Ethanol Trade as impacted by climatic variability: Lessons from the U.S-Brazil experience

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Abstract

This study analyzes the impact of climatic variability on ethanol trade between the Brazil and the U.S over a study period of 30 years, from 1980-2009. An econometric model was set up to estimate a net export supply function for Brazil, and a net import demand function for the U.S, as impacted by market and climatic variables. The climatic variables for the model were derived from prior literature, linking them to the yields of corn and sugarcane, which are feedstock for ethanol production in the U.S and Brazil respectively. The results suggest that climatic factors play an important role in the feedstock production for ethanol in these two countries, thereby influencing the direction of exports and imports. In South East Brazil, both low temperature and increased precipitation during winter show a positive relation with the net export supply. With regard to the net import demand in the U.S, it shows a negative relation with both increased summer precipitation and higher summer temperatures, while the relation with the average annual minimum temperature is positive. The outcome of this study provides an initial framework for conducting international trade policy studies for bio-fuels like ethanol, by incorporating climate change variables.

A. INTRODUCTION

Witnessing an increase in the global population levels, several countries have recognized the intensifying demand for food and energy, and have emphasized the development of renewable energy technologies in the past few decades. The importance of reducing dependence on nonrenewable sources of energy by switching to alternative sources like bio-fuels was specifically highlighted in the early 1970s (Martinez-Gonzalez, Sheldon and Thompson, 2007), with the imposition of an initial oil embargo by the OAPEC (Organization of Arab Petroleum Exporting Countries), and further with the dramatic increase in world oil prices after the lifting of the embargo. Consequently, the energy policies of several industrialized countries have been modified to promote bio-fuel production, specifically ethanol and bio-diesel, which are one of the most sought after sources of renewable energy. During this period, Brazil emerged as a pioneer in ethanol production, followed by the U.S, and thereafter both countries have expanded their ethanol industries to meet current demands and strengthen their capacities for future requirements. U.S and Brazil, have led the world ethanol production significantly in the years 2007-2009, and together accounted for more than 85% of the world ethanol production in these year (Table A1). Figure A1 provides a depiction of the trend in net ethanol imports and exports for the U.S and Brazil respectively, over the study period of 1980-2008. The inevitable link between agriculture and production of bio-fuels like ethanol in both Brazil and the U.S. highlights the fact that any impact on agricultural production of raw materials will directly affect the total ethanol production in these two countries. Given that ethanol production in the U.S and Brazil comes from corn and sugarcane respectively, it is imperative to understand the vulnerability of the ethanol industry to changes in agricultural production of these two commodities, which is highly impacted by climate. Figures A2 and A3 describe the movement in corn and sugarcane production in Iowa and South East Brazil respectively, with regard to average annual temperature and precipitation in the corresponding areas, over the period of 1990- 2009. Prior studies regarding ethanol trade have incorporated market variables which impact the supply and demand of ethanol in the two countries of study. However, the annual yield of both corn and sugarcane which are raw materials to the ethanol industry is directly impacted by climatic indicators like temperature and precipitation. The incorporation of these indicators while developing the ethanol trade models could be a useful tool to better predict the unexplained variability in ethanol trade between the two countries.

OBJECTIVE OF STUDY

To analyze the direction of impact of climatic indicators and market variables on the net ethanol export supply function of Brazil and the net ethanol import demand function for U.S over a 30 year study period.

Table A1:Global ethanol production and leading countries in the world (2007-2009)

Ethanol Production (Million gallons)						
Country	***2007***	***%***	***2008***	***%***	***2009***	***%***
USA	6,499	49.5%	9,000	51.9%	10,600	53.1%
Brazil	5,019	38.2%	6,472	37.3%	6,578	32.9%
EU	570	4.3%	734	4.2%	1,040	5.2%
China	486	3.7%	502	2.9%	542	2.7%
Thailand	79	0.6%	90	0.5%	435	2.2%
Canada	211	1.6%	238	1.4%	291	1.5%
Colombia	75	0.6%	79	0.5%	83	0.4%
India	53	0.4%	66	0.4%	92	0.5%
Australia	26	0.2%	26	0.2%	57	0.3%
Other	104	0.8%	128	0.7%	247	1.2%
Total	13,123	100.0%	17,335	100.0%	19,964	100.0%

