Import demand for Brazilian ethanol: a cross-country analysis

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Abstract

This study presents an empirical analysis of the import demand for Brazilian ethanol by its six major foreign buyers. The primary objectives of this study were to identify the economic factors affecting the demand for ethanol imports and to derive long-run price and income elasticities of import demand. These elasticities could be used to analyze the impact of government policies such as mandatory gasoline/ethanol blends and import tariffs. Import demand models were estimated with ordinary least squares (OLS), using quarterly time series data for the 1997-2007 time period. The results suggest that the factors influencing the import demand for ethanol vary across countries. Markets adopting mandatory blends of renewable fuels tend to have less price elastic import demand schedules. Ethanol imports were found to be price elastic and statistically significant in the Caribbean region (-1.66), Mexico (-2.08), Japan (-1.44) and Nigeria (-1.38), while import demand was price inelastic and not statistically different from zero in the US (-0.76) and Europe (-0.21). The regression results could not determine the impacts of import tariffs for the United States, Mexico and Nigeria on the quantity of imports because tariffs did not vary during the time period studied. Results show that mandatory gasoline/ethanol blends have been an important determinant of ethanol imports.

Keywords: Ethanol, Ethanol import demand elasticities, International ethanol trade, Brazilian ethanol exports

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1. Introduction

Recent developments on the world geopolitical stage have increased the global demand for ethanol. Many nations are searching for alternative energy solutions to overcome high and variable prices of petroleum associated with an unstable supply of oil and shifts in the demand for oil and to mitigate greenhouse gas (GHG) emissions contributing to global climate change [1].

Brazil, the leading ethanol exporter in the world, exported roughly 3.1 billion liters of ethanol in 2007 (Table 1). Published studies on the international ethanol trade are limited due to the recent development of this market. Elobeid and Tokgoz (2006) analyzed the global market impact of the removal of U.S. import barriers on ethanol. They found that U.S. ethanol production would be reduced and net imports would increase significantly with trade liberalization. Moreover, higher world ethanol prices would increase ethanol production in Brazil [2]. Gallagher et al. (2006) examined the competitive position between Brazilian ethanol produced from sugar and U.S. ethanol produced from corn, under the assumption of no import tariffs in the ethanol market. Their results suggested that neither the U.S. corn-based ethanol nor Brazilian sugar-based ethanol would gain significantly from a lowering of the U.S. import tariffs [3].

Koizumi and Yanagishima (2005) developed an international ethanol model and examined the implications of a change in the compulsory ethanol-gasoline blend ratio in Brazil on world ethanol and sugar markets. The simulation results implied moderate impacts on both markets due to liberalization of Brazilian policy [4].

In this context, the purpose of this study was to identify the factors affecting the import demand for ethanol in major importing nations and to estimate long run price and income elasticities. This study presents an econometric analysis of the import demand for Brazilian ethanol by the United States, the Caribbean region, Europe, Mexico, Japan and Nigeria, using quarterly time series data covering the period 1997-2007. The estimation of import elasticities can help policymakers predict trade flows and better anticipate the consequences of policy reforms and adjustment programs.

This article is organized as follows. Section 2 presents background information on the main ethanol importers and provides an overview of the previous literature on import demand modeling. Section 3 describes the econometric methodology used in this study. Section 4 summarizes the results of the import demand model for each region. Finally, discussion on further research needs and concluding remarks are presented in sections 5 and 6, respectively.

2. Background

2.1. International Ethanol Market

Ethanol is primarily used in two end-markets. Denatured ethanol is used as fuel, blended with gasoline or neat, while undenatured or potable ethanol is used for beverages and industrial organic chemical production. The rapid expansion of biofuels production and consumption around the globe is reshaping the international market for ethanol. A shift in ethanol production occurred in 2003, when oil prices increased steeply from US$ 31 to over US$ 41 per barrel. Moreover, the policies instituted by many countries to improve environmental properties for sources of energy and reduce dependency on imported oil have contributed to this trend. World ethanol production rose from 18.5 billion liters/year in 2001 to roughly 60 billion liters/year in 2007, mostly due to biofuels production [5].

International trade in ethanol has also expanded significantly over the past few years. According to the Global Trade Atlas (2007), global ethanol exports increased from 1.5 billion liters in 1997 to 7.1 billion liters in 2007 [6]. Currently, the international ethanol market is characterized by a semi-liberal trading regime, restricted by various government policies.

Brazil has a unique position in the international market for ethanol. Brazil possesses all the necessary resources and conditions to continue expanding its domestic ethanol industry. Brazil has enormous potential for agricultural expansion, enabling it to increase ethanol supply to meet growing demand. Brazilian ethanol is highly competitive due to low production costs and high agricultural and industrial productivity levels. Those characteristics are due to technological advances and low labor costs compared to other ethanol producing countries [7]. Furthermore, sugarcane fits Brazil's tropical climate and soil conditions and presents a higher energy balance compared to other feedstocks used for ethanol production, such as corn and wheat.

In 2007, Brazil exported approximately 3.5 billion liters of ethanol. The United States was the major importer in that year, importing roughly 859 million liters, followed by the Netherlands (809 million liters), the Caribbean region (704 million liters), Japan (364 million liters), Sweden (129 million liters), and Nigeria (123 million liters) (Table 1) [6].

2.1.1. Ethanol Fuel Market

To date, Brazil is the only nation to fully incorporate ethanol as an alternative to fossil fuels in the transportation sector. In 1975, the Brazilian government introduced the National Alcohol Program, Proálcool, as a response to the oil shock of 1973 and the decline in world sugar prices. Brazil now has a large-scale sugar-based ethanol industry and solid domestic demand due to mandated use and availability of Flex Fuel vehicles (FFVs). As a positive spillover from sugarcane productivity gains and low production costs, Brazil has become the largest ethanol exporter in the world [8].

