Effects of free gasoline prices on the ethanol sector in São Paulo[1]

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Abstract – Brazil is a particularly interesting case when it comes to the study of fuel prices and their effects on other sectors of the economy, since the oil-related industries in the country have some specific characteristics, such as the wide use of ethanol as a substitute for gasoline and the practiced fuel pricing policy by the government. The goal of the present study is to analyze how the situation in Brazil would have looked like, if fuel prices were not administrated by the government, and what the hypothetical effects of such a change in the policy on biofuel prices and demand would have been. For the purposes of the analysis, a hypothetical consumer gasoline price was constructed, using the provided by DATAGRO series of "interned" gasoline prices. The obtained results show that incorporating the fluctuations in the international crude oil price would have had positive effects on the ethanol sector in the state of São Paulo for the period 2011-2015, by pushing the hydrous ethanol price up, making it more profitable for sugarcane producers to direct their production to ethanol instead of sugar, and stimulating domestic ethanol demand as an alternative for conventional fossil fuels. Moreover, the hypothetical gasoline price would have led to lower gasoline consumption, thus, breaking the artificial demand for this fuel created by the government.

Keywords: demand elasticities, fuel pricing policy, hypothetical analysis

Efeitos de preços livres da gasolina sobre o setor do etanol em São Paulo

Resumo – O Brasil é um caso particularmente interessante quando se trata do estudo dos preços dos combustíveis e seus efeitos sobre outros setores da economia, uma vez que as indústrias relacionadas ao petróleo no País possuem particularidades, como o uso de etanol da cana-de-açúcar e a política de formação dos preços dos combustíveis praticada pelo governo. O objetivo deste estudo é analisar como teria sido a situação no Brasil se os preços dos combustíveis não fossem administrados pelo governo e os efeitos hipotéticos de tal mudança na política sobre os preços e a demanda por etanol. Para essa análise, foi construído um preço hipotético da gasolina livre, utilizando a série do preço "internado" da gasolina fornecida pela Datagro. Os resultados obtidos mostram que o preço livre da gasolina teria efeitos positivos para o setor do etanol no Estado de São Paulo para o período 2011–2015, levando ao aumento do preço dessa commodity, tornando a produção mais rentável para os produtores de cana-de-açúcar, e estimulando a demanda doméstica por etanol

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como alternativa para a gasolina. Além disso, o preço livre da gasolina teria levado a uma demanda menor por gasolina, quebrando assim a demanda artificial desse combustível criada pelo governo.

Palavras-chave: elasticidade da demanda, política de preços dos combustíveis, análise hipotética.

Introduction

Crude oil and conventional fossil fuels remain the main energy source worldwide. They are internationally traded goods and their prices are formed following the basic rules of supply and demand on the world market. Nevertheless, the prices of fuels in some countries do not follow the international price of crude oil, but rather diverge significantly. This trend is the result of two main factors that play a role simultaneously: government fuel pricing policies and taxation. In general, fuel price fluctuations are considered to have a significant negative impact on inflation rates, especially in developing countries, which is the main reason why governments adopt different fuel pricing mechanisms, which involve some degree of government intervention when it comes to the formation of the domestic fuel price.

The case of Brazil is particularly interesting when it comes to the study of fuel prices and their effects on other sectors of the economy, since the oil-related industries in the country have some specific characteristics, such as the wide use of ethanol produced from sugarcane as a substitute for gasoline and the practiced fuel pricing policy by the government. Until 1997, the state-controlled company Petrobras held a monopoly on all oil-related activities in the country, fuel imports were not allowed, and the price of all petroleum derivatives was established by the government. In the late 1990s, the first steps towards the liberalization of the fuel industry were taken: the sector was opened for competition, subsidies were removed, and the refinery price was liberalized.

Nevertheless, currently, fuel prices in the country are not entirely free to follow international crude oil price fluctuations. The ex-refinery price of all petroleum derivatives in Brazil is set by the state-controlled company Petrobras. This policy uses as a reference for the price adjustments the variations in the Brent crude oil price and the USD exchange rate published by the Central Bank of Brazil. The established pricing system aims at diminishing the negative effects that volatile fuel prices, accompanying the fluctuations in the international crude oil price, would have on the inflation rate in the country.

This pricing policy has been an important decision for the government, since the country has a history of periods with extremely high inflation. The fact that in Brazil the distribution system of goods relies mainly on road transportation implies that higher fuel prices will be passed on to the final prices of consumer goods, since the majority is transported by trucks. The inadequate infrastructure for using cheaper types of transportation, such as rail for instance, make the country dependent on road transport and, thus, almost all sectors of the economy become vulnerable to fuel price fluctuations.

The practiced policy by Petrobras, however, resulted in a significant divergence of the domestic fuel prices from the international price of crude oil. The fluctuations on the international oil market were not absorbed by the domestic gasoline and diesel prices in Brazil, which lowered the vulnerability of the domestic market to outside oil price shocks and fluctuations, but had severe consequences for the domestic economy.

In general, artificially low domestic petroleum product prices in times of expensive international crude oil can lead to financial difficulties for fuel suppliers and importers, fuel supply shortages, and lack of investment in the fuel sector (Kojima, 2009). For the specific case of Brazil, the artificially established gasoline and diesel prices have brought imbalances to the domestic economy and especially to Petrobras (Serigati, 2014). The profitability of the company deteriorated significantly, which, in turn, undermined the value of its shares and increased its indebtedness. Furthermore, private investment in the oil-related sectors reduced considerably, the Brazilian trade balance and the exchange rate were affected negatively.

Other sectors of the economy, especially the ethanol industry, suffered in the past few years as a result of the practiced fuel pricing policy in the country. The trend of lower share of gasoline in total fuel consumption, which had prevailed since 2003 reflecting the introduction of the flex-fuel vehicle and the consumers' preference for ethanol, was reversed in 2009 as a result of the artificially low gasoline price established by Petrobras. The attractiveness of the ethanol sector reduced, pushing away investors and leading to migration to sugar production from sugarcane. Keeping the price of conventional fuels artificially low undermined dramatically the competitiveness of the ethanol sector and the potential of this biofuel as fuel alternative.

The negative consequences of the established pricing policy in Brazil raise some fundamental questions, such as: Who is covering the losses of Petrobras and is the burden transferred to the final consumer?; Should the government let the price of fuels adjust to international crude oil price fluctuations?; What would the hypothetical impact of such a pricing policy be on the domestic economy and on the ethanol sector? These important questions have not been answered yet, thus, the study of how the situation in Brazil would have looked like if fuel prices were not administrated and what their levels would have been during the past decade, represents a relevant topic of research, which is addressed in the present paper.

