Estimating the Effects of U.S. Distortions in the Ethanol Market Using a Partial Equilibrium Trade Model

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In this paper we assess the impact of the elimination of trade distortions on imports from Brazil to the U.S. For this purpose, we estimate a partial equilibrium trade model – an ethanol export supply function for Brazil and an ethanol import demand function for the U.S.-, based on annual data from 1975 to 2006, and use the results to compute a "back-of-the-envelope" measure of the deadweight loss derived from those trade distortions as well as one derived from producing the 35 billion gallons proposed in the "Twenty in Ten" 2007 State of the Union Policy Initiative assuming the distortions are not eliminated. Two-stage least squares is used to estimate both functions, the world price of ethanol being treated as endogenous. This paper supports the idea that the U.S. and Brazil would reap gains from trade if trade distortions were eliminated.

Since the oil crisis of the 1970s, countries around the world, specifically those highly dependent on the movement of oil prices, have begun a quest for alternative sources of energy. Biofuels are one of the main sources; specifically ethanol and bio-diesel dominate the market. Brazil took steps some thirty years ago to reduce its dependency on oil, by building the necessary infrastructure for becoming the leader in the sugarcane-based ethanol industry. Following Brazil's example, the U.S. has decided to move towards reducing its oil dependence; essentially this has been done through two mechanisms: (a) the Energy Policy Act of 2005 requiring doubling the U.S.'s use of alternative fuels by fuel blenders to 7.5 billion gallons in 2012, a target that has now been surpassed by the "Twenty in Ten" 2007 State of the Union Policy Initiative that requires an increase in the supply of alternative fuels, by setting a mandatory fuels standard to assure 35 billion gallons of renewable and alternative fuels in 2017 (State of the Union Address 2007)[1]; and, (b) a government mandate requiring that ethanol be used instead of methyl-tertbutyl-ether (MTBE) for blending in reformulated gasoline as the latter has been shown to pollute ground water (Dougherty and English 2006).

Table 1 shows that Brazil and U.S. are the leaders in producing ethanol. Notice that Brazil dominated the market in 2004 and 2005 but it is just since 2006 that U.S. has begun to capture a slightly greater share of the market producing 36% of the total world ethanol production, while Brazil's share is 33.3%:

Table 1. Leading Ethanol Producing Countries, 2004-2006

Country	2004		Country	2005		Country	2006	
	(mil. gal. per year)	%		(mil. gal. per year)	%		(mil. gal. per year)	%
Brazil	**3,989**	**37.0**	**Brazil**	**4,227**	**35.9**	**Brazil**	**4,491**	**33.3**
United States	**3,400**	**31.6**	**United States**	**3,904**	**33.1**	**United States**	**4,855**	**36.0**
China	964	9.0	China	1,004	8.5	China	1,017	7.5
India	462	4.3	India	449	3.8	India	502	3.7
France	219	2.0	France	240	2.0	France	251	1.9
Russia	198	1.8	Russia	198	1.7	Germany	202	1.5
South Africa	110	1.0	Germany	114	1.0	Russia	171	1.3
United Kingdom	106	1.0	South Africa	103	0.9	Canada	153	1.1
Saudi Arabia	79	0.7	Spain	93	0.8	Spain	122	0.9
Spain	79	0.7	United Kingdom	92	0.8	South Africa	102	0.8
Others	1,164	10.8	Others	1,366	11.6	Others	1,623	12.0
Total	10,770	100.0	Total	11,790	100.0	Total	13,489	100.0

Source: Shapouri, and Salassi 2006; RFA.

Fossil fuel production is still more price-competitive than production of biofuels. In order to compensate for this gap in price competitiveness, the ethanol industry (as well as the other alternative biofuels industries) is heavily subsidized inside and protected from the outside in the U.S.[2] To illustrate the significance of trade distortions imposed in the ethanol industry, it is worth noting that U.S. imports of ethanol from Brazil face high tariffs: a 2.5 percent *ad valorem* tax, and a secondary tariff of 54 cents-per-gallon, imposed to offset the 51 cents-per-gallon domestic subsidy to refiners who blend ethanol with gasoline (Kopp 2006).[3]

The hypothesis of this study is that trade distortions prevent both the U.S. and Brazil reaping the gains from trade due to their comparative advantage[4], thus in our analysis we assess the impact of the elimination of those distortions through the estimation of a partial equilibrium trade model – an ethanol export supply function for Brazil and an ethanol import demand function for the U.S.-, the results of which will allow us to perform a "back-of-the-envelope" calculation of the deadweight loss (DWL) that they cause as well as the one incurred by the production of the 35 billion gallons of ethanol per year proposed by the "Twenty in Ten" policy initiative. Once the model is estimated, the degree of responsiveness of Brazilian exports to changes in the world price and the impact that changes in U.S. import demand have on the world price are analyzed as well. The latter will be accomplished by the estimation of the export supply price-elasticity and the import demand flexibility, which is then used in the computation of the deadweight loss to society in both countries.