The U.S. government has implemented a number of incentives over the years to promote its ethanol industry. The Clean Air Act Amendments of 1990 established a fuel oxygenate standard whereby reformulated gasoline had to contain at least 2.7% oxygen by weight in the winter season in 39 regional areas that had elevated levels of carbon monoxide (CO), and a minimum of 2% oxygen by weight year-round for 90 severe ozone non-attainment regional areas as of 1995. The main oxygenate fuel additives consumed were MTBE (Methyl Tertiary-Butyl Ether) and ETBE (Ethyl Tertiary-Butyl Ether).

The Energy Policy Act of 1992 stipulated gasoline blend requirements of 5.7 and 7.7% ethanol and designated ethanol blends containing at least 85% ethanol (E85) as alternative transportation fuels [9].

In 1999, environmental concerns about MTBE leakage from underground storage tanks and pipelines into groundwater supplies led several states to require gasoline stations to eliminate use of MTBE, with ethanol being the only effective substitute. By August 2005, 25 states had partially or completely banned the use of MTBE in gasoline, causing a significant expansion of the ethanol fuel additive market.

The establishment of a Renewable Fuels Standard in the Energy Policy Act of 2005 significantly increased the demand for ethanol. The government mandated the use of a minimum volume of renewable fuel into gasoline sold in the U.S.. This energy policy required the annual volume of renewable fuel to be blended into gasoline to be 20.44 billion liters (5.4 billion gallons) in 2008 and then to 28.39 billion liters (7.5 billion gallons) by 2012. The 2005 Energy Bill also eliminated the oxygen content requirement of 5.7, 7.7, and 10% for reformulated gasoline.

The U.S. government also provides tax incentives for gasohol use. In the Energy Tax Act of 1978 gasohol was defined as blend of 10% ethanol into gasoline. The excise tax exemption in 1990 was US$ 0.14 per liter of ethanol, extended in 1997 through 2007, however with a gradual reduction to US$ 0.13 per liter of ethanol in 2005 [9].

In December 2007 the federal government enacted the Energy Independence and Security Act designed to increase energy efficiency and the availability of renewable energy. This omnibus energy policy extended and increased the 2005 Renewable Fuel Standard (RFS). The mandated volume of renewable fuel was raised from 20.4 billion liters (5.4 billion gallons) to 34.11 billion liters (9 billion gallons) for 2008 and then increased to 136.4 billion liters (36 billion gallons) by 2022 (Table 2). So the 2007 legislation raised the mandated volume of renewable fuels approximately five-fold for the 2022 target date. Of the latter total, 79.5 billion liters must come from cellulosic ethanol and other advanced biofuels [10].

In addition to tax benefits provided to ethanol producers, the corn industry is a large recipient of agricultural subsidies, totaling approximately US$ 37.4 billion between 1995 and 2003 [9].

With the Food, Conservation, and Energy Act of 2008, federal tax credits provided to gasoline blenders was reduced from $0.51 per gallon to US$ 0.45 per gallon of ethanol under the Volumetric Ethanol Excise Tax Credit. Additionally, The United States has a long established *ad valorem* tariff of 2.5 percent. The 2008 Act extended until 2010 an additional duty of US$ 0.54 per gallon (US$ 0.1427 per liter) for imported ethanol, with duty-free status for imports from designated Central American and Caribbean countries up to 7 percent of the U.S. ethanol market as discussed next. [11].

The Caribbean region emerged as an important ethanol producer and trader, mostly oriented toward exports to the U.S.. Under the Caribbean Basin Economic Recovery Act (CBERA) amended in 1989, countries in Central America and the Caribbean are premitted to export ethanol from regional feedstocks into the U.S. duty free. Currently, CBERA countries import hydrous ethanol, mainly from Europe and Brazil, in order to process it and export dehydrated ethanol to the U.S. market [12].

CBERA countries face a U.S. tariff rate quota (TRQ) for ethanol derived from non-regional feedstocks. The TRQ is equal to 7% of the U.S. annual ethanol consumption (Table 3). This requirement was imposed to prevent pass-through operations, such as from Brazilian ethanol and European wine alcohol. According to the CAFTA-DR Facts (2007), the U.S. imported 640 million liters of ethanol from CBERA members in 2006, about 63.1% of the allowable quota. In that year, Costa Rica, El Salvador, Jamaica and Trinidad and Tobago were the only countries that exported ethanol under the Caribbean Basin Initiative (CBI) quota. Jamaica exported 259 million liters, Costa Rica 136 million liters, El Salvador 145.7 million liters and Trinidad and Tobago 99.3 million liters.

In Europe, ethanol production and trade have increased substantially since 2003, driven mainly by the rise of international oil prices and the growing concern about global warming. In 2006, more than 1.7 billion liters of ethanol were produced from wheat and sugar beets, representing 20% of total biofuels produced in Europe (Table 4).

EU-27 countries share common import duties for denatured and undenatured ethanol: US$ 0.152 and US$ 0.286 per liter, respectively [13]. According to Zarrilli (2006), 25% of the EU's ethanol imports from 2002 to 2004 were from Brazil. The remaining 75% of imports entered under preferential trade agreements[1], such as the Generalized System of Preferences (GSP), the Cotonou Agreement (ACP countries), the Everything but Arms (EBA) initiative, among others [14].

Mexico produces an average of 45 million liters of ethanol per year, primarily to supply the alcoholic beverage, chemical and pharmaceutical domestic industries. Ethanol fuel production in Mexico is marginal. Currently, Mexican ethanol consumption is 164 million liters and the 119 million liter shortfall is imported mainly from the U.S., Brazil and Cuba.

In order to promote production and use of biofuels, the Mexican government proposed a policy in 2006 to create a trust fund allowing renewable energy sources to supply 8% of national electricity generation needs by 2012. This trust fund would cover differentials between the costs of production and the market prices for biofuels. In 2007, the government passed the Biofuels Promotion and Development law, which aims to develop a legal framework to regulate the biofuel industry and the use of biofuels by implementing a required percentage blend of biofuels into fossil fuels.

Mexico has a mixed import tariff for denatured and undenatured ethanol equivalent to 10% *ad valorem*, plus US$ 0.36 per liter of imported ethanol [15]. Ethanol imports from Brazil increased until 2005 and then declined in 2006. Mexico imports primarily undenatured ethanol to supply the alcoholic beverage and chemical industries.

