Biofuels policies and fuel demand elasticities in Brazil: an IV approach

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Abstract

Brazil is a pioneer in biofuels policies. Due to previous concerns (diversification of energy matrix and rural development) and new concerns (environmental issues) it is important to know the marginal effects of the demand for ethanol and gasoline in order to prescribe appropriate public policies. In addition to the core marginal effects (price and income) of a regular demand estimations, cross prices marginal effects have special appealing in the Brazilian fuel market because of substitution possibility between ethanol and gasoline after 2003 with the novel of flex fuel cars. Regarding estimation strategies, we performed non-neighbors purchase prices as instruments for ethanol and gasoline prices to solve endogeneity issues. Results showed ethanol´s price elasticities around -1.5 and gasoline´s elasticities around -0.8. Regarding flex fuel cars influence on elasticities, results indicate price and cross prices with higher elasticities for both demands after the introduction of flex fuel cars.
Keywords: Ethanol, Gasoline, Demand, Panel Data, Instrumental Variables, Endogeneity.
JEL:Q41, Q4, C26.

Resumo

Brasil é um pioneiro em políticas ambientais. Devido a antigas preocupações (diversificação da matriz energética e desenvolvimento rural) e novas preocupações (preocupações ambientais) é importante saber os efeitos marginais da demanda de etanol e da de gasolina com intuito de direcionar adequadamente as políticas públicas. Adcionalmente aos principais efeitos marginais de qualquer demanda (renda e preço), preços dos substitutos têm um especial apelo no mercado brasileiro por conta da substitutibilidade entre gasolina e etanol pós-2003. Sobre as estratégias de estimação, usamos preços de compra dos não-vizinhos como instrumento para os preços da gasolina e do etanol, controlando problemas de endogeneidade. Os resultados indicam que o etanol tem elasticidade preço de -1,5 e a gasolina elasticidade de -0,8. A influência dos carros flex (pós-2003) é percebida com aumentos das elasticidades preço e preço cruzada para ambos os combustíveis.
Palavras-chave: Etanol, Gasolina, Demanda, Painel de Dados, Variáveis Instrumentais, Endogeneidade.

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1 Introduction

Biofuels is a convergent point of some major challenges for the world. They have implications for climate change, energy security and food competition. In Brazil biofuels policies began in 1970s for two main reasons: i) to reduce oil dependence; ii) rural development. At that time, there was a perfect scenario to welcome biofuels policies. There were oil crisis (oil prices were multiplied by 5 between Oct/1973 and March/1974) deteriorating balance trade of importers. In addition to this, there were also lower sugar prices putting down revenue of sugar cane farmers in Brazil. Hence, decision to produce ethanol from sugar cane reached many goals, reducing oil dependence, improving trade balance and subsidizing local farmers. During the oil prices in the 1980s, oil prices fall and directed the interest on biofuels in Brazil and also in other countries[1].

During 2000s the interest on biofuels policies rose again. At this time, there were even more reasons for that, mainly environmental concerns and oil prices´ volatility. Mainly after 2008, due to food crisis with the increasing of the most agricultural commodities prices and price volatility the discussion about competition between biofuels and food returned, making the two major economies (Europe and US) to rethink biofuels policies (OECD, 2013)[2].

Whatever is the motivation (environmental concerns, increase energy security, improve balance trade or subsidize local farms), it is important to know price elasticities of fuels. For example, considering Brazilian market, if a policy aims the reduction on gasoline consumption through increasing prices, it is important to answer some questions first: i) if prices are able to change consumption, what extent of change is needed? ii) which price should be increased (decreased) by taxes mechanism? For ethanol or gasoline Brazilian demand it is important to consider both prices (ethanol prices and gasoline prices) as demand determinants, which increase the set of choices for some policies and make Brazil a nice mirror for potential biofuels policies for other countries.

Once to know elasticities are important to propose public policies, how to estimates those properly is the next natural step. In this sense is important try to care about endogeneity problems caused by simultaneity among supply and demand. Without considering endogeneity problems, there is a downward bias (Davis and Kilian, 2011), estimation are toward to zero because of correlation between increases in demand and increases in prices, generating correlation between price and error term (price is endogenous).

Some methods has been used in literature to address this problem, the most common is Instrumental Variables (IV) approach. Most used instruments for gasoline prices are oil prices (time series level) and price of other refinery goods as kerosene and diesel prices (panel data level)[3]. In our study we used an approach close in spirit with Liu (2014)

[1] Some countries had similar public policies regarding to reduce oil dependence after oil shocks of 1970s, including Argentina, Costa Rica, Malawi, Sweden and Zimbabw. For more details see Johnson and Silveira (2014).

[2] The effects of biofuels on deforestation and global hunger, lack of supply capacity and the monetary cost of those policies are in debate. In these major markets, biofuels do not have a good energy balance. Ethanol from sugar cane has an energy balance (total of fossil fuel energy needed to produce) six times better than corn one. The same happens with CO2 reduction compared to gasoline; ethanol from sugar cane can reduce CO2 emissions in 84%, while corn can reduce emissions in 30%. For more details see Goldemberg and Guardabassi (2010).

[3] In a panel data with time effects the oil prices (instrument for gasoline demand) or sugar prices (instrument for ethanol) would be redundant with time effects, once they do not have variation intra panel, the international price of oil is the same for all states of some country.

constructing instruments with purchase prices of ethanol, gasoline and diesel excluding the prices of neighbors.

The goal of this paper is to investigate the gasoline and ethanol elasticites, focused on the changes led by the introduction of flex fuel cars in Brazil in 2003, on the marginal effects of ethanol and gasoline demands. In particular, the introduction of these cars increased the opportunity for consumers to arbitrage between these two fuels´ prices and, therefore, we expect to find evidence of greater demand substitution between these fuels. We hypothesize that the own and cross price elasticities of both ethanol and gasoline in Brazil increased in their magnitudes after flex cars and that these elasticities are higher than the world average, mainly because of the cited policy. We investigate these hypotheses using monthly data from 2001m7 to 2014m12. The inherent endogeneity problem is addressed with an Instrumental Variables (IV) approach in which we construct instruments with temporally and spatially lagged purchase prices of ethanol, gasoline and diesel from neighboring states and excluding the prices of nearest neighbors.

