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DEMAND FOR AUTOMOTIVE FUEL IN BRAZIL: An Empirical Analysis Using Cointegration Techniques

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ABSTRACT

Since 2003, the Brazilian fuel market offers two types of products to the consumers: gasoline C (a blend of anhydrous ethanol with gasoline A) and hydrated ethanol. Light cars reach the market equipped with so called 'flex fuel' engines, which can run on either type of fuel. The research study used cointegration techniques to estimate three econometric models, in the period between 2005 and 2012: in the first, the automotive fuel demand (joint demand of hydrated ethanol and gasoline C) was correlated with the weighted average prices of hydrated ethanol and gasoline C and consumer income; in the second, gasoline C demand was correlated with the relative prices of hydrated ethanol and gasoline C (Hydrated ethanol price/ Gasoline C price) and consumer income. In the third, the demand for hydrated ethanol was correlated with the relative price of hydrated ethanol and gasoline C and consumer income. The results shows that fuel demand have been inelastic with respect to the prices and the consumer income. It was also found a higher elasticity for the hydrated ethanol demand with respect to relative prices than the elasticity of gasoline C demand with respect to relative prices.

Keywords: *fuel market, gasoline C, hydrated ethanol, consumer income, fuel demand*

1. INTRODUCTION

Since the 1970s the Brazilian federal government fostered the large-scale use of hydrated ethanol as an automotive fuel. At the outset, this was a response to the oil crisis. Under government incentives, this innovation was promptly accepted by consumers and the production of hydrated ethanol grew sharply in parallel to increases in demand (Figueira et al., 2010). By the mid to the late 1980s the government lost its capacity to subsidize the expansion of hydrated ethanol production. As gasoline prices declined its demand fell sharply in the 1990s (Furtado et al., 2011).

In the early 2000s there was a second major innovation in the Brazilian automotive market, cars were equipped with the so-called 'flex fuel' engines which were able to run on both gasoline or ethanol, and as it reached the market this renewed the interest of consumers in ethanol (Marjotta-Maistro and Barros, 2003; Lima *et al*., 2013). The 'flex fuel' car owner can choose between gasoline C (a blend of anhydrous ethanol with gasoline A) and hydrated ethanol, because every gasoline station in Brazil offers these two products. Flex fuel cars entered the market in 2003 with a small share of 3.9% of total sales. By 2005, 'flex fuel' vehicles conquered most of the market (52.7%) for new motor vehicles. This proportion reached 91.5% by 2009 (Távora, 2011).

As of 2010, falling gasoline prices (since 2005) and the rise of hydrated ethanol prices caused a setback in the demand for the latter (see Figure 3 in Annexes). This was caused by the following three factors. Firstly, the production of raw material for ethanol (sugarcane) declined by excessive rainfall during the 2009/10 harvest and then by prolonged drought in 2010/11 pressurizing production costs. Secondly, this was combined with a lack of investment in the renewal of sugarcane plantation, a major factor in sustaining productivity (Pitta and Mendonça, 2010). Thirdly, in relation to gasoline prices, in Brazil, the state-owned oil company Petrobras controls 98% of the oil refining (ANP, 2013). Petrobras has been consistently holding nominal gasoline prices below inflation since 2005, thus causing a decrease in real prices. This was enabled by the falling oil price in international markets, especially in 2008, as well as the governmental pricing policy to avoid a rise in inflation (Colomer and Tavares, 2012).

When deciding whether to fill up with hydrated ethanol or gasoline C, the consumer takes into account individual preferences and the fuel prices at the time of purchase. Research indicates that to be competitive, the nominal prices of hydrated ethanol need to be less than a 70% fraction of the gasoline C price. This relationship results from the lower efficiency of ethanol when compared to gasoline. The average mileage of a vehicle running on ethanol is 70% of that achieved by the use of gasoline (Silva, 2013).

Several studies have estimated the elasticities of price and income of gasoline C and hydrated ethanol in Brazil (Burnquist and Bacchi, 2002; Alves and Bueno, 2003; Marjotta-Maistro and Barros, 2003; Farina *et al*., 2010; Souza, 2010 and Costa and Burnquist, 2013). These studies have advanced our knowledge about this aspect, but so far no analysis of elasticities of price and income for both gasoline and ethanol was undertaken. This research aims to fill this gap. The main goal of this paper is to analyze the price elasticity and income elasticity of demand for automotive fuels in Brazil in the period between 2005 and 2012. . The chosen time frame considers the period in which 'flex fuel' vehicle sales became the leader in the Brazilian market.

To meet this goal, cointegration techniques were used to estimate three econometric models: in the first, the demand for automotive fuels (joint demand of hydrated ethanol and gasoline C) was correlated with the weighted average prices of hydrated ethanol and gasoline C and aggregated wages as consumer income proxy; in the second, gasoline C demand was correlated with relative price of hydrated ethanol and gasoline C and aggregated wages as consumer income proxy; and in the third, the demand for hydrated ethanol was correlated with the relative price of hydrated ethanol and gasoline C and aggregated wages as consumer income proxy .

This article is organized as follows. Section 2 presents a review of the literature on the impacts of price and income on the demand for automotive fuels as measured by elasticity, with a focus on the Brazilian context. Section 3 discusses the econometric model and estimation strategies used here. Section 4 presents the results and analysis while section 5 concludes the paper.

2. LITERATURE REVIEW

During the 1970s and early 1980s societal concerns related to the availability of energy sources due to the rising prices of oil in the international market prompted academic interest and the production of a large number of econometric studies on the price elasticity of gasoline demand. In the 1990s, these concerns were renewed due to the need to understand the impacts of the use of fossil fuels on the emission of gases that cause the greenhouse effect (Espey, 1998).

Blum, Foos and Gaudry (1988) reviewed the models used to analyze gasoline demand. For the authors in the 1970s, most models used linear endogenous and exogenous variables. In the 1980s, the popularity of dynamic models increased, including the use of lagged variables and error components for the analysis of autoregressive residuals.