Source: Renewable Fuels Association (2012)

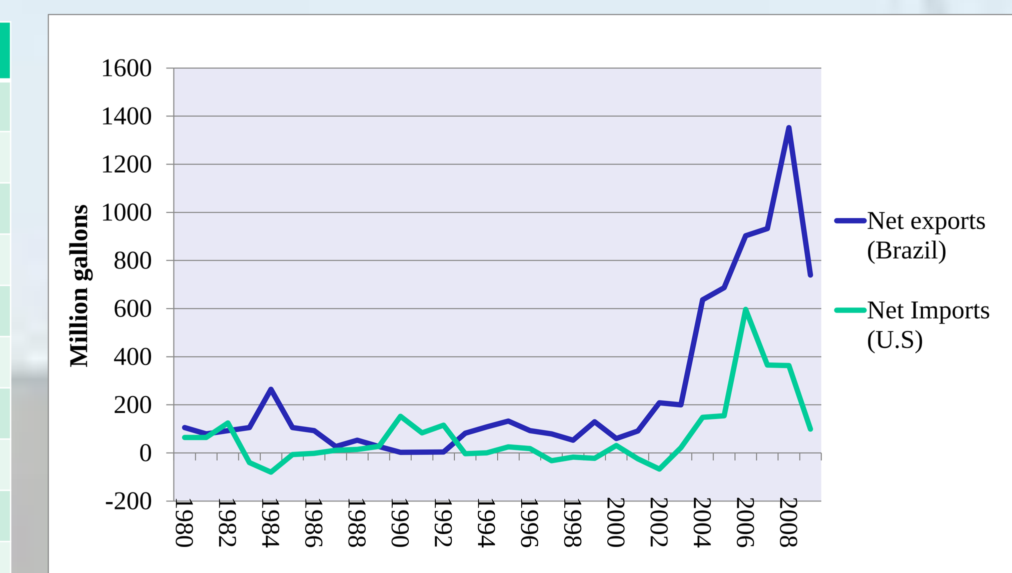


Figure A1: Net Brazilian Exports and Net U.S Imports (1980-2009)
Source: Data compiled from EIA Annual Energy Review (2011), Renewable Fuels Association (2012), and Uniao da Industria de Cana de Açúcar (ÚNICA), 2012

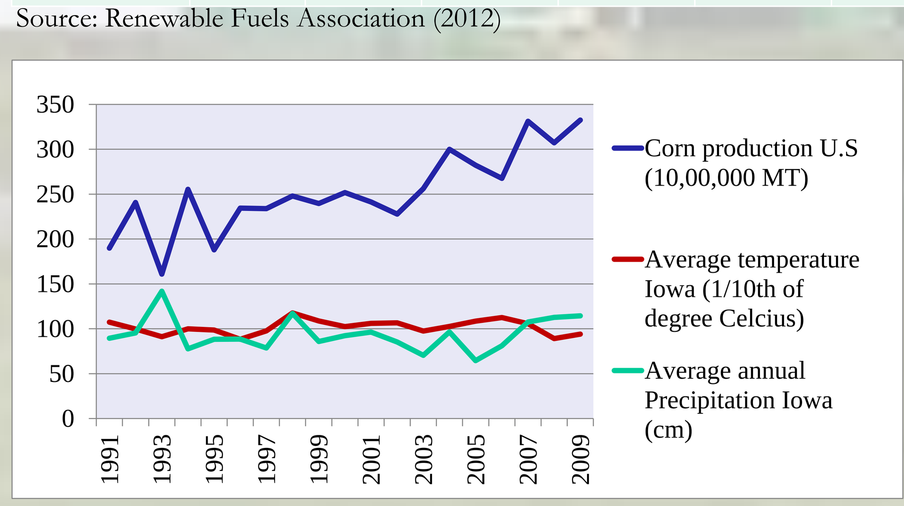


Figure A2: Total corn production in U.S and average annual precipitation and temperature in Iowa (1990-2009)
Source: Data compiled from EIA Annual Energy Review (2011), Renewable Fuels Association (2012), and NOAA (2012).