The paper makes several important contributions. By focusing on changes in price elasticities over time, we are able to consider the effect of an important change in the Brazilian market, the introduction of flex fuel cars. In addition, we improve the estimation of price elasticities using appropriate IVs to control for the simultaneity between prices and quantity that otherwise biases estimates towards zero. In comparing the IV results to OLS estimates and to previous estimates that did not control for this endogeneity, we find estimates that reveal larger price elasticities, that is, our own price ethanol demand elasticities are around -1.5 for and roughly 0.5 for the cross price elasticity. Likewise, gasoline demand elasticities are around -0.8 for the own price elasticity, 0.1 for the cross price elasticity. Both demands showed an income elasticity of around 0.8. Our findings indicate that the introduction of flex fuel cars changed the demand for light fuels in ways that have important implications for welfare and policy. When we used interacted time dummies to verify changes into demand shifts, the major shift change was found from period 1 (2001m1 – 2005m6) to period 2 (2006m1 – 2010m6), while the parameters from period 2 to period 3 (2010m7 – 2014m12) had just small changes. The changes were in the expected direction, with increasing in substition. This increased substitution has positive implications for consumer welfare, given that consumers are now less susceptible to a price increase in any market. On the other hand, it has the potential to make both markets more volatile.

The rest of the paper is organized as follows. First, we review the previous literature on the demand for light fuels in Brazil and provide some highlights of the Brazilian light fuels market. We then describe the challenges of properly estimating ethanol and gasoline demands, with special attention for the endogeneity and instruments issues. Finally the paper concludes with a discussion of the results, and in the last section we present the final remarks.

2 Background

2.1 Literature Review

Many studies worldwide with respect to demand for light fuels show gasoline as an inelastic good in the short and long run. Usually, long run elasticity tend to be larger because of a larger range of adjustment possibilities. These facts are in line with traditional microeconomics theory, once fuels have just a few alternatives in the short run, but these possibilities increase in the long run. For example, if gasoline price had an unexpected and permanent increase, the consumption of the next days probably would not change in a significant way, but with more time, consumers start to rethink their transportation strategies, generating larger changes in the demand.

Also from traditional microeconomics, demand for light fuels are modelled invariably using at least price and income as explanatory variables. Some studies, such as Burnquist and Bacchi (2002) and Cheung and Thomson (2004), do not use other controls and estimates demand using just these two variables. Two important surveys about gasoline demand are Dahl and Sterner (1991) and Espey (1998), and they showed a large range of econometric techniques used to estimate demand for light fuels, such as: time series, panel data, cross sections, instrumental variables and others. According to these surveys, estimated price elasticities were between $(-0.12; -0.44)$ in the short run and (-0.23;-1.05) in the long run, and income elasticities $(0.14; 0.58)$ in the short run and $(0.68; 1.31)$ in the long run. For a better view of other papers results we did a summary with the World average (surveys), one result for the US Market, one for Europe and the last results for the Brazilian Market.

It is possible to see in Table-1 that Brazilian Market usually shows larger elasticity than US and Europe. This fact is due to income levels and preferences, and now we also add flex fuel cars explanation for this elasticities differences. Santos (2013) (2012) estimated elasticites (price, cross-price and income) using a DOLS estimator for the long run and a GMM´s Arellano Bond. The effect of flex fuel on elasticities was small and/or insignificant (sample goes from Jul/2001 to Dec/2011 on quarterly basis). Freitas and Kaneko (2011) focused on effects of flex fuel cars on ethanol demand in Brazil, but carried out to estimate and explain the gasoline influence on ethanol demand, without taking inot account ex-ante and ex-post changes due to flex fuel cars.

Table 1: References about Demands for Light fuels

References[a]	Local	Time	Y	Short Run		Long Run	
				Price	Income	Price	Income
Dahl and Sterner (1991)b	World	1929- 1993	Gasoline	-0.24	0.80	-0.45	1.16
Espey (1998)[b]	World	1929- 1993	Gasoline	-0.23	0.30	-0.43	0.81
Burnquist and Bacchi (2002)	Brazil	1973- 1998	Gasoline	-0.23	0.96		
Alves and Bueno (2003)	Brazil	1974-1999	Gasoline	-0.47	0.12		
Roppa (2005)	Brazil	1979- 2000	Gasoline	-0.63	0.16		
Nappo (2007)	Brazil	1994-2006	Gasoline	-0.19	0.68		
Pock (2007)[c]	EU	1990-2004	Gasoline	(-0.02; -0.19)	(0.03; 0.23)	(-0.12; -0.84)	(0.16; 0.52)
Hughes et al. (2008)	USA	1974-2006	Gasoline			(-0.30; -0.43)	(0.47; 0.54)
Serigati et.al. (2010)[d]	Brazil	2001-2009	Ethanol	(-1.20 and 2.20)	(-1.20 and 1.80)		
Farina et. al. (2010)	Brazil	2001-2009	Ethanol	-1.23			
Souza (2010)[c]	Brazil	2001-2009	Gasoline	(-0.29; -0.37)	(0.07; 0.32)		
Souza (2010)[c]	Brazil	2001-2009	Ethanol	(-1.26; -1.82)	(0.20; 0.45)		
Freitas and Kaneko (2011)	Brazil	2003-2010	Ethanol	-1.43		-1.80	
Cardoso and Bittencourt (2012)	Brazil	2001-2011	Ethanol	-1.42	0.45	-3.30	2.82
Santos (2012)	Brazil	2001-2011	Ethanol	-1.52		-8.45	
Santos (2012)	Brazil	2001-2011	Gasoline	-0.78		-1.18	

Source: Authors.
Notes: a) References are listed by year of publication; b) These papers are surveys, hence it was reported the mean of all studies; c) Some authors have many estimates, so it was reported the interval.

So far we are talking about previous results in the literature about fuel demand, but what is the motivation to study fuel demand and why in Brazil? The answers will undergo key words such as energy security, long run oil shortage, alternative fuels and environmental concerns.