Dahl and Sterner (1991) reviewed the estimates for gasoline demand and focused on studies that analyzed the price elasticity and income elasticity. The objective was to compare the price elasticities and income elasticities in twenty-two (22) estimates of demand elasticities using ten (10) types of models, from the simplest, which included only price and income, to the dynamic models, which included the gasoline demand in the previous period and the lagged prices and income as explanatory variables. On average, the value of the income elasticity was 1.16 while for price elasticity it was -0.53, indicating an elastic demand for gasoline in relation to income variation and inelastic with respect to changes in gasoline price. The results for price elasticity were confirmed by more recent studies.

In the 1990s, several studies on gasoline demand used the co-integration technique and error correction models (Bacchi, 2009). In this respect see for instance Bentzen (1994), Eltony and Al-Mutairi (1995) and Ramahatan (1999). Bentzen (1994) analyzed a data series from 1948 to 1991 in Denmark. The short and long-term price elasticity was -0.32 and -0.41, respectively, and short and long-term elasticity in relation to the number of vehicles per capita was 0.89 and 1.04, respectively. Eltony and Murait (1995) used the cointegration model to analyze the demand for gasoline in Kuwait between 1970 and 1989. The price elasticity was -0.372 (in the short-term) and -0.462 (in the long-term) while the income elasticity of short and long-term was 0.472 and 0.919, respectively.

Ramanathan (1999) used a data series covering two periods (1972 to 1973 and 1993 to 1994). The long-term value found for the relationship between *per capita* income and gasoline demand in India was 2.682. In the meantime, the short-term value relating income variation and demand for gasoline was 1.178. The demand price elasticity was -0.209 and -0.319, in the short and long terms respectively.

Building on this tradition in the 2000s, several studies were performed to analyze the Brazilian market for gasoline C (Burnquist and Bacchi, 2002; Alves and Bueno, 2003; Marjotta-Maistro and Barros, 2003) and hydrated ethanol (Farina *et al*., 2010; Souza, 2010; Costa and Burnquist, 2013).

The results of the studies that focused on gasoline converged. They showed that gasoline was both price and income inelastic. The lack of price elasticity was in line with the international literature. Burnquist and Bacchi (2002) used cointegration techniques to estimate gasoline demand in Brazil, from 1973 until 1998. The results indicate that in the short term, demand for gasoline is inelastic to real income changes, given that an increase of about 1% in this variable causes an increase of about 0.6% in gasoline consumption. In the long run, income elasticity was slightly less than one. Regarding price elasticity of demand, the results show that gasoline consumption, in the context of the Brazilian economy, is apparently scantly sensitive to changes in prices of this fuel, both in the short and long terms.

Marjotta-Maistro and Barros (2003) analyzed the elasticity of the gasoline market in Brazil between 1995 and 2000. The results show that gasoline consumption is inelastic in relation to both consumer income and gasoline price changes, amounting to 0.20 and -0.62 respectively.

More recent studies started to compare gasoline and ethanol. Alves and Bueno (2003) used cointegration techniques to analyze gasoline demand, including in the model the price elasticity, as well as cross-price elasticity (relative to the price variation of hydrated ethanol) between 1974 and 1999. The results showed once again that gasoline demand was inelastic to price and income, while confirming the hydrated ethanol and gasoline relationship as substitute products.

Farina *et al*. (2010) used the cointegration analysis method to estimate demand equations, and studied the period running from July 2001 to August 2009. The elasticity calculated were: price elasticity of ethanol; -1.23 and cross-price elasticity of gasoline C relative to hydrated ethanol; 1.45.

Souza (2010) studied the demand for ethanol and gasoline C at the national level from 2001 until 2009. This author used the two-stage regression method to analyze the price and cross-price elasticity of hydrated ethanol and gasoline Type C. The analysis comprised two distinct periods, running from July 2001 to August 2006 and from September 2006 to December 2009, aiming to assess the impact of the increasing number of 'flex fuel' engine cars in the country on the variation of the elasticity. For hydrated ethanol in the first reporting period, the price elasticity was -1.26, the gasoline cross-price elasticity was 0.6226 and the income elasticity was 0.45. In the second period, the price elasticity of ethanol increased to -1.82, the income elasticity fell to 0.209 and the cross-price elasticity of gasoline rose to 2.035. This result indicates that as 'flex fuel' engines entered the market, the demand for ethanol became more prone to variation as it became easier for consumers to shift between the two types of fuel. Regarding gasoline, the price elasticity was -0.29 and -0.37 in the first and second period, respectively. The price elasticity of ethanol was not significant in the first period and was 0.16 in the second period.

Costa and Burnquist (2013) use the panel data technique to analyze the demand for gasoline from 2006 to 2011. The price elasticity of gasoline was -0.83 and the cross-price elasticity 0.64. Moreover, the elasticity over the 'flex fuel' vehicle fleet was 0.90.

Valle et al. (2013) have done research combining qualitative and quantitative data. They did about 1,400 interviews in eight Brazilian cities, querying consumer choices, particularly about different relative prices (i.e. the price of hydrated ethanol in relation to the price of gasoline). As it might be expected, there is a strong influence of the relative prices of ethanol and gasoline over consumer choice.

Our paper analyzes three aspects that were not explored by the studies discussed above. Firstly, it measures price elasticity and income elasticity for both fuels. Secondly, the analysis extends to the post-2010 period, when the price of hydrated ethanol increased in relation to gasoline C. Thirdly, the aggregate wages were also included as a proxy for variation in income in the models. In the next section we discuss the method used in our paper to advance these issues.

3. MATERIALS AND METHODS

In this section we describe the sources of data and the method used to undertake the analysis.

The data used in the paper were: the demand for hydrated ethanol and gasoline C in the Brazil, the real prices for hydrated ethanol, the real prices for gasoline, and real aggregated wages.