RELEVANT FACTS

Before developing the model it is of interest to show some relevant facts and figures that can help put into context the importance of the issues studied in this paper. During the last thirty years all of the major oil consumers and producers have been lowering their ratio of oil use to gross domestic product (GDP), mainly because of the rise in crude oil prices and the unstable political situations threatening supply from abroad (*The*

Economist 2006). Thus, many countries have begun to enhance the economic viability of alternative energy sources, specifically corn-ethanol in the U.S. and sugarcane ethanol in Brazil. In the particular case of ethanol, Brazil is still the world leader even though it produced slightly less ethanol than the U.S. in 2006, because the cost of making a gallon of ethanol from corn in the U.S. is approximately 30 percent higher than making a gallon of ethanol from sugarcane in Brazil (Weintraub 2007).

Babcock (2007) highlights three main disadvantages of producing ethanol from corn: (1) the great amount of energy it takes to grow corn and to produce ethanol; (2) the fact that expanded corn production could negatively affect soil and water resources as farmers till more acres and use land belonging to the Conservation Reserve Program and the Wetlands Reserve Program; (3) as corn farmers look for increased yields, the intensification of production could lead to larger nutrient and soil losses. However, he also remarks that there are two primary public benefits from increased production and consumption of biofuels: (1) using biofuels instead of fossil fuels can decrease the rate at which greenhouse gases build up in the atmosphere (notwithstanding, this gain can be undermined because fossil fuels like diesel fuel, pesticides, fertilizer, electricity used to pump irrigation water, and propane, are also used to deliver corn to ethanol plants, and because the amount of energy necessary to run an ethanol plant and to dry distillers grains); (2) if biofuels and other alternative energy sources comprise a larger share of U.S. total energy usage, energy security may increase. Brazil's sugarcane ethanol, on the other hand, reduces greenhouse gas emissions by a much greater amount than corn-based ethanol, and Brazilian ethanol imports surely increase energy diversification according to

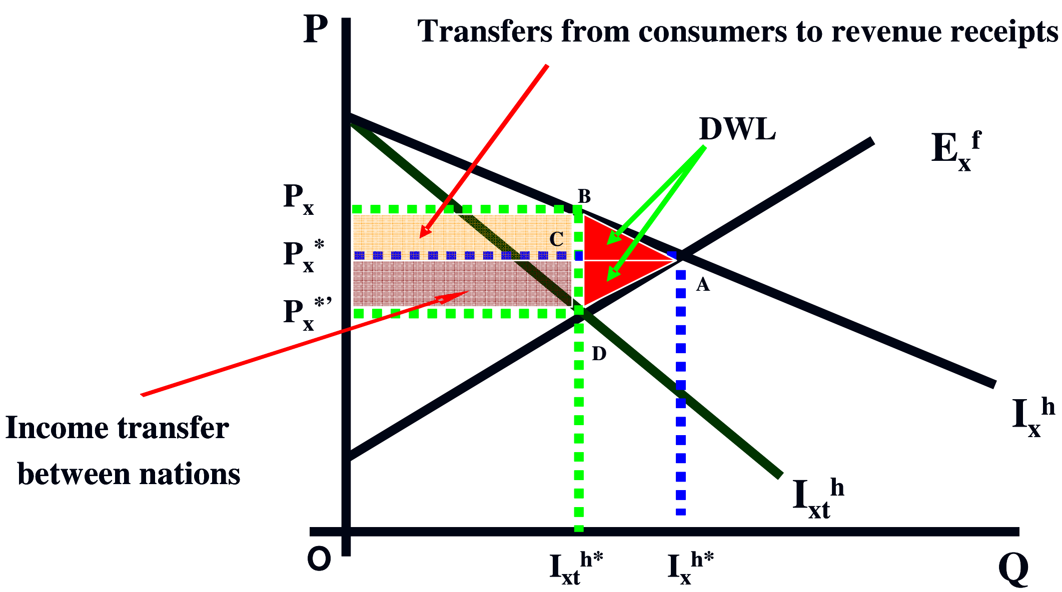
Babcock. Following this line of reasoning, Weintraub (2007) comments that corn-based ethanol burns up about seven times more fossil fuel per unit of energy produced than Brazil's cane-based ethanol, and also it will take a while for any other country to copy Brazil, where ethanol already accounts for 40% of the fuel used in cars.

Finally, it is important to address here the current debate that has arisen due to the increasing price of gasoline. According to The New York Times (May 24 2007), some oil executives are now warning that the current shortages of fuel could become a long-term problem, and surprisingly, they point to the uncertainty created by the government’s push to increase the supply of biofuels like ethanol in coming years. Executives such as John D. Hofmeister, the president of the Shell Oil Company, argue that the 2007 State of the Union Policy Initiative has forced many oil companies to reconsider or scale back their plans for constructing new refinery capacity. This is an example of the very diverse impacts that a policy like this can have, so it should be stressed that any welfare impact derived from an analysis of only the ethanol market would be understating the negative impact if it does not take into account the deadweight losses that it might be generating in other markets (such as the gasoline market just mentioned, but also the beef and the diary industries, and so on). Consequently, the “back-of-the-envelope” calculation of the DWL performed in this paper might be underestimating the real impacts on welfare to society.