Japan's capacity to become a large-scale crop ethanol producer is constrained by high opportunity costs of farmland and high farm prices for potential feedstocks [5]. Synthetic and fermented ethanol is produced in modest amounts to supply the domestic industrial alcohol market. The average Japanese output of synthetic ethanol, derived from ethylene, and fermented

[1] According to Zarrilli (2006), 61% of ethanol imports are duty-free and 9% have reduced import duties. Most the agreements are designed to enhance markets in less developed countries.

ethanol is 100 million liters and 15 million liters per year, respectively. Average domestic demand is around 400 million liters per year, which makes Japan one of the largest net importers of ethanol in the world [16]. For the last 10 years, Japan has consistently imported, on average, 442 million liters annually, 35.3% of which is imported from Brazil.

Japan has only recently developed policies promoting the use of ethanol fuel in the transportation sector. In 2003, Japan introduced a voluntary blending ratio of 3% ethanol (E3) into gasoline as an attempt to overcome high oil and ethylene prices and to meet its Kyoto treaty commitment of reducing greenhouse gas emissions by 6% by 2010. Despite the government attempts to stimulate the use of ethanol, consumption has remained small, partially because of a lack of fiscal incentives [17].

The Japanese Ministry of Environment also proposed a long-term target of a 10% biofuels blend in total fuel consumption by 2030. In order to meet this target, the ministry proposed the use of ethanol in the transportation sector, as E3 or ETBE. The implementation of this proposal would require a supply of 1.8 billion liters per year of fuel ethanol.

In 2005, Japan announced a gradual reduction in import tariffs for fuel ethanol to expand domestic availability (Table 5). WTO members were subject to 27.2% import duty on undenatured and denatured ethanol and this was lowered to 20.3% in 2007.

Nigeria's economic growth is mainly dependent upon on the oil sector. The government is implementing an ethanol fuel program as part of a policy to reduce imports of refined gasoline, conserve oil stocks, and enhance the agricultural sector [18]. The Nigerian government set a biofuel target to incorporate a blending ratio of 10% ethanol in gasoline (E10). The estimated gasoline consumption in Nigeria is 30 million liters per day, consequently the use of E10 would require 3 million liters of ethanol per day [16]. In addition to mandatory ethanol consumption, the government plans to develop local ethanol production. Nigeria has favorable climate conditions and abundant arable land and feedstocks for ethanol production, such as cassava, sugarcane, and corn. Nigeria produced 30 million liters of ethanol in 2005.

2.1.2. Ethanol Industrial Market

Ethanol is also used for non-fuel purposes, as a base for alcoholic beverage, solvents and other industrial applications. The global demand for industrial ethanol has changed in the last 10 years as chlorofluorocarbons (CFC), a chlorinated solvent, was heavily restricted in developed countries over environmental concerns regarding depletion to the ozone layer and replaced with ethanol and other oxygenated solvents [16]. The world market for industrial ethanol was estimated in 4.4 billion liters with only little growth experienced in recent years. The major markets for industrial ethanol are the United States, West Europe and Asia. The U.S. industrial ethanol market is estimated at 1 billion liters per year. Synthetic ethanol, both domestic and imported, corresponds to 22.2% of total industrial ethanol demand, while 77.8% is produced through fermentation process. The European demand for industrial ethanol has steadily constant between 0.9 and 1 billion liters. The highest rate of growth in the use of industrial ethanol was seen in the Asia/ Pacific region. The demand for industrial ethanol increased from 300 million liters in mid-1990s to over 1 billion liters in 2006. Overall, the demand for industrial ethanol is expected to rises as the Gross Domestic Product (GDP) of industrialized countries increases [16].

2.2. Import Demand Models

This section presents our model of import demand for ethanol. An appropriate import demand model depends primarily on the type of commodity under investigation Goldstein and Khan (1985). For instance, homogenous versus differentiated commodities would require different models. The assumption underlying the perfect substitutes model is the presence of homogenous goods traded under international commodity markets at a common price, where demand and supply interactions do not rely exclusively on price differentials between imported and domestic goods. The general structure of the perfect substitutes model is illustrated by equation (2.1). Quantity of imports (M_i) is a function of real domestic income (Y_i) and the price of the traded commodity (P_i).

$M_i = f(Y_i, P_i)$ equation (2.1)

The ability of a country to influence the world price of a homogenous commodity will be related to its international share of import demand, as well as its own price elasticity of demand and supply for that commodity [19] [20] [21].

The linear econometric representation of the import demand equation (2.1) is expressed by equation (2.2). The parameters α_1 and α_2 are the partial derivatives of $\partial M_i / \partial P_i$ and $\partial M_i / \partial Y_i$, respectively. Parameters α_1 and α_2 represent the responsiveness of the volume of imports to price and income changes. The random error (ε_i) is the stochastic disturbance term assumed to be independently and normally distributed with mean zero and constant variance.

$M_i = \alpha_0 + \alpha_1 P_i + \alpha_2 Y_i + \varepsilon_i$ equation (2.2)

Price and income elasticities of imports are useful tools to quantify the effects of international trade policies on economic welfare. For a commodity like ethanol the elasticities can be derived from the perfect substitutes model, expressed in equation (2.2).

The import price elasticity, represented by parameter α_1, is expected to have a negative sign, that is, price and quantity should move in opposite directions. Alternatively, the sign for income elasticity of import demand, α_2, may range from negative to positive. When real income increases, the demand for imported goods may increase, remain constant, or decrease. The direction of income effects depends on whether imported goods are assumed to be normal or inferior.

Model misspecification may affect the outcome of the econometric analysis. Potential issues such as autocorrelation, trends or seasonality should be considered. A challenging issue in specifying import demand equations is choosing the functional form. The most common functional forms are linear and log-linear. However, there are no clear theoretical criteria to select one or the other [22].