The time series for gasoline C and hydrated ethanol demand was obtained from the National Agency for Petroleum, Natural Gas and Biofuels (Agência Nacional de Petróleo, Gás Natural e Biocombustíveis, ANP (2013a) website. The monthly averages of ethanol and gasoline selling prices were kindly supplied provided from the ANP. The rate of inflation, the Consumer Price Index (Extended National Consumer Price Index Broad, IPCA) obtained by the Central Bank of Brazil (Banco Central Brazil, 2103a) website, was used to deflate prices.

The variable aggregated wages is measured by the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística – IBGE, 2013) and it is available from the Brazilian Central Bank (Banco Central do Brasil, 2013b) website. This series was also transformed into real values using the IPCA inflation index. This data was first reported by the Central Bank in January 2004; therefore, other studies in the literature use the GDP variable as a proxy for income variation. All time series run from 2005 to 2012.

The use of the aggregated wages results from the fact that this has grown at a faster pace than the GDP in the period. Between 2004 and 2012 real wages rose by 64% while the real GDP rose by 28.8%. The rise of real wages relative is mainly a result of the federal government policy to strengthen value of the national minimum wage (Vaccarezza, 2014).

To estimate the demand for automotive fuels we summed the demand for gasoline C and the demand for hydrated ethanol. Hence we obtained the dependent variable, which combined the demand for both types of fuels. Regarding the price variable, we used a weighted average prices of ethanol and gasoline C assigning a weight for each fuel in the domestic demand for fuel during the analysis period, see Equation 1.

$$P_{average} =\cdot a_1 \times p_{et} + a_2 \times p_{gas} \quad (1)$$

In Equation 1, a_1 is percent ethanol demand and a_2 percent gasoline demand in relation to the total fuel demand in the quarter.

The models for hydrated ethanol and gasoline C demand used the relative prices (RP) between hydrated ethanol and gasoline C prices (Hydrated ethanol price / Gasoline C price) following Valle et.al.(2013) research. The inclusion of this variable and not ethanol and gasoline C prices increased the significance level of models and the adherence to economic theory [1] and have a strong economic justification, because consumers analyze the relatives prices of hydrous ethanol and gasoline C at the pump to decide about which fuel they will consume. Some Brazilian gasoline stations offer the relative price for consumers to make their decision.

[1] We have done tests including the variables real price of hydrated ethanol and gasoline C and relative price in the models. We had these problems with the inclusion of the real prices of hydrated ethanol and gasoline C in the models: the real price of gasoline was not significant in explaining the demand for gasoline in the short term and the elasticity price of gasoline had a negative sign, typical of goods complementary, in the demand for hydrous ethanol. The negative signal can be explained by the increased demand for hydrous ethanol in a period that has occurred decrease in the real price of gasoline, as shown in Figure 3 of the Annex.

Cointegration techniques were used to obtain the desired coefficients. The Engle-Granger methodology firstly confirmed whether the model was cointegrated. It did so by testing the integration order of the variables and of the residual. To be cointegrated, all variables of the model must be integrated by the same order and the residual of the long-run equation must be stationary. Once these conditions were observed, we could calculate the long-run and the short-run estimators (Enders , 2010).

To check whether the variables were stationary we used the augmented Dickey-Fuller test, and the ADF-GLS and KPSS tests. According to BUENO (2008), the ADF-GLS and KPSS tests are necessary to complement the traditional augmented Dickey-Fuller test that was developed in the late 1970s and early 1980s and has low power.

Enders (2010) suggest that Dickey and Fuller test actually consider three different regression equations that can be used to test the presence of a unit roots:

$$\Delta y_t = a_0 + \gamma y_{t-1} + a_2 t + \Sigma \beta_i \Delta y_{t-i} + \varepsilon_t \quad (2)$$

$$\Delta y_t = a_0 + \gamma y_{t-1} + \Sigma \beta_i \Delta y_{t-i} + \varepsilon_t \quad (3)$$

$$\Delta y_t = \gamma y_{t-1} + \Sigma \beta_i \Delta y_{t-i} + \varepsilon_t \quad (4)$$

We first, use the τ_τ statistics to test the null hypothesis (H0: $\gamma = 0$), equation 2. If the null hypothesis of a unit root is rejected, there was no need to proceed further. Concluding that the $\{y_t\}$ does not contain a unit roots. If the null hypothesis is not rejected, we had to estimate a model without tendency, see equation 3. We then tested for the presence of a unit root using the τ_μ statisitcs. Here, if the null hypothesis is rejected, one can conclude that the model does not contain a unit roots. If the null hypothesis is not rejected, one can estimate a model without tendency. We then tested for the presence of a unit root using the use τ statistics, equation 4. If the null hypothesis of a unit root is rejected, one can conclude that the sequence does not contains a unit roots. Otherwise, one concludes that the sequence contains a unit root.

The ADF-GLS test is a variant of the Dickey–Fuller test for a unit root, in case where the variable to be tested is assumed to have a non-zero mean or exhibits a linear trend. The difference is that the test is done using the GLS procedure suggested by Elliott, Rothenberg and Stock. This gives a test greater power than the standard Dickey–Fuller approach. The KPSS stationary test was developed by Kwiatkowski, Phillips, Schmidt and Shin. (Cottrell and Lucchetti, 2012).

In the end, it is necessary to test if the long-run equation residuals are stationaries, we could perform a Dickey-Fuller test on the residual of long-term equation, see equation 5, this excludes the intercept term, but can use the augmented form if that the diagnostic checks indicates that the $\{e_t\}$ sequence exhibits serial correlation. To check the residuals stationaries use the critical values for the Engle-Granger Cointegration test (Enders, 2010).

$$\Delta \hat{e}_t = a_1 \hat{e}_{t-1} + \sum_{i=1}^{n} a_{i+1} \Delta \hat{e}_{t-i} + \varepsilon_t \quad (5)$$

If all series included in the analyzed equations have the same order of integration and the residuals are stationary, then cointegration techniques can be used. According to this technique, the coefficients of the explanatory variables are the long-term elasticity. In the case where the order of integration of the model variables is 1, the first difference of the variables in the model should be used while including the lag residual in the equation to obtain the short-term elasticity.