THEORETICAL BACKGROUND

The fundamentals of the analysis in the present study come from international trade theory and from the econometrics theory, the former is the basis for the setting of the equations used in the latter, so both of them complement each other in building a comprehensive partial equilibrium model of ethanol trade between Brazil and the U.S. In order to explain the international trade theory supporting our framework, Figure 1 shows a partial-equilibrium diagram of international trade in good *x*, where the home country *h* (in this case, the United States) imposes a tariff that raises the domestic price to P_x and reduces the foreign price to $P_x^{*'}$. In this setting it is assumed that both the home country and the foreign country *f* (in this case, Brazil) are large economies, which is in accordance with the characteristics of their ethanol markets, as discussed earlier. It can be seen in the graph that I_x^h is the import-demand function in the home country *h* (the U.S.) and the line E_x^f is the export-supply function for the foreign country (Brazil). The free trade equilibrium is at point *A*, with imports equal to OI_x^{h*} and price equal to P_x^*. When country *h* imposes a tariff, its tariff-distorted import-demand function becomes I_{xt}^h, so trade volume decreases, the domestic price in *h* rises to P_x, and the foreign price falls to $P_x^{*'}$. The higher price in *h* generates the following welfare effects: deadweight efficiency losses of area *CBA* and tariff revenue of $P_xP_x^{*'}BD$, which consists of a transfer from consumers to revenue receipts of $P_xP_x^{*'}BC$ and a terms-of trade gain of $P_xP_x^{*'}CD$. So the net gain or loss to country *h* is $P_xP_x^{*'}CD$-*CBA* (country *f* gains what *h* loses, or loses what *h* gains). The global net welfare loss is *ABD*.

Figure 1. Effects of an import tax in a partial equilibrium setting



Source: Markusen, Melvin, Kaempfer, and K.E. Maskus (1995).

It can be seen that behind the supply and demand functions being estimated stands the concept of welfare in both countries and the losses or gains from their mutual trade, this study takes advantage of this setting to generate a "back-of-the-envelope" calculation of the DWL caused by the *ad valorem* tax and the tariff imposed on Brazilian imports in the U.S. that will help gauge the actual impact of these distortions to society. Also, it should be noted that the estimated model includes all the trade distortions in the ethanol market, and our main interest will be in determining if the movements in prices and quantities shown in the figure will appear when eliminating all trade distortions in the U.S, through the study of demand and supply elasticities.

On the econometric theory side, the technique that is used to estimate the supply and demand functions just described, is Two-Stage Least Squares (2SLS), which is a special case of the instrumental variables technique, and a method that corrects for the problem that arises when we face a system of equations such as the one of our interest: all the endogenous variables (the price of ethanol in this case) are random variables, so a change in the disturbance term changes all the endogenous variables, since they are determined simultaneously, thus Ordinary Least Squares (OLS) estimators will be biased, even asymptotically (Kennedy 1998).

REVIEW OF THE LITERATURE

As the ethanol industry has only recently entered the researchers' agenda, there is not a very rich literature on the specific topic developed in this study; nevertheless, an exhaustive search led us to conclude that there are five relevant papers. The first, written by Gallagher, Guenter, Shapouri and Brubaker (2006), studies the international competitiveness of the U.S. corn-ethanol industry versus the Brazil's sugarcane-ethanol industry by estimating an econometric model of the processing cost differences using monthly data from January 1973 to June 2002. Gallagher et al. compute a cost advantage measure as the sum of the cost of sugar in ethanol production and the cost of ethanol transport from Brazil to the U.S. and then subtract both the net cost of corn in ethanol production (they distinguish between producing in wet or dry mills, wet mills produce ethanol and corn gluten meal, corn gluten feed, corn oil, and carbon dioxide (CO_2) as by-products, while dry mills produce ethanol dried distillers grains with solubles (DDGS) and CO_2 as by products) and the cost of energy in corn ethanol production. Afterwards, the authors use time series analysis on the cost advantage measure in order to discriminate between random weather shocks, sugar and corn market cycles, and financial policy changes. They conclude that the U.S. would often be an ethanol importer without taking into account the duties of U.S. or Brazil on ethanol imports, but that the U.S. could take an occasional or cyclical export position in the ethanol market.