Khan and Ross (1977) empirically tested the linear versus log-linear, and dynamic linear versus dynamic log-linear aggregated import equations using the Box-Cox (1964) analysis of transformation for trade data for the United States, Japan and Canada [23] [24]. The authors found that the linear and log-linear specifications had been widely used based on convenience. Their results indicated that the log-linear functional form (equation 2.3) is slightly better and more convenient than the linear form (equation 2.3), since price and income elasticities can be derived directly from the regression coefficients.

$$\log M_i = \alpha_0 + \alpha_1 \log P_i + \alpha_2 \log Y_i + \omega_i \qquad \text{equation (2.3)}$$

Another important issue in import demand modeling is the occurrence of simultaneity between the quantity and price variables. The presence of simultaneity violates the assumption of zero correlation between the import demand model variables and the error term. Consequently, the estimates may become biased, inconsistent and less efficient. Simultaneity bias can be addressed by using a two-stage model or by introducing instrumental variables [19]. These issues are addressed below in the context of estimating our model.

3. Method and Data

3.1. Model

Separate import demand equations were estimated for the major import markets for Brazilian ethanol – the United States, the Caribbean region, the European region, Mexico, Japan and Nigeria. For each market, a perfect substitutes import demand model was specified, representing the relationships between the quantity of imported Brazilian ethanol on one hand and the import price of ethanol, the world price of crude oil, real Gross Domestic Product (GDP), real exchange rates, and applied import tariffs (equation 3.1). A time trend variable was incorporated on the right hand side of the equation to mitigate some of the potential problems associated with using time series data. The time trend variable is often used as a proxy for an omitted variable that affects the dependent variable and is highly correlated with time. For instance, in the estimation of import demand functions a trend variable may be included as a proxy for gradual changes in consumer preferences [25]. A lagged dependent variable may represent the dynamic structure of the data, for instance, in this quarterly analysis, current imports of Brazilian ethanol may have been influenced to a greater extent by the prices of preceding quarters than by current prices because of adjustment costs or time needed to process information [22].

The multiple regression model used to estimate the long-run import demand for each selected market is:

$$QMeth_{ti} = \beta_1 + \beta_2 Peth_{ti} + \beta_3 Poil_t + \beta_4 GDP_{ti} + \beta_5 ExRt_{ti} + \beta_6 Tariff_{ti} + \beta_7 \, Trend + \beta_8 \, LagQMeth_{(t-1)\,I} + \varepsilon_{ti} \qquad \text{equation (3.1)}$$

Where:

QMeth = Quantity of ethanol imported, in billion liters, in quarter *t* and country *i*

Peth= Import price of ethanol, in 2007 U.S. dollars per liter

Poil = World import crude oil price, in 2007 U.S. dollars per liter

GDP = Real Gross Domestic Product (GDP), in 2007 billion U.S. dollars

ExRt = Real exchange rates, 2007 = 100 U.S. (USD per foreign currency and then indexed by GDP deflator)

Tariff = Import tariff, in 2007 U.S. dollars per liter

Trend = linear time trend, where t = 1 is equivalent to 1st quarter of 1997

LagQMeth = Lagged quantity of ethanol imported, in billion liters

ε = Estimated residual

and

i = country

t = time (from the 1st quarter of 1997 through the 3rd quarter of 2007)[2]

The signs for β_2, β_5, and β_6 are expected to be negative, while the signs for β_3 and β_4 are expected to be positive. Importers tend to purchase less ethanol as the price of ethanol, exchange rates and import tariffs increase. Conversely, when real GDP and world oil prices increase, the import quantity would be expected to increase, assuming that ethanol is a normal good and a substitute for gasoline.

Equation 3.1 is the standard specification of the import demand model for this study. However, other explanatory variables were included in some of the models to accommodate the peculiarities of each region. For instance, Caribbean and Central American countries have a unique ethanol trade flow, due to their duty free status vis-à-vis the U.S. under the Caribbean Basin Initiative. Ethanol imports by Caribbean and Central American countries from Brazil are primarily destined to supply the U.S. market through re-exports. Therefore, the U.S. quantity of ethanol consumption was included in the Caribbean region equation. Further, Richman (2006)

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[2] Time length varies per country. The observations showing zero imports could not be transformed into log form, therefore those observations were dropped.

hypothesized that the Renewable Fuels Standard (RFS), a regulation under the Energy Policy Act of 2005 requiring a minimum volume of renewable fuel to be blended into fossil fuels sold in the U.S., would reshape the demand for ethanol in the U.S. [26]. In order to test this hypothesis, a variable expressing the required renewable fuel blend was incorporated into the U.S. equation.

3.2. Data

The data used to estimate the import demand for Brazilian ethanol across countries were seasonally adjusted quarterly[3] observations from 1997 to 2007.[4] The importing countries taken into account were: the United States, Japan, Mexico, Nigeria, the Caribbean Basin Initiative countries (El Salvador, Jamaica and Costa Rica), and the Netherlands and Sweden, representing the major importers in Europe.

Values and quantities of Brazilian ethanol imported by each country were obtained from the Global Trade Atlas and the Brazilian Ministry of Development, Industry and Foreign Trade databases[5]. Unit prices were expressed in current U.S. dollars and ethanol quantities in billions of liters. These values were converted to 2007 U.S. dollars. The standard international commodity classification selected in this study was HS 2207:undenatured ethyl alcohol >=80% by volume alcohol strength and denatured ethyl alcohol other spirits of any strength. Although our data mix undenatured with denatured ethanol as well as different end-use markets, our choice to use ethanol at the 4-digit HS was based on the complexity of the international ethanol market. Brazil exports denatured ethanol mainly to attend fuel ethanol demand. Brazil also exports undenatured ethanol for both industrial and fuel purposes. In the case of the Caribbean region, most of trade is