4. RESULTS AND DISCUSSION

This section presents the results for the short and long-term elasticity for the automotive fuel market (encompassing both ethanol and gasoline C), gasoline C and hydrated ethanol. The requirements of the Engle-Granger test were met in order to use the cointegration model, to determine the short and long-term elasticities.

Automotive fuel demand

All procedures for testing Engle-Granger to the cointegration were implemented, see annexes. In relation to the individuals series analysis it was accepted an integration order of 1 - I(1) - for all series. However, we must make some comments on the individual results. The three tests indicated the I(1) to combined prices. The combined demand and aggregated wages are considered I (1) when seasonal dummies are included in the model augmented Dickey-Fuller and KPSS tests.

It is noteworthy that according to the Brazilian law, in the last quarter, civil servants and regularly registered private workers receive an additional salary, the so-called "thirteenth salary". Therefore, income rises in this quarter. Consequently data covering this period, before Christmas holidays and New Year, reflects a temporary increase in demand. This trend tends to disappear over the following quarters, when labour income goes back to its usual value.

In the short and long-term all variables were statistically significant. In the long-term the model includes a time trend variable as shown in Equation 6. Wooldridge (2006) argues that we must include the tendency in the equation to avoid bias in the estimators.

The Heteroscedastic model, corrected for both the short and long-term, proposed by the Gretl econometric package; version 1.9.9 (Gnu Regression, Econometrics and Time-series Library) was used. The procedure involves (a) an OLS estimation of the model, followed by (b) an auxiliary regression to generate an estimate of the error variance, and then finally (c) weighted least squares, using as weight the reciprocal of the estimated variance. In the auxiliary regression (b) we regress the log of the squared residuals from the first OLS on the original regressors and their squares. The log transformation is performed to ensure that the estimated variances are non-negative. Call the fitted values from this regression u*. The weight series for the final WLS is then formed as 1/exp(u *) (Cottrell and Lucchetti, 2012).

$$D_{fuel} =\cdot \alpha + \beta_1 P_{average} + \beta_2 W + \beta_3 T + \beta_4 D_4 + \varepsilon_t \qquad (6)$$

In the long-term model, the Normality of residuals test based on *Q*-Statistics χ^2 (2) = 0.44 with p-value =0.80, the normality of residuals. The economic analysis of the variables during the period showed an inelastic demand for automotive fuels in relation to the price index (-0.527), as shown in Table 1.

Thus, a price index variation of 1% triggers an inverse variation in demand for automotive fuels in the order of 0.527%. The long-term income elasticity was 0.338, so the 1% increase in wages triggered in the period an average increase of 0.338% in automotive fuel demand. Considering the standard error, no significant change was observed between the short and long term elasticities.

Table 1 - Results of long-term elasticities for automotive fuel demands.

	Coefficients	*Standard Error*	Ratio t	p-value
Constant	11.26	1.13	9.903	1.75e-010
Ln Average Prices	- 0.527	0.0517	-10,19	9.48e-011
Ln Aggregated Wages	0.338	0.098	3.44	0.0019
Trend	0.012	0.0016	7.50	4.52e-08
Seasonal dummy	0.027	0.0133	2.057	0.049

Source: Own elaboration.

Equation 7 is used for the short-term, the adjusted R^2 was 0.88 and the Durbin-Watson test was 2.03, thus rejecting the autocorrelation of residuals. The normality of the residuals was accepted since the short-term chi-square (2) = 0.826 with p-value 0.66 .

$$\Delta D_{Fuel} = \alpha + \beta_1 \Delta P_{average} + \beta_2 \Delta W + \beta_3 \varepsilon_{t-1} + \beta_4 D_4 + \mu \qquad (7)$$

Table 2: Results of short-term elasticities for fuel demand.

	Coefficients	*Standard Error*	Ratio t	p-value
Constant	0,007	0,002	2,74	0,01
Δ Ln Average prices	-0,56628	0,03	-14.14	1.02e-013
Δ Ln Aggregated Wages	0.44	0.04	9.485	6.25e-010
Error Correction	0.84	0.17	4.915	4.21e-05
Seasonal dummy	0.015	0.006	2.578	0.016

Source: Own elaboration.

Gasoline C demand

All the Engle-Granger test procedures to the cointegration were done, see annexes. It was accepted an integration order 1- I(1) - for all series. The three tests indicated the I(1) to series: gasoline demand and relative prices between

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ethanol and gasoline C. The aggregate income, as discussed above, is considered I (1) when seasonal dummies are included in the model.

Equation 8 used in the analysis of long-term elasticity of gasoline demand includes the relative price between ethanol and gasoline (Hydrated ethanol price/ Gasoline C price) and also a quadratic time trend. Wooldridge (2006) calls the quadratic time trend when including a linear tendency and a quadratic tendency in the equation.

$$D_{gas} = \alpha_0 + \beta_1 RP + \beta_2 W + \beta_3 T + \beta_4 T^2 + \varepsilon \quad (8)$$

Table 3 shows the long-term results for the residual normality test, chi-square (2) = 0.052 with p-value 0.97427, indicating the normality. The corrected Heteroscedastic model was also used due to the lack of homoscedasticity in the ordinary least squares model.

Table 3 - Results of long-term elasticities for gasoline C.

	Coefficients	*Standard Error*	Ratio t	p-value
Constant	9.89	1,001	9.88	1.84e-010
Ln Relative Prices	0.391	0.0705	5.544	7.09e-06
Ln Aggregated Wages	0.419	0,088	4.76	5.80e-05
Linear trend	-0.019	0.00279	-6.835	2.42e-07
Quadratic linear trend	0.00072	5.912e-05	12.18	1.76e-012

Source: Own elaboration.