The main objective of this work is to provide insights on the issue by analyzing the hypothetical effects that a market-oriented fuel pricing policy would have had on the fuel and biofuel prices and demanded quantities in the state of São Paulo between January 2011 and June 2016. The proposed method for performing the analysis is based on fitting a structural vector auto regression (SVAR) model to the data that incorporates the specific characteristics of the fuel and biofuel sectors in Brazil in order to estimate the demand elasticities for ethanol and gasoline. The obtained contemporaneous responses of the variables to changes in the price of gasoline were used afterwards for the calculation of a hypothetical ethanol price and demanded quantities for both types of fuels for a scenario in which the domestic price of gasoline followed the fluctuations in the international price of oil between 2011 and 2016.

The remainder of this paper is organized as follows: Section 2 briefly reviews the literature on fuel pricing policy and ethanol demand estimation in Brazil; Section 3 focuses on the methodology for performing the analysis; Section 4 develops the theoretical model applied in the paper; Section 5 describes the used data; Section 6 presents the main results; and Section 7 concludes with final remarks and suggestions for future research.

Literature review

Biofuel-related sectors price transmission and ethanol demand estimation

For the purposes of the proposed study, it is crucial to understand the interrelations between the ethanol sector and the sugar and gasoline markets in Brazil. Moreover, it is important to take into consideration the existing link between the hydrous and anhydrous ethanol sectors. First of all, sugar and ethanol in the country are produced from the same feedstock – sugarcane, which makes the two products competing on the supply side. Since most of the production plants in Brazil are specialized in producing both products, it is up to the producer to decide how to distribute its production, depending on market conditions. This specific characteristic of the sugar and ethanol sectors makes them closely interrelated, especially when it comes to price linkages. The findings of the empirical literature provide evidence for the existence of a long-term relationship between the prices of sugar and ethanol in the country (Rapsomanikis & Hallam, 2006; Balcombe & Rapsomanikis, 2008; Block et al., 2012; Bentivoglio et al., 2016).

Another important characteristic of the Brazilian biofuel sector is the fact that there are two types of ethanol produced in the country – hydrous ethanol, which is used in its pure form as a substitute for gasoline, and anhydrous ethanol, which is derived after dehydration and is used for blending with gasoline. Since the latter is a derivation of the former, it is expected that the prices of the two products are highly interrelated (Elobeid & Tokgoz, 2008).

When it comes to the relationship between hydrous ethanol and gasoline in Brazil, the two products act as substitutes on the demand side due to the existence of the so called flex-fuel vehicle, introduced in 2003, which allows the final consumer to choose what fuel to use – gasoline C (a blend of gasoline with 27% of anhydrous ethanol) or pure hydrous ethanol fuel, depending on the price relationship between the two products. Since ethanol is less efficient than gasoline, it makes sense to use this biofuel as a substitute as long as its price constitutes 70% of the price of gasoline. This specific characteristic of the fuel and biofuel sectors, which is rather unique for Brazil, implies that the two prducts are closely interrelated. There is a consensus in the empirical literature that there exists a long-term relationship between the prices of hydrous ethanol and of gasoline C in Brazil (Cavalcanti et al., 2011; Bentivoglio et al., 2016).

Regarding the effects of international crude oil prices on the oil-related sectors in the country, the results of the previously published studies support the hypothesis that the international crude oil price is exogenous and has influence on domestic fuel and biofuel prices (Rapsomanikis & Hallam, 2006; Balcombe & Rapsomanikis, 2008; Chen & Shaghaian, 2015).

These specific characteristics of the Brazilian fuel- and biofuel-related sectors should be taken into account when demand for fuels is analyzed. Ethanol demand estimation in Brazil has been a relevant research topic since the introduction of the flex-fuel vehicle in 2003, which made it possible for the consumer to choose between gasoline and ethanol as fuel alternatives. In the majority of studies on the topic, ethanol consumption is used as dependent variable, while various independent variables, such as price of the product and its substitutes, income, and vehicle fleet are included in the estimation of the equation for ethanol demand. Three major methodology approaches can be distinguished in the examined literature – time series analysis based on cointegration and VECM estimation; OLS regression estimation; and spatial panel model estimation.

The estimated short-term price elasticities of ethanol demand in the existing literature remain in the range between 0.55 and 1.96, while in the long-run this range is between 1.11 and 11.26 in absolute terms, indicating that ethanol demand is more sensitive to its own price changes in the long-run (Pontes, 2009; Randow et al., 2010; Santos & Faria, 2012; Cardoso et al., 2013). Similar conclusions can be derived for the cross-price elasticity with gasoline: the estimated values are higher in the long- than in the short-run, indicating higher substitutability between the two fuels in the long-run.

Moreover, the results of previous studies show that ethanol demand is more sensitive to changes in the price of gasoline than to its own price variations. There is a consensus in the literature that after the introduction of the flex-fuel vehicle in 2003 ethanol strengthened its position as a substitute for conventional fossil fuels (Serigati et al., 2010; Freitas & Kaneko, 2011) and the price and cross-price elasticities of ethanol demand increased (Souza, 2010). In addition, previous research has shown that ethanol demand is more income elastic than gasoline and appears to be more sensitive to the vehicle fleet, as well (Pontes, 2009; Cardoso et al., 2013).

Fuel pricing policy and simulation of free fuel prices

In the existing literature on the topic of interest there is no consensus whether the Brazilian government should move to a free fuel pricing policy where the prices of petroleum derivatives are determined entirely by the market, or not. Some authors (Viegas, 2011) argue that the total liberalization of the price of gasoline is essential for the country, especially for the ethanol industry, while others (Almeida et al., 2015; Oliveira & Almeida, 2015) think that a market-based approach for fuel prices is unfeasible. The majority of the reviewed works, however, conclude that a change in the practiced fuel pricing mechanism in Brazil is essential for the future development of the country.

Almeida et al. (2015) point out the negative impacts of the practiced fuel pricing policy in Brazil and the necessity of developing a new paradigm, which would be more suitable for the country, considering its specific characteristics. The authors perform a comparative analysis of the practiced fuel pricing policies in other countries and conclude that the full liberalization of fuel prices is not the best option for a country like Brazil, which has great concerns about the level of inflation. Thus, some degree of government control is needed and the policy of stabilization funds appears to be a better option.

According to Azevedo & Serigati (2015), the adopted strategy by the government of the president Dilma Rouseff of administrating prices as an instrument for reducing inflation in Brazil was inefficient, had negative impacts on investment and consumption decisions, and, in addition, was used as a strategy for winning elections. The authors conclude that administrating prices did not have a long lasting effect on inflation rate, since this measure does not deal with the real causes of inflation.