[3] The data used in this empirical analysis were quarterly because monthly ethanol imports from Brazil were highly irregular. Monthly data presented time lag issues.
[4] This means that major policy changes in the United States in December 2007 and June 2008 do not apply to the data in this study.
[5] Global Trade Atlas database: http://www.gtis.com/gta/; Brazilian Ministry of Development, Industry and Foreign Trade database: http://aliceweb.desenvolvimento.gov.br/

in undenatured ethanol, which is then denatured in order to meet the 'value-added' test required to enter into the United States duty-free. In the case of Europe, several Member States grant fuel-tax exemptions only to undenatured ethanol blended with gasoline. This article emphasizes the impacts of trade in fuel ethanol in the analysis because, according to the World Ethanol Outlook publication developed by L.O. Licht, the world market for industrial ethanol was estimated in 4.4 billion liters with only little growth in recent years, except by highly industrialized countries in the Asia/Pacific region where ethanol industrial demand grew from 300 million liters in the mid-1990s to around 1 billion liters in 2006. Therefore, it is expected that major variations in ethanol trade are driven by the boom in the global demand for fuel ethanol, especially in later years. Because trade in ethanol fuel is a recent phenomenon, the trade data on (denatured) ethanol fuel alone is insufficient. In the future, when more data is available, it would be ideal to separately analyze import demand for denatured and undenatured ethanol, since the demand for these different types of ethanol is likely to be driven by different factors.

Historical indicators of demand, such as real exchange rates and real Gross Domestic Product (GDP) values were collected from the U.S. Department of Agriculture (USDA) databases[6]. Historical Free On Board (F.O.B.) world crude oil prices, expressed in current dollars per liter, were obtained from the U.S. Department of Energy, Energy Information Administration (EIA) database[7]. These values were converted to 2007 U.S. dollars. The MFN *ad valorem* tariffs and specific duties were compiled from the World Trade Organization (WTO) International Trade and Tariff database[8]. The U.S. Renewable Fuel Standard and the U.S. ethanol consumption data were retrieved from the U.S. Environmental Protection Agency (EPA) and the

[6] U.S. Department of Agriculture database: http://www.ers.usda.gov/Data/Macroeconomics/
[7] Energy Information Administration database: http://www.eia.doe.gov/emeu/international/oilprice.html
[8] World Trade Organization Tariff database: http://www.wto.org/english/res_e/statis_e/statis_e.htm#tariff_data

U.S. Department of Energy, Energy Information Administration (EIA) databases[9], respectively. Data on sugarcane prices paid to producers in Brazil were obtained from the São Paulo State Agricultural Economics Institute[10] and from the Agrianual 2005 publication [27].

3.3. Estimation Issues

The models were subjected to a number of diagnostic tests to identify potential bias issues that could arise when analyzing time series and panel data. Particular attention was given to testing for serial correlation and heteroscedasticity in the errors, multicollinearity among explanatory variables, and endogeneity in the economic relationships.

In order to detect for serial correlation in the error distribution, the post-estimation Durbin-Watson, the Breusch-Godfrey LM and the Portmanteau tests were performed [28] [29] [30] [31] [32] [33]. In addition to these tests, the regression residuals were plotted against time and against model-predicted values. For the models using panel data the Wooldridge test and cluster analysis by country were applied [34]. The models were run with alternative functional forms to minimize heteroscedasticity and also to test for robustness. Further, the Prais-Winston estimators were used to estimate the magnitude of autocorrelation and re-weight the standard errors [35].

Also, for each country/region, a pairwise correlation test was used to examine the patterns of correlation among explanatory variables. Multicollinearity may cause overestimation of the standard errors of the regression coefficients and lower the t-statistics. Moreover, when two variables are closely multicollinear, one may capture part of the effect of the other [25].

Lastly, a simultaneity problem may arise when estimating import demand functions. The assumption of zero-conditional-mean ($Cov(X, u) \neq 0$) is violated when a regressor variable is

[9] U.S. Environmental Protection Agency database: http://www.epa.gov/OMS/renewablefuels/; Energy Information Administration (EIA) database: http://www.eia.doe.gov/emeu/mer/renew.html
[10] São Paulo State Agricultural Economics Institute database: http://www.iea.sp.gov.br/out/banco/menu.php

correlated with the error term. This condition may lead to ordinary least squares bias. The Durbin-Wu-Hausman test for endogeneity was performed to identify whether the import price of ethanol and import quantity were simultaneously determined [36]. The results for each country/region did not indicate simultaneity problems. The price of sugarcane was chosen as an instrument for the import ethanol price, as it satisfies two essential conditions. First, the price of sugarcane is highly correlated with the import price, representing 56 to 60% of ethanol production costs [9]. Second, sugarcane is an input factor on the supply side, thus it is not related to the import demand error term.

4. Results

For each market, a set of import demand equations was estimated using OLS and alternative model specifications and functional forms. Overall, the empirical evidence suggests that the models were not affected by endogeneity of the ethanol price in the import quantity equation. Further, the linear model fit the data than the double-log, log-linear, or linear-log forms.

Table 6 summarizes the parameter estimates of the final equations, their respective standard errors, the coefficients of determination (R^2), and the overall p-values. The expected sign for each parameter is shown at the top of the table.

The model for the United States explained 78% of the variation in quantity of ethanol imported from Brazil. Only the Renewable Fuel Standard requirement (RFS) coefficient was statistically significant. This result is probably explained by the fact that the Renewable Fuel Standard requirements, implemented in 2005, increased the US demand for ethanol fuel considerably. However, in the short run, domestic production was constrained by the limited number of ethanol plants, requiring large amounts of ethanol imports to meet domestic demand.

For the United States, estimated ethanol imports are price (-0.76) (p-value = 0.504) and income inelastic (24.39) (p-value = 0.252). Furthermore, neither of these coefficients is statistically different from zero at even a 10% level.

Diagnostic tests were performed to detect serial correlation and endogeneity. Although the Prais-Winston model specification and the inclusion of the linear trend variable were chosen to correct for serial correlation, the Durbin-Watson test and the residual plots still indicated signs of first-order positive autocorrelation. The Durbin-Wu-Hausman test for endogeneity generated a *p*-value equal to 0.7632 indicating that the OLS regression is consistent.

