Does the US have Market Power in Importing Ethanol from Brazil?

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1. Introduction

The Renewable Fuels Standards (RFS2) as enacted under the Energy Independence and Security Act 2007 (EISA) consists of two parts: a renewable fuel mandate and an advanced biofuel mandate. The conventional corn-based ethanol produced in the US only fulfills the requirements of the renewable mandate. The advanced mandate requires only those biofuels which reduce 50 percent or more of greenhouse gases (GHGs) (OECD/FAO, 2012). The advanced mandate increases at an increasing rate in coming years. In 2013, it required 2.75 billion gallons (10.41 billion liters) of advanced biofuels to fill this requirement which is scheduled to increase to 21 billion gallons (79.49 billion liters) by 2022 (EPA, 2010). Moreover, its share in the total mandate is also increasing. By 2022, the advanced biofuels portion is expected to be about 58 percent of the total RFS2 mandate.

Progress in the production of advanced biofuels in the US has not been as envisaged. The mandate for biomass-based diesel for 2012 was one billion gallons (3.78 billion liters) with actual production estimated at 969 million gallons (3.66 billion liters) (EIA, 2013). The mandate for cellulosic ethanol in 2012 was 500 million gallons (1.89 billion liters); however due to inadequate production, the US Environmental Protection Agency (EPA) revised the target to 10.45 million gallons (39.55 million liters). Even this target was not achieved as the US Energy Information Agency (EIA, 2012) estimated production of cellulosic ethanol for 2012 was 0.5 million gallons (1.89 million liters) only. Given the currently limited production of cellulosic ethanol, it is unlikely that the 16 billion gallons (60.56 billion liters) of cellulosic ethanol targeted to advanced biofuels by 2022 will be fulfilled unless the EPA revises its targets for the coming years.

Lowering the target amount of advanced biofuels required does not seem viable for the EPA, given the high proportion of the overall RFS2 target it represents. Since corn-based ethanol is explicitly prohibited from being considered as an advanced biofuel (EIA, 2012), two options seem likely. First, increase the quantities of sugarcane-based ethanol through imports, a classified advanced biofuel (EIA, 2012). Second option would be to increase the production of biodiesel in excess of its own mandate and use that excess to make up for the lack of other advanced biofuels such as cellulosic ethanol. Given the current economics and the state of biodiesel production in the US, import of sugarcane ethanol produced in Brazil is favored even with a $1/gallon tax credit for biodiesel (Irwin and Good, 2013). This is further reinforced by the fact that blenders already import ethanol from Brazil.[1, 2]

The strategic position of the US in importing ethanol from Brazil remains, to the authors' knowledge, unexplored. As shown by Helpman and Krugman (1989), trade policy instruments such as a tariff, a subsidy, or a quota may improve or worsen the welfare of trading partners depending on the structure of the international market in question. For example, when a country is a dominant importer and its importing firms are too small to exercise buyer power, the country can behave as a monopsonistic firm and buy the imported goods more cheaply by restricting imports with an optimal tariff (Vousden, 1990). Alternatively, if importers do have buyer power

[1] The assumption here is that the 'blend wall', which is a technical constraint in ethanol blending that does not allow blenders to blend more than 10 percent of the total gasoline volume of ethanol, would be circumvented in coming years.

[2] Realizing the strategic importance of Brazilian ethanol in fulfilling the advanced mandate, there have been calls to remove advanced biofuel mandate by the domestic ethanol industry, probably to evade competition from Brazilian ethanol (WSJ January 30, 2013). This is quite unlike in the past when domestic industries considered mandates as a policy instrument for protecting the US ethanol industry. This highlights the strategic importance of Brazilian ethanol for fulfilling RFS mandates.

then unrestricted imports will be the optimal trade policy. Despite the implication of market structure on trade policy, most of the past works with reference to US trade policy on ethanol imports have not considered US strategic position in international ethanol market[3].

Formal studies in the literature on the US–Brazil ethanol trade structure are sparse. To date this work has been focused on the US ethanol tax and tariff policies. Notable contributions include Elobeid and Tokoz (2008), de Gorter and Just (2008), de Gorter et al. (2009), Devadoss and Kuffel (2010), Yano et al. (2010), Lee and Sumner (2010), and Lasco and Khanna (2010). Studies on US market power in the international ethanol market are few if any and far between.

This paper is directed toward the initial steps to remedy this deficit. We adopt Baker and Breshnahan's (1988) and Goldberg and Knetter's (1999) methodology of estimating (inverse) residual demand elasticity to measure oligopoly power, but instead estimate the (inverse) residual supply to gauge the presence of oligopsony power. Unlike conventional supply elasticities of ethanol imports from Brazil such as those available from Elobeid and Tokoz (2008), de Gorter and Just (2008), and Lee and Sumner (2010) residual supply elasticities provide insight into market power. These insights are the result of including the strategic interdependence among import competing countries, including the US, Brazil, and other significant trade partners.

The next section provides some background information about Brazilian ethanol exports and a brief description of biofuels policies of major ethanol importing countries. Section 3 presents a theoretical base used to frame the empirical model, which is described in section 4. Section 5 details the data sources. Section 6 presents the results, and the final section summarizes and concludes with a trade policy implication of the results.