It is well-known that oil is a finite resource, therefore, moving in a direction to be less dependent of it is a fundamental necessity, but the question is about the right timing to do that. The world proved reserves[4] of oil passed from 1041.4 thousand million barrels

[4]Proved reserves can be calculated in different ways, but the most common is to use those quantities of oil that can be extracted with actual economic and engineering conditions. Therefore, increases in prices and/or better technology increase oil proved reserves.

(tmb) in 1993 to 1687.9 tmb in 2013 (BP, 2014). Which represents reserves 62% bigger than 1993 and 27% bigger than 2003. Increase in proved reserves made the R/P (proved reserves/production) of World be stable in values larger than 40 years since 1980, in 2013 the value of R/P is 53.3 years. It means that if nothing changes (technology, prices, consumption and discoveries), oil would last 53 years. This increase of R/P means that incorporation of proved reserves happened faster than increase in consumption (consumption increased 52% in the last 30 years, while proved reserves increased 62%).

Even with these good news for energy security, environmental concerns has gained a more important role, becoming a catalyst for changes toward a low carbon economy. In this context, ethanol from sugar cane seems to be a good option in the medium run. Changes toward clean energy have been constrained by costs, roughly it is possible to say that there is a trade-off between clean and cheap energy, and ethanol from sugarcane is a significant improvement regarding environmental and an alternative close in costs comparing with other alternative energies.

Here is important to point out that, if biofuels are being considered supported using environmental arguments, different crops have distinct energy balances and sugar cane is a better option regarding costs, land intensity and fossil balance related to corn (US production) and also regarding sugarbeet (Europe production) (Goldemberg and Guardabassi, 2010). Hence, we can say that ethanol from sugarcane are "cleaner" than other crops, and also it has a smaller impact on competition with food (once it is less land intensive).

Table 2: Ethanol features by different crops.

	Sugarcane (Brazil)	Corn (US)	Sugarbeet (Europe)
Energy Balance[a]	8.1-10	1.4	2.0
Production Cost (€/100 liters)	14.48	24.83	52.37
CO2 Reduction	84%	30%	40%
Production(liters/hectare)	6,741	4,182	5,510

Source: Goldemberg and Guardabassi (2010).
Notes: a) Energy output in a liter of ethanol over fossil fuel energy need to be produced. So, with one liter fossil fuel in Brazil it is possible to produce around seven times more ethanol than in US. This difference is due intensity in fertilizers of US production comparing with Brazilian one.

Whatever the motivation is (support local farms, environment, energy security), knowing elasticities of ethanol and gasoline demand are key assets. Policies aimed in increase local farmers´ demand for ethanol in Brazil and/or to reduce gasoline consumption should properly consider the role of both prices (ethanol and gasoline) on these demands. Income elasticities are also variables of interest to recognize the short terms shifts and to be used by private and public sectors. More than these two key variables, Brazil also brings the importance of cross elasticities to fuel demand estimations. Depending on our answers for elasticities, public policies could be better designed in a sense to figure if demands are price sensitive, which price is more sensitive, whether income increases will be followed by increases in fuel consumption, and in what extent.

2.2 Light Fuels in Brazil

Brazil is a special country regarding light fuels market. Because Brazilian fleet is composed by around 52% of cars that are able to use ethanol or gasoline, or a blend of two fuels (flex fuel cars), there is a need to include the alternative fuel price regarding both demands (ethanol and gasoline). Hence, not just the own price and income elasticities are important for Brazilian light fuel demand, but also the cross price elasticities. Studying changes and differences between Brazil and the rest of world could help to understand the impact of future and current biofuels policies.

Biofuels policies in Brazil started motivated by: i) reduction on oil dependence; ii) supporting local farmers with the increase of ethanol demand. Reduction of oil dependence was associated with a balance trade problem, with increases in oil prices (1970s), oil importers had their value of imports increased. During 1980s, with the fall of oil prices, interest on biofuel policies decreased in Brazil and around the world. At present, with Brazilian oil discoveries and agricultural commodities being exported, the arguments of energy security and balance trade were weakened, being local farmers support and the green fuel motivation stronger arguments nowadays.

These policies resulted in one of the most cleaner energy matrices in the world, with more than 46% of primary energy production coming from renewable sources in 2013 (EPE, 2014), from which 19% of total primary energy coming from sugar cane products. The statement that ethanol is an economically feasible alternative for oil in Brazil should be better explained. Ethanol is competitive with gasoline in Brazil though a whole institutional arrangement which is mainly composed by:

- Government Mandates - If nothing of hydrated ethanol is bought by flex fuel consumers, if they bought just gasoline, there is still 27% of anhydrous ethanol mixed in gasoline, which guarantees scale to producers;

- Car subsidies - Taxes on Industrialized Products (IPI)[5] are different between flex fuel cars and gasoline cars. The only situation when there are the same level of taxes for flex fuel and gasoline cars are for cars until 1000cc. For cars with larger engines (more than 1000cc) IPI tax is higher for pure gasoline cars than for flex fuel cars. It clearly increases potential demand for ethanol;

