Energy Policy 37 (2009) 5326–5333

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

# Automotive fuel consumption in Brazil: Applying static and dynamic systems of demand equations

Mariana Iootty [a,b,*], Helder Pinto Jr.[a], Francisco Ebeling [c]

[a] IE-UFRJ (Institute of Economics—Federal University of Rio de Janeiro), Energy Economics Group
[b] UFRRJ (Federal Rural University of Rio de Janeiro)
[c] Brazilian Petroleum Institute

ARTICLE INFO

*Article history:*
Received 7 May 2009
Accepted 29 July 2009
Available online 15 September 2009

*Keywords:*
Elasticity
Vector error correction model
Almost Ideal Demand System

ABSTRACT

This paper aims to investigate and explain the performance of the Brazilian demand for automotive fuels in the period 1970–2005. It estimates the price and income elasticities for all the available fuels in the automotive sector in the country: gasoline, compressed natural gas (CNG), ethanol and diesel. The analysis of the expenditure allocation process among these fuels is carried out through the estimation of a linear approximation of an Almost Ideal Demand System (AIDS) model. Two estimation methods were implemented: the static (through a seemingly unrelated regression) and a dynamic (through a vector error correction model). Specification tests support the use of the latter. The empirical analysis suggests a high substitutability between gasoline and ethanol; being this relation higher than the one observed between gasoline and CNG. The study shows that gasoline, ethanol and diesel are normal goods, and with the exception of ethanol, they are expenditure elastic. CNG was estimated as an inferior good.



## 1. Introduction

The demand of automotive fuel is an important topic in energy policy. The consumption sensibility to income and price changes can give great insights for policy makers relating, for instance, to climate change, optimal taxation and national security. The study of the automotive fuels demand in Brazil is especially relevant since in the last decades its automotive fuel market has witnessed relevant changes in the consumption structure, which used to be dominated by traditional fuels, such as gasoline and diesel.

In this changing context two periods can be identified. First, from 1970 to 1990, in a context of two oil crises, fuel consumption grew 4.5% per year and, in 1973, ethanol combustible came along as a part of a government program to reduce Brazilian foreign oil dependency. Compressed natural gas (CNG) has also been brought on as another innovation, in the end of the 1980's, although its consumption only begun to grow in the middle 1990's due to the government policy of fixing a substantial price differential in favor of CNG. So far, the Brazilian automobile industry fell short to produce CNG vehicles;[1] CNG consumers still have to install a kit which allows them to convert their vehicles between CNG as well as the original engine fuel. Most of CNG consumption in Brazil is related to light-duty trucks—such as taxi cabs, especially in the states of Rio de Janeiro and Sao Paulo, where the CNG stations network is relevant.

In the second period, from 1991 to 2005, overall combustible consumption grew at a rate of 2.8% per year. Another innovation was brought in, the flex fuel vehicles which are specially designed to run on gasoline and ethanol. In 2003, the production of flex fuel cars accounted for only 2.6% of the total automobile production; 3 years later, this number reached 75%.

The essential point to grasp here is that the introduction of flex fuel (gasoline/ethanol) vehicles and the raise of CNG have enlarged the options available to consumers to choose their automotive fue. These factors have modified, in some extent, the demand for captive fuels as gasoline. In this context, and given the assumption that demand elasticity is a useful tool to summarize the consumer's behavior, this paper tries to shed light on the performance of the Brazilian demand for automotive fuels.

The price and income elasticities of automotive fuels demand (especially gasoline) around the world have been extensively studied; see Basso and Oum (2007) for recent exercises, Goodwin et al. (2004) for a recent survey and Dahl and Sterner (1991) for thorough review. However, there are very few published papers on the estimation of demand elasticities for the Brazilian automotive fuels market. Alves and Bueno (2003) constitute a single work on this regard. Through a cointegration method they estimated the cross price elasticity between gasoline and ethanol, and find ethanol as an imperfect substitute for gasoline even in

* Corresponding author at: IE-UFRJ (Institute of Economics—Federal University of Rio de Janeiro), Energy Economics Group.
*E-mail addresses:* miootty@ie.ufrj.br (M. Iootty), francisco.ebeling@ibp.org.br (F. Ebeling).

[1] One notable exception is Fiat, who has started to produce CNG, Gasoline and Ethanol compatible engines.

0301-4215/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.enpol.2009.07.066

the long run. Even though relevant, this work has focused on the gasoline market, not shedding light on the demand for other automotive fuels in Brazil, as diesel, ethanol and CNG.

This paper goes one step further as it estimates the matrix of price and income elasticities—in relation to gasoline, ethanol, CNG and diesel. Two related estimation approaches are employed. First it uses the traditional linear approximation of the Almost Ideal Demand System (AIDS), originally developed by Deaton and Muellbauer (1980). This is a structural and static model which fulfills the desired theoretical properties of demand (homogeneity and symmetry restrictions) while also being parsimonious in terms of number of parameters to be estimated. In order to also analyze the dynamic aspect of the long run demand, this paper adopts a second approach of AIDS model using cointegration techniques based on Johansen (1988) procedures. The use of this second approach is especially relevant since the variables can be non-stationary, which could change the estimates of elasticities.