Equation 9 was used for the short-term. Table 4 shows the constant and standard errors. The adjusted R^2 was 0.682, the Durbin-Watson test was 1.65, thus rejecting the hypothesis of residual autocorrelation. The chi-squared test for normality of residuals yielded a p-value of 0.68, accepting the normality of residue and p-value of F-test was 7.21e-06.

$$\Delta D_{gas} = \alpha_0 + \beta_1 \Delta RP + \beta_2 \Delta W + \beta_3 \varepsilon_{t-1} + \beta_4 T + \mu \quad (9)$$

The coefficients were suitable according to economic theory, see Table 4. The elasticity of relative price (RP) was positive, as expected by the economic theory, indicating that a 1% change in the price ratio triggers a variation of 0.16% in gasoline demand in the short run and 0.419% in the long run. The greater sensitivity in the long run can be explained by the possibility of acquisition of 'flex fuel' vehicles, whose sale started in 2003 but won a majority market share in 2005. Wages also showed a higher sensitivity in the long term (0.419) compared to short-term (0.357) on the demand for gasoline. The result may indicate a change in the Brazilian consumer preference for gasoline relative to ethanol when income level increases.

Table 4: Results of short-term elasticities for gasoline C.

	Coefficients	*Standard Error*	Ratio t	p-value
Constant	-0.027	0.0101	-2.704	0.0119
Δ Ln Relative Prices.	0.164	0.0673	2.441	0.0218
Δ Ln Aggregated Wages	0.3573	0.06960	5.134	2.36e-05
Error Correction	0.4588	0.14	3.276	0.003
Linear Trend	0.0015	0.00035	4.393	0.0002

Source: Own elaboration.

Hydrated ethanol demand

All the Engle-Granger test procedures to the cointegration were done, see annexes. About the individuals series analysis it was accepted an integration order 1- I(1) - for all series. The three tests indicated the I(1) to series: ethanol demand and relative prices between ethanol and gasoline C. The aggregate income is considered I (1) when seasonal dummies are included in the model.

Equation 10 is the long-term model. Normality analysis of residuals showed chi-square = 1.250 with p-value 0.53518, asserting the normality of residuals. Like the model used to analyze gasoline, a quadratic time trend was

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included. In the long run, a 1% change in the relative price of hydrated ethanol to gasoline C generates a larger variation of 1.17% in the demand for gasoline C, see Table 5.

$$D_{et} =\cdot \alpha + \beta_1 RP + \beta_2 W + \beta_3 T + \beta_4 T^2 + \varepsilon \quad (10)$$

Table 5 - Results of long-term elasticities for hydrated ethanol.

	Coefficients	*Standard Error*	Ratio t	p-value
Constant	6.37	4.23	1.508	0.1433
Ln Relative Prices	-1.17	0.29	-3.995	0.0004
Ln Aggregated Wages	0.41403	0.3678	1.126	0.2702
Trend Linear	0.171673	0.0113	15.12	1.05e-014
Quadratic Trend	-0.0034	0.000279	-12.17	1.81e-012

Source: Own elaboration.

Equation 11 is the short-term model. The results were as follows: adjusted R^2, 0.587; P-value (F) 0.000015; Durbin-Watson, 1.92; therefore, the hypothesis of residual autocorrelation was rejected. The Chi-square test p-value of 0.3765 shows residual normality. A linear trend variable was also included in the model.

$$\Delta D_{et} =\cdot \alpha + \beta_1 \Delta RP + \beta_2 \Delta W + \beta_3 T + \beta_4 \varepsilon_{t-1} + \mu \quad (11)$$

In the short and long terms, only the constant was not significant. All other variables were statistically significant. The elasticity of the relative price between ethanol and gasoline was -1.17 and -1.28 for the long and short term, respectively; see Table 6. Both elasticities were expected from the economic view point while demand is inversely proportional to the relative prices. The elasticity of Aggregated Wages were also more elastic in the short-term (0.5396) than in the long-term (0.41403).

Table 6: Results of short-term elasticities for hydrated ethanol.

	Coefficients	*Standard Error*	Ratio t	p-value
Constant	0.103	0.046	2.220	0.035
Δ Ln Relative Prices	-1.2857	0.23	-5.590	3.14e-06
Δ Ln Aggregated Wages	0.5396	0.2389	2.258	0.0326
Error Correction	0.5186	0.1482	3.498	0.0017
Linear trend	-0.0042	0.0019	-2.195	0.0373

Source: Own elaboration

Discussion of the results to the Brazilian automotive fuel market

The elasticities of automotive fuel demand (joint demand of gasoline C and hydrated ethanol) have been inelastic with respect to the price in short and long-term (respectively 0.56 and 0.52) and aggregated wages in short and long-term (respectively 0.44 and 0.338). This values are very important for the building of fuel demand scenarios in Brazil. Such scenarios can support the environmental and energy policies in Brazil. This is so because the increase in the fuel demand has been more stable in the period than the variation of the demand for hydrated ethanol and gasoline C individually, see the figure 1 in annexes.

It was also found a higher elasticity for the hydrated ethanol demand in respect to relative prices in short and long-term (respectively -1.28 and -1.18) than the elasticities of gasoline demand with respect to relative prices in short and long-term (respectively 0.164 and 0.391). Probably, part of this gasoline C price inelasticity is as a result of the stock of vehicles that run on a single fuel, namely, gasoline C that were the majority produced before 2005 in relation to the Brazilian light vehicles fleet. These vehicles can only use gasoline C. The greater sensitivity to price change in the long term compared to the short-term may be due to the growth of the 'flex fuel' vehicle fleet in the more recent period.

The results regarding relative price elasticity suggest a difficult challenge for the consolidation of the Brazilian hydrated ethanol market. The research results indicate that the demand for hydrated ethanol and consequently market growth will occur only if the hydrated ethanol prices at the pump becomes relatively cheaper when compared to the of gasoline prices.