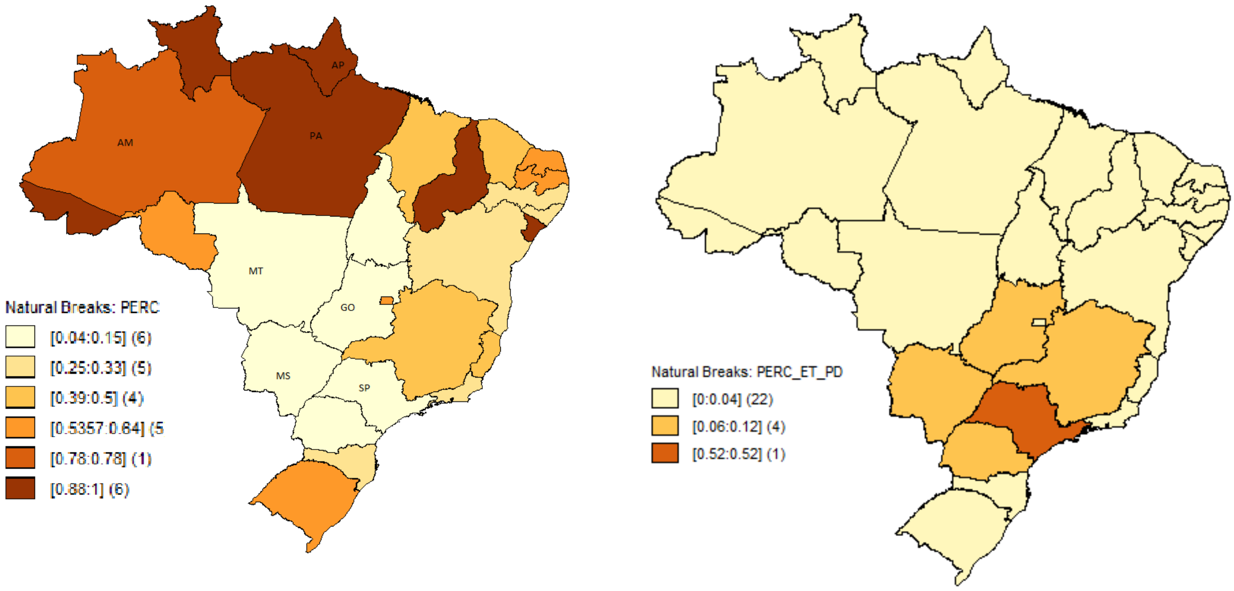
- Subsidies directly on fuels - There is a higher tax burden on gasoline than hydrated ethanol in Brazil (Jales and Costa, 2014). For state of São Paulo, for example, taxes were roughly 21% of final price for ethanol and 42% for gasoline.

Other interesting point is that ethanol is not homogeneously competitive across Brazilian states. One illustration can be done comparing purchase prices, the difference between the average purchase prices in the most expensive and in the cheapest state, which achieved 56% at ethanol market and just 13% at gasoline market. It illustrates a larger price dispersion in the ethanol regional markets. In some extent, these differences across states are due to logistic bottlenecks. In region North, for example, just a few states have ethanol prices competitive against gasoline ones. We constructed a map with the percentage of periods that gasoline is more competitive than ethanol[6] (Map (a) - Figure 1). The Map

[5] Acronym for "Imposto sobre Produtos Industrializados (IPI)" in Portuguese.

[6] Ethanol has a lower energy content than gasoline, so to compare both prices we should multiply gasoline price by a constant of 0.7. Hence, if $Ethanol_{P}rice/Gasoline_{P}rice > 0.7$, it means that gasoline is more competitive. Otherwise, ethanol is more competitive.

(b) (Figure-1) shows where are located ethanol production, the darker regions are the largest producers, the five states in the middle of the figure are the largest producers, which together represent 86% of total production[7].



(a) Percentage of periods that ethanol is more competitive.

(b) Location of Ethanol Production.

Figure 1: Spatial production and competitiveness of ethanol.

Consumption ratio between ethanol and gasoline (C_r) is defined here by the share of ethanol of each state in the Brazilian market (E_s), divided by gasoline participation (G_s). If (C_r) = 1, it means that the state´s consumption of gasoline and ethanol has the same pattern of consumption as the whole country. In the North (far from the largest consumer markets) the share (C_r) is 0.23, and hydrated ethanol consumption of those states are around 1.41% of total, while gasoline consumption is around 6.11% of total. Meanwhile, state of São Paulo[8] , the major producer and consumer has the share around 2.23, consuming 60% of ethanol and 27% of gasoline. These data show that even the government in Brazil sells the idea that ethanol could be an international commodity, with the actual oil prices, but it is competitive just in a few Brazilian states (close to producers), not in all of them.

3 How to estimate these demands?

Once clarified why to study Brazilian fuels market demand, in the next step we explain how to estimate these demands.

[7] All shares calculated for 2011 using National Agency for Petroleum, Natural Gas and Biofuels (ANP) available at ANP (2015)

[8] The state of São Paulo is the most populous in Brazil (22% of total), richest in absolute terms(32.6% of Brazilian GDP) and the second in per capita income.

3.1 Literature Instruments

In order to achieve equilibrium is natural a back and forth between supply and demand curves. Regarding a agricultural commodity for example, some increase in demand generates higher prices, higher prices increase supply, higher supply decreases prices, keeping other variables constant. Because price and quantity are equilibrium points of both curves and they are moving across time it could be a source of endogeneity, do not allowing correct estimation of demand and supply curves. There is a possibility to say that fuel price is exogenous if there is aninfinity elastic supply curve, not price sensible. Apparently it is not true for large countries. Anderson (2012), for example, argues that the pricing strategies at gas station level is not a function of short-term shift demand, so US retailers follow follow the same strategy, arguing that gasoline price is constructed just as function of oil prices without feedback process.

The most usual is to treat price as an endogenous variable as did by Liu (2014) and Hughes et al. (2008). The major bias source would be the positive correlation between demand and prices, biasing error and creating a toward zero bias. In a simple equation, endogeneity could be visualized as:

$$\begin{gathered} y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_k x_k + \mu, \\ E(\mu) = 0, \quad Cov(x_j, \mu) = 0, \quad j = 1, 2, ..., k-1. \end{gathered} \tag{1}$$

Note that the exogenous variables ($Cov(x_j, \mu) = 0$) go until x_{k-1} because x_k is our endogenous estimator. Be endogenous in an econometric sense means to be correlated with error term and not be generated out of the model. This feedback between model and variable makes impossible to properly verify the marginal effects, in other words $Cov(x_k, \mu) \neq 0$ is not a problem just for β_k, but for all β_j. We cannot consistently estimate Equation (1) using OLS.