The negative consequences of the practiced fuel pricing policy in Brazil for the ethanol sector have received attention in the existing literature, as well. Santos et al. (2015), for instance, discuss the main factors that led to the crisis of the ethanol sector from 2011. The authors mention three major determinants of this crisis, namely, the elevation of the production costs and the costs for external financing, the reduction in the margins, and the control of the price of gasoline. Santos et al. (2015) raise the question of the potential effects of liberalization of the price of gasoline on the ethanol sector in the country and suggest this research question as an interesting continuation of their work.

When it comes to the potential impact of free fuel prices in Brazil on the ethanol industry, Araujo (2013) analyzes how the variation of the price of gasoline in the country affects the performance of the ethanol sector. The author estimates the GDP of the sugar and ethanol industries for the period 2002-2012, using the actual gasoline prices for the studied period and a benchmark price of gasoline of the Gulf of North America. The obtained results point towards the existence of a significant impact of gasoline prices on all variables of the biofuel industry in Brazil, such as: production of hydrous and anhydrous ethanol, GDP of the sugar and ethanol sectors, and indebtedness of the industry. The article provides empirical evidence that the fuel pricing policy of the government has impact not only on the performance of Petrobras, but also on the performance of the sugar and ethanol industry in the country.

A simulation of free gasoline prices for the Brazilian economy was performed by Serigati (2014), who used two different approaches. The first originates in the calculation of a viable price of hydrous ethanol, from which the price of gasoline is derived assuming that the effective price ratio of 0.7 between the two prices is maintained. The second one is based on a simulation of an average gasoline price following the variations in the international crude oil price and, from there, the arbitrary fair price of ethanol is derived. Serigati (2014) concludes that the policy of controlling fuel prices has decreased the competitiveness of ethanol over time and at the same time has helped control inflation.

More thorough analysis of the potential effects of free fuel prices on the inflation rate in Brazil was performed by Corrêa & Teixeira (2014). The authors used U.S. gasoline and diesel prices as a proxy for free fuel prices in Brazil, in order to calculate the historical inflation index IPCA based on the prices from the U.S. market for the period 2003-2008. The obtained results show that only in 2003 and in 2008 the IPCA would have been higher than the actually observed inflation rate in the country, due to the free prices of gasoline and diesel.

Furthermore, Cunha (2015) developed a method for analyzing the direct and indirect effects of administrated fuel prices on the inflation index in Brazil using the input/output methodology. The obtained results show that the policy of controlling fuel prices was successful for mitigating the level of inflation in some of the studied years, but at the same time is associated with social costs and economic distortions related to this type of pricing policy. Cunha (2015) emphasizes the negative effects of the practiced fuel pricing policy in Brazil, indicating the distortions in the domestic price system, the deterioration of Petrobras' financial situation, the reduced attractiveness of the oil-related sector for investment, the negative impact on the ethanol sector, and the environmental costs as the main negative consequences of the practiced fuel pricing policy in Brazil. The proposed alternative policy by the author is the adoption of a measure of core inflation as an official index, which is supposed to exhibit less variation than the plain inflation index, and, thus, can serve as a better signal for adopting different economic policies.

Khanna et al. (2016) develop a partial-equilibrium model of the fuel, biofuel, and sugar sectors in Brazil in order to analyze the multi-sector impacts of the practiced fuel policies in the country. The authors simulate five alternative policy scenarios and compare the effects they would have had on the prices and the demanded and supplied quantities of sugar, ethanol and gasoline. They find that the status-quo policy scenario, which considers the existing mix of policies including a blend mandate, gasoline tax, ethanol tax credit, and oil price cap, leads to higher consumer prices of ethanol and gasoline, higher production of ethanol, lower sugar supply, increase in ethanol consumption, and decrease in gasoline demand in comparison to the baseline scenario of no policy. Moreover, the authors conclude that the choice of fuel policies in Brazil has not been guided by the pursuit of economic efficiency, but by policy objectives, such as tax revenue, increasing oil exports, and well-being of various interest groups.

Based on the literature review presented in this section, it can be concluded that a thorough study of the potential effects of free fuel prices in Brazil on the ethanol sector has not been previously performed. There exists no consensus in the literature whether the government should adopt a market-oriented fuel pricing policy or not, but the majority of researchers point out the necessity of a new pricing mechanism that is more transparent, does not allow abuse by the government, and does not have significant negative impact on the domestic economy, and especially on the ethanol industry.

Methodology

Stationarity tests

This study relies on time series techniques for performing the analysis, which requires taking into account some general statistical properties of the data a priori. In order to obtain consistent and reliable results, the data has to be first tested for stationarity and if the results point towards the existence of a unit root, then the time series has to be transformed into stationary data to proceed with the desired analysis. More precisely, stationarity implies the time-constancy of the statistical distribution and such a time series is considered to be a process integrated of order zero - I(0).

Common practice in time series modelling has involved the application of the augmented Dickey-Fuller (DF) and the Phillips-Perron (PP) tests for determining whether the data series is stationary or not. The proposed by Elliott et al. (1996) DF-GLS test, however, has significantly greater power and better overall performance in terms of small-sample sizes, dominating the ordinary DF tests. This test represents a modified version of the augmented DF test, since the series has been transformed by a generalized least-squares regression. The DF-GLS test is performed fitting a regression of the following form (Elliott et al., 1996):

$$y_t = \alpha + \beta y_{t-1} + \zeta_1 \Delta y_{t-1} + \zeta_2 \Delta y_{t-2} + \dots + \zeta_k \Delta y_{t-k} + \varepsilon_t \quad (1)$$

where k is the number of lags of first-differenced, detrended variables. The number of lags of the process has to be chosen appropriately. Lags should be added to the model only until they are significant, i.e. until there is no serial correlation in the error term. For this purpose, information criteria like the Ng-Perron, the Schwarz Criterion and the Modified Akaike Information Criterion are used.

There are two forms of the DF-GLS test – GLS detrending (where the series to be tested is regressed on a constant and a linear trend) and GLS demeaning (where only a constant appears in the first-stage regression). The null hypothesis of the DF-GLS test assumes that the is a random walk, possibly with drift. There are two alternative hypotheses depending on the chosen form of the test: is stationary about a linear time trend, and is stationary with a possible nonzero mean but with no linear time trend. Both versions of the test are used in the present study for testing for stationarity.

Structural vector auto regression (SVAR)

A vector auto regression process with *n* variables and *p* lags can be expressed in the following form (Hamilton, 1994):

$$y_t = c + \Phi_1 y_{t-1} + \Phi_2 y_{t-2} + \dots + \Phi_p y_{t-p} + \varepsilon_t \quad (2)$$

where y_t is a vector of stationary variables whose interrelations are analyzed, c denotes an $(n \times 1)$ vector of constants, Φ_j is an $(n \times n)$ matrix of autoregressive coefficients, and ε_t is a vector of independent and identically distributed (i.i.d.) error terms with variance-covariance matrix Ω.

