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THE IMPACT OF CHANGES IN DOMESTIC FUEL POLICIES ON THE BRAZILIAN ECONOMY

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Resumo

Para analisar as políticas de incentivo ao biocombustível, dois grupos de cenários foram propostos: políticas que aumentam os preços da gasolina, e políticas que reduzem o preço do etanol hidratado. Os resultados mostram que o consumo de etanol é maximizado quando um imposto federal de R$0,77/litro é cobrado sobre a gasolina C ou se os impostos sobre o etanol são eliminados. No entanto, enquanto no primeiro caso há redução do PIB e aumento dos preços dos combustíveis e das receitas do governo; a segunda situação gera um aumento do PIB e redução nas receitas do governo e na inflação.

Palavras-chave: Políticas de combustível; Mercado de etanol; Análise de cenário.

Abstract

In order to analyze incentive policies towards biofuel, two groups of scenarios have been proposed: policies that increase gasoline prices, and policies that reduce hydrous ethanol price. Results showed that hydrous ethanol consumption is maximized when a federal tax of BRL 0.77/liter is applied on gasoline C, or if all taxes on hydrous ethanol are eliminated. However, while higher gasoline taxation reduces GDP and increases fuel prices and government revenues, the elimination of hydrous ethanol taxes leads to higher GDP and lower government revenues and inflation.

Keywords: Fuel policies; Ethanol market; Scenario analysis.

JEL classification: Q41, Q42, Q43, Q48

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1 Introduction

The use of ethanol as fuel in Brazil dates back to the 1930s, when anhydrous ethanol was added to gasoline A, producing the so-called gasoline C. Further increasing the ethanol market, automobiles fueled exclusively by hydrous ethanol were first manufactured and commercialized in Brazil in 1979, with the primary purpose of reducing national dependence on oil imports. Thirty years later, technological evolutions in the automobile industry enabled the production of flex-fuel vehicles, which are equipped to be fueled either by hydrous ethanol or gasoline C, or any proportion of both desired by the consumer. Currently, almost 95% of the new light vehicles registered in Brazil use gasoline and/or hydrous ethanol (ANFAVEA 2016). This fact allowed the demand for hydrous ethanol to be determined by its relative price in relation to gasoline C in the market, requiring more efficient price policies to encourage the use of hydrous ethanol in place of gasoline C.

However, instead of maintaining a program to encourage biofuel use, the brazilian government changed its policy. In the following section, we describe some of the major policies adopted in Brazil in the last ten years. There is vast literature on the fuel market in Brazil estimating supply and, mainly, demand models (Alves & Bueno 2003, Azevedo 2007, Bacchi 2009, Burnquist & Bacchi 2002, Cardoso & Bittencourt 2012, Caroprezo 2011, Farina et al. 2010, Freitas & Kaneko 2011, Gomez 2010, Iooty et al. 2009, Luchansky & Monks 2009, Marjotta-Maistro & Barros 2003, Nappo 2007, Oliveira et al. 2008, Pinto Júnior et al. 2006, Pontes 2009, Rask 1998, Roppa 2005, Samohyl & Dantas 1998, Santos 2013, Serigatti et al. 2010, Schunemann 2007, Silva et al. 2009, Shikida et al. 2007, Souza 2010, Vilela & Pinto Júnior 2010, Von Randow et al. 2010). Nevertheless, in regard to studies that try to analyze the impact of brazilian fuel policies, including ethanol, as this study proposes, literature is more limited, and tends to focus on one specific policy. In this context, Costa & Burnquist (2016) estimated the effect of gasoline price control (one of the policies practiced in the last years) over the brazilian light fuel market (which includes hydrous ethanol and gasoline C). The authors demonstrate that gasoline price control stimulated hydrous ethanol along the period of 2006 to 2010, but had a negative effect on hydrous ethanol prices from 2011 to 2014. In 2015, the brazilian government benefited the hydrous ethanol market by using this policy – gasoline price control. Other studies that analyzed brazilian policies were Costa & Guilhoto (2010) and Costa & Guilhoto (2011), which investigated the changes in the ICMS tax rate in the states of Minas Gerais and São Paulo, respectively. In both studies, the authors reported economic benefits when this tax was reduced to favor hydrous ethanol.

Therefore, the objective of this analysis is to show how a wide range of policies, and/or their scope of action, could stimulate biofuel consumption in Brazil, as well as to estimate the potential gains in terms of positive social and economic externalities. This analysis would simulate changes in the market's equilibrium through shifts in biofuel supply and demand, and also in the country's demand for gasoline.

With the aim of conducting this analysis, the next section presents and discusses policies that have affected fuel prices in Brazil over the last fifteen years, and scenarios analyzed based on these policies. Section 3 describes the economic model used to simulate the impact of policy scenarios and their effects on the brazilian economy. The data for the scenarios used to simulate the new equilibriums is also presented, and the corresponding results are reported in Section 4. Finally, Section 5 concludes the study and some recommendations are presented and discussed.

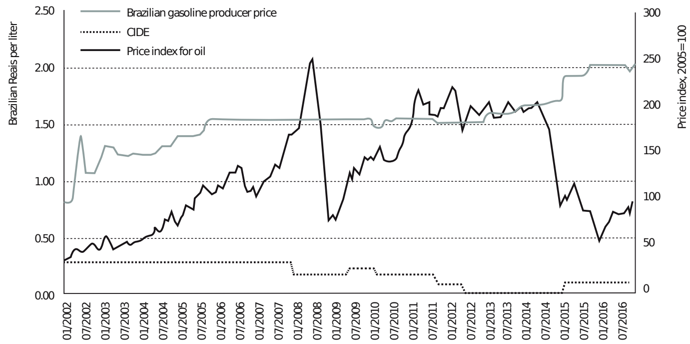
2 Recent policies in the brazilian fuel market

It has been argued that although fuel prices have been market-determined in Brazil since 2002, the sector remains subject to government intervention, particularly through changes in the tax system. Therefore, political forces, rather than market adjustments, are more likely to change fuel prices in the brazilian economy.

After the fuel market's deregulation in the beginning of the 2000s, a higher tax rate for gasoline, known as CIDE (Contribution for Interventions in the Economic Domain), was established by law in December 2001. This meant that gasoline prices were to be raised, and a greater share of the fuel demand was to be met by ethanol. However, policies set to stimulate the use of biofuels became less effective over time as government priorities and strategies changed. After 2008, this tax rate was reduced to prevent rising international oil prices from impacting brazilian gasoline (called "gasoline C") consumer prices, in an attempt to control inflation. Thus, when the oil price increased in 2008, the brazilian government reduced CIDE's absolute value from BRL 0.28/liter to BRL 0.18/liter. Similarly, another intervention increased the tax rate to BRL 0.23/liter in 2009, and this was followed by a tax reduction in 2011 (to BRL 0.15/liter), when oil prices increased. In 2012, a new value for CIDE was established at BRL 0.09/liter and the tax was finally eliminated later in that same year. Finally, the CIDE came back in 2015 (BRL 0.10/liter), and maintained this level until 2017. One scenario conducted in this study enables to estimate the effect of CIDE's return over gasoline C, considering the same value charged in 2002 (this scenario is described as scenario B).