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[3] Devadoss and Kuffel, 2010, Lee and Sumner, 2010, and Gorter et al. 2009 are some notable examples. Lasco and Khanna (2010), however, include the US market power scenario in analyzing US–Brazil ethanol trade.

The Brazilian fuel ethanol trade

The US and Brazil are major producers, consumers, and traders of fuel ethanol accounting for 87 percent of the world's production in 2011 (ISO, 2012). The US leads Brazil in the production and export of this fuel. Brazilian ethanol is primarily distilled from sugarcane and is regarded as environmentally friendly compared to the primarily corn based US product. Brazilian ethanol exports increased sharply in 2001 and peaked near 1.35 billion gallons (5.11 billion liters) in 2008 (ISO, 2012). Exports then dropped during the 2009-2011 period due to a smaller sugarcane crop in Brazil, but recovered in 2012, reaching 818 million gallons (about 3.1 billion liters) (UNICA, 2013).

The US is the largest importer of Brazilian ethanol, which accounted for 66 percent of total exports in 2012 and 28 percent of the total between 2001 and 2011 (MDICE, 2013). This relationship is likely to continue given ever increasing share of advanced mandates in the US (ISO, 2012).

As the third largest producer and consumer of ethanol in the world, the European Union (EU) plays a key role in global ethanol trade (ISO, 2012). The EU began to increase ethanol consumption during the mid-2000s as member countries instituted blending mandates, similar to the US (ISO, 2012). The EU's share of Brazil's ethanol exports between 2001and 2012 was about 20 percent with the Netherlands accounting for nearly 100 percent of the EU imports in 2012 (MDICE, 2013). The Renewable Energy Directive (RED) 2009, a part of the EU Energy and Climate Change Package, mandates member countries to obtain 10 percent of their transportation fuel from renewable sources (ISO, 2012). Additionally, the sustainability criterion in RED requires the use of biofuels that reduce at least 50 percent of GHG compared to fossil fuels starting in 2017.

Other major ethanol importers include the Caribbean Basin Initiative (CBI) countries (mainly Jamaica, El Salvador, and Costa Rica), Japan, South Korea, Nigeria, Mexico, and India. These countries along with the US and the EU accounted for 95 percent of Brazilian ethanol exports in 2012 (MDICE, 2013).

2. Theoretical framework

As mentioned earlier, the Goldberg and Knetter's (1999) framework is used to estimate US market power. This methodology is modified to estimate market power exerted by an importing country (buyer) on the exporting country (seller). In the original Goldberg and Knetter's (1999) work, market power is captured by the estimation of (inverse) residual demand elasticity. In this work, the (inverse) residual supply elasticity is estimated as a measure of importer (buyer) power. An exporting country's residual demand for a specific product is the difference between total demand by all importers and export supply by all rival exporting countries. Alternatively, an importing country's residual supply for a product is the difference between the total supply by all exporting countries minus the import demand by all rival importing countries. In the context of estimating buyer power of US importers in the sugarcane ethanol market, residual supply is the difference between Brazilian sugarcane ethanol supply and the demand by all countries that import Brazilian ethanol other than the US.

Conceptually the residual supply schedule the US importers face, is a function of changes in excess supply of ethanol from Brazil and the demand from importers in other competing countries. If the residual supply schedule is horizontal, i.e. a perfectly competitive market, the price of the Brazilian ethanol is completely determined by the other importers' demand. The US ethanol importers would not be able to induce any price changes based on the amount they import. Conversely, an upward sloping residual supply schedule faced by US importers would indicate some degree of market power as measured by the residual supply elasticity.[4] As the residual supply is influenced by Brazilian excess supply and competing demands from other countries, the variables representing exogenous shocks to Brazilian excess supply and other importing countries' import demands provide the necessary information to map out the residual supply schedule of US importers.

Brazilian domestic ethanol supply is derived from the profit-maximization problem of Brazilian ethanol producers represented in equation (1):

(1) $\pi_B = w^B Q_e^B + \boldsymbol{\omega Q_{bp}} - C_e(w_v, Q_e^B) - \boldsymbol{F_e}$

where π_B is profit from domestic ethanol production and sales, w^B and Q_e^B are the price and quantity of ethanol sold, $\boldsymbol{\omega}$ and $\boldsymbol{Q_{bp}}$ are the price and quantity vectors of ethanol by-products sold, C_e is the variable cost function. Costs are dependent on the price of variable inputs w_v, and the quantity of ethanol produced Q_e^B. Fixed costs are denoted by $\boldsymbol{F_e}$. Maximization of (1) with respect to Q_e^B yields the Brazilian domestic ethanol supply function (2):

(2) $Q_e^B = f(w^B, \boldsymbol{\omega}, w_v)$

The horizontal difference between the domestic supply of ethanol in Brazil and its domestic demand yields the country's excess ethanol supply for export (3):

(3) $Q_e^{ex} = f(w^B, \boldsymbol{W}, \boldsymbol{Z})$

where $\boldsymbol{W}$ is the vector of domestic ethanol supply shifters and $\boldsymbol{Z}$ is the vector of domestic demand shifters.

Brazilian ethanol is exported to *n* countries around the world, including the US. The import price facing US importers is denoted as $w^{US}$and the quantity of imports as Q_e^{US}. The other *n*-1

[4] Brazil being the largest exporter of sugarcane ethanol in the world, it is possible that it can exert considerable market power in the world ethanol market and more appropriate market structure in this context would be a bilateral oligopoly.

importing countries face import prices $w^2, \ldots, w^n$(in Brazilian currency, the real). The respective inverse supply functions are written as (4) and (5)[5].