In contrast, Koizumi (2003) explores the impacts of Brazil's ethanol production on the world ethanol and sugar markets. He develops a dynamic partial equilibrium model to analyze how an ethanol, energy or environmental policy in major producing countries (14 countries for the world sugar market and 11 for the ethanol markets) will affect not only the ethanol market but also the domestic and world sugar markets. The article also offers market perspectives to the year 2010 for both sugar and ethanol. Some of the main results are: (1) Brazil's ethanol production is projected to increase by 2.3 percent per year and its exports are predicted to increase 3.9 percent per year (while sugar exports are predicted to decrease), (2) the figures for the U.S. are 5.7 and -3.0 percent per year, respectively. Koizumi concludes that the government of Brazil can control not only domestic sugar and ethanol markets, but also the world sugar and ethanol price, and the only tool for controlling the movements in quantity and price is the anhydrous ethanol blend ratio because the rest of the variables are under no market regulation. Therefore, Koizumi postulates that Brazil has and will unarguably have a competitive advantage in the world ethanol market.

Elobeid and Tokgoz (2006a) analyze the impact of trade liberalization and removal of the federal tax credit in the U.S. on U.S. and Brazilian ethanol markets using a multi-market international ethanol model calibrated on 2005 market data and policies, where the general structure of the country model is made up of behavioral equations for production, consumption, ending stocks, and net trade. Their model solves for a representative world ethanol price (Brazilian anhydrous ethanol price) by equating excess supply and excess demand across countries. This study finds that trade barriers in the U.S. have been effective in protecting the ethanol industry and keeping domestic prices strong, because with the removal of trade distortions, the world ethanol price increases by 23.9% (this is the first scenario, which implies the removal of the trade barriers: the out-of-quota duties of 2.5 percent and the 54 cents per gallon tariff, for all U.S. ethanol imports; whereas in the second scenario where they remove the trade barriers and the federal tax credit for the refiners that blend ethanol with gasoline the increase in the world ethanol price is 16.51%). Along with the increase in the world price the demand for ethanol increases, and therefore net imports increase in the U.S. by 199.04% (136.97% in the second scenario). Thus, Brazil, with its comparative advantage of low-cost ethanol production, would benefit from the removal of U.S. duties (Brazilian net exports increase 63.96% in the first scenario and 44.01% in the second scenario) and depending on the prices of ethanol and sugar, Brazil may end up increasing both the production of ethanol and sugar by expanding its sugarcane area. This article and the other two that followed its publication, which I will summarize in the following paragraphs, develops the most comprehensive analysis found among the limited number of studies on ethanol markets and can be used as a baseline for any further study.

A month after the publication of the paper just reviewed, Elobeid and Tokgoz (2006b) published another study that adds to the analysis of the ethanol market by linking it to the energy and crop markets, specifically corn and sugarcane markets. The explanation they give for the importance of the latter markets is also critical for understanding the reasoning behind the inclusion of the price of corn and the price of sugar in the model developed in the present study: (1) the inclusion of the price of a feedstock such as corn is relevant because it constitutes the major cost for an ethanol plant, thus the cost of the feedstock is an important determinant of the profit margin for ethanol plants and determines the expansion of plant capacity; (2) including the price of sugarcane is mandatory given that ethanol in Brazil is produced primarily from sugarcane and a large number of the existing plants in Brazil are dual plants (they produce both commodities at a maximum ratio of 55 to 45), moreover, depending on the relative prices, these plants can switch between the production of sugar and ethanol.

Besides analyzing the scenarios in which shocks to corn and sugar prices are introduced exogenously to the baseline (the shocks are given at 20% for each commodity starting in 2006 and covering the period to 2015), Elobeid and Tokgoz (2006b) are also interested in gasoline price shocks. Their main motivation is the strong historical relationship between ethanol and gasoline prices in the U.S., whereas in the case of Brazil the link between ethanol and gasoline was weak but the increase in global interest in ethanol as a fuel alternative as well as the introduction of flex-fuel vehicles (FFVs) in 2003 has changed this relationship.

The authors set a non-spatial, multi-market world model linking ethanol to its input and output markets, and they solve for a representative world ethanol price (the Brazilian anhydrous ethanol price) by equating excess supply and excess demand across countries. Their model includes the following major policy parameters: the 51 cents per gallon volumetric ethanol excise tax credit that refiners receive for blending 10% ethanol with gasoline; the mandated requirement of ethanol blend in certain states; and the Renewable Fuels Standard (RFS) of the Energy Bill of 2005 (notice that the target implied by this has been surpassed by the "Twenty in 10" policy initiative discussed at the beginning of this paper). They show that an increase in gasoline prices affects the U.S. and Brazilian ethanol markets differently because of the characteristics of their respective vehicle fleets. This proves the importance of the composition of the vehicle fleet on the relative magnitudes of the complementarity and substitution relationships between ethanol and gasoline, because in the short run, with the limited number of FFVs in the U.S., the world ethanol price declines by about 1.9% because of lower U.S. demand, since net U.S. imports decline by 16.7%, thus Brazilian net exports decline by 5.3% as U.S. ethanol demand falls. Nevertheless, once the model allows that in the long run the number of FFVs in the U.S. increases, then U.S. net imports increase by 278.2%, thus the world ethanol price increases by 34.9%.