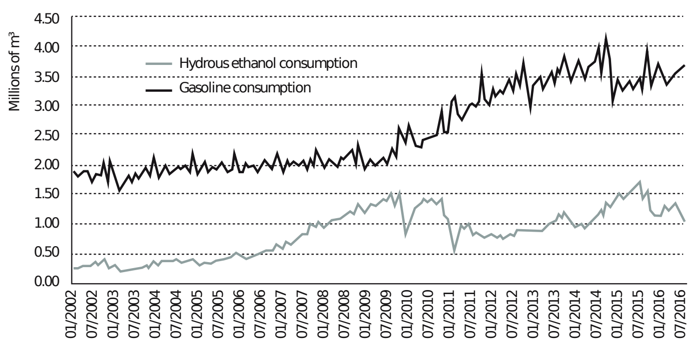
In addition to the CIDE tax rate, the government included a policy that ANP maintained the gasoline producer's price under their control. Figure 1 enables a comparison between the price of gasoline and global oil prices IMF (2017), ANP (2017), along with CIDE, showing that gasoline prices in Brazil did not follow the changes in international oil prices. Costa & Burnquist (2016) described this fluctuation by dividing fuel policies into three different phases: (i) until 2010, when they stimulated the use of biofuel; (ii) between 2011-14, when the government adopted the opposite policy; and (iii) after 2015 to date (2017), when we observed a regress to the first phase, increasing the taxes, but with some different market conditions. While in the first phase the gasoline price on the international market was higher and the government did nothing to control it, in the third phase that price dropped, and they maintained it at a higher level in the domestic market. This policy to steer domestic prices explains the behavior of fossil fuel and biofuel consumption over the analyzed period. As shown in Figure 2, in the period with a higher price index for oil and a stable gasoline price, gasoline consumption grew, in contrast to lower biofuel consumption.

In addition to these policy instruments (CIDE and control over gasoline producer price), brazilian fuels are subject to two other taxes: (i) PIS/COFINS (Social Integration Program/Contribution to Social Security Funding), also stipulated by the federal government, and (ii) ICMS (Tax on the Circulation of Goods and Services), which, unlike other policies, is stipulated by state government and may have different impacts in each state. However, while CIDE is applied only on gasoline C, PIS/COFINS and ICMS are included in both gasoline C and hydrous ethanol.



Sources: ANP (2017).

Figure 1: Monthly price index for global oil, brazilian gasoline producer (gasoline A) price and CIDE, a federal tax on gasoline C in Brazil



Source: ANP (2017)

Figure 2: Monthly values for hydrous ethanol and gasoline C consumption in Brazil. Period: 2002 to 2016.

PIS/COFINS did not change much in the analyzed period. A specific value in brazilian Real (BRL) per liter, was charged on fuels from 2002 to 2016, producing different rates depending on the fuel price. PIS/COFINS was BRL 0.26/liter for gasoline and BRL 0.168/liter for hydrous ethanol until August 2013. After September 1st (2013), the specific value changed to BRL 0.12/liter only for hydrous ethanol, remaining unchanged until 2016. One of the simulations conducted in this study enables an estimation of the effect of eliminating PIS/COFINS over hydrous ethanol – scenario D.

Regarding ICMS, a few brazilian states have maintained lower rates for hydrous ethanol in relation to gasoline (differential tax rate). Table A.1 in Appendix Appendix A lists the ICMS rates for gasoline and hydrous ethanol that prevailed in each brazilian state for the last analyzed year (2016). This table indicates that most states in the country charge an ICMS rate of 25%, and that less than half of the states – São Paulo, Paraná, Goiás, Rio de Janeiro, Bahia, Pernambuco, Rio Grande do Norte, Paraíba, Maranhão, Pará, Ceará, Minas Gerais and, more recently, Alagoas – set lower tax rates for hydrous ethanol than for gasoline. São Paulo, for example, has the lowest ICMS rate for hydrous ethanol, set at 12%, whereas the rate for gasoline is 25%. Rio de Janeiro is the state with the highest ICMS rate for gasoline, 31%, and 24% for hydrous ethanol.

As shown in Table A.1, the ICMS rate increased for gasoline in Alagoas, Bahia, Goiás, Minas Gerais, Paraná, Pernambuco, Rio Grande do Norte and Tocantins. The exception took place in Pará, where the ICMS decreased for gasoline from 30% in 2009 to 28% in 2010 and until 2016. The tax rate for ethanol also decreased in Alagoas, Bahia, Goiás, Minas Gerais, Pará, Paraíba and Pernambuco. Unlike the other states, Rio Grande do Sul (RS) and Tocantins (TO) increased this rate. In these two states, the tax rate increased from 25% (2002-2015) to 30% (2016) in RS and from 25% (2002-2015) to 27% (2016) in TO.

Despite these incentive policies for biofuel – reducing its ICMS tax, or raising the one for fossil fuel – this study analyzes a stronger condition, in which all states have this tax equal to the largest tax implemented for gasoline (scenario A), and equal to the smallest tax implemented for ethanol (scenario C).

In addition to these policies, the government mandates that a percentage of anhydrous ethanol be mixed with gasoline C as a policy parameter. But changes in this restriction were not considered in this study. This information, however, is important to evaluate the impact of policies for gasoline C and hydrous ethanol as described in Section 3, given that ethanol producers chooses between producing hydrous and anhydrous ethanol.

This paper considers the various combinations of federal and state tax policies applied to ethanol and gasoline in Brazil in order to encourage hydrous ethanol consumption, attempting to identify their impacts on this country's fuel market. The simulations used represent the following possible changes in fuel policies: (A) increased ICMS taxation on gasoline; (B) CIDE set at the same level as the one observed in 2002; (C) reduced ICMS taxation on hydrous ethanol; and (D) ICMS and PIS/Cofins set at zero for hydrous ethanol. The gasoline price control program to stimulate hydrous ethanol was not analyzed since this policy is already currently adopted. The first two simulations affect gasoline prices directly and the ethanol market indirectly. The last two policy changes affect the ethanol market directly. However, while in scenario (B) the prices in all brazilian states are affected with the same intensity, in scenarios (A), (C), and (D) the changes in fuel prices can affect each state differently, since they affect state taxes.

3 Methods and data

This section describes the methods and data used in the two subsections. The first Subsection (3.1) describes the scenarios analyzed in this study and the method and data used to estimate their impacts on hydrous ethanol and gasoline C markets, using supply and demand models for both fuels. However, the impact exerted on a specific market may generate important externalities across the economy. Thus, in order to investigate these secondary impacts, an input-output matrix was used. The second Subsection (3.2) describes a method to analyze this matrix and the data used to measure the estimated impact on the brazilian economy as a whole.