(4) $w^{US} = S^{US}(Q_e^{US}, w^2 \ldots\ldots\ldots\ldots\ldots\ldots w^n, \boldsymbol{W}, \boldsymbol{Z})$

(5) $w^k = S^k(Q_e^k, w^j, w^{US}, \boldsymbol{W}, \boldsymbol{Z})$ where *j* = 1,…….., *n*-2 and $j \neq k$.

Individual importers in these countries are assumed to face the same prices, costs and similar industry wide technology so when they maximize their individual profits, the quantity of ethanol demanded represents their individual derived demand which when aggregated becomes the country's demand for Brazilian ethanol. Profits of an individual US importer, *i* are given by (6):

(6) $Max_{q_e^i}\, \pi^i = P^{US}\, q_f^i\left(q_e^i, \boldsymbol{q_v^i}\right) - e\, w^{US} q_e^i - \boldsymbol{w_v^{us} q_v^i} - F^i$

where $q_f^i\left(q_e^i, \boldsymbol{q_v^i}\right)$ is the individual importer's production function of blended gasoline, with q_e^i quantity of imported ethanol and $\boldsymbol{q_v^i}$ the vector of other variable inputs. P^{US}, is the price of blended gasoline in dollars, with *e* the exchange rate of dollars to Brazilian reals, $\boldsymbol{w_v^{us}}$ the vector of variable input costs, and F^i the fixed costs.

The first order condition with respect to the import quantities of the above profit maximization problem equate the value of marginal product (VMP) of the import to the marginal expenditure (ME) of the import. However, in this case we denote the ME with perceived ME (PME), since importers are responding to their belief about the effect of rival importers' purchase on import price (Goldberg and Knetter, 1999). Solving for the import price from the first order condition gives equation (7):

(7) $w^{US} = e.VMP^i(eP^{US}, w_v^{us}, Q_e^{US}) - q_e^i S_1^{US}\left(1 + \sum_{j\neq i} \frac{\partial q_e^j}{\partial q_e^i}\right)\left(1 + \sum_{j\neq i} \frac{\partial w^{US}}{\partial w^k}\frac{\partial w^k}{\partial w^{US}}\right)$

[5] It should be noted here that these relationships are specified as an inverse of the typical quantity dependent relationships associated with supply functions. This inverse supply specification is in line with Bresnahan (1988) and Goldberg and Knetter's (1999) specification of inverse demand functions.

The slope of the US residual supply curve is denoted by S_1^{US}. By letting θ^i represent the first parenthesis term following the S_1^{US}term, (the strategic interdependence among the US importers); and λ^{US} represent the second parenthesis term (the strategic interdependence among the US importers and the importers from other competing countries), equation (7) is rewritten as (8).

(8) $w^{US} = e.VMP^i(eP^{US}, w_v^{US}, Q_e^{US}) - q_e^i S_1^{US}\theta^i\lambda^{US}$

The industry analogue of (8) is obtained by summing the weighted average of individual US importers, where the weights are the import shares s^i[6]. The summation yields equation (9):

(9) $\sum_i s^i\, w^{US} = e.\sum_i s^i\, VMP^i(eP^{US}, w_v^{US}, Q_e^{US}) - \sum_i s_i\, q_e^i S_1^{US}\theta^i\lambda^{US}$

Since $\sum_i s^i = 1$, it follows that $\sum_i s^i\, VMP^i(eP^{US}, w_v^{US}, Q_e^{US}) = VMP^{US}$

substituting $q_e^i = s_i.Q_e^{US}$ in (9) yields (10):

(10) $w^{US} = e.VMP^{US}(eP^{US}, w_v^{US}, Q_e^{US}) - Q_e^{US}S_1^{US}\theta^{US}\lambda^{US}$ where $\theta^{US} = \sum_i s_i^2\ \theta^i$

Analogous to (6) and (7), profits and first-order conditions of individual importers of other countries are given by (11) and (12):

(11) $Max_{q_e^j}\, \pi^j = eP^k\, q_f^j(q_e^j, q_v^j) - w^k q_e^j - e\, w_v^j q_v^j - F^j$

(12) $w^k = e.VMP^k(eP^k, w_v^k, Q_e^k) - Q_e^k S_1^k \theta^k \lambda^k$ where $k = 1, \ldots\ldots, n\text{-}1$

Simultaneously solving the system of *2(n-1)* equations defined by (5) and (12), result in the set of inverse import supply functions, one for each ethanol importer other than US importers. These functions are further simplified to a function of ethanol supply and demand shifters in Brazil ($\boldsymbol{W}, \boldsymbol{Z}$); ethanol import demand shifters from competing countries, eP^k and ew_v^k (prices of gasoline and other input costs), US imports Q_e^{US}, and the union of conduct parameter of countries competing with the US; Ω.

(13) $w^k = s^k(Q_e^{US}, \boldsymbol{W}, \boldsymbol{Z}, eP^k, ew_v^k, \Omega)$

[6] Goldberg and Knetter (1999) provide justification of this form of aggregation at an industry level.

Equation (13) is a partially reduced form of the inverse supply functions of the *n-1* competing countries. The dependence of the functions given by (13) on the US imports arises because only the rival import supply functions are solved for in (13). The reduced form is partial since US imports, Q_e^{US} are endogenous.