A structural vector auto regression is a VAR(p) process subject to short- or long-run restrictions placed on the relations in the VAR system, based on economic theory. An SVAR representation of equation (2) takes the following form:

$$B_0 y_t = k + B_1 y_{t-1} + B_2 y_{t-2} + \dots + B_p y_{t-p} + e_t \quad (3)$$

where B_0 is an $(n \times n)$ matrix of contemporaneous relationships between the variables, B_i's are $(n \times n)$ matrices of coefficients, and is an $(n \times 1)$ vector of structural innovations. Equation (3) can be written in terms of the polynomial $B(L) = B_0 + B_1 L + B_2 L^2 + \dots + B_p L^p$, where L is the lag operator:

$$B(L) y_t = e_t \quad (4)$$

Assuming that B_0 is invertible, equations (3) and (4) can be multiplied by B_0^{-1} on the left and solved for y_t, which results in the following reduced forms of SVAR:

$$y_t = B_0^{-1} k + B_0^{-1} B_1 y_{t-1} + B_0^{-1} B_2 y_{t-2} + \dots + B_0^{-1} B_p y_{t-p} + B_0^{-1} e_t \quad (5)$$

$$A(L) y_t = u_t \quad (6)$$

where $A(L) = B_0^{-1} B(L)$, $A_0 = I_0$, and $u_t = B_0^{-1} e_t$. The reduced form of the SVAR allows for removing the contemporaneous correlations in the system, thus, the coefficients can be further used for forecasting and impulse response function analysis. Equation (6) represents the short-term SVAR form, where the restrictions of the model are imposed on the matrices A and B, which are assumed to be nonsingular. The restrictions on the B_0 matrix model the contemporaneous relationship between the variables. Moreover, for the identification of the SVAR model, an orthogonality restriction should be imposed on the variance-covariance matrix of the residuals -Ω. This matrix should be diagonal, implying that the covariance between the residuals is restricted to be zero. The coefficients of the SVAR model are estimated using maximum likelihood method of estimation.

Every VAR or SVAR process can be written in a vector moving average form, where all the past values of y_t have been substituted by the past values of the error terms. The MA(∞) representation of Equation (6) takes the following form:

$$y_t = C(L)u_t \quad (7)$$

or

$$y_t = C(L)B_0^{-1}\, e_t \quad (8)$$

where $C(L)$ is an infinite polynomial of past innovations C_j, which can be obtained if the matrix $A(L)$ is known: $C(L) = (I - A(L)^{-1})$. Equations (7) and (8) represent the long-run SVAR form, in which the constraints are placed on the elements of the matrix C and are later on estimated using the maximum likelihood method.

Theoretical model

For the purposes of the present study, the theoretical model developed by Diehl (2012) is used as a basis for the analysis of the hypothetical effects of free gasoline prices on the Brazilian ethanol sector. This theoretical model captures the specific characteristics of the fuel and biofuel sectors in the country and consists of the following nine equations:

Hydrous ethanol consumption:

$$D_{HE,t} = \alpha_0 + \alpha_1 P_{HE,t} + \alpha_2 P_{G,t} + \alpha_3 Y_t + + \alpha_4 F_t + \varepsilon_{1,t} \quad (9)$$

Hydrous ethanol price:

$$P_{HE,t} = \beta_0 + \beta_1 P_{G,t} + \beta_2 P_{AE,t} + \varepsilon_{2,t} \quad (10)$$

Gasoline C consumption:

$$D_{G,t} = \delta_0 + \delta_1 P_{HE,t} + \delta_2 P_{G,t} + \delta_3 Y_t + + \delta_4 F_t + \varepsilon_{3,t} \quad (11)$$

Domestic consumer price of gasoline C (exogenous):

$$P_{G,t} = \varepsilon_{4,t} \quad (12)$$

Anhydrous ethanol price:

$$P_{AE,t} = \varphi_0 + \varphi_1 P_{S,t} + \varepsilon_{5,t} \quad (13)$$

Domestic sugar price:

$$P_{S,t} = \gamma_1\, \mathrm{P}_{IS,t} + \varepsilon_{6,t} \quad (14)$$

International sugar price (exogenous):

$$P_{IS,t} = \varepsilon_{7,t} \quad (15)$$

Income (exogenous):

$$Y_t = \varepsilon_{8,t} \quad (16)$$

Fleet (exogenous):

$$F_t = \varepsilon_{9,t} \quad (17)$$

where $D_{HE,t}$ is the quantity sold of hydrous ethanol at period t; $D_{G,t}$ is the quantity sold of gasoline C; $P_{HE,t}$ is the consumer price of hydrous ethanol, $P_{G,t}$ is the consumer price of gasoline C; $P_{AE,t}$ is the domestic producer price of anhydrous ethanol; $P_{S,t}$ is the domestic producer price of sugar; $P_{IS,t}$ is the international price of sugar; Y_t is income; and F_t is the alcohol and flex-fuel vehicle fleet.

This theoretical model incorporates the specific characteristics of the ethanol sector in Brazil, hence, accounts for the existing relationships between the ethanol sector and the sugar and gasoline markets. Equations (9) and (11) model the demand for hydrous ethanol and for gasoline C, respectively. The independent variables in the demand equations include price of the fuel of interest, price of its substitute, income, and alcohol and flex-fuel vehicle fleet. In equation (10) the independent variable is the consumer price of hydrous ethanol, which is modeled as a function of the price of gasoline C and the price of anhydrous ethanol considered as a proxy for the producer price.

Moreover, the so-developed model accounts for the formation of the domestic sugar price, which is modeled as dependent on the international sugar price in equation (14). This is justified by the fact that Brazil is a main player on the international sugar market, which implies that its domestic sugar sector is highly influenced by international factors. The domestic sugar price is considered to influence the domestic producer price of anhydrous ethanol, as shown in equation (13). The consumer price of gasoline, as well as the international price of sugar, the income and the vehicle fleet are considered to be exogenous variables in the model.

The nine equations presented above form the matrix of contemporaneous relations between the variables of the system. The restrictions imposed on this matrix are presented in Table 1, with the expected signs of the coefficients shown in brackets. In the demand equations for hydrous ethanol and gasoline C, the expected sign of the coefficient on the income is positive. The price of the respective product is expected to influence the demanded quantity in a negative way, while the price of the substitute should have a positive impact on consumption. The alcohol and flex-fuel vehicle fleet is considered to have a positive sign in the demand equation for ethanol and to influence negatively the demand for gasoline.