The paper is organized as follows. Section two describes the evolution of automotive fuels consumption profile in Brazil since the 1970s. Section three presents the data used. The following section describes the linear approximation of the static AIDS model and presents the first results. The fifth section develops the dynamic analysis using cointegration techniques and displays the results. The sixth, and last section, presents in a nutshell the main conclusions.

## 2. The evolution of automotive fuel matrix in Brazil

Table 1 presents the yearly consumption evolution in tones oil equivalent (toe) in the automotive vehicles fuel matrix since 1979. Two analytical periods must be highlighted. In the first one, between 1979 and 1990, the total fuel consumption presented a 2.2% growth per year, while the Gross National Product grew at a yearly mean rate of 2.05%.

In the period between 1979 and 1990, when one considers the individual performance of each series, ethanol is highlighted as the fuel with the highest yearly growth rate, of 71.3% per year. Indeed, the consumption level rose from 8000 toe, in 1979, to 5,205,000 toe, in 1990, causing an expressive accumulated growth. This significant expansion rhythm reflects the "Programa Nacional do Álcool" (National Ethanol Program), launched in 1973. Its second phase, which started in December 1978 was named "Proálcool", when the government decided to stimulate the production of vehicles with ethanol engines. In the first analytical period, it is also worth noticing the reduction in the gasoline consumption, which presented an accumulated fall of 28.5% between 1979 and 1990 (Graph 1).

In the second analytical period, between 1991 and 2005, the total automotive fuel consumption grew in a higher pace than the period before, having reached the expansion rate of 3% per year, while the GNP grew 2.4% per year. In this period, the negative point is the ethanol, with yearly fall of 3.9%. On the other hand, gasoline presented a growth rate of 3.5% per year, which reinforces the negative (substitution) relationship between the dynamics of consumption of gasoline and ethanol. An impressive highlight of this period was the CNG fuel expansion, which grew yearly 58%, having increased from 2000 toe in 1991 to 1,171,000 toe in 2005 (see Table 1).

Regarding diesel fuel, it is worth emphasizing its almost constant expansion rate. While in the first period, between 1979

**Table 1**
Annual fuel consumption of automotive vehicles ($10^3$ toe): 1979–2005.

| | CNG | Diesel | Gasoline | Ethanol | Total |
|---|---|---|---|---|---|
| 1979 | 0 | 10.902 | 10.397 | 8 | 22.491 |
| 1980 | 0 | 11.401 | 8.788 | 219 | 21.611 |
| 1981 | 0 | 11.280 | 8.413 | 709 | 21.014 |
| 1982 | 0 | 11.515 | 8.014 | 853 | 21.460 |
| 1983 | 0 | 11.025 | 6.847 | 1.504 | 20.549 |
| 1984 | 0 | 11.486 | 6.140 | 2.332 | 21.070 |
| 1985 | 0 | 11.846 | 6.043 | 3.103 | 22.124 |
| 1986 | 0 | 13.948 | 6.808 | 4.280 | 26.340 |
| 1987 | 0 | 14.689 | 5.931 | 4.546 | 26.306 |
| 1988 | 3 | 14.981 | 5.809 | 4.974 | 26.817 |
| 1989 | 2 | 15.868 | 6.527 | 5.641 | 28.905 |
| 1990 | 2 | 15.983 | 7.436 | 5.205 | 29.276 |
| **Average yearly annual growth (1979–1990)**[a] | −13.9% | 3.2% | −2.8% | 71.3% | 2.2% |
| **Accumulated growth rate (1979–1990)** | −36.1% | 46.6% | −28.5% | 63725.0% | 30.2% |
| 1991 | 2 | 16.587 | 8.059 | 5.225 | 30.751 |
| 1992 | 0 | 16.882 | 8.023 | 4.784 | 30.878 |
| 1993 | 22 | 17.325 | 8.436 | 4.931 | 32.012 |
| 1994 | 40 | 18.106 | 9.235 | 4.974 | 34.025 |
| 1995 | 43 | 19.280 | 11.057 | 5.069 | 37.250 |
| 1996 | 32 | 20.165 | 12.946 | 4.987 | 40.295 |
| 1997 | 41 | 21.422 | 14.156 | 4.233 | 42.530 |
| 1998 | 116 | 22.453 | 14.772 | 3.933 | 44.124 |
| 1999 | 140 | 22.704 | 13.770 | 3.594 | 43.412 |
| 2000 | 275 | 23.410 | 13.261 | 2.774 | 42.766 |
| 2001 | 503 | 24.071 | 12.995 | 2.170 | 42.946 |
| 2002 | 862 | 25.086 | 12.426 | 2.214 | 44.459 |
| 2003 | 1.169 | 24.252 | 13.115 | 1.919 | 44.329 |
| 2004 | 1.390 | 25.939 | 13.560 | 2.466 | 47.334 |
| 2005 | 1.711 | 25.804 | 13.595 | 2.885 | 48.073 |
| **Average yearly annual growth (1991–2005)** | 58.2% | 3.0% | 3.5% | −3.9% | 3.0% |
| **Accumulated growth rate (1991–2005)** | 97171% | 56% | 69% | −45% | 56% |

*Source*: own elaboration based on data from MME (2006).

[a] The annual growth rate of CNG was based on the period 1988/1990.