted R^2 and the Amemiya's adjusted R^2 are close to 60%. It indicates that 60% of the dependent variable's behavior are explained by independent variables and the time series components (Tab. 2).

Figure 1 presents the residuals correlograms of the gasoline demand model. As can be seen, residues are free of autocorrelation, that is, they correspond to white noise.

At the beginning of the series, January 2003, CIDE's rate was equal to R$ 0.38/liter on gasoline, while CIDE's rate on ethanol was R$ 0.07/liter. Both rates remained constant until December 2003. In this period, it is observed that the gasoline price elasticity and the ethanol-gasoline cross-price elasticity tend to become more elastic (Fig. 2). However, its sign is negative, but it should be positive, according to the economic theory.

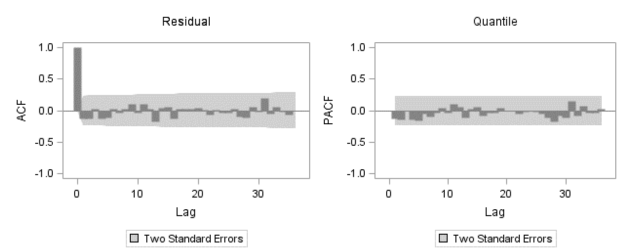
From January to December 2004, CIDE's rate on the gasoline price increased to R$ 0.41/liter, while this rate on ethanol remained at R$ 0.07/liter. In this period, the gasoline price elasticity had two distinct phases. Until the middle of 2004, the gasoline price elasticity continued to increase, in module, and reversed its trajec-

Tab. 3. Statistical indicators for the estimated structural model for the gasoline market, São Paulo State: Jan./2003 to May/2017.

Statistical Indicators	Statistical Adjustment Based on Residuals
Mean Squared Error	0.00281
Root Mean Square Error	0.05298
Mean Absolute Percentage Error	0.20257
R^2	0.60529
Adjusted R^2	0.59973
Random Walk R^2	0.63322
Amemiya's Adjusted R^2	0.58306

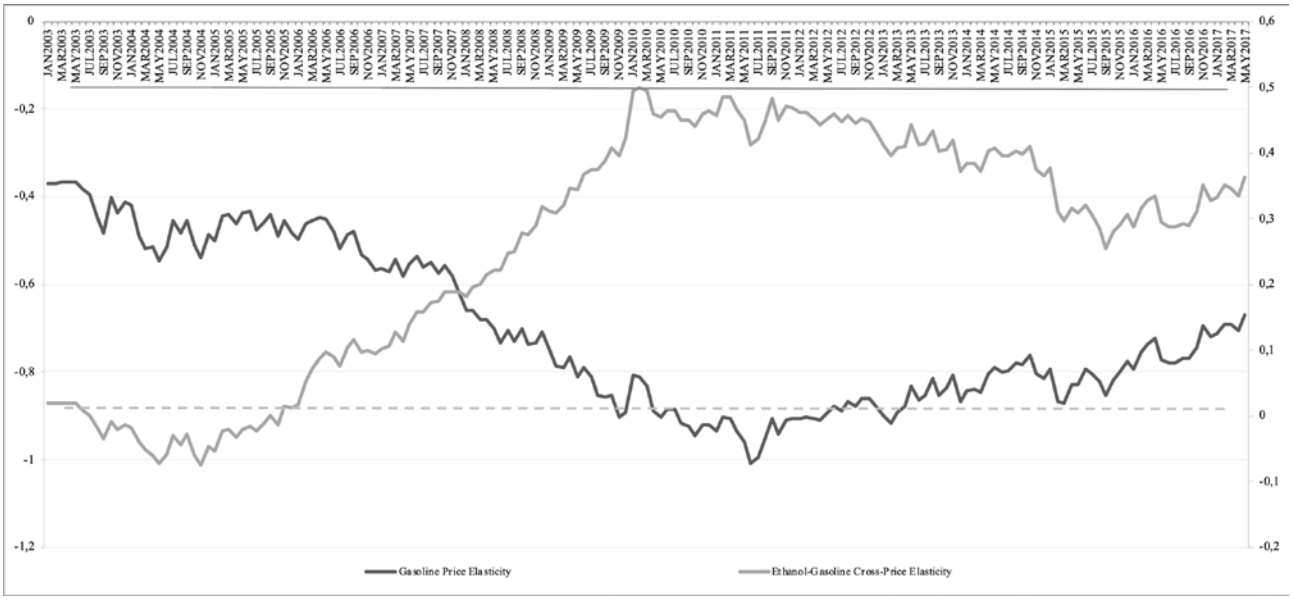
Source: Research results.