In the price equation for hydrous ethanol, the expected signs are positive for both the effect of changes in the price of gasoline and in the producer price of anhydrous ethanol. In turn, the price of anhydrous ethanol is expected to be positively influenced by the price of sugar, since the two products are considered competitors on the supply side. Finally, the international price of sugar is considered to have a positive effect on the domestic producer price of sugar.

As it can be seen in Table 1, the matrix of restrictions assumes that the consumption of fuels is contemporaneously influenced by all other relevant variables in the model, but at the same time it is not considered to have any contemporaneous impact on the prices included in the system. This structure follows the logics of the majority of studies examining fuel demand, which assume the price variables as exogenous. According to Rodrigues (2015), this way of modelling demand for fuels is based on the fact that domestic fuel prices more often than not are subject to government policies and regulations, on the one hand, and are tightly linked to the international price of oil, on the other. In the specific case of Brazil, the ex-refinery price of all crude oil derivatives is established by the state-owned company Petrobras, while the price of ethanol has a ceiling given by the price of

Table 1. Matrix of contemporaneous effects.

	$D_{HE,t}$	$P_{HE,t}$	$D_{G,t}$	$P_{G,t}$	$P_{AE,t}$	$P_{S,t}$	$P_{IS,t}$	Y_t	F_t
$D_{HE,t}$	1	(-)	0	(+)	0	0	0	(+)	(+)
$P_{HE,t}$	0	1	0	(+)	(+)	0	0	0	0
$D_{G,t}$	0	(+)	1	(-)	0	0	0	(+)	(-)
$P_{G,t}$	0	0	0	1	0	0	0	0	0
$P_{AE,t}$	0	0	0	0	1	(+)	0	0	0
$P_{S,t}$	0	0	0	0	0	1	(+)	0	0
$P_{IS,t}$	0	0	0	0	0	0	1	0	0
Y_t	0	0	0	0	0	0	0	1	0
F_t	0	0	0	0	0	0	0	0	1

gasoline (it should not exceed 70% of that price). These specifics of the fuel and biofuel sectors in the country justify the use of fuel prices as independent of domestic demand for fuels.

After estimating the coefficients of contemporaneous effects between the variables using the SVAR methodology, the obtained elasticities are used for the calculation of the hypothetical responses of the variables in the system to a new gasoline price that accompanies the international crude oil price fluctuations.

Data description

The empirical analysis is performed using the following data series:

1) Hydrous ethanol sales by distributors in liters (National Agency of Petroleum, Natural Gas and Biofuels - ANP);
2) Gasoline C sales by distributors in liters (ANP);
3) Consumer price of hydrous ethanol in R$/liter (ANP);
4) Consumer price of gasoline C in R$/liter (ANP);
5) Producer price of anhydrous ethanol in R$/liter (Center for Advanced Studies on Applied Economics/"Luiz de Queiroz" College of Agriculture - CEPEA/ESALQ);
6) Producer price of sugar in R$/sack (CEPEA/ESALQ);
7) International sugar price – futures contract for first delivery for Sugar No. 11 converted into R$/sack (NYSE);
8) Real average monthly income in R$ (Brazilian Institute of Geography and Statistics - IBGE);
9) Alcohol and flex-fuel vehicle fleet in units (Brazilian Automotive Industry Yearbook -ANFAVEA).

All data series are obtained from secondary sources, consist of monthly regional data for the state of São Paulo and refer to the period January 2011 - July 2016. In order to make the data comparable for the purposes of the study, all prices were converted to Brazilian currency, using the monthly nominal USD/BRL exchange rate published by the Central Bank of Brazil. All price data was transformed into real terms using as a deflator the IGP-di for December, 2015. Moreover, all volumes were transformed into *per capita* values, using the population of São Paulo obtained from IBGE. All data was transformed into log terms, which allows the interpretation of the estimated coefficients of the SVAR model as elasticities.

The simulated free consumer gasoline price was constructed using the provided by DATAGRO series of daily producer prices of gasoline that accompany the international crude oil price fluctuations. The company publishes regularly this hypothetical free price of fuels for Brazil denoted as "interned price" calculated considering all costs incurred in importing fuels to the domestic market. More precisely, the calculation of the "interned price" is based on the following formula:

RBOB Gasoline spot price NYMEX FOB ×
× *Exchange rate* + *trade margin* +
+ *ocean freight* + *insurance* + *customs costs* +
+ *inland freight*

The simulated daily price series for gasoline was transformed into monthly final consumer prices by adding the following components following the price composition of gasoline C published on the website of ANP: taxes - federal (CIDE, PIS/PASEP, Cofins) and state (ICMS for São Paulo); costs for blending with anhydrous ethanol; distribution and retailer transportation costs and margins.

The evolution of the hypothetical free gasoline C price since 2011 in comparison to the observed price of this fuel in the state of São Paul during the same period is shown on Figure 1. As it can be seen on the graph, the simulated free gasoline price exhibits significant fluctuation, while the actually observed domestic gasoline

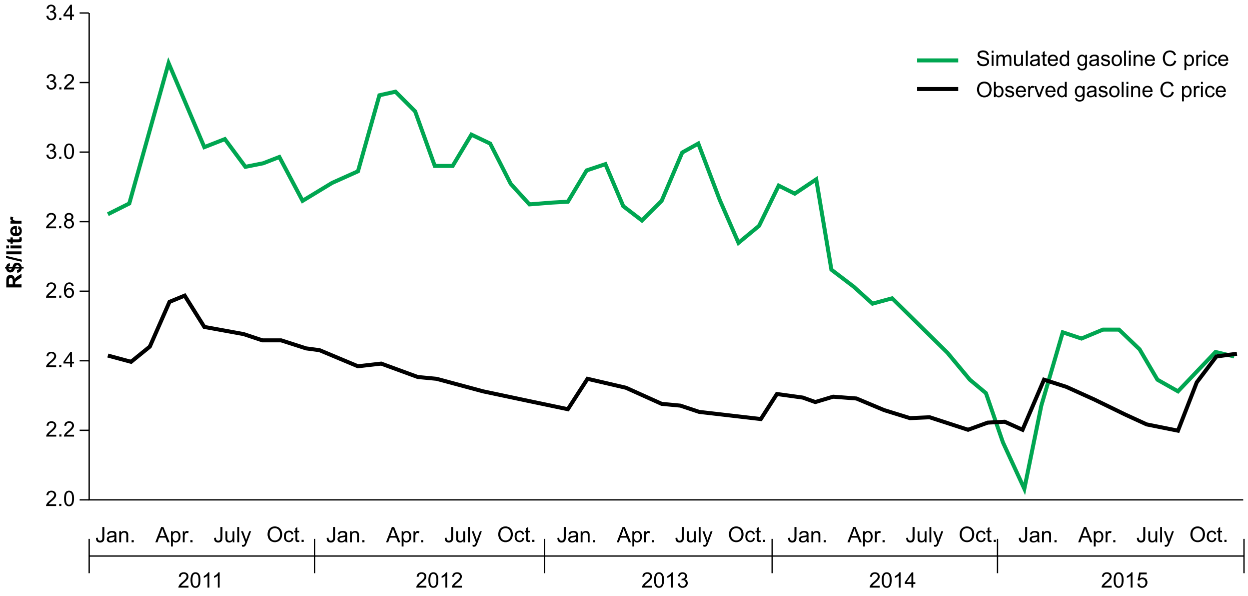

Figure 1. Observed vs. simulated monthly consumer price of gasoline C, São Paulo, 2011–2016.

price was rather stable between 2011 and 2016 – in the range of 2.2 and 2.6 R$/liter.