3.1 Scenarios analyzed and the reduced form equations model for the light vehicle fuel market in Brazil

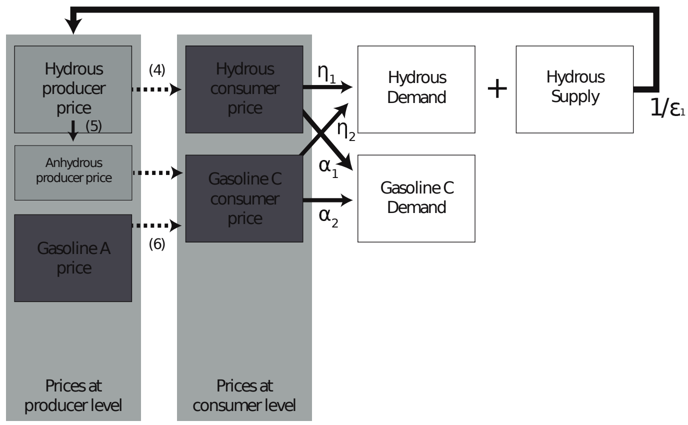
In this study, a reduced form equations model was applied to the brazilian light vehicle fuel market in order to find new points of equilibriums after changes in fuel policies. In Brazil, with the exception of trucks and buses (which run on diesel), most light vehicles are fueled by hydrous ethanol and/or gasoline C (which is a mixture of gasoline and anhydrous ethanol). Moreover, most of these vehicle owners may currently choose between these fuels when filling up as we move towards a situation where more than half of the country's vehicle fleet is flex-fuel.

The reduced form equations model is constructed through an analysis of the supply and demand for a specific market. These models were used to measure changes in the country's fuel market brought up by changes in the following scenarios:

- Scenario A assumes that ICMS on gasoline C in all states is 31%, which is the highest rate applied in the country (Rio de Janeiro).
- Scenario B changes the CIDE value to the one applied in the period between 2002 and 2008, which was BRL 0.28/liter. In terms of 2016 values, this rate of 2002 corresponds to BRL 0.77/liter (calculated based on the General Price Index – FGV, 2017), while it should be recalled that the CIDE rate set in 2016 was BRL 0.10/liter. Since this tax is set by the federal government, it is the same for all states.
- Scenario C assumes that the ICMS rate on hydrous ethanol in all states is fixed at 12%, the rate applied in the state of São Paulo, where the ICMS on this fuel is the lowest in Brazil. Scenario C also considers that the ICMS rate for São Paulo state is eliminated.
- Scenario D simulates the elimination of all taxes on hydrous ethanol, which means that ICMS, PIS and Cofins rates on this fuel are set to zero in all states.

Adjustments made to reach a new point of equilibrium after the shock (modeled change in the policy) in each scenario are shown in Figure 3. All policies analyzed here have a direct effect on the prices indicated by the shaded boxes in Figure 3. Thus, changes in fuel taxes have a direct impact on consumer prices, which in turn have an impact on the demand for both fuels (gasoline and hydrous ethanol). On the other hand, hydrous ethanol production meets the demand only if the producer price is also affected. This new hydrous ethanol producer price induces, again, a new change in the hydrous ethanol consumer price and, consequently, the demand for hydrous ethanol and gasoline, as well as the anhydrous ethanol producer price. Finally, anhydrous producer price also influences the gasoline consumer price and, consequently, the demand for both fuels.

For the estimation in each scenario described before, the consumer price for gasoline and ethanol, as well as their demanded volume were specific for each of the 27 brazilian states. However, producer prices and volume supplied for the fuels were considered as one and the same for the entire country: the ethanol producer prices were those stipulated in the major producer State, São Paulo, and the gasoline producer price (gasoline A) was considered as the average observed in the country. This distinction for the brazilian states was also made in scenario A, where the change was the same for all states. This was done because, even with the same shock, the impact on the consumer price in each state is different.



Source: Elaborated by the authors.

Figure 3: Interactive process in the fuel market to achieve a new point of equilibrium after shocks in fuel taxes, which directly affect the prices indicated by the shaded boxes.

Solid lines in Figure 3 indicate the use of price elasticity for supply and demand in the fuel market. These elasticities were estimated in other studies, as described in Table 1. Another set of relations involving fuel prices, important in finding the new price equilibrium after policy shocks, is shown in the Table A.1 and represents the fact that one price is used to calculate the other. The relations among these prices are shown in Equations (1), (2) and (3):

$$P_{h,P} = P_{h,C} - M_{he} - t_{he} \tag{1}$$

$$P_a = \theta \times P_{h,P} \tag{2}$$

$$P_{g,C} = \frac{[M_g + (P_a \times Share_a) + (1 - Share_a) \times P_{g,A}]}{1 - t_g} \tag{3}$$

where M_{he} represents the freight and marketing costs for the trade of hydrous ethanol, and M_g represents the same for gasoline C; $Share_a$ represents the percentage of anhydrous ethanol blended into gasoline C; $P_{g,A}$ is the price of gasoline A; t_{he} represents ICMS and PIS/Cofins rates applied on hydrous ethanol; and t_g represents the ICMS rate levied on gasoline C. PIS/Cofins and CIDE are included in the price of gasoline A ($P_{g,A}$).

Therefore, when the price of gasoline is subject to a shock, as in scenarios A and B, the change in its price also disturbs both demands: the one for hydrous ethanol, by a factor η_2, and the one for gasoline, by α_2. For the supply to meet this new demand, the producer price for hydrous ethanol should change by $1/\varepsilon_1$. This new producer price has two effects: one on the price of anhydrous ethanol, through a factor θ, which in turn affects the gasoline consumer price, as described in Equation (3); and another on the hydrous ethanol price at the consumer level, as described in Equation (2). These processes interact until the system reaches a point of equilibrium.

When the simulated shock affects the price of hydrous ethanol directly, as in scenarios C and D, the change in price disturbs the demands for both fuels, hydrous ethanol and gasoline, by an amount proportional to their own prices (η_1) and according to cross price (α_1) elasticities. As described before, for the supply to meet this new demand, the producer price for hydrous ethanol should change by $1/\varepsilon_1$. The process continues as previously described.

The impact caused by policy changes in all scenarios results in new supply and demand levels for hydrous ethanol. The increase in the sugarcane plantation area required to supply the volume of ethanol necessary to lead the hydrous ethanol market back to equilibrium was estimated by assuming that sugarcane and ethanol productivities are the same as those observed in the state of São Paulo (averaged for recent harvests). Productivity in this state is similar to that observed in the Center-West region, and higher than the remaining sugarcane-producing states in the country.

Data

In order to achieve the results for this first stage, some information about the brazilian fuel market is necessary. Table 1 contains the variables used, as well as their sources. Table A.1 in Appendix Appendix A shows the values of the ICMS rates, consumer price and demand for gasoline and hydrous ethanol in each brazilian state for the year analyzed as reference (2016).

Regarding the data described in this table, the least reliable regards elasticities, since it was obtained from a large number of studies which were conducted using various economic and econometric models and time periods, therefore resulting in different values. These models were defined considering the most recent estimates of those elasticities found in literature.