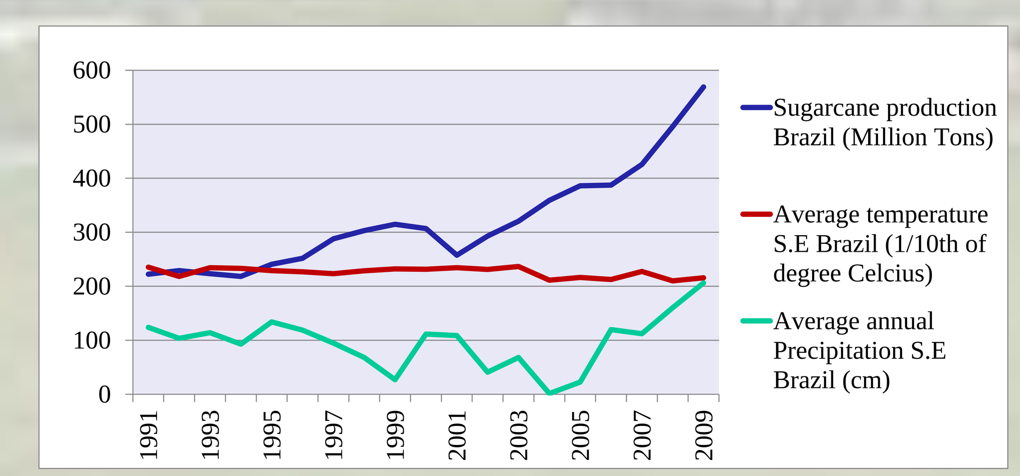
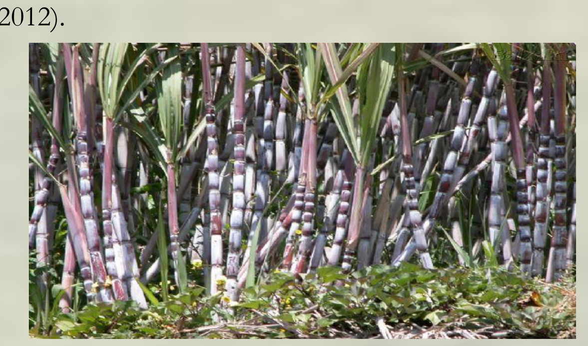


Figure A3: Total sugarcane production in Brazil and average annual precipitation and temperature in South East Brazil (1990-2009)
Source: Data compiled from Uniao da Industria de Cana de Açúcar (ÚNICA), 2012, and NOAA (2012).



B. METHODS

The theoretical background of this study is based on standard trade theory, and is studied as the case of two large countries (U.S. and Brazil), who are large enough to influence their terms of trade. This study contributes to a prior study by Martinez-Gonzalez, Sheldon and Thompson (2007), by estimating an export supply function for Brazil (represented by Net Brazilian exports), and an ethanol demand function for U.S (represented by Net U.S imports), as affected by the market variables (price of ethanol, price of sugar, price of corn, price of oil, real exchange rate, real gross domestic product of Brazil), and the climatic variables which impact the production of corn and sugarcane based ethanol in the U.S and Brazil respectively. For the purpose of generating representative climatic indicators for this study, specific ethanol production areas are chosen from within the two countries. For Brazil, the area of interest is the South East Sao Paulo state which accounted for 67% of the total ethanol production in the country in 2009 (Valdes, 2011), while for the U.S, it is the Midwestern state of Iowa which contributed towards 53% of the total U.S ethanol production in the year 2010 (USDA, 2011). Four weather stations from each production region (Brazil -Figure B1, and U.S – Figure B2) are chosen on the basis of availability of weather observations and proximity to the largest production areas of corn and sugarcane, in the respective study areas for generating the climatic variables. A partial equilibrium 2SLS (2 Stage Least Squares) model is set up in SAS, to estimate the impacts and significance of the market variables and the climatic indicators, on the overall ethanol trade between the two countries. The two equations to be estimated are as follows:

$\ln E_t = a0 + a1 \ln Peth_{,t-1} + a2 \ln E_{,t-1} + a3 \ln Psug_{,t} + a4 \ln Tmax\_Brazil_{,t} + a5 \ln Tmin\_Brazil_{,t} + a6 \ln Prcp\_Brazil_{,t} + a7 \ln days\_tmin\_winter\_below18\_Brazil_{,t} + a8 \ln tot\_prcp\_winter\_Brazil_{,t} + a9 \ln ER_{,t} + a10 \ln RGDPPCBr_{,t} + a11 \ln Poil_{,t} + \varepsilon t$ (1)

$\ln It = \beta 0 + \beta 1 \ln Peth_{,t} + \beta 2 \ln Poil_{,t} + \beta 3 \ln Pcorn_{,t} + \beta 4 \ln Tmax\_Iowa_{,t} + \beta 5 \ln Tmin\_Iowa_{,t} + \beta 6 \ln Prcp\_Iowa_{,t} + \beta 7 \ln tot\_summer\_prcp\_Iowa_{,t} + \beta 8 \ln days\_tmax\_summer\_above35\_Iowa_{,t} + vt$ (2)

Equation (1), estimates the export supply function of Brazil represented by E_t, and equation (2), estimates the import demand function of U.S represented by *It*. The exogenous variables used as instruments are: the price of oil, the price of sugar, the price of corn, the real GDP per capita of Brazil, the lagged price of ethanol, the lagged level of exports, and the climatic variables (Tmax_Iowa, Tmin_Iowa, Precipitation_Iowa, days of summer temperature > 35 ºC (Iowa), total summer precipitation (Iowa), Tmax_Brazil, Tmin_Brazil, Precipitation_Brazil, days of winter temperature (for months of October and November) < 18ºC (Brazil), and total winter precipitation (Brazil)). The descriptive statistics for important variables are provided in Table B1.

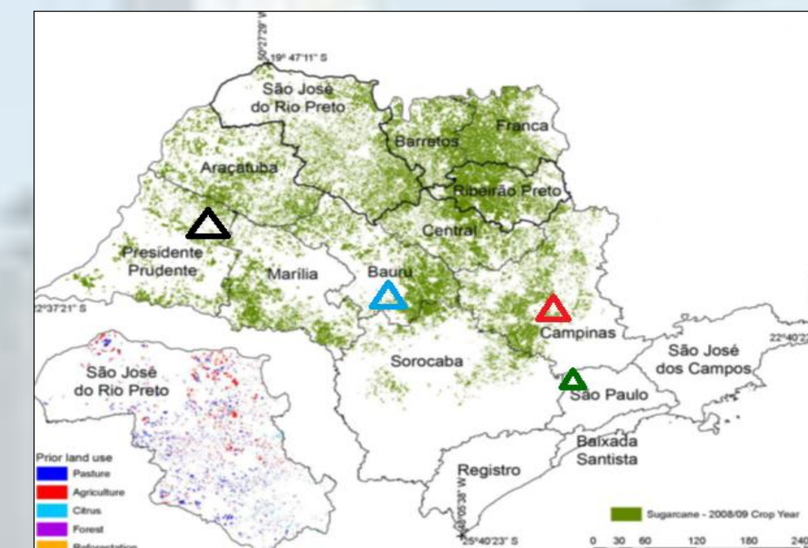


Figure B1:Weather Stations in São Paulo - Brazil for developing climatic variables for sugarcane production