In some estimations of gasoline demand is possible to find results inconsistent theoretically, as positive price elasticities or total price demands inelastic (Noll, 2013). The major reason for that is that demand increases are followed by price increases, creating a contemporaneous positive correlation between prices and demand, biasing estimators. In order to solve that, IV approach indicates that we need at least one **valid instrument** (z_1) for each endogenous variable (Wooldridge, 2010, p. 89). Valid instruments have to assure two features: i) an exogenous instrument ($(Cov(z_1, \mu)) = 0$); ii) a different from zero correlation between z_1 and x_k. Frequently, the practical concern is a tradeoff between relevance and exogeneity of instruments. The relevance of instrument is usually interpreted as different from zero partially correlation between instrument and the endogenous variable, once the coefficient of z_1 in x_k equation, θ_1, need to be different from zero:

$$x_k = \delta_0 + \delta_1 x_1 + \delta_2 x_2 + ... + \delta_{K-1} x_{K-1} + \theta_1 z_1 + r_K \tag{2}$$

The Equation (2) is considered as the first stage of an IV approach and its estimation should have $E(r_k) = 0$ and r_k uncorrelated with its explanatory variables. Regarding our instruments, for instance, it is easy to find significant coefficients, so we have strong instruments. The major problem is to find really exogenous instruments.

According to the literature, it is important to have in mind if database is a time series or a panel data. This feature makes a large difference for the instrument choice. Are international sugar prices good instruments for ethanol prices[9]? Depending on the type of database, for time series, the answer would be yes, but for panel data with time-effects, the answer would be negative. In a panel data with time effects, there is no reason to include a instrument with no variation intra-panel, this instrument will be cancelled, redundant, with time-effects. The same explanation is used to justify why international oil prices are not good instruments for gasoline prices at state level panel data.

Ramsey et al. (1975) and Dahl (1979) used other refinery goods as kerosene or diesel to instrument the gasoline price, but it is likely correlated being used as price demand instrument(Noll, 2013).

Following the literature in the attempts to find good instruments, Liu (2014) argues that the prices of other states can be used as instruments. They are correlated by supply side, being a good instrument for prices in each state, so the author used average price of non adjacent states. This approach is close in spirit to the use of some lagged spatial variable, but in spatial econometrics is more common to use information of closer states but the more distant ones.

3.2 Our Instruments

The hard task to find a good instrument for prices, a common attempt would be to get some instrument candidates from the supply side. This is the motivation to use oil prices as instrument for gasoline demand and sugar prices for ethanol demand (in a time series approach). Oil prices are one of most important costs for gasoline and the sugar price is an important component in the opportunity cost to produce ethanol.

Here we used **purchase prices** of diesel, gasoline and ethanol to construct our instruments. Therefore, our instruments are an average prices where just the prices of non-adjacent states are computed. We depart from a matrix of Ones (27 x 27) and reduced a Queen-1 matrix (27 x 27) from that. After that we row standard the results to get our NN-1 matrix. Then, NN-1 pre multiply prices matrix (27 x 162) to construct our instruments. This procedure is repeated also for Queen-2 contingency matrix (just to check if results are sensible to matrix choice).

Regarding positive contemporaneous correlation between demand and prices, we also used lagged prices trying to achieve more exogenous instruments. The justification here is that the farther temporally is the variable, the lower is the probability that this variable is correlated with error term in the mainly equation (second stage).

Because gasoline in Brazil is a blend (27% anhydrous ethanol + 73% gasoline) there is also the possibility of hydrated ethanol prices being endogenous in gasoline demand: increases in gasoline demand increases demand for anhydrous ethanol, which increases prices of anhydrous and hydrated ethanol. We believe that neglecting this problem leads to toward zero bias in ethanol prices in the gasoline demand, presenting insignificance in ethanol price estimated parameters. Hence, we also tested endogeneity of ethanol prices on gasoline demand.

[9] In Brazil the mainly crop used to ethanol production is sugarcane and there is a little arbitrage choice regarding the firms production, some firms can change the production between sugar and ethanol. So, the sugar price is relevant for the ethanol supply.

3.3 Model and Summary Statistics

Around the world is common to include population as a control for fuel demand. But is not a good option to capture the real fleet effects in Brazil. Because it is a middle income country, the **fleet** has changing in relation with population. In 2000 there were 8.4 people/vehicle, eleven years later this ratio was around 4 people/vehicle. Just to compare, US has a ratio around 1.25 people/vehicle, losing just for Monaco and San Marino[10]. We used the Denatran database to construct our fleet variable.

The other variables used to estimate fuel demand are the prices (own prices and substitute prices) and income proxies. Then, the basic model is:

$$\textbf{First Stage}: \qquad P_{1it} = \delta_0 + exogenous + instruments + \upsilon_{it} \tag{3}$$

$$\begin{aligned}
\textbf{Second Stage}: \quad & \\
Q_{it}^j = & \beta_1^j \hat{P}_{1it} + \beta_2^j P_{2it} + \beta_3^j Inc_{it} + \beta_4^j Fleet_{it}^j + \beta_5^j Fleet(ratio)_{it} * P_{1it} \\
& + \beta_6^j Fleet(ratio)_{it} * P_{2itj} + regional\ effects + time\ effects + \varepsilon_{it}
\end{aligned}$$

$$j = gasoline,\ ethanol; \qquad i = 1, 2, ..., N; \qquad t = 1, 2..., T. \tag{4}$$

The equation above is used to estimate both demands. The database is a panel data (NT) where N varies from 1 to 27 (number of sates in Brazil) and t varies from 1 to 162 (being 1 related to July/2001 and 162 to Dec/2014), so we have a panel with 4374 observations ($N.T$).

The quantities in the data set (Q_{it}^j) are the hydrated ethanol and gasoline-c sold at gas stations in barrel of oil equivalent quantities. Gasoline prices and ethanol prices are the monthly weighted averages of consumer prices provided by National Agency for Petroleum, Natural Gas and Biofues (ANP). The income proxy used here was a state-level tax (ICMS[11]). We are using ICMS instead of electrical consumption proxy for two reasons: i) do not input a fix effect[12]. ii) IMCS is a better proxy than energy consumption mainly because of technological changes towards energy-savings and environmental concerns which likely decrease the correlation between them (GDP and energy consumption).

We also have purchase prices of ethanol, gasoline and diesel, and these prices are weighted by the sales of each gas station and are provided by National Agency for Petroleum, Natural Gas and Biofues (ANP). We will use these prices as instruments for gasoline and ethanol price. Trying to have more exogenous instruments we will use similar strategy as Liu (2014), using just the prices of non-neighbors as instrument. So, "NN1" is reference to price of non-neighbors, NN1 being non-neighbors of first order. The NN2 matrix, of second order are also used just for consistency tests.