On the other hand, an increase in the U.S. corn price decreases the profit margin for ethanol plants and leads to a reduction in ethanol production, as a result, the U.S.

domestic ethanol price increases, making ethanol imports from Brazil relatively more attractive (thus U.S. net imports increase by 56.5%, the world ethanol price does so by 6.6% and Brazilian net exports increase by 17.4%). Finally, the scenario in which there is a shock that increases the world price of raw sugar diverts more sugarcane into the production of sugar relative to ethanol in Brazil. Consequently, Brazilian production is lower and its net exports decline by nearly 10%, this leads to an increase in the world ethanol price by 6.1% and a decline in U.S. net imports of 24.9%. The results of the scenarios show that ethanol and sugar prices tend to move together in Brazil.

Finally, Elobeid et al. (2007) make projections using a multi-product, multi-country deterministic partial equilibrium model updating U.S. ethanol production figures as well as its impacts on planted acreage, crop prices, livestock production and prices, and trade that were released by Elobeid and Tokgoz (2006a), but now they incorporate a number of more realistic assumptions. Following the lines of the latter study, they use the concept of a long-run equilibrium as an aid to understanding the eventual impact of the biofuels sector on agriculture (if the ethanol industry is in equilibrium, then there is no incentive to build new ethanol plants and there is no incentive to shut down existing plants). One of the assumptions they make to analyze their different scenarios are that cellulosic ethanol is not competitive under current policy incentives. The authors evaluate three scenarios: (1) higher oil prices combined with widespread adoption of flexible fuel vehicles, (2) removal of an additional seven million acres from the Conservation Reserve Program (CRP), (3) a repeat of the drought of 1988 combined with a 14.7 billion gallon ethanol mandate. They arrive at various important results but, particularly, the ones that concern the purpose of this paper are: (a) if oil prices are permanently 10 dollars per barrel higher than assumed in the baseline projections, U.S. ethanol will expand significantly, the magnitude of the expansion will depend on the future makeup of the U.S. automobile fleet; (b) if sufficient demand for E-85 from FFVs is available, corn-based ethanol production is projected to ramp up to over 30 billion gallons per year with higher oil prices; (c) U.S. corn acreage would increase to more than 110 million acres, largely at the expense of soybean and wheat acres; (d) equilibrium corn prices would rise to more than $4.40 per bushel if another 1988-type drought in 2012 occurs combined with a large mandate for continued ethanol production; (e) ethanol demand becomes the limiting factor to the growth of the ethanol sector, because as production increases, the price of ethanol has to fall relative to its energy value to encourage gas stations and car owners to purchase the product, these low prices eventually stop the expansion of the sector.

MODEL ESTIMATION

Data description

In order to estimate the partial equilibrium model, annual data were gathered from 1975 to 2006 for both Brazil and U.S., in the case of the variables for which only monthly or daily data were available their annual average was computed. The following table describes the source of the variables employed in estimating the model. It is important to highlight that in the case of the price of ethanol, ideally the Brazilian anhydrous ethanol price should be used as the world price (according to Elobeid and Tokgoz 2006a, 2006b), but it was not possible to get historical annual data for the whole period of interest so the U.S. ethanol price was used instead (for 1975-1981 ethanol prices were assumed to behave like gasoline prices given that historically the relationship between ethanol and gasoline prices in the U.S. has been strong (Elobeid and Tokgoz 2006b)). All real figures are on a 2000 basis.

Table 2. Sources of the Variables Employed to Estimate the Model[5]

Variable *[notation in model]*	**Sources** *[Units]*
Price of ethanol $[P_{eth,t}]$	Nebraska Ethanol Board, Energy Information Administration (EIA) *[real dollars per gallon]*
Net Brazilian exports $[E_t]$	Uniao da Industria de Cana de Açúcar (ÚNICA), Elobeid and Tokgoz (2006b) *[million gallons]*
Net U.S. imports $[I_t]$	Renewable Fuels Association (RFA) *[million gallons]*
Price of sugar $[P_{sug,t}]$	Economic Research Service-U.S. Department of Agriculture (ERS-USDA) *[dollars per pound]*
Price of oil $[P_{oil,t}]$	U.S. Department of Energy (US-DOE), Organization of Petroleum Exporting Countries (OPEC) *[dollars per barrel]*
Price of corn $[P_{corn,t}]$	ERS-USDA *[dollars per bushel]*
Price of gasoline $[P_{gas,t}]$	EIA *[dollars per gallon]*
Population and real gross domestic product (RGDP) $[RGDPPC_{Br,t}, RGDPPC_{US,t}]$	ERS-USDA *[million people, real billion dollars]*
Consumer Price Index (CPI)	ERS-USDA
Exchange rate	Escola Superior de Agricultura "Luiz de Queiroz"- Centro de Estudos Avançados em Economia Aplicada (ESALQ-CEPEA) *[dollars per real]*

The following two tables show the descriptive statistics of the variables employed. Table 3 shows their levels and Table 4 shows their natural logarithms.