Until the beginning of 2015, the domestic price of gasoline in the state of São Paulo remained below the simulated free price. This trend, however, changed in the end of 2014 with the dramatic drop in the international price of crude oil, which led to a period of a few months when the simulated market gasoline price was lower than the observed price in the region.

What draws attention on the graph, is the significant divergence between the two gasoline price series through time. Until the beginning of 2014, the average difference between the two prices was approximately 0.7 R$/liter – a rather high value, which suggests that the effects of the hypothetical free fuel pricing policy on the biofuel market in the country would have been significant, as well.

Results

Prior to performing the analysis, the data series were tested for stationarity using the DF-GLS test. Both models of the test were used – model 1, which includes only constant, and model 2, which assumes the existence of both constant and linear trend. The number of lags was chosen using the modified Akaike information criterion (MAIC). All variables are found to have a unit root in level and to be stationary in their first difference (all data series are I(1)). Thus, the estimation needs to be performed using the data in first difference.

After testing the variables for stationarity, the analysis proceeds with the fitting of the SVAR model and estimating the matrix of contemporaneous effects. As mentioned earlier, there are restrictions imposed on this matrix in order to identify the SVAR model. Two lags were included in the system, which were chosen using the information criteria AIC and SC in their multi-equational form. The estimated coefficients of the contemporaneous effects matrix presented in Table 2 have the expected signs and are statistically significant with the only exception of the fleet in the equation for hydrous ethanol demand.

In the demand equation for hydrous ethanol, the magnitude of the estimated coefficient for the price of gasoline C indicates that ethanol consumption responds considerably to contem-

Table 2. Estimated matrix of contemporaneous effects.

	$D_{HE,t}$	$P_{HE,t}$	$D_{G,t}$	$P_{G,t}$	$P_{AE,t}$	$P_{S,t}$	$P_{IS,t}$	Y_t	F_t
$D_{HE,t}$	1	-2.214*	0	3.180*	0	0	0	1.770*	0.295
$P_{HE,t}$	0	1	0	0.900*	0.218*	0	0	0	0
$D_{G,t}$	0	1.650*	1	-2.346*	0	0	0	0.972*	-1.655*
$P_{G,t}$	0	0	0	1	0	0	0	0	0
$P_{AE,t}$	0	0	0	0	1	1.175*	0	0	0
$P_{S,t}$	0	0	0	0	0	1	0.438*	0	0
$P_{IS,t}$	0	0	0	0	0	0	1	0	0
Y_t	0	0	0	0	0	0	0	1	0
F_t	0	0	0	0	0	0	0	0	1

Note: * statistically significant at 1% probability; ** statistically significant at 5% probability; *** statistically significant at 10% probability; _ statistically insignificant.

poraneous variations in the price of its substitute in this market segment. A 1%-change in the consumer price of gasoline C causes approximately 3.2%-increase in the demanded quantity of hydrous ethanol. Biofuel consumption responds significantly to changes in its own price, as well: a 1%-change in the consumer ethanol price causes a 2.2%-decrease in the demand for this commodity. Regarding the sensitivity of ethanol consumption to income, a positive elasticity of 1.7% was estimated by the model.

The obtained results are higher than the estimated values in the majority of other studies that analyze ethanol demand in Brazil. The estimated short-term elasticities in the existing literature remain between 0.55 and 1.96. One of the main reasons for this upward bias of the results is the rather small number of observations. It is expected that using a sample for a longer period will result in lower values of the estimated elasticities.

In the equation for the consumer price of hydrous ethanol all coefficients are statistically significant. An increase of 1% in the price of gasoline C is found to cause a contemporaneous response in the price of ethanol of 0.9%. A 1%-increase in the price of anhydrous ethanol, which was used as a proxy for the producers market, has a 0.2% impact on the price of its hydrous equivalent - a result very similar to the one obtained by Diehl (2012).

In the gasoline demand equation, all estimated coefficients are statistically significant. A 1%-increase in the price of ethanol generates a 1.6%-increase in the consumption of gasoline C, while an increase in the price of gasoline by 1% causes a drop in its sales of 2.3%. These estimated values show that domestic demand for gasoline in the state of São Paulo was elastic during the observed period. The obtained values are higher than in the existing literature, where the short-term own price elasticities of gasoline demand are round about 0.4 (Diehl, 2012; Santos, 2013), while the long-term ones appear to be higher in absolute terms, reaching 1.186 (Santos, 2013). When it comes to the income elasticity of gasoline demand, it is found to be equal to 0.9%, which is a result close to the estimated values in the existing literature (Silva et al., 2009; Farina et al., 2010; Santos, 2013).

The price of anhydrous ethanol responds positively to changes in the domestic price of sugar. This result is in line with the expected, since ethanol and sugar compete on the supply side. It implies that when the price of sugar increases, sugarcane producers have an incentive to produce more sugar instead of ethanol, which leads to higher ethanol prices due to lower supply. Domestic sugar prices, on the other hand, appear to respond positively to international sugar price changes.

After obtaining the elasticities for the gasoline and ethanol sectors from the SVAR model estimation, the analysis proceeds with examining the hypothetical effects of a domestic gasoline price that accompanies the international crude oil price fluctuations. The response of the three variables of interest (ethanol price, fuel and biofuel demand) to the simulated freely fluctuating gasoline price were calculated for the observed period and are shown in the figures below.

Figure 2 illustrates the hypothetical response of the price of hydrous ethanol to the simulated free gasoline price. The ceiling on the price of ethanol was accounted for in this calculation. Since ethanol use is viable only while its price is less than 70% of the price of gasoline due to its lower efficiency, its price was not allowed to exceed this threshold. For the periods when the calculated hypothetical price of ethanol was above 0.7 of the simulated price of gasoline, the former was set to be equal to 0.7 of the latter.