[10] The data of US, Monaco and San Marino is available at World Bank Database. For Brazil see the National Motor Vehicle and Traffic Department Database (Denatran).

[11] Abbreviation in Portuguese for *Imposto sobre Circulação de Mercadorias e Serviços.*

[12] Energy consumption on monthly basis is available just at region-level (dividing Brazil into 5 regions and not into 27 states) which input a fix effect by region when we tried to construct the variable by state.

Table 3: Summary statistics

Variable	Obs	Mean	Std. Dev.	Units
Ethanol Prices (P_{eth})	4374	1.841	.426	R$
Gasoline Prices (P_{gas})	4374	2.525	.381	R$
Diesel Prices (P_{die})	4374	1.894	.44	R$
id	4374	14	7.79	States
time (months)	4374	578.5	46.77	July/2001 to December/2014
Amount Ethanol (bep)	4374	103794.8	332049.6	barrel of oil equivalent
Amount Gasoline (bep)	4374	468475.5	707858.9	barrel of oil equivalent
Income (Inc)	4291	688526.2	1304074	R$
Fleet ($Fleet$)	4374	2.67e+07	5680398	number of cars
Inflation Index (IPCA)	4374	1.468	.225	Index (July-2001 = 1)
Gasoline Prices (N1)(P_{gas}_N1)	4266	2.162	.322	R$
Ethanol Prices (N1)(P_{eth}_N1)	4104	1.539	.372	R$
Diesel Prices (N1)(P_{die}_N1)	4266	1.552	.386	R$

Source: Authors.

4 Results

4.1 Preliminary Results

Regarding endogeneity issues we should to do two basic questions:

i Is there an endogeneity problem?

ii Is there a valid instrument?

The first question we tried to answer using the Durbin-Wu-Hausman approach (testing the consistency through differences between OLS and 2SLS estimators) and using control function approach (including residuals of first stage regressions into second stage). Using both approaches, own prices are endogenous in ethanol and gasoline demands, as expected. We also have an intuition that ethanol price is endogenous in the gasoline demand, so shocks on demand for gasoline could be transmitted to ethanol prices by anhydrous ethanol channel. This channel causes negative contemporaneous correlations between ethanol prices and gasoline demand, when we should expected positive correlations. Hence, we also test the endogeneity of ethanol prices on gasoline demand. Another way to achieve the same result is using the residuals of the first stage in the main regression. If the coefficient of the estimated residuals is different from zero, we also have endogeneity problems (Wooldridge, 2010, p. 130).Using both approaches, ethanol price showed to be endogenous in both demands, and gasoline price is endogenous in its own demand.

After confirmed the endogeneity problem in both demands, we estimated these using instruments for prices, but what we should expected from the results? First of all, we would expect negative own prices elasticities, since we are estimating a demand curve and not a supply one. Regarding all other key parameters (alternative fuel price, income and fleet) we expected positive elasticities for gasoline demand, for example more income, fleet or alternative fuel price, more demand for gasoline, ceteris paribus. More than these basic expectations, we also expected more elastic prices and cross price parameters for ethanol demand than for gasoline demand, because ethanol demand is basic flex fuel fleet (higher arbitrage degree)[13].

Table 4: Ethanol Demand

	Gasoline Purchase Prices	Ethanol Purchase Prices	Diesel Purchase Prices
	lnqeta	lnqeta	lnqeta
lnFleet	0.546***	0.728***	0.469***
	(4.85)	(5.87)	(4.39)
ln_Pg	0.463***	0.510***	0.549***
	(3.58)	(4.03)	(4.15)
ln_Income	0.810***	0.746***	0.870***
	(45.37)	(39.28)	(51.75)
Pe_hat_i1	-1.494***		
	(-16.35)		
Pe_hat_i2		-1.645***	
		(-17.73)	
Pe_hat_i3			-1.542***
			(-16.85)
_cons	-9.232***	-11.55***	-8.691***
	(-4.93)	(-5.59)	(-4.86)
N	4156	4003	4156

t statistics in parentheses

Source: Authors. On top of each column is indicated witch instrument was used.

First stage is not reported here, but instruments showed be highly significant parameters.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4 shows ethanol as an elastic good, which is a different feature from fuel market abroad. Basically all results, including some surveys, found fuel market as a price inelastic good ($E_p < 1$) (considering gasoline market).). But it seems that ethanol market, mainly because possibility of arbitrage regarding flex fuel cars, became a fuel market with less inelastic price. Due to the used log-linear functional form, coefficients can be interpreted directly as elasticities, so ethanol has elasticities around (-1.5) for the Brazilian market and these results are at the top range of other elasticities estimations from the literature. Literature range is between (-1.5) and (-1.2), being the higher values for the most recent papers (Santos, 2013; Farina et al., 2010; Cardoso and Bittencourt, 2013; Freitas and Kaneko, 2011).

Regarding income elasticity estimations, we found values slight smaller than a unit, indicating that expansion of income has a large impact on ethanol demand, comparable with international average marginal effects. These income elasticities‘ results are larger than the ones for the US and Europe, for example. Hughes et al. (2008)(USA) and Pock (2007)(Europe), for example, did not find income elasticities larger than 0.52, even considering long run parameters. This follows the intuition that increases in income should have smaller impact in high income level countries than middle income ones.

[13] Since 2006 there is no pure ethanol cars production, being that pure ethanol fleet is around of 2% and tending to be zero in the long run.

Other important point is the results' robustness regarding instruments choice. Even if we are not sure that ethanol purchase prices are the ideal instruments, the other two instruments performed pretty close. Cross prices elasticities on ethanol demand and the effects of gasoline prices were around a third of ethanol prices' effects. This shows that ethanol demand is more sensitive to its own price than gasoline demand.