Costa Rica, El Salvador and Jamaica were grouped to perform a cross sectional time series analysis explaining the factors influencing the Caribbean import demand for Brazilian ethanol. Because most of the ethanol imported from Brazil is re-exported to the U.S. market, U.S. ethanol consumption was included as an explanatory variable. The model was estimated using ordinary least squares (OLS) estimation with random effects (RE). Cluster analysis was applied to the Caribbean equation. The coefficients for import price of ethanol, real GDP, tariff, real exchange rate and the U.S. ethanol consumption were found to be statistically significant (p-value < 0.05). The coefficients for the import ethanol price and U.S. ethanol consumption have the expected signs. The signs of the coefficients for real GDP, tariff and exchange rates, however, did not conform to expectations.

For the Caribbean region, import volume was found to be price elastic (with an elasticity of -1.66). Contrary to expectations, income elasticity was negative (-3.67). The negative income elasticity may imply that as real income grows, the Caribbean region will import less Brazilian ethanol, indicating that the ethanol re-export business is smaller with higher Caribbean incomes. This conclusion seems plausible since most of ethanol imports are destined for the U.S. market, rather than for domestic consumption. The Wooldridge test (p-value = 0.1877) and the Durbin-Wu-Hausman test (p-value = 0.5378) indicated no presence of serial correlation or endogeneity, respectively.

The Netherlands and Sweden were grouped to perform a cross sectional time-series analysis explaining factors affecting the European import demand for Brazilian ethanol. According to the Global Trade Atlas (2007) data, on average, these countries accounted for 72% of total European imports of Brazilian ethanol from 1997 to 2006 [6].

The import demand function was estimated using ordinary least squares (OLS) estimation with random effects (RE). Cluster analysis was applied to the European equation.
The equation explained 65% of the variation in the dependent variable. The parameters for the price of oil, real GDP, applied tariffs and exchange rates were statistically significant (p-value < 0.05). Except for the applied tariff, the coefficients have the expected signs.

As the import price of ethanol was not statistically significant, quantity of imports by the European region was found to be price inelastic (-0.21). This was expected since the Netherlands and Sweden have set biofuels consumption targets of 2% of total fuel usage. However, these countries have little ethanol production due to the competition between food and energy crops for limited arable land in that part of the world [9].

The estimated income elasticity was positive, however the magnitude is quite high (14.05). The elasticity seems overestimated since there is no theoretical evidence supporting such responsiveness of ethanol importers to changes in real income. The model was tested for serial correlation and simultaneity. The results did not imply serial correlation and the Durbin-Wu-Hausman test (p-value = 0.7765) indicated that the OLS regression is consistent.

Before modeling the import demand for Mexico, a pairwise correlation test was performed to identify any strong correlation among the independent variables. The test indicated that the import price of ethanol and the tariff variable were 99% correlated and real GDP and world price of oil were 94% correlated. Therefore, in order to avoid multicollinearity issues, only the import price of ethanol, real GDP and real exchange rates were included in the regression. According to Blalock (1963), high correlation between explanatory variables may generate sampling error, which may make it difficult to assess their relative importance in determining the dependent variable [37].

The equation explained 51% of the variation in the dependent variable. The coefficients for import price of ethanol and Mexico's real exchange rate were statistically significant (p-value < 0.05) and had the expected signs. Real income was not significant and had the incorrect sign. This result implies that Mexican ethanol trade is related to expenditure rather than to income. Magee (1975) commented that [38]:

> "*If devaluation led a country to eliminate all expenditure in one period and use its entire income to accumulate cash through exports, imports would fall to zero. A model with imports related to expenditure would predict the drop in imports, while a model with imports related to income would not.*"

The estimated price elasticity of demand was -2.08. This indicates that Mexican importers are quite responsive to price changes; a 1% increase in price would lead to a 2% reduction in ethanol imports. In order to test for serial correlation of the residuals the Portmanteau test for white noise was applied. The test was not significant (p-value = 0.0982), thus failing to reject the null hypothesis of no white noise problem. Also, the residuals were plotted against time and the fitted values suggested no serial correlation. The Durbin-Wu-Hausman test for endogeneity did not indicate simultaneity bias from the OLS estimation.

The model for Japan explained 77% of the variation in the quantity of ethanol imports from Brazil. Only the parameters for the import price and the tariff were statistically significant (p-value < 0.05), but the sign for the tariff was different from expected. The price elasticity derived from the model was -1.44, indicating that the Japanese import demand for Brazilian ethanol is price elastic. This response to price changes was expected since Japan does not have mandatory policies for biofuel use. Most of the imported ethanol is directed to the chemical and beverage industry. Moreover, Japan produces synthetic ethanol from ethylene which can be substituted for imported ethanol.

The Breusch-Godfrey LM test and the residual plots indicated no presence of serial correlation on the error term. Lastly, The Durbin-Wu-Hausman test for endogeneity (p-value = 0.1103) did not indicate simultaneity bias from the OLS estimation.

Computation of pairwise correlation coefficients indicated that Nigeria's import tariff and import price of ethanol variables were 99.9% correlated and that the world oil price and real GDP were 92% correlated. In fact, these high correlation coefficients were expected given that import duties did not vary during the period under investigation, and Nigeria has a petroleum-based economy, which accounts for 20% of its GDP [39]. Therefore, the tariff and world oil price variables were removed from the model to avoid multicollinearity problems.

In the final equation for Nigeria, the R^2 was 0.54 and the import price of ethanol was the only significant variable explaining Nigerian's ethanol imports. The estimated price elasticity of demand is elastic and has the expected sign (-1.38). Income elasticity is also elastic (1.35), however not statistically different from zero. The Portmanteau test for white noise indicated no presence of serial correlation and the Durbin-Wu-Hausman failed to reject the null hypothesis of no endogeneity between quantity of imports and ethanol price. The residual plots suggested the existence of a heteroscedasticity problem.

5. Discussion

According to our results for the United States, the introduction of the Renewable Fuels Standard (RFS) sharply changed the nature of demand for imported ethanol. In fact, the implementation of the RFS in 2005 has vastly expanded ethanol demand in the U.S. Because this demand was related to mandated U.S. domestic usage (i.e., the RFS), it is price inelastic with regard to ethanol and crude oil. Moreover, applied import tariffs over the time period examined have not changed substantially, and this limited our ability to measure their impacts on trade.