As it can be seen on the graph, domestic gasoline prices that follow market conditions would have resulted in higher hydrous ethanol prices than the observed ones in the state of São Paulo between 2011 and 2016. This trend would have persisted until the beginning of 2015, when the global crude oil price suffered a significant drop. The hypothetical hydrous ethanol price would have stayed in the range of 2.4 R$/liter - 3.2 R$/liter prior to 2015, while the observed price remained in the range of 2.0 R$/liter - 2.9 R$/liter during this period. These results indicate the importance of international crude oil price fluctuations for the domestic biofuel sector in Brazil. The price of ethanol appears to be rather sensitive to such fluctuations, but, in reality, it is indirectly controlled by the government through the practiced fuel pricing policy of defining the ex-refinery price of gasoline and is kept at levels below the simulated ones.

After calculating the hypothetical price of hydrous ethanol for a scenario in which the government set free the price of gasoline in 2011, it is possible to calculate the hypothetical effects of such a change in the pricing policy on the demand for ethanol and for gasoline. Since demand quantities respond to changes in the

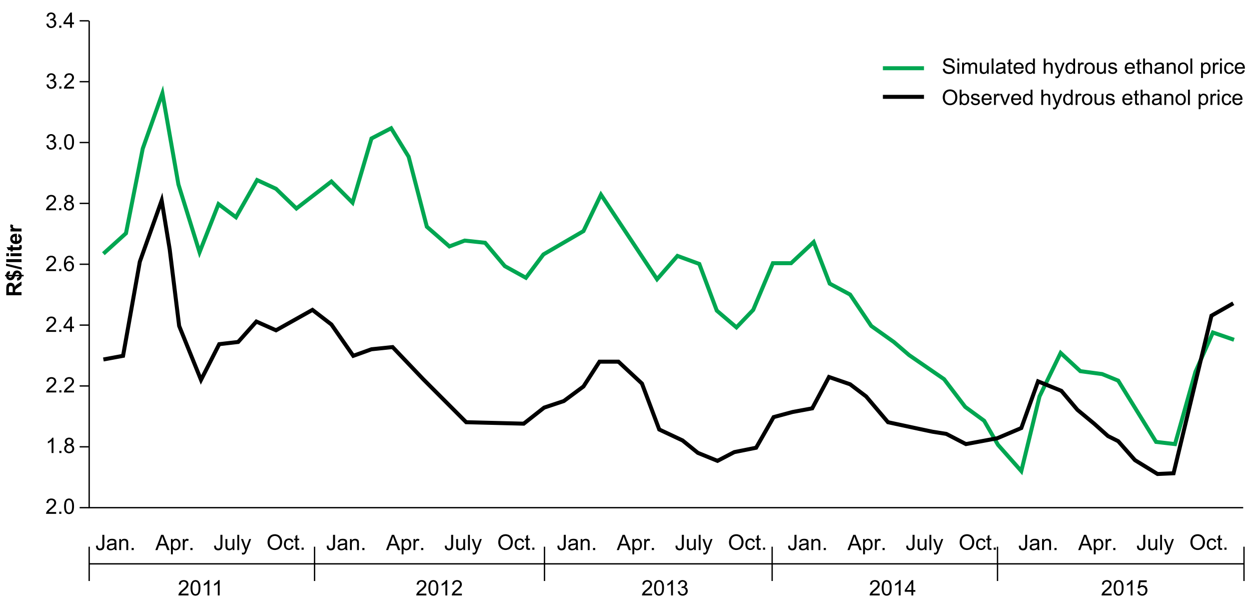

Figure 2. Observed vs. hypothetical price of hydrous ethanol.

prices of both fuels, the demanded values were calculated considering the simulated hypothetical prices of gasoline and of ethanol.

Figure 3 plots the observed and the hypothetical demand for gasoline C between 2011 and 2016. Gasoline demand responds negatively to impulses in its own price and positively to any shock in the price of hydrous ethanol. The net effect of both hypothetical prices was taken into consideration when calculating the hypothetical gasoline demand. This demand is found to be lower than the observed one during the analyzed period, with the exception in the end of 2014 and the beginning of 2015, when it slightly surpassed the observed gasoline consumption. The reason for this exception lies in the historically low international crude oil prices from this period, which made gasoline rather cheap worldwide and would have resulted in higher demanded quantities for this type of fuel in the state of São Paulo, if the practiced policy by the government was allowing it.

The obtained results show that higher gasoline prices accompanying international crude oil price fluctuations would have caused lower gasoline consumption in the state of São Paulo. Thus, the hypothetical free gasoline price would have broken the artificially created demand for gasoline in the country, which was the result of the government policy of keeping domestic fuel prices at lower levels than their international equivalents. This finding indicates the importance of the trends in the international oil market for domestic fuel and biofuel prices and consumption in Brazil.

Freely fluctuating gasoline prices would have had a significant impact on the hydrous ethanol consumption, as well. In general, demand for ethanol responds negatively to changes in its own price and positively to changes in the price of its substitutes. Thus, the hypothetical consumption of hydrous ethanol for the state of São Paulo for the period 2011-2016 was calculated using the net effect of the simulated prices of both gasoline and ethanol. The obtained results are plotted in Figure 4.

As it can be observed on the graph, free market gasoline prices would have resulted in higher ethanol demand during the analyzed period in comparison to the observed demanded quantities in the state of São Paulo, with the only