Table 5: Gasoline Demand

	Gasoline Purchase Prices	Ethanol Purchase Prices	Diesel Purchase Prices
	lnqgas	lnqgas	lnqgas
pe_hat_i2	0.105*	0.0884	0.103*
	(1.98)	(1.72)	(1.99)
ln_income	0.801***	0.801***	0.803***
	(136.59)	(141.69)	(142.26)
ln_fleet	0.359***	0.356***	0.347***
	(9.92)	(10.34)	(10.05)
pg_hat_i1	-0.871***		
	(-10.39)		
pg_hat_i2		-0.900***	
		(-11.15)	
pg_hat_i3			-0.934***
			(-11.49)
_cons	-3.111***	-3.040***	-2.881***
	(-5.13)	(-5.28)	(-4.99)
N	4003	4003	4003

t statistics in parentheses

Source: Authors.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

In the gasoline demand estimation (Table 5) all instruments also performed closely. The difference is that in gasoline demand we used instruments for the own price and for substitute good price (endogeneity with gasoline prices because of anhydrous portion into gasoline). Therefore, in the second column estimates we have multicollinearity because ethanol purchase prices are used for construction of both prices. This might be the reason for ethanol price not being significant.

Regarding own elasticities (gasoline prices' parameters) we found higher elasticities than international evidence, probably because of a combination among higher arbitrage (flex fuel cars) and a smaller income in Brazil. Comparing with Brazilian evidence, we found parameters close to (Santos, 2013)($E_p = -0.78$), for example. The elasticities of gasoline demand were roughly half of the ethanol elasticities. This may indicate that ethanol demand is more price sensible than gasoline. It is an expected result because ethanol demand is almost totally composed by flex fuel cars.

Income parameters were almost the same for ethanol and gasoline demand estimations, so the impacts from income increases would be the same for ethanol and gasoline demands.

4.2 Are the elasticities constant? The role of flex fuel cars

Most of the studies in the literature use log-linear specification for light fuel demand estimation. In addition to the facilities to interpret directly the parameters as elasticities, come also the imposition that elasticities are constant for the whole sample. Therefore, this assumption will be relaxed allowing different price and cross price elasticities along the time. We also allowed differences into income elasticies, but it was around 0.8 for both demands along the time.

We would expect higher cross elasticities after the introduction of flex fuel cars, considering just the Brazilian market, and the current literature confirms that. But we believe that there are mixed effects causing that: i) the older literature does not account for endogeneity, thus tends to underestimate elasticities (as explained earlier, do not account for endogeneity and has a toward zero bias into these demands); ii) flex fuel cars introduction, tending to increase arbitrage between both fuels, increasing cross price and own price elasticities, becoming fuel more price sensible. Hence, in order to account for changes in elasticities during the time we interacted price and cross price parameters with time dummies.

Time dummy variables regarding 2006m1 and 2010m7 split our sample into 3 equal periods. The justification to use 2006 and not 2003 (the beginning of flexfuel cars production) is because flexfluel fleet was so small in 2003 that would not be important enough to change elasticities. The proportion of flexfuel cars in the first period went from zero to 8% of total cars. In the end of the second period (2010) flex fuel cars reached 37%, and in the end of our sample this proportion was around 52%. Another important event in 2006 was that flexfuel cars production exceeded gasoline cars' production. Table 6 shows the results of the estimates coefficients after re-parametrization.

Ethanol price and cross price elasticities had a large increase from period 1 (2001m1-2005m12) to period 2 (2006m1-2010m6), and the changes for period 3 were small. Other important result is that in the period 1, cross price coefficient of ethanol demand shows an insignificant result, but in the next two subsequent periods it showed significant results.

The gasoline demand had the same behavior, with a larger increase in elasticities from first to second period and just a little change from second to third period. Again, the cross price coefficient was not significant in the first period, becoming significant in the following periods. These results regarding cross price elasticities (for both ethanol and gasoline) could be interpreted as the lack of power of substitution to change demand of fuel without flex fuel cars (in the first period).

Table 6: Price Elasticities Across Time

	(1) Ethanol Demand	(2) Gasoline Demand
Ep(etha) - time - 1	-0.690***	0.00107
	(-5.71)	-0.01
Ep(etha) - time - 2	-3.136***	0.258***
	(-21.61)	-3.35
Ep(etha) - time - 3	-3.398***	0.334***
	(-17.15)	-3.38
Ep(gas) - time - 1	0.206	-0.675***
	-1.55	(-6.80)
Ep(gas) - time - 2	1.327***	-0.988***
	-9.45	(-10.40)
Ep(gas) - time - 3	1.281***	-0.912***
	(8.00)	(-8.51)
N	4003	4156

Source: Authors.
Notes: Intervals: Time 1: 2001m1-2005m12; Time 2: 2006m1-2010m6; Time 3: 2010m7-2014m12.

In terms of the choice of time used, we constructed around 90 regressions for each demand consisting on subsample of 3-year observations. Because it is a moving window sample, the first observations in the first sample is 2001m7-2004m6; the second is 2001m8-2004m7, and so on. The most interesting result of this approach was that we could note exactly when the cross price elasticites became significant, when the confidence interval of cross price elasticities is above zero. It happens with subsamples from 2006m7 to 2009m6 for the ethanol demand, and from 2007m1 to 2009m12 for gasoline demand (Figure in Appendix).

5 Final Remarks

Using purchase prices of non-neighbors for price instruments, we estimated the ethanol and gasoline demands. The most important findings were:

i) Ethanol ($Ep = 1.5$) and gasoline ($Ep = 0.8$) are price sensible, with higher elasticities than the elasticities in the US and Europe, for example. Hence, public policies driven by prices could be applied;

ii) Cross elasticities were significant in both demands, so ethanol and gasoline are actually complementary goods for the Brazilian Market and any public policy addressed to one market should take into account spillovers to the other market. It is clear that this change occurred after the introduction of flex fuel cars introduction, since in the fist sub sample (small or zero flex fuel fleet) the cross price elasticities for both demands were not significantly different from zero and in the second period they became significant and with the positive expected sign;

iii) Using a moving window sample we reached a most accurate threshold from where the cross elasticities were significant for both demands. In other words, in these intervals gasoline and ethanol are actually part of the same market;

iv) After the introduction of flex fuel cars, there were an increase in the own price elasticities in both demands;

v) Accounting for endogeneity in both demands generated a larger elasticities coefficients for gasoline (comparing to previous literature addressed to Brazilian market), but quite similar results regarding ethanol demand.