In addition to the variables shown in Table 1, other important variables in this study are: values of trade and transport margins for both fuels (M_{he} and M_g) and the price coefficient between hydrous and anhydrous prices (θ). These variables were calculated using Equations (4) to (6) for the values observed in 2016.

$$M_{he} = P_{h,P} - P_{h,C} - t_{he} \tag{4}$$

$$\theta = \frac{P_a}{P_{h,P}} \tag{5}$$

$$M_g = P_{g,C} \times (1 - t_g) - (P_a \times Share_a) - (1 - Share_a) \times P_{g,A} \tag{6}$$

These equations were derived from the algebraic manipulation of Equations (1) to (3).

The results obtained from this first step were incorporated into the input-output matrix to evaluate their impacts on the economy. The next Subsection (3.2) describes the methods and data used in the second part of the analysis.

Table 1: Variables used and their sources

Variables	Description	Source
Volume demanded of hydrous ethanol and gasoline C by brazilian states in 2012	D_h, D_g	Brazil (2017*a*) UNICA (2017) and ANP (2017)
Tax rates for hydrous ethanol and gasoline C, by brazilian states, in 2012	t_{he}, t_g	FECOMBUSTÍVEIS (2017); State Secretariats of Finance (2017)
Consumer price of hydrous ethanol and gasoline C, by brazilian states, in 2012	$P_{h,C}, P_{g,C}$	ANP (2017)
Producer price of sugar, hydrous and anhydrous ethanol, in 2012	$P_S, P_{h,P}, P_a$	CEPEA (2017)
Producer price of gasoline A, in 2012	$P_{g,A}$	ANP (2017)
Import price of gasoline A, in 2012	$P^I_{g,A}$	Brazil (2017*a*)
Share of anhydrous ethanol in gasoline C, in 2012	$Share_a$	Brazil (2017*b*)
Price demand elasticities for hydrous ethanol	ν_1, ν_2	Constanza et al. (2016)
Price supply elasticities for hydrous ethanol	ϵ_1	Costa et al. (2016)
Price demand elasticities for gasoline C	α_1, α_2	Constanza et al. (2016)

3.2 Using the Input-Output matrix to analyze the impact on brazilian

This study sought to analyze the impact on the brazilian economy of the expected changes in the hydrous ethanol and gasoline C sectors for each scenario according to the methodology described in Subsection 4.1. The approach adopted for this identifies the relationships among all the brazilian sectors. The analysis is based on a matrix of technical coefficients derived from the input-output matrix of the brazilian economy for 2009 – which was the most recent data available for the brazilian economy. This matrix (A) represents the relationships of intermediate demand. The production value in the economy (matrix X) can be described as:

$$AX + Y = X \tag{7}$$

where Y is the matrix of final demand. This can be rearranged to:

$$X = (I - A)^{-1} \times Y \tag{8}$$

Where X represents the output of the economy and $(I - A)^{-1}$ takes into account direct and indirect impacts and is described as the Leontief inverse matrix (Miller & Blair 2009).

From this Leontief inverse matrix we obtain the type I output multipliers. These multipliers are the direct and indirect effects of the changes in the brazilian demand (Y). We can also find the income effects corresponding to the increase in household demand resulting from the direct and indirect effects of the rise in economic activity: type II multipliers. This last impact is obtained by closing the model with respect to households. In this case, the Leontief inverse matrix is derived from a matrix $\bar{A}$ of technical coefficients, where household consumption is treated as endogenous, hence the sector multipliers are calculated from the matrix $(I - \bar{A})^{-1}$.

Thus, the total output of the economy that is driven to meet the change in final demand is obtained as follows:

$$X = (I - \bar{A})^{-1} \times Y \tag{9}$$

where $(I - \bar{A})^{-1}$ is the new Leontief inverse matrix.

Recapping: The impact multipliers, i.e. matrices $(I - A)^{-1}$ and $(I - \bar{A})^{-1}$, were used to calculate the impact on the brazilian economy by the changes in fuel demand (Y) obtained in Subsection 4.1. While the impact estimated by $(I - A)^{-1}$ represents the direct and indirect impacts on the brazilian economy, the impact estimated by $(I - A)^{-1}$ also represents the income effects, in addition to the direct and indirect impacts. These impacts were estimated separately for two regions of Brazil: The state of São Paulo, and other brazilian states. This separation is important, considering the state tax (ICMS) on fuels in São Paulo is very different from other states in Brazil and, consequently, the impacts are different in these regions. The following Item ("Inter-regional analysis") describes how we analyzed the impacts from one region to another, and Item "Input-output matrix data" describes the estimated input-output matrix used in this study.

However, not only do the fuels' volumes change (as described in Subsection 3.1), but the producer price and some taxes from the analyzed scenarios change as well. Then, Item "Shocks in the Input-output matrix" describes how all changes were incorporated as shocks in this matrix and how the results were obtained.

The impacts on the brazilian economy were not measured only based on the value of production (X) as described in Equation (9). We calculated the impacts on the economy in terms of: the number of individuals employed (Z_E), the value of remuneration (wages plus social contributions) (Z_R), the value of imports (Z_M), Gross Domestic Product – GDP ($ZGDP$) and taxes collected (Z_T). To this end, the production value (δX) is multiplied by a coefficient for each of these variables, as described in Equation (10):

$$Z_{(n \times l),k} = [\text{diagonalized}(C_{(n \times n),k})] \times X_{n \times l} \tag{10}$$

where $k = E$ (number of employed individuals), R (value of remuneration), M (value of imports), GDP (Gross Domestic Product), or T (taxes collected by the government). The coefficients C_k were obtained in the input-output matrix by dividing the value of each variable (C_E, C_R, C_M, C_{GDP} and C_T), in each n economy sector, by its production value (X).

Inter-regional analysis

The inter-regional analysis is developed based on a set of intra-regional (within a specific region) and inter-regional (between a given region and all others) input coefficients. This provides a more realistic inter-regional framework for the analysis of the brazilian trade flow. This study used a brazilian inter-regional input-output matrix with two regions. Region L indicates São Paulo state and region M specifies the other brazilian states.

The matrix of technical coefficients for region L (A^{LL}) can be constructed to represent the n sectors of brazilian economy, such as:

$$A = \begin{bmatrix} a_{11}^{LL} & a_{12}^{LL} & \cdots & a_{1n}^{LL} \\ a_{21}^{LL} & a_{22}^{LL} & \cdots & a_{2n}^{LL} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1}^{LL} & a_{n2}^{LL} & \cdots & a_{nn}^{LL} \end{bmatrix} \tag{11}$$

And the matrices A_{LM} , A_{ML} and A_{MM} can be represented in a similar form.