Fig. 1. Autocorrelation and partial autocorrelation of residuals of the structural model of gasoline demand, São Paulo State: Jan./2003 to May/2017.



Source: Research Results.

Fig. 2. Gasoline price elasticity and ethanol-gasoline cross-price elasticity evolution, São Paulo State: Jan./2003 to May/2017.



tory, becoming less elastic, whereas the ethanol-gasoline cross-price elasticity continued with a negative sign.

From January 2005 to December 2008, there was a reduction in CIDE's rate on gasoline to R$ 0.21/liter, while CIDE's rate on ethanol was zero. In this period there are two interesting moments. According to Figure 2, from January to July 2005, the gasoline price elasticity fluctuated, but it did not change its level. From August 2005 to December 2008, the gasoline price elasticity became more elastic, that is, the reduction in CIDE's rate on the gasoline price has made the gasoline demand more sensitive because it increased the competitiveness of gasoline in relation to ethanol.

As for the ethanol-gasoline cross-price elasticity, in the same period, it is verified that up to November 2005 this elasticity continued with the negative sign, but from December 2005 there was an upward trend. These behaviors confirm that, despite CIDE's rate on ethanol is zero, the reduction in this rate on gasoline had a greater impact on both gasoline and ethanol demand than on the reduction in CIDE's rate on ethanol.

Results seem to be related to another relevant factor, such as the uncertainties in the fuel market, the expansion of flex-fuel vehicles from 2004, and the great expansion of the ethanol supply from the 2004/2005 crop year.

The great entry of flex-fuel vehicles into the Brazilian market is a possible explanation for the behavior of the ethanol-gasoline cross-price elasticity, which has contributed to make demand more elastic, as it has provided the consumer with a substitute product. With the flex-fuel vehicles, the consumer decision between gasoline and ethanol is made in each fueling and not more at the time of vehicle purchase.

It can be inferred that the evolution of flex-fuel vehicles sales and the reduction in the market for gasoline-driven cars, coupled with the reduction in CIDE's rate on gasoline price, influenced trend in the gasoline price elasticity and in the ethanol-gasoline cross-price elasticity. This up ward trend in both elasticities continued between January and December 2009, evidenced by the two elasticities which had divergent trajectories, both becoming less inelastic (Fig. 1).

It is important to remember that, in that period, CIDE's rate on gasoline decreased from R$ 0.21/liter to R$ 0.14/liter, while this rate on ethanol remained at zero. Thus, it can be inferred that the reduction in CIDE's rate on gasoline and the consolidation of flex-fuel vehicles in the Brazilian market significantly altered the elasticities of the fuel market.

From January 2010 to January 2011, CIDE's rate on gasoline was raised to R$ 0.17/liter, whereas it remained at zero on ethanol. In this period, while the gasoline price elasticity continued to increase in modulus, the ethanol-gasoline cross-price elasticity reached its highest value throughout the analyzed period (January 2003 to May 2017), approaching 0.5, then presented a small retraction and returned to increase at the end of the period, as shown in Figure 2. On the other hand, in the same period, whilst the fleet of gasoline-driven vehicles continued to decline, the fleet of flex-fuel vehicles continued to grow, but at decreasing rates, possibly due to the economic crisis occurred in 2008.

From February to April 2011, CIDE's rate on gasoline was reduced to R$ 0.11/liter, and CIDE's rate ethanol remained at zero. Apparently, this gave rise to the trajectories of the two elasticities in March. The trajectory of the gasoline price elasticity, initially descending, rose and, in the end, returned to its downward trajectory. Regarding to the ethanol-gasoline cross-price elasticity, there was a movement in the opposite direction. Despite the period, it was possible to observe that changes in fuel prices affected consumers behavior, even in the short-term.

From May 2011, CIDE's rate on gasoline was readjusted to R$ 0.17/liter, keeping CIDE's rate on ethanol at zero until December 2011. In this period, for both elasticities, two similar movements are identified, but in the opposite direction. The gasoline price elasticity reached its lowest value during all the analyzed period, resulting in unit elasticity in June 2011, then reversed the trajectory. Cross-price elasticity trajectory presented opposite movement. It is necessary to emphasize two aspects: first, both elasticities, which previously tended to diverge in their respective trajectories, began to converge and showed co-movement behaviors. Second, the increase in the CIDE's rate on gasoline price initially impacts both elasticities by changing the respective trajectories. On the vehicle market side, it is observed that the flex-fuel vehicles fleet continued to increase, however, at lower rates, especially because of the reduction in the ethanol supply (Santos, 2016). These facts can explain the changes in the respective elasticities.