Caribbean import demand is driven mainly by the U.S. ethanol demand. Caribbean countries take advantage of a regional trade agreement (the Caribbean Basin Initiative) by importing low cost ethanol from Brazil and reselling it to the U.S. duty-free. Because import demand is price elastic, ethanol imports from Brazil fluctuate depending on price changes. The model results gave unexpected signs for real GDP, exchange rates and tariffs coefficients, making it difficult to interpret their significance. Perhaps, a more sophisticated model may capture the true impact of these factors on imports into this region.

The results for the European region suggested that import demand is highly responsive to changes in income and that the price of ethanol does not have a significant influence on European imports. Rather, increases in world oil prices encourage ethanol imports as a substitution effect. This result was expected since the European countries are crude oil and diesel net-importers and have encouraged the use of ethanol through fuel-tax exemptions. Moreover, ethanol importers seem to have benefited from the devaluation of the U.S. dollar relative to the Euro (€).

The results for Mexico indicated that import demand for ethanol is more closely related to expenditure rather than to income, since only the price of ethanol and the exchange rate variables were statistically significant. Import demand was found to be price elastic (-2.08). The effects of import tariffs could not be captured by the model because applied tariffs on ethanol did not change over the time period examined.

Lastly, for Japan and Nigeria the import price of ethanol was the most significant variable explaining the demand for Brazilian ethanol. This indicates that these countries are able to substitute other energy sources, such as fossil fuels, depending on their relative prices. Based on the results for the U.S. and the EU, if mandatory blending is implemented in these countries, their import demand may also become less price elastic.

Overall, the results suggested that countries that have adopted policies promoting the use of biofuels tend to have a less elastic import demand for ethanol. Further, the regression results suggest that income growth has little impact on import demand for ethanol.

The models did not provide useful results regarding the effect of import tariffs on ethanol imports. Conceptually, as the market evolves towards trade liberalization, new market opportunities should arise for less developed countries interested in producing ethanol. Further, Brazil should be able to capture a larger share of the market.

As noted above, the initial objective of the study was to explain factors affecting the market for fuel ethanol only. However, data on ethanol fuel are limited and sparse. Over the sample period, ethanol for fuel represented about 20% of the total ethanol trade, while industrial ethanol represents the remaining 80%. Therefore, the data used in this analysis aggregated trade volumes for fuel and industrial ethanol. Possibly, other variables beyond the ones employed in the analysis may help to further explain import demand, such as prices of crops used to produce ethanol (for instance, sugar and corn) and factors affecting the industrial ethanol sector. As the market for ethanol fuel evolves on a global scale and more data become available, it will be possible to better distinguish the factors influencing imports for each industry.

Further studies should include the emerging markets for ethanol fuel, such as India and China. Rapid economic growth in these countries is driving up their energy demand, and ethanol is certain to play a role in their energy mix. In recent years, India became the third-largest net oil importer in the world, after the U.S. and China. The transportation sector is expanding rapidly as vehicle stocks increase as a result of rising household income [40].

India is introducing biofuels into its market to overcome fossil fuels dependency. In the Union Budget of 2002-2003 the government attempted to encourage ethanol blended fuel by introducing a mandatory blending of 5% ethanol in gasoline in 9 states[11] and 4 union territories[12]. Moreover, the government set an excise duty concession of Rs 0.75 per liter of gasoline-ethanol blend. In 2006, the mandatory blending of 5% ethanol was extended nationwide, although subject to ethanol supply availability. The government set a target to increase the ethanol share in gasoline to 10% by 2012 [40].

To support the domestic sugar industry, the Indian government supports the sugar price at Rs 15 (US$ 0.33) for every liter of ethanol produced [9]. India has a large sugarcane industry and surplus sugar and molasses are being allocated towards ethanol production. India's average annual ethanol output varies from 1.2 to 1.8 billion liters, mostly oriented for potable and industrial purposes [41].

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[11] The states include: Andhra Pradesh, Goa, Gujarat, Haryana, Karnataka, Maharashtra, Punjab, Tamil Nadu and Uttar Pradesh.

[12] Union Territories: Chandigarh, Dadra & Nagar Haveli, Daman & Diu and Pondicherry.

The use of biofuels in China is still relatively small. Although uncertain due to concerns regarding food-versus-energy competition, demand for ethanol fuel is expected to grow since the government developed an ambitious program to stimulate its consumption [9]. The Chinese vehicle market is increasing because of rapid economic development. Consequently, demand for energy has increased and China became one of the largest crude oil net importers in the world. Biofuels are seen as an alternative to diversify transportation fuels [42].

Lastly, partial equilibrium models are often vulnerable to the criticism that they fail to capture the economy-wide effects of changes in equilibrium prices and quantities. Although the import demand model used in this study to determine the factors affecting ethanol trade is simple, some insights on ethanol trade were uncovered, thus helping in the formulation of more complex and dynamic models.

6. Conclusions

The global ethanol market has expanded significantly in recent years as a result of high crude oil prices, instability in the Middle East, environmental concerns regarding carbon emissions and policies promoting the use of biofuels. Brazil has emerged as the world's largest ethanol exporter. As the international ethanol fuel market evolves, it is important to understand the characteristics of the international market for this biofuel. In order to better understand the international trade in biofuels, this research attempted to outline factors affecting the import demand for ethanol fuel from Brazil. Several import regions - the United States, the Caribbean region, the European region, Mexico, Japan and Nigeria - were selected based on historical import volumes and diversity of internal domestic characteristics that might drive import demand. Indeed, we found differences in the factors driving import demand, and in the income and price elasticities of import demand.

The factors affecting the volume of imports vary across countries. Markets adopting mandatory blends of renewable fuels tend to have a less price elastic import demand. Ethanol imports were found to be price elastic in the Caribbean region (-1.66), Mexico (-2.08), Japan (-1.44) and Nigeria (-1.38), while import demand was price inelastic in the U.S. (-0.76) and the European region (-0.21). Based on these results, ethanol demand is expected to be inelastic over price ranges where the mandates apply and almost perfectly elastic at high oil (and ethanol) prices. Another apparent difference among countries is the lack of an effect of import tariffs in some regions (i.e., the United States, Mexico and Nigeria) but not in others (i.e. Caribbean, Europe and Japan). These results must be interpreted with caution, however, because tariffs in the former group did not vary during the study period. Therefore, for those countries where tariffs varied during the study period, there were significant effects on ethanol imports; however, the positive signs of these coefficients preclude any simple conclusions regarding these effects.