The Leontief system can be represented as:

$$\left\{ \begin{bmatrix} I & M & I \\ \Lambda & \Lambda & \Lambda \\ I & M & I \end{bmatrix} - \begin{bmatrix} A^{LL} & M & A^{LM} \\ \Lambda & \Lambda & \Lambda \\ A^{ML} & M & A^{MM} \end{bmatrix} \right\}^{-1} \times \begin{bmatrix} Y^{L} \\ \Lambda \\ Y_{M} \end{bmatrix} = \begin{bmatrix} X^{L} \\ \Lambda \\ X^{M} \end{bmatrix}$$

where $Y_L = (I - A^{LL}) \times x^L - A^{LM} \times x^M \quad e \quad Y^M = -A^{ML} \times x^M + (I - A^{MM}) \times x^M$. Matrices A, X and Y, can be estimated as follows:

$$A = \begin{bmatrix} A^{LL} & M & A^{LM} \\ \Lambda & \Lambda & \Lambda \\ A^{ML} & M & A^{MM} \end{bmatrix}; \quad X = \begin{bmatrix} x^{L} \\ \Lambda \\ x^{M} \end{bmatrix} \quad \text{and} \quad Y = \begin{bmatrix} Y^{L} \\ \Lambda \\ Y^{M} \end{bmatrix}$$

Input-output matrix data

The input-output matrix for Brazil was estimated for 2009, which is the most recent data available for the brazilian economy (IBGE 2011). The method used is presented by Costa & Guilhoto (2010).

In addition to this process of transforming the most recent data from the National Accounts into the economy's input-output matrix, the following modifications were also performed in the matrix: (a) separation of the brazilian matrix between the state of São Paulo and the rest of the country; and (b) breakdown of the sugarcane sector within the agricultural sector, and of the anhydrous and hydrated ethanol sectors within the ethanol sector.

The first modification (item a) is justified because the objective of the study is to identify the impacts predominantly for the state where the change in ICMS rate is simulated. The breakdown of the sectors most directly affected by the shock (item b) is important for the results in this simulation to be better estimated. In the case pointed out, the sugarcane sector is the main supplier of inputs for the production of hydrated ethanol and, therefore, any changes affecting this sector are meaningful. The ethanol sector was broken down into anhydrous ethanol and hydrated ethanol, since the behavior of both their sales and ICMS payments are very different for each product: in the anhydrous ethanol sector, alcohol is commercialized as an input for the production of gasoline C; in the hydrated ethanol sector, alcohol is sold directly to the final consumer. Thus, their breakdown enables a better simulation of the impacts on the economy.

In order to assess the impact of each shock on the amount of collected taxes, in addition to the aforementioned changes in the input-output matrix, it is also necessary to change the tax coefficients (ICMS and PIS/Cofins) for the regions under analysis.

Shocks in the Input-output matrix

In Subsection 4.1, the following changes were described in the country's fuel market for the identified scenarios: (i) variation in the final demand for hydrated ethanol and gasoline C in the state of São Paulo, (ii) changes in the price to the producer of hydrated and anhydrous ethanol, (iii) variation in the final demand for hydrated ethanol and gasoline C in the rest of the country. This section describes how these changes were incorporated into the input-output matrix.

Regarding items (i) and (iii), it is shown that a variation shock in the final demand (Y), as described in Equation (9), is enough for an analysis of the impacts on the economy. However, the shocks in the matrix are included considering basic prices and, as changes in demand should be the only variable to influence these results, we must use the same basic price practiced by each respective sector in the original matrix. Therefore, these basic prices ($P_{b,j}$) were calculated by dividing the production values (X_j) of the impacted sectors ("alcohol" for the ethanol and "petroleum and coke" derivatives for gasoline C) by their respective volumes produced in 2009, which was the year used to make the input-output matrix (Vol_j). These prices were multiplied by the new volumes demanded of these products obtained in the first part (D_h and D_g), respectively with $j = h$ for ethanol and $j = g$ for gasoline (C). In the scenario where the demand for gasoline C is reduced, we considered that this reduction is explained by two shocks, one applied to the sector that produces gasoline A, and another to the anhydrous ethanol sector. For the first, part of the shock corresponds to a reduction of up to 3 billion cubic meters in gasoline A imports, which was the amount of gasoline A imported by Brazil in 2016. For the ethanol sector, the shock was entirely made by reducing the brazilian production of anhydrous ethanol.

For item (ii), i.e. changes in the price to the producer of hydrated and anhydrous ethanol, the assessment of this shock's impacts on the brazilian economy was measured by including, for each scenario, a corresponding addition to the ethanol producer's income, whether hydrated or anhydrous. This increase in the income changes the value of the multiplier type II described in Equation (9), $(I - \bar{A})^{-1}$, and consequently, in other economic variables based on it. Finally, the shock on tax changes was included. Unlike CIDE, ICMS and PIS/Cofins are charged as a percentage of the price to the consumer. Thus, the changes on taxes with respect to the basic scenario occur not only when the shock reformed their coefficients, but in all scenarios where changes in consumer fuel prices occur.

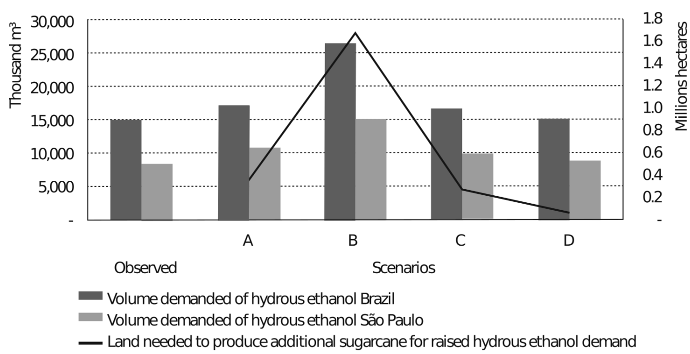
4 Results and Discussion

As indicated in Section 3, this section presents and analyzes the estimated impact due to each policy change in the following markets: the light vehicle fuel market (Subsection 4.1), and in the overall brazilian economy (Subsection 4.2). All results are described for the state of São Paulo and for all other brazilian states separately.

4.1 Impact on the light vehicle fuel market

Before presenting and discussing the results, we need to define the values of the elasticities used in the reduced form equations model to reach a new point of equilibrium after each shock described in the six scenarios in Section 3. These elasticities and their respective sources are: $\eta_1 = -1.47$ (Constanza et al. 2016), $\alpha_1 = 0.16$ (Constanza et al. 2016), $\varepsilon_1 = 0.75$ (Costa et al. 2016), $\eta_2 = 3.43$ (Constanza et al. 2016), and $\alpha_2 = -0.81$ (Constanza et al. 2016) [1].

The impacts on prices resulting from the scenarios described in Subsection 4.1 are summarized in Table 2. They include the observed and simulated consumer and producer prices of hydrous ethanol and the consumer price of gasoline for the year 2016. Figures 4 and 5 show the demand for hydrous ethanol and gasoline, respectively. In Figure 4, the black line shows the area of land (in hectares) needed to produce the additional volume of ethanol in each assessed scenario. Table 3 complements the results with the percentage changes in each of the variables being analyzed for scenarios A-D. In Figure 5, the volume of gasoline A imported by Brazil in 2016 is also represented. This volume was important when we analyzed impacts on the brazilian economy (in the following section).



Source: Search results.