Table 3. Descriptive Statistics of the Variables in Levels

Concept	Price of ethanol	Net Brazilian exports	Net U.S. imports	Price of sugar	Price of oil	Price of corn	Price of gasoline	Brazil's real GDP per capita	U.S. real GDP per capita
Mean	1.93	243.79	47.69	0.17	33.88	3.51	1.68	3,156.09	28,598.13
Median	1.66	102.52	19.98	0.13	26.60	2.93	1.50	3,175.70	28,359.63
Maximum	3.44	898.19	653.30	0.66	78.20	8.63	2.61	3,689.98	38,680.73
Minimum	1.01	56.01	3.11	0.06	12.97	1.73	1.12	2,601.85	20,069.26
Std. Dev.	0.69	226.63	115.77	0.14	16.15	1.77	0.41	270.34	5,325.78
Observations	32	32	32	32	32	32	32	32	32

Table 4. Descriptive Statistics of the Variables in Natural Logarithms

Concept	Price of ethanol	Net Brazilian exports	Net U.S. imports	Price of sugar	Price of oil	Price of corn	Price of gasoline	Brazil's real GDP per capita	U.S. real GDP per capita
Mean	0.60	5.11	2.92	-1.97	3.42	1.15	0.49	8.05	10.24
Median	0.51	4.63	2.99	-2.03	3.28	1.07	0.41	8.06	10.25
Maximum	1.24	6.80	6.48	-0.42	4.36	2.16	0.96	8.21	10.56
Minimum	0.01	4.03	1.13	-2.74	2.56	0.55	0.11	7.86	9.91
Std. Dev.	0.35	0.87	1.23	0.58	0.44	0.45	0.23	0.09	0.19
Observations	32	32	32	32	32	32	32	32	32

Econometric model

As discussed earlier, the method followed in estimating the export supply and import demand functions is 2SLS. Given that Table 2 enumerates the notation assigned to each variable, it will not be described again in this section, but it should be added that *t* represents a trend variable. The following model was estimated:

$$(1) \ln E_t = \alpha_0 + \alpha_1 \ln P_{eth,t} + \alpha_2 \ln P_{sug,t} + \alpha_3 \ln P_{oil,t} + \alpha_4 \ln RGDPPC_{Br,t} + \alpha_5 t + \varepsilon_t$$

$$(2) \ln P_{eth,t} = \beta_0 + \beta_1 \ln I_t + \beta_2 \ln P_{eth,t-1} + \beta_3 \ln P_{corn,t} + \beta_4 \ln P_{gas,t} + \beta_5 \ln RGDPPC_{US,t} + \beta_6 t + \upsilon_t$$

Using the TSLS option of EViews for obtaining the estimation of the first equation, which is the one that needs to be instrumentalized, and correcting each of the equations either for heteroskedasticity or for serial correlation if necessary[6], the following results were obtained:

Table 5. Estimation of the Export Supply Function (Brazil)

Dependent Variable: Natural logarithm of net Brazilian exports		
Variable	**Coefficient**	**P-value**
constant	-1.2713	0.8506
ln price of ethanol	0.2376	0.3682
ln price of sugar	-0.0048	0.9571
ln price of oil	-0.1349	0.3899
ln Brazil's RGDPPC	0.5908	0.4917
trend	0.1128	0.0008
Autoregressive term for correction of serial correlation: AR(1)	0.8629	0.0000
Relevant Statistics		
Prob (F)	0.0000	
Durbin-Watson	2.2239	

Table 6. Estimation of the Import Demand Function (U.S.)

Dependent Variable: Natural logarithm of the price of ethanol		
Variable	**Coefficient**	**P-value**
constant	4.1043	0.3787
ln net U.S. imports	0.0874	0.0151
ln price of ethanol (-1)	0.0039	0.9700
ln price of corn	0.0028	0.9698
ln price of gasoline	0.9760	0.0000
ln U.S. RGDPPC	-0.3833	0.4104
trend	-0.0205	0.013
Relevant Statistics		
Prob (F)	0.0000	
Durbin-Watson	2.3653	

Notice that the R^2 and the adjusted R^2 were not reported in the tables - this is because a feature of TSLS models is that these statistics and all related measures are biased. Another drawback of TSLS models is that they tend to exhibit high multicollinearity between the explanatory variables, so it is not surprising to see that some of the variables in the model show either positive or negative correlation, and are still statistically significant.