Despite the reduction in CIDE's rate on gasoline to R$ 0.07/liter from November 2012 to June 2013, and remaining CIDE's rate on ethanol at zero in the same period, there is another rally in the trajectories of both elasticities. In this period both elasticities tend to become more inelastic (Fig. 2), starting a new period of stabilization highlighting the gasoline competitive advantage, although in 2013 the flex-fuel vehicles had reached the apex of sales. This set of indicators shows that the flex-fuel vehicle success is not related to the ethanol competitiveness itself.

Until April 2015 CIDE's rate on gasoline was zero, as well as that one on ethanol. In this period, both elasticities had more inelastic trajectories, as seen in Figure2. Even with both rates equal zero, elasticities tended to become more inelastic, i.e. apparently the price effect was exceeded by the income effect. This period is characterized by uncertainties in policies, falling income, rising unemployment, and the reduction in vehicle sales in general. In other words, both elasticities became less sensitive, that is, changes in gasoline prices induced less variation in the quantity demanded of gasoline, and the same effect in relation to the increase in ethanol. This means that even with CIDE's rate being zero, the price effect was not offset by the income effect, that is, the magnitude of the fall in consumer income more than offset the effect related to the reduction in the gasoline price.

In May 2015 CIDE's rate on gasoline was adjusted to R$ 0.10/liter. The impact of this increase is evident in the behavior of the elasticities in Figure 2, since, from June 2015, the gasoline elasticity price presented ascending trajectory, becoming more inelastic. The ethanol-gasoline cross-price elasticity had reversed its downward trend, assuming an upward trend, that is, it became less inelastic. Possibly, the economic uncertainty in this period may have induced consumers to be more sensitive to changes in the ethanol price than in the gasoline price, even with the increase in CIDE's rate on gasoline. However, it is important to highlight that ethanol supply growth was lower than the growth in consumption of the Otto cycle fuels. Therefore, ethanol naturally reduced its market share since exports also declined.

4.2 Ethanol demand model

Based on the estimated coefficients for the ethanol market, it is verified that, on the means side, all coefficients are statistically significant for the significance level of 1% (Tab. 4).

In economic terms, there is a variation of 1% in income, which induces to a variation of 1.72% in the amount of ethanol demanded, forming an elastic relationship between these two variables. Compared to the gasoline market, the income effect in the ethanol market is much more elastic (0.98 for gasoline versus 1.72 for ethanol). It was also necessary to insert eight dummy variables to estimate the model, being three Additive Outlier (AO) and five Level Shift (LS) variables.

According to Table 5, the indicators show that results are robust, since MSE, RMSE and MAPE are close to zero, indicating that the differences between the observed and estimated values are very close, that is, they emphasize that the model is well-adjusted.

Indicators based on the R^2 criterion are also adequate, since the adjusted R^2 and the Amemiya's adjusted R^2 are close to 80%. It indicates that 80% of the dependent variable's behavior are explained by independent variables and the time series components (Tab. 5).

Figure 3 presents the residuals correlograms of the gasoline demand model. As can be seen, residues are free of autocorrelation, that is, they correspond to white noise.

Tab. 4. Structural model's estimates results for the ethanol market, São Paulo State: Jan./2003 to May/2017.

Component	Parameter	Estimate	Standard Error of the Estimate	*t*-value	*p*-value
Irregular	Error Variance	0.00059115	0.0002163	2.73	0.0063
LGDPBR	Coefficient	1.72552	0.24632	7.01	<0.0001
AO01[1]	Coefficient	0.32829	0.05374	6.11	<0.0001
LS37[2]	Coefficient	0.36825	0.05758	6.40	<0.0001
LS12[3]	Coefficient	0.34281	0.04140	8.28	<0.0001
AO09[4]	Coefficient	-0.14010	0.03757	-3.73	0.0002
LS20[5]	Coefficient	-0.20986	0.04903	-4.28	<0.0001
LS99[6]	Coefficient	-0.33941	0.06872	-4.94	<0.0001
LS49[7]	Coefficient	0.19258	0.05442	3.54	0.0004
AO100[8]	Coefficient	-0.33938	0.05987	-5.67	<0.0001
Lgasolineprice	Error Variance	0.00427	0.0016307	2.62	0.0089
Lethanolprice	Error Variance	0.00116	0.0005553	2.10	0.0361

Source: Research results.