Substituting these *n-1* inverse supply equations from (13) into equation (4) yields inverse residual supply for the US importers, which is now a function of US imports, shifters of Brazilian ethanol supply and demand, and shifters of ethanol import demands of ethanol importers other than US importers, as presented in (14) and (15):

$$(14)\ w^{US} = S^{Res.US}(Q_e^{US}, w^2(Q_e^{US}\boldsymbol{W}, \boldsymbol{Z}, eP^2, ew_v^2, \Omega)\ \dots\dots w^n(Q_e^{US}\boldsymbol{W}, \boldsymbol{Z}, eP^n, ew_v^n, \Omega), \boldsymbol{W}, \boldsymbol{Z})$$

$$(15)\ w^{US} = S^{Res.US}(Q_e^{US}, \boldsymbol{W}, \boldsymbol{Z}, eP^k, ew_v^k, \Omega)$$

The (inverse) supply function in (15) takes into account the strategic interdependence among importers by including the conduct parameter Ω, and hence represents the (inverse) residual supply faced by US importers in importing ethanol from Brazil.

Since both w^{US} and Q_e^{US} are endogenous in (15), estimation of (inverse) residual supply requires using an appropriate methodology to account for the simultaneous nature of these variables. The quantity of ethanol imports to the US (Q_e^{US}) is identified by shifters of US import demand of Brazilian ethanol. The demand shifters (P^{US} and w_v^{US}) in equation (10) are associated only with US import demand, while the demand shifters in equation (15) ($eP^k$and ew_v^k) shift only competing country's import demands, making the (inverse) residual supply equation identified when equations (10) and (15) are estimated simultaneously.

Typically oligopsony power for the i^{th} importer is measured by the relative markdown as shown in equation 16:

$$(16)\ \frac{VMP^i - w^i}{w^i} = \frac{\lambda^i}{\varepsilon^i}$$

where λ^{i} is the conjectural elasticity with values ranging from 0 (perfect competition) to 1 for (monopsony), and ε^{i} is the elasticity of input supply.

Asche et al.(2009) posit that since oligopsonists operate as monopsonists on their own residual supply, the elasticity of residual supply has a direct correspondence to the relative mark-down. However, because the residual supply elasticity itself is dependent on the buyers' conjectures, the conjectured residual supply may differ from actual residual supply and there may not be a direct correspondence with the relative mark-down. In the case of oligopoly, Baker and Bresnahan (1988) show that the elasticity of residual demand can represent a relative mark-up if the conjectured residual demand coincides with the actual residual demand. They show that in cases such as a Stackelberg leader, a dominant firm model, a competitive market, and a monopoly, the residual demand elasticity is identical to the relative mark-up. Oligopsony being the mirror image case of oligopoly, a similar argument is made here for oligopsony power. Therefore, given the dominance of the US as a buyer of Brazilian ethanol, the elasticity of residual supply is expected to reflect market power if the conjectured residual supply coincides with the actual residual supply. Independent of its exact correspondence with the relative mark down, the slope of residual supply in itself provides the notion that the US has some degree of market power as a buyer.

The residual supply elasticity (ε^{US}) of US ethanol imports from Brazil is found by taking the reciprocal of the inverse residual supply elasticity (μ^{US}), which is derived by differentiating equation (15) with respect to Q_e^{US}. The functional form here is specified as a double logarithmic, yielding equation (17):

$$(17)\quad 1/\varepsilon^{US} = \mu^{US} = \frac{\partial \ln S^{Res.US}}{\partial \ln Q_e^{US}} + \sum_j \left(\frac{\partial \ln S^{Res.US}}{\partial \ln w^k}\right)\left(\frac{\partial \ln w^k}{\partial \ln Q_e^{US}}\right)$$

where *j* and *k* = 1,…….., n-1.

The first component on the right of the equal sign in equation (17) measures the direct effect of US ethanol imports on its inverse residual supply. The next component takes into account the effect of its competitor's reactions on its imports. The first term in the parenthesis of the second component captures the shift in US residual supply due changes in the import prices of competitors and is expected to be negative. The second term in parenthesis captures the effect of US imports on the prices paid for ethanol imports by competing importers, and is expected to be positive. Given these relationships, as the intensity of competition among ethanol importers increases, the magnitude of the second component in equation (17) increases, resulting in a decrease in magnitude of inverse residual supply elasticity, $\mu^{US}$and correspondingly increase in the elasticity of residual supply to US, ε^{US} (Asche et al., 2009).

3. Empirical specification

The econometric model used to estimate US (inverse) residual supply (equation 15) is given in equation 18:

$$(18)\quad lnw_t^{US} = \alpha + \mu^{US}\, lnQ_{et}^{US} + \tau_w ln\, \boldsymbol{W_t} + \tau_z ln\boldsymbol{V}_t + \epsilon_t$$

where $w_t^{US}$is the monthly US import price of Brazilian ethanol in dollars/gallons; Q_{et}^{US} is the monthly quantity of US ethanol imports in gallons; $\boldsymbol{W}_t$ is the vector of supply shifters of Brazilian ethanol; $\boldsymbol{V_t}$ is the vector of ethanol demand shifters in Brazil and competing importing countries. The parameter μ^{US} represents the inverse residual supply elasticity of ethanol imports facing the US, and τ_w and τ_z are the parameters associated with Brazilian excess supply shifters, and demand shifters in Brazil and competing countries.