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5. FINAL CONSIDERATIONS

This study measured the income and price elasticities for the automotive fuel demand in Brazil. The Brazilian automotive fuel market has, for many years, commercialized both hydrated ethanol and gasoline C. The demand was fostered by the launch of motor vehicles equipped with 'flex fuel' engines, which became the market leader since 2005. In this context, the study analyzed the markets for gasoline C, hydrated ethanol and automotive fuels (joint demand of gasoline C and hydrated ethanol).

By analyzing the elasticities of demand for automotive fuels (joint demand of hydrated ethanol and gasoline C) we found that the price elasticity of automobile fuels was -0.517 in the long-term and -0.581 in the short-term. Aggregated wage elasticity was 0.564 in the long-term and 0.586 in the short-term. When considering the standard error, there is no significant variation of the long-term and short-term errors.

It was also found stronger elasticities for the hydrated ethanol demand in respect to relative prices (Prices of Hydrated Ethanol Price/ Prices of Gasoline C) in short and long-term (respectively -1.28 and -1.18) than the elasticities of gasoline demand with respect to relative prices in short and long-term (respectively 0.164 and 0.391). Probably, part of this gasoline C price inelasticity is as a result of the persistence of the stock of vehicles produced before 2005 in the Brazilian light vehicles fleet that run solely on gasoline C. The greater sensitivity to price change in the long term compared to the short-term may be due to the growth of the 'flex fuel' vehicle fleet in the period

It is necessary to undertake new studies in the future to measure the price and income elasticities in the demand for hydrous ethanol, gasoline C and for both fuels. The price and income elasticities of demand for hydrous ethanol and gasoline C may change in the future due to the relatively short time of sale of flex-fuel vehicles in the Brazilian market, because there are many cars in the Brazilian fleet produced before 2005 that run solely on gasoline C and with time these cars will be out of circulation. Another important source of research from the results obtained with this study is to perform simulations of scenarios using the demand for Brazilian automotive fuels (joint demand for hydrous ethanol and gasoline C). Because there have been a recurring need for gasoline imports to meet the domestic demand. To avoid these imports, Petrobras is investing to expand refining capacity of gasoline in Brazil. It would be very important to compare the expanding refining capacity with demand simulations to examine if will occur deficit or surplus between production and domestic demand and the role of hydrous ethanol in the Brazilian fuel market in these scenarios.

Others researchs need to be done about the future characteristics of the Brazilian fuel market. The research results indicate that the demand for hydrated ethanol and consequently market growth will occur only if the hydrated ethanol prices at the pump becomes relatively cheaper when compared to the of gasoline prices. It is necessary to analyse the possibilities to do that. Because, relative prices could be more friendly to ethanol depending on the increasing of gasoline C prices at the pump and/or the decrease of hydrated ethanol price at the pump. In the first case, this could happen through the increase of prices charged by Petrobras or through a tariff increase on gasoline. The first possibility is more probable because the company is importing gasoline and is not transferring the increases in costs to Brazilian consumers. Other possibility is the decrease of the hydrated ethanol prices at the pump. This could be feasible by government subsidies or through efficiency gains in the ethanol production and delivery. The option for government subsidies is unlikely to happen at the moment because the Brazilian government is under pressure to reduce public spending. In relation to cost reduction, some efforts to increase the infrastructure reduce the distribution costs are ongoing and could influence the market in the short term.

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ANNEXES

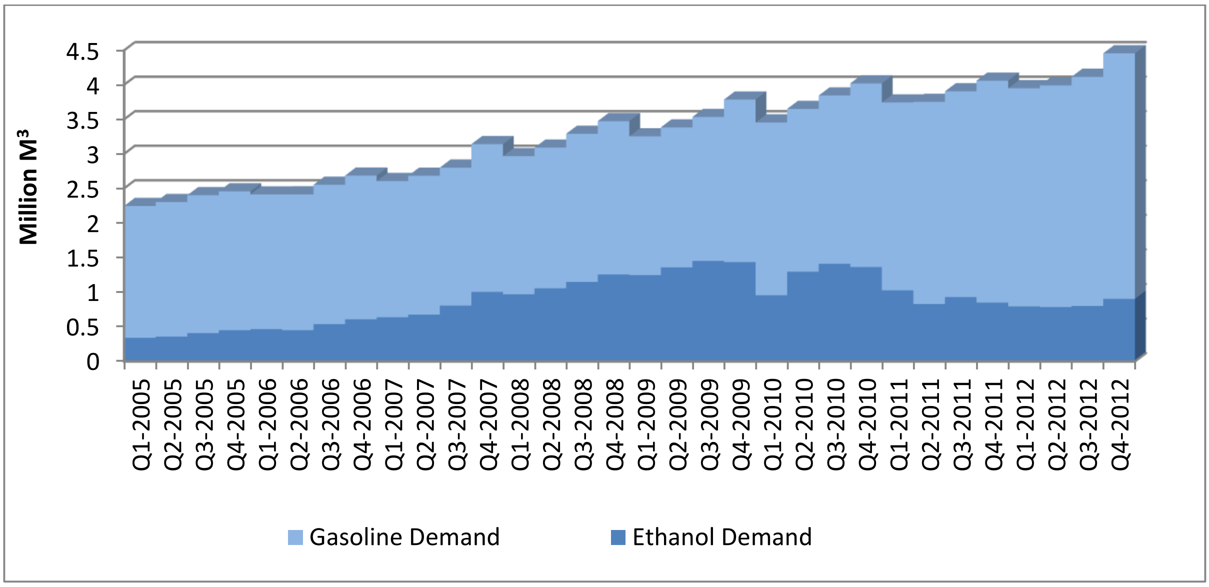

Figure 1: Demand for hydrated ethanol, gasoline and combined (2005-2012).
Source: ANP (2013)