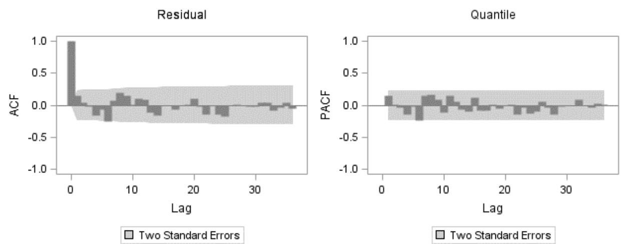
[1]Dummy, Additive Outlier in January 2003; [2]Dummy, Level Shift in January 2006, [3]Dummy, Level Shift in December 2003, [4]Dummy, Additive Outlier in September 2003, [5]Dummy, Level Shift in August 2004, [6]Dummy, Level Shift in March 2011, [7]Dummy, Level Shift in January 2007, and [8]Dummy, Additive Outlier in April 2011.

Tab. 5. Statistical indicators for the estimated structural model for the ethanol market, São Paulo State: Jan./2003 to May/2017.

Statistical Indicators	Statistical Adjustment Based on Residuals
Mean Squared Error	0.00541
Root Mean Square Error	0.07354
Mean Absolute Percentage Error	0.27457
R^2	0.83691
Adjusted R^2	0.83225
Random Walk R^2	0.57592
Amemiya's Adjusted R^2	0.82294

Source: Research results.

Fig. 3. Autocorrelation and partial autocorrelation of residuals of the structural model of ethanol demand, São Paulo State: Jan./2003 to May/2017.



Source: Research results.

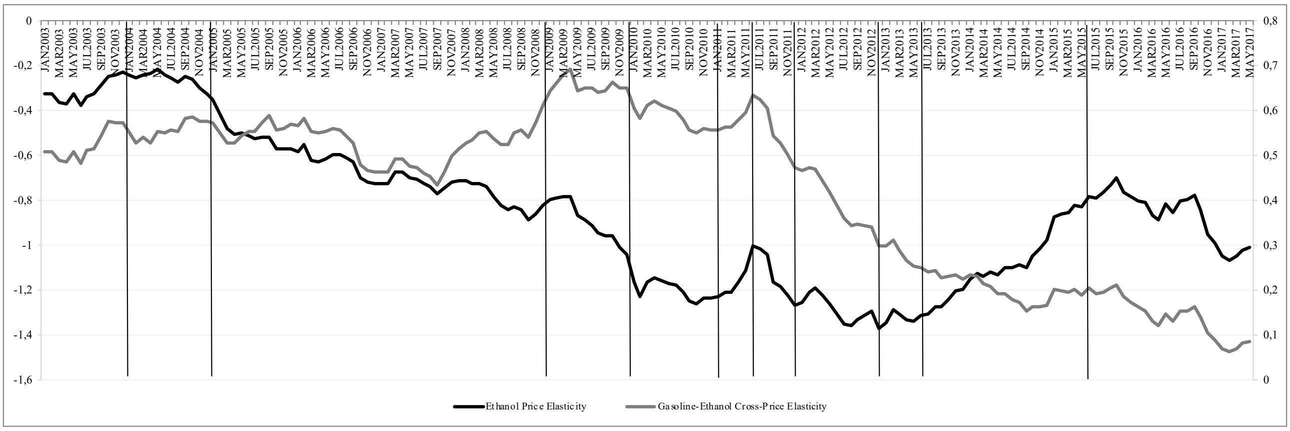
Between January and December 2003, CIDE's rates on gasoline and ethanol were R$ 0.38/liter and R$ 0.07/liter, respectively. In this period, while the ethanol price elasticity became more inelastic with an upward trajectory, the gasoline-ethanol cross-price elasticity became more elastic presenting an upward trajectory (Fig. 4).The increase in the flex-fuel market possibly justifies the respective elasticities behavior.

From January to December 2004, CIDE's rate on gasoline price increased from R$ 0.38/liter to R$ 0.41/liter, while this rate on ethanol remained at R$ 0.07/liter. In this period, the ethanol price elasticity increased in magnitude at the end of the period, becoming less inelastic. Contrary movement occurred in relation to the gasoline-ethanol cross-price elasticity, as it tended to become more inelastic at the end of the period (Fig. 4).