The EU, Japan, South Korea, Jamaica, and Nigeria are identified as the relevant competing importers. Mexico and India are omitted considering the small volumes of Brazilian ethanol they imported in recent years. As the Jamaican share in Brazilian ethanol exports is more than the combined share of El Salvador and Costa Rica, imports from Jamaica are used to represent the CBI countries.

Due to the endogeneity of Q_{et}^{US}, two-stage least squares method is used to estimate equation (15) with US import demand shifters acting as an instrument for Q_{et}^{US}. The variables included as the demand shifters are US retail gasoline price, the exchange rate of dollars to the real, and the monthly US corn price[7].

Brazil operates many dual plants which switch between ethanol production and sugar production depending on whichever is most profitable. This fact makes the sugar/ethanol price in Brazil an important determinant of ethanol supply. Unfortunately monthly data on Brazilian sugar prices are not available. World sugar prices are used as a proxy since Brazil is the largest single producer and exporter of sugar in the world (Haley, 2013). The variable representing ethanol demand shifters in Brazil are represented by the monthly aggregate sales/registration of pure ethanol/flex fuel vehicles in that country. Brazilian ethanol exports to the US exhibit a seasonal pattern that start to rise in May/June and reach a maximum during the month of August and decline thereafter. To capture this seasonal pattern seasonal control variables are added to the model.

The shifters of ethanol demand of the *n-1* competing importers include exchange rates between the real and the respective currencies, and the price of gasoline. In cases where the monthly price of gasoline is not available for all countries within a group, a representative country within the group is used as a proxy. Such as case for the EU which is represented by the

[7] As corn is a major feed stock for ethanol production in the US, corn prices highly influence domestic ethanol supply and expectedly import demands for ethanol.

Netherlands, the largest importer of that group. In cases where the importing countries are not part of a group and have no monthly gasoline prices, world crude oil price are substituted. The version of equation (18) used for estimation is as follows:

$$(19)\ lnw_t^{US} = \alpha + \mu^{US}\, lnQ_{et}^{US} + \sum_i \beta_{1i} ln\, D_{it} + \sum_j \beta_{2j} ln\, e_{Brt}^{j} + \beta_3 ln\, P_{gt}^{Ned} + \beta_4 ln\, P_{ot}^{w} + \beta_5 ln\, P_{st}^{W} + \beta_6 Brv + \epsilon_{1t}$$

Where D_{it} are dummy or indicator variables that capture the seasonal effects; e_{Brt}^{j}, exchange rates among the ethanol importing countries j with the Brazilian real; P_{gt}^{Ned}, retail price of gasoline in the Netherlands; P_{ot}^{w}, world crude oil price; P_{st}^{W}, world sugar price, and Brv, monthly number of pure alcohol or flex fuel vehicles sold/registered in Brazil. The endogenous variable Q_{et}^{US} is instrumented by P_{gt}^{US}, US monthly retail price of gasoline; e_{Brt}^{US}, exchange rate between Brazil and the US, and P_{ct}^{US}, US average monthly corn price.

The a priori expectations of the independent variables on the US import price, w_t^{US} are as follows: The inverse residual supply elasticity, μ^{US} is expected to be positive. Parameters β_{2j} which show the effect of changes in the exchange rates are expected to be negative - as the currency of an importing country depreciates, it is expected that its imports fall resulting in an outward shift of the US import supply and fall in the import price. Gasoline and world crude oil price coefficients β_3 and β_4 may be either positive or negative depending on the relationship between gasoline and ethanol consumption in the importing countries[8]. If ethanol and gasoline are substitutes in all countries, as gasoline and world crude oil prices increase all countries including the US will increase demand for ethanol imports, increasing import price for all. However, if ethanol and gasoline are complements (as in the case of a fixed ethanol blending

[8] If the recommended blending proportion for ethanol-gasoline has been attained, i.e. 'blend wall' is binding then we see a complementary relation in ethanol and gasoline consumption. However, if blend wall is not binding, substitution relationship will be operational.

proportion, with no substitution possibility) for all of the competing countries prices will fall. More likely however, some substitution and complementarity will occur making the outcome ambiguous. An increase in world sugar price, β_5 or the number of registered Brazilian flex fuel vehicles, β_6 are expected to positively impact the US import price by reducing Brazilian ethanol excess supply.

4. Data sources

Monthly data for the period between 2002 and 2013 are obtained from various sources. US ethanol import volumes from Brazil and corresponding FOB value (free on board at the exporter's port of delivery) in dollars are obtained from the foreign trade data base of Brazilian Ministry of Development, Industry, and Foreign Trade (Alice Web2 data base). The FOB values are converted into FOB unit prices by dividing them by corresponding import volumes. The FOB data corresponds to the standard international commodity classification HS 2207: un-denatured ethyl alcohol of at least 80 percent strength and denatured ethyl alcohol of any strength. Ethanol imported from Brazil is primarily an un-denatured ethyl alcohol which is denatured upon arrival in the US. Since the majority of these imports are converted into denatured ethanol and used for fuel (Farinelli, 2009 and MDICE, 2013), the aggregated data (i.e. data for HS 2207 classification) is used. Monthly US and the Netherlands gasoline retail price data for regular gasoline are obtained from the EIA website. Monthly US corn prices are accessed from the USDA National Agricultural Statistic Services (NASS) data base. Monthly data on the world crude oil prices come from the World Bank data base. Monthly world sugar price match those reported in the USDA Economic Research Service (ERS) 'sugar and sweeteners year book' data base. The monthly sales of Brazilian alcohol/flex fuel vehicle purchases are compiled from information provided by the Brazilian Automotive Industry Association, ANFAVEA website (http://www.anfavea.com.br/carta.html).