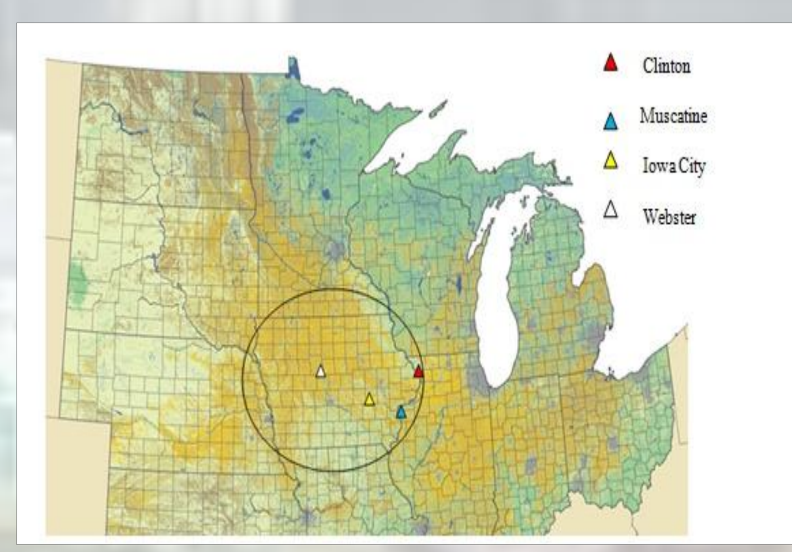


Figure B2:Weather Stations in Iowa- U.S for developing climatic variables for corn production

Table B1. Descriptive Statistics of market and climatic variables used in the model

Variable	*Obs.*	*Minimum*	*Maximum*	*Mean*	*Std. Deviation*
Price of ethanol ($/gal)	30	2.20	1.43	0.30	1.10
Net Brazilian exports (mn gal)	30	1352.36	248.27	341.66	2.64
Net U.S. imports (mn gal)	30	731.14	76.25	177.59	0.001
Price of sugar ($/lbs)	30	0.04	0.29	0.10	0.05
Price of corn ($/bu)	30	1.45	4.78	2.46	0.68
Price of oil ($/barrel)	30	10.87	94.04	27.78	19.24
Real GDP-Brazil per capita (real$)	30	3612.51	5210.18	4272.97	389.46
Exch. rate (real/$)	30	1.12	3.52	1.88	0.65
Tmax_Iowa (Celcius)	30	13.90	17.75	15.86	0.88
Tmin_Iowa (Celcius)	30	3.10	6.78	4.52	0.84
Prcp_Iowa (mm)	30	523.75	1418.23	911.07	181.15
Tmax_ Brazil (Celcius)	30	25.08	29.40	27.66	1.31
Tmin_ Brazil (Celcius)	30	12.73	18.80	16.86	1.42
Prcp_ Brazil (mm)	30	14.30	2218.75	1050.03	473.25

C. RESULTS

From the estimation of Brazilian exports as the dependent variable in the export supply function, it is clearly evident that there exists a positive relation between exports and the world price of ethanol, as mentioned in Table C1. The own price elasticity of export supply is 2.62., and the inclusion of the lagged dependent variable allows us to calculate the long-run price elasticity of export supply to be 7.136. Exports show a positive relation with exchange rate, as well as the real GDP of Brazil. With regard to the climatic variables, ethanol exports show a positive correlation with annual average of daily maximum temperature, and a negative relation with the annual average of daily minimum temperature and precipitation. With regard to the seasonal variables, there exists a positive relation between exports and days of winter temperature below 18^0C, as well as with total winter precipitation. One of the important discussion points with regard to the export supply is that among the different market and climatic variables, only the lagged price of ethanol, and the lagged dependent variable are statistically significant at 0.05 and 0.10 significance levels. The statistically significant estimates for the above two parameters, indicate the strong impact of prices on the export supply, which is further enunciated by the fact that the export supply is price elastic in both the short and long run, as indicated by the price elasticities. From Table C2, we observe a negative relation between imports and the world price of ethanol, and the own-price elasticity of import demand is -5.121. Also, there is a positive relation between price of oil and the import demand. Further, the import demand shows a positive relation with the price of corn, which implies that as corn prices increase, it is cheaper to import fuel ethanol. Among the climatic variables, the import demand shows a negative relation with average annual daily maximum temperature and average annual precipitation. The average annual daily minimum temperature shows a positive relation with import demand. Among the seasonal variables, the import demand shows a negative relation with summer precipitation, which is also in accordance with the fact that higher summer precipitation, would lead to better corn yields, and therefore promote ethanol production and reduce dependence on imports. Also, there is a negative relation between numbers of days in summer exceeding 35 degrees and the import demand. With regard to statistical significance among the market variables for the import demand, only the price of oil was significant at the 0.05 level. Comparing with the export supply that showed no statistical significance with regard to oil prices, we can conclude that the prices of oil make a significant impact on the import demand when compared to the export supply. The climatic variables showed significant results with regard to the average annual daily minimum temperature in Iowa (at 0.05 level), and numbers of days in summer exceeding 35 degrees in Iowa (at 0.10 level). This finding indicates that minimum temperatures exert an important influence on corn production, which in turn impacts the import demand.