The fact that the ethanol price elasticity tends to become more elastic may be related to the rapid expansion of flex-fuel vehicles sales in the analyzed period. Therefore, the increase in CIDE's rate on gasoline and keeping on CIDE's rate on ethanol, coupled with the presence of a substitute product for the gasoline-driven vehicle, conditioned both elasticities to diverge at the end of the period, since the ethanol price elasticity became more inelastic, while the opposite occurred with the gasoline-ethanol cross-price elasticity.

Between January 2005 and December 2008, CIDE's rate on gasoline reduced to R$ 0.21/liter, and it remained at zero on ethanol. From January 2005 to June 2007, both elasticities followed the same direction, that is, while the ethanol price elasticity became more elastic, the gasoline-ethanol cross-price elasticity became more

Fig. 4. Ethanol price elasticity and gasoline-ethanol cross-price elasticity evolution, São Paulo State: Jan./2003 to May/2017.



inelastic. After July 2007 until December 2008, the ethanol price elasticity continued its trajectory and became even more elastic. Nonetheless, the gasoline-ethanol cross-price elasticity trajectory reversed its position and became more elastic, with the trajectories of both elasticities becoming divergent.

It should be noted that in this period occurred several facts that may have contributed to both elasticities trajectories, among which the following stand out: i) flex-fuel vehicle sales grew at increasing rates; ii) sales of gasoline-driven vehicles declined significantly; iii) the government, aimed at containing inflation, insured that fossil fuels prices did not be transferred totally to the domestic consumer in the period prior to the international financial crisis in 2008 (Santos, 2016).

From January to December 2009 there was a further reduction in CIDE's rate on gasoline to R$ 0.14/liter, remaining CIDE's rate on ethanol at zero. In this period, the ethanol elasticity-price continued to fall, that is, this elasticity become increasing in magnitude, even becoming equals to one in December 2009, while the gasoline-ethanol cross-price elasticity also became more elastic, reaching its value equals to 0.7 (Fig. 4). Possibly, this fact is showing the increase in the substitution effect between both fuels, and the productive chain complexity, which responds immediately to the measures that result in competitive factors imbalance. On the other hand, it needs one or two crops, or even a complete cycle sugarcane cultivation to respond to the measures of balance in supply (six or seven years) (Santos, 2016).

In January 2010, CIDE's rate on gasoline rose to R$ 0.17/liter, and again the CIDE's rate on ethanol remained at zero. These rates were into force until January 2011. While the ethanol price elasticity continued becoming more elastic, exceeding the value of -1.2, the gasoline-ethanol cross-price elasticity trended to become more inelastic, that is, less sensitive to price changes.

As already mentioned, between February and April 2011, CIDE's rate on gasoline was reduced to R$ 0.11/liter, while it remained at zero on ethanol. It is observed that the reduction in CIDE's rate on gasoline changed the trajectories of both elasticities because the ethanol supply was limited, since it is the final period of the off-season, in which historically the ethanol price becomes higher than the gasoline price. While the ethanol price elasticity became more inelastic, the gasoline-ethanol cross-price elasticity became more elastic (Fig. 4). Therefore, the reduction in CIDE' rate on gasoline made this fuel even more competitive in relation to ethanol.

From May 2011, CIDE's rate on gasoline was R$ 0.17/liter and it remained at zero on ethanol until December 2011. The ethanol price elasticity became more elastic, exceeding the value of -1.2, while the gasoline-ethanol cross-price elasticity became much more inelastic (Fig. 4). Based on these behaviors, it is observed that ethanol has become more competitive in relation to gasoline, and the Brazilian economy crisis was reflected on the light vehicle market, which presented decreasing rates. Therefore, it can be inferred that the reduction in consumer income was relevant to change the respective price effects in the ethanol market.

Between January and October 2012, CIDE's rate on gasoline was reduced to R$ 0.14/liter and it remained at zero on ethanol. The trajectories of both elasticities continued in downward direction. The ethanol price elasticity reached the value of -1.3 and, the gasoline-ethanol cross-price elasticity fell much more sharply, tending to 0.3 (Fig. 4).