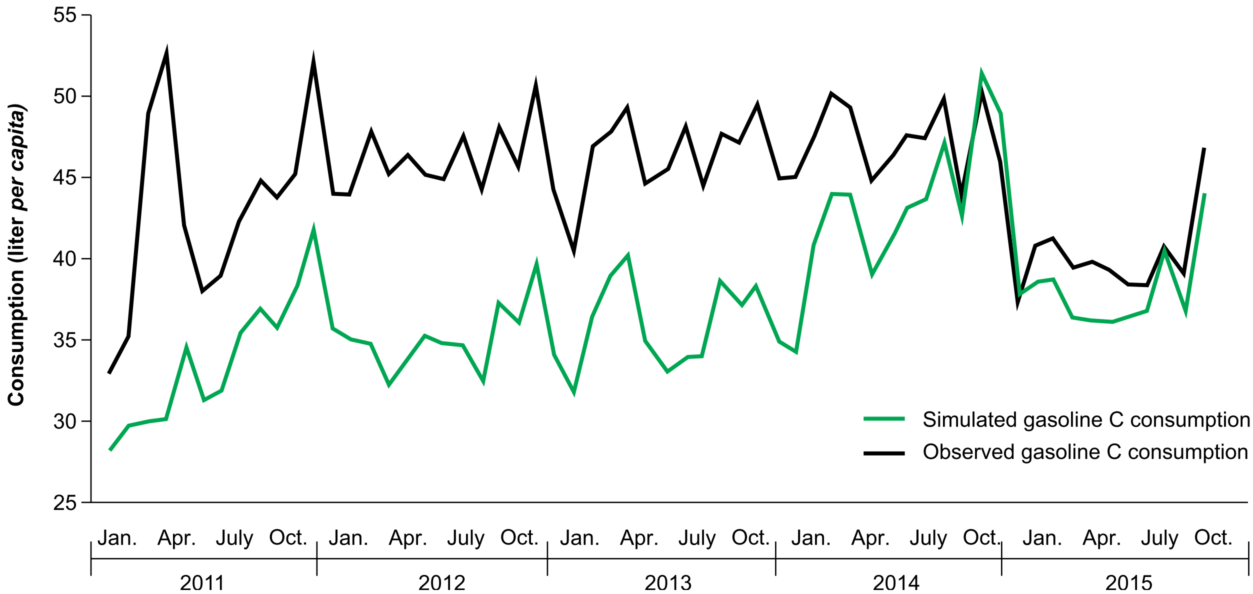

Figure 3. Observed vs. hypothetical consumption of gasoline C.

exception in the second half of 2014. This result is particularly interesting for all agents involved in the ethanol industry in Brazil, since it shows how the sector could have been stimulated if gasoline prices were following the trends on the international oil market. If this additional biofuel demand was actually observed between 2011 and 2014, there would have been an incentive for higher local ethanol production, implying that more sugarcane would have been directed towards ethanol and less sugar would have been produced during this period.

The obtained results provide empirical evidence that the ethanol sector would have been incentivized as a result of a market-oriented pricing policy, and most probably the crisis, which the sector was facing after 2011, could have been mitigated. The government control of gasoline prices is considered one of the main reasons for the underperformance of the ethanol sector in Brazil, making this product more vulnerable and less competitive (Azevedo & Serigati, 2015; Santos et al., 2015). The findings illustrated on Figure 4 show the potential advantages of gasoline prices that follow international crude oil price fluctuations for the ethanol industry in the country.

Conclusions

The present study analyses the hypothetical effects of a gasoline price that accompanies the movements in international oil prices on the fuel and biofuel sectors in the state of São Paulo for the period 2011-2016. The specific characteristics of these sectors in Brazil were taken into account when fitting an SVAR model to the data. The results of the estimation of the matrix of contemporaneous effects show that the consumption of hydrous ethanol and of gasoline, as well as the price of ethanol, respond significantly to the variations in the consumer price of gasoline. The estimated price elasticities for the observed period were used for the calculation of the response of the price of ethanol, and of fuel and biofuel demand to a gasoline price that is allowed to accompany the price fluctuations on the international oil market. For the purposes of the analysis, a hypothetical consumer gasoline price was constructed, using the provided by DATAGRO series of "interned" gasoline prices.

The obtained results show that gasoline prices that followed market conditions would have had positive effects on the ethanol sector in the state of São Paulo during the analyzed period,

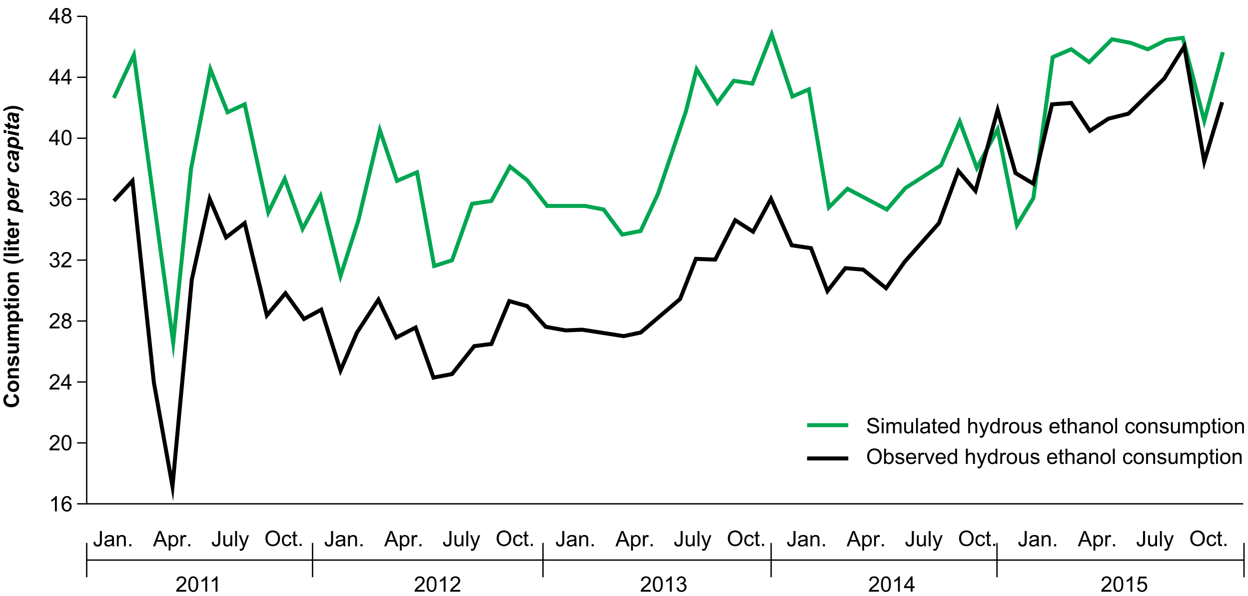

Figure 4. Observed vs. hypothetical consumption of hydrous ethanol.

by pushing the hydrous ethanol price up, making it more profitable for sugarcane producers to direct their production to ethanol instead of sugar, and stimulating domestic ethanol demand as an alternative for conventional gasoline fuel. Moreover, the hypothetical free gasoline price would have led to lower demand for gasoline, hence, breaking the "artificial" demand for this type of fuel created by the government by keeping the gasoline price lower than its international equivalents.

The performed analysis provides empirical evidence that the practiced fuel pricing policy in Brazil had negative impact on the ethanol sector in the state of São Paulo for the period of interest, reducing the competitiveness of this product as a substitute for conventional fossil fuels and, thus, undermining the performance of one of the most important sectors, in which the country was a worldwide leader both in terms of production and exportation until 2011. There is a need for reformulating the fuel and biofuel policies by the Brazilian government, otherwise the ethanol sector will not be able to recover from the recent crisis.

The results of the present research are limited by the rather low number of observations, thus, performing the analysis for a larger sample would provide an interesting continuation for the study. In addition, estimating the hypothetical effects of free gasoline prices for other regions in Brazil, as well as for the country as a whole, is considered to be an important step for future research.

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