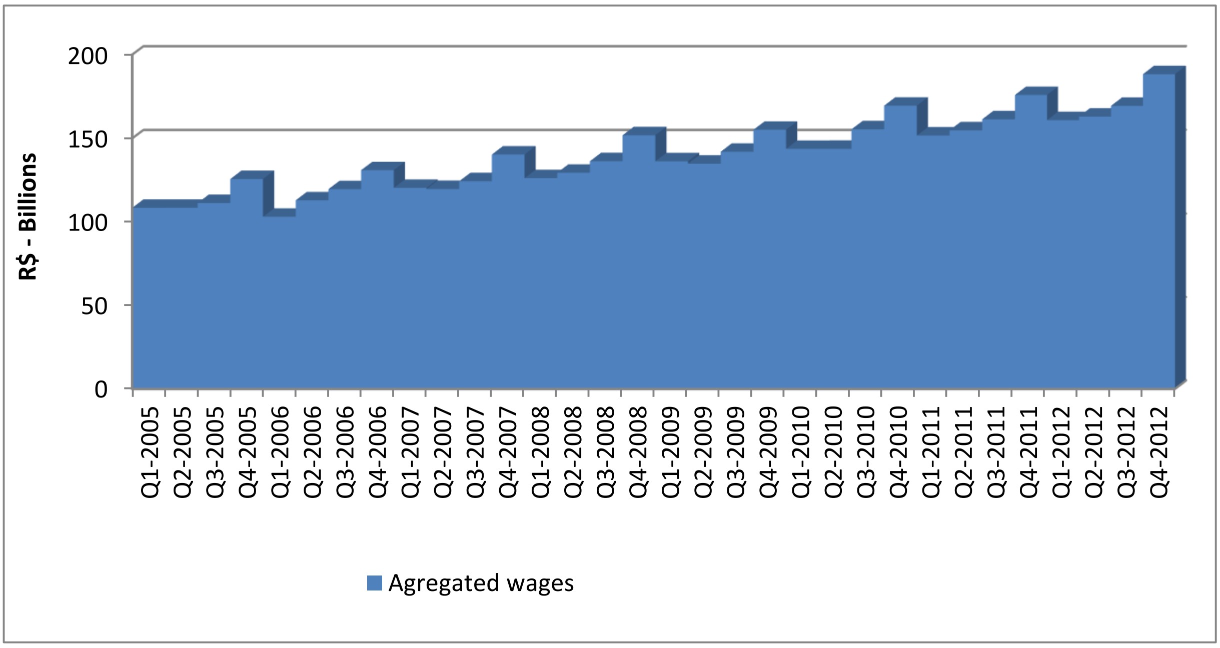

Figure 2: Evolution of Real Wages in the period (Base: December 2012)
Source: Banco Central do Brasil (2013)

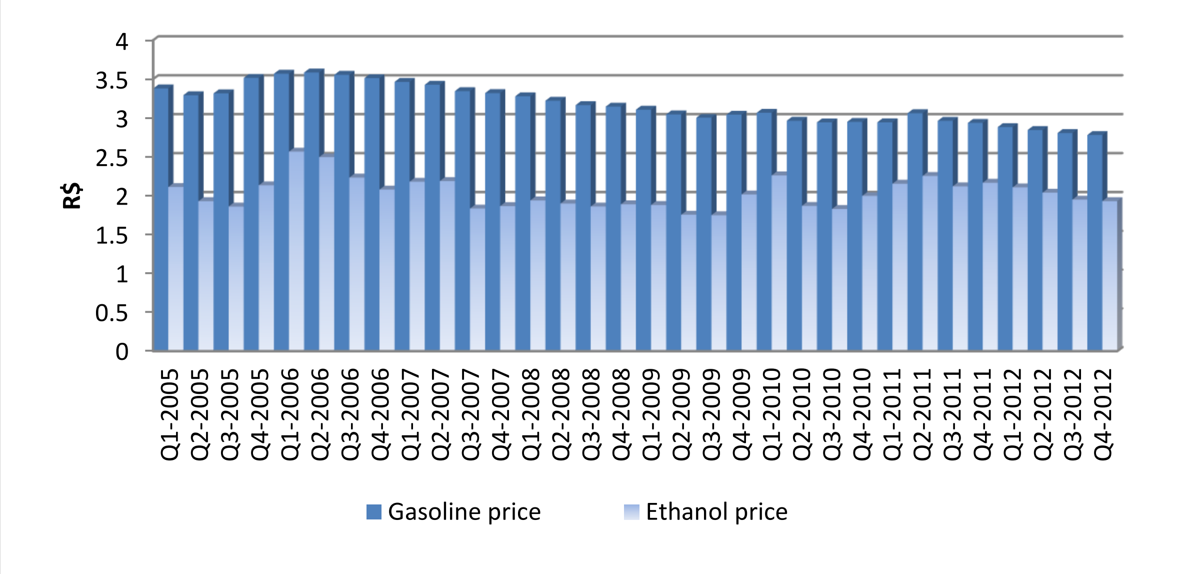

Figure 3 - Evolution of real prices of gasoline and hydrated ethanol (Base: December 2012).
Source: Own elaboration