Interpretation of the results

Export supply function of Brazil: From Table 5 it can be observed that the signs of the coefficients were as expected: (i) there is a positive relation between exports and the world price, this is in accordance with the basic trade model used in the analysis; (ii) the negative effect on exports of the price of sugar arises because there is a substitution between sugar and ethanol production at the firms' plants, such that if there is a higher price of sugar there is a shift to this product and a reduction in the production of ethanol available for export; and, (iii) the negative effect of a rise in the oil prices on the export supply is due to a substitution effect in Brazil between oil and ethanol, i.e., the domestic demand for ethanol rises if the price of oil increases such that available production for exports is reduced in order to satisfy domestic needs, also this effect may be due to some kind of "green" effect that comes into play once oil becomes expensive. The real GDP per capita is included only for the purpose of controlling for macroeconomic effects on net Brazilian exports (the same reasoning applies for the estimation of the U.S. import demand function) therefore its sign and impact is not relevant for the purpose of this study, this also applies for the trend included in the regressions (which helps to prevent the possibility the coefficients capture spurious relationships between the variables).

The result that is critical in this equation, due to it being an important variable for the "back-of-the-envelope" calculation of DWL, is the price elasticity of the export supply, which was found to be 0.24% (this number implies that an increase in 1% in the price of ethanol would increase Brazilian net exports by 0.24%).

Import demand function of the U.S.: In the case of the results shown in Table 6, the signs of the coefficients are also as expected: (i) there is a positive relation between imports and the world price of ethanol, which again is in accordance with the trade model; (ii) the positive effect on the price of ethanol when the price of corn goes up is due to the fact that, when the corn price increases, the profit margin for ethanol plants decreases leading to a reduction in ethanol production and to an increase in the U.S. domestic ethanol price, which makes ethanol imports from Brazil relatively more attractive (net imports increase so the world price of ethanol ramps up) as described by Elobeid and Tokgoz (2006b); (iii) a positive effect on the price of ethanol when the price of gasoline rises agrees with the fact that historically these prices have moved in the same direction in the U.S. (nevertheless, recall that Elobeid and Tokgoz (2006b) found that this impact might be different depending on the composition of the vehicle fleets through time).

The specification of the import demand equation will not allow for computing the elasticity but it can easily give us a measure of flexibility (the inverse of the elasticity). From Table 6, it can be observed that the flexibility is 0.09%, which means that an increase in imports of ethanol from Brazil by 1% will increase the world price by 0.09%. The inclusion of the lag of the price of ethanol is designed to capture the effect of the impacts of changes in price in the immediate last period, it can also help compute the long run flexibilities. Nevertheless, in this case, the short and long-run flexibilities are very similar, 0.0874 versus 0.0877, respectively, so it does not make a big difference to employ one or another, thus the short run flexibility will be used in the calculation of the DWL.

Calculation of the DWL of trade distortions

As mentioned before, the results derived from the partial equilibrium model will be used to arrive at a "back-of-the-envelope" calculation of the DWL caused by the existing trade distortions (we will focus on the 2.5% *ad valorem* tax and the 54 cents per gallon tariff) in the ethanol trade between Brazil and U.S. They will also be useful in a similar calculation for the impact of producing the 35 billion gallons per year in 2017 proposed by the "Twenty in Ten" policy initiative holding the following assumptions: (1) there is no intention to eliminate trade distortions; (2) the elasticities of demand and supply remain constant throughout the ten-year period; (3) the ratio of imports to total production of ethanol in the U.S. remains constant at its 2006 level (13.46%).

In order to compute the DWL we used the following formula,

$$(3) DWL = \frac{1}{2} t^2 P^* Q^* \frac{E_s E_d}{E_s - E_d}$$

where:

t = tax

P^* = pretax market price (the price of ethanol in this case)

Q^* = pretax quantity (the equilibrium volume of ethanol traded in the market)

E_s = price elasticity of supply

E_d = price elasticity of demand (this will be the inverse of the flexibility found when estimating the import demand function)

The quantities and prices that were used in the model include the trade distortions, thus the first step was to obtain the corresponding ones without the trade distortions (every calculation will be done on the average value of each variable to get a representative measure of magnitudes). Given some assumptions, the following results were obtained:

Table 7. DWL from Current Conditions of the Market

Concept	**Value**
P	1.93
Q	145.74
P^*	1.35
Q^*	361.19
E_s	0.24
E_d	11.45
DWL	*17.30*

Table 8. DWL from the "Twenty in Ten" Policy Initiative

Concept	**Value**
P	7.20
Q	4709.71
P^*	7.92
Q^*	4718.56
E_s	0.24
E_d	11.45
DWL	*1,324.75*

Table 7 shows that under the current trade distortions, the DWL to society in both countries is $17.3 million (2000 dollars). Including the "Twenty in Ten" Policy Initiative, the DWL rises to $1,324.75 million in 2017. These magnitudes illustrate that the accumulated negative impact on welfare of trade distortions over time can reach very high levels.

CONCLUSIONS

This paper contributes to the discussion of whether or not the U.S. should reduce tariffs and taxes imposed on the imports of Brazilian sugarcane ethanol by estimating a partial equilibrium model – an export supply function and an import demand function- using 2SLS.