Table C1. Estimation of the Export Supply Function (*Et*) for Brazil

Parameter	*Estimate*	*Approx. Std Err*	*Pr > |t|*
Intercept	-24.6738	45.9501	0.5982
ln price of ethanol (-1)	2.6284	1.436	0.0848*
ln net Brazilian exports (-1)	0.6317	0.1793	0.0026**
ln price of sugar	0.3725	0.9343	0.6951
ln Exchange Rate	1.0737	1.0995	0.3425
ln real gross domestic product_ Brazil	0.7854	3.7772	0.8377
ln price of oil	-0.1571	0.6044	0.798
ln Tmax_Brazil	6.4020	6.4046	0.3315
ln Tmin_Brazil	-1.6753	2.273	0.4712
ln Prcp_ Brazil	-0.2822	0.2431	0.2617
ln days_tmin_winter_below18_ Brazil	0.6915	1.0653	0.5249
ln tot_prcp_winter_ Brazil	0.4708	0.5869	0.4335

Durbin ***h*** Statistic (Serial Correlation Test for lagged dep.) = 0.1845 Pr > h (0.4268)
**significant at 0.05 level, *significant at 0.10 level

Table C2. Estimation of the Import Demand Function (*It*) for U. S

Parameter	*Estimate*	*Approx. Std Err*	*Pr > |t|*
Intercept	48.3837	36.6059	0.2012
ln price of ethanol	-5.1216	4.2691	0.2443
ln price of oil	4.81714	1.5284	0.005**
ln price of corn	0.2341	1.7921	0.8973
ln Tmax_Iowa	-15.469	10.2747	0.1478
ln Tmin_Iowa	6.3543	2.9101	0.0411**
ln Prcp_Iowa	-3.5329	3.076	0.2643
ln tot_summer_prcp_iowa	-0.4971	1.1292	0.6645
ln days_tmax_summer_above35_Iowa	-0.2991	0.1615	0.0788*

Durbin Watson Statistic (Serial Correlation Test) = 1.1083
**significant at 0.05 level, *significant at 0.10 level

D. Conclusions

The conclusive findings indicate that compared to the export supply of ethanol from Brazil, the import demand of ethanol for U.S. is significantly influenced by climatic changes, especially with regard to average annual minimum temperature and higher summer temperature. Also both the export supply and the import demand of ethanol for Brazil and U.S respectively, are price elastic in nature. Further, the price of oil exerts a significant influence on the import demand when compared to the export supply. This study could generate interesting discussions regarding the incorporation of multiple climatic variables besides temperature and precipitation, which impact plant growth and yields at critical stages of production. Also, it paves way for developing predictive models, using future climate projections for incidents of extreme weather events like drought, floods, and storms, to predict the movement of trade for bio fuel commodities like ethanol which use agricultural inputs as raw materials. This research will also be a motivation for conducting international trade policy studies for bio-fuels like ethanol by incorporating climate change variables. This is crucial as energy policies of developed countries will witness significant changes, as they try to switch from fossil fuel intensive sources to alternative sources of energy like ethanol.

Major references

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