Monthly exchange rates of the real with the dollar, euro, yen, and won are extracted from those reported by the US Federal Reserve website. Monthly exchange rates between the real and the naira come from the Central Bank of Nigeria website. Similarly monthly exchange rates between the real and Jamaican dollars are obtained from the Bank of Jamaica website.

5. Results

Six different models or specifications of equation (19) are estimated using two-stage least squares method. Coefficient estimates and accompanying statistical analysis for these six models are presented in Table 1. In the first stage of estimation, US imports are instrumented by the US monthly gasoline price and corn price. The monthly gasoline price reflects ethanol demand condition in the US while corn prices influence domestic supply[9].

Model 1 and 2 are identical except for the seasonal control variables, model 1 has monthly controls and model 2 uses quarterly control variables. As anticipated, the inverse residual supply elasticity estimates are positive and statistically significant for both models (0.084 and 0.074, respectively). The corresponding reciprocal elasticities are 11.904 and 13.33 respectively, indicating a highly elastic residual supply curve. The seasonal control variables for both models indicate limited influence of seasonality – the month of August and the third quarter statistically differ from their respective bases, January and the first quarter.

Unfortunately these two outcomes are less than ideal due to possible multi-collinearity, and first order auto correlation concerns. The correlation matrix among the six exchange rates presented in Table 2 confirms that they are highly correlated and the residuals of these two

[9] The results from the over-identification test and the validity of instrument test to justify the appropriateness of these instruments are presented later in this section.

models are positively correlated as indicated by their respective Durbin-Watson (DW) statistics (1.19 and 1.20) which fall well below the lower bound 5 percent level of significance. Moreover these models have a high level of correlation among the instruments and their error terms, as indicated by the highly significant F-values of the over-identification test (Table1). While the signs on the residual supply elasticities and coefficient estimates of other variables are generally consistent with the expectation, these concerns warrant exploring alternative model specifications.

To address the collinearity issue, the exchange rate variables are transformed into their 'principal components'. The 'principal components' transformation is a statistical technique used to capture patterns in a data set of multiple variables by the use of Eigen-values and Eigen-vectors of the correlation matrix of the variables in the original data (Smith, 2002 and Jolliffe, 2002). Table 3 presents the Eigen-values from the transformation of the six exchange rate variables. Because the first three Eigen-values explain close to 98 percent of the variation in the raw data (Table 3), exchange rate variables in models 1 and 2 are replaced by their first three principal components. This replacement transforms model 1 to 3 and model 2 to 4. The inverse residual supply elasticity estimates from the transformed models (0.235 from model 3 and 0.239 from model 4) are relatively larger in magnitude and their level of significance increased to 95 percent confidence level. The implied residual supply elasticities are 4.25 and 4.18, respectively about one third of their previous estimates, but still highly elastic. Use of the principal components helped mitigate some of the multi-collinearity and the first order autocorrelation concerns. The newly estimated DW statistics of models 3 and 4 (1.58 and 1.66) are closer to 2 but still within the inconclusive range. All the parameter estimates associated with the principal components are significant (Table 1).

Just as it is in model 1 and 2, seasonality is significantly present only in August for model 3 and the third quarter for model 4. Both model 3 and 4 have the same base periods as model 1 and 2. The signs on parameter estimates for gasoline price and world crude oil price remain unchanged but the magnitudes of these coefficients increased and are of greater statistical significance. Compared to the first two models, the second two indicate competing countries play a larger role in influencing the residual supply of Brazilian ethanol to the US. Brazilian domestic excess supply shifters, world sugar price and pure ethanol or flex fuel vehicle registrations are not statistically significant indicating they have little effect on residual ethanol supply to the US.

Knowing the high correlation among the variables presented in Table 2, a possible gain from adding three additional variables to the principal components may improve the estimates. These variables include gasoline price in the Netherlands, world crude oil prices and world sugar prices. Model 5 added the fossil fuel prices, both gasoline price in the Netherlands and world crude oil prices as additional variables into the principal component array. Model 6 added world sugar prices as an additional variable to the principal components of model 5. Eigen-values and the proportion of variation captured by them are presented in Tables 4 and 5 respectively for models 5 and 6. With seasonal variation in the data adequately captured by the quarters we pursued with only quarters as the seasonal control variables for the two new models.

The statistically significant inverse residual supply elasticity estimates from models 5 and 6 are 0.140 and 0.138 with corresponding reciprocal residual supply elasticities of 7.14 and 7.25 respectively. These estimates are about midway between the estimates from the first and second pairs of models. The additional variables in the principal components do not significantly further mitigate the collinearity concerns. The DW statistics (1.466 for model 5 and 1.473 for model 6) fall below the 5 percent level of significance indicating possible positive first order correlation among the residuals. The magnitude of the estimated coefficients for all variables in the models 5 and 6 are slightly smaller than those of models 3 and 4. All the principal component coefficient estimates are significant, but the coefficients on supply shifters (world sugar price and Brazilian vehicle sales in model 5 and Brazilian vehicle sales in model 6) are not, making models 5 and 6 results similar to models 3 and 4 with respect to shifts in ethanol import demand in competing countries and shifts in Brazilian ethanol excess supply.