From the estimation of the export supply function of Brazil, a positive relation between the exports and the world price was found implying a price elasticity of 0.24%, which is in accordance with the basic trade model used in this study. On the other hand, the estimation of the import demand function derived a flexibility of 0.09%, which is again in accordance with the trade model and implies a positive relation between imports and the world price of ethanol.

Among the other relevant results from the estimation of the model are: (a) there is a negative effect on exports if the price of sugar increases because there is a substitution between sugar and ethanol production at the firms' plants; (b) there is a negative effect of a rise in the oil prices on the export supply due to a substitution effect in Brazil between oil and ethanol; (c) there is a positive effect on the price of ethanol when the price of corn goes up because this leads to a reduction in ethanol production and to an increase in the U.S. domestic ethanol price, which increases its net imports and rises the world price of ethanol; (d) there is a positive effect on the price of ethanol when the price of gasoline rises which agrees with the fact that historically these prices have moved in the same direction in the U.S.

Finally, a "back-of-the-envelope" calculation shows that under the current trade distortions, the DWL to society in both countries is $17.3 million in real terms (2000 dollars). Including the "Twenty in Ten" Policy Initiative, the DWL rises to $1,324.75 million in 2017. These magnitudes illustrate that the accumulated negative impact on welfare of trade distortions over time can reach very high levels, signaling that the elimination of trade distortions or at least the reduction of the tariffs imposed by the U.S.

on ethanol imports from Brazil would benefit the society as Brazil would be exploiting its comparative advantage in producing ethanol (even though U.S. produced slightly more ethanol than Brazil in 2006, Brazil is still the least-cost producer of the market).

There are some other issues that must be taken into account when further analyzing the ethanol market. First, the necessary political arrangements for the removal of the US tariff imposed on ethanol imported from Brazil will be difficult to implement and costly to reach because there are vested interests in the industries affected. Second, there is a great deal of research in the U.S. for alternative energy sources besides ethanol, this includes either developments in the bio-diesel industry or other substitute inputs (switch-grass, sugar beets, peach pits, etc). And, third, an analysis of Brazilian social and land costs is also critical in determining the possible impacts of a policy causing an increase in the demand for sugarcane ethanol in Brazil; there are potential environmental, health and labor costs to the Brazilian population involved in this decision such that by only taking into account the direct market impacts we do not get a full picture of the problem.

FOOTNOTES

[1] The "Twenty in Ten" initiative has the goal of reducing U.S. projected annual gasoline usage by 20 percent. The target mentioned in this paper is planning to displace 15 percent of that projected gasoline use. Meanwhile, the other 5 percent reduction will be obtained by reforming and modernizing Corporate Average Fuel Economy (CAFE) standards for cars and extending the current light truck rule. President Bush's proposal will also increase the scope of the current Renewable Fuel Standard (RFS), expanding it to an Alternative Fuel Standard (AFS), which will include sources such as corn ethanol, cellulosic ethanol, biodiesel, methanol, butanol, hydrogen, and alternative fuels. It is also important to highlight that, for the sake of energy security, President Bush expects most of the expanded fuel standard to be met with domestically-produced alternative fuels; nevertheless, he is not discarding importing alternative fuels because he considers that it will also increase the diversity of fuel sources.

[2] Brazil also provided high subsidies to ethanol producers in the early years of its ethanol development but thanks to the advancement of technology the direct subsidies were terminated, nonetheless there are still indirect subsidies for the infrastructure in terms of transportation and distribution of ethanol. It is expected that U.S. will need to provide the same kind of support for the development of infrastructure as ethanol use increases (Weintraub 2007).

[3] It should be noted that Brazil grants government credit to the sugar industry to cover 60% of its storage costs in order to guarantee ethanol supplies, it has also mandated their

use in government fleet vehicles (Biofuels Taskforce of the Australian Government 2005), thus, Brazil is not free of domestic trade distortions but the interest of this study is focused on the U.S. ethanol industry.

[4] According to the Renewable Fuels Association (RFA), 119 ethanol refineries are currently operating in the U.S. (data as of May 2007), with an additional 86 plants either under construction or on expansion. However, U.S. production of ethanol from corn is limited by the availability of agricultural land suited to corn production and competing food demand for corn (Kopp 2006). The trade-off between those alternative uses of land leads us to really reconsider if the U.S. should continue imposing high tariffs on the imports of ethanol from Brazil. Babcock (2007) develops an outstanding analysis of the impact of production of ethanol on corn and states that corn use by ethanol plants is projected to increase by 1.7 billion bushels in 2007 and by at least another 900 million bushels in 2008. He also argues that corn acreage will have to increase in 2008 by at least three million acres above 2007 intended levels just to keep up with demand, so the only way that this level of corn production can be sustained is with high corn prices.

[5] Raw data used in this paper are available on request and further information can be obtained in the following website: http://aede.osu.edu/programs/Anderson/trade/.

[6] Further details about the procedure followed to arrive at the final specification of the model are available upon request from the authors.

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