Figure 4: Volume of hydrous ethanol demanded in Brazil and in the state of São Paulo, and area of land required to meet the additional demand for sugarcane: Observed in 2016, and simulated in each scenario (A-D)

In the first two scenarios (A and B), gasoline C prices were affected by changes in taxes: in A, ICMS goes to 31% in all States, and CIDE reaches BRL 0.77/liter in B. In scenario A, the producer and consumer prices for hydrous ethanol increase 21% and 15% respectively, while in scenario B the producer price rises more than 100% and the consumer price rises 79% (in Brazil and the state of São Paulo). However, hydrous ethanol consumption in Brazil increased by 16% and 79%, respectively, in scenarios A and B. The increase in

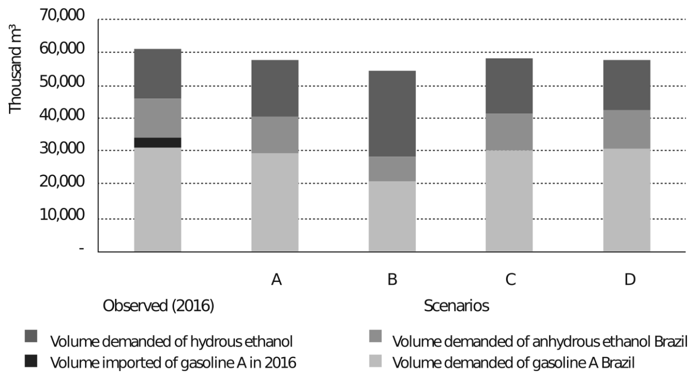
[1] Although there are several references about the elasticities used in this study, as referenced in the introduction of this study (mainly to the hydrous ethanol demand), the elasticities used were chosen considering those estimated with the most recent data available. The elasticities of hydrous ethanol and gasoline demand employed in this study applied data between 2006 and 2015 for their estimation. For the ethanol supply, the data to estimate the elasticity used in this study was from 2000 to 2013.

Table 2: Prices of gasoline and hydrous ethanol observed in 2016 and simulated in each scenario, in Brazilian Reais per liter

		Producer price of hydrous ethanol	Consumer price of hydrous ethanol		Consumer price of gasoline C in Brazil*
			Brazil*	São Paulo	
Observed (2016)		1.69	2.70	2.55	3.69
Scenarios	A	2.04	3.11	2.96	4.06
	B	3.47	4.82	4.58	5.77
	C	1.96	2.69	2.52	3.82
	D	1.76	2.64	2.50	3.73

Note: * Consumer prices in Brazil was estimated considering the consumption-weighted average of each state.
Source: Search results.

demand for hydrous ethanol, in spite of the increased prices for this same product, is explained by the price rise in gasoline C, from BRL 3.69/liter to BRL 4.06/liter and BRL 5.77/liter in scenarios A and B, respectively (Table 2). Thus, the increase in demand for hydrous ethanol corresponds to a reduction in the demand for gasoline C of 6% (scenario A) and 34% (scenario B). To supply the volume demanded at the current levels of productivity observed and assuming that anhydrous ethanol and sugar production does not change, the cultivated area would have to expand an additional 335,000 hectares and 1,662,000 hectares, respectively, in scenarios A and B (Figure 4).



Source: Research results.

Figure 5: Volume of gasoline A, anhydrous and hydrous ethanol demanded in Brazil: observed in 2016 and simulated in each scenario (A-D)

Table 3: Percentage changes in variables estimated in each scenario in comparison to 2016

		A	B	C	D
Producer price of hydrous ethanol		21.0%	106.0%	16.0%	4.0%
Consumer price of hydrous ethanol	Brazil	15.0%	79.0%	0.0%	−2.0%
	São Paulo	16.0%	79.0%	−1.0%	−2.0%
Consumer price of gasoline		10.0%	57.0%	4.0%	1.0%
Volume demanded of hydrous ethanol	Brazil	16.0%	79.0%	12.0%	3.0%
	São Paulo	23.0%	77.0%	14.0%	3.0%
Volume demanded of gasoline		−6.0%	−34.0%	−3.0%	−1.0%
Volume demanded of gasoline and hydrous ethanol, in an equivalent volume of gasoline		−2.0%	−12.0%	−0.2%	−0.5%

Source: Research results.

Comparing the results thus far, we see that, in scenario B, the impacts on the fuel market are higher than in scenario A. Moreover, implementing scenario B should be politically simpler than raising ICMS. As ICMS is a state tax, each of the 27 brazilian states that apply ICMS on gasoline at a rate lower than 31% should increase their rates, whereas the decision about CIDE or price control on gasoline is taken just at the federal level.

Although scenarios A and B predict the highest incentives to hydrous ethanol production, one negative effect of these first scenarios is the increase in fuel prices, which is acknowledged as a major cause of inflation in Brazil. Therefore, in the subsequent scenarios (C and D), we consider the impact of cutting taxes and, consequently, reducing fuel prices.

As described in Section 2, ICMS rates for hydrous ethanol vary from state to state, ranging from 12 to 30%. Thus, in scenario C, the ICMS on hydrous ethanol in all states was made equal to the rate practiced in the state of São Paulo (12%), which eliminated its tax. Under these conditions, the demand for hydrous ethanol in the country could go from 14.58 million m^3 to 16.38 million m^3 (Figure 4). The corresponding calculated hydrous ethanol producer price goes from BRL 1.69/liter to BRL 1.96/liter (Table 2). Even though the producer price increases as expected, the consumer price is subject to a small reduction from BRL 2.70/liter to BRL 2.69/liter (Table 2). There is also a need to dedicate an additional 258,000 hectares to sugarcane production in order to meet this demand (Figure 4), assuming there are no changes in anhydrous ethanol and sugar production. It is interesting to note a slight increase in the price of gasoline C (from BRL 3.69/liter to BRL 3.82/liter). This occurs in this scenario, as well as in scenario D, due to the interaction process described in Figure 3 and the impact on the price of anhydrous ethanol. The current and estimated anhydrous ethanol producer prices go from BRL 1.87/liter to BRL 2.22/liter in scenario C, and to BRL 1.99/liter in scenario D. Since scenario C considers that the ICMS for São Paulo state is eliminated, the hydrous ethanol consumer price in this state decreases from BRL 2.55/liter to BRL 2.52/liter (Table 2), with an increase in demand shown in Figure 4 (from 8.3 million m^3 to 9.5 million m^3). Because of the overall raise in the demand for biofuel, the demand for gasoline C in Brazil dropped from 43 to 41.6 million m^3 (i.e. the sum of gasoline A and anhydrous ethanol in Figure 5) countrywide.

Another alternative that does not lead to inflation is scenario D, where the tax rate for PIS/Cofins (a federal tax) was eliminated. In that case, hydrous ethanol consumer prices drop from BRL 2.70/liter to BRL 2.64/liter (Table 2), despite the 4% increase in the producer price for this biofuel. In that case, the estimated increase in consumption of hydrous ethanol is 3% and the equivalent reduction in gasoline C consumption is 1%. Assuming that the prices of other sugarcane products remain stable, the expansion of the area dedicated to producing sugarcane in order to supply for the additional consumption would be approximately 66,000 hectares.