Given the multi-collineartity concern is minimized by including principal components of exchange rates only; the DW statistic for model 4 is closer to 2, and that it adequately captures the seasonality makes it the model of choice. In addition, the validity of the instruments in explaining US imports is tested for model 4. This test is done by regressing US ethanol imports on all of the exogenous variables including US gasoline and corn prices. The maximum likelihood results in Table 6 indicate that the two instruments are jointly significant in explaining the endogenous variable. Moreover, the over-identification test statistics presented at the bottom of Table 1 for model 4 also indicates that these instruments are not correlated with the error terms of the model. Therefore, we consider the instruments used for the model valid.

The model 4 findings show that the residual supply elasticity of ethanol supply from Brazil are highly elastic, indicating a small degree of market power of the US importers in importing ethanol from Brazil. The residual supply shows a positive seasonal increase during the third quarter. More importantly, the effect of import demand from competing countries in determining residual supply to the US is evident by the fact that exchange rate effects captured by principal components, gasoline price in the Netherlands, and the world crude oil price are highly significant. Conversely, the excess supply shifters in Brazil are found to have no significant influence on the residual supply.

6. Summary and conclusion

The ever increasing requirement in the US to blend higher volumes of advanced biofuels with gasoline and the shortfall in domestic production to fulfill this requirement; imports of ethanol from Brazil will likely take on an even more vital role. The strategic position of the US importers as the buyers of Brazilian ethanol is analyzed based on the residual supply elasticity of ethanol imports from Brazil. The residual supply elasticity is found to be highly elastic: a small percent change in price results in much larger percent change in quantity supplied, as much as 4.18 times. This elasticity is consistent with an upward sloping supply curve indicating a small degree of US importer market power.

Using arguments proposed in the new trade theory (Helpman and Krugman, 1989), a dominant ethanol importing country such as the US can gain by restricting ethanol imports from its trade partner, Brazil, by imposing an optimal tariff when individual importers do not recognize their market power. The reasoning is that under free trade, where import demand intersects residual supply, the marginal cost of an extra unit of ethanol imported by the US from Brazil exceeds the value of that unit. An optimal tariff would restrict imports to a level where the marginal cost and the value of the unit are equal. The empirical evidence from this work suggests that US importers are already exercising some degree of market power and imports of ethanol are occurring at the oligopsony equilibrium. Therefore from the US perspective, an additional restriction using a tariff would not be welfare improving[10].

[10] However, it should be noted that the optimal imports would be different if all US importers collude and act as a single firm.

While this work provides valuable information to those interested in ethanol imports, it is not exhaustive since it does not account for the possibility of bilateral oligopoly, which is possible since Brazil is the world's dominant exporter of sugarcane ethanol and the US its dominant importer. A fruitful avenue of future research would be to extend the empirical analysis to a residual supply/demand model that distinguishes between alternative oligopoly solutions: US dominance, Brazilian dominance or some other structure in between.

Table 1: Alternative model specifications and the parameter estimates

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Intercept	-12.610***	-12.328***	0.584	0.887	-0.794	-1.061
	(3.737)[+]	(3.609)	(1.253)	(1.309)	(1.005)	(0.954)
Log (US imports)	0.084*	0.074*	0.235**	0.239**	0.140***	0.138**
	(0.046)	(0.043)	(0.099)	(0.104)	(0.050)	(0.055)
February	-0.018		0.027			
	(0.100)		(0.169)			
March	-0.003		0.185			
	(0.106)		(0.193)			
April	-0.096		0.356			
	(0.115)		(0.215)			
May	-0.018		0.160			
	(0.105)		(0.183)			
June	-0.090		0.023			
	(0.103)		(0.171)			
July	-0.162		-0.108			
	(0.106)		(0.173)			
August	-0.245***		-0.369*			
	(0.116)		(0.195)			
September	-0.095		-0.505			
	(0.101)		(0.169)			
October	-0.047		-0.111			
	(0.103)		(0.172)			
November	-0.065		-0.132*			
	(0.103)		(0.172)			
December	0.107		0.187			
	(0.105)		(0.182)			
Quarter 2		-0.0009		0.105	0.046	0.053
		(0.059)		(0.108)	(0.081)	(0.081)
Quarter 3		-0.145**		-0.233*	-0.177**	-0.172*
		(0.069)		(0.120)	(0.089)	(0.089)
Quarter 4		0.012		-0.086	0.018	0.027
		(0.063)		(0.113)	(0.082)	(0.080)
Log (Euro/Real)	-0.982**	-1.014**				
	(0.455)	(0.429)				
Log (Yen/Real)	0.042	0.080**				
	(0.335)	(0.313)				
Log (Won/Real)	0.094	0.046				
	(0.369)	(0.351)				
Log (Jamaican $/Real)	0.352	0.372				
	(0.439)	(0.423)				
Log (Naira/Real)	1.987***	1.967***				
	(0.647)	(0.637)				
Principal Component 1			0.456***	0.468***	0.136***	0.149***
			(0.167)	(0.174)	(0.038)	(0.031)
Principal Component 2			-0.447***	-0.453***	-0.102**	-0.115***
			(0.159)	(0.165)	(0.045)	(0.032)
Principal Component 3			-0.601**	-0.628**	-0.162**	0.137*
			(0.285)	(0.295)	(0.082)	(0.074)
Log (Netherlands gasoline	-0.639	-0.440	-4.414**	-4.247**		
price)	(0.846)	(0.774)	(1.699)	(1.700)		
Log (World crude oil price)	0.508**	0.446*	1.028**	0.922**		
	(0.253)	(0.240)	(0.404)	(0.405)		
Log (World sugar price)	-0.212	-0.178	-0.683	-0.682	0.150	
	(0.241)	(0.232)	(0.467)	(0.482)	(0.204)	
Log (Number of Brazilian	-0.015	-0.021	-0.072	-0.088	-0.059	-0.056
vehicles)	(0.052)	(0.050)	(0.086)	(0.090)	(0.063)	(0.062)
DW Statistics	1.191	1.205	1.586	1.661	1.466	1.475
Number of observation	130	130	130	130	130	130
R^2	0.816	0.810	0.605	0.570	0.670	0.671
Over-identification test F-value	3.54**	3.95**	0.37	0.33	0.02	0.28