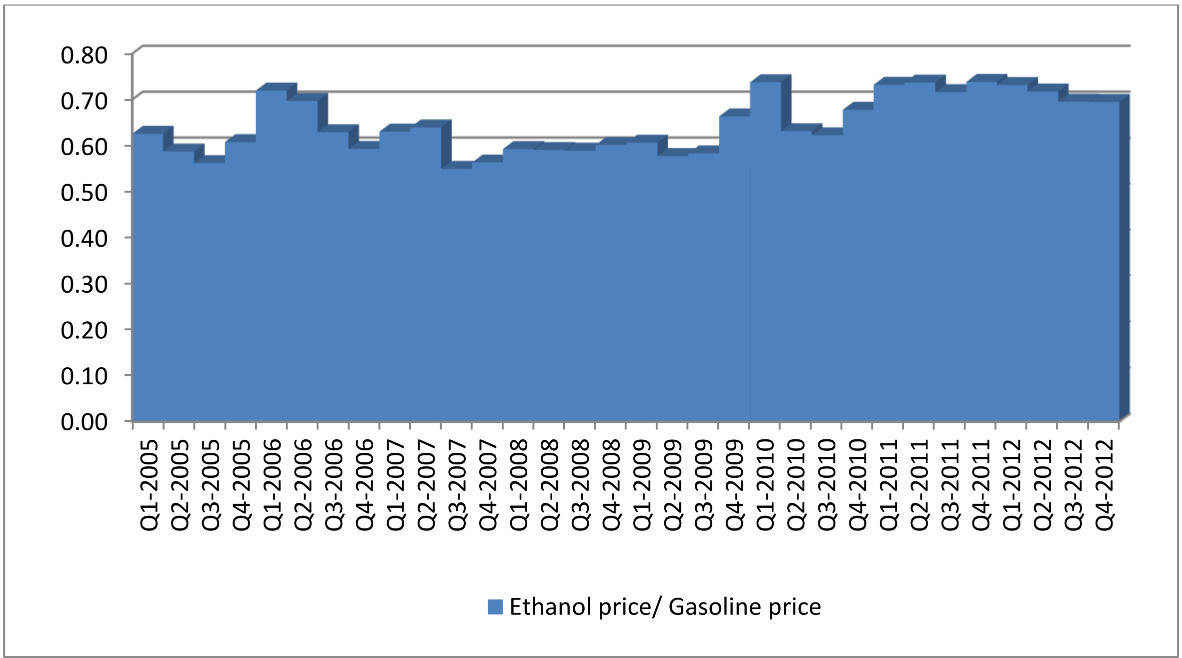

Figure 4: Evolution of the relative price between ethanol and gasoline C.
Source: Own elaboration

Table 1: Critical values for Dickey-Fuller tests (number of observations) 50

Level of Significance	Constant and trend	Constant	Without constant and trend
0.01	τ_{τ} = -4.15	τ_{μ} = -3.58	$\tau = -2{,}62$

Source: Enders (2010)

Table 2: Results of the each variable estimated in level.

Series	Estimated value - τ_{τ}	Estimated value τ_{μ}	Estimated value τ	LAGS
Δ LnD ethanol	-1.21	-2.18	1.16	0
Δ Ln D combined	-1,373	-0,8	2.58	0
Δ Ln D gas	-1.29	0.81	2.371	0
Δ Ln Combined Price	-2.019	-1.56	- 1.0	0
Δ Ln Relative Prices	-1.58	-1.17	-1.1	0
Δ Ln Aggregated	-2.79	-1.9	5.57	4

Obs: the Δ Ln D combined and Δ Ln Aggregated included seasonal dummy s
Source: Own elaboration

Table 3: Results of the each variable estimated in first level.

Series	Estimated value - τ_{τ}	Estimated value τ_{μ}	Estimated value τ	LAGS
ΔΔ LnD ethanol	-5.617			0
ΔΔ Ln D combined	-6.97			0
ΔΔ Ln D gas	-6.02			0
ΔΔ Ln C combined Price	-6.044			0
ΔΔ Ln Relative Prices	-4.15			0
ΔΔ Ln Aggregated Wages	-6.79			4

Obs: the Δ Ln D combined and Δ Ln Aggregated included seasonal dummy s.
Source: Own elaboration

Table 4: Critical values for the KPSS test.

10%	5%	1%
0.354	0.476	0.713

obs: The null hypothesis is that the variable is stationay.
Source: GRETL

Table 5: Results of the KPSS tests in level.

	Estimated values	LAGs
Δ Ln D et	0.517	0
Δ Ln D comb	0.87	0
Δ Ln D gas	0.8	0
Δ Ln Combined Price	0.65	0
Δ Ln Relative Prices	0.52	0
Δ Ln Aggregated Wages	0,73	4

Obs: the Δ Ln D combined and Δ Ln Aggregated included seasonal dummy s
Source: Own elaboration

Table 6: Results of the KPSS tests in first difference.

	Estimated Values	LAGs
Δ Δ Ln D et	0,527	0
Δ Δ Ln D comb	0,19	0
Δ Δ Ln D gas	0,37	0
Δ Δ Ln Combined Price	0,09	0
Δ ΔLn Relative Prices	0,066	0
Δ Δ Ln Aggregated Wages	0,11	4

Obs: the Δ Ln D combined and Δ Ln Aggregated included seasonal dummy s.
Source: Own elaboration

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Table 7: Critical values for the ADF-GLS test.

10%	5%	2,5%	1%
-2,89	-3,19	-3,46	-3,77

Source: GRETL

Table 8: Results of the ADF-GLS test in level.

	Estimated Values	LAGs
Δ Ln D et	-1,13	0
ΔLn D comb	---------	----
ΔLn D gas	-3.36	0
ΔLn Combined Price	-6.66	0
ΔLn Relative Prices	-3,06	0
ΔLn Aggregated Wages	-----	----

Source: Own elaboration

Table 9: Results of the ADF-GLS test in first diference.

	Estimated Values	LAGs
ΔΔ Ln D et	-5.26	4
ΔΔ Ln D comb	----	---
ΔΔ Ln D gas	-6.19	0
ΔΔ Ln Combined Price	-6.66	0
ΔΔ Ln Relative Prices	-6.24	0
ΔΔ Ln Aggregated Wages	-----	----

Source: Own elaboration

Table 10: Critical Values for the Engle-Granger Cointegration Tests. Two variables

1%	5%	10%
-4.123	-3.461	-3.130

Source: : Enders (2010)

Table 11: Calculated values of the cointegrated tests.

Models	Values
Combined demand	-3.63
Gasoline C demand	-3.37
Hydrated Ethanol demand	-3.563

Source: Own elaboration

Therefore, it is accepted the cointegration equations for Combined Fuel Demand with 1% significance level, and Gasoline and Ethanol Demand, both with 5% confidence.