There was a slight reduction in total fuel demand by light vehicles in all scenarios analyzed. The reduction in hydrous ethanol plus gasoline, in an equivalent volume of gasoline, was 3%, 12%, 0.2%, and 0.5% in scenarios A, B, C, and D, respectively (Table 3). Thus, increasing positive taxes on gasoline is by far the greenest option. In the next item, we analyze the impact of the changes observed for each scenario assessed, considering 2016 prices for the entire market of goods and services in the brazilian economy.

4.2 Impact on the brazilian economy due to changes in the fuel market

Initially, all shocks described in Subsection 3.2 were calculated. For such, the volumes of the impacts estimated in Figures 4 and 5 (reduced gasoline A imports), considered for the state of São Paulo and all the remaining states separately, were multiplied by the producer prices of hydrous and anhydrous ethanol and gasoline A (anhydrous ethanol and gasoline A being used to produce gasoline C) from the input-output matrix. These prices were calculated, resulting in BRL 0.75/liter for hydrous ethanol, BRL 0.84/liter for anhydrous ethanol and BRL 1.30/liter for gasoline A in the state of São Paulo, and BRL 0.84/liter for hydrous ethanol, BRL 0.92/liter for anhydrous ethanol and BRL 0.92/liter for gasoline A in all the remaining states. The application of different shocks separately for the state of São Paulo and the remaining states is important, since policies adopted by São Paulo are very different from those followed by other brazilian states. Therefore, by proceeding in this manner, we are able to more accurately estimate the impacts on the brazilian economy.

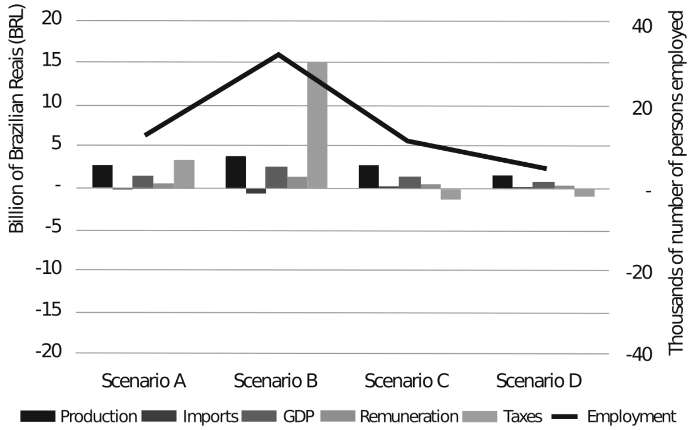
The values obtained from these demand shocks in each analyzed scenario are presented in Table 4. Similarly, Table 4 presents the values of the shocks on the coefficients of ICMS, PIS/Cofins and CIDE for each scenario, which were calculated considering changes in rates (ICMS and PIS/Cofins) or in tax values (CIDE), as well as in fuel prices to the final consumer, as described in Subsection 3.2. Finally, the changes in remuneration in ethanol production – both anhydrous and hydrated – caused by changes in the producer price, as shown in Table 3, were used to estimate the new inverse Leontief matrices.

Table 4: Shocks inserted in the inter-regional input-output matrix

Scenarios		Base	A	B	C	D
State of São Paulo						
Demand (million Reais)	Hydrous	6,240	7,700	11,053	7,126	6,440
	Gasoline A	9,548	8,923	6,529	9,449	9,623
	Anhydrous	2,089	1,911	1,398	2,023	2,061
Hydrous ethanol	ICMS	0.173	0.201	0.310	0.000	0.169
	PIS/Cofins	0.133	0.155	0.239	0.132	0.000
Gasoline C	ICMS	0.390	0.515	0.610	0.403	0.394
	PIS/Cofins	0.144	0.159	0.226	0.149	0.146
	CIDE	0.000	0.000	0.504	0.000	0.000
Additional remuneration to ethanol producer (million Reais)	Hydrous	0,000	1,737	8,623	1,340	344
	Anhydrous	0,000	1,251	5,764	991	338
Other Brazilian States						
Demand (million Reais)	Hydrous	5,243	5,562	9,567	5,759	5,407
	Gasoline A	20,150	21,651	15,087	22,050	22,477
	Anhydrous	7,784	7,399	5,156	7,536	7,682
Hydrous ethanol	ICMS	0.548	0.558	0.599	0.572	0.485
	PIS/Cofins	0.203	0.207	0.221	0.212	0.179
Gasoline C	ICMS	0.408	0.515	0.514	0.458	0.412
	PIS/Cofins	0.151	0.159	0.190	0.170	0.152
	CIDE	0.000	0.000	0.302	0.000	0.000
Additional remuneration to ethanol producer (million Reais)	Hydrous	0,000	1,210	6,004	933	240
	Anhydrous	0,000	694	3,195	549	187

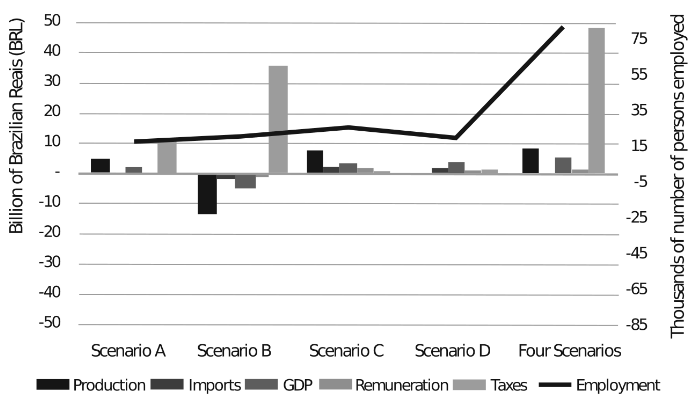
Source: Research results.

With the shocks having been carried out in a different manner in the state of São Paulo compared to the rest of Brazil, the impacts of these shocks on the brazilian economy are presented in the same way. Figures 6 and 7 present the total impacts (direct, indirect and income effect) on the brazilian economy, respectively, for the shocks in the São Paulo states and in the other brazilian states. These impacts are associated with the number of people employed and the values of: production, imports, GDP, tax revenues, and remuneration within all activities of the economy stimulated by the difference between the shocks described in scenarios A to D and in the base scenario. In spite of the shocks being simulated with 2009 prices, since the input-output matrix used to assess these impacts is based on that year, all monetary values of impacts measured in this section have been converted to 2016 prices.



Source: Research results.

Figure 6: Changes in the number of workers employed and values of production, imports, GDP, tax collection and remuneration for all activities in the brazilian economy stimulated by the shocks described in Table 4 for São Paulo state, in each of the scenarios analyzed in relation to the basic scenario



Source: Research results.