Our price elasticities' estimations are just an indicative of how prices could respond for shocks. It is possible that the nature of the shock is important for demand responses. For instance, Coglianese et al. (2015) argue that taxes changes could have a larger effect than regular changes. In other words, 10% reduction on demand caused by oil costs would be a smaller reduction on demand than the same increase driven by taxes. The reasons for that would be the exposition of taxes changes in the media and the persistence of shocks by taxes, media exposition and tax aversion by consumers.

As the most demand studies, our results are exposed to the Lucas Critique. Even being a short run estimate, the accuracy of the model depends on what the extent of changes is, severe shocks increasing the possibility of parameters change and become harder to make predictions.

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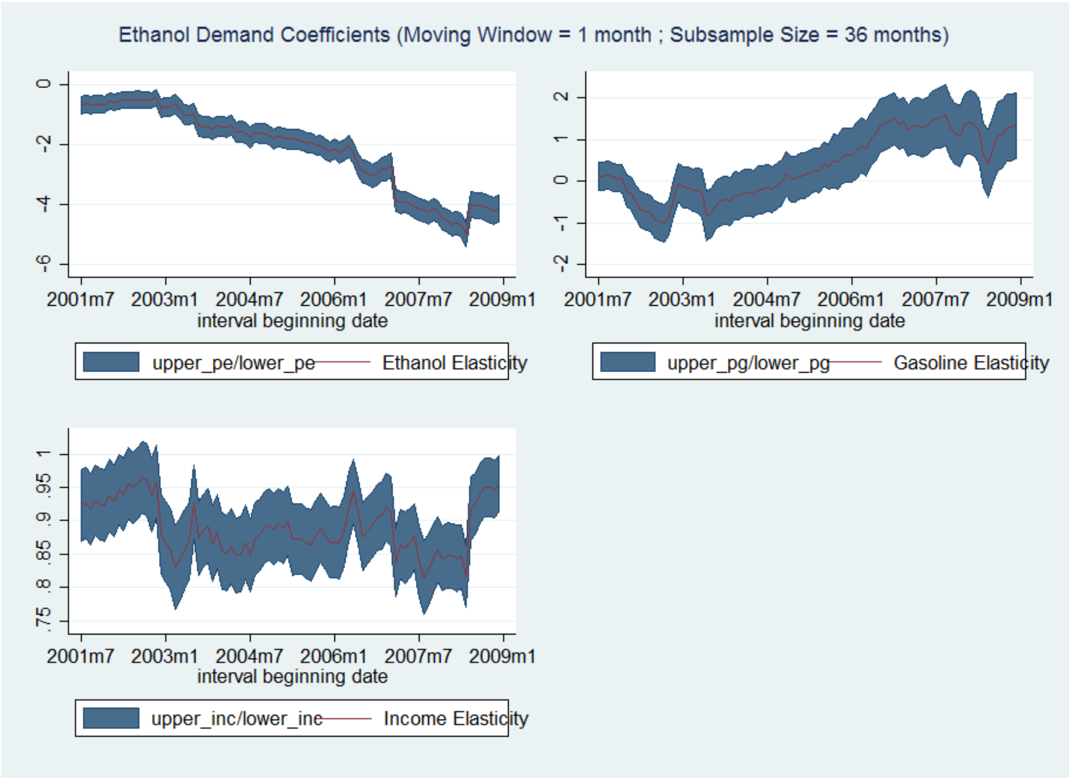
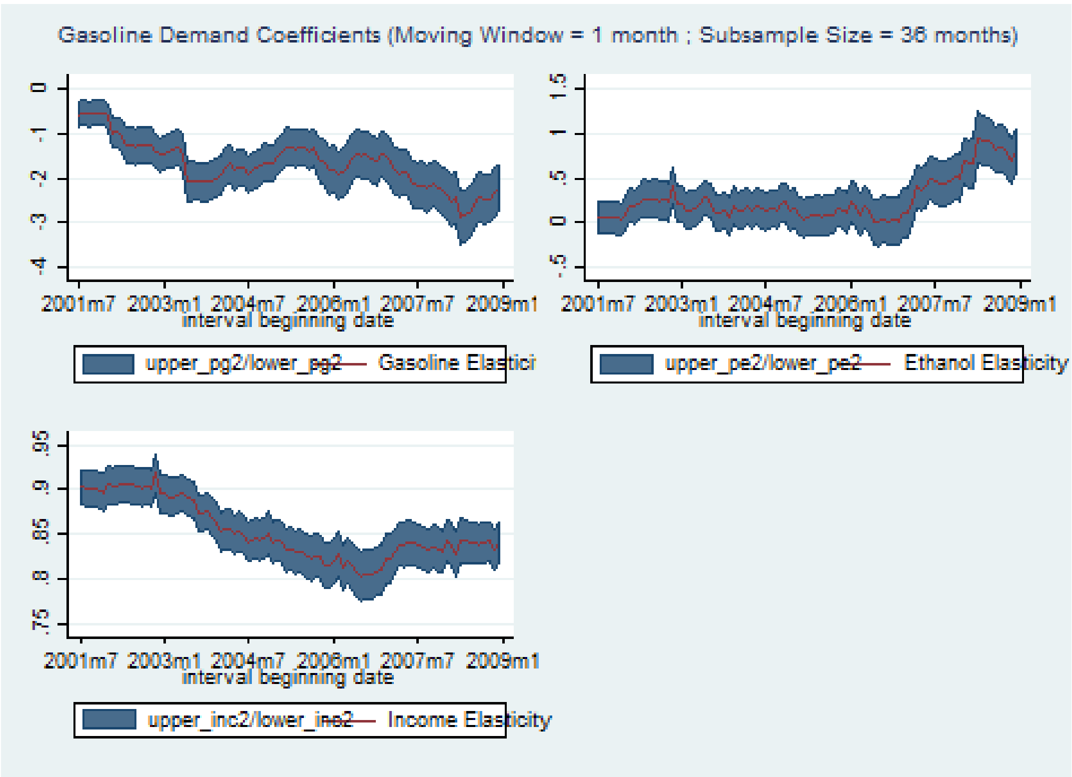
Appendix



(a) Ethanol Graph



(b) Gasoline Graph

Graphs with Moving Window.