******* Statistically significant at ≤ 0.01 level of significance
****** Statistically significant at > 0.01 and ≤ 0.05 level of significance
***** Statistically significant at > 0.05 and ≤ 0.10 level of significance
[+] Values in the parenthesis are standard error of the estimates

Table 2: Correlation among the exchange rates, world crude oil, and world sugar price variables

Pearson Correlation Coefficients, N = 138

	$/Re	Euro/Re	Yen/ Re	Won/Re	Jam $/Re	Naira/Re	Netherlands gas price	World oil price	World sugar Price
$/Re	1.000	0.968	0.680	0.869	0.919	0.910	0.840	0.858	0.769
Euro/Re	0.968	1.000	0.646	0.809	0.900	0.869	0.892	0.870	0.712
Yen/ Re	0.680	0.646	1.000	0.401	0.398	0.367	0.431	0.444	0.161
Won/Re	0.869	0.809	0.401	1.000	0.897	0.882	0.656	0.694	0.792
Jam $/Re	0.919	0.900	0.398	0.897	1.000	0.972	0.869	0.868	0.883
Naira/Re	0.910	0.869	0.367	0.882	0.972	1.000	0.824	0.837	0.912
Netherlands gas price	0.840	0.892	0.431	0.656	0.869	0.824	1.000	0.960	0.707
World oil price	0.858	0.870	0.444	0.694	0.868	0.837	0.960	1.000	0.743
World sugar Price	0.769	0.712	0.161	0.792	0.883	0.912	0.707	0.743	1.000

Table 3: Eigen values of the correlation matrix from the six exchange rate variables

	Eigenvalue	Proportion	Cumulative
1	5.042	0.840	0.840
2	0.692	0.115	0.955
3	0.180	0.030	0.985
4	0.051	0.008	0.994
5	0.025	0.004	0.998
6	0.008	0.001	1.000

Table 4: Eigen values of the correlation matrix from the six exchange rate variables, the Netherlands gasoline price, and the world crude oil price

	Eigenvalue	Proportion	Cumulative
1	6.625	0.828	0.828
2	0.747	0.093	0.922
3	0.471	0.059	0.980
4	0.063	0.008	0.988
5	0.052	0.007	0.995
6	0.025	0.003	0.998
7	0.011	0.001	0.999
8	0.005	0.001	1.000

Table 5: Eigen values of the correlation matrix from the six exchange rate variables, the Netherlands gasoline price, the world crude oil, and sugar price

	Eigenvalue	Proportion	Cumulative
1	7.369	0.819	0.819
2	0.854	0.095	0.914
3	0.494	0.055	0.969
4	0.151	0.017	0.985
5	0.058	0.007	0.992
6	0.034	0.004	0.996
7	0.025	0.003	0.998
8	0.009	0.001	1.000
9	0.005	0.001	1.000

Table 6: Maximum livelihood estimates for testing validity of instruments

Variables	Estimates
Intercept	2.3171
	(7.368)+
Log US gasoline price	1.354
	(2.693)
Log Corn price	1.816**
	(0.787)
Quarter 2	-0.323
	(0.391)
Quarter 3	-0.300
	(0.405)
Quarter 4	0.204
	(0.375)
Principal Component 1	-1.512***
	(0.277)
Principal Component 2	1.765***
	(0.343)
Principal Component 3	1.825***
	(0.690)
Log (Netherlands gasoline price)	8.301**
	(3.599)
Log (World crude oil price)	-1.660
	(2.066)
Log (World sugar price)	3.930***
	(1.048)
Log (Number of Brazilian vehicles)	0.687**
	(0.311)
AR1	-0.286**
	(0.095)
Number of observation	130
R^2	0.43
F-value for joint significance of first two variables in the model	2.96*

******* Statistically significant at ≤ 0.01 level of significance
****** Statistically significant at > 0.01 and ≤ 0.05level of significance
***** Statistically significant at > 0.05 and ≤ 0.10level of significance
+ Values in the parenthesis are standard error of the estimates

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