Clearly, further research should be conducted on this topic. Time series data on ethanol fuel are limited, making the interpretation of any econometric estimation difficult. Moreover, a more dynamic model structure should be developed in order to capture the economy-wide effects of demand changes, due to seasonality, oil price shocks, ethanol crop failures, policy reforms, to name a few. This study, although simple, has provided some insights as to the relative importance of income, prices and energy policies in driving ethanol imports, and by extension other biofuels. It should also prove useful as a benchmark for future studies on this topic which will benefit from more data (as the market unfolds) and possibly more sophisticated analytical models.

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Table 1 – Major Importers of Brazilian Ethanol

	Imports from Brazil (million liters)			% Share		
Region	**2005***	**2006***	**2007***	**2005**	**2006**	**2007**
World	2,167.32	2,853.65	3,061.69	100.00	100.00	100.00
United States	221.31	1,599.12	843.41	10.21	56.04	27.55
Netherlands	205.95	252.10	585.72	9.50	8.83	19.13
Japan	260.08	164.13	315.26	12.00	5.75	10.30
Jamaica	109.22	72.33	287.54	5.04	2.53	9.39
El Salvador	105.74	160.14	224.40	4.88	5.61	7.33
Costa Rica	105.39	70.03	149.10	4.86	2.45	4.87
Nigeria	112.04	22.28	114.89	5.17	0.78	3.75
Sweden	219.39	167.44	96.11	10.12	5.87	3.14
Mexico	59.81	38.13	43.63	2.76	1.34	1.42
India	410.76	10.07	0.00	18.95	0.35	0.00

*Calendar year
Source: Global Trade Atlas (2007).

Table 2 – Renewable Fuel Standard Schedule under the U.S. Energy Independence and Security Act of 2007

Calendar Year	Applicable volume of renewable fuel to be blended with gasoline (billion liters)
2008	34.1
2009	42
2010	49
2011	52.7
2012	57.5
2013	62.6
2014	68.6
2015	77.6
2016	84.3
2017	90.8
2018	98.5
2019	106.1
2020	113.6
2021	125
2022	136.4

Source: Energy Policy Act of 2005. Public Law 109-58, Aug. 8, 2005; Sissine, (2007); and American Coalition for Ethanol, http://www.ethanol.org/index.php?id=78&parentid=26.

Table 3 – U.S. Caribbean Basin Tariff Rate Quotas – TRQ (million liters)

Year	TRQ	Exports to the U.S.	Fill rate (%)
2000	349	227	64.9
2001	427	164	38.4
2002	455	172	37.8
2003	502	231	46
2004	707	265	37.4
2005	910	391	43
2006	1014	640	63.1

Source: Tokgoz and Elobei, 2006; CAFTA-DR Facts, 2007.

Table 4 – EU-27 Ethanol Market (million liters)

	2006	**2007**	**2008** (estimated)
Production	1707.55	2927.99	4649.59
Consumption	1569.36	2473.76	5406.66
Imports*	578.34	831.60	1159.20
Exports*	127.48	233.48	271.66

*Trade outside European community
Source: Eurostat, 2007

Table 5 – Japanese Import Tariff Reduction Schedule

Year	Import Duty (%)
2006	23.8
2007	20.3
2008	16.9
2009	13.4
2010	10

Source: World Ethanol Markets (2006)

Table 6 – Models and Coefficients to Estimate Import Demand for Brazilian Ethanol

Country/Region (expected sign)	Model	Constant	Peth (-)	Poil (+)	GDP (+)	Tariff (-)	ExRt (-)	RFS (+)	USEthD (+)	R^2	P ›| F |
United States	Linear Prais-Winston	-2.36 (1.89)	-0.19 (0.29)	-0.20 (0.38)	0.0002 (0.0001)	3.29 (2.54)	n/a	0.02* (0.009)	n/a	0.78	0.000
Caribbean	Linear Prais-Winston	0.05* (0.018)	-0.10* (0.03)	0.02 (0.04)	-0.004* (0.0009)	0.24* (0.09)	0.00005* (0.00002)	n/a	0.02* (0.003)	0.63	0.000
European	Linear Cluster analysis	-0.59* (0.16)	-0.02 (0.04)	0.09* (0.04)	0.001* (0.0003)	0.51* (0.06)	0.01* (0.006)	n/a	n/a	0.65	n/a
Mexico	Linear Prais-Winston	0.33 (0.3)	-0.15* (0.05)	n/a	-0.0003 (0.0004)	n/a	-0.10* (0.005)	n/a	n/a	0.51	0.010
Japan	Linear Prais-Winston	-0.76 (0.41)	-0.18* (0.06)	-0.18 (0.09)	0.00009 (0.00008)	0.47* (0.13)	0.0006 (0.0004)	n/a	n/a	0.77	0.000
Nigeria	Linear Prais-Winston	0.003 (0.05)	-0.06* (0.03)	n/a	0.0003 (0.001)	n/a	n/a	n/a	n/a	0.54	0.009

*coefficients have significant t-values
Standard Errors are in parenthesis
Peth = Import price of ethanol, in 2007 U.S. dollars per liter
Poil = World import crude oil price, in 2007 U.S. dollars per liter
GDP = Real Gross Domestic Product (GDP), in 2007 billion U.S. dollars
Tariff = Import tariff effects, in 2007 U.S. dollars per liter
ExRt = Real exchange rates, 2007 = 100 U.S. (USD per foreign currency and then indexed by GDP deflator)
RFS = Ethanol required under the Renewable Fuel Standard, in billion liters
USEthD = U.S. ethanol demand, in billion liters
Trend = linear time trend, where t = 1 is equivalent to 2nd quarter of 1997