Figure 7: Changes in the number of workers employed and values of production, imports, GDP, tax collection and remuneration for all activities in the brazilian economy stimulated by the shocks described in Table 4 for the other brazilian states, in each of the scenarios analyzed in relation to the basic scenario

In both conditions (Figures 6 and 7), since scenarios A-B have the increase in fossil fuel price to the final consumer due to a tax raise, the impact on taxes collected by the government increased in these scenarios as well. In turn, the fuel prices are reduced in scenarios C-D due to the reduction of taxes on renewable fuel. As a consequence, the impacts on taxes were negative in relation to the base scenario. We observed different conclusions while analyzing the impacts on São Paulo State or the other brazilian states. For the first, the impacts in scenarios A-B were better for the economy than in scenarios C-D. We can see in Figures 6 and 7 that, taking into account the increase in government taxes, the net results of scenarios A-B were more beneficial to the economy than the other scenarios, in relation to the base scenario. However, for the latter, the impacts on production and GDP were better in scenarios C-D compared to scenarios A-B. In addition to the drop in fossil fuel consumption and the impacts on the goods and services markets measured in this study, these scenarios also had reduced price levels and inflation.

The impacts due to the shocks analyzed separately for São Paulo state and the other brazilian states (Figures 6 and 7, respectively), was important to show the different behavior from the scenario B impact. We can observe in Figures 6 and 7 that, regarding the impacts seen in the base scenario, there was a more significant decrease in production, GDP and employment in scenario B in the other brazilian states, where the return of CIDE to the levels observed in 2002 was simulated. However, for this scenario, we have three other favorable considerations regarding the use of the simulated policy: firstly, a greater impact on the value of taxes collected. Secondly, a stronger reduction in fossil fuel consumption, as described in the previous section. And finally, the reduction in demand for gasoline A described in Table 4 (since the reduction in demand was greater than the volume imported in 2012) could not induce lower production of this fuel and its subsequent negative impact on the Brazillian economy as described, since the gasoline not consumed domestically could still be exported. This occurs because the international market for gasoline is not very restrictive and protective if compared to the ethanol international market. Thus, a reduction in the domestic demand for ethanol in Brazil has a greater impact on its production than gasoline. However, even with reduced production in all brazilian states, the number of employed people still increases when compared to the base scenario. This shows that these policies also have a positive social impact. Nevertheless, by using all of these four policies together (as we can see in the last scenario presented in Figure 7), the negative impact observed if only scenario B is implemented in the other brazilian states disappears.

Thus, the analysis made in this study is important to provide the brazilian government with information on the impacts caused by each policy analyzed for the fuels. Moreover, this analysis could also be considered as an investigation of how much the brazilian economy has lost without any of these changes in fuel policies.

5 Conclusion

Currently, energy demand is one of the most important issues governments must address. One economically important use of energy involves transportation. Light vehicles comprise the predominant means of private transportation, which leads to many problems to brazilian cities, such as traffic jams and pollution. Thus, public transport should be encouraged, and one way to do this, apart from increasing the availability and quality of public transport, is by increasing the price of fuel used by light vehicles.

Furthermore, fossil fuel can be replaced by renewable energy sources. In Brazil, the most important among these is ethanol. Once it became possible for consumers to fuel their vehicles with either one or the other (as in flex-fuel vehicles), taxing these two types of fuels at different rates became one of the main mechanisms to stimulate the use of renewable fuel. Thus, if we have at least two fuels that represent substitute goods, as is the case of gasoline C and hydrated ethanol in this study, reducing the taxation in the sector that has a greater impact on the economy, at the expense of the other products, tends to bring benefits. Such gains are not only economic, but social as well (in regard to the labor market) and, in the case of the products analyzed in this study, environmental benefits may also be obtained (in the form of reduced greenhouse gas emissions). According to Meira Filho & Macedo (2010), the use of ethanol contributed to reduce emissions in the sectors of transportation and electric power by 22% in 2006, and this percentage is expected to reach 43% in 2020.

This study shows different economic directions that could be given to several policies for the brazilian fuel market. However, to assist the government in this issue, further studies are needed, such as estimates of the impact of national gasoline prices on inflation.

Other important conclusions from these results indicate that: tax cuts may bring benefits superior to those brought up by government spending; political decisions should be based on economic studies with clear results on the economy; political decisions bring gains and losses for the economy and this trade-off must be evaluated; the input-output matrix is an important tool for policy analysis; and its updating and detailing should be prioritized by the responsible agencies.

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Appendix A

Table A.1: ICMS tax rate, consumer price and volume demanded for hydrous ethanol and gasoline C, in 2016, for each Brazilian States

	ICMS for hydrous ethanol	ICMS for gasoline	Hydrous ethanol consumer price	Gasoline consumer price	Volume demanded for hydrous ethanol	Volume demanded for gasoline
	(%)	(%)	(R$/litro)	(R$/litro)	(m^3)	(m^3)
Acre	25%	25%	3.35	4.09	7,604	136,818
Alagoas	23%	27%	3.23	3.78	31,762	453,962
Amapá	25%	25%	3.58	3.65	539	151,538
Amazonas	25%	25%	3.22	3.73	38,371	634,173
Bahia	19%	28%	3.02	3.78	306,047	2,210,593
Ceará	25%	27%	3.29	3.91	143,300	1,372,176
Distrito Federal	25%	25%	3.10	3.69	42,982	1,199,589
Espírito Santo	27%	27%	3.10	3.68	41,294	947,149
Goiás	22%	29%	2.88	3.81	1,058,503	1,531,089
Maranhão	25%	27%	3.09	3.58	35,476	928,346
Mato Grosso	25%	25%	2.64	3.72	599,950	616,554
Mato Grosso do Sul	25%	25%	2.83	3.51	116,194	741,872
Minas Gerais	14%	29%	2.86	3.71	1,447,289	4,512,741
Pará	26%	28%	3.45	3.98	36,913	1,154,585
Paraíba	23%	27%	2.99	3.66	85,045	694,590
Paraná	18%	29%	2.73	3.63	1,245,240	2,881,573
Pernambuco	23%	29%	3.01	3.70	205,720	1,441,150
Piauí	25%	25%	3.11	3.66	35,914	596,027
Rio Grande do Norte	25%	27%	3.27	3.83	54,800	651,680
Rio Grande do Sul	30%	30%	3.48	3.87	68,923	3,463,356
Rio de Janeiro	24%	31%	3.20	3.92	480,808	2,684,904
Rondônia	25%	26%	3.46	3.88	14,529	431,574
Roraima	25%	25%	3.59	3.88	1,448	129,944
Santa Catarina	25%	25%	3.04	3.52	74,866	2,700,772
São Paulo	12%	25%	2.55	3.50	8,356,469	9,990,516
Sergipe	27%	27%	3.15	3.68	25,192	398,252
Tocantins	27%	27%	2.71	3.86	30,666	363,558
Brazil					14,585,844	43,019,082
Standard Deviation	4%	2%	0.28	0.14	1,581,259.19	1,976,647.51
Maximum	30%	31%	3.59	4.09	8,356,468.94	9,990,516.46
Minimum	12%	25%	2.55	3.50	539.00	129,943.60

Source: Research results.