In November 2012, CIDE's rate on gasoline was reduced to R$ 0.07/liter and it remained at zero on ethanol, remaining until June 2013. Initially, the trajectory of the ethanol price elasticity continued to fall reaching elasticity with a value close to -1.3, the highest elasticity in modulus throughout the analyzed period. Later, it reversed the trajectory and became less elastic. The gasoline-ethanol cross-price elasticity continued its downward trajectory, increasing its inelasticity (Fig. 4).

In July 2013, CIDE's rate on both gasoline and ethanol was zero. It was in force until April 2015, when the curves of both elasticities converged. From January 2014 to April 2015, both curves presented divergent behavior, distancing from each other. The intensity by which the ethanol price elasticity has become more inelastic is higher than the move towards the greater inelasticity of the gasoline-ethanol cross-price elasticity curve, since the former showed a steeper slope than the second (Fig. 4). The possible explanation for this behavior may be due to the political-economic crisis in the analyzed period, since the fall in industrial production, coupled with increase in unemployment, negatively impacted consumers' income, resulting in a sharp drop in vehicle sales. Negative impact of the income effect may have outweighed the price effect, that is, even gasoline having become cheaper, which is a positive price effect, the quantity sold for both gasoline and ethanol became more inelastic.

In May 2015, CIDE's rate on gasoline increased again and remained at R$ 0.10/liter, keeping CIDE's rate on ethanol at zero until May 2017, the last month analyzed in this research. At the beginning of this last period the ethanol price elasticity presented an ascending trajectory, becoming more inelastic. From January 2016, this trajectory was reversed and reached the value of -1.068 in January 2017, a situation in which the ethanol price elasticity was again elastic. Meanwhile, the trajectory of the gasoline-ethanol cross-price elasticity continued in its downward trajectory, becoming increasingly inelastic.

5. CONCLUSION

The aim of this paper was to identify the path of the gasoline price elasticity, ethanol price elasticity, ethanol-gasoline cross-price elasticity and the gasoline-ethanol cross-price elasticity for the flex-fuel vehicle market, as well as to discuss the taxation policies impact of CIDE on the ethanol and gasoline markets from 2003 to 2017. It was during this period that hydrated ethanol and gasoline became substitute products, since flex-fuel cars allowed the fuel supply decision to be made at each fueling. Consumers were used to comparing fuel prices to decide which one is better at each fueling. Thus, the analysis of price elasticities of each fuel and of cross-price elasticities were important both for the evaluation of taxation measures and for the analysis of policies to support light fuels production and pricing (Otto Cycle) in Brazil.

Regarding this last aspect, this research showed the intensity in which CIDE displaced equilibrium prices and favored the ethanol market. Data also showed how consumers reacted to price changes in the analyzed period, and how flex-fuel vehicles were important for the consumer who had different reactions from the period when cars used only one type of fuel. Thus, CIDE played an important role in price discrimination between hydrated ethanol and gasoline, inducing gasoline substitution for ethanol at a time when CIDE's rate increased on gasoline and remained at zero on ethanol.

Another conclusion is that CIDE could have played an important role in the induction of ethanol sales if its rates had remained stable in the period. As this did not occur, the period was marked by different phases and behaviors of the cross-price elasticities that alternated periods of price elasticity with those of price inelasticity.

In this regard, the policy was positive in favor of the biofuel supply that benefits health in urban centers; despite the oscillation of the gasoline rate. It had negative effects on the production chain, for example: i) generating uncertainties for investments in a long production chain (six years); ii) reducing operating margins of producers when CIDE is low and raising margins when it is high, being both not dynamic effect measures in the economy.

It is important to highlight the need to define priorities and plan more consistently other measures to improve the fuel market in Brazil, including taxation. Such planning is important to create a medium- and long-term scenario that allows stakeholders to study their investments, boosting the ethanol supply and other products linked to the production chain. Thus, large variations in installed capacity and product supply in the market can be avoided, as well as creating an environment more conducive to investments in productivity.

From the environmental point of view and people's health, a tax such as CIDE should boost differentiated consumption of ethanol, whose effects are noticeable in large cities due to ethanol's capacity to reduce greenhouse gas emissions (GHG) and pollutants. In this regard, data presented in this paper allow future research using, for example, GHG emission reduction calculation in function of the amount of CIDE or its different rates.

It should be noted that this paper has not exhausted the theme of the use of public policies for boosting renew able fuels consumption. There is a lot of research on this subject, including understanding consumer decisions, besides price, to understanding the real efficiency of flex-fuel vehicles when using ethanol and gasoline in different combinations of anhydrous and hydrated ethanol.

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